

**DEPARTMENT OF  
OCEANOGRAPHY  
UNIVERSITY OF  
WASHINGTON**

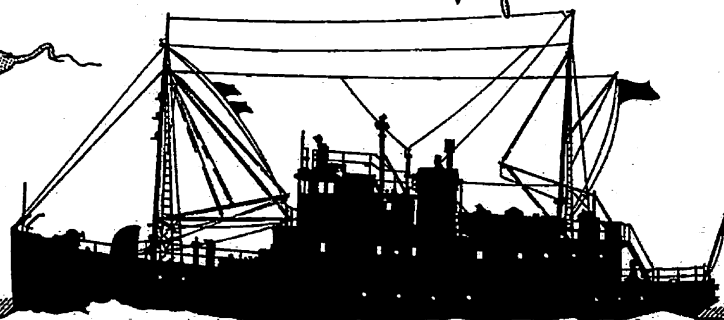
**THE COLUMBIA RIVER DISCHARGE AREA  
OF THE NORTHEAST PACIFIC OCEAN  
A LITERATURE SURVEY**

by

**George C. Anderson, Clifford A. Barnes,  
Thomas F. Budinger, Cuthbert M. Love,  
and Dean A. McManus**

**U. S. Atomic Energy Commission  
Contract No. AT(45-1)-1385**

**Reference M61-25  
July 1961**



**SEATTLE 5, WASHINGTON**

UNIVERSITY OF WASHINGTON  
DEPARTMENT OF OCEANOGRAPHY  
Seattle 5, Washington

THE COLUMBIA RIVER DISCHARGE AREA  
OF THE NORTHEAST PACIFIC OCEAN  
A LITERATURE SURVEY

by

George C. Anderson, Clifford A. Barnes,  
Thomas F. Budinger, Cuthbert M. Love  
and Dean A. McManus

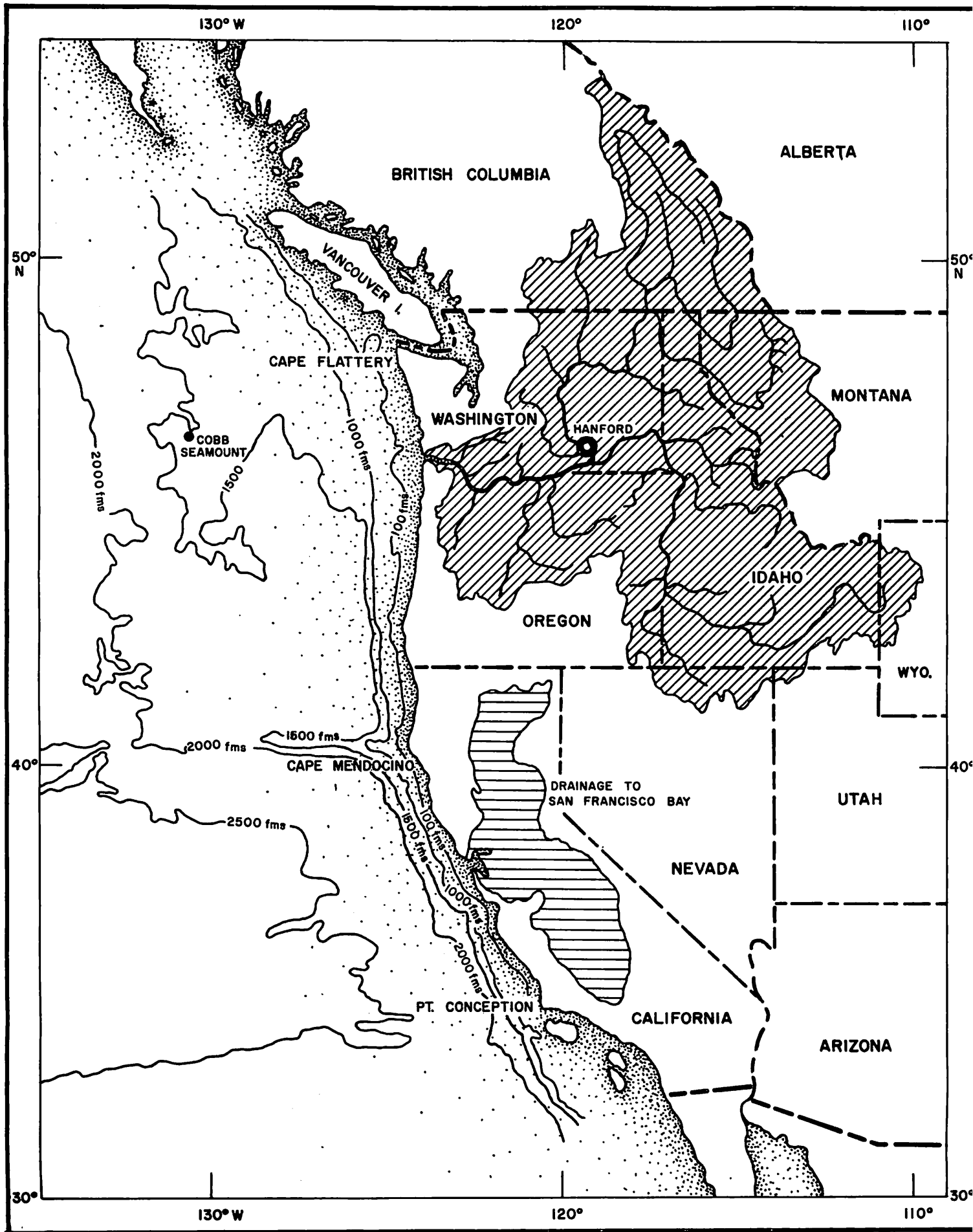
U. S. Atomic Energy Commission  
Contract No. AT(45-1)-1385

Reference M61-25  
July 1961



RICHARD H. FLEMING  
Executive Officer

Reproduction in whole or in part is permitted  
for any purpose of the United States Government.



**Columbia River Drainage Basin and Adjacent Sea**

## FOREWORD

This literature survey has been prepared in connection with the research program entitled "Columbia River Effects in the Northeast Pacific". It is intended as a work paper to provide a listing of references pertinent to the oceanography of the geographical area which either is influenced by the effluent of the Columbia River or whose waters might appreciably influence the movement and mixing of this effluent. Broadly, the entire North Pacific Ocean, as well as the drainage system of the Columbia River and of nearby rivers, are involved to some extent; and the subject matter appropriately should cover many aspects of physical, chemical, biological and geological oceanography. Practically, it has been necessary to restrict the area considered and subject matter to that of primary importance for the initial pursuit of field work. The existing literature has been reviewed and references on the local oceanographic regime have been compiled. In addition, a number of selected references on river load, flow rates and drainage basin environment of the upstream area have been included to establish the general characteristics of the river. By intent, only a limited number of general references are included.

In arrangement, the text is divided into three main sections which treat, in order, the physical and chemical oceanography, the biological oceanography and the geological oceanography. Each section abstracts pertinent aspects of the current status of knowledge in the subject subfields. Specific reference is made in the text to a few selected entries in the bibliography which follows each section. The entries in the section bibliographies are arranged in the general sequence of the subheadings in the text. There is some duplication of entries between sections in a few cases where the subject matter is relevant to different subfields.

Most of the references in the physical and biological sections are annotated, whereas a number in the geological section are listed without annotation. Some of the latter pertain to current and continuing work not adequately evaluated, and in some cases unpublished.

Only summary consideration has been given to the Columbia River upstream from the estuary and to material having little apparent bearing on the oceanography of the river effluent. No attempt has been made to relate the knowledge in the major disciplines to radioactive waste disposal, and references pertaining specifically to radiation chemistry for the most part have been excluded. This literature survey should be regarded as the initial installment of a continuing study to which additional references will be added as the study progresses. It should not be regarded in any sense as a published or completed document.

## TABLE OF CONTENTS

|   |     |
|---|-----|
| FRONTISPIECE . . . . .                            | ii  |
| FOREWORD . . . . .                                | iii |
| INTRODUCTION . . . . .                            | 1   |
| <u>SECTION I: PHYSICAL OCEANOGRAPHY</u> . . . . . | 2   |
| HYDROLOGY AND METEOROLOGY . . . . .               | 3   |
| Hydrology . . . . .                               | 3   |
| Precipitation and Evaporation . . . . .           | 4   |
| Wind . . . . .                                    | 4   |
| Wind Effect on the Sea . . . . .                  | 4   |
| PHYSICAL OCEANOGRAPHY . . . . .                   | 6   |
| Offshore Water Structure . . . . .                | 6   |
| Coastal Water Structure . . . . .                 | 6   |
| Ocean Circulation . . . . .                       | 7   |
| Tidal Currents . . . . .                          | 8   |
| Estuarine Circulation . . . . .                   | 9   |
| CHEMICAL OCEANOGRAPHY . . . . .                   | 10  |
| General . . . . .                                 | 10  |
| Dissolved Solids . . . . .                        | 10  |
| Oxygen . . . . .                                  | 10  |
| Phosphate . . . . .                               | 11  |
| Silicon . . . . .                                 | 11  |
| BIBLIOGRAPHY . . . . .                            | 12  |

|   |    |
|---|----|
| <u>SECTION II: BIOLOGICAL OCEANOGRAPHY</u> . . . . .  | 43 |
| INTRODUCTION . . . . .                                | 44 |
| BIOLOGICAL REGIMES . . . . .                          | 44 |
| Phytoplankton . . . . .                               | 44 |
| Zooplankton . . . . .                                 | 45 |
| Bays and Estuaries . . . . .                          | 45 |
| METHODS OF STUDY . . . . .                            | 45 |
| General . . . . .                                     | 45 |
| Identification of Organisms . . . . .                 | 46 |
| Light Measurements . . . . .                          | 46 |
| BIBLIOGRAPHY . . . . .                                | 47 |
| <br>  |    |
| <u>SECTION III: GEOLOGICAL OCEANOGRAPHY</u> . . . . . | 61 |
| HINTERLAND . . . . .                                  | 62 |
| Physiography . . . . .                                | 62 |
| Regional Geology . . . . .                            | 62 |
| Economic Geology and Geography . . . . .              | 62 |
| Coastal Estuaries . . . . .                           | 62 |
| SEDIMENTS . . . . .                                   | 63 |
| Columbia River . . . . .                              | 63 |
| Beach Sediments . . . . .                             | 64 |
| Offshore Sediments . . . . .                          | 64 |
| Foraminifera. . . . .                                 | 65 |
| MAPS AND CHARTS . . . . .                             | 65 |
| BIBLIOGRAPHY . . . . .                                | 66 |

## INTRODUCTION

This literature survey is a step in a general program directed towards a better understanding of the seaward distributary system of the Columbia River, an understanding which is necessary for determining the ultimate disposition of materials transported by the river. No major river emptying into the sea has been completely mapped from its mouth to its seaward detectable terminus. Conventional river studies have ended at the river mouth or in a more or less confined estuary in an arm of the sea immediately downstream. Studies of somewhat diluted sea water in coastal areas have been concerned with the overall water and salt budgets and the interaction of fresh water and sea water along a broad front. Only near the river mouth has water from a particular river been distinguished uniquely from that of other rivers as well as from the ambient sea.

The water from the Columbia extends from the river mouth as a surface plume in which the salinity increases downstream. With salinity as a guide its course can be tracked more than 300 miles in the Northeast Pacific Ocean, and its water is detectable over an area approaching 100,000 square miles in extent. As dilution of the sea can come from precipitation and from general runoff, low salinity alone does not identify water from a particular river. The addition of fresh water is only one of many important influences of a river on the sea. Dissolved inorganic and organic substances also are carried to the sea. Certain of these enter into the biological cycle of the ocean. Some are precipitated on contact with sea water and together with the suspended material carried by the river contribute to the near- and offshore sediments. Thus the river can affect the physics, chemistry, biology and geology of the sea. The various ways in which this might occur and the extent to which and area over which it will be manifested are unknown. A base is needed for evaluating the river's influence on the ocean environment. It is the authors' intent that the assembled bibliography serve as a reference base from which the study of the Columbia River effects in the Northeast Pacific Ocean can begin.

**SECTION I: PHYSICAL OCEANOGRAPHY**

## HYDROLOGY AND METEOROLOGY

Hydrology

The Columbia River drains a basin of 259,000 square miles lying mostly in the Pacific Northwest of the United States. The remainder is in the province of British Columbia in Canada. Eighty-five percent, or about 220,000 square miles, is within the United States and constitutes about 7 percent of the Nation's area or twice the area of the British Isles. The basin includes nearly all of Idaho, most of Washington and Oregon, the western part of Montana, smaller areas in Wyoming and Nevada, and the northwestern tip of Utah (c.f. frontispiece). The headwaters of the main stem of this river are in a mountain lake of British Columbia 2,650 feet above sea level. After flowing 465 miles through Canada the river enters the United States near the northeast corner of Washington and discharges into the Pacific Ocean through a broad estuary at the coast boundary between Oregon and Washington. The largest tributary is the Snake River. West of the Cascades and downstream from the gaging station near The Dalles, the tributaries of major importance are the Cowlitz River from the north and the Willamette River from the south. The Columbia is somewhat more than 1,200 miles long.

The mean annual discharge of the Columbia River is 243,000 cubic feet per second (over 174 million acre-feet per year). This represents 91 percent of the total gaged discharge into the Pacific Ocean south of the Strait of Juan de Fuca to and including the Umpqua River (43°40' N), or about 79 percent of the total discharge to but excluding San Francisco Bay. If the Strait of Juan de Fuca and San Francisco Bay discharges are included the Columbia accounts for approximately 52 percent of the total. However, these figures tend to be misleading because the seasonal discharge varies widely with source. The Columbia River discharge reaches a maximum in June whereas the combined discharge of the coastal rivers south to the Umpqua reaches a maximum of about 80,000 cfs during the months of December, January and February when the Columbia River discharge is near its minimum of about 153,000 cfs. During these winter months the Columbia River contributes about 66 percent, and in September when the discharge of the coastal rivers is at a minimum, 98 percent of the total discharge. The month of maximum coastal runoff is usually February during which 25 times more freshwater is discharged than during September. The above discharge rates are somewhat low because the lower reaches of the Columbia and Coastal rivers are not gaged. The ungaged area is probably about 10 percent of the coastal watershed. (U. S. Geological Survey, 1952-1960, 1955a; U. S. Geol. Survey Water Resources Division, Tacoma, 1955).

Note should be made of the numerous dams constructed across the Columbia River and its tributaries during the last 20 years (U. S. Department of the Interior, 1947) and the effect these dams have had on river flow and sediment transport.

The role of ground water is believed to be of little importance from the oceanographic standpoint. But the level fluctuation, dissolved-solids composition, and circulation of ground water is an important problem along the reaches of the River particularly in the lowland areas. Studies in the Willamette-Puget Lowland and in the alluvium of most of the larger coastal valleys have shown an abundance of ground water.

### Precipitation and Evaporation

The mean annual precipitation in the coastal and immediate off-shore areas of the Northeast Pacific Ocean influenced by the Columbia River discharge is estimated to exceed 120 cm/year. Precipitation exceeds evaporation and essentially the entire ocean area under consideration is one of net dilution, the surplus of precipitation being least in the west and south and increasing to a maximum of more than 90 cm/year off the coast of British Columbia and southeastern Alaska. South of the Columbia River the surplus decreases to near zero at San Francisco Bay (Jacobs, 1951). The precipitation over the Columbia River drainage basin and contiguous coastal drainage basins is as variable as the topography. In the Columbia River Basin alone, the yearly average can vary from less than 20 to over 300 centimeters depending on the location. The mountainous areas receive generally heavy precipitation, much of it in the form of snow. The plateaus lying in the rain shadow of the Cascade Mountains receive little precipitation of any kind. More information is needed on precipitation and evaporation at sea; however, the routine observations as made by the Weather Bureau are adequate for use in considering the gross water budget.

### Wind

The seasonal cycle of winds over the Northeast Pacific Ocean is largely determined by the circulation about the North Pacific high-pressure area and the Aleutian low-pressure area. In the summer the high-pressure area occupies a mean position centered approximately at  $40^{\circ}\text{N}$ ,  $150^{\circ}\text{W}$  and favors predominantly northwest and north winds over the coastal areas of Oregon and Washington. In winter, the high-pressure area moves south and east to a mean position at about  $30^{\circ}\text{N}$ ,  $138^{\circ}\text{W}$ . At the same time the Aleutian low moves south from the Bering Sea to about  $52^{\circ}\text{N}$ ,  $180^{\circ}\text{W}$  and increases in extent and intensity until it effectively dominates the circulation of the Northeast Pacific. The resulting winds are frequently of gale force and range in direction from southeast at the coast to southwest in the offshore region.

Although general wind information may suffice for a gross consideration of the circulation, detailed measurements along the coast and over the effluent waters of the Columbia are wholly inadequate.

### Wind Effect on the Sea

The effect of wind in driving and mixing fresh water discharged into the open ocean is one of the most important phenomena to consider in assessing the distribution of Columbia River effluent. The interaction between wind and a water surface has been a subject of considerable theoretical investigation and controversy. An adequate account of this interaction has yet to emerge. There are two facets of this interaction: wave generation (Jeffreys, 1925; Ellison, 1956; Miles, 1960) and wind drift current formation (Van Dorn, 1952; Munk, 1955). Both topics have been approached from different but not necessarily contradictory viewpoints. Although the literature is replete with theoretical discussions on wave formation and drift currents these do not provide a basis for adequately predicting the wind influence on the drift and set of the Columbia Plume. Seemingly, without first investigating the basic processes

involved in the generation of drift currents, any attempt to evaluate the wind effect on the Columbia River plume would be open to some question; however, voluminous observations of wind waves (Groen and Dorrestein, 1958) and wind currents (Haight, 1942) furnish a basis for empirical equations which will permit a rough estimate of wind effect and serve as a model for guiding studies in the effluent plume. The velocity of the surface current is a function of the stress of the wind and the eddy viscosity. The difference in viscosity between the fresh water layer and the under-lying sea water will reflect a differential movement between the surface and some depth, which will be larger than the differential movement between the surface and the same depth for areas not covered by the plume. Little is known of this phenomenon.

## PHYSICAL OCEANOGRAPHY

Offshore Water Structure

The Northeast Pacific Ocean area affected in measurable degree by the Columbia River runoff extends from the Washington coast south past  $40^{\circ}\text{N}$  and westward at that latitude as far as 250 miles offshore in the summer. During the winter the area affected is poorly defined. This area as well as the whole Northeast Pacific Ocean is characterized by the presence of three distinct zones or water layers. These zones are the result of excess precipitation, fresh water runoff from the Columbia River and coastal drainage, wind mixing, and other less well understood or known causes. The mechanisms whereby these zones are established have not been adequately described. The upper surface zone outside the river plume is about 90 meters thick and is characterized by a small increase in salinity with depth but a large decrease in temperature. Below this is a boundary zone or halocline wherein temperature remains relatively constant while the salinity increases rapidly with depth (Tully, 1957; Fleming, 1958; Dodimead, 1960). The halocline varies in thickness between 60 and 100 meters, and its base is identified throughout the region by a constant salinity of  $33.8 \text{ }^{\circ}/\text{oo}$ .

Immediately below the surface the mass field is characterized by a shallow zone of uniform density; then a layer of increasing density associated with decreasing temperature. In the summer there is usually a thin constant density layer immediately above the top of the halocline. Throughout the halocline the density increases with depth. The lower zone which extends from the bottom of the halocline to the abyss is characterized by a gradual increase in density with depth.

In the offshore region the vertical salinity gradients are small at all times but tend to be greater in summer than in winter. The summer gradients are brought about by advection and high precipitation, and are preserved under conditions of strong thermal stability. The excess of precipitation over evaporation is greater in the winter than in the summer, but there is diminished stratification because the cooling of surface waters reduces the thermal stability and therefore enhances the effectiveness of mixing by the strong winter winds.

Coastal Water Structure

The general structure described above obtains both in the offshore and coastal regions; however, in the latter the characteristics of the upper zone are modified by the processes of tidal mixing and coastal runoff. Low salinity water of the coastal region has been observed as far south as  $40^{\circ}\text{N}$  where it extended as a tongue from the Columbia mouth with its extremity separated from the coast by more saline water. The low salinity belt north of the Columbia appears to be continuous along the entire coast into the Gulf of Alaska. The relation and influence of this low salinity water on the ocean dynamics have not been adequately studied. The influence of the Columbia and coastal river discharges is certainly great. Conversely,

the influence of the ocean systems and winds on this effluent is considerable. Very little is known of the behavior of river water at sea from either the theoretical or descriptive viewpoints.

The local appearance of relatively cold saline water along the coasts of Washington and Oregon during summer has been attributed to upwelling. When the surface waters are moved offshore by winds from the northwest, some of the water deficit is replaced by deeper water (Sverdrup, 1938). This upwelled water is relatively cold and saline and has a high phosphate and a low oxygen concentration. Where ample runoff continuously replaces surface water as it is transported seaward by winds, upwelled water presumably will be blanketed by less saline water and not break through to the surface. Thus it might appear only occasionally in areas covered by effluent from the Columbia River or from the Strait of Juan de Fuca. Between the strait and the Columbia and along most of the Oregon coast south of the Columbia, local runoff in summer is seldom sufficient to entirely blanket the upwelled water. Upwelled water apparently comes from depths of less than 300 meters (Sverdrup, 1938; Doe, 1955). Better documentation is needed for the times at which upwelling occurs in particular localities, the intensity of upwelling, and the period required for upwelled water to attain the surface characteristics of ambient water. In winter predominantly southerly winds drive surface water inshore and maintain a region of low rather than high salinity all along the coast.

### Ocean Circulation

In the region off the coasts of Washington and Oregon the major water movement is that of the southerly-setting California Current. During the summer, flow is toward the south in both the nearshore and offshore regions but in the winter the nearshore flow is toward the north while the offshore current sets to the south. The westwind drift of the North Pacific sets eastward and upon approaching the North American continent diverges well offshore near  $45^{\circ}\text{N}$ , the northern arm feeding a gyral in the Gulf of Alaska. A southern arm turns southward to form the California Current. The latitude at which this apparent split occurs varies with longitude and at  $140^{\circ}\text{W}$  is approximately  $50^{\circ}\text{N}$  in summer and about  $43^{\circ}\text{N}$  in winter. Off the Washington and Oregon coasts in winter, the Davidson Current feeds water northward inshore. This entire area is characterized by weak and poorly defined currents which are easily influenced by temporally changing wind patterns and local bathymetric irregularities. The current drift as computed from the dynamic topography of the sea surface (Barnes and Paquette, 1954; Doe, 1955; Fleming, 1955) is small, with average values of the order of 5 cm/sec or less and maxima up to 20 cm/sec (10 miles per day) in spring and summer. The speed at 300 meters is half that at the surface. The principal characteristics of movement as shown by drift bottle studies (Thompson and Van Cleve, 1936; Dodimead, 1958; Reid, 1960) corroborate the pattern depicted by the dynamic topography.

In the absence of wind and background ocean circulation, one would expect the Columbia River water, in response to geostrophic forces, to extend in a plume northward from the river mouth. However, in summer and autumn wind and current carry the plume of water having a salinity less than  $32.0 \text{ ‰}$  and a temperature somewhat higher than that of the ambient water over 200 miles to the southwest. This southwestward movement of relatively fresh

water at this period of year is in agreement with both the southerly set of the local oceanic circulation and southerly directed winds. During winter, the northward setting Davidson Current coupled with southerly winds and low runoff favor a northward transport of Columbia River water but the circulation is poorly defined.

Sverdrup (1947) has shown that the main features of mass transport in the eastern equatorial Pacific can be derived from the average wind stress distribution. This work is supported by that of Reid (1948), Stommel (1948) and Munk (1950) and indicates that the total steady-state transport of mass and accompanying currents depends primarily on the curl of the wind stress components acting on the surface of the ocean. This steady-state model of mass transport has been applied to extensive calculations of transports in the North Pacific Ocean for the years 1955, 1956, 1957, 1958 (Fofonoff, N. P., 1960). Charts of the monthly mass transports are being prepared on a continuing basis (Fofonoff and Froess, 1960). Fofonoff (1954) has shown that it is not possible to account for the observed features of an ocean current in terms of wind stress alone although this is the predominant force. The arguments of Sverdrup and other investigators have ignored thermodynamic processes and lateral friction. From Fofonoff's work it appears that an adequate understanding of the ocean circulation cannot be achieved until the baroclinic structure of the ocean can be interpreted quantitatively in terms of suitable mathematical models which include thermodynamic processes. It appears possible that an analysis of the relationship between the wind stress and the prevailing currents in the Columbia River effluent area, with consideration of the local boundary condition will provide an insight into this system. The relationship between wind and water movement will be a powerful tool for a theoretical examination of the conditions which would be expected in winter and summer if the Columbia River did not exist.

### Tidal Currents

The tidal currents contribute to the flushing of estuaries, accelerate the mixing of river and sea water, and are directly related to processes of erosion and deposition of sedimentary material. These are known at particular locations in navigational waters as in the approaches to ports and at the mouths of coastal systems emptying into the sea (various U. S. Coast and Geodetic Survey publications). Too few measurements have been made far enough from land influence to establish the true strengths and patterns of tidal currents which exist over the shelf area off the Washington and Oregon coasts. Some observations have been made on Cobb Seamount (300 miles off the Willapa Harbor) in which tidal components can be detected (Barnes and Paquette, 1957) but these are incomplete. The Pacific Oceanographic Group of Canada is now making some current measurements on the shelf off Vancouver Island. Direct current measurements in a time series are needed for the surface, mid-depths and the bottom across the shelf off and flanking the Columbia River, and also at the bottoms of the local depressions crossing the slope, such as the Astoria Canyon.

### Estuarine Circulation

The Columbia River from the head of tidewater to the river mouth is a rather narrowly confined positive type estuary for which the runoff at all times greatly exceeds the evaporation. The circulation upstream from the mouth varies primarily with the stage of river runoff but is influenced by tide, wind and the configuration of the river bed (National Marine Consultants, 1961). During flood tide, a wedge of salt water intrudes at the mouth of the river and extends a variable distance up the river near the bottom. Above this deeper salt water wedge an upper layer transports seaward some salt picked up from the lower layer and a net amount of fresh water somewhat less than the average fresh water drainage. During ebb, water-level falls and water leaves the channel at an accelerated rate as a displacement flow in response to the hydrostatic force. The river water in the estuary becomes somewhat enriched in salt as it moves downstream over the salt water wedge, and the enrichment continues as the river plume moves seaward from the coast. Eventually the plume no longer can be distinguished from the ambient ocean water. Outside the entrance bar the river effluent moves as a surface brackish layer with 180° of lateral freedom. The movement and mixing of this water is influenced by the local oceanic circulation, tidal currents of the shelf and slope, winds and waves. The upper layer transports seaward a net amount of fresh water equal to the river runoff. At the same time its salt concentration is increasing, so there must be a net transfer of salt from the lower to the upper layer in the estuary (Tully, 1949; Pritchard, 1952), and also in the open sea (Tully and Barber, 1961). This occurs by salt diffusion and by entrainment of relatively high salinity water from the lower layer. Lateral mixing also occurs but the mechanisms of the mixing processes are poorly known. Existing theories require observational verification some of which is available from model studies (Rouse and Dodu, 1955; Cromwell, 1960). An evaluation of the mixing processes is vital to the distribution of the Columbia River water and its dissolved constituents.

## CHEMICAL OCEANOGRAPHY

General

The composition of the dissolved constituents in the Columbia River system changes from that characteristic of the upstream drainage to that dominated by the sea beyond the river mouth. Major constituents common to both the ocean and the river are so highly concentrated in sea water that the individual constituents offer little promise over salinity as a tool for tracing the Columbia River seaward. Distinctive substances of potential use as tracers are the radioactive isotopes carried by the river, and perhaps some of the naturally occurring trace elements or organic compounds. These constituents, all of which occur in low concentration, would be involved to an unknown extent in the flocculation which occurs in the estuary. Moreover, they probably enter into the biological cycle to an extent that any cogent evaluation of river effects would require more knowledge of the local food chain than now exists. The general composition of the Columbia River is known from the records of the U. S. Geological Survey, and that of the North Pacific from various oceanographic studies.

Dissolved Solids

The annual contribution of dissolved solids by the Columbia River drainage is 19 million metric tons. This is equivalent to about 20 percent of that carried by the Mississippi River. The concentration of the dissolved solids in the Columbia River is approximately one thousandth that of the North Pacific Ocean into which it flows. The relative composition of sea salts differs from that of fresh water salts and the composition of the latter varies from one river to another. The major cations of the sea listed in order of decreasing concentration are: sodium, magnesium, calcium, potassium, silicon; whereas, the Columbia River cations in order of decreasing concentration are: calcium, silicon, sodium, magnesium, potassium. The major anions listed in order of decreasing concentration for the sea are: chloride, sulfate, carbonate; whereas, for the Columbia River the order is: carbonate, sulfate, chloride.

The specific conductance for the surface ocean water of this region is about  $0.03 \text{ (ohm}\cdot\text{cm)}^{-1}$ ; whereas that of the Columbia River water is about  $10^{-4} \text{ (ohm}\cdot\text{cm)}^{-1}$ . At a given temperature the conductivity of both river and sea water increase with an increase in the amount of dissolved solids.

Oxygen

In the surface layers of the North Pacific Ocean the concentration of dissolved oxygen is at approximately its saturation value due to aeration and the photosynthesis of plants. Below the euphotic zone the concentration decreases in response to respiration and decay. The maximum value in terms of saturation generally occurs at depths between 25 and 50 meters. Below this depth there is a steady decrease to a minimum value of under 5 percent in saturation at about 750 meters and then a gradual increase. This condition obtains in both coastal and offshore regions.

### Phosphate

Phosphate, one of the principal nutrients of the sea, is found in higher concentrations in the North Pacific than in either the Atlantic or Indian Ocean. The maximum values occur well below the surface and usually at a greater depth than that of the oxygen minimum. Values greater than one microgram atom per liter are found at the surface north of 45°N, increasing to values as great as 3 µg-atom/l at a depth of 200 meters. Over the Northeastern Pacific Ocean the horizontal distribution of phosphate at 100 meters depth and the horizontal distribution of zooplankton are very much alike (Reid, 1958). Inshore, an abundance of plankton is apparently associated with areas of upwelled water. The concentration of phosphate in fresh water is relatively low, frequently less than one percent of that of the coastal sea water.

### Silicon

The vertical distribution of silicon increases from about 10 microgram-atoms per liter at the surface to values near 200 microgram-atoms per liter in the abyss. The Columbia River water contains an average concentration of 200 µg-at/l. If not obscured by the effects of biological activity, the discharge of this relatively high silicon content water might significantly affect the surface silicon distribution of the coastal waters.

## BIBLIOGRAPHY

|   |    |
|---|----|
| HYDROLOGY AND METEOROLOGY . . . . .                                     | 13 |
| A. HYDROLOGY . . . . .  | 13 |
| B. METEOROLOGY AND WIND EFFECT . . . . .                                | 14 |
| PHYSICAL OCEANOGRAPHY . . . . .   | 16 |
| A. GENERAL . . . . .  | 16 |
| B. OCEAN CIRCULATION AND WIND STRESS . . . . .                          | 20 |
| C. ESTUARIES . . . . .  | 23 |
| CHEMICAL OCEANOGRAPHY . . . . .   | 26 |
| AVAILABLE DATA . . . . .  | 29 |
| A. OBSERVATIONS IN THE NORTHEAST PACIFIC OCEAN . . . . .                | 29 |
| B. ATLASES AND AVERAGE CONDITIONS . . . . .                             | 38 |
| C. BIBLIOGRAPHIES, DATA INVENTORIES AND<br>LITERATURE SURVEYS . . . . . | 41 |

## HYDROLOGY AND METEOROLOGY

A. HYDROLOGY

Brooks, J. E.

1961. Average Annual Runoff of Principal Streams, Oregon Almanac and Book of Facts 1961-1962. Binford and Mort, p. 138.  
(This work contains the latest available information on the State of Oregon land and natural resources.)

Griffin, W. C.

1956. Water Resources of the Portland, Oregon and Vancouver, Washington Area. U. S. Geological Survey Circular, vol. 372, no. 4, p. 45.

Grover, Nathan C. and Glenn L. Pacher

1940. Summary of Records of Surface Waters in Washington. U. S. Geological Survey, Water-Supply Paper 870, 456 pp.  
(Stream-flow records in Washington up to 1919 representing an aggregate of 1,120 years at 209 gaging stations are summarized in Water-Supply Paper 492. Similar records for the period October 1, 1919 to September 30, 1935, representing an aggregate of 1,470 years at 203 gaging stations, are summarized in this volume.)

Landes, Henry

1905. Preliminary Report on the Underground Waters of Washington. U. S. Geological Survey Water Supply Paper 111, pp. 0-85.

Mundorff, M. J., J. M. Weigle and G. D. Holmberg

1955. Ground Water in the Yelm Area, Thurston and Pierce Counties, Washington. U. S. Geological Survey Circular, vol. 356, no. iii, p. 58.

Thompson, M. Ray

1936. Water Sources, State of Washington, Bibliography of Publications, 1869-1936, Part VII. Washington State Planning Council, Olympia, pp. 701-751.

Tyler, Richard G.

1938. Water Resources of Washington. University of Washington, Engineering Experiment Station Report No. 4, 61 pp.

U. S. Bureau of Reclamation

1947. The Columbia River. U. S. Department of the Interior, Washington, vol. 1, parts 1 and 2, 398 pp.  
(A comprehensive report on the development of the water resources of the Columbia River Basin for irrigation, power production, and other beneficial uses in Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming.)

U. S. Geological Survey

- 1952-1960. Surface Water Supply of the United States: Part 11. Pacific Slope Basins in California; Part 12. Pacific Slope Basins in Washington and Upper Columbia River Basin; Part 14. Pacific Slope Basins in Oregon and Lower Columbia River Basin. Geological Survey Water-Supply Papers, U. S. Department of the Interior, (Annual volumes.)

(Annual volumes which give records of stage, discharge, and content of streams, lakes, and reservoirs. Each part is published as a separate volume.)

U. S. Geological Survey

1955a. Compilation of Records of Surface Waters of the United States through September 1950. Geological Survey Water-Supply Papers Nos. 1316, 1317, 1318. U. S. Department of the Interior, Washington, D. C.

(Summarize the discharge records from gauged streams of the Pacific slope basins in Washington, Oregon, and California and the Columbia River Basin.)

1955b. Monthly and Yearly Summaries of Hydrographic Data in the State of Washington. Geological Survey Water-Supply Bulletin No. 6, Tacoma, Washington, 836 pp.

(Includes a summary of the monthly mean discharge from 1879 to 1953 of the Columbia River gauged at The Dalles.)

B. METEOROLOGY AND WIND EFFECT

Church, Phil E.

1954. Climates of the Pacific Northwest. The Pacific Northwest, edited by Otis W. Freeman and Howard H. Martin, New York: John Wiley & Sons, Chapter 6, pp. 95-117

Cromwell, T.

1960. Pycnoclines in a Tank. Journal of Marine Research, vol. 18, no. 2, pp. 73-82.

(Tank experiments which demonstrate the behavior of pycnoclines under different conditions of mixing.)

Groen, P. and Dorrestein, R.

1958. Zeegolven, Kon. Ned. Met. Inst. report no. 11.

(Virtually all the data on wind waves published prior to 1957 have been used to obtain average wave characteristics as a function of wind duration and wind speed.)

Haight, F. J.

1942. Coastal Currents Along the Atlantic Coast of the United States. U. S. Department of Commerce, Coast and Geodetic Survey Special Publication No. 230, 70 pp.

(Partially summarizes thirty years of drift pole current measurements made by lightships along the east coast.)

Jacobs, W. C.

1951. The Energy Exchange between the Sea and Atmosphere and some of its Consequences. University of California Scripps Institution of Oceanography Bulletin, vol. 6, no. 2, pp. 27-122, 67 figs.

(Includes the only available information on precipitation and evaporation for the region of investigation.)

Jeffreys, H.

1925. On the Formation of Water Waves by Wind. Proceedings of the Royal Society of London, ser. A, vol. 107, pp. 189-206.  
(The theory is advanced that the wind presses more strongly on the slopes of the waves facing it than on the sheltered slopes, and it is when the resulting tendency of the waves to grow is just able to overcome viscosity that waves are first formed.)

Keulegan, G. H.

1951. Wind Tides in Small Closed Channels. Journal of Research of the National Bureau of Standards, vol. 46, no. 5, pp. 358-381.

Miles, J. W.

1960. On the Generation of Surface Waves by Turbulent Shear Flows. Journal of Fluid Mechanics, vol. 7, pp. 469-478.

Munk, W. H.

1955. Wind Stress on Water: An Hypothesis. Quarterly Journal of Royal Meteorological Society, pp. 320-332.  
(Over water, the function of the two-dimensional spectrum of an irregular surface is not independent of the wind velocity, and hence the form drag is proportional to the wind speed cubed rather than the speed squared as obtains for a solid surface.)

Reed, T. R.

1931. Gap Winds of the Strait of Juan de Fuca. Monthly Weather Review, vol. 59, no. 10, pp. 373-376.  
(Discussion of high percentage of easterly gales at Tatoosh Island and the reasons for their occurrence.)

Reid, R. O. and W. H. Clayton

1953. Transfer Processes Operating at the Ocean Boundaries. Second Annual Report, Project 30, Agricultural and Mechanical College of Texas, Department of Oceanography, 26 pp.  
(Preliminary report on the evaluation of wind stress upon the sea surface for varying conditions of wind speed. The evaluation was based on the Prandtl-von Kármán theory.)

Rosby, C. G. and R. B. Montgomery

1936. On the Momentum Transfer at the Sea Surface. Papers in Physical Oceanography and Meteorology. Massachusetts, vol. 4, no. 3, 30 pp.

Rouse, H. and J. Dodu

1955. Diffusion Turbulente a travers une Discontinuite de Densite. La Houille Blanche, August - September, no. 4, pp. 522-532.  
(In English).  
(Model experiments which show that: Agitation of a fluid layer has no effect upon a neighboring layer of slightly different density except in the immediate vicinity of the interface between them, that interface remaining continuously defined.)

Stewart, R. W.

1961. The Wave Drag of Wind over Water. *Journal of Fluid Mechanics*, vol. 10, pt. 2, pp. 189-194.

(It is shown to be probable that a large proportion of the drag exerted by a water surface on the wind is in the form of wave drag. As a result the usual relation between the wind profile and the surface stress and roughness length are modified. In particular, close to the surface the relation between the transport of momentum and that of heat and water vapour are different from that obtaining over a rough solid surface.)

Sverdrup, H. U.

1946. The Humidity Gradient over the Sea Surface. *Journal of Meteorology*, vol. 3, no. 1, pp. 1-8.

(It is shown that the transfer of water vapor and momentum obey similar laws and that the sea surface at wind velocity below 5 m/sec behaves as a hydrodynamically smooth surface and at velocities above 7 m/sec as a hydrodynamically rough surface with roughness length 0.6 cm.)

Van Dorn, W. G.

1952. Wind Stress Over Water. Scripps Institution of Oceanography, Technical Report No. 52-60, 23 pp. (unpublished).

#### PHYSICAL OCEANOGRAPHY

##### A. GENERAL

Aron, William

1960. The Distribution of Animals in the Eastern North Pacific and Its Relationship to Physical and Chemical Conditions. University of Washington, Department of Oceanography, Technical Report No. 63.

(Contains a discussion of the relationship of the distribution of mid-water trawl catches to oceanographic conditions. Areas near British Columbia and Washington coasts are included.)

Bennett, E. B.

1959. Some Oceanographic Features of the Northeast Pacific Ocean During August 1955. *Journal of the Fisheries Research Board of Canada*, vol. 16, no. 5, pp. 565-633

Budinger, Thomas F.

1957. Geology, Biology and Hydrography of Cobb Seamount. University of Washington Thesis.

Budinger, Thomas F. and Betty J. Enbysk

1960. Cobb Seamount, A Deep-Sea Feature off the Washington Coast. University of Washington, Department of Oceanography, Technical Report No. 60.

(Discussion of the topography, geology, biology and hydrography of the area. The section on hydrography deals with currents, water structure, and details of temperature structure in the upper layer.)

Dodimead, A. J.

1961. Some Features of the Upper Zone of the Sub-Arctic Pacific Ocean. International North Pacific Fisheries Commission, Bulletin No. 3, pp. 11-24.  
(Temperature and salinity structures and depth of the upper zone. West Coast of Vancouver Island and Washington are included in discussion. References.)

Doe, L. A. E.

1951. Sea Surface Temperatures 1950-51. Fisheries Research Board of Canada, Progress Report, Pacific No. 88, pp. 53-56.  
(Discussion of the distribution of surface temperature along the British Columbia coast and offshore as determined by cruises in 1950-51.)

1955. Offshore Waters of the Canadian Pacific Coast. Journal of Fisheries Research Board of Canada, vol. 12, no. 1, pp. 1-34.  
(Results of four oceanographic surveys, 1950-52. Discussion of temperature and salinity structure, surface currents, water masses and T-S curves, upwelling. Maps. references.)

Fleming, R. H.

1955. Review of the Oceanography of the Northern Pacific. International North Pacific Fisheries Commission, Bulletin No. 2, pp. 1-43.
1958. Notes Concerning the Halocline in the Northeastern Pacific Ocean. Journal of Marine Research, vol. 17, no. 28, pp. 158-173.

Fleming, R. H. and F. E. Elliott

1952. Some Physical Aspects of the Inshore Environment of the Coastal Waters of the United States and Mexico. Proceedings of the 7th General Assembly - 17th Congress International Geographical Union, Washington, pp. 409-416.  
(Includes discussion of the discharges of drainage basins of the United States and a summary of the coastal temperature and salinity conditions.)

Fofonoff, N. P.

1960. Description of the Northeastern Pacific Oceanography, In California Cooperative Oceanographic Fisheries Investigation Reports vol. VII, January 1960, pp. 91-95.

Geyer, R. A.

1950. Occurrence of Pronounced Periodic Salinity Variations in Louisiana Coastal Waters. Journal of Marine Research, vol. 9, pp. 100-110.

Herlinveaux, R. H.

1953. How to Predict Tidal Currents in Juan de Fuca Strait. Fisheries Research Board of Canada, Progress Report, Pacific No. 95, pp. 48-51.  
(Presentation of a set of rules for determining the direction and velocity of tidal currents in the subject area; also a short discussion on the nature of those currents.)

Hollister, H. J.

1953. Daily Seawater Observations on the Pacific Coast of Canada. Pacific Oceanographic Group, Manuscript Report File N 7-1-3-1, October 15, 1953, Nanaimo.  
(Results of daily observations. Discussion of climatic changes along Canadian coast as reflected by seawater observations.)
1954. What was the Temperature of the Sea Water on the British Columbia Coast in 1952? Fisheries Research Board of Canada, Progress Report, Pacific No. 98, pp. 6-9.  
(Discussion of coastal temperatures as observed at light stations. The 1952 temperatures were colder than a ten-year average. The locations of the sampling stations are classified into four types.)

Holway, Ruliff S.

1905. Cold Water Belt along the West Coast of the United States. University of California Publications, Bulletin of the Department of Geology, vol. 4, no. 13, pp. 263-286.  
(Temperature observations of TUSCARORA and ALBATROSS. General temperature conditions of the North Pacific Ocean, including a belt of cold water along the coast. Explanation of cold water: sinking of cold water south of Aleutians, movement southward at depths and then upwelling along coast due to shape of bottom.)

National Marine Consultants

1961. Wave Statistics for Twelve Most Severe Storms Affecting Three Selected Stations off the Coast of Washington and Oregon During the Period 1950-1960, prepared for the U. S. Army Engineers District, Seattle and Portland. Santa Barbara, California, 9 pp.

Pacific Oceanographic Group of the Fisheries Research Board of Canada

1956. Review of Canadian Oceanographic Studies in the North Pacific Ocean, 1955-56. Manuscript Report File N 7-20-6, October 24, 1956, Nanaimo.  
(Part of a report to the Director of the Pacific Biological Station. Temperature distribution and cycles, salinity and oxygen distribution, water masses, circulation.)

Pickard, G. L. and D. C. McLeod

1953. Seasonal Variations of Temperature and Salinity of Surface Waters of the British Columbia Coast. Journal of Fisheries Research Board of Canada, vol. 10, no. 3, pp. 125-145.  
(A study of the temperature and salinity observations made over a 13-year period along British Columbia coast. Discussion of variations in these properties and the factors involved.)

Powell, Donald E., Dayton L. Alverson, and Robert Livingstone, Jr.

1952. North Pacific Albacore Tuna Exploration-1950. U. S. Fish and Wildlife Service Fishery Leaflet No. 402.  
(The "magic number" according to Powell *et al.* is 57°F. This is the lowest surface temperature at which albacore are likely to be caught.)

Reid, J. L., Jr.

1960. Oceanography of the Northeastern Pacific Ocean during the Last Ten Years, In California Cooperative Oceanographic Fisheries Investigation Reports vol. VII, p. 77.

Robinson, M. K.

1960. Statistical Evidence Indicating No Long-Term Climatic Changes in the Deep Waters of the North and South Pacific Oceans. Journal of Geophysical Research vol. 65, no. 7, pp. 2097-2116.

Sverdrup, H. U.

1938. On the Process of Upwelling. Journal of Marine Research, vol. 1, no. 2, pp. 155-164.  
(Shows that the processes of upwelling are far more complicated than previously described. Thorough analysis of and discussion of upwelling phenomena based on the data in the following reference.)

Sverdrup, H. U. and R. H. Fleming

1941. The Waters off the Coast of Southern California, March to July 1937. Bulletin of Scripps Institution of Oceanography, vol. 4, no. 10, pp. 261-378.

Sette, Oscar E. and John D. Isaacs (editors)

1960. Symposium on "The Changing Pacific Ocean in 1957 and 1958", In California Cooperative Oceanic Fisheries Investigations Reports, vol. 7, January 1960. Marine Research Committee, California Department of Fish and Game, pp. 13-217.  
(Discussion of meteorological, physical oceanographic, and biological evidences of changes in the Pacific during 1957-58. Washington, Oregon coastal areas are included in the area under discussion.)

Tibby, Richard B.

1941. The Water Masses off the West Coast of North America. Journal of Marine Research, vol. 4, no. 2, pp. 112-121.  
(A discussion of the distribution of various water masses in the area named based on analysis of temperature-salinity relationships.)

Tully, John P.

1937. A Warmer Summer. Biological Board of Canada. Progress Reports of Pacific Biological Station, Nanaimo, No. 31, pp. 16-18.  
(Discussion of warmer surface temperatures during the summer of 1936 as compared to 1935, as observed at five light stations along the British Columbia coast.)

Tully, John P.

1937. Report on Dynamic Studies off the Canadian Pacific Coast, 1936. Transactions of the American Geophysical Union, 18th Annual Meeting, Part I, pp. 228-231.  
(Description of seasonal cycles of surface temperature and salinity, the effect of meteorological conditions on coastal currents, discussion of gradient and tidal currents off the west coast of Vancouver Island and near the entrance to the Strait of Juan de Fuca.)
1937. Seasons in the Sea. Biological Board of Canada, Progress Reports of Pacific Biological Station, Nanaimo, No. 33, pp. 11-12.  
(Discussion of how seasons in the sea are governed by the temperature cycle of the water. Illustrated by a graph of temperature cycle at Quatsino station. This information is incorporated into Tully, 1937, Trans. A. G. U.)
1937. Why is the Water Along the West Coast of Vancouver Island so Cold? Biological Board of Canada, Progress Reports of the Pacific Biological Station, Nanaimo, No. 34, pp. 13-15.  
(A simplified explanation of the upwelling induced by northwest winds along the Vancouver Island coast.)

Tully, John P. and E. Bertram Bennett

1952. Project "Offshore", Coastal Temperatures, and Tuna. Fisheries Research Board of Canada, Progress Report of Pacific Coast Stations, No. 92, October 1952, pp. 6-9.  
(Preliminary results from offshore oceanographic and tuna catch data. The temperature picture off Vancouver Island in August 1950 was anomalous as this was a good tuna year. The 1951 temperature picture was regular and there were poor tuna catches.)

Tully, J. P. and L. A. E. Doe

1957. Surface Waters off the Canadian Pacific Coast. Proceedings of the 8th Pacific Science Congress, 1953, vol. 3, pp. 571-584. Quezon City, Philippines.  
(Contains a discussion of water properties, origin of water masses, and circulation in the area mentioned.)

Tully, J. P. and A. J. Dodimead

1957. Canadian Oceanographic Research in the North Pacific Ocean. Fisheries Research Board of Canada, Manuscript Report, Pacific Oceanographic Group, Nanaimo, February 28, 1957 File N 7-20-6.  
(Distribution and structure of temperature and salinity, water masses, and mechanisms causing these distributions.)

## B. OCEAN CIRCULATION AND WIND STRESS

Barnes, C. A. and Robert G. Paquette

1957. Circulation Near the Washington Coast. Proceedings of the 8th Pacific Science Congress, vol. 3, pp. 585-608.  
(Discusses the water circulation off the coasts of Vancouver Island, Washington and Oregon by means of dynamic topographies and the GEK. Includes a time study in direct measurement of currents on Cobb Seamount.)

Barnes, Clifford A. and Robert G. Paquette

1954. Circulation Near the Washington Coast. University of Washington, Department of Oceanography, Technical Report No. 17.  
(Results of oceanographic measurements and current studies; comparison of GEK and other current measurements.)

Dodimead, A. J.

1958. Report on Oceanographic Investigations in the Northeast Pacific Ocean During August 1956, February 1957, and August 1957. Fisheries Research Board of Canada, Manuscript Report Series (Oceanographic and Limnological) No. 20, Pacific Oceanographic Group, Nanaimo.  
(Discussion of temperature and salinity distribution and structure, water masses and calculated currents. Maps.)

Dodimead, A. J., and H. J. Hollister

1958. Progress Report of Drift Bottle Releases in the Northwest Pacific Ocean. Journal of Fisheries Research Board of Canada, vol. 15, no. 5, pp. 851-865.  
(Report on drift bottle releases from Station Papa and at other ocean locations. The results substantiate the seasonal changes shown by the geopotential topography. Charts show the probable drifts, including some along the British Columbia and Washington coasts.)

Fofonoff, N. P.

1954. A Theoretical Study of Zonally Uniform Oceanic Flow. Department of Oceanography, Brown University Technical Report NR-083-050.  
(A mathematical model of a zonally uniform ocean is constructed in order to investigate the steady circulation and the non-homogeneous distribution of density maintained by elementary thermodynamic processes. It is concluded that thermodynamic processes affecting the density of sea water cannot be neglected in the study of zonally uniform currents in the ocean.)

1960. Transport Computations for the North Pacific Ocean, 1955. Fisheries Research Board of Canada, Manuscript Report Series No. 77, Pacific Oceanographic Group, Nanaimo.  
(The steady-state model of mass transport has been applied to extensive calculation of transports in the North Pacific Ocean. Charts representing the monthly means of Ekman and total mass transport are shown together with charts of the integrated total and geostrophic transport for 1955.)

Fofonoff, N. P. and C. Froese

1960. Programs for oceanographic computations and data processing on the electronic digital computer ALWAC III-E. M-1 Miscellaneous Programs. Fisheries Research Board of Canada, Manuscript Report Series (Oceanographic and Limnological) No. 72, 35 pp.  
(Gives the details of the computations and a description of the computer program for determining the components of Ekman and total transport from atmospheric pressure observations.)

- Marmer, H. A.  
 1926. Coastal Currents Along the Pacific Coast of the United States. U. S. Coast and Geodetic Survey, Special Pub. No. 121, Washington. (Based on observations at five lightships. Description of tidal, non-tidal and wind currents at each station. Included are Columbia River, Umatilla Reef and Swiftsure Lightships.)
- McEwen, George F.  
 1928. Ocean Surface Drift in the Pacific Coastal Belt off North America. Proceedings of the Third Pacific Science Congress, vol. 1, pp. 191-198.  
 (Calculation of surface currents from temperature data collected by naval vessels. This work was done to obtain an independent check on the work of Marmer (1926) relating surface currents to winds. Conclusion is that along the Pacific Coast the observed winds constitute the chief cause of the main surface currents.)
- Munk, W. H.  
 1950. On the Wind-Driven Ocean Circulation. Journal of Meteorology, vol. 7, no. 2, pp. 79-93.  
 (Attempt to account theoretically for the main features in the general ocean circulation. Concludes that the circulation in the upper layer of the oceans is the result chiefly of the stresses exerted by the winds.)
- Reid, R. O.  
 1948. The Equatorial Currents of the Eastern Pacific as Maintained by the Stress of the Wind. Journal of Marine Research, vol. 7, no. 2, pp. 74-99.  
 (Verifies that, in the eastern equatorial Pacific, the predominant features of the distribution of mass and of mass transports of water can be accounted for semiquantitatively in terms of the wind stress alone. Thermodynamic processes and lateral friction are ignored.)
- Reid, Joseph L., Jr., Gunnar I. Roden and John G. Wyllie  
 1958. Studies of the California Current System, In California Cooperative Oceanic Fisheries Investigations, Progress Report 1 July 1956 to 1 January 1958. Marine Research Committee, California Department of Fish and Game, pp. 27-56.  
 (Discussion of winds, currents, water masses, distribution and variation of properties, relation of the environment to plants and animals, non-seasonal variations in the system. Discussion includes Oregon and Washington coasts.)
- Sverdrup, H. U.  
 1940. The Currents of the Pacific Ocean and their Bearing on the Climates of the Coast. Science, vol. 91, no. 2360, pp. 273-282.
1947. Wind-Driven Currents in a Baroclinic Ocean; With Application to the Equatorial Currents of the Eastern Pacific. Proceedings of the National Academy of Sciences, vol. 33, no. 11, pp. 318-326.  
 (Derivation of equations which relate the distribution of mass, and corresponding mass transport to wind stress. Excellent agreement was found between the mean wind stress and the distribution of mass and accompanying currents of the equatorial Pacific Ocean.)

Thompson, W. F. and R. VanCleve

1936. Life History of the Pacific Halibut. Report of the International Fish Commission, vol. 9, pp. 50-61. Drift bottle studies.

Tully, John P.

1938. Some Relations Between Meteorology and Coast Gradient-Currents off the Pacific Coast of North America. Transactions of the American Geophysical Union, 19th Annual Meeting, Part I, pp. 176-183.

(Summary of meteorological and oceanographic conditions off the west coast of Vancouver Island during various seasons of the year and their effect on the ocean currents.)

1942. Surface Non-Tidal Currents in the Approaches to Juan de Fuca Strait. Journal of the Fisheries Research Board of Canada, vol. 5, no. 4.

### C. ESTUARIES

Burt, Wayne V.

1956. Flushing of Pollutants in the Yaquina River Estuary. Oregon State College, School of Science, Technical Report No. 1.

Burt, Wayne V. and Lowell D. Marriage

1957. Computation of Pollution in the Yaquina River Estuary. Sewage and Industrial Wastes, vol. 29, no. 12, pp. 1385-89.

(Computations using equations of Stommel (1953-same journal) and measured salinity and river flow data give the expected distribution of pollutants in the estuary.)

Burt, Wayne V. and John Queen

1957. Tidal Overmixing in Estuaries. Science, vol. 126, no. 3280, pp. 973-74.

(A discussion of the process of eddy diffusion caused by tidal currents in Coos Bay.)

Burt, Wayne V. and W. Bruce McAlister

1959. Recent Studies in the Hydrography of Oregon Estuaries. Research Briefs, Fish Commission of Oregon, vol. 7, no. 1, pp. 14-27.

(Discussion of classification of estuaries according to the system of Pritchard, and how the Oregon estuaries fit into this classification. Applications of oceanographic data to biological and engineering problems in Oregon estuaries.)

Callaway, Richard J.

1960. Prospectus for an Oceanographical Investigation of the Umpqua River Estuary and Related Studies of the Umpqua River Basin. U. S. Public Health Service, Water Supply and Pollution Control Program, Region IX, Portland, Oregon.

- Committee on Tidal Hydraulics, U. S. Army Corps of Engineers  
 1960. Present and Potential Channel Maintenance Problems in Lower Columbia Estuary. 13 pp. (30-page discussion).  
 (Comments and recommendations by the committee after examining results of 1959 prototype study, include jetty rehabilitations, problems of shoaling, selection of spoil areas, and extent of salt water intrusion. A model study is suggested.)
- Cromwell, T.  
 1960. Pycnoclines in a Tank. Journal of Marine Research, vol. 18, no. 2, pp. 73-82.  
 (Tank experiments which demonstrate the behavior of pycnoclines under different conditions of mixing.)
- Eriksen, Arne and Lawrence D. Townsend  
 1940. The Occurrence and Cause of Pollution in Grays Harbor, Washington. State Pollution Commission, Pollution Series, Bulletin No. 2.  
 (Includes data from stations near the mouth of Grays Harbor: Data from chemical analyses: Chlorinity, dissolved oxygen, and pH are given.)
- Herlinveaux, R. H.  
 1953. Surface Tidal Currents in Juan de Fuca Strait. Pacific Oceanographic Group, Manuscript Report File N 7-27, May 15, 1953, Nanaimo.  
 (Description of tidal currents, methods of prediction.)
- Hickson, R. E.  
 1953. Salinity Observations Columbia River in 1936. U. S. Army Engineers, Portland. Memorandum dated 10 April 1953 (Mimeographed).  
 (On file at Portland District Office.)  
 (A discussion of the salinity distribution from the mouth of the river to Harrington Point.)
- National Marine Consultants  
 1961. Oceanographic Study for Breakwater Sites located at Yaquina Bay, Siuslaw River, Umpqua River, and Coos Bay, Oregon, prepared for U. S. Army Engineers District, Portland. Santa Barbara, California, 14 pp.
1961. Oceanographic Study for Columbia River Entrance, prepared for U. S. Army Engineers District, Portland. Santa Barbara, California, 15 pp. plus diagrams.  
 (This reference was not examined. Contents include wave refraction diagrams.)
- Pritchard, D. W.  
 1952. Estuarine Hydrography, In Advances in Geophysics, vol. 1. Academic Press Inc., New York, pp. 243-280.

Ratray, Maurice, Jr.

1957. On the Offshore Distribution of Tide and Tidal Current. Transactions of the American Geophysical Union, vol. 38, no. 5, pp. 675-680.

(The tides and tidal currents in offshore regions where the frictional effect is negligible are obtained from the tides at the adjacent shore stations by an approximate solution of the tidal equations. Data from Umatilla Reef Lightship are used as an example.)

Rouse, H. and J. Dodu

1955. Diffusion turbulente a travers une discontinuite de densite. La Houille Blanche, August - September No. 4, pp. 522-532. In English.

(Model experiments which show that: "Agitation of a fluid layer has no effect upon a neighboring layer of slightly different density except in the immediate vicinity of the interface between them, that interface remaining continuously defined.")

Schultz, E. A. and H. B. Simons

1957. Fresh Water - Salt Water Density Currents, A Major Cause of Siltation in Estuaries. U. S. Army Corps of Engineers Committee on Tidal Hydraulics Technical Bulletin No. 2, pp. 1-28.

(Describes various types of saline wedges as related to mixing in the Columbia River estuary. Describes various types of shoals formed including deposition at the mouth of the river.)

Thompson, Thomas G. and Kenneth T. Barkey

1938. Observations on Fjord-Waters. Transactions of the American Geophysical Union, 19th Annual Meeting, 1938, pp. 254-260.

(Distribution of temperature, salinity, density, oxygen, nitrites, silicates and phosphates in Seymour Inlet (west coast of British Columbia) and adjacent waters. Discussion of water movements and structure.)

Trites, R. W.

1956. A Study of the Oceanographic Structure in British Columbia Inlets and Some of the Determining Factors. Fisheries Research Board of Canada, Manuscript Report, Atlantic Oceanographic Group, St. Andrews, N. B.

(Discussion of salt balance and diffusion coefficient. Describes technique for determining total water inflow using precipitation observations and river flow measurements, also a method for determining seaward movement of brackish layer.)

Tully, John P.

1937. Oceanography of Nootka Sound. Journal of Biological Board of Canada, vol. 3, no. 1, pp. 43-69.

(Describes characteristic tidal circulation in a canal, a fiard and and a fiord. The oxygen content gives evidence of upwelling offshore. A zone of photosynthetic activity is present.)

Tully, J. P.

1949. Oceanography and Prediction of Pulp Mill Pollution in Alberni Inlet. Fisheries Research Board of Canada, Ottawa, 169 pp.

1952. Notes on the Behaviour of Fresh Water Entering the Sea. Proceedings of the Seventh Pacific Science Congress, vol. 3, pp. 267-288, Wellington.  
(Theoretical discussion illustrated with examples from Alberni Inlet, Chatham Sound, and the west coast of Vancouver Island.)

Tully, J. P. and F. G. Barber

1960. An Estuarine Analogy in the Sub-Arctic Pacific Ocean. Journal of the Fisheries Research Board of Canada, vol. 17, no. 1, pp. 91-112.

(Discusses entrainment process, a unidirectional upward transfer of sea water coupled with a random mixing process in the halocline, as applied to the open sea.)

U. S. Army Corps of Engineers

1960. Interim Report on 1959 Current Measurement Program, Columbia River at Mouth, Oregon and Washington. On file, District Library, Portland, Oregon.

Vol. 1, 15 pp (Describes program and methods.)

Vol. 2 - 4 (Describe velocity, direction, and volume of flow, tide gaging, and salinity data from 7 ranges across lower 57 miles of the Columbia River.)

#### CHEMICAL OCEANOGRAPHY

Clarke, Frank W.

1924. The Composition of the River and Lake Waters of the United States. U. S. Geological Survey Professional Paper 135, 199 pp.  
(Columbia River covered.)

Columbia Basin Inter-Agency Committee, Subcommittee on Water Pollution  
1952. Inventory of Published and Unpublished Sediment-Load Data and Chemical Analysis of Surface Waters in the Pacific Northwest, 1951. Administrative use only, 44 pp. (mimeographed).  
(Chehalis River and tributaries included.)

Haendler, Helmut M. and Thomas G. Thompson

1939. The Determination and Occurrence of Aluminum in Sea Water. Journal of Marine Research, vol. 2, no. 1. pp. 12-16.  
(Method of analysis. Results of samples taken at Friday Harbor and at stations off Cape Flattery.)

Richards, F. A.

1957. Oxygen in the Oceans, In Treatise on Marine Ecology and Paleoecology. (Ed. J. W. Hedgpeth). Geological Society of America, New York, vol. 1, Chapter 9.  
(Discusses the phenomena of oxygen minimum in the oceans.)

- Robeck, Gordon G., Croswell Henderson and Ralph C. Palange  
1954. Water Quality Studies on the Columbia River. U. S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati.  
(This publication deals mostly with the river itself. However, the results of a few radio activity measurements made at Astoria are given.)
- Robinson, Rex J. and Henry E. Wirth  
1934. Free Ammonia, Albuminoid Nitrogen and Organic Nitrogen in the Waters of the Pacific Ocean off the Coasts of Washington and Vancouver Islands. Journal du Conseil, vol. 9, no. 2, pp. 187-195.  
(Methods of analysis, description and analysis of results based on stations off Vancouver Island, offshore from Cape Flattery, and in the Strait of Juan de Fuca.)
- Thompson, Thomas G. and Raymond W. Bremner  
1935. The Occurrence of Iron in the Waters of the North-East Pacific Ocean. Journal du Conseil, vol. 10, no. 1, pp. 39-47.  
(Includes results of analyses from stations off Washington and Vancouver Island and Gulf of Alaska.)
- Thompson, Thomas G., Joseph W. Lang and Lucile Anderson  
1927. The Sulfate-Chloride Ratio of the Waters of the North Pacific. Publications of the Puget Sound Biological Station, vol. 5, pp. 277-292.  
(Methods of analysis, discussion of results, and data. Areas studied include Grays Harbor.)
- Thompson, T. G., B. D. Thomas, and C. A. Barnes  
1934. Distribution of Dissolved Oxygen in the North Pacific Ocean. James Johnston Memorial Volume, University of Liverpool Press, pp. 203-234.
- Utterback, C. L. and Wilhelm Jorgensen  
1934. Absorption of Daylight in the North Pacific Ocean. Journal du Conseil, vol. 9, no. 2, pp. 197-209.  
(Results of measurements of total vertical absorption coefficients with a submarine photometer at stations off Washington and Vancouver Island coasts. Comparison with inshore and lake measurements by others.)
- Wirth, Henry E., Thomas G. Thompson and Clinton L. Utterback  
1935. Distribution of Isotopic Water in the Sea. Journal of the American Chemical Society, vol. 57, pp. 400-404.  
(The discussion includes results from one station 90 miles west of Cape Flattery. Comparison of density between water distilled from tap water.)
- U. S. Geological Survey  
1959. Study and Interpretation of the Chemical Characteristics of Natural Water. Department of Commerce, Geological Survey Water-Supply Paper 1473, Washington, 269 pp.

U. S. Geological Survey

1961. Quality of the Surface Waters of Washington, January 1959 - July 1960. Data Report of the State of Washington prepared by Pollution Control Commission, Department of Conservation U. S. Geological Survey.

## AVAILABLE DATA

A. OBSERVATIONS IN THE NORTHEAST PACIFIC OCEAN

Association d' Oceanographie Physique, Union Geodesique et Geophysique Internationale

- 1940. Monthly and Annual Mean Heights of Sea Level, up to and Including the Year 1936. Publication Scientifique No. 5.
- 1950. Monthly and Annual Mean Heights of Sea Level, 1937 to 1946, and Unpublished Data for Earlier Years. Publication Scientifique No. 10.
- 1953. Monthly and Annual Mean Heights of Sea Level, 1947 to 1951, and Unpublished Data for Earlier Years. Publication Scientifique No. 12.

(All three volumes contain data from Victoria, Seattle, and Clayoquot, B. C.)

Barnes, Clifford A. and Thomas G. Thompson

- 1938. Physical and Chemical Investigations in Bering Sea and Portions of the North Pacific Ocean. University of Washington Publications in Oceanography, vol. 3, no. 2.  
(Some observations of surface temperature, salinity and pH apply to the area under consideration.)

Burt, Wayne V.

- 1956. Hydrography of Oregon Estuaries Prior to June 1956. Oregon State College, School of Science, Data Report No. 2.  
(Contains a tabulation of oceanographic data from Oregon estuaries, including temperature, salinity, and current velocity.)

Callaway, Richard J.

- 1961. Physical and Chemical Oceanographic Data, Umpqua River Estuary. U. S. Public Health Service, Water Supply and Pollution Control Program, Region IX, Portland, Oregon. Part I: December 14-15, 1960; Part II: January 25-26, 1961.  
(Both parts contain physical, chemical and current measurement data from stations inside the river entrance.)

Canadian Joint Committee on Oceanography

- 1956. Physical, chemical and plankton data record. Project NORPAC, July 26 to September 1, 1955. Prepared by Pacific Oceanographic Group, Nanaimo, B. C. File N-6-17-4(2), February 1, 1956.  
(Contains tabulated data. Sta. 1-3, 82-85 are applicable to the area under consideration.)

Collias, Eugene E., Cuthbert M. Love and Robert G. Paquette

- 1956. Eastern North Pacific and Gulf of Alaska Offshore Physical and Chemical Data, April 1954 - January 1955. University of Washington, Department of Oceanography Technical Report No. 49.  
(This and other University of Washington reports cited in this section contain tabulated physical and chemical data from oceanographic stations.)

Dodimead, A.J., K. B. Abbott-Smith and H. J. Hollister

1960. Oceanographic Data Record, North Pacific Survey, January 12 to February 10, 1960. Manuscript Report Series (Oceanographic and Limnological) No. 63, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.

(This and other Canadian data reports cited in this section contain tabulated physical and chemical data from oceanographic stations and, in some cases, reproductions of BT traces.)

Note: In citing future reports in this series the phrase "Manuscript Report Series (Oceanographic and Limnological) No. . ." will be abbreviated as "MSS . . .".

Dodimead, A. J., L. F. Giovando, R. H. Herlinveaux, R. K. Lane, and H. J. Hollister

1960. Oceanographic Data Record, North Pacific Surveys, July 10 to September 6, 1960. MSS No. 82, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.

Favorite, Felix, and Cuthbert M. Love

1957. Northeast Pacific Ocean and Gulf of Alaska Physical and Chemical Data, Summer and Fall 1955. University of Washington Department of Oceanography, Special Report No. 28.

Favorite, Felix and Glenn Pedersen

1958. North Pacific and Bering Sea Oceanography, May - September, 1957. A Preliminary Tabulation of Oceanographic Data collected by Vessels of the U. S. Fish and Wildlife Service Engaged in a Study of the Distribution and Migration of Salmon in the North Pacific and the Bering Sea. U. S. Fish and Wildlife Service, Seattle.

(Contains tabulated data. One station, Paragon 25 at 50°N, 130°W near the north end of Vancouver Island applies to area under consideration.)

1959. North Pacific and Bering Sea Oceanography, 1958. U. S. Fish and Wildlife Service. Special Scientific Report, Fisheries No. 312.

(Contains tabulated station data and surface temperature and weather observations from BT lowerings. Three Pioneer stations, Nos. 103, 104, 105 are applicable to the area under consideration, also some of the BT data.)

Fleming, ~~Richard H.~~ and Staff

1956. ~~NORPAC 1955~~, M. V. Brown Bear, August 1 to September 19, 1955. Preliminary Data Report. University of Washington Department of Oceanography, Special Report No. 22.

1958. Physical and Chemical Data, North Pacific Ocean, Brown Bear Cruise 176, July - September, 1957, for the International Geophysical Year of 1957-58. University of Washington Department of Oceanography, Special Report No. 29.

1959. Physical and Chemical Data, North Pacific Ocean, Brown Bear Cruise 199, July - August 1958, for the International Geophysical Year of 1957-58. University of Washington Department of Oceanography, Special Report No. 30.

- Goodman, Joe and Thomas G. Thompson  
 1940. Characteristics of the Waters in Sections from Dutch Harbor, Alaska, to the Strait of Juan de Fuca and from the Strait of Juan de Fuca to Hawaii. University of Washington Publications in Oceanography, vol. 3, no. 3.  
 (Contains tabulated data. Stations 10-12 Oglala (1935) first section and 1-4 of second section apply to the area under consideration. Some of the Northland (1938) surface data also applies.)
- Herlinveaux, R. H., O. D. Kennedy, H. J. Hollister  
 1960. Oceanographic Data Record, Coastal-Seaways Project, November 16 to December 11, 1959. MSS No. 58, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.
- Hollister, H. J.  
 1960. Bathythermograms and Meteorological Data Record, Swiftsure Bank and Umatilla Reef Lightships, 1959. MSS No. 62, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.  
 (Contains reproductions of BT traces and a tabulation of meteorological data, both obtained twice daily.)
- Igelsrud, Iver, Rex J. Robinson and Thomas G. Thompson  
 1936. The Distribution of Phosphates in the Sea Water of the Northeast Pacific. University of Washington Publications in Oceanography, vol. 3, no. 1, pp. 1-34.  
 (Contains data from Catalyst (1932) stations.)
- Lane, R. K., J. Butters, W. Atkinson, H. J. Hollister  
 1961. Oceanographic Data Record, Coastal and Seaways Projects, February 6 to March 2, 1961. MSS 91, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.
- Lane, R. K., J. Butters, W. R. Harling, H. J. Hollister  
 1961. Oceanographic Data Record, Coastal Project, November 27 to December 9, 1960. MSS 84, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.
- Lane, R. K., R. H. Herlinveaux, W. R. Harling, H. J. Hollister  
 1960. Oceanographic Data Record, Coastal and Seaways Projects, October 3 to 26, 1960. MSS 83, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.
- Lane, R. K., J. H. Meikle, H. J. Hollister  
 1960a. Oceanographic Data Record, Coastal Project, May 4 to 14, 1960. MSS 70, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.
- 1960b. Oceanographic Data Record, Coastal Project, June 6 to 16, 1960. MSS 76, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.
- Love, Cuthbert M.  
 1957. Northeast Pacific Ocean Physical and Chemical Data, Summers of 1955 and 1956. University of Washington, Department of Oceanography Technical Report No. 55.

Love, Cuthbert M.

- 1957. Physical and Chemical Data--Gulf of Alaska, Spring and Summer 1956 and Spring 1957. University of Washington, Department of Oceanography Technical Report No. 56.
- 1959. Physical and Chemical Data, North Pacific Ocean, Gulf of Alaska, and Bering Sea, Summer of 1956. University of Washington, Department of Oceanography Special Report No. 31.
- 1960. Physical and Chemical Data for a Portion of the Northeast Pacific Ocean Extending from the Coasts of Washington and British Columbia Westward to 131°W, April 1956 - April 1958. University of Washington, Department of Oceanography Technical Report No. 66.

Manzer, J. I. and H. J. Hollister

- 1960. Data Record of Bathythermograms Observed by Fisheries Research Board Chartered Fishing Vessels, March - September 1959. MSS 66, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.  
(Contains reproductions of BT traces.)

Matudaira, Y.

- 1936. Report of the Surface Observations Along the Routes of the Cruise of the Training Ship "Shintoku Maru". Journal of Oceanography, vol. 9, no. 1, p. 81.  
(Contains tabulations of surface data. Cruise 22 from Kobe to Coos Bay to Auckland, passed through the area under consideration.)

NORPAC Committee

- 1960. Oceanic Observations of the Pacific: 1955. The NORPAC Data Prepared by the NORPAC Committee, University of California Press and University of Tokyo Press, Berkeley and Tokyo.  
(Contains tabulated data from all agencies participating in the NORPAC operation.)

Pacific Oceanographic Group of the Fisheries Research Board of Canada

- 1950. Pacific Coast Data Record, Offshore Survey 1936. Manuscript Report, Nanaimo.
- 1952. Pacific Coast Data Record, Offshore Survey, August 1-14, 1951. Manuscript Report, Nanaimo.
- 1955. Physical and Chemical Data Record, Juan de Fuca Strait Project, 1951-52. MSS Report. File N-6-24(1), April 30, 1955, Nanaimo.
- 1955. Data Record, Barkley Sound, April 4-27, 1950. MSS Report. File N-7-21, December 15, 1955, Nanaimo.
- 1956. Physical and Chemical Data Record, Approaches to Juan de Fuca Strait, 1936-1938. MSS Report. File N-7-1-3(1), November 15, 1956, Nanaimo.

- Pacific Oceanographic Group of the Fisheries Research Board of Canada
1957. Physical, Chemical and Plankton Data Record, North Pacific Survey, July 31 - September 2, 1956. MSS Report. File N-7-1-3(2), May 31, 1957, Nanaimo.
1957. Physical, Chemical and Plankton Data Record, North Pacific Survey, January 23 to March 4, 1957. MSS Report. File N-7-1-3(2), August 15, 1957, Nanaimo.
1957. Physical, Chemical and Plankton Data Record, North Pacific Survey, July 23 to August 30, 1957. MSS 4, Nanaimo.
1958. Bathythermograms and Meteorological Data Record, Swiftsure Bank and Umatilla Reef Lightships, June 1954 to December 1956. MSS 8, Nanaimo.  
(Contains reproductions of BT traces and a tabulation of meteorological data.)
1958. Physical, Chemical and Plankton Data Record, North Pacific Survey, March 11 to April 10, 1958. MSS 16, Nanaimo.
1958. Physical, Chemical and Plankton Data Record, Coastal Surveys April 25 to December 17, 1957. MSS 17, Nanaimo.
1958. Bathythermograms and Meteorological Data Record, Swiftsure Bank and Umatilla Reef Lightships, 1957. MSS 22, Nanaimo.  
(Contains reproductions of BT traces and a tabulation of meteorological data.)
1958. Physical and Chemical Data Record, North Pacific Surveys, Western Aleutians and Bering Sea, June 27 to August 14, 1958. MSS 28, Nanaimo.
1958. Physical and Chemical Data Record, North Pacific Surveys, Continental Shelf and Gulf of Alaska, July 22 to August 16, 1958. MSS 29, Nanaimo.
1959. Physical and Chemical Data Record, Coastal Seaways Project, November 12 to December 5, 1958. MSS 36, Nanaimo.
1959. Bathythermograms and Meteorological Data Record, Swiftsure Bank and Umatilla Reef Lightships, 1958. MSS 37, Nanaimo.  
(Contains reproductions of BT traces and a tabulation of meteorological data.)
1959. Physical and Chemical Data Record, North Pacific Surveys, January 20 to February 15, 1959. MSS 43, Nanaimo.
1959. Physical and Chemical Data Record, Coastal Seaways Project, March 31 to April 22, 1959. MSS 47, Nanaimo.
1959. Oceanographic Data Record, P.N.L. Surveys, 1958. MSS 49, Nanaimo.
1959. Oceanographic Data Record, Coastal-Seaways Project, June 8 to July 1, 1959. MSS 52, Nanaimo.

Pacific Oceanographic Group of the Fisheries Research Board of Canada

Sea Water Temperature, Salinity and Density on the Pacific Coast of Canada. Manuscript Report, Nanaimo.

|                        |                  |
|------------------------|------------------|
| Vol. I, 1914 to 1934   | Vol. XI, 1951    |
| Vol. II, 1935 to 1937  | Vol. XII, 1952   |
| Vol. III, 1938 to 1939 | Vol. XIII, 1953  |
| Vol. IV, 1940 to 1941  | Vol. XIV, 1954   |
| Vol. V, 1942 to 1943   | Vol. XV, 1955    |
| Vol. VI, 1944 to 1945  | Vol. XVI, 1956   |
| Vol. VII, 1946 to 1947 | Vol. XVII, 1957  |
| Vol. VIII, 1948        | Vol. XVIII, 1958 |
| Vol. IX, 1949          | Vol. XIX, 1959   |
| Vol. X, 1950           |                  |

(These volumes contain tabulations of daily temperature, salinity and density (up to 1951) observations.)

- Paquette, Robert G., Eugene E. Collias, and Cuthbert M. Love  
 1954. Eastern North Pacific Offshore Physical and Chemical Data Observed During 1952. University of Washington, Department of Oceanography Technical Report No. 22.
1954. Eastern North Pacific Offshore Physical and Chemical Data, April - June 1953. University of Washington, Department of Oceanography Technical Report No. 23.
1954. Eastern North Pacific Offshore Physical and Chemical Data, July - September 1953. University of Washington, Department of Oceanography Technical Report No. 34.
- Queen, John and Wayne V. Burt  
 1955. Hydrography of Coos Bay. Oregon State College, School of Science, Data Report No. 1.  
 (This reference was not examined.)
- Sands, Walter Casper  
 1937. Hydrodynamical Investigations off the Pacific Coast of North America. Thesis of the University of Washington.  
 (Contains data from a few Catalyst (1935-36) stations off the Washington coast and Queen Charlotte Islands.)
- Strickland, J. D. H.  
 1958. Data Record and Discussion, a Special British Columbia Coastal Survey Measuring Chemical and Light Attenuation Properties, June 23 to July 4, 1958. MSS 30, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.  
 (Contents are indicated by the title.)
- Sverdrup, H. U., et al.  
 1943. Oceanic Observations of the Scripps Institution in 1939. Records of Observations, Scripps Institution of Oceanography, vol. 1, no. 2.  
 (The data from E. W. Scripps Cruise VIII includes stations off the Oregon coast.)

- Tabata, S., C. D. McAllister, D. G. Robertson, and H. J. Hollister  
 1960. Data Record Ocean Weather Station "P" (latitude 50°00' N, longitude 145°00' W), January 21 - November 24, 1959. MSS No. 59. Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.  
 (Also contains station data taken enroute to and from Station "Papa" which are applicable to the area under consideration.)
- Thompson, Thomas G., Bertram D. Thomas and Clifford A. Barnes  
 1934. Distribution of Dissolved Oxygen in the North Pacific Ocean. James Johnstone Memorial Volume, University of Liverpool. Also University of Washington Publications in Oceanography, Supplementary Series No. 21.  
 (Contains temperature, chlorinity, oxygen, phosphate, density, carbon dioxide and silicate data from Catalyst (1932-33) stations off Washington and Vancouver Island coasts.)
- U. S. Army Engineer District, Portland  
 1960. Interim Report on 1959 Current Measurement Program Columbia River at Mouth, Oregon and Washington, 1 September 1960. (On file at Portland District Office)  
 Vol. 1 contains a description of the program and methods.  
 Vol. 2 - velocity data  
 Vol. 3 - direction data  
 Vol. 4 - flow, tide gauge, and salinity data.
- U. S. Bureau of Fisheries  
 1921. Dredging and Hydrographic Records of the U. S. Fisheries Steamer Albatross 1911 - 1920. Bureau of Fisheries Document No. 897 (Appendix III to the Report of the U. S. Commissioner of Fisheries for 1920.)  
 (Data collected off the Oregon-Washington coasts in 1914-15 are tabulated on pp. 82-143. These data are mostly bottom notations, surface and air temperatures.)
- U. S. Coast and Geodetic Survey  
 1958. Density of Sea Water at Tide Stations, Pacific Coast North and South America and Pacific Ocean Islands. Coast and Geodetic Survey Publication 31-4. Fifth Edition. Washington. (Includes data from Oregon-Washington coasts.)
1956. Surface Water Temperatures at Tide Stations, Pacific Coast North and South America and Pacific Ocean Islands. Special Publication No. 280. Fifth Edition. Washington. (Includes data from Oregon-Washington coasts.)
1959. United States Coast Pilot, No. 7, Pacific Coast: California, Oregon, Washington and Hawaii. 8th Edition, U. S. Department of Commerce, Washington, U. S. Government Printing Office. 383 p.
1961. Current Tables, Pacific Coast North America and Asia for the Year 1961. U. S. Department of Commerce, Washington, D. C.

## U. S. Coast and Geodetic Survey

1960. Tide Tables, High and Low Water Predictions West Coast North and South America 1961. U. S. Department of Commerce, Washington, D. C. 223 pp.

## U. S. Navy Hydrographic Office

1934. Dynamic Oceanographic Data for the Central Eastern Pacific Ocean and Surface Temperature and Salinity Data for the Eastern Pacific Ocean. Hydrographic Office Publication No. 212. Washington.  
(Some of the tabulated surface temperature and salinity data observed by naval vessels are applicable to the area under consideration.)

## University of California, Scripps Institution of Oceanography

- 1935-1960- Daily Surface Water Temperature and Salinity at Shore Stations of Washington, Oregon, California and Baja California Coasts. Data Archives Scripps Institution of Oceanography.

(Tabulation of daily sea water temperature and at some stations daily salinity. Information available for Swifsure, Umatilla, Neah Bay, Depoe Bay, Columbia River, Port Orford, Crescent City, and Blunts reef.)

1956. NORPAC Hydrographic Data. Scripps Institution of Oceanography Reference 56-4.

(Includes tabulated oceanographic station data from the area off the Oregon-Washington coasts.)

1957. Surface Water Temperatures at Shore Stations, United States West Coast and Baja California, 1955. Scripps Institution of Oceanography Reference 57-28.

(Contains tabulations of daily temperature, also means, maxima, minima, range and standard deviations. Stations in Oregon-Washington are included.)

1960. Surface Water Temperatures at Shore Stations, United States West Coast and Baja California, 1956-1959. Scripps Institution of Oceanography Reference 60-27.

(In this second volume the contents were changed and monthly means, 10-day means, maxima, minima, range and standard deviation are published.)

Oceanic Observations of the Pacific. University of California Press, Berkeley and Los Angeles.

1957. Volume containing 1949 observations.

1960. Volume containing 1950 observations.

(Contains all available oceanographic data from the Pacific collected by several agencies, also maps showing the number of BT observations available in the Pacific area. Both volumes contain data from the area under consideration.)

University of California, Scripps Institution of Oceanography,  
Marine Life Research

The following reports contain data from the Oregon Coast,  
i.e., north of 42°N latitude:

- 1949. Physical and Chemical Data, Cruise 2, March 28 to April 12, 1949.
- 1949. Physical and Chemical Data, Cruise 3, April 28 to May 14, 1949.
- 1949. Physical and Chemical Data, Cruise 5, July 1 to July 16, 1949.
- 1950. Physical and Chemical Data, Cruise 7, September 5 to September 18, 1949.
- 1950. Physical and Chemical Data, Cruise 8, October 3 to October 20, 1949.
- 1950. Physical and Chemical Data, Cruise 9, November 8 to November 25, 1949.
- 1951. Physical and Chemical Data, Cruise 17, 5-19 August 1950.
- 1951. Physical and Chemical Data, Cruise 18, 6-22 September 1950.

University of California, Scripps Institution of Oceanography Manuscript  
Data.

Unpublished data from three Pioneer (1928) stations and from two Serrano (1949) stations off Oregon coast are available at Scripps Institution of Oceanography. Copies also on file at University of Washington, Department of Oceanography.

University of Washington, Department of Oceanography, Manuscript Data

Unpublished data from the following Brown Bear cruises are on file:

- Cruise 202: September - October 1958, Coasts of Washington and Vancouver Island
- Cruise 234: June - July 1959, Coast of Washington
- Cruise 235: July 1959, Gulf of Alaska
- Cruise 254: March 1960, Western Pacific
- Cruise 265: June 1960, Washington Coast
- Cruise 275: January 1961, Coasts of Oregon and Washington
- Cruise 280: March 1961, Coasts of Oregon and Washington
- Cruise 282: April 1961, Coast of Washington
- Cruise 287: May 1961, Coasts of Oregon and Washington

Westley, Ronald E.

- 1958. Observations of Sea Water Temperature, Density and Salinity, State of Washington, 1951-1957. Washington Department of Fisheries, Hydrographic Data, vol. 1, no. 2, 86 pp. (mimeographed). (Includes observations from Grays Harbor and Willapa Bay.)

Wyatt, Bruce and Richard Callaway

- 1961. Physical Hydrographic Data Offshore from Newport, Oregon, for July 1958 to July 1959. Oregon State College, Department of Oceanography, Data Report No. 4, Ref. 61-1. (Contains data from a line of oceanographic stations running from the entrance to Yaquina Bay to 25 miles offshore.)

## B. ATLASES AND AVERAGE CONDITIONS

Deitch, Samuel

1937. A Table of Monthly Mean Sea-Water Temperatures for 30 Stations of the United States and Alaska. Bulletin of the American Meteorological Society, vol. 18, no. 12, p. 390.  
(There is no mention of from what data the means were taken.)

McGary, James W. and Thomas M. Naito

1957. Wind Atlas of the North Pacific. U. S. Fish and Wildlife Service, Special Scientific Report, Fisheries No. 243, Washington.  
(A summary of average wind speeds in the Pacific north of 30°N. Conditions are portrayed by a series of five charts for each month.)

Dodimead, A. J.

1960. Atlas of Oceanographic Data, North Pacific Survey, January 12 to February 10, 1960. Fisheries Research Board of Canada, MSS Report Series, No. 69, Pacific Oceanographic Group, Nanaimo.  
(Contains charts and cross-sections of various properties measured during the subject cruises.)

Dodimead, A. J. and F. Favorite

1961. Oceanographic Atlas of the Pacific Subarctic Region, Summer 1958. MSS Report Series, No. 92, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.  
(Contains charts and cross-sections compiled from data from twelve oceanographic cruises which took place during the subject period.)

Fofonoff, N. P.

- Transport Calculations for the North Pacific Ocean. Manuscript Report Series, Fisheries Research Board of Canada, Pacific Oceanographic Group, Nanaimo.  
1960. MSS 77 - contains 1955 data.  
1960. MSS 78 - contains 1956 data.  
1960. MSS 79 - contains 1957 data.  
1960. MSS 80 - contains 1958 data.  
(These volumes contain a series of charts for various months of the year showing the following: atmospheric pressure, meridional component of Ekman transport, zonal component of Ekman transport, meridional component of total mass transport, integrated total transport, and integrated geostrophic transport.)

Leipper, Dale F. and Project Staff

1954. Summary of North Pacific Weather Station Bathythermograph Data, 1943-1952. Texas A & M Research Foundation, Project 29, Technical Report No. 7.  
(Contains graphical summaries of temperature conditions.)

Muromtsev, A. M.

1958. Basic Patterns of the Hydrology of the Pacific Ocean. Oceanographic Institute, Leningrad (in Russian). (There is a supplement (atlas) in a separate volume. Main volume contains averages by ten-degree squares of temperature, salinity, density, and oxygen at various levels for most of the Pacific. The supplement contains charts and cross-sections of the above data.)

NORPAC Committee

1960. Oceanic Observations of the Pacific: 1955, the NORPAC Atlas Prepared by the NORPAC Committee. University of California Press and University of Tokyo Press, Berkeley and Tokyo. (Companion to the NORPAC volume. Contains charts of the properties observed by all participating agencies.)

Pacific Oceanographic Group, Fisheries Research Board of Canada

1959. Atlas of Physical and Chemical Data, North Pacific Surveys, January 20 to February 15, 1959. MSS Report Series, No. 50, Nanaimo. (Contains charts and cross-sections of various properties measured during the subject cruises.)

Patterson, J.

1933. Water Temperatures on the Pacific and Their Effect on the Weather of Canada. Proceedings of the 5th Pacific Science Congress, vol. 3, p. 1775. (Contains a table of normal sea-surface temperatures by five-degree squares for each week of the year along certain ship routes in the Pacific, based on observations from 1923-1932. There is also a table of departure from normal for each season of each year listed and graphs of mean temperatures and departures from normal.)

Robinson, Margaret K.

1957. Sea Temperature in the Gulf of Alaska and in the Northeast Pacific Ocean, 1941-1952. Bulletin of Scripps Institution of Oceanography, vol. 7, no. 1, pp. 1-98, University of California Press, Berkeley and Los Angeles. (The main feature of this work is a series of charts showing the average temperature at the surface and the 100-, 200-, 300- and 400-foot levels for each month. These charts are based on 16,000 BT observations taken over an eleven-year period. There is also a discussion of the methods used in processing the data and of the errors involved.)
1960. Temperature and Salinity Anomaly Charts for Twenty-Four Canadian and American Shore Stations Based on a Common Reference Period. University of California, Scripps Institution of Oceanography, Reference 60-30. (Contains graphical summaries of temperature and salinity anomalies along the Pacific Coast, based on the years 1949-1958).

U. S. Fish and Wildlife Service, Pacific Oceanic Fishery Investigations.  
 Sea Surface Temperature, Anomaly of Sea Surface Temperature and  
 Distribution of Observations (10-day period) Northeast Pacific.  
 (A series of charts showing the above-mentioned properties for  
 the 10-day period in the middle of each month. These were  
 issued by P.O.F.I. from October 1957 to December 1959.)

U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, San Diego  
 Biological Laboratory

Sea Surface Temperature Charts, Eastern Pacific Ocean.  
 (Starting with January 1960 issuance of similar charts was taken  
 over by the San Diego Biological Lab. Monthly charts are issued for  
 each month of the year covering the area  $20^{\circ}$  -  $52^{\circ}$  N, coast to  $180^{\circ}$ .  
 In addition, 15-day charts of surface temperature only are issued  
 April through October. These cover the area  $25^{\circ}$  -  $52^{\circ}$  N, coast  
 to  $135^{\circ}$  W.)

U. S. Navy, Chief of Naval Operations

1956. Marine Climatic Atlas of the World. Vol. II, North Pacific Ocean.  
 NAVAER 50-1C-529, U. S. Government Printing Office. Washington.  
 (Contains monthly or seasonal charts of many surface and upper  
 air properties. Seasonal charts of air-sea temperature difference  
 are included.)

U. S. Navy Hydrographic Office

1947. Atlas of Surface Currents of the Northeastern Pacific Ocean.  
 Hydrographic Office Publication No. 570. Washington.  
 (One map for each month. Current roses for  $5^{\circ}$  squares. Also  
 shows surface temperature isotherms (every  $5^{\circ}$ F).)

1944. World Atlas of Sea Surface Temperatures, second edition.  
 Hydrographic Office Publication No. 225. Washington. (Reprinted 1948)  
 (Monthly contoured charts for each ocean.)

U. S. Weather Bureau

1938. Atlas of Climatic Charts of the Oceans. Weather Bureau No. 1247,  
 NAVAER 50-11OR-25. Washington.  
 (Meteorological data are presented by means of monthly or seasonal  
 charts. Included are monthly charts of sea-surface temperature by  
 five-degree squares.)

Manuscript Data Purchased from National Weather Records Center,  
 U. S. Weather Bureau, by University of Washington, Department of  
 Oceanography and Oregon Fish Commission. Copies on file at  
 University of Washington Department of Oceanography.

Job No. 8110: Monthly mean air and sea surface temperature for  
 Marsden square 157 ( $45^{\circ}$ - $50^{\circ}$ N,  $125^{\circ}$ - $130^{\circ}$ W) for the years 1937-1952  
 (months March through August only).

Job No. 9325: Similar data for 5 Marsden squares for 1937-1954  
 (all months) Square 158 ( $40^{\circ}$ - $45^{\circ}$ N,  $130^{\circ}$ - $135^{\circ}$ W) is applicable to  
 area under consideration.

(No job number): Monthly mean sea surface temperature for a number  
 of Marsden squares in the Pacific for various years up to 1936  
 (all months). Squares applicable to this project include  
 $40^{\circ}$ - $45^{\circ}$ N,  $120^{\circ}$ - $125^{\circ}$ W;  $40^{\circ}$ - $45^{\circ}$ N,  $125^{\circ}$ - $130^{\circ}$ W;  $40^{\circ}$ - $45^{\circ}$ N,  $130^{\circ}$ - $135^{\circ}$ W  
 (No. 158);  $45^{\circ}$ - $50^{\circ}$ N,  $120^{\circ}$ - $125^{\circ}$ W;  $45^{\circ}$ - $50^{\circ}$ N,  $125^{\circ}$ - $130^{\circ}$ W (No. 157);  
 $45^{\circ}$ - $50^{\circ}$ N,  $130^{\circ}$ - $135^{\circ}$ W. Some data start in 1911.

University of California, Scripps Institution of Oceanography,  
Marine Life Research Program

1951. Preliminary Report of Temperature and Salinity, Cruises 15 through 25 - 6 June 1950 to 16 May 1951. Scripps Institution of Oceanography Reference 51-11.  
(Contains plots of temperature at 10 and 50 m for all cruises and of salinity at 10 m for Cruises 15-18. Cruises 17 and 18 reached the Oregon coast (north of 42°N).

C. BIBLIOGRAPHIES, DATA INVENTORIES, AND LITERATURE SURVEYS

Grier, Mary C.

1941. Oceanography of the North Pacific Ocean, Bering Sea and Bering Strait: A Contribution Toward a Bibliography. University of Washington Publication, Library Series, vol. 2.  
(A good bibliography, but now twenty years old.)

Love, Cuthbert M.

1956. Sources of Oceanographic Data for a Portion of the North Pacific Ocean. University of Washington, Department of Oceanography Special Report No. 25.  
(An annotated listing of sources of data for the area 20°-55°N, west coast of North America to 150°W, for the years 1916-1954.)

Saur, J. F. T.

1958. Sources of Time-Series Oceanographic and Meteorological Data of the Pacific Ocean. U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Stanford, California Ocean Research Note 8 (Preliminary). Unpublished.  
(A comprehensive annotated list of sources of time-series data, summaries and charts of mean values, and special data collections.)

U. S. Navy Hydrographic Office

1958. Index to Oceanographic Station Data. Special Publication 12. Washington.  
(An index of all station data on file at the Hydrographic Office arranged by area. "North Pacific Ocean" includes the area under consideration.)
1960. Inventory of BT Data (National Oceanographic Data Center), World Wide, all Oceans and Seasons. Special Publication 12, (Part II). Washington.  
(Maps show number of BT observations available for each Marsden square for 3-month periods.)

University of Washington, Department of Oceanography

1954. Puget Sound and Approaches, A Literature Survey  
Vol. I, Geography, Climatology, Hydrology  
Vol. II, Geology, Volcanology, Seismology, Geomagnetism,  
Geodesy, Hydrography  
Vol. III, Physical Oceanography, Marine Biology, General  
Summary.

(Summarized, tabular and graphical information on the subjects listed. There is a large bibliography on each subject.)

1955. Coos Bay, Oregon, A Literature Survey. 142 pp. (dittoed).  
(This work is in the form of an abstract of the current knowledge of each subject covered. The subjects include: geography, climatology, hydrology, regional geology, geophysics, recent sedimentation, hydrography, physical oceanography, and marine biology. There are tables and a bibliography for each section.)
1955. Grays Harbor, Washington, A Literature Survey. 142 pp. (dittoed).  
(This work is in the form of an abstract of the current knowledge of each subject covered. The subjects include: geography, climatology, hydrology, regional geology, geophysics, recent sedimentation, hydrography, physical oceanography, and marine biology.)

SECTION II: BIOLOGICAL OCEANOGRAPHY

## INTRODUCTION

For the Northeast Pacific Ocean there exists little information on the quantitative and qualitative distribution of the smaller pelagic organisms and the relation of that distribution to the environmental conditions. The effect of a large fresh water discharge into an otherwise wholly marine environment is virtually unknown. The influence of the Columbia River is of major importance in the seasonal, vertical and geographical distribution of plankton. Major research must be conducted first to determine the distribution of organisms and then to relate the effect of the Columbia effluent on the biological regime. Only then will it be possible to evaluate the local effects as the Columbia Plume changes in size and location throughout the annual cycle of runoff.

Because a study of the effects of the Columbia River on the distribution and productivity of plankton is a pioneering investigation, many references included in the present survey have been drawn from outside areas, with particular emphasis on the North Pacific Ocean. Included in the bibliography are references pertinent to methods of collection, analysis and identification of plankton. Some references are also given for research in other areas or on general plankton problems. References pertaining to studies made in the freshwater environment of the Columbia River and those on the contiguous littoral area have been largely excluded.

## BIOLOGICAL REGIMES

Phytoplankton

Several studies have been made of phytoplankton composition and standing stock in the North Pacific Ocean, but unfortunately, most were based on net samples and therefore do not include the nanoplankton. Allen (1936) and Cupp (1937) have made extensive observations using surface net samples and have described some seasonal and geographic variations in the Northeast Pacific including Alaskan waters. At low latitudes of the North Pacific, there have been extensive studies of phytoplankton standing stock and productivity measurements (Holmes, 1958; Doty, 1960; McGary, 1960). Holmes has included some measurements seaward from the area of immediate Columbia River influence. From the 1958 cruise of the *Vitiaz*, Koblenz-Mishke (1960) report measurements from one or two stations in or near the area of Columbia River effect plus many measurements from elsewhere in the North Pacific. However, these studies were not of a seasonal nature. To the north, the Pacific Oceanographic Group in Canada have made intensive measurements at Ocean Station PAPA (50°N, 145°W). Weekly studies during a six week period were made of plant nutrients, standing stock and rate of phytoplankton photosynthesis. Doty and Oguri (1957) and Shimada (1958) have reported diurnal fluctuations in productivity and chlorophyll content from 24 hour studies in the tropical Pacific. More general works on phytoplankton production and environmental factors in the oceans have been discussed by Steemann Nielsen (1960) and Sorokin (1959).

## Zooplankton Studies

Relatively little has been done on the pelagic zooplankton of the Northeast Pacific Ocean with the exception of zooplankton volume measurements (Norpac Atlas, 1955) and a seasonal study of zooplankton volumes with qualitative enumeration of species off the coast of Washington (Frolander, unpub. Ms). Much of the work in the North Pacific has been in the direction of the relationship of plankton distribution to water masses (Aron, 1960; Beklemishev, 1960). Biere (1959) has described the distribution of 27 species of planktonic chaetognatha in the Pacific and their relationship to water masses. Johnson (1938) has made a study of the copepod Eucalanus elongatus Dana in which two subspecies were shown to overlap somewhat in distribution, but the division line was located near the latitude of the Strait of Juan de Fuca. McAllister (1961) conducted a study of the vertical distribution of zooplankton along with a seasonal study of the organisms in surface water at Ocean Station PAPA. He concluded that the zooplankton found there was representative of that in a wide area of the Gulf of Alaska.

## Bays and Estuaries

The major bays and estuaries bordering the study area are the Strait of Juan de Fuca, Grays Harbor, Willapa Harbor and the entrance to the Columbia River. Smaller bays are found along the Oregon coast. The discharge from all of these bays can be expected to influence biological conditions seaward, the extent of the influence depending upon the amount and composition of the discharge. The University of Washington, Department of Oceanography (1954, 1955a, 1956b) has contributed literature surveys which include references to biological work done in Puget Sound and the Strait of Juan de Fuca, Grays Harbor, and Coos Bay, Oregon. Several references cited in these surveys and more recent unpublished work of this department establish some of the biological conditions to be expected in the Strait of Juan de Fuca. References to a surface phytoplankton survey, in connection with a pollution problem, and a beach survey are listed in the work on Grays Harbor. In Coos Bay, Oregon the major emphasis of biological work has been on benthos and littoral algae. At the present time, there is underway a seasonal study of primary production in relation to oyster production in Willapa Harbor (Westley, unpub.). Klement and Wallen (1960) have compiled a list of references on aquatic radiobiology which contains titles to many studies conducted on the fauna and flora of the Columbia River in relation to the Hanford Atomic Operations.

## METHODS OF STUDY

### General

A study of the Columbia River effluent and contiguous ocean areas from the biological standpoint involves coordinated investigations of both phytoplankton and zooplankton relative to environmental conditions. These investigations should include comparisons between coastal and offshore regimes, the seasonal influence, and vertical distribution. A primary difficulty encountered in marine plankton research is the selection of

suitable methods which will make possible comparison with other investigations. Recently, major attempts have been made to overcome these problems with international symposia directed at their solutions.

Especially significant among these was the "Symposium on Primary Production" held at Bergen in 1957. In October, 1961 a "Symposium on Zooplankton Production" will be held in Copenhagen. The most useful references listed in this section are Steemann Nielsen (1958) and Strickland (1960) on measurements of primary production and Braarud (1958) on microscopic examination and enumeration of phytoplankton organisms. At present, there is no up-to-date standard reference work that may be cited for zooplankton technique, and none will be available until the results of the Copenhagen symposium are published.

### Identification of Organisms

Proper taxonomic identification is often very difficult in those areas where the biological composition is little known. The Pacific is still largely unknown but some significant guides are available. Cupp (1943) should prove to be especially useful for the identification of diatoms, Brodskii (1950) - copepods, Banner (1947, 1948 and 1950) and Boden, *et al.* (1955) - mysids and euphausiids; and Tesch - heteropods and pteropods. The literature survey by Grier (1941) contains many useful references pertaining to the identification of other groups of invertebrates which might be encountered. It should be stated that although there are great gaps in our knowledge of the taxonomy of plankton organisms, there is sufficient knowledge of the major taxonomic groups to justify comprehensive studies of plankton distribution.

### Light Measurements

As light intensity is generally known to be one of the major limiting factors for phytoplankton production in temperate latitudes of the North Pacific Ocean, it is essential that it be measured in the various parts of the study area on a continuing basis. One of the simpler, but highly useful, measurements of light penetration into the sea can be made with a Secchi disc. This device is useful not only for obtaining the relative amount of light available to the organisms but also can be used to calculate the depth of the euphotic zone and might be indicative of the size of the standing crop, especially in offshore waters. More refined techniques, using underwater photometers, can be used to determine extinction coefficients more accurately and with the use of color filters to determine the spectral composition of light at different depths in the euphotic zone. These methods have been adequately reviewed and the significance of light to photosynthesis discussed by Holmes (1957) and Strickland (1958). Kimball (1928) has published tables for the computation of mean solar radiation at different latitudes but shipboard measurements of incident radiation by continuous recording are preferable.

## BIBLIOGRAPHY

|   |    |
|---|----|
| BIOLOGICAL REGIMES . . . . .                      | 48 |
| A. PHYTOPLANKTON . . . . .                        | 48 |
| B. ZOOPLANKTON . . . . .                          | 51 |
| C. BAYS AND ESTUARIES . . . . .                   | 54 |
| METHODS OF STUDY . . . . .                        | 55 |
| A. GENERAL . . . . .                              | 55 |
| B. IDENTIFICATION OF PLANKTON ORGANISMS . . . . . | 57 |
| C. LIGHT MEASUREMENTS . . . . .                   | 60 |

## BIOLOGICAL REGIMES

A. PHYTOPLANKTON

Allen, W. E.

1926. Remarks on Surface Distribution of Marine Plankton Diatoms in the East Pacific. *Science*, vol. 63, pp. 96-97.  
(Early net sample collections - mostly California and south.)

1928. Investigations on Phytoplankton in the Pacific Ocean. *Proceedings of the 3rd Pacific Science Congress*, vol. 1, pp. 250-263.

1936. Surface Plankton Diatoms in the North Pacific Ocean in 1934. *Madroño*, vol. 3, no. 6, pp. 1-3.

Cupp, E. E.

1937. Seasonal Distribution and Occurrence of Marine Diatoms and Dinoflagellates at Scotch Cap, Alaska. *University of California, Bulletin of the Scripps Institution of Oceanography Technical Series*, vol. 4, pp. 71-100.  
(Report on the findings of a series of daily surface collections of marine diatoms and dinoflagellates taken at Scotch Cap Light on Unimak Island, Alaska from August 1, 1926 to June 30, 1933.)

Doty, M. S.

1960. Algal Productivity of the Tropical Pacific as Determined by Isotope Tracer Techniques. *University of Hawaii Annual Report to Atomic Energy Commission*.  
(The most recent in a series of six annual unpublished reports concerning a detailed investigation of phytoplankton production in the tropical Pacific Ocean.)

Doty, M. S. and M. Oguri

1957. Evidence for a Photosynthetic Daily Periodicity. *Limnology and Oceanography*, vol. 2, no. 1, pp. 37-40.  
(Description of a 5.7-fold variation in the ability of oceanic phytoplankton to photosynthetically fix carbon depending upon the time of day the productivity is determined.)

Fleming, R. H.

1955. Review of the Oceanography of the Northern Pacific. *International North Pacific Fisheries Commission Bulletin No. 2*, 43 pp.  
(Contains many references to the biology of the north Pacific with the exception of Japanese publications.)

Holmes, R. W.

1958. Surface Chlorophyll a, Primary Production, and Zooplankton Volumes in the Eastern Pacific Ocean. *Conseil International Exploration de la Mer, Rapp. et Proc.-Verb.*, vol. 144, pp. 109-116.  
(Summary of productivity data in the Northeastern Pacific Ocean showing relationships to the physical and chemical environment.)

Kiselev, I. A.

1959. In Regards to the Flora of Algae in the River Mouth Basins along the Shore of the Azov Sea. Works of the 6th Conference on the Problems of the Biology of Interior Waters, Academy of Sciences, USSR, (10-19 June 1957), pp. 218-222.  
(In Russian. English translation available.)

1959. Composition of Phytoplankton in the Sea Water of South Sakhalin and the South Kuril Island Group. Exploration of the Far-Eastern Seas of the USSR, Part VI, Works of the Kurilo-Sakhalin Expedition, vol. 2, pp. 162-172.  
(In Russian. English translation available.)

Koblentz-Mishke, O. I.

1957. Phytoplankton Production in the Northwestern Part of the Pacific Ocean During the Spring of 1955. Reports of the Academy of Science, USSR, vol. 116, no. 6, pp. 1029-1032.  
(In Russian. English translation available.)

1958. The Dissemination of Several Species of Phytoplankton in Connection with the Principle Currents of the Western Region of the Pacific. Reports of the Academy of Science, USSR, vol. 121, no. 6, pp. 1012-1014.  
(In Russian. English translation available.)

1960. On the Study of Primary Production in the Sea by Soviet Scientists. Int. Rev. ges. Hydrobiol., vol. 45, no. 3, pp. 319-326.  
(Presents data by Soviet workers and some others on surface primary productivity measurements in the Pacific Ocean as well as other areas.)

Kon, H.

1953. On the Distribution of Phytoplankton in the Northeast Part of the Pacific in Autumn. Journal of the Oceanographic Society, Japan, vol. 9, no. 2, p. 109.  
(Phytoplankton distribution in autumn, 1951 showed good accordance with hydrographic conditions. Where 2 water masses meet, the population showed features characteristic of both water masses.)

Lohmann, H.

1908. Untersuchungen zur Feststellung des vollstaendigen Gehaltes des Meeres an Plankton. Wiss. Meeres. Kiel, NF, vol. 10, pp. 129-370.  
(Calculations of phytoplankton plasma volumes.)

McAllister, C. D., T. R. Parsons and J. D. H. Strickland

1960. Primary Productivity at Station "P" in the Northeast Pacific Ocean. J. Cons. Intern. Explor. Mer, vol. 25, no. 3, pp. 240-259.  
(Location 50°N, 145°W. Work done between 10 July and 21 August 1959 - to monitor summer productivity at a fixed point in the open ocean. Weekly measurements were made of all major nutrients, the standing crop of particulate organic matter and in situ rate of phytoplankton photosynthesis.)

- McGary, J. W.  
1960. Biological and Oceanographic Observations in the Central North Pacific July - September 1958. U. S. Fish and Wildlife Service, Special Scientific Report No. 358, 107 pp.  
(Includes observations of zooplankton volumes and measurements of primary production, plant pigments, midwater trawling, and underwater illumination between 155° and 175°W and 41° to 48°N.)
- Parsons, T. R.  
1960. A Data Record and Discussion of Some Observations Made in 1958-1960 of Significance to Primary Productivity Research. Fisheries Research Board of Canada, MSS Report Series, No. 81, 19 pp.  
(Measurements of plant pigments, phytoplankton numbers and some associated chemical information at Ocean Station "P", Departure Bay and Pendrell Sound.)
- Ryther, J. H.  
1960. The Plankton Ecology, Related Chemistry and Hydrography of the Sargasso Sea. Geographic Variations in Productivity. Bermuda Biological Station, Final Report to the Atomic Energy Commission.  
(A discussion of the manner and degree to which light and nutrients control and limit the rate of primary production in the sea. The range and magnitude of the process in representative parts of the ocean are considered.)
- Scripps Institution of Oceanography, University of California.  
Operation Wigwam, Report to the Scientific Director, Project 2.5, 1956. Effects of nuclear explosions on marine biology. Weapons Test Report WT-1013, La Jolla, California.  
(Contains chapters by different authors on phytoplankton and zooplankton investigations, midwater trawl surveys and uptake of radioisotopes by marine organisms.)
- Semina, H. J.  
1960. The Influence of Vertical Circulation on the Phytoplankton in the Bering Sea. Int. Rev. ges Hydrobiol., vol. 45, no. 1, pp. 1-10.  
(A comparison of vertical stability with phytoplankton.)
- Shimada, B. M.  
1958. Diurnal Fluctuations in Photosynthetic Rate and Chlorophyll "a" Content of Phytoplankton from Eastern Pacific Waters. Limnology and Oceanography, vol. 3, no. 3, pp. 336-339.  
(Measurements were made of photosynthetic activity and chlorophyll "a" content of phytoplankton samples taken at regular intervals over a 46-hour period in May 1957.)
- Sorokin, U. I.  
1959. On the Influence of Water Mass Stratification upon the Primary Photosynthetic Production in the Sea. Journal of General Biology, vol. 20, no. 6, pp. 455-465.  
(In Russian, English translation available.)

- Sorokin, U. I. and M. V. Kozlyaninob  
 1957. The Determination of the Dependence of Phytoplankton Photosynthesis on Water Mass Illumination in the Sea of Japan and the Pacific Ocean. Reports of the Academy of Sciences, USSR, vol. 116, no. 5, pp. 863-865.  
 (In Russian.)
- Steemann Nielsen, E.  
 1960. Productivity of the Oceans. Annual Review of Plant Physiology, vol. 11, pp. 341-362.  
 (A general discussion of phytoplankton standing stock, productivity and factors governing production in the oceans.)
- Steemann Nielsen, E. and E. Aabye Jensen  
 1957. Primary Oceanic Production. The Autotrophic Production of Organic Matter in the Oceans. Galathea Report, vol. 1, pp. 47-136.  
 (Measurements of primary production and interpretation of the data collected from the Galathea in the Atlantic, Indian and Pacific Oceans.)
- Sverdrup, H. U.  
 1953. On Conditions for the Vernal Blooming of Phytoplankton. J. Cons. Perm. Internat. Explor. Mer., vol. 18, no. 3, pp. 287-295.
- Westley, R.  
 Willapa Bay Hydrographic and Productivity Project. Washington Department of Fisheries, Shellfish Investigation.  
 (Study in progress.)

## B. ZOOPLANKTON

- Aron, W.  
 1959. Midwater Trawling Studies in the North Pacific. Limnology and Oceanography, vol. 4, no. 4, pp. 409-418.  
 (Summary of midwater trawl studies in the North Pacific during the summer of 1957. Includes description of diurnal and geographic variations as related to oceanographic conditions.)
1960. The Distribution of Animals in the Eastern North Pacific and Its Relationship to Physical and Chemical Conditions. University of Washington, Department of Oceanography Technical Report No. 63, 65 pp. plus 156 appendix pp.  
 (Results of three cruises during 1957 and 1958. Concerns the relationship which exists between physical and chemical conditions and the resident biological population obtained with a modified version of the Isaacs-Kidd midwater trawl.)

Bieri, R.

1959. The Distribution of Planktonic Chaetognatha in the Pacific and their Relationship to Water Masses. *Limnology and Oceanography*, vol. 4, no. 1, pp. 1-28.  
(Geographic extents of 27 species in the Pacific. A sharp boundary exists in the Eastern Pacific at 18° - 20°N latitude and is associated with temperature, O<sub>2</sub>, and probably salinity gradients.)

Beklemishev, C. W.

1960. Biotope and Community in Marine Plankton. *Int. Rev. ges. Hydrobiol.*, vol. 45, no. 2, pp. 297-301.  
(Description of some of the features important in the distribution of plankton in the North Pacific. Particular emphasis is placed upon the distribution of water masses.)

Beklemishev, C. W. and V. A. Burkov

1958. The Dependence Between the Plankton Distribution and the Distribution of Water Masses in the Frontal Region in the North-Western Pacific. *Trans. Inst. Oceanol.*, vol. 27, pp. 55-65.  
(In Russian.)

Beklemishev, C. W. and E. A. Lubny-Gertsik

1959. Zooplankton Distribution in the Eastern North Pacific in Winter, 1958-1959. *C. R. (Doklady) Academy of Science, USSR*, vol. 128, no. 6, pp. 1271-1273.  
(In Russian.)

Beklemishev, C. W. and N. V. Parin

1960. Pelagic Biogeographical Boundaries in the North Pacific in Winter 1958-59. *Trans. Inst. Oceanol.*, vol. 41, pp. 257-265.  
(In Russian. Discussion of the division of the North Pacific into the boreal region and tropical regions between which is a zone of mixed zoogeographical origin in the North Pacific Drift.)

Beklemishev, C. W. and H. J. Semina

1956. On the Structure of the Biogeographical Boundary between the Tropical and the Boreal Regions in Pelagic Regions of the Western North Pacific. *C. R. Academy of Science, USSR*, vol. 108, no. 6.

Bogorov, V. G. and M. E. Vinogradov

1955. Some Essential Features of Zooplankton Distribution in the Northwestern Pacific Ocean. *Trudy Inst. Okeanologii, Academy of Science, USSR*, vol. 18, pp. 113-123.  
(In Russian.)

Frolander, H. F.

- Quantitative Estimation of the Seasonal Variations of Zooplankton off the Coast of the State of Washington. University of Washington, Department of Oceanography, unpublished manuscript.  
(Seasonal studies of zooplankton volumes and qualitative net samples, July 1956 to February 1958.)

Graham, H. W.

1934. The Distribution of the Plankton of the Pacific as Related to Some Physical and Chemical Conditions of the Sea Water. Proceedings of the 5th Pacific Science Congress, vol. 3, pp. 2035-2043.  
(North of 40° or 45°N there is abundant plankton which extends in the east, southward along the west coast of North America. In the South Pacific bordering Antarctica abundant plankton population extends in the east, northward along the west coast of South America. The rest of the South Pacific and tropical Pacific have medium quantities while the central part of the north Pacific supports a poor population. Differential distribution of plankton appears to be caused by variations in the vertical stability of the water.)

Hida, T. S.

1957. Chaetognaths and Pteropods as Biological Indicators in the North Pacific. U. S. Fish and Wildlife Service, Special Scientific Report No. 215, 13 pp.  
(Chaetognaths occurred in greatest abundance in the subtropical zone; Pteropods were an important constituent in both subtropical and transition zones.)

Johnson, M. W.

1938. Concerning the Copepod Eucalanus elongatus Dana and Its Varieties in the Northeast Pacific. Bulletin of Scripps Institution of Oceanography, Technical Series, vol. 4, no. 6, pp. 165-180.  
(E. bungii bungii occurs in more northern waters, but overlaps with E. bungii californicus, a more southern variety. E. bungii bungii is capable of reproducing in Bering Strait within the Arctic Circle. Only larvae of the southern variety have been identified in the waters south of the Straits of Juan de Fuca. E. bungii bungii seems to be dominant off the Straits of Juan de Fuca - southern limit not established.)

Lea, H. E.

1955. The Chaetognaths of Western Canadian Coastal Waters. Journal of Fisheries Research Board of Canada, vol. 12, no. 4, pp. 593-617.  
(Purpose was to determine species and distribution. Collections were made in the summers of 1953 and 1954 in 11 regions along the British Columbia coast.)

Marumo, R.

1957. Plankton as the Indicator of Watermasses and Ocean Currents. The Oceanographical Magazine, vol. 9, no. 1, pp. 55-63.  
(Gives four examples where plankton populations in the western North Pacific are used as well as temperature and chlorinity in the identification of water masses.)

McAllister, C. D.

1961. Zooplankton Studies at Ocean Weather Station "P" in the Northeast Pacific Ocean. Journal of Fisheries Research Board of Canada, vol. 18, no. 1, pp. 1-29.  
(Location: 50°N - 145°W. Compares this station with other areas; vertical distributions; seasonal cycle at the surface; pronounced diurnal variation in the concentration of surface zooplankton. Zooplankton abundance at Station "P" appears representative of that in a wide area of the central Gulf of Alaska.)

Nakai, Z.

1941. Plankton in the Pacific Ocean. Kaiyo no Kagaku, vol. 2, no. 3, pp. 45-52.  
(In Japanese.)

1952. On Quantitative Distribution of Plankton Reproduced in the Northern Pacific. Fish Agency, Min. Agric. Forestry, Tokai Reg. Fisheries Research Lab, Special Publication No. 2, pp. 1-6.  
(Area: 6° - 54°N from May to July, 1952. Found much greater quantities of macroplankton in the northern area than in the southern. None of the species which occurred during this study were common to both areas.)

Nakai, Z. and K. Honjo

1954. A Preliminary Report on Surveys of Plankton and Salmon Stomach Contents from the North Pacific, 1952. Fish. Agency, Min. Agric. Forestry, Tokai, Reg. Fisheries Research Lab, Special Publication No. 3, pp. 6-12.  
(Area: Waters adjacent to the Aleutian Islands. The quantitative distribution of plankton from net hauls and from plankton found in salmon stomachs. Mostly copepods occurred in the net hauls while Thysanoessa was abundant in the salmon stomach contents.)

Oceanic Observations of the Pacific.

1955. The NORPAC Atlas. University of California Press and University of Tokyo Press. 1960.

South Pacific Fishery Investigations

1952-1955. Zooplankton Volumes of the Pacific Coast, 1951. U. S. Fish and Wildlife Service Special Scientific Report  
1952 - # 73, 37 pp.  
1953 - #100, 41 pp.  
1954 - #125, 54 pp.  
1955 - #161, 35 pp.  
(Plankton volume data.)

Thraillkill, James R.

1956. Relative Areal Zooplankton Abundance off the Pacific Coast. U. S. Fish and Wildlife Service, Special Scientific Report, Fisheries No. 188.  
(An atlas-type publication containing maps showing plankton volumes for various months from March 1949 - December 1955 off the west coast of U. S. and Baja, California. Some of the earlier maps cover the Oregon coast.)

### C. BAYS AND ESTUARIES

Klement, A. W. and I. E. Wallen

1960. A Selected List of References on Marine and Aquatic Radiobiology. Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.  
(Contains many references to radiobiological work done in the Columbia River with reference to Hanford operations.)

- University of Washington, Department of Oceanography  
 1954. Puget Sound and Approaches. A Literature Survey. Volume III,  
 175 pp.  
 (Contains a summary, with references, of biological studies  
 made within Puget Sound and approaches to it.)
- 1955a. Grays Harbor, Washington. A Literature Survey. 142 pp.
- 1955b. Coos Bay, Oregon. A Literature Survey. 142 pp.

#### METHODS OF STUDY

##### A. GENERAL

- Bogorov, B. G.  
 1959. On the Standardization of Marine Plankton Investigations.  
 Int. Rev. ges. Hydrobiologie, vol. 44, no. 4, pp. 621-642.  
 (Recommendations concerning the collection and treatment of  
 both phytoplankton and zooplankton in order to make different  
 studies comparative.)
- Braarud, T.  
 1958. Counting Methods for Determination of the Standing Crop of  
 Phytoplankton. Rapp. et Proc.-Verb. Cons. Internat. Explor.  
 Mer., vol. 144, pp. 17-19.  
 (Discusses suitable methods for satisfactory numerical estimation  
 of oceanic plant communities.)
- Creitz, G. I. and F. A. Richards  
 1955. The Estimation and Characterization of Plankton Population by  
 Pigment Analysis. III. A Note on the Use of "millipore"  
 Membrane Filters in the Estimation of Plankton Pigments.  
 Journal of Marine Research, vol. 14, no. 3, pp. 211-216.  
 (Concerns the use of membrane filters in the Richards with  
 Thompson (1952) method of estimating plankton pigments.)
- Fleming, R. H.  
 1940. Composition of Plankton and Units for Reporting Populations  
 and Production. Proceedings of the 6th Pacific Science  
 Congress, vol. 3, pp. 535-540.  
 (Discusses: 1. Ratios between essential constituents of  
 marine organisms; 2. Rational units for reporting quantities  
 of plankton and numerical relationships between these units.  
 Literature review; table of plankton equivalents: C:N:P  
 ratios and quantitative methods.)
- Gillbricht, M.  
 1952. Untersuchungen zur Produktionsbiologie des Planktons in der  
 Kieler Bucht. I. Die zeitliche und räumliche Verteilung des  
 Planktons und die quantitativen Beziehungen zwischen Plankton-  
 Chlorophyll- und Seston Gehalt. Kieler Meeresf., vol. 8, no. 2,  
 pp. 173-191.  
 (Discussion of particulate matter (seston); Detrital chlorophyll.)

- Goldberg, E. D., M. Baker and D. L. Fox  
1952. Microfiltration in Oceanography Research. I. Marine Sampling with the Molecular Filter. *Journal of Marine Research*, vol. 11, p. 194.  
(Method for the determination of total suspended particulate matter.)
- Lund, J. W. G. and J. F. Talling  
1957. Botanical-Limnological Methods with Special Reference to the Algae. *Botanical Review*, vol. 23, pp. 489-583.  
(Almost 800 references, many of which deal with studies on marine problems.)
- Palmer, C. M. and T. E. Maloney  
1954. A New Counting Slide for Nanoplankton. *American Society of Limnology and Oceanography*, Special Publication 21.  
(Description and use of a new slide for counting very small organisms.)
- Richards, F. A. with T. G. Thompson  
1952. The Estimation and Characterization of Plankton Populations by Pigment Analysis. II. A Spectrophotometric Method for the Estimation of Plankton Pigments. *Journal of Marine Research*, vol. 11, pp. 156-172.  
(A semimicro spectrophotometric method is described for the estimation of chlorophyll a, b and c and of astacin and nonastacin type carotenoids.)
- Steemann Nielsen, E.  
1958. Experimental Methods for Measuring Organic Production in the Sea. *Rapp. et Proc.-Verb. Cons. Internat. Explor. Mer.*, vol. 144, pp. 38-46.  
(A discussion of the oxygen and carbon-14 techniques for investigation of the production of organic matter by phytoplankton.)
- Strickland, J. D. H.  
1960. Measuring the Production of Marine Phytoplankton. *Fisheries Research Board of Canada, Bulletin No. 122*, 172 pp.  
(A comprehensive discussion of the techniques used in phytoplankton research.)
- Strickland, J. D. H. and T. R. Parsons  
1960. A Manual on Sea Water Analysis. *Fisheries Research Board of Canada, Bulletin 125*, 185 pp.  
(The format of this manual is designed specifically for the instruction and use of analysts undertaking established or new oceanographic chemical analyses under operational conditions. Basic working instructions are given in detail.)

B. IDENTIFICATION OF PLANKTON ORGANISMS

Banner, A. H.

1947. The Taxonomic Study of the Mysidacea and Euphausiacea (Crustacea) of the North-Eastern Pacific, Part I, Mysidacea, from Family Lophograstridae through Tribe Erythropini. Transactions of the Royal Canadian Institute, vol. 26, pp. 345-399.
1948. A Taxonomic Study of the Mysidacea and Euphausiacea (Crustacea) of the North-Eastern Pacific, Part II, Mysidacea, from the Tribe Mysini through Subfamily Mysidellinae. Transactions of the Royal Canadian Institute, vol. 27, pp. 65-125.
1950. A Taxonomic Study of the Mysidacea and Euphausiacea (Crustacea) of the North-Eastern Pacific, Part III, Euphausiacea. Transactions of the Royal Canadian Institute, vol. 28, no. 1, pp. 1-63.
1954. New Records of Mysidacea and Euphausiacea from the Northeastern Pacific and Adjacent Areas. Pacific Science, vol. 8, no. 2, pp. 125-139.
1954. A Supplement to W. M. Tattersall's Review of the Mysidacea of the United States National Museum. Proceedings of the U. S. National Museum, vol. 103, no. 3334, pp. 575-583.

Boden, B. P., M. W. Johnson and E. Brinton

1955. The Euphausiacea (Crustacea) of the Northern Pacific. Bulletin of Scripps Institution of Oceanography, vol. 6, pp. 287-400. (Taxonomy on a "wide geographic basis". Area: Columbia River, south to below the tip of Baja California plus material from elsewhere in the Pacific. Includes descriptions, distributions and taxonomy.)

Brodskii, K. A.

1950. Calanoida of the Far Eastern Seas and the Polar Basin of the USSR. Akademiia Nauk, Soiuz sovetskikh sotsialisticheskikh Republik, Opredeliteli po faune SSSR, izdavaemye zoologicheskim Institutom Akademii Nauk SSSR, (Moskva-Leningrad), vol. 35, 441 pp. (Partial translation of selected section by R. E. Duncan and L. V. Sagen, Translation series, No. 25, U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Seattle, Washington.)

Clemens, W. A. and G. V. Wilby

1946. Fishes of the Pacific Coast of Canada. Fisheries Research Board of Canada, Bulletin 68, 368 pp. (The systematics, distribution, life histories and illustrations of the fishes of the Pacific Coast of Canada, complete with a key to family and species. New edition is imminent.)

Cupp, E. E.

1943. Marine Plankton Diatoms of the West Coast of North America. Bulletin of Scripps Institution of Oceanography, University of California, vol. 5, no. 1, pp. 1-238.  
(Description of centric diatoms likely to be found in the northeast Pacific Ocean.)

Davis, C. C.

1949. The Pelagic Copepoda of the Northeastern Pacific Ocean. University of Washington Publications in Biology, vol. 14, pp. 1-118.  
(Area: San Francisco Bay to the Aleutians including inland waterways of Washington and British Columbia. Taxonomic with keys and figures.)

Gran, H. H. and E. C. Angst

1931. Plankton Diatoms of Puget Sound. Publications of the Puget Sound Biological Station, vol. 7, pp. 417-519.  
(Description of a small number of plankton diatoms found in the Puget Sound region.)

Grier, M. C.

1941. Oceanography of the North Pacific Ocean, Bering Sea and Bering Strait: A Contribution Toward a Bibliography. University of Washington Publication, Library Series, vol. 2, 290 pp.  
(Bibliography of publications pertaining to oceanography and biology.)

Hustedt, F.

1930. Die Kieselalgen in Dr. L. Rabenhorst's Kryptogamen-Flora. Leipzig, Band 7, Teil 1, 920 pp.  
(Description of the centric diatoms of European regions many of which apply to the Pacific Ocean region.)
1931. Die Kieselalgen in Dr. L. Rabenhorst's Kryptogamen-Flora. Leipzig, Band 7, Teil 2, 736 pp.  
(Description of the pennate diatoms of European regions many of which apply to the Pacific Ocean region.)

Kokubo, S.

1960. Plankton Diatoms, 2 ed., 230 pp. Tokyo.  
(Author draws material from many sources and therefore the book represents a good starting place for the identification of various diatoms from the Pacific Ocean area.)

McGowan, J. A.

1960. The Systematics, Distribution and Abundance of the Euthecocosmata of the North Pacific. University of California, Scripps Institution of Oceanography, Ph.D. Thesis.  
(Identification of Pteropods.)

- Scheffer, V. B. and J. W. Slipp  
 1948. The Whales and Dolphins of Washington State with a Key to the Cetaceans of the West Coast of North America. *American Midland Naturalist*, vol. 39, no. 2, pp. 257-337.  
 (Contains a checklist of whales and dolphins of Washington waters, description of shore whaling industry, notes on anatomy and behavior and a key to the Cetaceans of the West Coast of North America.)
- Schiller, J.  
 1937. Dinoflagellatae in Dr. L. Rabenhorst's *Kryptogamen-Flora*. Leipzig, Band 10, Teil 2, 589 pp.  
 (Description of the dinoflagellates of the European area. Many of the organisms described occur in the Pacific region.)  
 1930. Flagellatae in Dr. L. Rabenhorst's *Kryptogamen-Flora*. Leipzig, Band 10, Teil 1, 273 pp.  
 (Description of the flagellates of the European area. Many of the organisms described occur in the Pacific region.)
- Tattersall, W. M.  
 1951. A Review of the Mysidacea of the United States National Museum. *U. S. National Museum Bulletin* 201, 292 pp.
- Tesch, J. J.  
 1946. The Thecosomatous Pteropods; I. The Atlantic. *Dana Report* No. 28, 82 pp.  
 (Identification of Pteropods.)  
 1948. The Thecosomatous Pteropods; II. The Indo-Pacific. *Dana Report* No. 30, 45 pp.  
 (Identification of Pteropods.)  
 1949. Heteropoda. *Dana Report* No. 34, Fig. 1-44, Pl. I-V.  
 (Identification of Heteropoda.)  
 1950. The Gymnosomata; II. *Dana Report* No. 36.  
 (Identification of Pteropods.)
- Wailles, G. H.  
 1929. The Marine Zooplankton of British Columbia. *Museum (Vancouver) and Art Notes*, vol. 4, no. 4, pp. 159-165.  
 1937. Canadian Pacific Fauna (Protozoa-Sarcodina). *Biological Board of Canada, University of Toronto Press*, 14 pp.  
 (Taxonomic description of the Sarcodina of the Northeast Pacific Ocean.)  
 1939. Canadian Pacific Fauna (Protozoa-Mastigophora). *Fisheries Research Board of Canada, University of Toronto Press*, 45 pp.  
 (Taxonomic description of the Mastigophora of the Northeast Pacific Ocean.)  
 1943. Canadian Pacific Fauna (Protozoa-Ciliata, Suctorina). *Fisheries Research Board of Canada, University of Toronto Press*, 46 pp.  
 (Taxonomic description of the Ciliata and Suctorina of the Northeast Pacific Ocean.)

Wilson, C. B.

1950. Copepods Gathered by the United States Fisheries Steamer "Albatross" from 1887 to 1909, Chiefly in the Pacific Ocean. U. S. National Museum Bulletin 100, vol. 14, no. 4, pp. 141-141. (General taxonomy.)

C. LIGHT MEASUREMENTS

Holmes, R. W.

1957. Solar Radiation, Submarine Daylight, and Photosynthesis. Geological Society of America Memoir 67, vol. 1, pp. 109-128. (Instrumentation for measurements, a review of the characteristics of penetration of water by light, and the relation of underwater light to photosynthesis and associated processes.)

Kimball, H. H.

1928. Amount of Solar Radiation that Reaches the Surface of the Earth on the Land and on the Sea and the Methods by which it is Measured. Monthly Weather Review, vol. 56, pp. 393-398. (Author wants to determine if knowledge of meteorological conditions over the oceans, and of the relation between meteorological conditions and solar radiation intensities at the surface of the earth, is not sufficient to enable us to compute mean solar radiation intensities for different latitudes. He concludes that with reliable climatological data the radiation intensity over the ocean can be computed with reasonable accuracy.)

Lane, R. K., J. Butters, W. Atkinson and H. J. Hollister

1961. Oceanographic Data Record. Coastal and Seaways Projects, February 6 to March 2, 1961. Fisheries Research Board of Canada, MSS Report Series, No. 91, 128 pp. (Physical and chemical observations from 48° to 55°N and the coast to 141°W. Secchi disc observations at each station.)

Strickland, J. D. H.

1958. Solar Radiation Penetrating the Ocean. Journal of the Fisheries Research Board of Canada, vol. 15, no. 3, pp. 453- (A review of requirements, data and methods of measurements, with particular reference to photosynthetic productivity.)

SECTION III: GEOLOGICAL OCEANOGRAPHY

## THE HINTERLAND

### Physiography

From east to west across the Pacific Northwest are the broad north-south bands of the Cascade Mountains, the Puget-Willamette Lowland, the Coast Ranges, and a very narrow coastal plain. The Columbia River which drains over 200,000 square miles east of the Cascades flows across these four physiographic sections along the Washington-Oregon state line. Only the coastal plain and western slope of the Coast Ranges have direct significance on the present study from the aspect of marine geology. The Puget-Willamette Lowland, the Cascade Mountains, and the plateau country to the east, however, are drained by, and thus affect, the flow and composition of the Columbia River.

The drainage basin hydrology is discussed in Section I.

### Regional Geology

The Coast ranges are composed of Lower to Middle Tertiary sediments, mainly fine to coarse clastic rocks with volcanic detritus in part, but including debris of plutonic rocks derived from the east. The sequence is marine with thick units showing graded bedding. To the east the units grade into littoral, brackish, and continental sediments. Interbedded pillow volcanics are present in the Eocene and Oligocene parts of the sequence. The seaward-dipping Tertiary to Recent strata forming the coastal plain are also composed of slightly folded and faulted clastic sediments and volcanics.

### Economic Geology and Geography

Farming, mining, and lumbering are the three basic industries in the economy of the Columbia River Basin. These activities affect the local composition of dissolved solids and sediments. Of particular importance are beach-placer deposits of chromium, platinum, and associated heavy metals along the coast of southwestern Oregon (Day and Richards, 1906; Griggs, 1945). The processing of silica sand (Wilson, Skinner, and Couch, 1942) might also have some affect on the sediment type distribution. Perhaps of greatest importance, however, are various phases of the lumber industry (Freeman and Martin, 1954) which the sawdust, wood chips, or pulp processing by-products might locally affect the composition of suspended and dissolved solids in the river water. The effect of numerous dams on the Columbia River was noted in Section I.

### Coastal Estuaries

The largest estuaries along the coast, omitting the Columbia River, are Grays Harbor and Willapa Bay in southwestern Washington. Very little information is available on sediments and physical conditions in Willapa Bay; however the literature available on neighboring Grays Harbor has been

collected and summarized by the Department of Oceanography, University of Washington (1955b). The inner harbor is poorly sampled. A similar summary by the same organization (1955a) of previous investigations is available for Coos Bay, Oregon.

The coastal plain is less than ten miles wide along much of the area and reaches a maximum of about 20 miles in width near the Columbia. For some distance north and south of the mouth of the Columbia there are long stretches of sandy beach with associated belts of dunes. Bays or estuaries are partly cut off from the sea by spits and bars of sand. Although a few prominent headlands interrupt the shoreline near the Columbia and along parts of the Oregon coast, steep sea cliffs, 50 to 300 feet high, face the sea along most of the northern two-thirds of the Washington coast. At the base of the cliffs is a rocky platform, up to two miles in width, which is usually exposed at low tide.

Inland from the coastal plain in the north are the Olympic Mountains, about 4,000 square miles of ridges rising to 8,000 feet near the center. South of the Olympics are low hills and irregular lowlands to the Columbia River, beyond which are the Coast Ranges of Oregon rising from a level of 1,700 feet in the north to 3,500 feet in the south (Fenneman, 1931).

## SEDIMENTS

### Columbia River

The relation of the rocks forming the valley of the Columbia to the sediment carried by the river is at present uncertain. The sedimentary and volcanic formations in the valley comprise one of the most nearly complete records of the Late Cenozoic terrestrial history of the Western United States (Lowry, 1952). General discussions of the geology are also included in the works of Bretz (1919) and Hodge (1938).

The bulk of the knowledge of sediment transport by the Columbia River is in reports on file with the Portland District, U. S. Army Corps of Engineers. Sediment concentrations in the Willamette River and its tributaries have been measured, and low rates of transport have been realized (U. S. Army Corps of Engineers, 1954). Measurements of sediment concentration and relation to discharge have been made at some localities on the Columbia, as at Vancouver, Washington (U. S. Army Corps of Engineers, 1961), but the most intensive study has been along the lower 60 miles of the river. These studies included current speed and direction, temperature, and salinity measurements along seven ranges across the river (U. S. Army Corps of Engineers, 1960a, 1960b; Committee on Tidal Hydraulics, 1960) and together with bottom samples will form the basis for a movable-bed model of the lower part of the Columbia River to be constructed at the Waterways Experiment Station, Vicksburg, Mississippi. Preliminary interpretations of these measurements have helped define the environmental conditions associated with shoaling at the mouth of the Columbia (Lockett and Kidby, 1961). The importance of the salt water intrusion in regards to river flow and sediment dispersal, especially shoal formation, is now generally realized. A discussion of this particular aspect of sedimentation is given in several works (Lockett and Kidby, 1961; Schultz and Simmons, 1957). The history of the jetties at the mouth of the Columbia

reveals the degree of changes in shoaling and the shifting of the isobaths with time as erosion and deposition alter the bottom near the Columbia (Hickson and Rodolf, U. S. Army Corps of Engineers, 1938).

Textural and mineralogical studies of bottom samples from the lower part of the Columbia and its tributaries are presently in progress by the Geology Section of the Portland District, Corps of Engineers.

### Beach Sediments

Most of the previous investigations of the beach sediments along the Washington-Oregon coast have been associated, directly or indirectly, with the so-called "black sands". These sands are local concentrations of certain dark, heavy minerals, mainly magnetite, ilmenite, and chromite. Typically, the reports describe the type of deposit, mineralogy, origin, and distribution (Griggs, 1945; Honar, 1918; Pardee, 1934). The most comprehensive reports are a series on the Oregon coast by Twenhofel (1943, 1946a, 1946b, 1946c). According to Twenhofel the black sand deposits are found on present beaches and in deposits beneath elevated coastal plains. Prevailing southwesterly winds concentrate the sand south of the promontories or at the north side of embayments. Fluctuations in sea level caused changes in the position of embayments and promontories with resultant changes in deposition of black sands. These studies have included examination of coastal physiography, roundness, sorting, and size distribution of beach sands, heavy mineral determination, and investigations of streams discharging along the coast. All of the previous studies of the beach sediments, most of which deal only with the Oregon coast, are of a general reconnaissance nature and none have included considerations of wave, current, and surf conditions except in broadest generalities. Exceptions to this, however, are provided by the beach and surf studies of Bascom and McAdam (1947) and Isaacs (1947) which include numerous photographs of conditions in early autumn and late summer, respectively. Sedimentologic investigations of some Oregon beaches are presently being pursued by the Department of Geology, University of Wisconsin.

Along most of the Oregon and southwestern Washington coasts are large dune masses which on the coast of northern Oregon are related to the mouths of bays and rivers. Each dune mass originally consisted of a massive parabolic complex built by the southwest winds of winter. The rising sea has since eroded large parts of these masses. A transverse-ridge pattern has developed on the coastal dune sheets of Oregon wherever the shore is bordered by a level strip free from obstacles. The ridges lie essentially at right angles to the northerly sea breeze of summer. Winter winds partially destroy these ridges but, because of the wetness of the sand, cannot establish a corresponding system of their own (Byrd, 1950; Cooper, 1934, 1953, 1954, 1958).

### Offshore Sediments

Knowledge of sediments off the coast of Washington and Oregon is extremely limited. Bottom type designations on U. S. Coast and Geodetic Survey charts furnish most of the information available for the narrow continental shelf, although studies are underway for regions off the Oregon

coast by the Department of Oceanography, Oregon State University. Preliminary analysis made at the Department of Oceanography, University of Washington, of a few bottom samples from the area indicate a sandy texture for much of the shelf sediment. Locally, as near the Strait of Juan de Fuca, large areas of gravel are found, but mud is the most commonly reported sediment. Additional sources of information are samples taken on the seventh cruise of the Carnegie (Revelle, 1944), on Scripps' Operation Northern Holiday (Wooster, 1951), and Scripps' Cascadia Expedition (Menard, 1955).

Approximately 300 miles offshore is a northward-trending seamount chain (Nayudu, 1961), on which Cobb Seamount is a prominent feature. This appears to be a pre-Late Eocene volcano which has been terraced by wave abrasion and subsequently subsided about 500 fathoms (Budinger, 1957). This seamount chain forms a barrier for terrigenous material. It is believed that the large area of sedimentation between the seamount chain and the mainland is a result of the retaining effect of the chain. The sedimentation area becomes deeper toward the south where exits occur around the southern end of the seamount chain (Menard, 1955). Not only are terrigenous sediments present in the area (Menard, 1953; Tyler, 1951), but also there are some sediments with abundant pelagic components, as Globigerina-rich silts and clays (Nayudu, 1959).

### Foraminifera

A reconnaissance survey of papers relating to foraminifera present in the Washington-Oregon coastal waters is included. More than 60 of the 80 reports deal with Recent benthonic and pelagic foraminifers, although only a few deal specifically with the area under study (Cushman and Todd, 1947; Detling, 1958; Jarman, in progress). Most of the remaining papers describe Cenozoic foraminifers from the coastal formations. Research on the foraminifers of the Northeast Pacific Ocean is in progress at the Department of Oceanography, University of Washington (Enbysk, 1961; Smith, 1961).

### MAPS AND CHARTS

A list of maps and charts is included. Most of these are geologic maps published in various series by the U. S. Geological Survey, but also included are river and harbor charts published by the U. S. Army Corps of Engineers and charts of the U. S. Coast and Geodetic Survey.

## BIBLIOGRAPHY

|                                 |    |
|---------------------------------|----|
| HINTERLAND . . . . .            | 67 |
| A. PHYSIOGRAPHY . . . . .       | 67 |
| B. REGIONAL GEOLOGY . . . . .   | 68 |
| (1) General . . . . .           | 68 |
| (2) Petrology . . . . .         | 71 |
| (3) Stratigraphy . . . . .      | 73 |
| C. ESTUARIES . . . . .          | 76 |
| (1) Coos Bay . . . . .          | 76 |
| (2) Grays Harbor . . . . .      | 78 |
| SEDIMENTS . . . . .             | 80 |
| A. COLUMBIA RIVER . . . . .     | 80 |
| B. BEACH SEDIMENTS . . . . .    | 84 |
| C. OFFSHORE SEDIMENTS . . . . . | 88 |
| D. FORAMINIFERA . . . . .       | 94 |
| MAPS AND CHARTS . . . . .       | 97 |

## HINTERLAND

A. PHYSIOGRAPHY

Atwood, Wallace W.

1940. The Physiographic Province of North America. Ginn and Company, Boston, 536 pp.

Buwalda, J. P.

1927. Pleistocene and Recent Topographic Changes in Pacific Coast States. National Research Council Bulletin, vol. 61, pp. 39-43.

Dicken, S. N.

1954. Western Oregon and Washington, in Freeman and Martin, The Pacific Northwest. John Wiley & Sons, New York, pp. 54-64.

Fagerlund, G. O. and F. I. Fagerlund

1954. Olympic National Park [Wash.], U. S. National Park Service Natural History, vol. 1, p. 67.

Fenneman, N. M.

1931. Physiography of Western United States. McGraw-Hill Book Co., Inc., New York, pp. 442-465.  
(General description and discussion of area.)

Grover, Nathan C. and Glenn L. Pacher

1940. Summary of Records of Surface Waters in Washington. U. S. Geological Survey, Water-Supply Paper 870, 456 pp.  
(Stream-flow records in Washington up to 1919 representing an aggregate of 1,120 years at 209 gaging stations are summarized in Water-Supply Paper 492. Similar records for the period October 1, 1919 to September 30, 1935, representing an aggregate of 1,470 years at 203 gaging stations, are summarized in this volume.)

Smith, Warren D.

1933a. Physiography of the Oregon Coast. Pan American Geologist, vol. 59, no. 2, pp. 97-114.  
(Describes shoreline processes and evaluation of the coast as well as individual inlets and bays.)

1933b. Special Physiographic Features of Oregon Coast. Pan American Geologist, vol. 59, no. 3, pp. 190-206.  
(Describes shoreline processes and evolution of the coast as well as individual inlets and bays. Includes Coos Bay area in discussions.)

1933c. Special Physiographic Features of Oregon Coast. Pan American Geologist, vol. 59, no. 4, pp. 241-258.

1942. Physical Framework of the Northwest Geology and Geomorphology of Region West of the Cascade Mountains, in Freeman and Martin, The Pacific Northwest. John Wiley & Sons, New York, pp. 41-57.  
(Describes the coastal area.)

## U. S. Geological Survey

1960a. Surface Water Supply of the United States, 1959. Part 12, Pacific Slope Basins in Washington and Upper Columbia River Basin. U. S. Geological Survey, Water-Supply Paper 1636, 402 pp.

1960b. Surface Water Supply of the United States, 1959. Part 14, Pacific Slope Basins in Oregon and Lower Columbia River Basin. U. S. Geological Survey, Water-Supply Paper 1638, 300 pp.

B. REGIONAL GEOLOGY(1) General

Allen, John Eliot and Ewart M. Baldwin

1944. Geology and Coal Resources of the Coos Bay Quadrangle, Oregon. State of Oregon Department of Geology and Mineral Industries, 157 pp. (Describes in detail the stratigraphy, paleontology and structure in the Coos Bay Area. Latter part of bulletin is concerned primarily with the coal deposits of Eocene Age to present.)

Arnold, Ralph

1906. Geological Reconnaissance of the Coast of the Olympic Peninsula, Washington, Bulletin of Geological Society of America, vol. 17, pp. 451-468. (Contains a description of the topography and physical features of the Olympic Mountains and the coastal region, plus a description of their geology.)

Baldwin, E. M.

1959. Field Trip, Eugene to Coos Bay via Reedsport. State of Oregon Department of Geology and Mineral Industries Bulletin 50.

Bostwick, D. A.

1959. Field Trip, Corvallis to Depoe Bay via Newport. State of Oregon Department of Geology and Mineral Industries Bulletin 50.

Butler, G. M. and G. J. Mitchell

1916. Preliminary Survey of the Geology and Mineral Resources of Curry County, Oregon. State of Oregon Bureau of Mines and Geology, Mineral Resources of Oregon, vol. 2, no. 2.

Danner, W. R.

1952. A Brief Guide to the Geology of the Olympic National Park, Washington. Rocks and Minerals, vol. 27, no. 7, pp. 339-346, no. 8, pp. 348-350.

1955. Geology of Olympic National Park. University of Washington Press, Seattle, 68 pp.

(Includes chapter on the Olympic Ocean Strip, a 50-mile section of coast north of Grays Harbor.)

Diller, J. S.

1898. Roseburg folio. U. S. Geological Survey Atlas Series No. 49.

1899. The Coos Bay Coal Field, Oregon. U. S. Geological Survey 19th Annual Report, Part 3, pp. 309-376.  
(Describes topography, marine benches, alluvium, Empire (miocene), Arago (Eocene) divided into Coaledo (younger) coal member and Pulaski (older). Coaledo contains brackish water fossils, Pulaski very few. Coal in basins. Two geologic maps, many cross and stratigraphic sections.)

1901. Coos Bay, Oregon (topography, sedrocks, sands, ignrocks). U. S. Geological Survey folio 73, 5 pp., 4 maps.  
(Topography of the Pacific Coast and Coos Bay quadrangle. Sedimentary rocks - myrtle (Cretaceous) Pulaski (Eocene), Coaledo formation (development and structure of coal seams) Empire (Neocene). Coos Conglomerate and marine sands of Pleistocene age. Igneous rocks - serpentine and basalts. Gold has been found in Pleistocene sand deposits.)

1903. Port Orford folio. U. S. Geological Survey folio 89.

Dodds, R. Kenneth

Geology and Stratigraphy of the Western Half of the Svenson Quadrangle, Oregon. Master's Thesis, University of Oregon, in progress.

Geology and Stratigraphy of the Astoria, Svenson, Cannon Beach and Saddle Mountain Quadrangles, Oregon. U. S. Army Corps of Engineers field work nearly completed.

Dott, Robert H., Jr.

1955. Eocene Submarine Slumping and Graded Bedding at Coos Bay, Oregon. Geological Society of America Bulletin (Abstract), vol. 66, no. 12, pt. 2, p. 1552.  
(Describes sedimentary features in clastic formation exposed in sea cliffs. Suggested origin of features is slumping and turbidity currents.)

Duncan, D. C.

1953. Geology and Coal Deposits in Part of the Coos Bay Coal Field. U. S. Geological Survey Bulletin 982-B.  
(General geology and description of major coal deposits in the Coos Bay area. Estimation of coal reserves based on drilling program.)

Foster, R. J.

1957. The Tertiary Geology of a Portion of the Central Cascade Mountains, Washington. Dissertation Abstracts, vol. 17, no. 9, p. 1982.

Freeman, O. W. and H. H. Martin

1954. The Pacific Northwest. John Wiley & Sons, New York, 2nd ed. 540 pp.

- Howard, John K.  
General Geology of the Cape Sebastian - Gold Beach Area, Oregon. Master's Thesis, University of Wisconsin, begun Summer 1960.
- Koch, John G.  
1960. Geology of Humbug Mountain Area, Oregon. Master's Thesis, University of Wisconsin.
- Oles, K. F.  
1957. The Geology and Petrology of the Crystalline Rocks of the Beckler River--Nason River Area, Washington. Dissertation Abstracts, vol. 17, no. 4, p. 838.
- Shenon, P. J.  
1933. Geology and Ore Deposits of the Takilma-Waldo District, Oregon. U. S. Geological Survey Bulletin 846-B.  
(Describes the mineral (and relations to the geology) of the area.)
- Snively, Park D., Jr. et al.  
Intrusive Rocks in the Central Part of the Coast Ranges of Oregon. U. S. Geological Survey and State of Oregon Geology and Mineral Industries, Part I, Department Bulletin in progress.
- Treasher, R. C.  
1942. Geologic History and Map of the Portland Area, Oregon. State of Oregon Department of Geology and Mineral Industries, Short Paper No.7.  
  
1943. Reconnaissance Geologic Survey in Curry County along Coast Highway from Gold Beach to California State Line. Geological Society of Oregon Country Geological News Letter, vol. 9, no. 13.
- Washburne, C. W.  
1914. Reconnaissance of the Geology and Oil Prospects of Northwestern Oregon. U. S. Geological Survey Bulletin 590. 111 pp.  
(General geology and topography of the region.)
- Weaver, Charles E.  
1945. Geology of Washington and Oregon and its Relation to Occurrence of Oil and Gas. Bulletin of the American Association of Petroleum Geologists, vol. 29, no. 10, pp. 1377-1415.  
(A discussion of the general geology and geologic history is worked into the subject of oil and gas in Oregon and Washington.)
- Wells, F. G., P. E. Hotz and F. W. Carter  
1949. Preliminary Description of the Geology of the Kerby Quadrangle, Oregon. State of Oregon Department of Geology and Mineral Industries Bulletin 40.
- Widmier, John M.  
Stratigraphy and Structure of the Brookings - Cape Ferrelo Region, Oregon. Doctoral Thesis, University of Wisconsin, begun Summer 1960.
- Wilkinson, W. D. and W. D. Lowry and E. M. Baldwin  
1946. Geology of the St. Helens Quadrangle, Oregon. State of Oregon Department of Geology and Mineral Industries Bulletin 31.

(2) Petrology

Allen, John Eliot

1945. A Vanadium-Bearing Black-Sand Deposit of Middle Mesozoic Age in Central Curry County, Oregon. Geological Society of Oregon Country News Letter, vol. 11, no. 4, p. 21.

Allen, Victor T. and Robert L. Nichols

1943. Cowlitz High-Alumina Clay Deposit, near Castle Rock, Washington. Geological Society of America Bulletin, vol. 54, no. 12, p. 1823.

1946. Weathered Gravels and Sands of Oregon and Washington. Journal of Sedimentary Petrology, vol. 16, no. 2, pp. 52-62.

Brown, R. E.

1942. Some Manganese Deposits in the Southern Oregon Coastal Region. State of Oregon Department of Geology and Mineral Industries Short Paper No. 9

Campbell, C. D. and S. K. Runcorn

1956. Magnetization of the Columbia River Basalts in Washington and Northern Oregon. Journal of Geophysical Research, vol. 61, no. 3, pp. 449-458.

(The remanent magnetization of late-tertiary lavas in seven sections of Columbia River basalts has been examined. At least three field reversals during their eruption are indicated.)

Cook, Earl Ferguson

1943. Cowlitz High-Alumina Clay Deposit Near Castle Rock, Washington. B.S. Thesis, University of Washington.

Day, David T. and R. H. Richards

1906. Useful Minerals in the Black Sands of the Pacific Slope, in Mineralogical Resources of U.S. for 1905. U. S. Geological Survey, pp. 1175-1258.

Diller, J. S.

1914. Mineral Resources of Southwestern Oregon. U. S. Geological Survey Bulletin 546, 147 pp.

Felts, Wayne M.

1938. A Granitorite Stock in the Cascade Mountains of Southwestern Washington. Ph.D. Thesis, Cincinnati University.

Granquist, Donald Paul

1945. Utilization of Titaniferous Magnetite (in Cascades). M.S. Thesis, University of Washington.

Griggs, H. B.

1945. Chromite-Bearing Sands of the Southern Part of the Coast of Oregon. U. S. Geological Survey Bulletin 945E, pp. 113-150.

Hill, Myron Donald

1935. Manganese Ores of the Olympic Mountains. B.S. Thesis, University of Washington.

- Kaiser, William  
 Petrology of Basement Rocks and Sediments in the Port Orford Region. Master's Thesis, University of Wisconsin, begun Summer 1960.
- Kauffman, Albert J., Jr.  
 1952. Industrial Minerals of the Pacific Northwest. U. S. Bureau of Mines Information Circular 7641, 75 pp.  
 (Includes discussion of industrial minerals - quantity and location in Oregon and Washington.)
- Kelly, Hal J., Henry M. Harris and Herbert G. Schlinker  
 Study of Nepheline Syenite from Lincoln and Lane Counties, Oregon. U. S. Bureau of Mines and Oregon State Department of Geology and Mineral Industries, in progress.
- Laval, William Norris  
 1957. Primary Structures of the Columbia River Basalt Flows, South-Central, Washington. (Abstract) Geological Society of America Bulletin, vol. 68, no. 12, pt. 2, p. 1867.  
 (Brief description of structures and lithology of basalt in south-central Washington.)
- McHenry, J. R.  
 1952. Clay Mineralogy of Recent Glacial Alluvium Soils of Western Washington. Soil Science, vol. 78, no. 4, pp. 281-285.  
 (Six samples of agriculturally valuable land in the Puyallup were found to have high phosphate-fixing ability. A series of laboratory determinations were subsequently run.)
- Popoff, C. C.  
 1955. Cowlitz Clay Deposits near Castle Rock, Washington. U. S. Bureau of Mines Report, inv. 5157, ii, p. 60.  
 (The most valuable clays are confined to a 50-foot bed overlying volcanic breccia; both formations presumably are of early Tertiary age.)
- Ramp, Len  
 Chromite in Southwestern Oregon. State of Oregon Department of Geology and Mineral Industries, to be published.
- Schlicker, Herbert G.  
 Economic Geology of the Intrusive Rocks in the Central Part of the Coast Ranges of Oregon. State of Oregon Department of Geology and Mineral Industries, to be published.
- Smith, Thaddeus Oliver  
 1926. Glass Materials of the State of Washington. B.S. Thesis, University of Washington.
- Toengeo, Albert L., James J. Dowd, et al.  
 1948. Movable Reserves, Petrography, Chemical Characteristics and Washability Tests of Coal Occurring in the Coos Bay Coal Field, Coos County, Oregon. U. S. Department of the Interior, Bureau of Mines Technical Report 707, 56 pp.  
 (Includes descriptions of the Coos Bay area, topography, geology and climate.)

- Wells, F. G., L. R. Page, and H. L. James  
 1940. Chromite Deposits in the Sourdough Area, Curry County, and the Briggs Creek Area, Josephine County, Oregon. U. S. Geological Survey Bulletin 922-P, pp. 461-496.
- Wilson, Hewitt, K. G. Skinner, and A. H. Couch  
 1942. Silica Sands of Washington, University of Washington Engineering Experiment Station Bulletin 108, 76 pp.
- Youngberg, E. A.  
 1947. Mines and Prospects of the Mount Reuben Mining District, Josephine County, Oregon. State of Oregon Department of Geology and Mineral Industries Bulletin 34.
- Zvanut, Frank Joseph  
 1935. Purification of Quartz Sands and Muscovite of the Pacific Northwest. Master's Thesis, University of Washington.

### (3) Stratigraphy

- Anderson, F. M.  
 1958. Upper Cretaceous of the Pacific Coast. Geological Society of America Bulletin, Memoir 71, 378 pp.  
 (Upper Cretaceous sequences occur from Mexico to British Columbia. The Oregon-Washington sequences are similar to those in Baja California but in neither area are the thicknesses comparable to the California region. In the whole region, Upper Cretaceous seem to rest unconformably on various Lower Cretaceous or old rocks. Five hundred and four species of invertebrates were recorded.)
- Arnold, Ralph and Harold Hannibal  
 1913. The Marine Tertiary Stratigraphy of the North Pacific Coast of America. Proceedings of the American Philosophical Society, vol. 52, no. 212, pp. 559-605.  
 (Describes formations in the Grays Harbor area with maps and lithology. Also describes Coos Bay area with maps and lithology.)
- Brown, R. D., Jr., P. D. Snavely, Jr., and H. D. Gower  
 1956. Lyre Formation (redefinition), Northern Olympic Peninsula, Washington. American Association of Petroleum Geologists Bulletin, vol. 40, no. 1, pp. 94-107.  
 (Detailed geologic mapping in the Northern Olympic Peninsula has shown the Lyre formation can now be divided into two mappable units. Strata are conglomerate, sandstone and siltstone. Once thought to be Oligocene, they are now defined as early Eocene.)
- Dall, William H. and Gilbert D. Harris  
 1892. Correlation Papers: The Neocene of North America. U. S. Geological Survey Bulletin 84, 349 pp.  
 (Correlation on the coast from Port Orford to Cape Blanco, Coos, Bay, Yaquina Bay, Tillamook Head.)

- Dott, R. H., Jr.  
Eocene Sedimentation and Paleogeography Around Coos Bay, Oregon.  
University of Wisconsin field work completed 1960.
- Durham, J. W.  
1950. Cenozoic Marine Climates of the Pacific Coast. Geological Society of America Bulletin 61, pp. 1243-1264.  
(Early Tertiary poles and continents were in approximately the same position as at present. In Paleocene, the 20°C marine isotherm was north of 49°N lat. Beginning its shifting south in Middle Oligocene, it reached its present position by Middle Pliocene. Since then it has oscillated back and forth.)
- Etherington, Thomas John  
1930. Stratigraphy and fauna of the Astoria Miocene of Southwestern Washington. Ph.D. Thesis, University of California, Berkeley.
- Grosvenor, Edward Rickman  
1934. A Geological Report on a Section of Tertiary Sediments at Coos Bay, Oregon. Thesis, University of Washington, 19 pp.
- Hendriksen, D. A.  
1956. Eocene Stratigraphy of the Lower Cowlitz River - Eastern Willapa Hills Area, Southwestern Washington. Washington Department of Conservation Development, Division of Mines and Geology Bulletin 43, p. 122.  
(Physiography and topography briefly discussed.)
- Hertlein, Leo G. and Colin H. Crickmay  
1925. A Summary of the Nomenclature and Stratigraphy of the Marine Tertiary of Oregon and Washington. Proceedings of the American Philosophical Society, vol. 64, pp. 224-282.  
(Includes Coos Bay and Grays Harbor formation.)
- Howe, Henry V. W.  
1922. Faunal and Stratigraphic Relationships of the Empire Formation, Coos Bay, Oregon. University of California, Department of Geological Sciences, vol. 14, no. 3, pp. 85-114.  
(Distribution, description and fossil content of the Empire formation and overlying Coos conglomerate. Gives faunal proof of Pliocene age of both.)
- Imlay, Ralph W., et al.  
1959. Relations of Certain Upper Jurassic and Lower Cretaceous Formations in Southwestern Oregon. American Association of Petroleum Geologists, vol. 43, no. 12, pp. 2770-2785.  
(Concerns formations - Myrtle, Riddle and Days Creek. Some of the Myrtle mapped by Diller is excluded and reassigned to the Dothan formation. The Riddle is 1000' siltstone of the latest Jurassic above which lies 2000' of the Days Creek - massive sandstone and siltstone.)
- Natland, M. L.  
1957. Paleoecology of West Coast Tertiary Sediments. Geological Society of America Memoir 67, vol. 2, pp. 543-572.

Park, C. F., Jr.

1950. Structure of the Volcanic Rocks of the Olympic Peninsula, Washington. Geological Society of America Bulletin, vol. 61, no. 12, pt. 2, p. 1529.

(It is concluded that the structure of the Peninsula is not a simple anticline (as previously concluded) and that rock formation which has been called the Solduc formation includes material of Oligocene and possibly younger age.)

Rau, W. W.

1958. Stratigraphy and Foraminiferal Zonation in some of the Tertiary Rocks of Southwestern, Washington. U. S. Geological Survey Oil and Gas Inv. Map OC-57. 2 sheets.

Schenck, Hubert G.

1927. Marine Oligocene of Oregon. Bulletin of Department of Geological Sciences, University of California, vol. 16, no. 12, pp. 449-460. (General discussion of Oligocene in Oregon, relation of Oligocene to Eocene, includes stratigraphy of Coos Bay district.)

1928. Stratigraphic Relations of Western Oregon Oligocene Formations. Bulletin of Department of Geological Sciences, University of California, vol. 18, no. 1, pp. 1-50. (General discussion of oligocene stratigraphy in Western Oregon including Eugene district, Coos Bay, Yaquina, Alsea Bay districts.)

Snively, P. D., Jr.

1951. McIntosh Formation, Centralia-Chehalis Coal District, Washington. American Association of Petroleum Geologists Bulletin, vol. 35, no. 5, pp. 1052-1061.

(The name McIntosh formation is proposed for more than 4000-5000 feet of dark gray marine siltstone and claystone, and interbedded achosic and basaltic sandstone which crops out in the Centralia-Chehalis coal district, Lewis and Thurston Counties, Washington.)

1954. Geology and Coal Resources of Centralia-Chehalis District, Lewis and Thurston Counties, Washington. Science, vol. 119, no. 3091, pp. 419-420.

(Short, general discussion of the stratigraphy and economic possibilities of the area.)

Turner, F. E.

1938. Stratigraphy and Mollusca of the Eocene of Western Oregon. Geological Society of America Special Papers No. 10, pp. 26-40. (Contains a description of the Cape Arago section exposed along the ocean front south of Coos Bay. Invertebrate faunal list plus fossil localities also included.)

Weaver, Charles E.

1937. Tertiary Stratigraphy of Western Washington and Northwestern Oregon. University of Washington, Seattle, 266 pp. (Detailed report on area including maps, diagrams, and sections.)

1944. Correlation of the Marine Cenozoic Formations of Western North America. Bulletin of Geological Society of America, vol. 55, no. 5, pp. 569-598. (Correlation chart with annotations describing local areas along Washington-Oregon coast.)

Weaver, Charles E.

1945. Stratigraphy and Paleontology of the Tertiary Formations at Coos Bay, Oregon. University of Washington Publications in Geology, vol. 6, no. 2, pp. 31-62.  
(Detailed discussions of Tertiary strata exposed along ocean front in Coos Bay area.)

C. ESTUARIES

(1) Coos Bay

Brown, Stuart G. and R. C. Newcomb

- n.d. Ground Water on North End of North Spit at Coos Bay, Oregon. U. S. Geological Survey Ground Water Branch, Portland, Oregon, (on file).  
(Contains extent of dunes, rainfall, runoff and storage, evaporation and storage, ground water, and physical description of sands.)

University of Washington, Department of Oceanography

1955. Coos Bay, Oregon - A Literature Survey. University of Washington Department of Oceanography, 142 pp.

U. S. Army Corps of Engineers

- n.d. Analysis of Bottom Sand from Bar and Channel Areas for Coos Bay. Portland, Oregon District (on file).  
(Ten curves for survey obtained between 1952 and 1954.)
- n.d. Cubic Yards of Dredged Material Removed from Coos Bay. Portland, Oregon District (data on file).  
(1949 through 1954 summarized for this survey.)
- n.d. Coos Bay Bar, Oregon, Shipments over the Bar in Thousands of Tons, 1880-1923. Portland, Oregon District Map File No. CB-1-107.1
1908. Coos Bay and Bar Entrances, Oregon. 60th Congress House Document No. 958, 12 pp.
1916. Borings near Entrance. Portland, Oregon District Map File No. CB-1-62 and CB-1-63.
1917. Coos Bay Harbor, Oregon. 65th Congress House Document No. 325. 18 pp.
1919. Borings at Pigeon Point Reef, September - October. Portland, Oregon District, File No. CB-1-83.
1921. Borings at Guano Rock Reef, Surveyed August. Portland, Oregon District Map No. CB-1-92.
1922. Coos Bay Harbor and Isthmus Slough, Oregon. 67th Congress-2nd Session House Document No. 150, 38 pp.

## U. S. Army Corps of Engineers

1926. Entrance Surveys of March and October with Cross Sections showing Amount of Material Excavated and a profile along Charnel Range. Portland, Oregon District, File No. CB-1-138.
- 1927a. Coos Bay, Oregon. 70th Congress, 1st Session House Document No. 110, 37 pp.
- 1927b. Pigeon Point Reef Borings, Compiled from Surveys 1916, 1919, 1926, 1927. Portland, Oregon District, Map File CB-1-147.
1928. Progress Profile, South Jetty and North Getty. Portland, Oregon District, Map No. CB-1-163.
1930. Entrance, Cross Sections Between Jetties. Portland, Oregon District, Map No. C-1-182.
1931. Profile Along Channel Line, March - October. Portland, Oregon District, Map File No. CB-1-209/1.
- 1932a. Tidal and Silt Scour Relations. Portland, Oregon District, Map File No. CB-1-209/2.
- 1932b. Comparative Channel Cross Sections. Portland, Oregon District, Map File No. CB-1-209/3.
- 1932c. Paths of Maximum Bottom Velocities in Estuary Channel. Portland, Oregon District, Map File No. CB-1-209/4.
- 1932d. Bottom Material Analysis and Rate of Settlement. Portland, Oregon District, Map File No. CB-1-209/12.
1936. Coos River and Tributaries, Preliminary Examination. Portland, Oregon District, Map File No. CB-2-1.
1946. Coos Bay, Oregon. 79th Congress, 2nd Session, Senate Document No. 253, 33 pp.
1948. Coos Bay at Charleston, South Slough, Oregon. 80th Congress, 2nd Session, House Document No. 646, 20 pp.
1949. Job History, Dredging and Rock Removal. Portland, Oregon District (on file, 14 photos).  
(Includes air photos of Coos Bay obtained during Contract No. W35-026-eng-3808 for removal of rock and overburden in Coos Bay Channel from Guano Rock to Empire.)

## Williams, Howel

1953. The Ancient Volcanoes of Oregon (describes the origin of Coos Bay area). Oregon State System of Higher Education Eugene, 68 pp.  
(Describes the origin of the area.)

(2) Grays Harbor

Department of Oceanography, University of Washington

1955. Grays Harbor, Washington: A Literature Survey. University of Washington Department of Oceanography, 142 pp.

Henderson, J. R.

1952. Preliminary Total Intensity Aeromagnetic Maps of Part of Grays Harbor, Washington. Division of Mines and Geology, State Department of Conservation and Development (unpublished).

## Port of Grays Harbor

1926. Annual Report of the Manager and Chief Engineer. Washington State, 96 pp. (typewritten).

(Concerned with the condition of the harbor, dredging, bar formation, and cargo. Diagrams, maps, and photos.)

1927. Annual Report of the Manager and Chief Engineer. Washington State, 104 pp. (dittoed).

(Concerned with dredging, surveys, and initial current surveys, no data presented. Diagrams, maps, and photos.)

1948. Annual Report of the Manager and Chief Engineer. Washington State, 42 pp. (dittoed).

(An annual report containing data on dredging, damage by storms, etc., vessel statistics.)

## U. S. Army Corps of Engineers

1916. Grays Harbor Bar, Washington. 64th Congress, 2nd Session, House Document No. 1729, 48 pp.

1933. Grays Harbor and Chehalis River, Washington. 73rd Congress, 1st Session, House Document No. 53, 58 pp.

1934. Grays Harbor, Washington, in House of Representatives, Committee on Rivers and Harbors. 74th Congress, 1st Session, Document No. 2, 36 pp.

1936. Grays Harbor and Chehalis River, Washington, Beach Erosion at the Unloading Wharf, field notes, etc. Original data on file Seattle, Washington District.

1951a. Bar and Entrance Conditions, October 1949, Grays Harbor, in Harbor Entrance Hydrography showing location of samples.

Map File No. E-5-1-44, plate A-10.  
(Samples described in text.)

1951b. Grays Harbor and Chehalis River, Washington, Basis of Design for Protection of Point Chehalis and South Jetty, with Appendix A: Beach Erosion Studies, and Appendix B: Plans Investigated. Original material at Seattle, Washington District, 37 pp.

(Geomorphology, composition of beach and offshore zones, tides, local and offshore winds, waves and swells, storms, and their effect, shore-line changes, offshore depth changes shown in tables, figures, and plates.)

- 1951c. Bar and Entrance Condition, November 1950, Grays Harbor, in Harbor Entrance Hydrography Showing Location of Samples. Map File No. E-5-1-44, plate A-11. (Samples described in text.)

Model Study of Grays Harbor and Point Chehalis, Washington. Waterways Experiment Station, Vicksburg, Mississippi, (type-written).

1951. 1st Interim Report in 2 vols.  
 1951. 2nd Interim Report in 1 vol.  
 1951. 3rd Interim Report in 1 vol.  
 1951. 4th Interim Report in 2 vols.  
 1952. 5th Interim Report in 3 vols.

(Discusses results and shows data in the form of photos of patterns made by time exposures of surface current directions. Tables and plates also included.)

1954. Grays Harbor and Chehalis River, Washington, Design Memo No. 3-- West Shore Revetment at Point Chehalis. On file Seattle, Washington District, 14 pp. (Recent erosion studies and sounding lines shown presenting history of change in bottom topography about Point Chehalis.)
- n.d. A Set of Four Photographs Showing the Changing Shape of the Spit North of the South Jetty at Grays Harbor, 1900-1942. Original data Seattle, Washington District. (Photos obtained by cutting cards to the outline of the spit found on various maps of the spit and racking them in proper order, from 1900 to 1941. These racked cards were then photographed.)
- n.d. Erosion on Point Chehalis at Grays Harbor South Jetty. Original report on file Seattle, Washington District, 6 pp. (typewritten). (History of erosion based on surveys, effect of jetties described.)
- n.d. Grays Harbor and Chehalis River, Washington, South Beach Profiles, Plan of Beach Cross Sections. Original data on file Seattle, Washington District. (High water lines drawn for the following surveys: May 1936, Dec. 1943, Sept. 1944, June 1946, and May 1947).
- n.d. Point Chehalis, Computation of Erosion. Original data on file Seattle, Washington District. (Result of study shows net accretion 1936-1940 was 515,057 cu. yds.; net erosion 1940-1945 was 6,527,193 cu. yds.)

## SEDIMENTS

A. COLUMBIA RIVER

Allen, John Eliot

1932. Contributions to the Structure, Stratigraphy and Petrography of the Lower Columbia River Gorge. Master's Thesis, University of Oregon.

Allen, John E.

1959. Columbia River Gorge: Guide Book for G.S.A. Field Trip Excursions. State of Oregon Department of Geology and Mineral Industries Bulletin 50.

Barton, Manes

1951. A Progress Report on Suspended Sediment Sampling in Several Western Oregon and Western Washington Streams. Research Notes of Pacific Northwest Forest and Range Experiment Station No. 75, Portland, Oregon, 19 pp. (mimeographed).

Bretz, J. Harlen

1919. The Late Pleistocene Submergence in the Columbia River of Oregon and Washington. Journal of Geology, vol. 27, no. 7, pp. 489-506.

(Reviews previous references to a Champlain submergence in the lower drainage of the Columbia River and tries to eliminate erroneous interpretations and correlate data character and extent of the submergence with the Pleistocene history of northwestern Washington.)

Clarke, Frank Wigglesworth

1924. The Composition of the River and Lake Waters of the United States. U. S. Geological Survey Professional Paper 135, 199 pp.  
(Columbia River mentioned.)

Columbia Basin Inter-Agency Committee on Water Pollution

1951. Inventory of Published and Unpublished Sediment-Load Data and Chemical Analysis of Surface Waters in the Pacific Northwest. Administrative Use Only. 44 pp. (mimeographed).

Committee on Tidal Hydraulics, U. S. Army Corps of Engineers

1960. Present and Potential Channel Maintenance Problems in Lower Columbia Estuary. pp. 1-13 plus 30-page discussion.  
(Comments and recommendations by the committee after examining results of 1959 prototype study, include jetty rehabilitations, problems of shoaling, selection of spoil areas, and extent of salt-water intrusion. Suggests model study.)

Foster, R. F.

1959. Research and Development Programs Related to the Disposal of Reactor Effluent to the Columbia River. 86th Congress Joint Committee on Atomic Energy Hearings on Industrial Radioactive Waste Disposal, vol. 2, pp. 1010-1047.

Gottschalk, L.

1942. Notes on Reservoir Silting and Suspended-Load Measurements in Washington. U. S. Department of Agriculture-Soil Conservation Service, Sedimentation Section, Office of Research Special Report No. 2, 15 pp. (mimeographed).

Hickson, R. E. and F. W. Rodolf

1951. History of Columbia River Jetties, in Johnson, J. W., ed.: Proceedings of First Conference on Coastal Engineering. Council on Wave Research, The Engineering Foundation, Berkeley, California, pp. 283-298.  
(History of jetties with series of charts with soundings of Columbia River entrance from 1792 to 1950. Includes cross sections of jetties and chart showing change in 40-foot isobath and shoreline between 1885 and 1950.)

Hodge, Edwin T.

- 1938a. Market for Columbia River Hydroelectric Power Using Northwest Minerals--Northwest Silica Minerals--Silica Localities of the Pacific Northwest. U. S. Army Corps of Engineers, Portland, Oregon, 175 pp.
- 1938b. Geology of the Lower Columbia River. Geological Society of America Bulletin 49, no. 6, pp. 831-930.  
(Describes the general geology of the lower Columbia River and shows how the river came to have its present course through the Cascade Mountains.)

Holdridge, Claire P.

1937. The Lower Columbia River Trip. Geological Society of the Oregon Country News Letter, vol. 3, no. 18, pp. 196-200.

Kelly, J. V.

1947. Columbia River Magnetite Sands, Clatsop County, Oregon, Pacific County, Washington--Hammond and McGowan Deposits. U. S. Bureau of Mines, Report of Investigations 4011, 7 pp.

Landes, Henry (and others)

1934. Geology and Mineral Resources - Columbia River and Minor Tributaries - Vol. 2. 73rd Congress House Document 103, pp. 578-588, 1068-1112, 1178-1210, 1412-14 , 1476-1484.

Lockett, J. B.

1959. Interim Consideration of the Columbia River Entrance. Journal of Hydraulics Division Proceedings of the American Society of Civil Engineers, vol. 85, no. HY1, pp. 17-40.  
(Proposes prototype study of flow in lower Columbia River. Describes problem of shoaling and dredging in Columbia entrance.)

- Lockett, J. B. and H. A. Kidby  
 1961. Prototype Measurements of the Columbia River Estuary. Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, vol. 87, no. HYL, pp. 57-83.  
 (Modern methods of measuring flow characteristics of the Columbia River entrance system define the environmental conditions affecting the problem of shoaling in the entrance area and reveal phenomena which appear to have important significance relating to this problem.)
- Lowry, W. D.  
 1952. Late Cenozoic Geology of the Lower Columbia River Valley, Oregon and Washington. Geological Society of America Bulletin, vol. 63, no. 1, pp. 1-24.  
 (The formations present in the valley of the Columbia River constitute one of the most nearly complete records of the late Cenozoic terrestrial history of Western America. The area discussed extends from the Cascade Mountains on the east to the Pacific Ocean. It includes the lower Columbia River Valley and the Willamette Valley as far south as Salem.)
- Mundroff, Maurice John  
 1959. Geology and Ground-Water Resources of Clark County, Washington, with a Description of a Major Alluvial Aquifer along the Columbia River. U. S. Geological Survey - open file service, 660 pp.  
 (Although stressing mainly the water yield of the area, this paper gives an insight into the geology of Clark County - both igneous and sedimentary.)
- Schultz, E. A. and H. B. Simmons  
 1957. Fresh Water - Salt Water Density Currents, a Major Cause of Siltation in Estuaries. U. S. Army Corps of Engineers Committee on Tidal Hydraulics Technical Bulletin No. 2, pp. 1-28.  
 (Describes various types of saline wedges as related to mixing in the estuary. Describes various types of shoals formed, including deposition at mouth of Columbia River.)
- U. S. Army, Corps of Engineers  
 Ten-Year Record of Dredging in Lower Columbia River. On file District Engineer's Office, Portland, Oregon.  
 (Charts showing location and amount of material in disposal areas from 1950-1960, below mi. 57.)
1938. Mouth of the Columbia River, Oregon and Washington. U. S. Army, Corps of Engineers, Portland, Oregon, 15 pp.  
 (Discussion of jetty construction at mouth of Columbia, with profiles of jetties and sounding charts of river entrance in 1851, 1885, 1913, 1937.)

## U. S. Army, Corps of Engineers

1952. Columbia River and Tributaries. Government Printing Office, Washington, D. C., Vol. 3, pp. 803-806, 824-825, 874-880, 889-890; Appendix D, pls. 13-16, 18, 24, pp. 901-904, 918-919; Appendix E, pls. 10-13, pp. 966-967, 972-974, 990-991; Appendix F, pls. 14-17, 21, 25, 28, 29, 36, 37. Vol. 4, pp. 1439-1441, 1478-1481, 1495-1496, 1498, 1561, 1590; Appendix I, pl. 24. Vol. 6, pp. 2326-2328, 2347, 2366-2367, 2424-2425, 2427-2428, 2430-2432, 2435-2436, 2440-2441, 2442; Appendix K, pl. 25, pp. 2521-2523, 2583; Appendix L, pl. 18, pp. 2710-2712, 2713; pt. 2, pls. 14-17, 19-22. Vol. 8, pp. 3215, 3294, 3309.

1954. Report on Sedimentation Willamette River Basin, Oregon, December 1948 - July 1951. On File, District Library, Portland, Oregon, pp. 1-16 plus charts. (Measures of sediment concentration in Willamette and tributaries. Suspended sediment rates and bed-load movement are comparatively low in Willamette Basin. Many graphs of sediment load and river discharge, gradation curves of river bottom samples.)

1960a. Interim Report on 1959 Current Measurement Program, Columbia River at Mouth, Oregon and Washington. On file, District Library, Portland, Oregon. Vol. 1 - 15 pp.; vol. 2 - velocity data; vol. 3 - direction of flow data; vol. 4 - flow volume, tide gage, and salinity data. (Vol. 1 describes program and methods. Vols. 2-4 present data from measurements along 7 ranges across lower 57 miles of the Columbia.)

1960b. Summary of Interim Report on 1959 Current Measurement Program, Columbia River at Mouth, Oregon and Washington. On file, District Library, Portland, Oregon. (Summary of 4 volume interim report of 1 September 1960 prepared by U. S. Army Engineer District, Portland.)

1961. Sedimentation Investigation Lower Columbia and Lower Willamette Rivers, July 1959-August 1960. On file District Library, Portland, Oregon, pp. 1-17 plus charts and graphs. (Sediment concentration curves, total load, suspended material relations to discharge. Measures at Hood River, Vancouver (Columbia), and Newberg (Willamette).)

## U. S. Bureau of Reclamation

1947. The Columbia River: a Comprehensive Departmental Report on the Development of the Water Resources of the Columbia River Basin for Review Prior to Submission to the Congress. Vol. I, pp. 188, 189, 212-214, 223-224, 226, 228, 254, 289, 304, 306.

## U. S. Geological Survey

Geology of the Columbia River Gorge, Oregon. U. S. Geological Survey (in preparation).

Walker, F. C. and W. H. Irwin  
 1954. Engineering Problems in Columbia Basin (Washington) Varied Clay. American Society of Civil Engineers Proceedings, vol. 80, no. 515, p. 18.

Williams, I. A.  
 1916. The Columbia River Gorge--its Geologic History. Oregon Bureau of Mines, Geology and Mineral Research of Oregon, vol. 2, no. 2.

## B. BEACH SEDIMENTS

Baldwin, Ewart M.  
 1945. Some Revisions of the Late Cenozoic of the Southern Oregon Coast. Journal of Geology, vol. 53, no. 1, pp. 35-46.  
 (Describes marine terraces in Coos Bay area and Cape Blanco.)

Bascom, Willard N.  
 1951. The Relationship Between Sand Size and Beach-Face Slope. Transactions of the American Geophysical Union, vol. 32, no. 6, pp. 866-874.  
 (A series of diagrams is presented which illustrates the variability of sand size and beach-face slope and the relationship between the two as observed on 20 Pacific Coast beaches.)

Bascom, Willard and Donald McAdam  
 1947. Beach and Surf Conditions on Beaches of the Oregon and Washington Coasts between October 9, 1946 and November 18, 1946. University of California, Department of Engineering, Lab Memorandum HE-116-247, 54 pp.  
 (Includes profiles, surf conditions, tire impressions, sand samples, and water table profiles. Data for Humboldt Bay, Coos Bay, and Grays Harbor areas. Large number of photos obtained in survey which were not included in the report.)

Byrd, Nathan L.  
 1950. Vegetation Zones of Coastal Dunes Near Waldport, Oregon. Thesis, Oregon State College, 44 pp.  
 (Study of dune vegetation in an area north of Coos Bay. Environmental factors studied.)

Cooper, William S.  
 1934. Types of Pacific Coast Dunes. Annals of Association of American Geographers, vol. 24, no. 1, p. 46.  
 (Describes sand dunes and types of dunes. Coos Bay dunes used as an Oregon example.)  
 1953. Transverse-Ridge Pattern on the Coastal Sand Dunes of Oregon. Geological Society of America Bulletin (abstract), vol. 64, no. 12, pt. 2, pp. 1501-1502.  
 (The transverse-ridge pattern is richly developed on the coastal dune sheets of Oregon wherever the shore is bordered by a level strip free from obstacles. The ridges lie essentially at right angles to the north-northwest sea breeze of summer.)

Winter winds partially destroy these ridges but, because of the wetness of the sand, cannot establish a corresponding system of their own. Slow motion photographs of smoke streams are included.)

Cooper, William S.

1959. Sand-Dune Development and Sea-Level Changes on the Coast of North Oregon. Bulletin of the Geological Society of America (Abstract), vol. 65, no. 12, pt. 2, p. 1373.  
(The important dune masses on the coast of northern Oregon are related to the mouths of bays and rivers. Each originally consisted of a massive parabola complex built by the southwest winds of winter. The rising sea has since eroded large parts of these masses.)

1958. Coastal Sand Dunes of Oregon and Washington. Geological Society of America Memoir 72, 170 pp.  
(The environment of the coastal dunes of Oregon and Washington, forms and processes, and a description of the dune localities of the Oregon-Washington coast and an account of their history.)

Day, David T. and R. H. Richards

1906. Useful Minerals in the Black Sands of the Pacific Slope. U. S. Geological Survey, Mineralogical Resources of the United States for 1905, pp. 1175-1258.

Griggs, H. B.

1945. Chromite-Bearing Sands of the Southern Part of the Coast of Oregon. U. S. Geological Survey Bulletin 945E.  
(Describes type of deposits, mineralogy, origin and distribution, and reserves of chromite-bearing sands.)

Gullivee, F. P.

1899. Shoreline Topography. Proceedings of the American Academy of Arts and Sciences, vol. 34, no. 8, pp. 151-258.  
(Comprehensive dissertation. Grays Harbor shown as example of bay-delta. Coos Bay shown as an example of sea intention versus river intention.)

Honor, R. R.

1918. Notes on the Black Sands Deposits of Southern Oregon and Northern California. Department of the Interior, Bureau of Mines Technical Paper 196, 42 pp.  
(A comprehensive report covering from Coos Bay to Crescent City, includes location, analyses and values.)

Hundhausen, Robert J.

1947. Chromiferous Sand Deposit in the Coos Bay Area, Coos County, Oregon. U. S. Bureau of Mines Report Inv. 4001, 13 pp.

Isaacs, John D.

1947. Beach and Surf Conditions on Beaches of the Oregon and Washington Coast between August 27 and September 27, 1945. University of California, Department of Engineering Lab Memorandum HE-116-229, 125 pp.  
(Covers beaches off Grays Harbor and Coos Bay. Photos

of beach and surf conditions and tire impressions. Beach profiles, sieve analysis of sand samples shown in tables and diagrams.)

Johnson, Douglas W.

1919. Shore Processes and Shoreline Development. John Wiley and Sons, New York, 584 pp.  
(Not specifically applicable to survey area but useful in analyzing shore processes involved in shoreline development.)

Johnson, J. W. and R. L. Wiegēl

1953. Summary of Research on Waves, Surf, and Beaches (Pacific). University of California Institute of Engineering Research, Series 3, issue 350, pt. I, 29 pp.

Marmer, H. A.

1949. Sea Level Changes Along the Coasts of the United States in Recent Years. Transactions of the American Geophysical Union, vol. 30, no. 2, pp. 201-204.  
(In recent years, there has been observed a rise in sea level along the Pacific coast--averaging out to a few hundredths of a foot per year.)

McLaughlin, Willard T. and Robert I. Brown

1942. Controlling Coastal Sand Dunes in the Pacific Northwest. U. S. Department of Agriculture, Circular 660, 46 pp.  
(Causes, extent, and methods of control discussed. Includes Grays Harbor and Coos Bay.)

Pardee, J. T.

1929. Platinum and Black Sand in Washington. U. S. Geological Survey Bulletin 805, pp. 1-15.  
(General history of mining and geology of the Washington coastal areas.)
1934. Beach Placers of the Oregon Coast. U. S. Geological Survey Circular 8, 41 pp.  
(Description of the beaches, terraces, and history of the Oregon coast in the vicinity of Coos Bay and south to the Rogue River. Describes the gold and platinum deposits of the black sands. N.S. and E.W. sections of South Slough at Coos Bay shown among shore profiles.)

Sahu, Basanta K.

Theoretical and Laboratory Investigation of Beach and Dune Sands between Port Orford and Coos Bay. Doctoral Thesis, University of Wisconsin, in progress.

Smith, Warren D.

1933. Geology of the Oregon Coastline. Pan-American Geologist, vol. 59, no. 1, pp. 33-44.  
(Describes, among the other areas along the coast, the general geology of the Coos Bay area.)

Smith, Warren D.

1940. Oregon Shoreline. Geological Society of America Bulletin (Abstract), vol. 51, no. 12, pt. 2, p. 2033.  
(This paper deals with some of the more essential features of the Oregon coast and particularly some of the recent changes that have taken place.)

Snively, P. D. and H. E. Vokes

1949. The Coastal Area Between Cape Kiwanda and Cape Foulweather, Oregon. U. S. Geological Survey Map OM 97

Stephenson, Edgar L.

1945. Magnetometer Surveys on Black Sands of the Oregon Coast. U. S. Bureau of Mines Report Inv. 3814, 18 pp.  
(Sands contain gold, ilmenite, magnetite, garnet, zircon and chromite. Also includes discussion of surface features.)

Thomas, C. E.

1937. An Investigation of some Oregon Sands with a Statistical Study of the Predictive Values of Tests. Oregon State College Engineering Experiment Station Bulletin 8, 62 pp. 20 figs.

Todd, D. K. and R. L. Wiegel

1951. Local Storms of the Pacific Coast and their Effects on Wave and Beach Conditions. University of California Institute of Engineering Research Wave Investigation Technical Report HE-116-324, 15 pp.  
(The meteorological situations causing local storms in near coastal areas are investigated because of the erosive action on beaches of high, short-period waves generated. Two local storms at Oceanside, California, are examined in detail.)

Twenhofel, W. H.

1943. Origin of the Black Sands of the Coast of Southwest Oregon. State of Oregon Department of Geology and Mineral Industries Bulletin 24, 25 pp.  
(Black sand deposits are found on present beaches and in deposits beneath elevated coastal plains. Prevailing southwesterly winds concentrate the sand south of promontories or at the north side of embayments. Fluctuations in sea-level caused change in position of embayments and promontories with resultant changes in deposition of black sands.)
- 1946a. Mineralogical and Physical Composition of the Sands of the Oregon Coast from Coos Bay to the Mouth of the Columbia River. State of Oregon Department of Geology and Mineral Industries Bulletin 30, 64 pp.  
(Shore physiography, character and composition of the beaches, and mineral analysis including mechanical analysis and identification of heavy minerals.)
- 1946b. Beach and River Sands of the Coastal Region of Southwest Oregon with Particular Reference to Black Sands, Part 1. American Journal of Science, vol. 244, no. 2, pp. 114-139.  
(Description with mechanical and mineral analyses of sands between Coos Bay and Pistol River. Rounding, sorting, and sizing are considered. Sands of streams flowing over coastal areas are considered.)

Twenhofel, William H.

- 1946c. Beach and River Sands of the Coastal Region of Southwest Oregon with Particular Reference to Black Sands, Part 2. American Journal of Science, vol. 244, no. 3, pp. 200-214.  
(This part of the report describes the minerals in the sand.)

University of California Department of Engineering

1946. Notes on Reconnaissance of Miscellaneous Pacific Beaches May 21 - September 29, 1945. University of California Department of Engineering, Fluid Mechanics, Berkeley, HE-116-223, 51 pp. (typewritten).  
(Captions accompanying the photos constitute the report. Photos show surf conditions, beaches, and sand dunes in the various areas studied.)

### C. OFFSHORE SEDIMENTS

Arrhenius, G.

1952. Sediment Cores from the East Pacific. Swedish Deep-Sea Expedition Report 5, 277 pp.

Arrhenius, G., G. Kjellberg, and W. F. Libby

1951. Age Determination of Pacific Chalk Ooze by Radio Carbon and Titanium Content. Tellus, vol. 3, no. 4, pp. 222-229.  
(Measurements have been carried out on the average radiocarbon activity of a sediment core of eupelagic chalk ooze and the age of the lower boundary was calculated by integration of the radiocarbon decay function.)

Barnes, C. A. and R. G. Paquette

1954. Circulation near the Washington Coast. University of Washington Department of Oceanography, Technical Report No. 17, 31 pp.  
(The Washington coast, being mountainous, has considerable runoff to the sea from heavy precipitation in winter and the melting of the snow in early summer. Two concentrated sources of fresh water are the Strait of Juan de Fuca and the Columbia River which drain large inland areas. In this general area, 7 R. V. Brown Bear cruises (1952-1953) measured circulation patterns.)

Betz, F. and H. H. Hess

1942. The Floor of the North Pacific Ocean. Geographical Review, vol. 32, pp. 99-116.  
(A general survey of the North Pacific Ocean's bathymetry with the main interest in the islands of Hawaii and eastern island arcs.)

Budinger, T. F.

1957. Cobb Seamount, a Deep-Sea Feature off the Washington Coast. Master's Thesis, University of Washington Department of Oceanography, 94 pp.  
(The Cobb Seamount is a deep-sea feature 270 nautical miles west of Grays Harbor, Washington. It rises from a base at 1,500 fathoms below the sea surface to within 18.5 fathoms of the surface and

covers an area of 240 square nautical miles. It is concluded to be a pre-late Eocene volcano which has been terraced by wave abrasion and which has subsided about 500 fathoms subsequent to its formation.)

Budinger, T. F. and Betty J. Enbysk

1960. Cobb Seamount, A Deep Sea Feature off the Washington Coast. University of Washington Department of Oceanography Technical Report No. 60, 87 pp.  
(A general study of the Cobb Seamount including bathymetric topography of the area, fathograms, photographs of bottom samples, bottom samples, and temperature, salinity and chemical data.)

Carritt, D. E. and J. H. Harley

1957. Precipitation of Fission Product Elements on the Ocean Bottom by Physical, Chemical, and Biological Processes, in The Effects of Atomic Radiation on Oceanography and Fisheries, Publ. No. 551. National Academy of Sciences--National Research Council, Washington, D. C., pp. 60-68.  
(An attempt to define the processes by which radioactive waste material may be carried to the ocean floor and thus be kept out of human environment; notes the conditions under which these several processes can be expected to operate and ~~assesses~~ the extent to which these processes have been responsible for the removal of activity from the bottom in cases where bottom accumulation has been measured.)

Carsola, Alfred J., R. S. Dietz and R. D. Russell

1949. Submarine Geology of Two Northeast Pacific Sea Mounts (abstract). Geological Society of America Bulletin, vol. 60, no. 12, p. 1878.  
(Survey, bottom photograph and bottom samples have been taken from Erben and Noname banks--two flat-topped seamounts lying 800 and 600 miles west of San Diego. Both are thought to be basaltic cones truncated by wave action. The truncated summits lie 400 fathoms (Erben) and 280 fathoms (Noname) lower than present sea level.)

Curray, Joseph R.

1956. Dimensional Grain Orientation Studies of Recent Coastal Sands. American Association of Petroleum Geologists, vol. 40, no. 10, pp. 2440-2456.  
(A strong tendency for elongate grains to align themselves with their long dimensions parallel with the direction of the depositing current of water or air. Averages are approximately perpendicular to the beach trend.)

Department of Oceanography, University of Washington

1960. Physical and Chemical Data for a Portion of the Northeast Pacific Ocean Extending from the Coasts of Washington and British Columbia Westward to 131°W, April 1956-April 1958. University of Washington Department of Oceanography Technical Report No. 66, 201 pp.  
(Contains oceanographic data collected during eight offshore cruises of the R.V. Brown Bear made during the period April 1956 to April 1958. Includes offshore and Cobb Seamount cruises.)

Dietz, R. S.

1955. Manganese Deposits on the Northeastern Pacific Sea Floor. California Journal of Mines and Geology, vol. 51, pp. 209-220. (Dredging by H.M.S. Challenger, the U.S.S. Albatross, U.S.S. EPC(R) and vessels of the Scripps Institution of Oceanography shows extensive deposits of manganese nodules on the sea floor and crusts of manganese dioxide cover many seamounts. Also, relatively high concentrations of iron and the trace elements nickel, copper, and cobalt are present.)

Hamilton, E. L.

1956. Sunken Islands of the Mid-Pacific Mountains. Geological Society of America Memoir 64, 85 pp. (A study of five flat-topped seamounts 600-1100 miles west of Hawaii. The flat-topped guyots are submerged between 700 and 900 fathoms.)

Hough, J. L.

1953. Pleistocene Climatic Record in a Pacific Core Sample. Journal of Geology, vol. 61, no. 3, pp. 252-262. (A core taken in the Southeastern Pacific had several alternating layers of red clay and globigerina ooze. The red clay is indicative of cold water, while the ooze is correlated to warmer water conditions.)

Inman, Douglas L.

1957. Wave-Generated Ripples in Nearshore Sands. U. S. Beach Erosion Board Technical Memo 100, 42 pp. (Ripples were found to always be present on sandy bottoms when the significant orbital velocity had a value between 1/3 and 3 feet per second. The type of ripple was related to the size of the sand and the nature and rigor of wave motion. In areas of abundant sand, the largest and least dense material occurred on the ripple crests and the finest and heaviest in the trough. On more rocky bottoms, this relationship was often reversed.)

Inman, D. L. and T. K. Chamberlain

1955. Particle-Size Distribution in Nearshore Sediments. Society of Economic Paleontologists and Mineralogists, no. 3, pp. 106-129. (A study in patterns of the areal variation in the distribution of sediments along the California and Gulf of Mexico coasts.)

Menard, H. W., Jr.

1953. Pleistocene and Recent Sediment from the Floor of the Northeastern Pacific Ocean. Geological Society of America Bulletin, vol. 64, pp. 1279-1294. (Sediment from seven dredge hauls includes glacial marine drift - deposited over several hundred thousand square miles in the northeast Pacific. In more recent times blue mud has spread out from shore.)

Menard, Henry W., Jr.

1954. Topography of the Northeastern Pacific Sea Floor. Geological Society of America Bulletin (Abstract), vol. 65, no. 12, pt. 2, p. 1284.

(Dominant features of the northeastern Pacific sea floor are four great fracture zones--subparallel bands of grossly irregular topography which transect the whole area in a westerly direction. Characteristic features of the topography are volcanoes, linear ridges and seascarps. Distinctive topographic provinces lie between fracture zones.)

- 1955a. Deep Sea Channels, Topography and Sedimentation. American Association of Petroleum Geologists Bulletin, vol. 39, no. 2, pp. 236-255.

(Turbidity accounts for many minor topographic features of the present day Northeast Pacific Ocean. Relationships between basins, channels, topography and sedimentation are discussed.)

- 1955b. Deformation of the Northeastern Pacific Basin and the West Coast of North America. Bulletin of the Geological Society of America, vol. 66, pp. 1149-1198.

(Four great bands of unusually irregular topography named "fracture zones" have been discovered in the northeastern Pacific basin, and three have been traced into western North America. The fractured area covers 8,000,000 square miles and the parallel trend indicates a single origin. It is tentatively concluded that an annular convection current rising near the Hawaiian Islands and sinking near North America stressed the crust and produced the fracture zones by plastic deformation.)

1959. Geology of the Pacific Sea Floor. Scripps Institution of Oceanography Contribution No. 1086.

(Concerns the general geologic and bathymetric features of the Pacific Ocean floor.)

Menard, H. W. and R. S. Dietz

1952. Mendocino Submarine Escarpment. Journal of Geology, vol. 60, no. 3, pp. 266-278.

(Describes escarpment and gives bathymetric charts. Considers three hypothesis of origin.)

Moore, D. G.

1955. Rate of Deposition Shown by Relative Subsidence of Foraminifera. American Association of Petroleum Geologists Bulletin, vol. 39, no. 8, pp. 1594-1600.

(Assuming a constant rate of production of Foraminifera, depositional rate of total sediment was calculated from seven deep borings in San Antonio Bay, Texas.)

Nayudu, Y. R.

1959. Recent Sediments of the Northeast Pacific. Ph.D. Thesis, University of Washington, 217 pp.  
(This study is based on 150 slope and deep-sea sediment cores from the Northeast Pacific. The area can be delineated into seven well defined sedimentary types--terrigenous deposits (pebble to clay), terrigenous deposits (fine sand to clay) with diatoms (less than 20%), diatom rich sediments with fine sand to clay, clay with Radiolaria, Globigerina-rich silts and clays, glacial marine remnants with diatoms, and Katami volcanic ash. Source areas and the depositional history of the area are discussed.)

1961. Origin of Seamount Terraces and Guyots as Suggested by the Petrographic Evidences from Cobb and Bowie Seamounts (abstract). Tenth Pacific Science Congress, Honolulu, Hawaii.

Nichols, H.

1950. New Seamounts in the North Pacific. Geographical Review, vol. 40, pp. 457-461.  
(A new seamount, at a depth of 665 fathoms, was recorded at 50°10' N, 141°59' W, some 400 nautical miles southwest of the Queen Charlotte Islands (Canada), on September 26, 1949, by the United States Coast and Geodetic Survey Ship Explorer.)

O'Brien, M. P.

- n.d. Oceanography of Coastal Harbors. U. S. Army Beach Erosion Board, Washington, D. C. (on file).  
(Sections on Grays Harbor, Coos Bay, and Humboldt Bay include description, tides, tidal current, waves, wind, sand samples and beach profiles, sand movement, and structures.)

Powell, D. E., D. L. Anderson and Robert Livingstone, Jr.

1952. North Pacific Albacore Tuna Expedition, 1950. U. S. Fish and Wildlife Service Fishery Bulletin 402, 56 pp.

Revelle, R. R.

1944. Marine Bottom Samples Collected in the Pacific Ocean by Carnegie on its Seventh Cruise. Carnegie Institute, Washington Publication 556, 182 pp.  
(An account of the general character of 75 samples of deep-sea deposits in the southeastern and north Pacific. Also includes distribution of the various deposit types, chemical, mechanical, X-ray and other types of analyses (including biological).)

Rex, Robert W. and Edward D. Goldberg

1957. Quartz Content of Pelagic Sediments of the North Pacific Ocean. Geological Society of America Bulletin (Abstract), vol. 68, no. 12, pt. 2, p. 1843.  
(The quartz contents of pelagic clays from the Eastern Pacific Ocean show a marked latitudinal dependence with a maximum around 30°N. Quartz appears to be transported mainly by air.)

Shipek, C. J.

1960. Photographic Study of some Deep-Sea Floor Environments in the Eastern Pacific. Bulletin of the Geological Society of America, vol. 71, pp. 1067-1074.  
(Nine lowerings in excess of 4500 m along a track between San Diego, California and Valparaiso, Chile.)

Tocher, Don

1955. Earthquakes off the North Pacific Coast of the United States. Geological Society of America Bulletin (Abstract), vol. 66, no. 12, pt. 2, p. 1666.  
(Epicenters of most of the larger earthquakes occurring off the coast of Northern California and Oregon lie in two zones. One zone includes the Gorda Escarpment which extends nearly due west from Punta Gorda. The other zone extends northwestward from the region of Cape Mendocino, indicating a linear extension of the San Andreas Rift Zone as far as Latitude 44° or 45° N.)

Tyler, S. A.

1931. The Petrography of some Bottom Samples from the North Pacific Ocean. Journal of Sedimentary Petrology, vol. 1, pp. 12-22.  
(Sixteen samples of mud and one of sand, dredged from the bottom of the North Pacific Ocean, at depths ranging from 276 feet to 13,134 feet, are described, and their mineral constituents determined. Complete chemical analyses of eight samples are given.)

Utterback, Clinton Louis

1938. Radium Content of some Inshore Bottom Samples in the Pacific Northwest. Journal of Marine Research, vol. 1, no. 3, pp. 187-191.  
(Measurement of radium content from 24 bottom samples from Puget Sound, Strait of Juan de Fuca, and Georgia Strait.)

Waldichuk, Michael

1960. Containment of Radioactive Waste for Sea Disposal and Fisheries off the Canadian Pacific Coast. Disposal of Radioactive Wastes, Conference Proceedings, Monaco, 1959, vol. 2, pp. 57-77.
1961. Sedimentation of Radioactive Wastes in the Sea. Fisheries Research Board of Canada Circular No. 59, 24 pp.  
(Discusses effect of processes and controls of sedimentation on radioactive material. Describes Pacific coast water and sedimentation, and possible influence on radioactive waste dispersal. Includes 40-title bibliography dealing with radioactive waste deposition in the sea.)

Wooster, W. S.

1951. Operation Northern Holiday. University of California, Scripps Institution of Oceanography Ref. 51-46.  
(Presents general results of cruise in Northeastern Pacific Ocean. Summarizes observations and sample analyses and gives plans for future work.)

D. FORAMINIFERA

Bagg, R. M., Jr.

1912. Pliocene and Pleistocene Foraminifera. U. S. Geological Society Bulletin 513, 153 pp.

Bandy, Orville L.

1950. Some Later Cenozoic Foraminifera from Cape Blanco, Oregon. Journal of Paleontology, vol. 24, no. 3, pp. 269-281. (The lithology and significant fossils of the Cenozoic formations exposed at Cape Blanco, Oregon are discussed briefly. Twenty-four species of Foraminifera are described, figured and analyzed; four new species and two new varieties are reported. Information is introduced which raises a question as to the correlation of the terrace beds at the Cape with the Elk River beds just north of Elk River.)
1952. Miocene Foraminifera from Erben Bank. Contribution of Cushman Lab for Foram. Research, vol. 3, no. 1, pp. 16-20.

Brady, H. B.

1884. Report on the Foraminifera Dredged by H.M.S. Challenger during the Years 1873-1876. Report of Voyage Challenger, vol. 9, 814 pp.

Cole, W. S.

1957. Foraminifera of the Cenozoic--annotated bibliography. Geological Society of America Memoir 67, vol. 2, pp. 757-762.

Cushman, J. A.

- 1910-1916. A Monograph of the Foraminifera of the North Pacific Ocean. U. S. National Museum Bulletin 71, 596 pp.
1927. Recent Foraminifera from off the West Coast of America. Bulletin of Scripps Institution of Oceanography Technical Series, vol. 1, no. 10, pp. 119-188.
1932. Some Recent Angulogerinas from the Eastern Pacific. Contribution of the Cushman Lab for Foram. Research, vol. 8, pp. 44-48.

Cushman, J. A. and Irene McCulloch

1939. A Report on some Arenaceous Foraminifera. Allan Hancock Pacific Expedition, vol. 6, no. 1, pp. 1-113, pl. 1-12.
1940. Some Nonionidae in the Collections of the Allan Hancock Foundation. Allan Hancock Pacific Expedition, vol. 6, no. 3, pp. 145-178, pl. 17-20.
1942. Some Virguliniinae in the Collections of the Allan Hancock Foundation. Allan Hancock Pacific Expedition, vol. 6, no. 4, pp. 179-230, pl. 21-28.
1948. The Species of Bulimina and Related Genera in the Collections of the Allan Hancock Foundation. Allan Hancock Pacific Expedition, vol. 6, no. 5, pp. 231-294, pl. 29-36.

- Cushman, J. A. and Irene McCulloch  
1948. Three New Names of Recent Pacific Foraminifera. Contribution of the Cushman Lab for Foram Research, vol. 24, p. 76.
- Cushman, J. A. and F. L. Parker  
1940. The Species of the Genus *Bulimina* Having Recent Types. Contribution of the Cushman Lab for Foram. Research, vol. 16, pt. 1, pp. 7-23.
- Cushman, Joseph A., Roscoe E. Stewart and Katherine C. Stewart  
1947. Five Papers on Foraminifera from Tertiary of Western Oregon. State of Oregon Department of Geology and Mineral Industries Bulletin No. 36, pp. 0-111.
- Cushman, J. A. and Ruth Todd  
1943. The Genus *Pullenia* and Its Species. Contribution of the Cushman Lab for Foram. Research, vol. 19, pt. 1, no. 241, pp. 1-23.
1947. Foraminifera from the Coast of Washington. Contribution of the Cushman Lab for Foraminifera Research Special Publication No. 21, pp. 1-23, 4 pls.
- Dall, William H.  
1907. Notes on Some Upper Cretaceous Volutidae, with Descriptions of New Species and a Revision of the Groups to which they Belong. Smithsonian Institute of Washington, Miscellaneous Collections, vol. 50, pp. 1-23.  
(Study began with Tertiary fauna of Coos Bay. Described as same species as those of upper Cretaceous. Discusses family Volutidae and compares with forams elsewhere in the world.)
1909. Contributions to Tertiary Paleontology of the Pacific Coast: I - The Miocene of Astoria and Coos Bay, Oregon. U. S. Geological Survey Professional Paper 59, 278 pp.  
(Tertiary description of Astoria and Coos Bay, including invertebrate fauna. Thirteen appendices covering early reports by T. A. Conrad, J. D. Dana, B. F. Shepard, P. P. Carpenter, not usually available.)
- Detling, Mildred Riechers  
1946. Foraminifera of the Coos Bay Lower Tertiary, Coos County, Oregon. Journal of Paleontology, vol. 20, no. 4, pp. 348-361.
1958. Some Littoral Foraminifera from Sunset Bay, Coos County, Oregon. Cushman Foundation for Foram. Research, vol. IX:2, no. 179.
- Emiliani, C.  
1954. Depth Habitats of some Species of Pelagic Foraminifera as Indicated by Oxygen Isotope Ratios. American Journal of Science, vol. 252, pp. 149-158.  
(Different species of pelagic Foraminifera occupy different habitats depending on temperature and water density.)

- Enbysk, B. J.  
1961. Foraminifera from Northeast Pacific Cores. Tenth Pacific Science Congress, Honolulu, Hawaii (Abstract).
- Flint, J. M.  
1899. Recent Foraminifera. Annual Report of the U. S. National Museum, pp. 249-349, 80 pls.
- Hamilton, E. L.  
1953. Upper Cretaceous, Tertiary and Recent Planktonic Foraminifera from Mid-Pacific Flat-Topped Seamounts. Journal of Paleontology, vol. 27, no. 2, pp. 204-237.
- Jarman, Gary C.  
Foraminifera and Associated Sediments of the Coastal Waters in the Vicinity of Newport, Oregon. Master's Thesis, Oregon State University, in progress.
- Jones, Robert W.  
1960. Lower Tertiary Foraminifera from Waldport, Oregon. Master's Thesis, Oregon State University.
- Lalicker, C. G. and Irene McCulloch  
1940. Some Textulariidae of the Pacific Ocean. Allan Hancock Pacific Expedition, vol. 6, no. 2, pp. 115-143, pls. 13-16.
- Myers, E. H. and W. S. Cole  
1947. Annotated Bibliography - Foraminifera. Geological Society of America Memoir 67, vol. 1, pp. 1075-1082.
- Rau, Weldon W.  
1946. Foraminifera from Oligocene Lincoln Formation in the Porter Area, Washington. Master's Thesis, Iowa State University.  
1948a. Foraminifera from the Porter Shale, Grays Harbor County, Washington. Journal of Paleontology, vol. 22, no. 2, pp. 152-174.  
1948b. Foraminifera from Miocene Astoria Formation in Southwest Washington. Journal of Paleontology, vol. 22, no. 6, pp. 774-782.  
1950. Tertiary Foraminifera from the Willapa River Valley of Southwest Washington (Abstract). Geological Society of America Bulletin, vol. 61, no. 12, pt. 2, p. 1540.  
1951. Tertiary Foraminifera from the Willapa River Valley of Southwestern Washington. Doctoral Thesis, Iowa State University 1950; Journal of Paleontology, vol. 25, no. 4, pp. 417-453.  
1956a. Foraminiferal Zonations in the Tertiary Sequence of Southwestern Washington. Journal of Sedimentary Petrology, vol. 26, no. 2, p. 207; Journal of Paleontology, vol. 30, no. 4, p. 1026.

Rau, W. W.

- 1956b. Foraminifera from the McIntosh Formation (Eocene) at McIntosh Lake, Washington. Cushman Foundation Foraminifera Research Contribution, vol. 7, no. 3, pp. 69-78.

Basic Studies of the Microfauna of the Newport Embayment, Newport, Oregon. U. S. Geological Survey, in progress.

Smith, A. B.

1961. A Comparison of the Distributions of Living Planktonic Foraminifera and Globigerina-Rich Sediments, (abstract). Tenth Pacific Science Congress, Honolulu, Hawaii.

Distribution of Living Planktonic Foraminifera in the Northeast Pacific Ocean, in progress.

Sohn, Israael G.

1948. Two New Marine Ostracods from the Tertiary of Washington. Journal of Paleontology, vol. 22, no. 4, pp. 482-485.

#### MAPS AND CHARTS

Baldwin, E. M.

1956. Geologic Map of the Lower Siuslaw River Area, Oregon. U. S. Geological Survey Map OM 186.

Revision of the Dallas and Valsetz Geologic Maps, Oregon. State of Oregon Department of Geology and Mineral Industries, began August 1960.

Boardman, Leona

1949. Geologic Map Index of Washington. U. S. Department of the Interior, Geological Survey, Washington, D. C.

Gard, L. M., Jr.

1954. Geology of the Starbuck Quadrangle, Washington. U. S. Geological Survey Geological Quadrangle Map GQ 34, Scale 1:62500.

Henderson, John R., et al.

1958. Grayland Quadrangle, Grays Harbor and Pacific Counties, Washington. U. S. Geological Survey Geophysical Inv. Map GP-176.

Henderson, John R., Jr., Natalie S. Tyson et al.

1958. Aberdeen Quadrangle, Grays Harbor and Pacific Counties, Washington. U. S. Geological Survey Geophysical Inv. Map GP-177.

Henderson, John R., et al.

1958. Montesano Quadrangle, Grays Harbor and Pacific Counties, Washington. U. S. Geological Survey Geophysical Inv. Map. GP-178.

## Henderson, John R., et al.

1958. Malone Quadrangle, Grays Harbor and Lewis Counties, Washington. U. S. Geological Survey Geophysical Inv. Map GP-179.
1958. Rochester Quadrangle, Thurston, Grays Harbor and Lewis Counties, Washington. U. S. Geological Survey Geophysical Inv. Map GP-180.
1958. Tenino Quadrangle, Thurston and Lewis Counties, Washington. U. S. Geological Survey Geophysical Inv. Map GP-181.
1958. Part of the Yelm Quadrangle, Thurston and Lewis Counties, Washington. U. S. Geological Survey Geophysical Inv. Map GP-182.
1958. Cape Shoalwater Quadrangle, Pacific County, Washington. U. S. Geological Survey Geophysical Inv. Map GP-183.
1958. South Bend Quadrangle, Pacific County, Washington. U. S. Geological Survey Geophysical Inv. Map GP-184.
1958. Willapa Quadrangle, Pacific County, Washington U. S. Geological Survey Geophysical Inv. Map GP-185.
1958. PeEll Quadrangle, Pacific and Lewis Counties, Washington. U. S. Geological Survey Geophysical Inv. Map GP-186.
1958. Adna Quadrangle, Lewis County, Washington. U. S. Geological Survey Geophysical Inv. Map GP-187.
1958. Centralia Quadrangle, Lewis County, Washington. U. S. Geological Survey Geophysical Inv. Map GP-188.

## Koch, John G.

Mapping of Humbug Mountain Area to be extended South and East for doctoral thesis, University of Wisconsin, begun summer 1960.

## Snively, P. D., Jr.

1951. Geology of the Eastern Part of the Centralia-Chehalis Coal District, Lewis and Thurston Counties, Washington. U. S. Geological Survey Coal Inv. Map and Text, vol. 68.

## Snively, Park D., Jr. and Holly C. Wagner

Detailed Geologic Mapping of the Cape Foulweather, Euchre Mountain, Yaquina, Toledo, Waldport, and Tide Water 15-minute Quadrangles, Oregon and Related Stratigraphic and Petrographic Studies in the Central Part of the Oregon Coast Ranges. (in progress).

## Trimble, D. E.

1954. Geology of the Haas Quadrangle, Washington. U. S. Geological Survey Geological Quadrangle Maps GQ-43, Scale 1:62500.
1957. Geology of the Portland Quadrangle, Oregon - Washington. U. S. Geological Survey Geological Quadrangle Map GQ-104, Scale 1:62500.

## U. S. Army Corps of Engineers

n.d. Grays Harbor, Washington - Maps. Seattle District Survey Map File No. E-5-7-16/1 to 54.  
(Survey of bar and entrance from 1862 through 1953, a total of 54 surveys, including all U. S. Coast and Geodetic Survey work.)

1954. Project and Maps (active and inactive River and Harbor and Flood Controls Projects are shown), Portland District.

## U. S. Geological Survey

Geologic Map of the Lower Umpqua River Area. U. S. Geological Survey Oil and Gas Investigation Series OM Map, work completed and being edited (1960).

Proposed Cooperative Geologic Mapping Venture Between the U. S. Geological Survey and State of Oregon Department of Geology and Mineral Industries in Camas Valley, Dutchman Butte Region, Southwest Oregon, expected to begin 1961.

Vokes, H. E., Hans Norbistrath and P. D. Snively

1949. Geology of the Newport-Waldport Area, Lincoln County, Oregon. U. S. Geological Survey Map OM-88.

Vokes, H. E., P. D. Snively and D. A. Myers

1951. Geology of the Southern and Southwestern Border Areas of the Willamette Valley, Oregon. U. S. Geological Survey Map OM-110.

Vokes, H. E., D. A. Myers and Linn Hoover

1954. Geology of the West Central Border Area of the Willamette Valley, Oregon. U. S. Geological Survey Map OM-150.

Waldron, H. H.

1954. Geology of the Hay Quadrangle, Washington. U. S. Geological Survey Geological Quadrangle Map GQ-48, Scale 1:62500.

Waldron, H. H., and L. M. Gard, Jr.

1955. Geology of the Penawawa Quadrangle, Washington. U. S. Geological Survey Quadrangle Map GQ-56, Scale 1:62500.

Warren, W. C. et al.

1945. Geology of Northwestern Oregon, West of the Willamette River and North of Latitude  $45^{\circ}15'$ . U. S. Geological Survey Map OM-42.

Wells, F. G.

1955. Preliminary Geologic Map of Southwestern Oregon West of Meridian  $122^{\circ}$  West and South of Parallel  $43^{\circ}$  North. U. S. Geological Survey Map ME-38.

Wells, F. G. and G. W. Walker

1953. Geology of the Galice Quadrangle, Oregon. U. S. Geological Survey Map GQ-25.