Prospectus For

AN OCEANOGRAPHICAL INVESTIGATION OF THE UMPQUA RIVER ESTUARY AND RELATED STUDIES OF THE UMPQUA RIVER BASIN

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FORWARD

This report discusses anticipated problems associated with the pollution of the Umpqua River estuary in Oregon. The method of studying these problems by oceanographical techniques is outlined. Proposed studies relating to the Umpqua River Basin are examined.
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INTRODUCTION

Industry is becoming increasingly aware of the Northwest as a base of industrial operations. Associated with this increase will be greater and more complex problems of industrial waste pollution. As interior rivers and streams approach a point where further pollution would seriously interfere with beneficial water uses, the land bordering estuarine and coastal waters will be looked to for industrial location.

As fresh areas are cut over for the harvest of timber and replanted to sustain timber yields, and as more land is cleared for agricultural and urban development, the effects of watershed operations on the quality of estuarine waters will be more and more in evidence.

While the problem of marine pollution has been of considerable interest to the U. S. Public Health Service, little direct research in this area has been attempted. In the program outlined below, oceanographical methods and techniques will be applied to problems associated with the pollution of Northwest estuaries.

Because of the large volume of sea water available for dilution of waste material, the ocean is often considered an ideal location for an effluent outfall. Tidal estuaries, which also provide fairly large dilution volumes, are sometimes efficient removers of pollutants. Although these environments may be considered preferable to lakes and inland streams for the location of pollutant outfalls, there are certain factors that must be considered before their efficiency can be rated. To begin with, we know little about the flushing characteristics of Northwest
estuaries. The circulation pattern of Oregon estuaries has not been well established. Coefficients of diffusion have not been ascertained with regard to various stages of river runoff. The coastal oceanography of the region is known only slightly. Fundamental research on the near-shore oceanography of Oregon is practically non-existent. We cannot state categorically that an outfall located 100 feet or 2 miles into the ocean will be a suitable solution to any given situation. This is so because we must consider such factors as: what will be the effect of pollutants on fisheries, on aesthetic use of beaches, on tourist usage of coastal waters, on sport fishing activities, on municipal and industrial water requirements, etc. We must be in a position to better answer these questions as they arise.

Although immediate results might be obtained from a study of near-shore ocean circulation in the vicinity of existing or proposed ocean outfalls, the personnel and equipment requirements for this type of research are costly and necessitate greater resources than this initial study provides. However, much useful information can be gained from estuarine research which, although not directly convertible to ocean situations, can be used as a foundation for a program to be followed in ocean studies.

The Umpqua River Estuary of Oregon (fig. 1) was selected as the first area of study. The reasons why the Umpqua was chosen are:
1) accessibility, 2) importance to the economy of the region, 3) little pollution is now added to the estuary, 4) there have been proposals to construct pulp mills on the Umpqua, with effluent being discharged into the estuary or upstream of it.
The Umpqua is in a relatively pure state. One might inquire as to why one would choose a pure system when the object is to study estuarine pollution. The answer, of course, lies in the fact that we must know what the natural conditions obtaining are before we can filter out the contributions played by pollution to, for example, the dissolved oxygen budget of the estuarine waters. Another argument can be made by stating that no two estuaries are alike, either with respect to their physical boundaries or the physical structure of their waters. This is true, but the methods of studying different estuaries are the same; it is the collection, analysis and interpretation of data that differs.
OBJECTIVES

Our first objectives will be to define the estuary in terms of the physical, chemical and biological characteristics of the marine environment. Knowing these, one will be able to predict the influence of a given waste material on the environment and from this determine the effects on, for instance, the fisheries or recreational use of the Umpqua region.

The horizontal and vertical distribution of temperature, salinity and velocity usually determines the type of classification of an estuary. The usual classification of estuaries is in terms of the degree of mixing of salt and fresh waters and is discussed briefly in Appendix A.

The density distribution in the estuary may be obtained from temperature and salinity of the water (see Appendix B). The density distribution determines the stratification of water, hence, will show whether a given pollutant will (if discharged at the surface) sink or be transported in the surface waters.

The flushing rate of an estuary can be estimated from a knowledge of mean velocity data and from the vertical and horizontal salinity structure.

A knowledge of the structure of the waters is essential in an understanding of circulation within the estuary.

Finally, an important objective of this program is to illustrate how estuarine pollution studies can contribute to furthering the work of
the Public Health Service and the States in carrying out their responsi-
bilities in the control of water pollution.
A good deal of original work on estuaries has been performed by Pritchard who defined (1955) an estuary as "... a semi-enclosed coastal body of water having a free connection with the open sea and containing a measurable quantity of sea salt."

Pritchard has classified estuaries as type A, B, C or D, the type being a function of vertical and horizontal salt distribution (see Appendix A).

At times of high runoff, salt water intrusion into the Umpqua penetrates upstream only 3 or 4 miles. During low runoff periods salt is found as far upstream as 18 miles.

For our purposes we will regard the period of low flow as defining the estuary, i.e. the 'measurable quantity of sea salt' at low flow (about 18 miles upstream) is the upper limit of the system.

The Umpqua poses many problems in that with the procession of the seasons the classification of the estuary changes from type A (salt wedge) to B (partly mixed) to D (well mixed). Existing theoretical studies of diffusion due to turbulent mixing have considered only the well mixed estuary. Data presented by Burt and McAlister (1959) have shown that the Umpqua was well mixed for only one month out of the six months considered. At times of high runoff, it is safe to say that any pollutant introduced into the estuary upstream of salt water penetration will be flushed out rather quickly, since seaward non-tidal drift will predominate.
Estuarine Oceanography

Strictly speaking, the physical, chemical, biological, geological and bacteriological aspects of an estuary should be included in any oceanographic investigation. Of primary importance is the determination of the physical and chemical features of estuarine waters and the investigation of biological populations present in these waters.

Physical Characteristics

By the physical characteristics of an estuary, we mean the temperature structure of the water, the density and velocity distribution, tidal and mixing characteristics, and the general circulation pattern. The main purpose of studying the physical characteristics of the water is to enable one to estimate diffusion effects and to predict the probable path of waste discharge.

Chemical Characteristics

The chemical characteristics of saline waters may influence the physical structure of the water. For instance the salt distribution determines, in part, the density structure of water (see Appendix B).

The dissolved oxygen distribution is, of course, of primary concern in a pollution problem.

Tidal replenishment of dissolved oxygen will be studied with regard to the oxygen requirements of various waste materials.

At present it is planned to keep laboratory work to a minimum until such time as we are able to determine which chemical analyses are truly meaningful. We feel it would be unwise to overburden ourselves with
laboratory work until we have gained fundamental knowledge of the various physical factors involved in the general circulation pattern.

**Biological Characteristics**

An understanding of the physical processes involved in water circulation is always required in a study of estuarine pollution. Biological studies are a necessary and often more important adjunct of this type of investigation. For instance, researchers have demonstrated that certain species of organisms act as indicators of pollution.

Preliminary biological work should consist of the description and enumeration of principal planktonic species, benthic organisms and algal communities. Ecological rather than taxonomic aspects of the biological populations will be emphasized.

The necessary field work can ordinarily be accomplished in conjunction with routine hydrographic surveys. Further field and laboratory work will be required for productivity studies.
AUXILIARY INFORMATION

Although extensive field work will be needed, much useful and necessary information can be obtained from records of climatology, run-off and tides. An analysis of existing data on precipitation, evaporation, winds, air temperature and cloud cover is anticipated. This data will be examined and utilized in the analysis of information obtained in the field. These records are available from the U. S. Weather Bureau.

When we consider the fresh water budget of a system we know that the amount of fresh water present is due to that added by river runoff, precipitation, ground water and condensation. Water is lost from the system by flow out of the estuary, evaporation and seepage. The analysis of the above-mentioned Weather Bureau data allows one to estimate the positive and negative contributions of precipitation, condensation and evaporation to the fresh water budget.

Similar considerations apply to a heat budget study, for here wind velocity and cloud cover data, as well as evaporation and precipitation data, are required.

Tides and Mixing

Tides on the Pacific Coast are "mixed," that is, there is a significant inequality in height in the two high and low waters occurring each day.

The degree of mixing of fresh and saline waters is determined by the amount of energy available to accomplish this mixing. Besides mixing...
due to turbulent diffusion there are two obvious mechanisms that provide energy to be dissipated in the form of mixing: that from wind stress on the water surface and from tides.

Mixing from wind stress is greatest in shallow estuaries. This stress is proportional to the square of the wind velocity at the water surface. Wind mixing of shallow, broad estuaries may dominate the circulation where the tides are slight.

The greatest source of energy for mixing is found in the tides. At the Umpqua River entrance the mean tidal range is 5.1 feet. Burt and McAlister (1959) have pointed out that the tidal range in the Mississippi Estuary is about 0.5 feet, or about one tenth that of Oregon estuaries. Since tidal energy is approximately proportional to the square of the tidal range, it can be easily seen that there is about 100 times as much energy available for mixing in the Umpqua River as in the Mississippi.
SAMPLING PROGRAM

The configuration of the Umpqua estuary is such that the flood tide advances up the estuary in the form of a progressive wave. The velocity of this wave is about 8 knots. It has been shown by others that the mean of a few low-water samples and the mean of a large number of samples taken at all stages of the tide have virtually the same significance. The technique involved here is termed the "same-slack" procedure. The results obtained by single mid-channel "same-slack" stations are often more valid than those obtained from cross-sectional data. One disadvantage of taking low water samples is that they may not reveal pollution intentionally discharged at high water when dilution is at a maximum.

Despite the above-named disadvantage, it is proposed to utilize the same-slack technique in the Umpqua. It will also be necessary to obtain anchor station data over a tidal cycle at about three locations. The location of these anchor stations can be best chosen after examination of some longitudinal sections obtained after two or three cruises. Besides revealing changes in properties with the procession of tidal stages, time-series velocity data can be used to determine fresh water runoff volumes. If $V_e$ is the volume transport on the ebb tide, $V_f$ the transport on the flood tide, then river runoff transport, $R$, is

$$R = V_e - V_f.$$  

In a two-layer system, the net ebb and flood velocities, the cross-sectional area of each layer and the duration of ebb and flood tide are
required to determine $V_e$ and $V_f$. It is doubly urgent to determine ebb and flood transports since there are no gaging stations situated near the Umpqua estuary at this time.

The equipment to be used in the investigation is listed in Appendix C.

Upon the completion of each field trip data reports, with limited interpretations of results obtained, will be issued as appendixes to this Prospectus.
POLLUTION OF ESTUARIES

In the introduction we noted that one of the objectives of this program would be to better establish the physical characteristics of the estuary which must be considered in determining or forecasting the effect of various effluents on estuarine waters.

Pollution problems in estuaries are complex. A small amount of organic waste may act as a beneficial plankton fertilizer and thus aid in the productivity cycle, especially in snow-fed mountain waters; yet this amount may be construed as detrimental to other users of the receiving waters.

In the case of anadromous fisheries, pollution of estuarine waters may be of such strength as to seriously debilitate young downstream migrants, yet be of insufficient strength to noticeably affect adult fish. When one considers the pollution problem with respect to fisheries alone and bears in mind that a regime may support a bottom, pelagic, anadromous and shell fishery, then it is not likely that effects of pollution on, e.g., bottom fish will be identical to the effects on salmon fingerlings. This is especially true in the light of recent work by the U. S. Public Health Service which has shown that there is a tremendous range of response between different species of fish to seemingly minute quantities of various toxic substances.

Published reports of the Oregon Fish Commission indicate that about 8 per cent of coastal Dungeness crab catches, which have fluctuated between 6 and 11 million pounds per year, are landed in the Umpqua. Fish
Commission statistics for the years 1950-1953 show that about 6.7 percent of a total landing of 590,900 pounds of Oregon estuary bay clams were accounted for in the Umpqua estuary. It is also interesting to note that tourist catches of bay clams often exceed those made by commercial fishermen. It is obvious that deleterious pollution effluents would unbalance the shellfishing economy of Oregon and also adversely influence tourist activities.

Oregon coastal areas reserved for public use by legislature are used extensively by tourists and local citizens for recreational activities. Pollution, whether it be of the air or water, is a problem of concern not only to those using coastal areas for recreational and aesthetic reasons but to those service industries and home owners located near the sites where pollution occurs.
While we shall restrict ourselves to field studies of water containing a "measurable quantity of sea salt," we realize that we are not dealing with an isolated system. During periods of high runoff there is little salt water penetration into the Umpqua. This fact alone points out the need for work in the river basin itself, for it will be here that most of the observed physical and chemical properties of the estuarine water originated.

An indirect evaluation of pollutants contained in river water may be made by an examination of the economic base of the river basin. An economic study of the Umpqua River Basin will be pursued in conjunction with the oceanographic program. Included in this study will be an analysis of economic factors important to the basin to which growth projections will be applied. The status of plant facilities, water uses, water quantities and requirements, both present and projected, will be determined.

Watershed characteristics of the Umpqua River drainage area will be studied with regard to the influence of timber production, harvesting, agriculture and other major operations on the quantity and quality of water produced in the basin. Such projects as dam construction, road building and poor logging practices can also affect water quality by increasing the sediment load of rivers.
SUMMARY

1. The Umpqua River estuary in Oregon has been selected as the initial area of research in an oceanographical program concerned with estuarine pollution.

2. Physical, chemical and biological features of the estuarine waters will be studied in relation to the control of estuarine pollution.

3. The effect of either estuarine or ocean outfalls on the current and projected beneficial water uses of surrounding areas will be determined.

4. Conclusions will be developed from oceanographical studies which will guide in the waste treatment required of cities, industries and land users who will discharge their wastes, either directly or indirectly, into coastal or estuarine waters.

5. Related studies of the Umpqua River Basin will determine the present and projected economic base of the region, the influence of agricultural and other operations on the quantity and quality of water in the drainage basin, the influence of various projects on the sediment load of the Umpqua River and its tributaries.
LITERATURE CITED

Burt, Wayne V., and W. Bruce McAlister
Research Briefs, Fish Commission

Pritchard, D. W.
Proceedings American Society Civil
Engineers, Vol. 81, Separate 717,
pp. 1-11.
APPENDIX A

CLASSIFICATION OF ESTUARIES

Pritchard's (1955) generally accepted classification of coastal plain estuaries formed by the drowning of river mouths divides estuaries into four major types: A, B, C, D. The estuary type depends on the density stratification as indicated by the salinity and circulation pattern; density stratification being governed by river inflow, tidal action and the width and depth of the estuary.

Type A Estuary

The type A estuary (fig. 2A) occurs when the ratio of river flow to tidal flow is relatively large or when the width to depth ratio of the estuary is relatively small. Here there is a well-defined salt wedge penetrating upstream along the bottom, with a relatively fresh layer of water overlying the wedge. There is a net upward flux of salt into the fresh layer; continuity is maintained by upstream movement of the wedge of ocean origin.

Type B Estuary

In the type B estuary (fig. 2B) there is a less well-defined interface between the salt and fresh layer as in the type A. Again, there is a net flow upstream along the bottom and net outflow at mid-depth to the surface. Unlike the type A estuary, the stability of the type B estuary is such as to allow large scale vertical mixing.

1/ Burt and McAlister (1959) find no evidence of type C estuaries in Oregon.
Figure 2: Estuarine Circulation Types (adapted from Pritchard, 1955). A. Two-layered system; B. Partly-mixed system; D. Well-mixed system. (This figure taken from Burt and McAlister, 1959)
Type D Estuary

The type D estuary (fig. 2D) is sometimes referred to as sectionally homogeneous in that the salinity distribution becomes uniform both vertically and laterally. There is a salinity gradient directed upstream. The type D estuary occurs at periods of low river flow or when the width to depth ratio is large. The energy required for mixing is supplied by the tides.
APPENDIX B
INSTRUMENTATION AND ANALYSIS

In this section we will briefly discuss proposed methods of instrumen-
tation and analysis.

At this time only a small amount of laboratory work is anticipated
due to limited personnel. It will be necessary in the future to increase
the laboratory work load to include measurements of B.O.D., P.B.I., and
M.P.N. Until that time only routine examinations of in situ dissolved
oxygen and pH will be made.

In deep sea oceanographic work the accuracy of measurements in the
determination of the so-called geostrophic currents is critical. Temper-
ature is reported to the nearest hundredth of a degree centigrade and
salinity is now sometimes reported to the nearest part per million. Such
accuracy is not required, nor especially meaningful, in an environment
where wide fluctuations take place in a matter of minutes.

In the beginning of our field work we shall endeavor to ascertain
the time and space distribution of temperature, salinity, velocity, and,
as mentioned before, pH and dissolved oxygen.

Temperature at depth is most easily measured by a bathythermograph.
This instrument is equipped with a stylus which leaves a trace on a smoked
glass slide. The slide is placed in a calibrated grid and the trace gives
a continuous record of temperature versus depth. Used in conjunction with
a reversing thermometer (accurate to \(\pm 0.01^\circ C\)) the bathythermograph can
provide a permanent, accurate record of temperature in a matter of minutes.
Salinity is determined by the modified Mohr method which involves precipitation of AgCl in the presence of an indicator.

Actually, one determines salinity (S) from chlorinity (Cl), the relationship being

\[ S = 0.03 + 1.805 \text{ Cl}. \]

The titration method of salinity determinations is somewhat laborious, and much use will be made of calibrated hydrometers to facilitate the work. We are also investigating commercial outlets manufacturing portable temperature-conductivity bridges.

A knowledge of salinity is important for a number of reasons. It is a nearly conservative concentration\(^2\); the non-conservative processes altering the salinity concentration need not concern us here. Diffusion of pollutants may occur upstream of the pollution source. Theoretical studies have shown that this diffusion is to the limit of salt water intrusion.

In conjunction with temperature and pressure, the salinity of a particle of water determines the density of the water, or

\[ \rho = \rho(s, t, p) \]

where

- \( \rho \) = density,
- \( s \) = salinity,
- \( t \) = temperature,
- \( p \) = pressure.

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\(^2\)Consider a cube fixed in space. If the salinity changes from, say, 30 \%oo to 31 \%oo the change is due to water of salinity 31 \%oo being brought into the cube (advection) and/or to the turbulent flux of salt into the cube (eddy diffusion). A non-conservative concentration, such as oxygen, is altered locally by advection, diffusion and biological or biochemical processes.
Oceanographers usually report density at atmospheric pressure, or
\[ \sigma_{s,t,1} = \sigma_t = (\rho_{s,t,1} - 1)10^3. \]
Here pressure is equal to one atmosphere and \( \sigma_t \) is a shorthand method of eliminating the first two digits in the density value. If \( \rho_{s,t,1} = 1.02512 \), then \( \sigma_t = 25.12 \). Convenient tables exist for finding \( \sigma_t \) at intervals of 0.01°C and 0.01‰ of salinity.

The horizontal distribution of \( \sigma_t \) gives an idea as to streamlines of flow. The vertical distribution of \( \sigma_t \) indicates the degree of stratification and the stability of water.

Dissolved oxygen samples collected at different depths will be analyzed in the field, when possible, or in the laboratory.

Velocity measurements will be made with the Pritchard-Burt confined drag meter. This meter is a biplane arrangement of marine plywood, weighted for making measurements at depth.
APPENDIX C

LIST OF EQUIPMENT TO BE USED IN INVESTIGATION

The following list of equipment, most of which is now on hand, will be used in the Umpqua River estuarine program. It is anticipated that items will be added to this list as the program progresses.

Temperature

Bucket thermometers
Reversing thermometers
Bathythermograph
Resistance bridge, for in situ measurements

Salinity

Hydrometer
Determination by modified Mohr method (titration)
   Knudsen buret
   Knudsen pipet
Conductivity bridge, for in situ measurements

Water Sample Collection

Nansen bottles
Frautschy bottles
Plastic buckets

Biological Sample Collection

Plankton nets
Clarke-Bumpus plankton meter
Scoopfish (for bottom samples)
Dredges (for bottom samples)
Snappers (for bottom samples)
Miscellaneous Equipment

Bathythermograph slides and grids
Chlorinity bottles
Hydrographic wire
Messengers
Meter wheel
Oxygen bottles
Hand winch
Reversing thermometer readers
Reversing thermometer frames
Copenhagen water ampules
Wire angle indicator
pH meter
Pritchard-Burt confined drag velocity meter
Tide staffs
Tide recorders
Thermographs