Crystal Orr

From:	Meriel Darzen [meriel@crag.org]
Sent:	Monday, June 24, 2019 3:26 PM
To:	Planning Department; Jill Rolfe
Subject:	Oregon Shores JCEP Remand Comments - First Open Record Period
Attachments:	Ltr. Oregon Shores Comments on Remand Open Record 6.24.19.pdf; Ex A Newell1998.pdf; Ex B McCauley.pdf; Ex C Arneson.pdf; Ex E DSL app excerpt.pdf; Ex F Henderson Marsh Mitigation Plan.pdf; Exhibit D Warrenton Oregon LNG OPN 030416.pdf

Hi Jill

Please find attached Oregon Shores' comments and exhibits for the rebuttal period ending today. Please confirm receipt of these comments and the exhibits. Although we intended to serve other parties with these comments, as we understood that to have been ordered by the Hearing Officer, after reviewing the letter from counsel for JCEP, we will wait for clarification from the Hearing Officer before serving any other parties.

Thank you

Meriel

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Exhibit: 43
Date: 6/24/19

OREGON SHORES
CONSERVATION COALITION

June 24, 2019

Via Email to: planning@co.coos.or.us

Coos County Planning Department
c/o Planning Director Jill Rolfe
Coos County Courthouse
250 N. Baxter
Coquille, Oregon 97423

Re: County Remand File No. REM-19-001/LUBA Case No. 2016-095 – Open Record Comments

Dear Hearings Officer Stamp:

Please accept these comments from the Oregon Shores Conservation Coalition and its members (collectively "Oregon Shores"), which was an original party to the LUBA appeal of the underlying applications, File Nos. HBCU-15-05/CD-15-152/FP-15-09 (collectively, "Omnibus I"). These comments are intended to be responsive to issues that arose in the public hearing on June 10, 2019 and specifically questions that you raised to the parties and as to which you requested additional briefing or information.

Please continue to notify us of any further decisions, reports, or notices issued in relation to this Application.

I. The Proposed Use will cause a substantial and unreasonable interference with the public trust and therefore does not meet the criteria in Policy 5 of the CBEMP.

a. Prior court interpretations of public trust doctrine support the determination that JCEP's proposed uses will substantially and unreasonably interfere.

The Public Trust Doctrine, which dates back to the Roman Empire and was first codified in the Magna Carta, is today an established tenet of state law in Oregon. This doctrine establishes a duty of the state to protect commonly held interests for the benefit of the public as a whole. This duty entails that no public rights, whether they be to navigation or fishing, can be infringed upon for the benefit of a private party. The public trust encompasses "waters of the United States," as well as the submerged lands. *See Ill. C.R. Co. v. Ill.*, 146 U.S. 387, 456-459 (1892). Any loss of access for fishing, recreation or navigation would constitute a loss of rights protected by the doctrine. According to Professor Michael Blumm, "[t]he public trust doctrine in Oregon has a long and venerable history, dating to numerous nineteenth and early twentieth century court decisions that consistently recognized public rights in navigable waters."[1] Shortly after statehood, Oregon courts acknowledged paramount public rights of navigation, fishing, and commerce in navigable-in-fact waterways, regardless of bed ownership.[2] Oregon was also one of the first states to recognize recreation as commerce protected under the public navigation easement. For example, in *Guilliams v. Beaver Lake Club*, 195 P 437, 443 (Or 1918), the Oregon Supreme Court upheld a trial court ruling that a landowner could not build a flood control dam that would interfere with the public use of a nearby lagoon for recreation during high water.

The relevance of the doctrine to this land use application is that Goal 16 requires a local government to disallow dredging and/or filling if the use or alteration unreasonably interferes with public trust rights. This requirement is, in turn, a part of the county's requirements for a permit for uses requiring removal/filling in the Coos Bay estuary. CBEMP Policy 5. As discussed below, the proposed alterations and uses substantially and unreasonably interfere with the public trust.

b. JECP's proposed interference with public trust rights is unreasonable because it will obstruct an entire waterway and it is not necessary.

The record demonstrates that JCEP's use of Coos Bay will be a substantial interference with the channel as it is used for public trust uses. As discussed in the *Weise* case, the Coos Bay channel is a public highway for vessels. And, the record is clear that when an LNG tanker is entering or

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[1] Blum, Michael and Erika Doot, "Oregon's Public Trust Doctrine," Environmental Law Vol. 42, No 1 (2012).
[2] *See e.g. Weise v. Smith*, 3 Or 445, 450 (1869) (stating that navigable waterways are "public highways" that each person has "an undoubted right to use… for all legitimate purposes of trade and transportation."; *Hinman v. Warren*, 6 Or 408, 411-12 (1877) (commenting that as "owner of the tide lands, [the state] had the power… to sell the same. It has, however, no authority to dispose of its tide-lands in such a manner as may interfere with the free and untrammeled navigation of its rivers, bays, inlets, and the like."); *Wilson v. Welch*, 7 P 341, 344 (Or 1885); *Bowlby v. Shively*, 30 P. 154, 156 (Or 1892) (holding that title to tidelands acquired from the state continues to be burdened by the *jus publicum* and "subject only to the paramount right of navigation."), *aff'd* 152 US 1, 52-54 (1894).

exiting Coos Bay, it will be a complete obstruction to the channel for long periods of time during critical periods of commercial and recreational fishing and other uses of the bay. According to the traffic study in 2008, LNG tankers can only exit the channel at high tide, during daylight, in winds that are less than 25 knots. R. 2904. There is a 500-yard safety area that would effectively shut down boat traffic in and out of the bay for the entirety of the carrier's journey. R.1817. Even if the dredging allowed the tankers to navigate the channel at any tide, the security zone would still effectively shut down the bay. *See* R. 2682.

Clausen Oyster company has stated they have a barge that requires high tide to traverse the bay to reach their oyster beds. R.6372. Additionally, crabbers use the bay to catch crabs and could be impacted by dredging and tanker travel. Many of the crab and clam harvesting areas are situated in or around the proposed dredging area. R. 2682. Crabbing and clamming activity occurring within the 500-yard security zone would be forced to cease and move out of the way. R.1216. Crabbing activity occurs within 30 minutes at slack high tide. See Mike Greybill comments, included with previous Oregon Shores testimony.

In addition to harming the right to fish, JCEP will substantially impede the public's right to navigation to the detriment of those living and working in the bay. The tankers entering and leaving the bay need strict conditions of high-tide, daylight, and winds under 25 knots. A 500-yard security zone extending around the tanker effectively shuts down the bay for the 90 minutes that the tankers need to enter or exit, and based the application this would occur approximately every other day as tankers were entering and leaving. While restricting all boats wanting to use the bay, this would be especially detrimental to other professional boats who need high-tide in the bay. Clausen Oysters has entered into the record that it requires high-tide to move its largest barge to the oyster beds. Furthermore, crabbing is most effective and most often conducted around high tide. Crab boats would be restricted from their practice while a tanker is in the bay. The loss of ability to conduct commercial oystering, crabbing and fishing activities every other day during the critical hours of operation is comparable to blocking a public highway during rush hour every other day. It is a total obstruction of a navigable waterway in a manner and at a time that prevents its use for the protected public trust rights, including but not limited to fishing, crabbing and recreation. It is an unreasonable interference with public trust.

There is minimal caselaw in Oregon addressing the specific situation where one vessel will block a waterway for long and regular periods of time and whether that constitutes a substantial interference. However, in a recent similar proposal for an LNG terminal in the City of Warrenton in Clatsop County, the City's Hearings Officer reviewed whether proposed LNG tankers with a similar 500-foot security zone would impact local commercial and recreational fishing to the point of substantially interfering with the public trust. The standard being applied in that land use process was identical to that being applied here. The Hearing Officer made the following conclusions, among others, relating to the public trust:

- "Oregon's view of the public trust doctrine is broad an encompasses public ownership in the state's fish and wildlife resources and wetlands.
- The exclusion zones around the proposed LNG tankers would create "significant limitations on both commercial and recreational fishing that are already heavily-constrained by other exclusions, temporary and spatial limitations."

- "the testimony of affected fishing organizations and individual fishers is also compelling and credible evidence that these impacts are real and that they significantly (unreasonably) impact public trust rights."

The Warrenton Hearing Officer ultimately concluded that the impacts to the public trust were unreasonable and denied the LNG terminal for failure to comply with this applicable criterion, among others. The City of Warrenton decision was not appealed. A copy of that decision is attached as Exhibit D.

c. **There will be an unreasonable interference with the public trust from the proposed alteration and use because of the long-term impacts to the fishing and crabbing resources in the bay.**

Throughout the nineteenth century the Oregon Supreme Court recognized the broad public navigation rights in waters with state-owned beds, as well as those with private beds. *See e.g. Weise, supra; Felger,* 3 Or 455, 458 (1869). In *Columbia River Fishermen's Protective Union v. City of St. Helens*, 87 P2d 195, 197-199 (1939), the Oregon Supreme Court directed the the lower court to enjoin the City of St. Helens and two paper mills from polluting the Lower Columbia River in a manner that destroyed fish stocks and damaged the fishermen's equipment. Oregon has recognized that dredging of the beds of navigable waterways is permissible only where the proposed use or alteration will not unreasonably interfere with the public trust rights. Statewide Planning Goal 16. In this case, as set forth below, the dredging itself, including the maintenance dredging planned for every three years, will unreasonably interfere with the public trust because it will result in the unreasonably diminish the fishing and crabbing stocks that utilize the habitat that will be destroyed as a result of the dredging.

The Hearing Officer should not rely on the representations of applicant and citations to the FERC record that cite certain studies for the proposition that the bay and habitats impacted by the dredging will recover in short periods of time because the studies do not support this conclusion. Newell et al. (1997)[3], which was cited to by FERC in its prior Biological Assessment (see Rec 2051) is purported to state that the benthic community within the Coos Bay estuary would return to pre-dredging conditions after 4 weeks. R. 1903. However, this conclusion misconstrues the cited research. Newell (1997) contains a table stating that the benthic fauna in Coos Bay Oregon had a post-dredging recovery time of 4 weeks, citing to a different study, McCauley et al (1976).[4] The table also says the habitat of Coos Bay is disturbed mud and states that the larger the grain size of the substrate, the longer a benthic community generally takes to return to its previous state. This is because as substrate grows larger, more complex k-selective species tend to colonize these areas. Complex k-selective species, such as Dungeness crab and clams, can take up to ten years to recolonize after a dredging event.[5] More frequent dredging prevents k-selective species from colonizing, allowing r-selective species such as worms to grow

[3] See Exhibit A: Newell et al., 1997, *The Impact of Dredging Works in Coastal Waters: A Review of the Sensitivity to Disturbance and Subsequent Recovery of Biological Resources in the Sea Bed*, 36 OCEANOGR. MAR. BIOL. 127–178, at 39.

[4] See Exhibit B: McCauley et al. , 1976, *Benthic Infauna and Maintenance Dredging: A Case Study*, 11 WATER RES. 233–242.

[5] See Exhibit A: Newell et al, at 39, (1997).

quickly. R-selective species are those whose adaptation strategies involve using resources to have lots of offspring which develop very quickly, counting on a few surviving to adulthood in order to procreate. K-selective species are those that take longer to develop. Newell refers to many of these K-selective species as "equilibrium" species, requiring undisturbed deposits to colonize. As an example, Figure 2 lists *Cancer* (Dungeness Crab) as an equilibrium species.[6] Thus, where larger substrate is present, such as sand, it will take potentially up to 10 years, for Dungeness crabs, a primary commercial species, to recolonize the bay.

McCauley et al. (1976), cited by Newell (1997) provided a case study of a single dredge. The sample dredge took place in the mouth of the Isthmus Slough. The most abundant species present in the benthic communities consisted mainly of r-selective species, such as small polychaetes, or marine worms. The survey area of the dredge was routinely dredged every two years prior to the survey. This area was able to return to a similar level of benthic communities in four weeks. Arneson (1976) provided a survey of different substrates of Coos Bay. The proposed dredging area in the bay is classified a "fine sand.[7]" The area of the *McCauley* survey, relied upon by FERC is classified as "silt." Therefore, the McCauley survey is inapplicable and unreliable as substantial evidence for the justification of the proposed dredging.

Thus, as set for the above, the science cited by JCEP selectively chooses one small facet of a table to highlight and use as validation for a lack of impact from dredging the bay. Not only does this table not apply to the current situation, the rest of the paper explains why dredging the bay will be hugely detrimental to the bay community. Newell explains that different substrate habitats allow different type of benthic organisms to colonize.[8] The finer the substrate, generally the less complex and more r-selective species are found.[9] While Table 5 does list Coos Bay as having a recovery time of 4 weeks after a dredging event, this statement is misleading for the as discussed above: that study was not conducted in the same substrate as the JCEP proposal.[10] McCauley (1976), is a case study concerning one small dredge.[11] The dredge occurred in the mouth of the Isthmus Slough in an area that was previously dredged every two years. This repeated dredging prevented any equilibrium species, like Dungeness crabs, from ever recolonizing, meaning they were not present in the initial, pre-dredge survey of the area. Furthermore, in a substrate survey of Coos Bay in Arneson (1976), the Isthmus Slough contained 'silt,' whereas the sediment of the proposed JCEP dredging area is fine sand.[12] Fine sand has a much larger grain size than silt and is able to support much more complex benthic communities, as demonstrated by the Dungeness crabs that are present.[13]

Newell states that even on fine grained deposits, areas with low current velocity can take up to 5-10 years to recolonize. This time can be even longer for areas of sand and gravel, such as around

[6] *Id.* at 8, Figure 2.
[7] See Exhibit C: Robert Arneson, 1975, *Seasonal Variation in Tidal Dynamics, Water Quality, and Sediments in the Coos Bay Estuary*, at 143-145.
[8] Newell et al., *supra* note 1.
[9] *Id.*
[10] *Id.* at p 36, Table 5.
[11] See Exhibit B: McCauley et al. at 233.
[12] Arneson, *supra* note 3.
[13] Newell et al., *supra* note 1.

the mouth of the bay. Newell also states that an area of 100m on each side of the track of the dredging vessel are directly impacted by sediment deposition. In the narrow area of Coos Bay, a 650ft swath of dredging would cause grievous injury to the resident crab and clam populations. The science cited in the record supports a finding that the destruction caused by this dredging activity will be felt over the next decade and perhaps even longer, as continued maintenance dredging would be necessary. Applicant admits in its DSL application that maintenance dredging will be required every three years for the first ten years and every five years after that.[14] Therefore even if recovery of benthic communities take a shorter period, that recovery will be undone by maintenance dredging and the communities will not reestablish.

In conclusion, the proposed dredging activity will have an outsized effect on resident populations of crab and bivalve species, and will be felt at every level of the ecosystem of Coos Bay. This action will directly affect anyone who fishes in the bay, whether recreationally or for their livelihood. The studies relied on by the applicant actually indicate that there will be a long-term and unreasonable impact on the public trust. As discussed above, the Hearing Officer in the City of Warrenton decision found that the impacts resulting from dredging and loss of wetlands as well as the impacts to navigation from the security zones around the tanker resulted in an unreasonable interference with the public trust. See Exhibit D: Warrenton Decision at 30. Oregon Shores respectfully requests that the Hearing Officer in this matter do the same and deny the LNG terminal permit.

II. JCEP has failed to meet the other criteria required to approve the permit for the terminal.

As to the issue of the mitigation for impacts to Wetland J, attached as Exhibit F is the Henderson Marsh Mitigation Plan which includes Condition 16, requiring the applicant to comply with mitigation as set forth in the plan for wetlands not specifically listed, such as Wetland J. Applicant has submitted no such compliance plan for its disturbance of Wetland J.

As to the issue of whether applicant can obtain other requirement permits, the Hearing Officer should find that the required federal FERC permit is unavailable because that permit was denied and when applicant reapplied, it submitted an application for a *different* use that the one at issue in this proceeding. For example, the new FERC application is for an LNG terminal without a power station and which does include workforce housing. The inclusion or removal of the power plant as part of the development is a major change in the use because it substantially changes the economics of the project. As a result, there is no pending FERC application for the terminal as proposed is this proceeding and applicant has not stated that it intends to apply for such a permit to match this proposal. JCEP has been further unwilling to update this application to reflect its change in plans. Thus the Hearings Officer should find that the FERC permit for this project is not available and the applicant cannot meet the criteria in CBEMP Policies 5, 8 and 30.

[14] See Exhibit E: Excerpt of DSL Application.

On remand, JCEP has failed to demonstrate that the proposed uses meet the applicable criteria or that the County can make findings to satisfy the issues remanded by LUBA.

Sincerely,

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Encl. Exhibits A through E.

The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed

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THE IMPACT OF DREDGING WORKS IN COASTAL WATERS: A REVIEW OF THE SENSITIVITY TO DISTURBANCE AND SUBSEQUENT RECOVERY OF BIOLOGICAL RESOURCES ON THE SEA BED

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Abstract The present review provides a framework within which the impact of dredging on biological resources that live on the sea bed ("Benthic" communities) can be understood, and places in perspective some of the recent studies that have been carried out in relation to aggregates dredging in European coastal waters. The impact of dredging works on fisheries and fish themselves, and on their spawning grounds is outside the scope of this review. We have, however, shown that empirical models for shelf waters such as the North Sea indicate that as much as 30% of total fisheries yield to man is derived from benthic resources, and that these become an increasingly important component of the food web in near-shore waters where primary production by seaweeds (macrophytes) and seagrasses living on the sea bed largely replaces that by the phytoplankton in the water column. Because dredging works are mainly carried out in near-shore coastal deposits, and these are the ones where benthic production processes are of importance in supporting demersal fish production, our review concentrates on the nature of benthic communities, their sensitivity to disturbance by dredging and land reclamation works, and on the recovery times that are likely to be required for the re-establishment of community structure following cessation of dredging or spoils disposal.

Essentially, the impact of dredging activities mainly relates to the physical removal of substratum and associated organisms from the seabed along the path of the dredge head, and partly on the impact of subsequent deposition of material rejected by screening and overspill from the hopper. Because sediment disturbance by wave action is limited to depths of less than 30m, it follows that pits and furrows from dredging activities are likely to be persistent features of the sea bed except in shallow waters where sands are mobile. Recent studies using Acoustic Doppler Current Profiling (ADCP) techniques suggest that the initial sedimentation of material discharged during outwash from dredgers does not, as had been widely assumed, disperse according to the Gaussian diffusion principles used in most simulation models, but behaves more like a density current where particles are held together during the initial phase of the sedimentation process. As a result, the principal area likely to be affected by sediment deposition is mainly confined to a zone of a few hundred metres from the discharge chute.

Our review suggests that marine communities conform to well-established principles of ecological succession, and that these allow some realistic predictions on the likely recovery of benthic communities following cessation of dredging. In general, communities living in fine mobile deposits, such as occur in estuaries, are characterized by large populations of a restricted variety of species that are well adapted to rapid recolonization of deposits that are subject to frequent disturbance. Recolonization of dredged deposits is initially by these "opportunistic" species and the community is subsequently supplemented by an increased species variety of long-lived and slow-growing "equilibrium" species that characterize stable undisturbed deposits such as coarse gravels and reefs.

Rates of recovery reported in the literature suggest that a recovery time of 6-8 months is charactristic

of many estuarine muds where frequent disturbance of the deposits precludes the establishment of long-lived components. In contrast, the community of sands and gravels may take 2-3 yr to establish, depending on the proportion of sand and level of environmental disturbance by waves and currents, and may take even longer where rare slow-growing components were present in the community prior to dredging. As the deposits get coarser along a gradient of environmental stability, estimates of 5-10yr are probably realistic for development of the complex biological associations between the slow-growing components of equilibrium communities characteristic of reef structures.

Most recent studies show, however, that biological community composition is not controlled by any one, or a combination of, simple granulometric properties of the sediments such as particle size distribution. It is considered more likely that biological community composition is controlled by an array of environmental variables, many of them reflecting an interaction between particle mobility at the sediment-water interface and complex associations of chemical and biological factors operating over long time periods. Such interactions are not easily measured or analyzed, but the results suggest that the time course of recovery of an equilibrium community characteristic of undisturbed deposits is controlled partly by the process of compaction and stabilisation that occurs following deposition.

Biological community composition thus reflects changes in sediment composition, but is also in equilibrium with seabed disturbance from tidal currents and wave action, both of which show spatial variations and interactions with water depth. The processes associated with compaction and stability of seabed deposits may, therefore, largely control the establishment of long-lived components of equilibrium communities and account for the dominance of opportunistic species in the initial stages of colonization in unconsolidated deposits of recently sedimented material after the cessation of dredging

Introduction

The importance of benthic communities in marine food webs leading to commercially exploitable yields of fish has been widely recognized. Early models for the North Sea (see Steele 1974) suggested that of net primary production by the phytoplankton, approximately 80% was consumed by pelagic herbivores such as copepods and eup-ausiids, and 20% fell to the seabed as a detrital input to the benthic community. At each step of the food web, relatively large amounts (80-90%) of the material entering the consumers is remineralized and returned to the water column to support further primary production by the phytoplankton, leaving a small proportion incorporated into the biomass of the consumer.

Because of the complexity of marine food webs, and the major dissipation of energy at each step of the food chain, the empirical model proposed by Steele (1965, 1974) for the North Sea and shown in Fig. 1 indicates that out of 100gC m^{-2} yr^{-1} produced at the sea surface as net primary production by the phytoplankton, only 0.3 g C m^{-2} yr^{-1} appears as yield to man through the pelagic food web, and approximately 0.13 g Cm^{-2} yr^{-1} from demersal fish. Despite the huge dissipation of materials that occurs at each step in the food web, however, sufficient carbon evidently flows through the detrital food web, even in plankton-based ecosystems such as the North Sea, for as much as 30% of total fish production to be dependent on conversion through the community which lives on the sea bed.

More recent analyses of the trophic structure and fluxes of carbon in shelf waters of the North Sea by Joiris et al. (1982) suggest that as much as 50% of the annual phyto-plankton production sinks to the sea bed as detritus and is supplemented by faecal

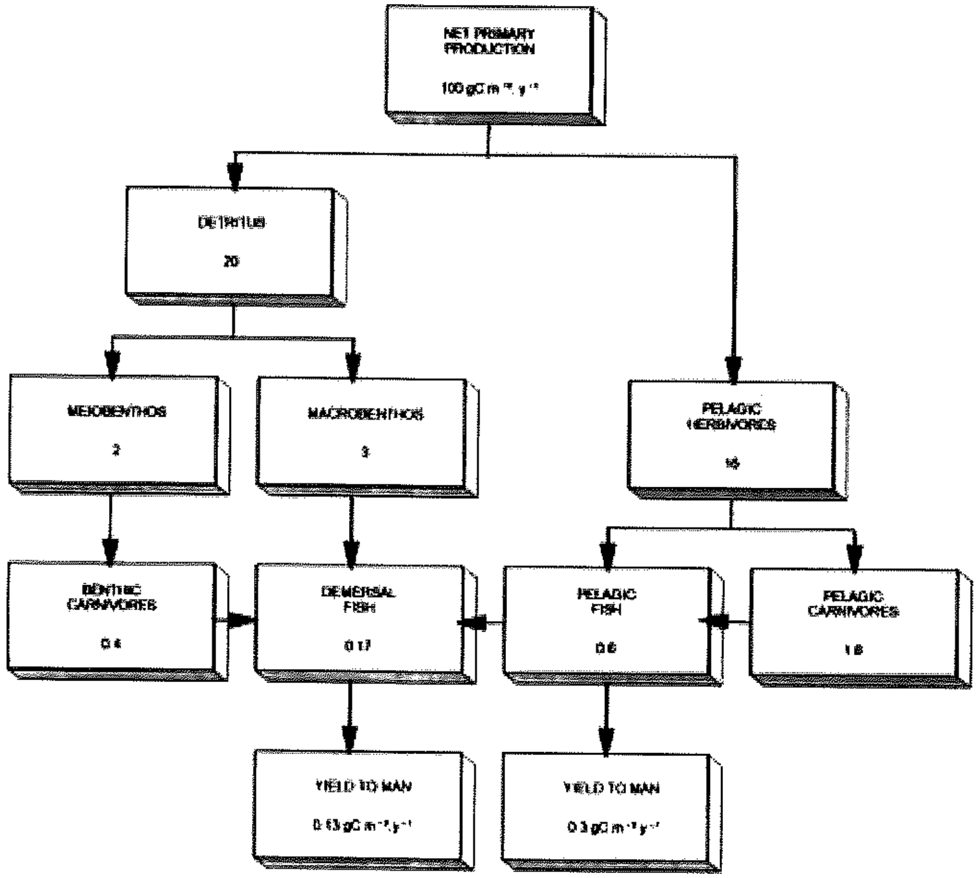


Figure 1 Simplified empirical carbon flow diagram for the phytoplankton-based ecosystem of the shelf waters of the North Sea. Note that, of the 100g C m^{-2} yr^{-1} of sea surface produced by the phytoplankton, the yield to man through pelagic food webs and pelagic fish is estimated to be 0.3g C m^{-2} yr^{-1} whereas that through benthic food webs is 0.13 g C m^{-2} yr^{-1}, or about 30% of the total exploitable fish yield to man. (Based on Steele 1965).

pellets of the zooplankton (see also Smetacek, 1984). The benthos is thus heavily implicated in carbon flow in coastal systems, and becomes of increasing importance in shallow waters where production by benthic algae (macrophytes) and seagrasses largely replaces that derived from the phytoplankton (see also Taylor & Saloman 1968, Thayer et al. 1975, Mann 1982, Moloney et al. 1986, Newell et al. 1988).

Benthic communities thus play a central role in the transfer of materials from primary production by the phytoplankton, benthic macrophytes and coastal wetlands through the detrital pool into higher levels in the food web, including commercially exploitable fish. Most estimates suggest that even in phytoplankton-based systems such as the North Sea, the yield to man through the benthos to demersal fish stocks is likely to approach 30-40% of that derived through the pelagic system. Partly for this reason, the populations of benthic communities which live on, and in, the deposits on the seabed have been widely studied in investigations of the integrated effects of disturbance from a variety of natural and other sources.

Early studies include extensive physiological-toxicological work on the potential impact of suspended sediments on commercially significant target organisms (Loosanoff 1962, Sherk 1971, Sherk et al. 1972, 1974, Bright & Ellis 1989, Jokiel 1989, for review, see Moore 1977). Such studies have been extended to include the potential impact of dredging works on the ecology of biological communities in coastal embayments and estuarine ecosystems (Jones & Ellis 1976, Morton 1977, Conner & Simon 1979, Johnston 1981, Ellis & Heim 1985, Ellis & Taylor 1988, Ellis & Hoover 1990, Giesen et al. 1990, Onuf 1994).

Comprehensive studies of the impact of dredging for marine aggregates and sand on marine communities in European waters have been carried out by Millner et al. (1977), Pagliai et al. (1985), Sips & Waardenburg (1989), van Moorsel & Waardenburg (1990, 1991), and Kenny & Rees (1994, 1996). Reviews of the impact of sand and gravel extraction include those of the International Council for the Exploration of the Sea (ICES, 1975, 1977, 1992a,b, 1993), Gayman (1978), de Groot (1986), Nunny & Chillingworth (1986), Hurme & Pullen (1988), Lart (1991) and Charlier & Charlier (1992). A recent review for the Minerals Management Service, US Department of the Interior containing a number of specific case histories on the impact of marine mining has been given in a C-CORE publication (1996; see also Ellis 1987).

Despite the work that has been carried out over the past 30 years, the non-biologist could be forgiven for being bewildered by the diversity of the results and the difficulties of making more than the most general predictions on the effects of dredging activities including the extraction of marine aggregrates on biological resources. Essentially, most studies show that dredging itself is usually accompanied by a significant fall in species numbers, population density and biomass of benthic organisms. The rate of recovery is, however, highly variable depending (among other factors) on the type of community that inhabits the deposits in the dredged area and surrounding deposits, the latitude and the extent to which the community is naturally adapted to high levels of sediment disturbance and suspended particulate load.

In general, rapid rates of initial recolonization have been reported for some coastal deposits where the organisms are mainly mobile "opportunistic" species that have a rapid rate of reproduction and growth. Such organisms may also be able to recolonize the deposits by migration of the adults (see McCall 1976, Conner & Simon 1979, Saloman et al. 1982, Guillou & Hily 1983, Pagliai et al. 1985, van der Veer et al. 1985, Clarke & Miller-Way 1992, Rees & Dare 1993, van Moorsel 1994). In contrast, long-lived and slow-growing species, especially those in high latitudes may take several years before larval recruitment and subsequent growth of the juveniles allows estoration of the original community composition and biomass. The process of "recovery" following environmental disturbance is generally defined as the establishment of a successional community of species which progresses towards a community that is similar in species composition, population density and biomass to that previously present, or at non-impacted reference sites (C-CORE 1996; see also Ellis & Hoover 1990). Typically, values range from up to one year in fine-grained deposits such as muds and clays (Ellis et al. 1995), although even in the fine deposits that characterize coastal ecosystems such as the Dutch Waddensea, van der Veer et al. (1985) report that recolonization takes 1-3 yr in areas of strong currents but up to 5-10yr in areas of low current velocity. Longer recovery times are reported for sands and gravels where an initial recovery phase in the first 12 months is followed by a period of several years before pre-extraction population structure is attained (van Moorsel 1994, Kenny & Rees 1996).

Even longer times may be required for biologically-controlled communities that characterize coarse deposits (see Garnett & Ellis 1995), although the evidence is conflicting for coral reef communities. Some studies report long-term damage to coral resources from sedimentation associated with dredging (Dodge & Vaisnys 1977, Bak 1978, Dodge & Brass 1984, Madany et al. 1987, Hodgson 1994; for review see Maragos 1991). Other studies suggest that corals themselves may be tolerant of short-term increases in siltation associated with dredging (Marszalek 1981, Brown et al. 1990) but that modification of community structure of other components of reef communities such as fish species are detectable after multivariate analysis of species composition (Dawson-Shepherd et al. 1992).

Recovery times following disturbance from a variety of sources, including dredging work, may be extended in colder waters at high latitudes where communities typically comprise large slow-growing species that may take many years for recolonization and growth. In a Swedish fjord system, for example, a recovery that was indistinguishable from natural variations was established only after 8 yr following closure of a pulp mill (Rosenberg 1976), whereas de Groot (1979; see also Wright 1977, Aschan 1988) reports that recovery of communities within the Arctic Circle may take more than 12 yr compared with estimates of approximately 3yr for deposits off the coast of the Netherlands. Similar extended timescales for recolonization by the benthic community have been reported for Antarctic waters by Oliver & Slatterly (198 1).

The concept of "recovery" of biological resources is itself not an easy one to define for complex communities whose composition can vary over time, even in areas that remain undisturbed. Whether a community is identical in species composition and population structure following cessation of dredging thus to some extent begs the question of whether the biodiversity would have remained stable over that period in the absence of disturbance by dredging. Probably a more practical approach to the question of "recovery" will be the recognition of the establishment of a community that is capable of maintaining itself and in which at least 80% of the species diversity and biomass has been restored.

This implies a substantial restoration of the carrying capacity of the benthic food webs leading to fish, even though the precise species composition may not be identical to that recorded in the pre-dredged system. This issue of whether biological resources have been restored, and how this should be assessed, is of considerable importance in areas such as Canadian coastal waters where recovery of seabed resources forms part of a Statutory obligation following cessation of mining (D. V. Ellis pers. comm.).

Despite the complexity of the results for specific dredged areas, some firm general principles governing community structure following environmental disturbance have emerged in recent years and these appear to be generally applicable to a wide variety of communities both on the land and on the sea bed. The application of such concepts to coastal communities allows some credible predictions on the scale of impact of environmental disturbance such as that imposed by dredging and dredged spoils disposal and, more important, gives some insight into how long it might take for recovery in dredged areas and the surrounding deposits once dredging has ceased.

The object of the present review is to provide a framework within which the biological impact and subsequent recovery of benthic resources can be understood, with examples drawn mainly from the impact of dredging works in near-shore waters and estuarine systems.

General features of community structure

Most general models of community structure are based on the concept that biological communities do not form a series of distinct groups or assemblages along an environmental gradient, but show a corresponding gradient in community composition. Species that colonize habitats with unpredictable short-term variations in environmental conditions at one end of an environmental gradient of stability are subject to frequent catastrophic mortality. Such conditions occur in many shallow-water, intertidal and estuarine habitats and are characterized by populations which tend to have a high genetic variability that allows at least some components of the population to survive environmental extremes (see Grassle & Grassle 1974, Guillou & Hily 1983). Such organisms are thus selected for maximum rate of population increase, with high fecundity, dense settlement, rapid growth and rather a short life cycle. They are well suited to rapid invasion and colonization of environments where space has been left by a previous catastrophic mortality, whether this has been induced by natural factors or disturbance by man.

Such components have been designated "r-strategists" in a pioneer work by MacArthur & Wilson (1967; see also Pianka 1970), although we prefer to use the term "opportunists" for all such early colonizing species. Opportunists rely on a large investment in reproductive effort, rather than on mobility, for success in colonizing habitats made available by the catastrophic destruction of the previous community (see Gadgil & Solbrig 1972, McCall 1976).

Many communities living in unstable environments may comprise small, highly mobile species that are able to take advantage of recently created empty habitats quickly and to colonize them with large populations. These mobile colonizers are often associated with frequently-disturbed habitats (see Osman 1977). We distinguish these as "mobile opportunists" (see also MacArthur 1960, Grassle & Grassle 1974). All such mobile opportunists are r-strategists with life-cycle traits of small size, high fecundity, rapid growth and high mortality.

Under the stable conditions that occur at the other end of the environmental continuum, the community is controlled mainly by biological interactions, rather than by extremes of environmental variability. Here the organisms have an "equilibrium strategy" in which they are selected for maximum competitive ability in an environment that is already colonized by many species and in which space for settlement and subsequent growth is limiting. Such organisms are designated "K-strategists" or " equilibrium species " and devote a larger proportion of the resources to non-reproductive processes such as growth, predator avoidance and investment in larger adults (MacArthur & Wilson 1967, Gadgil & Bossert 1970, McCall 1976). Between these two extremes are communities whose species may be intermediate between those that occur at the extremes of the environmental gradient and have different relative proportions of opportunistic r-strategists and equilibrium K-strategists. The characteristics of r-selected and K-selected equilibrium species are summarized in Table 1 (based on McCall 1976, Rees & Dare 1993), although it should be emphasized that the distinction is to some extent an arbitrary one, and is blurred in habitats that are subject to only mild environmental disturbance.

Table 1 Table summarizing the population characteristics of r-selected opportunists and K-selected equilibrium species (based on Pianka 1970, McCall 1976, Rees & Dare 1993, Holt et al. 1995).

Early colonizing species *r*-selected	Equilibrium species *K*-selected
1. Mainly opportunistic species (a) early reproduction (b) many reproductions per year (c) rapid growth (d) early colonizers (e) often catastrophic mortality	1. Equilibrium species (a) delayed reproduction (b) few reproductions per year (c) slow growth (d) late colonizers (e) low death rate
2. Small body size	2. Large mobile animals
3. Generally surface deposit feeders	3. Deposit and suspension feeders
4. Short life span; generally <1 year	4. Long life span; several to many years
5. Population size variable, usually well below carrying capacity of environment and recolonized frequently	5. Fairly constant in time; saturated community in equilibrium with carrying capacity of environment. No recolonization necessary
6. Brood protection with investment of energy into larval food provision (lecithotrophic)	6. No brood protection: larvae widely distributed in the plankton.
Streblospio benedicti *Capitella capitata* *Owenia fusiformis* *Ampelisca abdita* *Scolelepis fuliginosus* *Chaetozone setosa* *Jassa marmorata*	*Nephtys incisa* *Ensis directus* *Sabellaria spinulosa* *Arctica (Cyprina) islandica* *Echinocardium cordatum* *Nephrops norvegicus* *Melinna cristata* *Nucula sp.* *Amphiura filiformis* *Terebellides sp.* *Virgularia mirabilis* *Gari fervensis* *Tellina crassa* *Venerupis rhomboides* *Dosinia exoleta* *Scoloplos armiger* *Abra alba*

Changes in the structure and physical size of the infauna along a gradient of environmental conditions have been described in relation to organic pollution by Pearson & Rosenberg (1978) and in relation to physical disturbance by Rhoads et al. (1978), Oliver et al. (1980) and by Gray & Pearson (1982). These are illustrated in a schematic diagram in Fig. 2. Essentially, such studies show that community composition of benthic infauna (those that live within the deposits) along an environmental gradient is the result of a complex interaction between physico-chemical factors that operate at one end of the gradient and biologically-controlled interactions under the more uniform environmental conditions that occur in deeper waters (see Sanders 1969, Boesch & Rosenberg 1981).

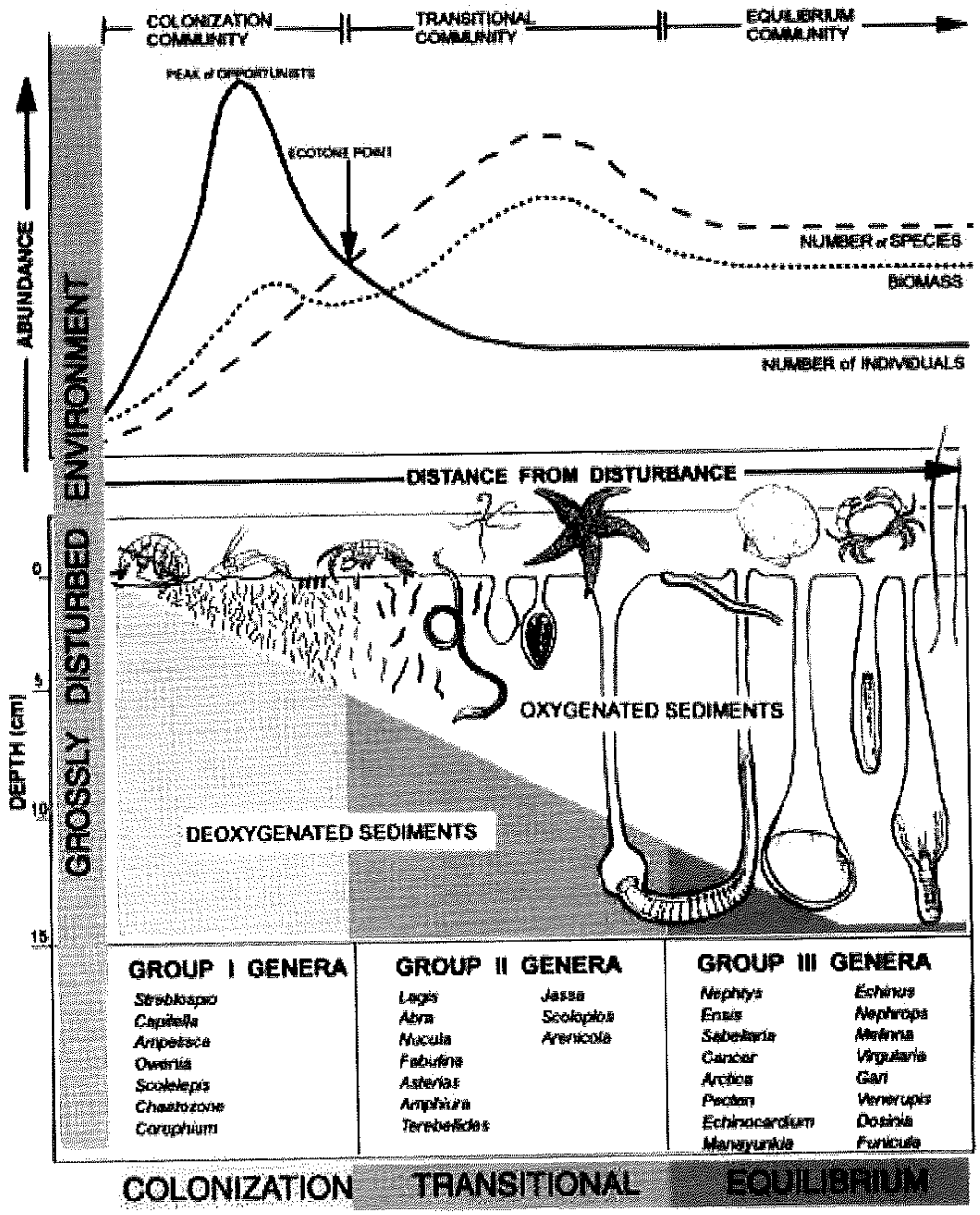


Figure 2 Pictorial diagram showing the ecological succession that characterizes benthic communities through a gradient of environmental disturbance. Note that in highly disrupted environments (on the left side of the diagram) few organisms may be capable of survival. In polluted or semi-liquid muds the sediments are colonized by few (resistant) species but which can attain very high population densities. As the stability of the environment increases, these opportunistic r-selected species are replaced by increased species variety, including slower growing K-selected species. Finally in environments of high stability the community is dominated by equilibrium species with complex biological interactions between members of the community. (Based on Pearson & Rosenberg 1978, Rhoads et al. 1978).

The large species that comprise the burrowing infauna of stable habitats and those with low organic content maintain oxygen levels in the deposits down to considerable depths (see Flint & Kalke 1986) and often have complex interactions with neighbouring species, including smaller species whose survival depends on their association with large burrowing components (Fig. 2). The importance of bioturbation in both enhancing species diversity and in exclusion of potentially competitive species has been widely documented (Gray 1974, Rhoads 1974, Lee & Swartz 1980, Carney 1981, Rhoads & Boyer 1982, Thayer 1983). Comprehensive reviews by Pearson & Rosenberg (1978) and Hall (1994) summarize the impact of disturbance by a wide variety of factors including storms, dredging, fishing and biological activities on benthic community structure.

Biological interactions may also control community composition on the surface of the deposits. The presence of surface-dwelling bivalves, for example, may allow colonization by barnacles, ascidians and other epifaunal species that would not otherwise occur in the surface of the sediments. In other stable habitats, the activities of suspension-feeding mussels produce consolidated silt deposits that then allow deposit feeders such as the polychaete Amphitrite, the burrows of which in turn provide specialized shelter for the commensal scale worm, Gattyana (Newell, 1979).

Several studies have shown that the activities of the infauna may also inhibit, rather than facilitate, the occurrence of potential competitors for space. In an important study by Rhoads & Young (1970) it was shown that the benthic environment may be significantly modified by the burrowing and feeding activities of deposit-feeding organisms. This bioturbation results in the production of an uncompacted surface layer of faecal material that may result in the transfer of fine material to the sediment-water interface by turbulent mixing (Wildish & Kristmanson 1979, Snelgrove & Butman 1994) and may lead to the exclusion of potential competitors by deposit feeders (Woodin 1991, Woodin & Marinelli 1991). This inhibition of one type of population by the activities of another has been termed "amensalism" by Odum & Odum (1959) and has since been described in many habitats (Aller & Dodge 1974, Nichols 1974, Driscoll 1975, Eagle 1975, Johnson 1977, Myers 1977a,b, Brenchley 1981, de Witt & Levinton 1985, Brey 1991, Flach 1992).

Loss of these "key species" in K-dominated equilibrium communities following dis-turbance by dredging or other activities can lead to a collapse of the entire biologically-accommodated community even though individual species may be apparently tolerant of environmental disturbance. The colonial polychaete *Sabellaria spinulosa* for example, provides a complex habitat that is associated with a wide variety of species which would not otherwise occur (see Holt et al. 1995). This polychaete undergoesa natural cycle of accretion and decay along with the associated community with a periodicity of from 5-10yr (Wilson 1971, Gruet 1986). Disturbance of communities that are dominated by K-strategists may therefore take many years for recovery of their full community composition even though recolonization by individual components may occur comparatively rapidly.

As the amount of organic matter in the sediments increases along a gradient towards the fine silts and muds that characterize estuarine habitats, the larger species and deep-burrowing forms are replaced by large numbers of relatively inactive small suspension-feeding and surface deposit feeders including polychaete worms, bivalves and holothurians. This reduction in the species diversity and extent of sediment bioturbation results in an increased sediment stability and a restriction of the oxygenated layer to the surface of the sediments. Species in the intermediate parts of the environmental gradient shown in Figure 2 are thus relatively smaller than their counterparts in deeper waters and comprise a "transitional community" that is confined to a restricted habitat in the surface oxygenated layer of sediment and includes components that have many intermediate characteristics between typical r-selected opportunists and K-selected equilibrium species.

Because the K-selected components in the community live for longer, the individuals must be able to tolerate short-term changes in environmental conditions including siltation. They therefore have generally wider limits of physiological tolerance than r-selected opportunistic species that respond to environmental change by selection of genetically adapted components of the population during each of the many reproductive cycles per year.

The transitional community comprises more species than the equilibrium community shown in Figure 2 because of invasion by opportunistic species, but the species variety and mean size rapidly decline as the organisms are increasingly crowded into the upper oxygenated layer at the sediment - water interface. The region between this transitional community and those dominated by large populations of a restricted variety of small opportunists has been referred to as the "ecotone point" by Pearson & Rosenberg (1978) and is shown in Figure 2.

Finally at the extreme end of the physical gradient shown in Figure 2, there is a further restriction of habitat space to the upper oxygenated layer of sediment. This results in a progressive elimination of species and to communities dominated by opportunistic r-strategists that are selected for small size, high fecundity and an ability to recolonize rapidly following catastrophic mortality (see Pearson & Rosenberg 1978, Gray & Pearson 1982). Very high population densities of these r-selected opportunists can occur (the "Peak of Opportunists" in Figure 2) before these decline as organic pollution or high environmental disturbance eliminates even these rapid colonizers.

A useful tool for determining the extent of impact of environmental impact from a variety of sources is a plot of the proportional contribution of each species in the community to the overall population density of the assemblage as a whole. These curves have been designated "K-dominance curves" by Lambshead et al. (1983) and have been widely used in environmental impact studies in recent years (Warwick 1986, Clarke & Warwick 1994). Obviously the equilibrium communities characteristic of undisturbed (or unpolluted) environments have a high species diversity and each com-ponent species makes a relatively small contribution to the overall population density. Conversely, as a point source of disturbance is approached the (sensitive) species are replaced by large numbers of those (resistant) members of the community that are capable of survival. This can lead to as much as 80-90% of the population being dominated by only one or two opportunists or r-selected species at the Peak of Opportunists shown in Figure 2.

A typical set of results taken from one of our surveys of coastal communities in the eastern English Channel is shown in Fig. 3 (Newell & Seiderer, 1997c). From this it can be seen that as much as 78% of the community in unstable, unconsolidated, mobile deposits at Site 1 was represented by just one species, the opportunist amphipod crustacean *Ampelisca brevicornis,* and that additional species each made only a relatively small contribution to the population. Further along the gradient of sediment stability in mixed sands and shells at Site 2, the dominance by one species *(Sabellaria* sp.) alone was approximately 45%. Finally, in the stable environmental conditions of coarse gravels and boulders at Sites 3 and 4 there was a very large species variety of over 300 and a relatively uniform species distribution with dominance values of only 12-15%.

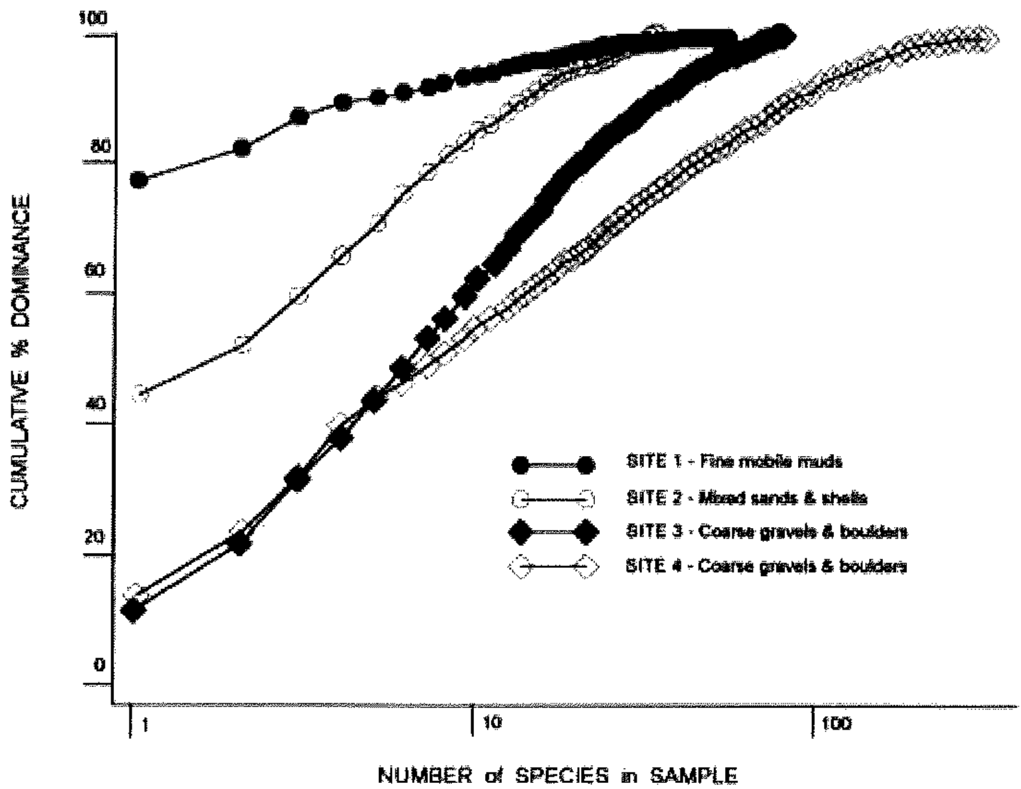


Figure 3 A set of typical K-dominance curves showing the proportional contribution of individual species to the overall community in fine mobile muds, in mixed sands and shells and in stable habitats of coarse gravels and boulders off the Kent coast at West Varne in 1996. The fine mobile muds are dominated by the opportunist amphipod crustacean, Ampelisca brevicornis, whereas the more stable deposits have a higher total species complement each of which makes a relatively small contribution to the overall population density. (Based on Newell & Seiderer 1997c).

Estimation of K-dominance curves adjacent to dredging works and other point sources of environmental disturbance is thus potentially useful because it can be used as a relatively simple index to define the area of immediate impact. It can also be used to determine whether this is enlarging or decreasing with time, without the necessity of the complex analysis of community structure that is required for interpretation of the wider impact on community structure in the transition zone.

These distinctions between the lifestyles and adaptive strategies of opportunists and K-selected equilibrium species are of fundamental importance because they go some way towards accounting for the differences in the rate of recovery that has been recorded for biological resources following disturbance by episodic events such as dredging. Clearly, the species composition and rate of recovery of biological communities following cessation of dredging will depend to a large extent on whether the original communities were dominated by opportunists or equilibrium species, and on the time that is required to develop the complex associations which characterise interactions between the K-dominated equilibrium community. Knowledge of the key faunal components and their lifestyle thus allows some predictions on the impact of dredging and spoils disposal on biological resources and on the subsequent rate of recovery of marine community composition following cessation of dredging.

Ecological succession and the recolonization process

These general features of the structure of benthic communities apply not only to successional stages along a gradient of environmental variability, but also to the successive sequence of populations that recolonize deposits after the cessation of environmental disturbance. McCall (1976) and Rees & Dare (1993) have recognized the occurrence of three main types of benthic components of marine communities based on the distinction between r-selected opportunistic species and K-selected equilibrium species. Group I species comprise those that colonize first after a community has been removed by disturbance. They comprise large populations of small sedentary tube-dwelling deposit feeders that have rapid development, many generations per year, high settlement and death rates. Examples include the polychaete worms *Streblospio, Capitella capitata,* and *Owenia fusiformis* as well as the amphipod *Ampelisca.* That is, the Group I community comprises mainly r-strategist opportunistic species.

Group II species comprise mainly bivalve molluscs such as *Tellina, Nucula* and *Abra,* the tube worm *Lagis (=Pectinaria)* and the common starfish *(Asterias rubens).* There is no absolute distinction between this community and the primary colonizers, but the components attain a lower peak abundance than the smaller opportunistic species and have slower recruitment and growth rates. Finally Group III species comprise larger slow-growing K-strategist equilibrium species such as the polychaete *Nephtys*, the reef-forming Ross worm *(Sabellaria),* razor shell *(Ensis),* sea urchins such as *Echinocardium* and *Echinus,* scallops *(Pecten),* the ocean quahog *(Arctica islandica),* the edible crab *(Cancer pagurus)* and larger burrowing crustaceans such as *Nephrops* and *Callianassa.*

The changes in species variety, abundance of individuals and biomass during the recolonization process are shown in Fig. 4. Inspection of this figure shows that initially the sediments are almost devoid of benthic macrofauna.

The initial colonizing species are few, but the number of individuals (population density) increase rapidly with time to a peak of (Group I) opportunistic species. As time passes, the short-lived opportunistic species (r-strategists) decrease in numbers and biomass as more species invade the area. This transition point where the community is poor in population density and biomass is the same ecotone point shown on the spatial gradient in Figure 2.

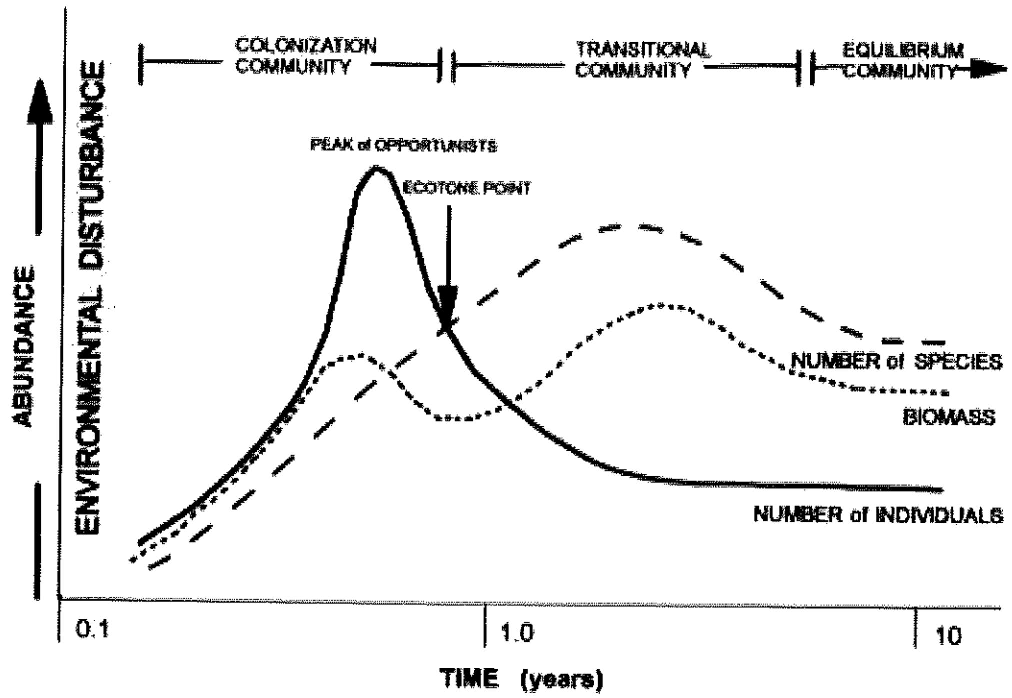


Figure 4 Schematic diagram showing a colonization succession in a marine sediment following cessation of environmental disturbance. Initial colonization is by opportunistic species which reach a peak population density generally within 6 months of a new habitat becoming available for colonization after the catastrophic mortality of the previous community. As the deposits are invaded by additional (larger) species, the population density of initial colonizers decliners. This ecotone point marks the beginning of a transitional community with high species diversity of a wide range of mixed r-selected opportunistic and K-selected equilibrium species. This period may last for 1-5 yr depending on a number of environmental factors, including latitude. Provided environmental conditions remain stable, some members of this transition community are eliminated by competition and the community as a whole then forms final equilibrium community comprising larger, long-lived and slow growing species with complex biological inter-actions with one another. (Based on Pearson & Rosenberg 1978).

Prior to this, the community is characterized by large populations of a few small opportunistic species; after this time the species variety increases, as does the biomass, but the population density declines. This Group II community is a transitional one where the maximum number of species has invaded the newly-available space, and is followed by a phase where some species are eliminated by competition and the community returns to the (somewhat lower) species composition and biomass characteristic of the undisturbed Group III community.

The sequence shown in Figure 4 indicates that colonization is likely to follow a definite time course of progressive invasion by large numbers of opportunistic species in the first instance, followed by a wider species diversity during the transitional phase and finally by a consolidation phase when competition between the K-strategist equilibrium species for the limited space available results in the elimination of some of the transitional colonizers (see also Warwick et al. 1987). The biological diversity in any particular community will then reflect the frequency of disturbance and represent a balance between invasion and subsequent growth of colonizers, and losses by extinction and displacement (see Huston 1994). In areas where environmental disturbance is unevenly distributed, this may lead to a mosaic of communities, each at different stages of the successional sequence shown in Figure 4 (see Johnson 1970, Grassle & Sanders 1973, Whittaker & Levin 1977, Connell 1978), and may partly account for the patchiness of marine communities in dredged areas.

The time taken for recovery of the full species composition and for subsequent exclusion of some of the transition community following the growth of larger K-strategist equilibrium species in a particular area will depend largely on the components that occur under natural conditions. In shallow water and estuarine conditions, where the community is in any case dominated by opportunistic species, recovery to the original species composition may be very rapid and coincide with the Peak of Opportunists point in Figure 4. In the stable environmental conditions of deeper waters, the replacement of the initial colonizers in the transitional community following complex biological interactions between the K-selected equilibrium species may take several years.

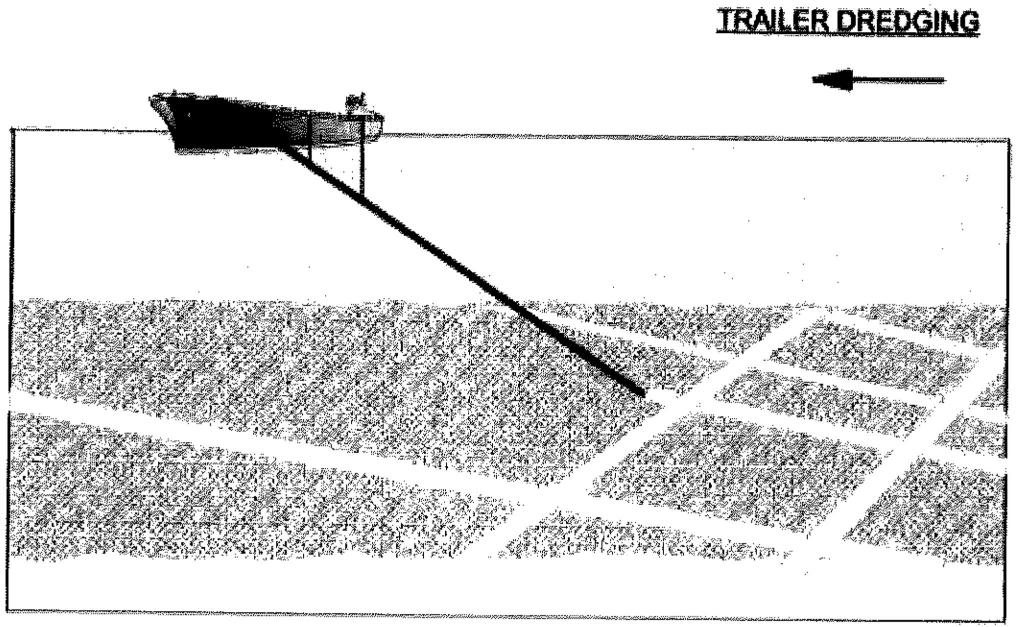
The physical impact of dredging

Impact within the dredged area

The increased exploitation of marine deposits and the physical impact of dredging works has been widely reviewed (see Dickson & Lee 1972, Shelton & Rolfe 1972, Cruikshank & Hess 1975, Eden 1975, Millner et al. 1977, de Groot 1979, van der Veer et al. 1985, Glasby 1986, Lart 1991, Gajewski & Uscinowicz 1993, ICES 1993, Land et al. 1994, Whiteside et al. 1995, Hitchcock & Drucker 1996). Most of the sea-going aggregate dredgers are self-contained and use a centrifugal suction pump to lift the aggregates from the sea bed into a hopper where the material is screened before being transferred to the hold. The *in situ* reserves for economic exploitation normally range from 15-55% gravel. Unless the material is otherwise suitable for direct use as a beach feed or landfill (see Hess 1971), the sand : gravel ratio in the final cargo is adjusted to between 50 : 50 and 65 : 35 depending on customer requirements, local geology and ship performance (A. Hermiston pers.comm).

A proportion of the dredged deposits may therefore be returned to the sea bed through reject chutes when there is a larger proportion of fine material than is required for a commercially viable cargo. In most aggregate deposits the fines comprise only 1-2% of the total and are dominated by the silt fraction although significant quantities of sand may also be discharged in the immediate vicinity of the dredger to increase the gravel component of the cargo. Overspilling of water via spillways from the hopper will also contain some fine sands that are maintained in suspension by the turbulence within the hopper.

Essentially the physical impact of dredging works is dependent partly on the method of dredging, and partly on the amount and grade of deposits rejected by screening (if used) and overspill from the hopper. Two main methods of dredging are used for gravels extraction in European coastal waters. These are anchor hopper dredging and trailer suction hopper dredging and are illustrated in Fig. 5. In anchor dredging thevessel is stationary and dredges the deposits from a sequence of specific points on the sea floor



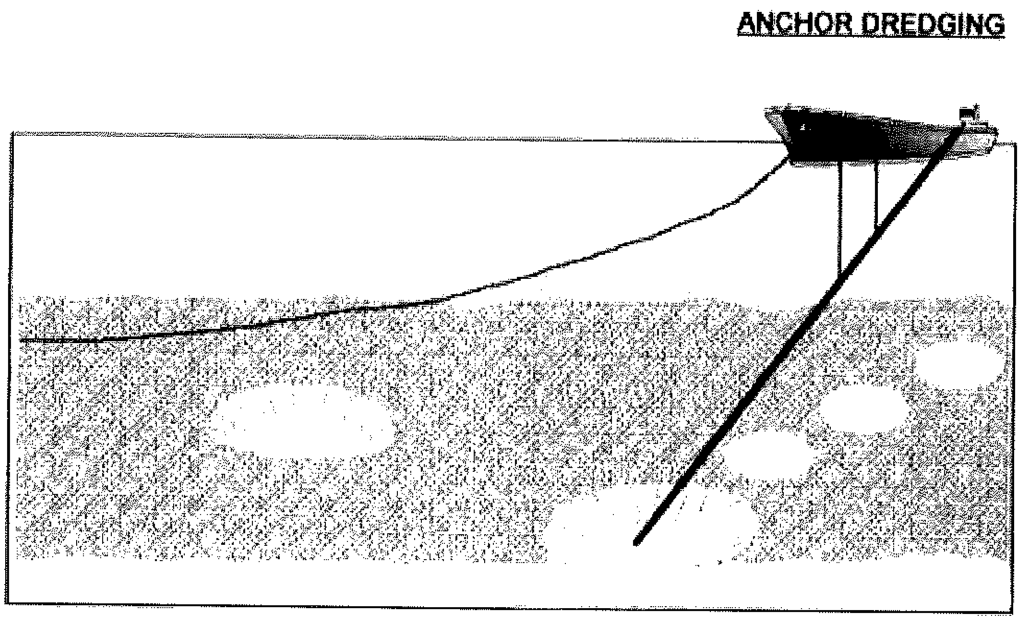


Figure 5 Diagram showing the two principal methods of dredging for marine aggregates in European coastal waters. Upper diagram shows the furrows left on the sea bed by trailer suction dredging while the vessel is under way. In this case the sea bed is crossed by a series of tracks which are 2-3m wide and up to 50cm deep. Lower diagram shows the pits left on the sea bed by anchor dredging. In this case the vessel is anchored and the dredged pits may reach as much as 75 m in diameter and 20 m in depth. (Based on Dickson & Lee 1972).

and can therefore leave pits or depressions on the sea bed that may reach as much as 20 m in depth and 75 m in diameter (Cruikshank & Hess 1975, Dickson & Lee 1972).

Because the deposits required for marine aggregates are coarse, and sediment disturbance by wave action is in any case limited mainly to depths of less than 30m even during storm conditions, it follows that not only is the fauna likely to be removed in patches from the dredged areas, but such pits are likely to be persistent features of the sea bed topography for several years except in areas where the sands are mobile (Eden 1975). Dickson & Lee (1972) studied the recovery of test pits dug by anchor dredge in gravel deposits in the Hastings Shingle Bank off the south east coast of England. They found that the pits were very slow to fill and were still visible after two years. In another study, van der Veer et al. (1985) described the recovery of pits in sandy sub-strata in the Dutch Wadden Sea. They showed that in this instance pits in channels with a high current velocity filled within one year, but those in the lower current velocities which occur in tidal watersheds took 5-10yr to fill whereas those in tidal flat areas were still visible after 15 yr.

Such sediment movement as does occur is mainly through slumping of the sides of the furrows and subsequent infilling by fine particulates transported by tidal currents into the furrows that reduce current velocity and act as sediment traps. This can lead to heavily anoxic sediments and to colonization by a community which differs considerably from that in the original deposits (Dickson & Lee 1972, Shelton & Rolfe 1972, Kaplan et al. 1975, Bonsdorff 1983, Hily 1983, van der Veer et al. 1985, Hall 1994).

A second method of marine aggregate dredging is for the ship to extract deposits by suction through one or two pipes deployed while the vessel is slowly under way (Figure 5). In this case, side-scan sonar records show that the seabed within the boundaries of licenced extraction areas in the southern North Sea is crossed by a series of dredge tracks that are 2-3 m wide and up to 50 cm deep (van Moorsel & Waardenberg 1990, Kenny & Rees 1994) although deeper troughs of up to 2m were recorded from areas where the dredge head had crossed the area several times. Davies & Hitchcock (1992) reported dredge cuts of between 20-55cm depth and 3-3.8m width in commercially exploited deposits of the Bristol Channel. Somewhat deeper troughs of up to 70cm were reported for the Baltic (Gajewski & Uscinowicz 1993). In this case removal of the surface 0.5 m of deposit would be sufficient to eliminate the benthos from the deposits in strips, the total removal depending on the intensity of dredging at a particular worked site.

Despite the shallower depth of removal, the evidence suggests that infilling of the troughs from trailer suction dredging takes at least 12 months in the Baltic and is achieved partly by slumping from the sides and partly by transport of fine material by bottom currents into the sediment traps formed by the dredged furrows (Kaplan et al. 1975, Hily 1983, van der Veer et al. 1985, Gajewski & Uscinowicz 1993). Progressive removal of the original sandy gravel and its replacement by fine sand has also been reported for the sediments off Dieppe by Desprez (1992). In the case of experimental furrows dredged by trailer suction in gravel deposits of the southern North Sea off the Suffolk coast of England, even shallow depressions of only 20-30cm depth were still visible on side-scan sonar records made up to 4yr later (Millner et al. 1977). In contrast, dredge furrows in the Bristol Channel have been reported to disappear within 2 to 3 tides because of high sediment mobility (pers. obs.).

Rather unexpectedly, Kenny & Rees (1994, 1996) found an increase in the particle size of deposits in the dredged areas, possibly reflecting the exposure of coarse deposits at depth below the surface gravel layers. In this study, which was carried out in the southern North Sea, the dredged furrows were visible with side-scan sonar even after 2yr. Similar results have been reported for dredging tracks off the French coast at Dieppe (Desprez 1992) although winter storms obliterated tracks within a few months on the

Klaver Bank in the Dutch sector of the North Sea (Sips & Waardenberg 1989, van Moorsel & Waardenberg 1990, 1991). In general, dredge tracks will persist for varying times depending on the rate of local sediment fluxes, recent measurements suggesting 1-4 days only for the Norfolk Banks, but periods as long as 1-4yr for more stable deposits off the Owers to the east of the Isle of Wight (A. Hermiston pers.comm.).

Thus both anchor dredging and trailer suction dredging have an important potentialimpact on the biology of the dredged areas, since no benthos is likely to occur below the dredged depth. This can be expected to lead to a patchy distribution of organisms, reflecting the differences between the dredged furrows and the intervening undredged surfaces. Such recolonization as occurs within the dredged areas is likely to be by migration of adults through transport on tidal currents (Rees et al. 1977, Hall 1994); by transport in sediments slumping from the sides of the pits and furrows (McCall 1976, Guillou & Hily 1983); by the return of some undamaged components through outwash from the chutes and spillways (see Lees et al. 1992, Ministry of Agriculture, Fisheries and Food 1993); and by colonization and subsequent growth of larvae from neighbouring populations. In this case, a clear succession of colonizing species is to be anticipated, leading to the establishment of definite clusters or patches in benthic community composition, depending on the type of deposits that have infilled the dredged areas and the time since the recolonization sequence started.

Impact adjacent to the dredged area

Although a good deal of concern has been expressed about the possible impact of marine aggregate extraction on coastal resources (see ICES 1992a,b), the possible scale of impact outside the immediate dredged area from the settlement on the sea bed of fine material temporarily suspended by marine aggregates dredging is poorly understood.

Hitchcock & Drucker (1996) have summarized values for material lost through the hopper overflow spillways and from the reject chutes during the screening process on a typical modern trailer suction dredger of 4500 t hopper capacity operating in UK waters off the coast of East Anglia. Table 2 shows the size distribution for the material lost through the reject chute and spillway, while the total screened load quantities are summarized in Table 3. These show that during a recorded average loading time of 290 min, 12 158 t of dry solids and 33 356 t of water were pumped by the dredge pump.

Table 2 Size distribution of overspill and reject material from a typical modern trailer suction dredger of 4500 t hopper capacity (based on Hitchcock & Drucker 1996).

Particle size (mm)	Proportion in discharge (%)	
	Spillway	Reject chute
<0.063	38.0	1.0
0.063–0.125	14.0	0.9
0.125–0.250	5.7	8.9
0.250–0.500	12.9	31.4
0.500–1.000	9.2	27.3
1.000–2.000	3.3	12.0
>2.000	16.9	18.5

The data show that 4185 t of dry solids are retained as cargo, while 7223 t of dry solids are returned overboard because of rejection by screening, and a further 750t from overspill.

It is also clear that some 1338 t of material >2.0mm (representing 18.5% of the 7235 t in the reject chute - see Table 2) is lost overboard through the reject chute and a further 126 t (representing 16.9% of the 750 t in the spillway - see Table 2) from the spillway. This equates to a loss rate of 76.9 kgs^{-1} of particles >2.0mm from the screening reject chute and 7.2 kg s^{-1} from overspill. Assuming that the dredger moves at an average speed of 1 knots, the flux of material >2.0mm entering the water column is 39.6 kg s^{-1} m^{-1} from the screening reject chute and 3.7 kg s^{-1} m^{-1} from the spillways. Much of this material is in the size range 2.0-10.0mm and falls rapidly to the seabed with little horizontal displacement during screening. Video recordings during normal loading operations show that such material deposits on the seabed directly under the dredge vessel (Davies & Hitchcock, 1992).

Finer sand and silt fractions discharged during dredging and screening amount to 5824 t from the reject screening chutes and 338 t from overspill. This is equivalent to a deposition rate of 334 kg s^{-1} and 19.4 kg s^{-1}, respectively. In addition to the sand fraction, up to 213 t (12.2 kg s^{-1}) of muddy sediment (<0.063 mm diameter) may be lost through the rejection process and 285 t (16.4 kg s^{-1}) from overspill. The material may be expected to settle more slowly than the sand-sized fraction and has a typical settling velocity of 0.1-1.0mm s^{-1}.

In its simplest form, the settlement velocity and residence time of such particles in the water column can be estimated from Stoke's Law. If the residence time of particles in the water column is known, the duration and speed of currents will then determine the excursion pattern before settlement. Estimates of dispersion of fine material based on these Gaussian diffusion principles suggest that very fine sand particles may travel up to 11 km from the dredge site, fine sand up to 5 km, medium sand up to 1 km and coarse sand less than 50m (H. R. Wallingford 1994, cited in Hitchcock & Drucker 1996).

Similar estimates based on the settlement velocity of fine silt-sized particles (<0.063 mm diameter) suggest that this material could remain in suspension for up to 445 tidal cycles and be carried for as much as 20 km on each side of a point source of discharge. Most recent studies made on the dispersion of sediment plumes generated from dredging operations suggest, however, that the area of impact of outwash from dredging activities is smaller than estimates based on Gaussian diffusion models, especially where the proportion of silt and clay in the deposits is low. This appears to be due to complex cohesion properties of the discharged sediment particles that settle to the seabed as a density current and do not conform to settlement rates based on the specific gravity and size of the component particles themselves.

Table 3 Typical screened load quantities for a suction dredger of 4500 t hopper capacity (based on Hitchcock & Drucker 1996).

	Dry solids (tonnes)	Water (tonnes ±5%)
Quantity pumped	12 158	33 356
Quantity retained	4185	874
Quantity reject through screening	7223	13 499
Quantity lost through overspill	750	21 387
Total losses	7973	34 886

A detailed study by Gajewski & Uscinowicz (1993) in relation to trailer dredging in the Baltic showed that the width of the plume, as determined by the light extinction in the water, did not exceed 50m. Settlement of the suspended matter onto the sea floor was measured by a series of sediment traps deployed approximately 1 m above the sea bed. When the dredger was discharging mainly fine sand (0.25-0.125 mm) at a concentration of approximately 11000 mg l^{1}, it was found that deposition of 7500- 15 000g m^{2} were recorded in the troughs during dredging. The settlement in traps deployed 50m away from the dredger's route was, however, less than $1220gm^{-1}$. At distances greater than 50m the amount of material settling on the sea floor decreased rapidly (Fig. 6).

More recently, Acoustic Doppler Current Profiling (ADCP) techniques have been used to determine plume dispersion in relation to spoils dispersal from both commercial aggregate dredgers (Hitchcock & Dearnaley 1995, Hitchcock & Drucker 1996) and in relation to capital dredging works and sand mining (Land et al. 1994, Whiteside et al. 1995). Remote airborne and satellite imagery has also proved to be a useful tool in defining the contours of sediment dispersal (Whiteside et al. 1995).

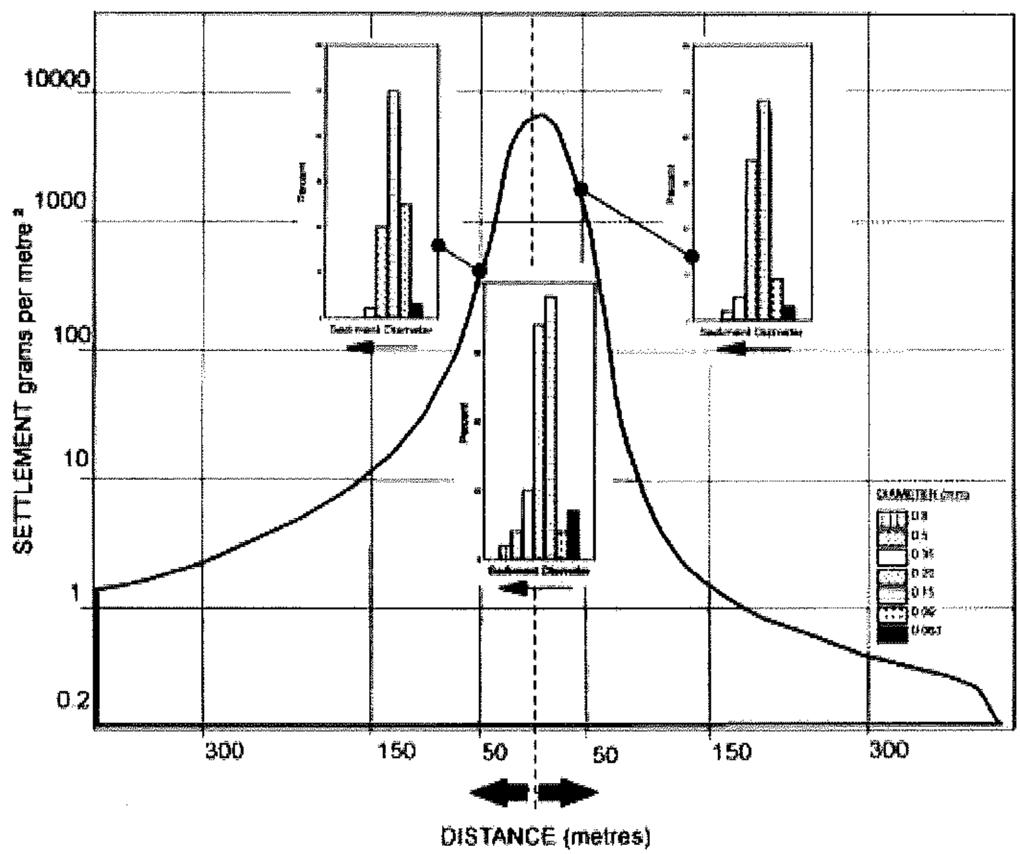


Figure 6 Diagram showing the settlement of sand during dredging operations from trailer dredging in the Baltic. Particle size profiles for the sediments deposited in the track of the dredger and 50m on each side of the dredger are also shown. Note that the main deposition of sand from flow-off from dredging operations was confined to distances within 150m on each side of the track of the dredger. (After Gajewski & Uscinowicz 1993).

These studies confirm that the initial sedimentation of material discharged during outwash from dredgers does not, as had been widely assumed, disperse according to the Gaussian diffusion principles used in most simulation models, but behaves more like a density current where particles are held together by cohesion during the initial phase of the sedimentation process. As a result, the principal area likely to be affected by sediment deposition is much less than the "worst case" scenarios predicted from conventional Gaussian diffusion simulation models, and is mainly confined to a zone of a few hundred metres from the discharge chutes.

A recent study by Whiteside et al. (1995; see also Johanson & Boehmer 1975, Gayman 1978) has shown that the behaviour of plumes discharged during sand dredging can best be regarded as comprising an initial "dynamic phase" during which the sediment-water mixture descends rapidly to the sea bed as a density current jet at a rate that depends on the overflow density, the diameter of the discharge pipe, the water depth, the velocity of discharge and the speed of the dredger. During its passage through the water column and following impact with the sea bed the sediment is dispersed into the water and forms a well-defined plume astern of the dredger. This second longer phase has been referred to as the "passive phase" of dispersion by Whiteside et al. (1995) and starts approximately 10min after outflow. During this phase the material behaves in a relatively simple settling mode according to Stokes' Law, the plume then decaying to background levels after a period of 2-3 h.

Their study showed that approximately 100 m (corresponding to approximately 3 min from the overflow) astern of a dredger working in Hong Kong waters the plume surface sediment concentrations were from 75-150mgl^{-1}. Levels were halved in 10 min and reduced to 20-30 mg l^{-1} after 30 min. This approached the recorded background suspended solids concentration of 10-15 mgl^{-1} and indicated that only a relatively small proportion of the fines category (< 63 µm) remained in the water column at the start of the passive phase of dispersion 10min after discharge. Even then, their data suggest that the settlement rate of the plume continued to be more rapid than simple particle settlement would suggest.

A plume dispersion model developed by Whiteside et al. (1995) for the surface layer (the upper 8 m of the water column) for up to 40 min after discharge is shown in Fig. 7 and compares well with summed plume decay measurements in the vicinity of the dredger. The contours for sediment deposition evidently remain as a narrow band extending for approximately 100m on each side of the track of the dredging vessel, much as recorded by Gajewski & Uscinowicz (1993) for Baltic waters.

Very similar rapid rates of deposition and decay of sediment outwash plumes have been recorded by Hitchcock & Drucker (1996) who studied plume generation and decay from four dredge vessels ranging in capacity from 2000-5000 t during normal loading operations off the coast of East Anglia, UK. During the plume tracking exercise peak current velocities reached 0.6 m s^{-1} and the water depth was approximately 22m. The concentration of total suspended sediment discharged was approximately 2500mg l^{-1} comprising mainly sand-sized material and with < 30mg l^{-1} mud (< 0.063 mm diameter).

The total concentration of suspended solids in the water column at different depths and distances from the dredger measured by water sampling and optical transmissometers is summarized in Fig. 8. The corresponding values for silt-sized material (<0.063 mm) are shown in Fig. 9. These data show that concentrations of sand-sized material are reduced to background levels over a distance of only 200-500m from the point of release into the water column and that the concentration of even silt-sized particles is reduced to background values of 2-5 mg l^{-1} over a similar distance. This very

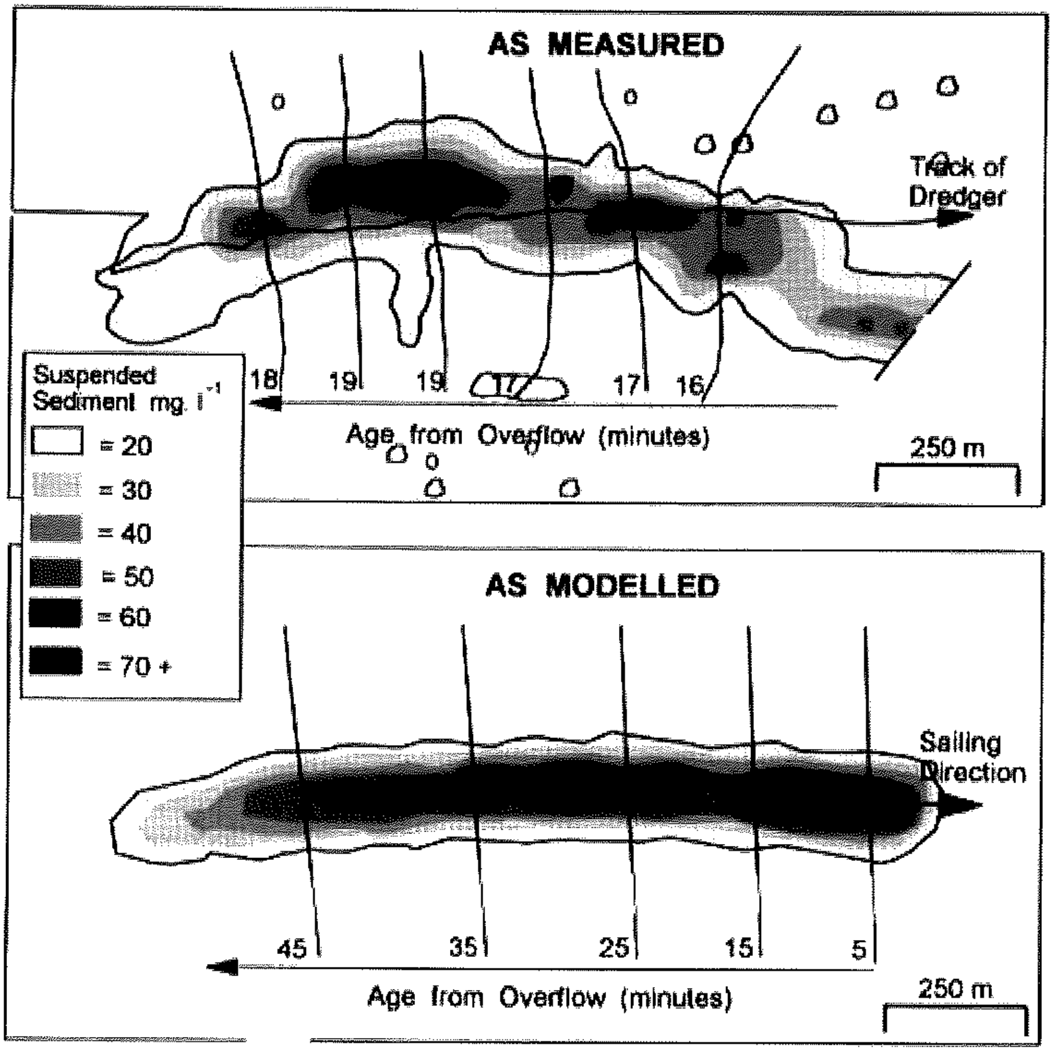


Figure 7 Diagram showing contours for suspended sediment concentrations astern of a trailer dredger operating in Hong Kong waters. Upper diagram shows the contours as measured in the upper 8m of water across the plume at various arbitrary time intervals during field studies of a sediment plume from 16-19min after discharge. Lower diagram shows the output of a simulation model developed for sediment dispersion based on rapid initial sedimentation during a dynamic phase and a second longer passive phase which starts approximately 10min after outflow. (After Whiteside et al. 1995).

rapid reduction in suspended sediment concentrations is similar to that reported by Whiteside et al. (1995).

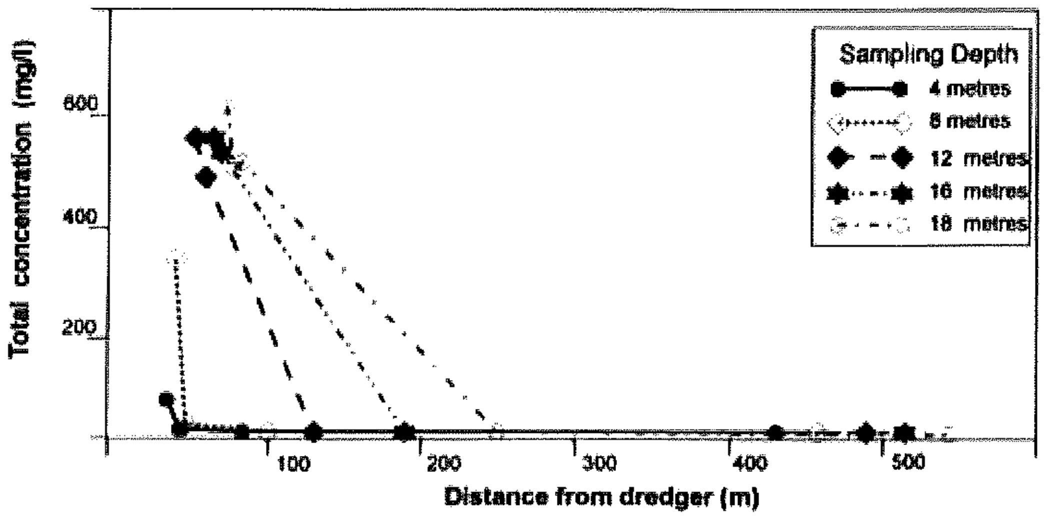


Figure 8 The total concentration of suspended solids in the water column at different depths and distances from the dredger measured by water sampling and optical transmissometers. (After Hitchcock & Drucker 1996).

Although suspended sediment concentrations in the plume were not significantly different from background levels beyond 400-500 m from the point source of discharge using conventional water sampling and optical transmissometer techniques, it is interesting to note that it is possible to track the plume using ADCP techniques over a distance of up to 3.5 km. A series of typical sections across a discharge plume at varying distances from 80m up to 3335 m away from a dredger is shown in Fig. 10. This shows clearly the decay of the plume to background levels at approximately 400m, but that a residual impact is detectable up to 3.5 km by ADCP methods.

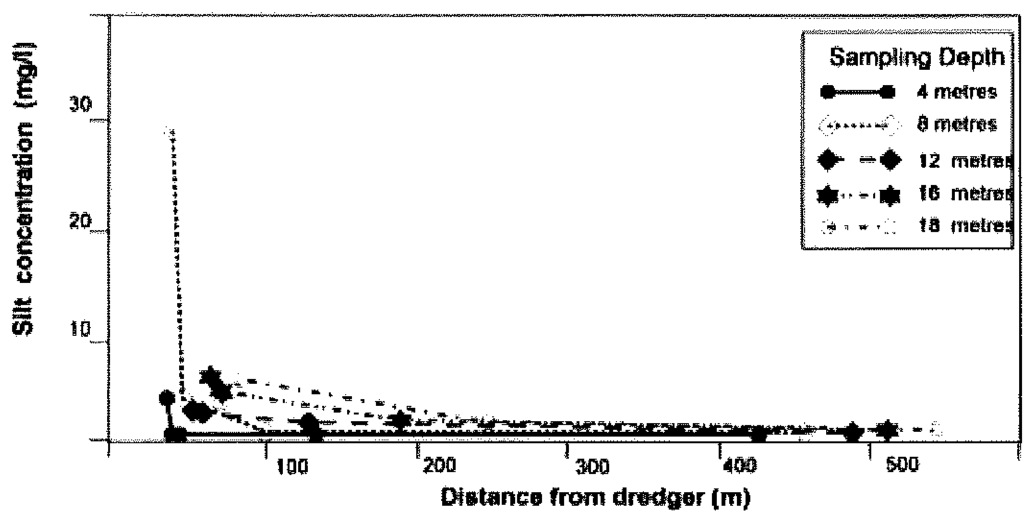


Figure 9 The concentration of silt-sized material (<0.063 mm) in the water column at different depths and distances from the dredger measured by water sampling and optical transmissometers. (After Hitchcock & Drucker 1996).

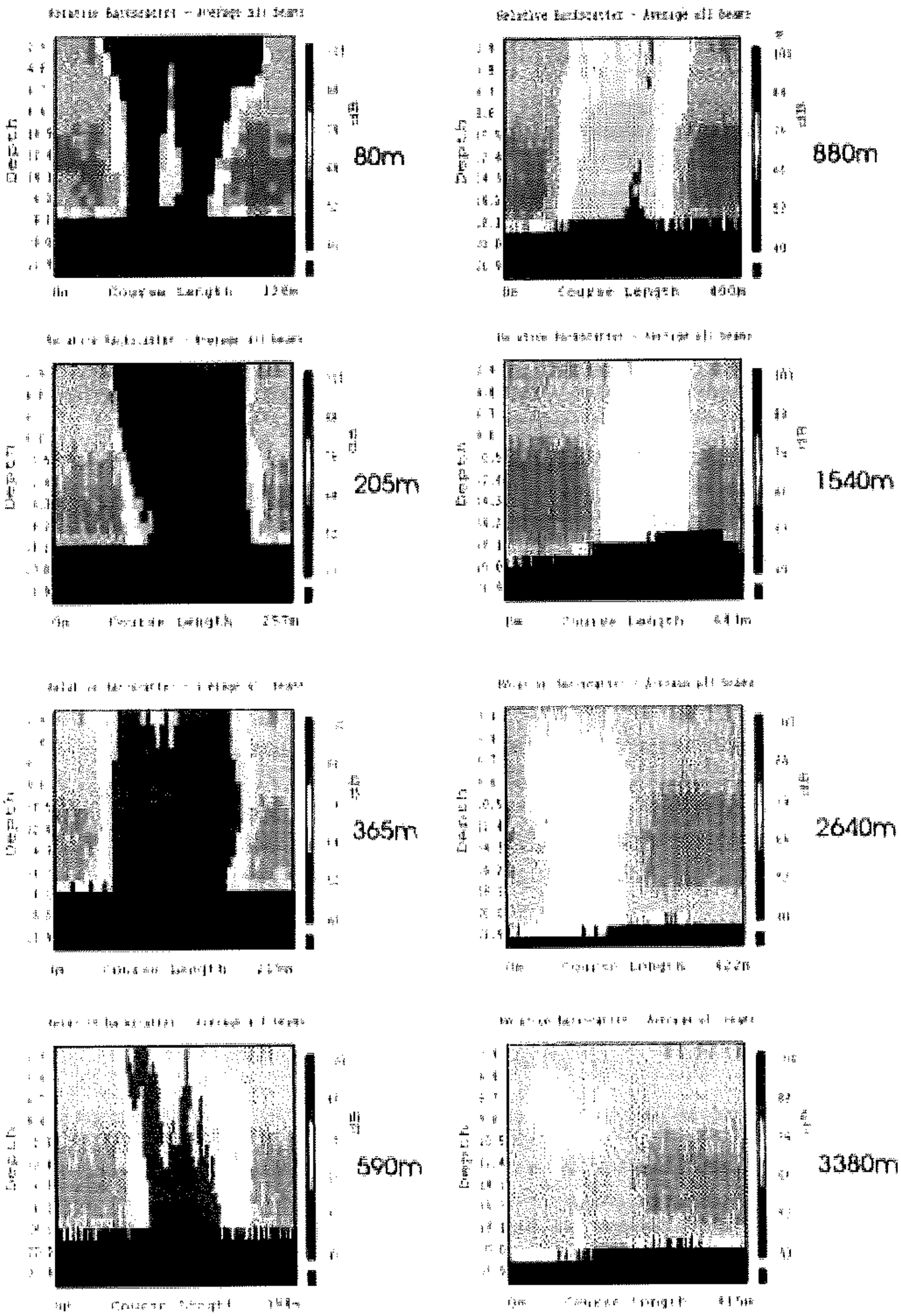


Figure 10 Acoustic Doppler Current Profiler (A DCP) acoustic backscatter across the plume of a dredger at varying distances downstream (m). Water speed 100cm s^{-1}. Note that although sedimentation is achieved within 880m, the relative backscatter suggests an additional "plume", perhaps representing entrained air bubbles, biochemical precipitates or organic matter released from the sediment, which extends up to 3380m astern of the dredger. (After Hitchcock & Drucker 1996).

Whether this residual impact is caused by air bubbles or organic matter becoming entrained into the water column during the dredging operation is at present unknown. However, it is noteworthy that there is now a good deal of evidence that suggests that disturbance of marine sediments may release sufficient organic matter into the water column to enhance benthic production.

These results for the dispersion of sediment in the water column thus suggest that sedimentation is rapid and is confined to the immediate vicinity of the discharge. They confirm earlier studies of Poiner & Kennedy (1984; see also Willoughby & Foster 1983) who reported that sediment deposition generated from dredging activities in Moreton Bay, Queensland was confined to the immediate vicinity of the dredging works. Concentrations of suspended sand-sized material were reported to decay to background levels over a distance of only 200-500m from the point of release into the water column from a commercial aggregate dredger. They estimated that the sediment deposition 500m outside the boundary of the dredged area was 29.6 kgm^{-2} (23mm m^{-2}). At 1 km deposition was 21.2kg m^{-2} (16mm m^{-2}), a t 1.5km it was 15kg m^{-2} (12mm m^{-2}), at 2km it was 10.7kg m^{-2} (8mm m^{-2}) and finally at 2.5km from the boundaries of the dredged area the estimated deposition was less than 7.6kg m^{-2} (6mm m^{-2}).

There is a good deal of evidence from other surveys that disturbance of sediments by dredging may release sufficient organic materials to enhance the species diversity and population density of organisms outside the immediate zone of deposition of particulate matter. Disturbance of the sediments may thus enhance benthic production outside the immediate zone of deposition provided that contaminants from polluted sediments are not associated with the disposal of spoils. Stephenson et al. (1978) and Jones & Candy (1981) both document the enhanced diversity and abundance of benthic faunas near to dredged channels. Poiner & Kennedy (1984) showed that there was an enhancement of benthic biota close to dredged areas at Moreton Bay, Queensland and that the level of enhancement decreased with increasing distance from the dredged area up to a distance of approximately 2 km. They ascribe this to the release of organic nutrients from the sediment plume, a process which is well known from other studies (Ingle 1952, Biggs 1968, Sherk 1972, Oviatt et al. 1982; Walker & O'Donnell 1981).

The results reviewed above thus suggest that the impact of dredging activities mainly relates to the physical removal of substratum and associated organisms from the seabed along the path of the dredge head and to the impact of subsequent deposition of sediment from outwash during the dredging process. The evidence from direct studies on the sedimentation of particulate matter suggests that the impact of sedimentation on biological resources on the seabed is likely to be confined to distances within a few hundred metres of the dredger where the deposits are sands and gravels. It should be remembered, however, that discharge of dredge spoils from maintenance and capital dredging works in estuaries may result in much larger dispersion plumes that reflect the dominantly fine particles and strong current flows that occur in estuaries, and that the same processes, which result in the release of dissolved organic matter, can also result in the release of bound surface contaminants from the sediments into the water column.

The impact of dredging on biological resources

Sensitivity to Disturbance

The impact of disturbance by the dredge head during marine aggregate dredging has been reviewed on pp. 14-17. The effects of sediment deposition and spoils disposal outside the immediate boundaries of dredged areas in coastal waters has also been widely studied and includes extensive physiological-ecological work on a wide variety of animals including plankton, benthic invertebrates and fish species (for reviews, see Sherk 1971, Moore 1977). Early studies by Loosanoff (1962) showed that different species of commercially significant filter-feeding molluscs were differently affected by suspended sediment. Subsequent studies by Sherk (1971) and Sherk et al. (1974) included both plankton and fish species. They showed that, as in the case of bivalves, fish species have varying tolerances of suspended solids, filter-feeding species being more sensitive than deposit feeders and larval forms being more sensitive than adults (see also Matsumoto 1984).

Many of the macrofauna that live in areas of sediment disturbance are well adapted to burrow back to the surface following burial (see Schafer 1972). Studies by Maurer et al. (1979) showed that some benthic animals could migrate vertically through more than 30cm of deposited sediment, and this ability may be widespread even in relatively deep waters. Kukert (1991) showed, for example, that approximately 50% of the macrofauna on the bathyal sea floor of the Santa Catalina Basin were able to burrow back to the surface through 4-10cm of rapidly deposited sediment. A good deal of the apparent recolonization of deposits following dredging or spoils disposal may therefore reside in the capacity of adults to migrate up through relatively thin layers of deposited sediments (see also Ellis & Heim 1985) or to migrate in during periods of storm-induced disturbance (see Hall 1994).

There is good evidence that the activities of filter-feeding bivalves, in particular, can play an important part in controlling the natural phytoplankton and seston loads in the water column (Cloern 1982) to an extent that food may become a limiting resource in the benthic boundary layer at the sediment-water interface (Wildish & Kristmanson 1984, Frechette et al. 1989, 1993; see also Dame 1993, Snelgrove & Butman 1994) as well as on coral reef flats and in cryptic reef habitats (Glynn 1973, Buss & Jackson 1981). Because the suspension-feeding component is evidently highly effective in removing particulate matter from sea water, the release of large quantities of suspended matter can lead to a loss of suspension-feeding components through clogging of the gills. This has led to a corresponding increase in the community of deposit feeders in some areas such as St Austell Bay off the southwest coast of England (Howell & Shelton 1970).

In general, however, most recent studies of filter feeders that live in coastal waters show that bivalves, in particular, are highly adaptable in their response to increased turbidity such as can be induced by periodic storms, dredging or spoils disposal and can maintain their feeding activity over a wide range of phytoplankton concentrations and inorganic particulate loads (Shumway et al. 1985, 1990, Newell et al. 1989, Newell & Shumway 1993 Iglesias et al. 1996, Navarro et al. 1996, Urrutia et al. 1996). Although these studies on the physiology of individual species can give some insight into the differing susceptibilities of the macrofauna to increased turbidity, or to burial from dredger outwash, in general it is difficult to make predictions of the impact of dredging on whole communities from the results of studies on individual species. Partly for this reason, and because the interactions between the components of natural populations are complicated in space and time, most recent studies on the impact of spoils disposal and dredging works have been carried out on whole communities, rather than individual species. Such studies have concentrated on three main features of benthic communities, namely the number of individuals (population density), number of species (the diversity) and the biomass (to give an index of the growth following recolonization).

Sampling is conventionally carried out by means of a grab that allows collection of a sediment sample from a known area of seabed deposits, which are then eluted through a l-mm mesh sieve to extract the macrofauna. Sediment samples from fine deposits such as occur in coastal embayments, lagoons and estuaries are relatively easy to obtain by means of equipment such as the van Veen and Smith-McIntyre grabs, the Ponar grab (Ellis & Jones 1980), or the Day grab whose jaws are held closed by the tension of the wire from which the grab is suspended rather than by a spring-loaded mechanism (see Holme & McIntyre 1984). Sampling of coarser gravel deposits is complicated, however, by the fact that the larger stones become trapped between the jaws of conventional grabs, leading to extensive losses through "washout" from the grab. Partly because of this problem, most work on coarser deposits has been carried out with semi-quantitative dredges such as the Anchor dredge (Forster 1953, Holme 1966, Kenny et al. 1991) or the Ralier du Baty dredge used by Davoult et al. (1988).

More recently, however, Sips & Waardenburg (1989) and Kenny & Rees (1994) have used a Hamon grab for quantitative studies on the fauna of gravels and sands. This grab takes a scoop out of the seabed deposits, rather than relying on the dosure of opposing jaws (see Holme & McIntyre 1984). This greatly reduces the problem of fauna losses through "washout" during the sampling process and the Hamon grab is now widely used in the quantitative evaluation of the benthos in coarse sands and gravels.

Such studies emphasize that the macrofauna may vary considerably even over relatively short distances, and that a proper understanding of the distribution of benthic communities is necessary if damage to potentially important communities is to be avoided during dredging operations. Figure 11 shows, for example, the distribution of two important members of the benthic community in mixed gravel, sand and muddy deposits off the coast of East Anglia in August 1996 (Newell & Seiderer 1997b). Inspection of this figure shows that the main population of the reef-building tubeworm, *Sabellaria spinulosa* (called Ross by the fishermen) occurs in the northwestern part of the survey area, and corresponds with a localized patch of coarse stones and cobbles that give sufficient stability to support a rich reef community. This species may be predated upon by the pink shrimp *(Pandalus)* and is potentially important as a feeding ground for a variety of demersal fish species (see Warren, 1973).

In contrast, the populations of the comb worm *(Lagis = Pectinaria koreni)* occur in mobile muddy sands in the southwest of the survey area. This species is an important prey item for sole *(Solea solea),* dab *(Limanda limanda* and plaice *(Pleuronectes platessa)* (see Lockwood 1980, Basimi & Grove 1985, Carter et al. 1991, Horwood 1993, also Peer 1970) and therefore represents a food resource within the survey area that requires conservation.

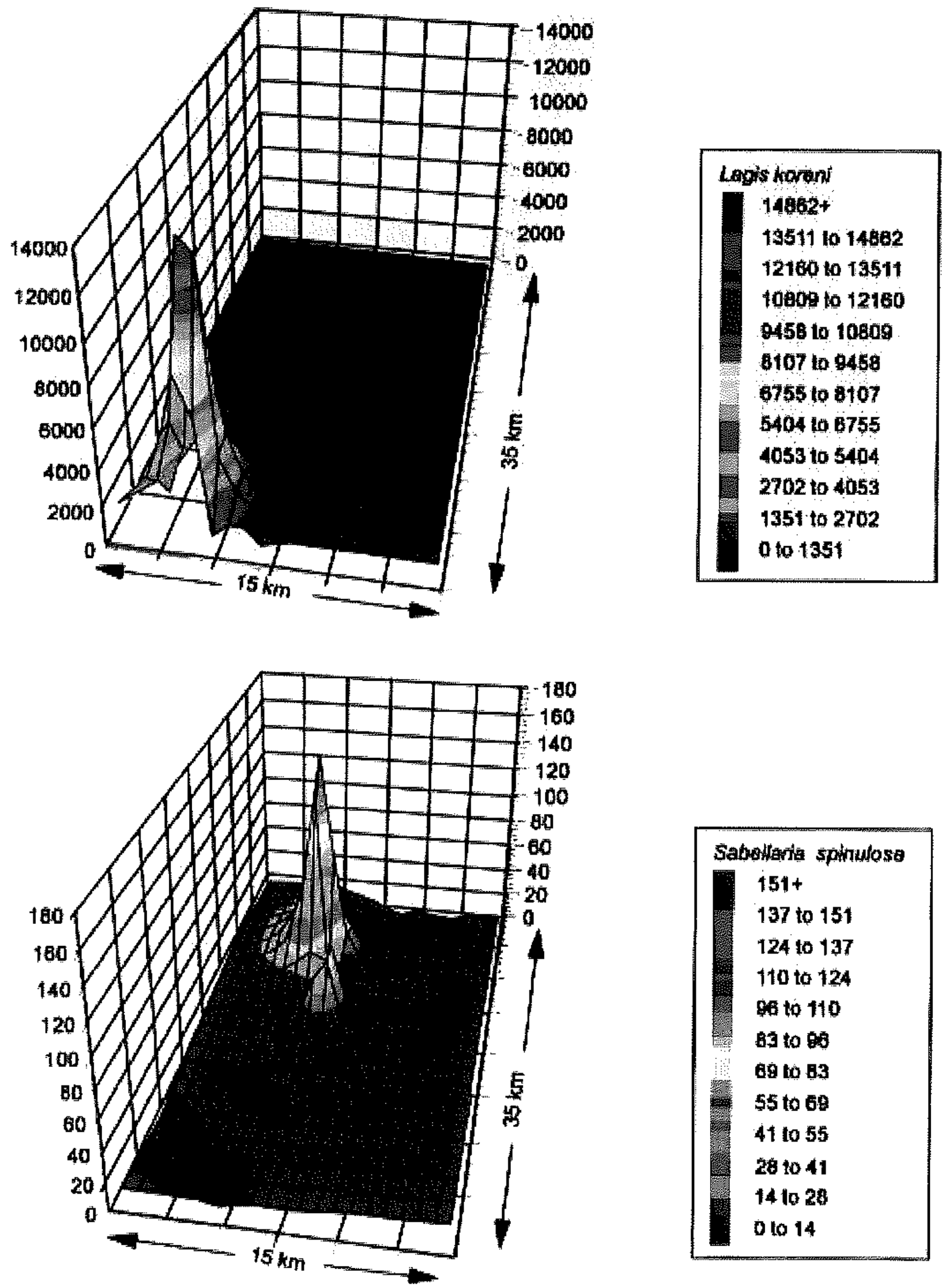


Figure 11 Schematic diagram of a survey area in the southern North Sea off Suffolk showing the distribution of the comb worm (*Lagis koreni*) in fine deposits of the survey area, and that of the colonial "Ross" worm (*Sabellaria spinulosa*) in areas where coarse boulders provide a stable environment for development of reef-forming species. Population density in numbers of individuals per 0.25 m^2 Hamon grab sample. (Newell & Seiderer 1997b).

Impact of dredging on diversity and abundance

The impact of dredging on benthic communities varies widely, depending, among other factors, on the intensity of dredging in a particular area, the degree of sediment disturbance and recolonization by passive transport of adult organisms (see Hall 1994) and the intrinsic rate of reproduction, recolonization and growth of the community that normally inhabits the particular deposits.

Some examples of the impact of dredging on the species variety, population density (number of individuals) and biomass of benthic organisms from a variety of habitats ranging from muds in coastal embayments and lagoons, to oyster shell deposits, and to sands and gravel deposits in the southern North Sea are summarized in Table 4. This shows that both maintenance dredging and marine aggregates dredging can be expected to result in a 30-70% reduction of species diversity, a 40-95% reduction in the number of individuals, and in a similar reduction in the biomass of benthic communities in the dredged area.

Despite the major impact of dredging on benthic community composition within dredged areas, there is little evidence that deposition of sediments from outwash through the chuteways during the dredging process has a significant impact on the benthos outside the immediate dredged area. Poiner & Kennedy (1984) showed that the population density and species composition of benthic invertebrates adjacent to dredging works on sandbanks in Moreton Bay, Queensland, Australia increased rapidly outside the boundaries of the dredged area, as might be anticipated from the relatively small amounts of sediment that are deposited beyond a few hundred metres of the dredger trail (see Figs 6 and 7 and p. 24). The population density and species diversity recorded from a transect across a dredged area in Moreton Bay in July 1982 by Poiner & Kennedy (1984) is shown in Fig. 12.

Table 4 Table showing the impact of dredging on benthic community composition from various habitats.

Locality	Habitat type	% Reduction after dredging			Source
		Species	Individuals	Biomass	
Chesapeake Bay	Coastal embayment muds-sands	70	71	65	Pfitzenmeyer 1970
Goose Creek, Long Island, NY	Shallow lagoon mud	26	79	63-79	Kaplan et al. 1975
Tampa Bay, Florida	Oyster shell	40	65	90	Conner & Simon 1979
Moreton Bay, Queensland, Australia	Sand	51	46	-	Poiner & Kennedy 1984
Dieppe, France	Sands-gravels	50-70	70-80	80-90	Desprez 1992
Klaver Bank, Dutch Sector, North Sea	Sands-gravels	30	72	80	van Moorsel 1994
Lowestoft, Norfolk, UK	Gravels	62	94	90	Kenny & Rees 1994
Hong Kong	Sands	60	60	-	Morton 1996
Lowestoft, Norfolk, UK	Sands-gravels	34	77	92	Newell & Seiderer 1997a

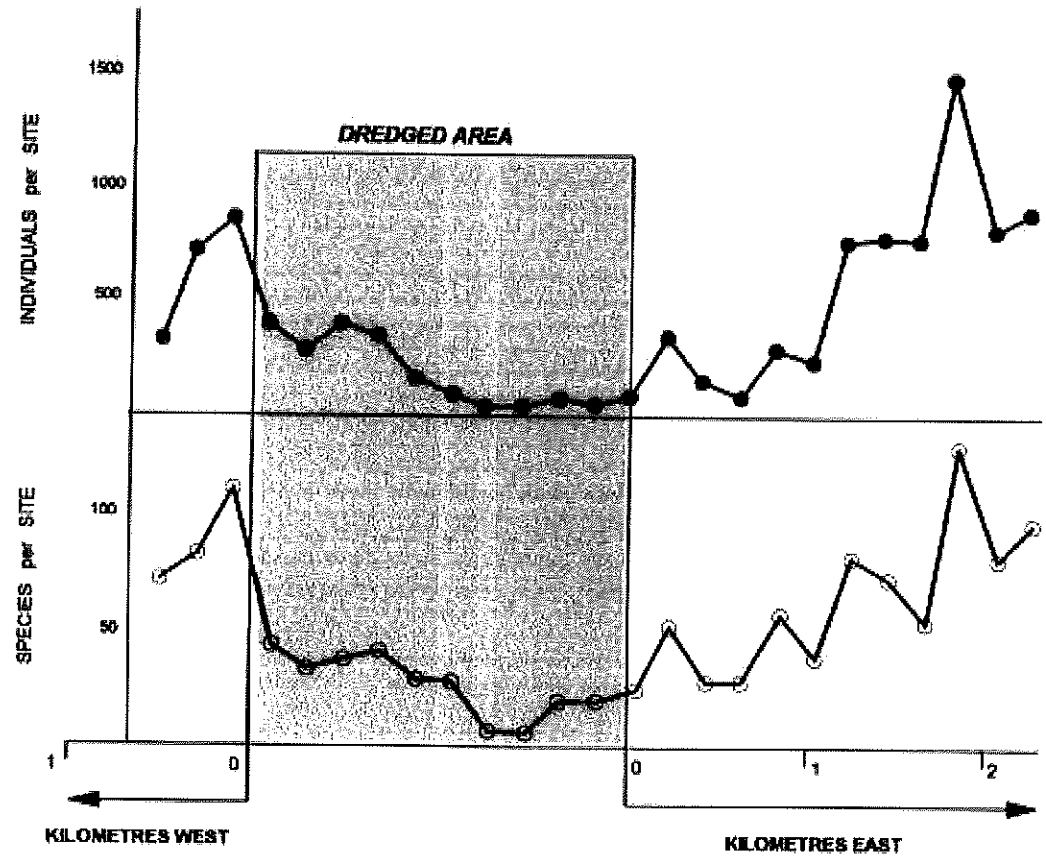


Figure 12 Diagram showing the number of individuals and species of benthos recorded in July 1982 on a transect crossing a dredged area on a sublittoral sandbank in Moreton Bay, Queensland, Australia. Note that species variety and population density increased rapidly outside the immediate boundaries of the dredged area. (Based on Poiner & Kennedy 1982).

Other than this study, there is surprisingly little detailed information on the precise boundaries of biological impact or "footprint" surrounding areas that have been dredged for sands and gravels. The circumstantial evidence from the boundaries of sediment deposition suggest, however, that biological impact is likely to be confined to the immediate vicinity of the dredged area.

One of the problems with assessing the impact of dredging works and the recovery of benthic communities over time is that biological communities are often subject to major changes in population density and community composition, even in areas that are apparently unaffected by dredging. Variations in the population density and species composition of the large bivalve population recorded between 1988 and 1991 in the sand and gravel deposits of the Klaver Bank in the Dutch sector of the North Sea by van Moorsel (1994) are shown in Fig. 13. This shows the major change in population of the bivalve, *Dosinia exoleta* between the summer of 1988 and the spring of 1989 and the loss of the large bivalve, *Arctica islandica* from the deposits even before aggregate extraction had taken place.

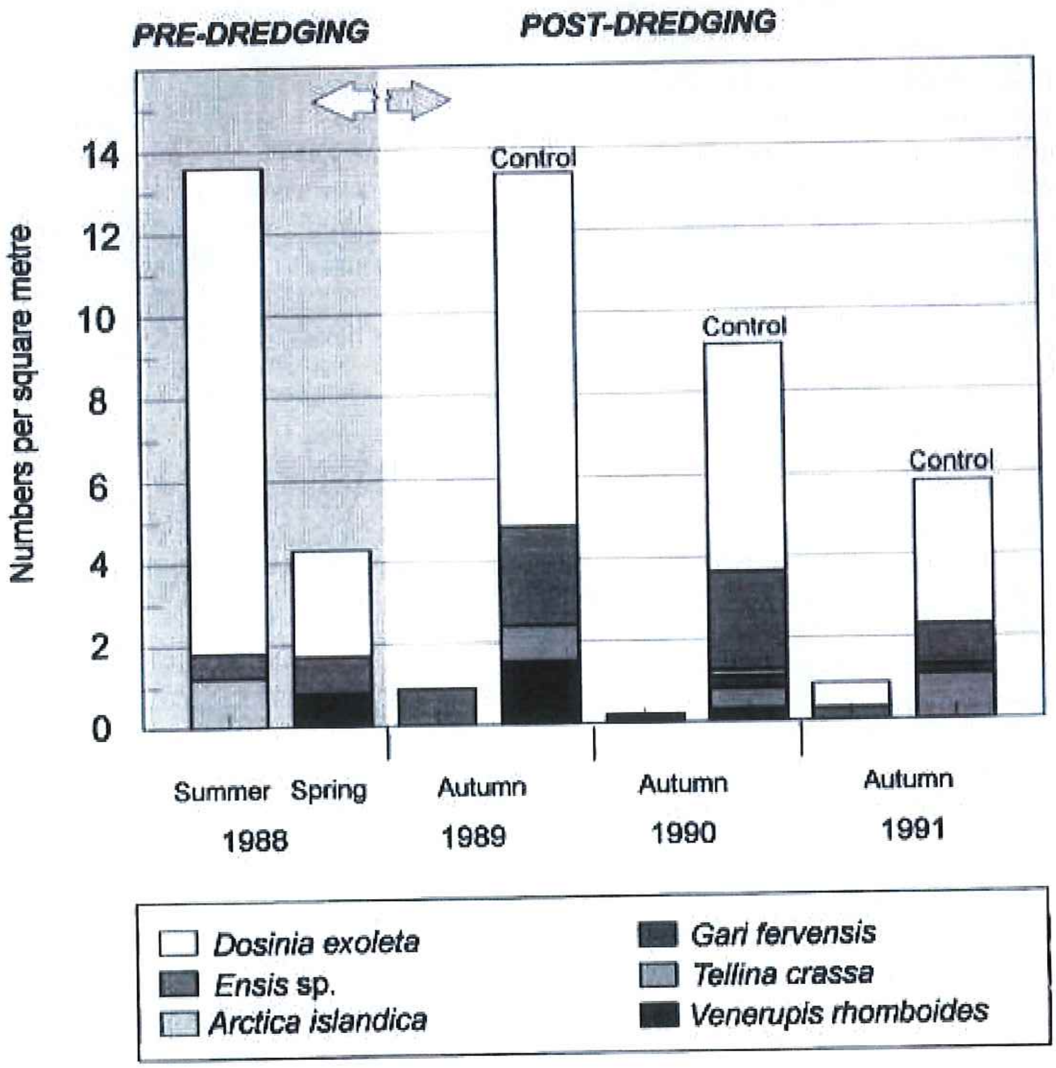


Figure 13 Diagram summarizing the changes in population density and species composition of large bivalves on the Klaver Bank in the southern North Sea between 1988 and 1991. Pre-dredging values in 1988 show major seasonal changes in density and species composition. After dredging in the summer of 1989, large differences in population density and species composition emerged between dredged and control areas, and these differences persisted for at least two years. (After van Moorsel 1994).

A short period of aggregate extraction was carried out in the study area on the Klaver Bank in the summer of 1989. Thereafter, clear differences emerged between the large populations of bivalves in control areas outside the dredged zone and those within the dredged area, despite the natural variations in species composition and population density that evidently occurred in the deposits of the survey area. These differences persisted until the end of the survey period in autumn of 1991, suggesting that this slow-growing component of the benthos remains impacted for at least 2yr after cessation of dredging.

The process of recolonization and recovery

These complex changes in community structure following dredging, and which occur during the recovery process, are difficult to assess by mere inspection of the data for species composition, population density and biomass. Most recent studies on community structure in relation to environmental gradients, therefore, whether these are natural or induced by man, use relatively sophisticated analytical techniques that incorporate the type of species as well as their individual population densities and biomass to assess changes in community structure. The use of these techniques is beyond the scope of this review, but useful accounts for the biologist are given in Kruskal (1977), Hill (1979), Field et al. (1982), Heip et al. (1988), Magurran (1991), Warwick & Clarke (1991), Clarke & Ainsworth (1993), Clarke & Warwick (1994, and references cited therein).

Probably the most widely-used method is detrended correspondence analysis (DECORANA), an ordination technique that arranges stations along axes according to their similarity in species composition (Hill 1979). This is often used in association with two-way indicator species analysis (TWINSPAN) to identify species that characterize particular parts of an environmental gradient such as might be imposed, for example, by dredging or spoils overspill, or communities in relation to wider spatial gradients (see Eleftheriou & Basford 1989).

A second approach is the use of non-parametric multivariate analyses of community structure as outlined by Field & McFarlane (1968), Field et al. (1982) and Clarke & Warwick (1994). This procedure has recently become available in a convenient software package PRIMER (Plymouth Routines in Multivariate Ecological Research) and is now widely used in the analysis of benthic community structure in European coastal waters.

Despite problems in the interpretation of long-term studies on the abundance and composition of marine communities, studies that are carried out over even relatively short time periods can give important information on the recovery process following cessation of dredging. The most comprehensive analysis of the impact of dredging on community composition and on the process of recolonization and recovery in mixed gravel deposits is that of Kenny & Rees (1994, 1996). They carried out an intensive dredging programme by suction trailer dredger in an experimental area off Lowestoft, Norfolk in the southern North Sea and subsequently monitored the recovery over a period of 8 months in the first instance, although this was increased to 2yr in an extended study of the recolonization process (Kenny & Rees 1996). Dredging occurred in April 1992, during which the suction dredger SAND HARRIER removed a total of 52 000 t of mixed aggregates from an area measuring 500m by 270m, an estimated 70% of the surface deposits down to an average depth of 0.3 m having been removed from the experimental area. The species variety, population density and biomass in the experimentally dredged site was then compared with that in a reference site nearby over the 8-month period between March and December 1992.

The results from their study are summarized in Fig. 14. This shows that the number of species in the dredged site declined from 38 to only 13 species following dredging, whereas the number of species remained at about 35 during the 8-month period at the reference site. The number of species in the dredged area subsequently increased somewhat in the following 7 months, suggesting that some recolonization occurs even over this relatively short time.

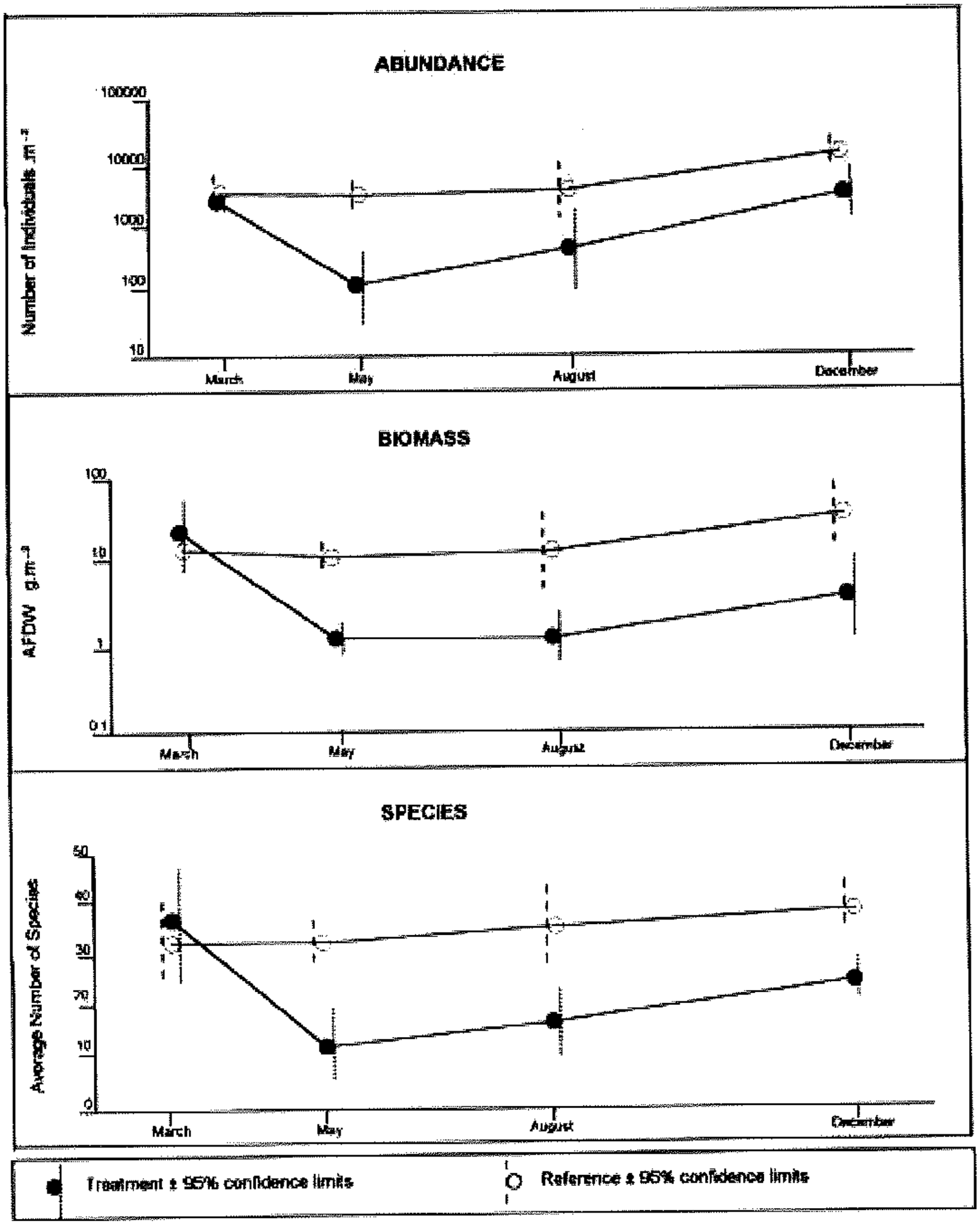


Figure 14 Graphs showing the mean values for the abundance of individuals (No. per m^2) from five Hamon grab samples each of 0.25 m^2 taken in a dredged site and at a reference site. Dredging occurred in April, and samples were taken in the pre-dredged deposits in March 1992 and through to December 1992. Values for the biomass are expressed as g AFDW m^{-2} from five Hamon grab samples. The average number of species in each of the five Hamon grab samples is also shown. The 95% confidence limits are indicated as bars. Note that there was a significant increase in species variety and abundance during the 7-month post-dredging period, but that the biomass increased only slowly. This indicates that recruitment was mainly of small individuals by larval settlement. Despite this recolonization, it is clear that population density, biomass and species variety had not recovered at the end of the 7-month post-dredging period. (After Kenny & Rees 1994).

The average population density for all taxa of 2769 individuals recorded by Kenny & Rees (1994) prior to dredging was reduced after dredging to only 129 ind. m^{-2}, compared with a relatively uniform invertebrate population density of 3300 ind. m^{-2} in the reference site. Again, the population density showed a significant increase in the 7 months after dredging had ceased.

Inspection of Figure 14 shows that the high biomass of 23 g AFDW m^{-2} was reduced to only 1g AFDW m^{-2} after dredging. This reflects the removal of relatively large macrofaunal species, such as the mussel *Modiolus modiolus,* from the dredged sediments and was followed by a slower rate of increase in the post-dredging period than that recorded for population density. This implies that recolonization was initially by small individuals that then grew relatively slowly during the 7 months after dredging had ceased.

Figure 15 shows the output of a non-metric multidimensional scaling (MDS) ordination (see Kruskal 1977, Kruskal & Wish 1978, Field et al. 1982) of the data for the macrofauna sampled in gravel deposits before dredging of the experimental site off Norfolk, and in the 7 months after dredging (after Kenny & Rees 1994). Their multivariate analysis of community structure prior to dredging and in the months following dredging shows a number of important features of the recolonization process that

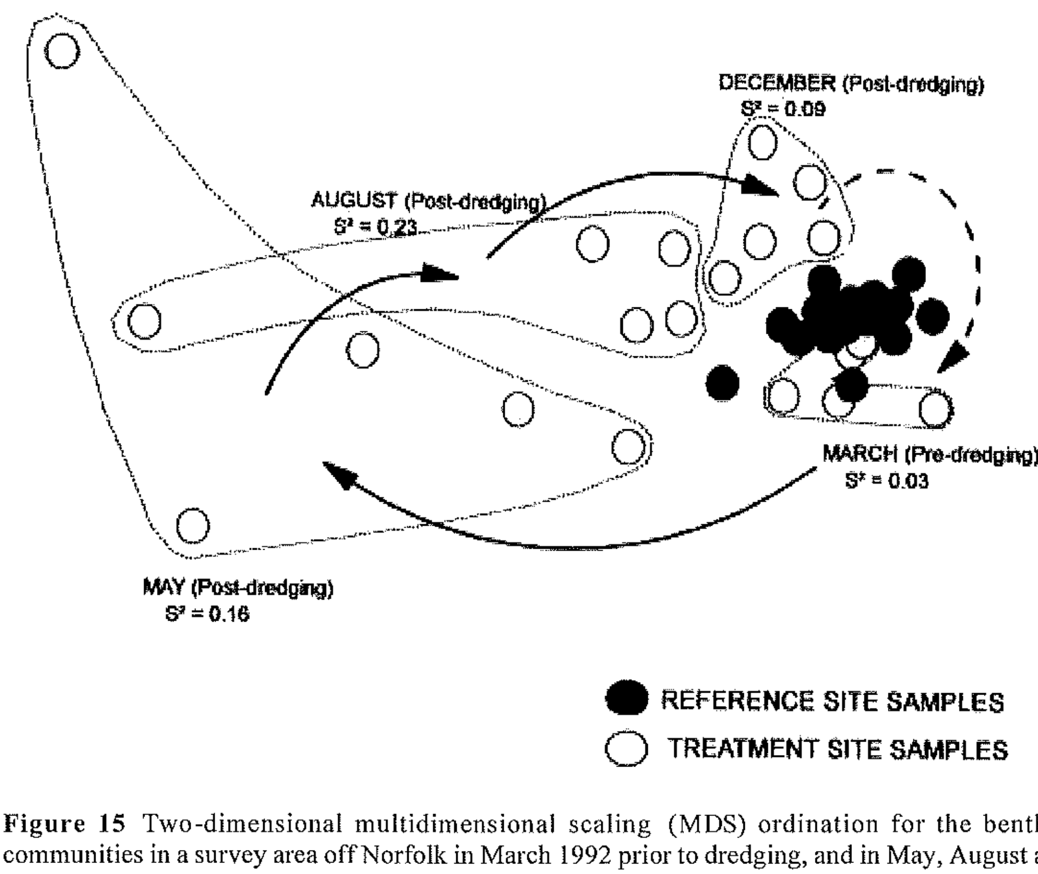


Figure 15 Two-dimensional multidimensional scaling (MDS) ordination for the benthic communities in a survey area off Norfolk in March 1992 prior to dredging, and in May, August and December 1992. Note that dredging of the experimental area resulted in an initial impact on community structure which differed from that in control areas and to that in the deposits prior to dredging. In the following months community structure became more similar to that in the undredged deposits, but was still distinct at the end of the 7-month post-dredging period. (After Kenny & Rees 1994).

highlight the general principles of succession outlined in Fig. 2 (p. 8).

The first point that is clear from their results is that the community within the dredged site prior to dredging in March 1992 formed a small "cluster" on the MDS ordination. This indicates that the communities sampled within the experimental site were similar to one another, and were also evidently very similar to those in the reference site since they are close together on the MDS ordination.

The experimental area was again sampled in May 1992, 1 month after completion of dredging. At this stage it can be seen from Fig. 15 that dredging had resulted in two important changes in community structure. First, the communities in all the samples from the dredged site were well separated in the MDS plot from those in March and from those in the reference site. This implies a major change in community composition following dredging. Secondly, the communities at each of the sampling sites within the dredged area were different from one another. This is indicated by the fact that they have an increased derived variance (S2) and no longer form a tight "cluster" on the MDS ordination shown in Fig. 15 (see also Warwick & Clarke 1993). This increased variance would be expected when some samples were taken from the dredged furrows themselves whereas others were from areas between furrows.

One of the interesting features of this study is that it shows that much of the initial process of colonization of the gravel deposits off the Norfolk coast was accomplished within the following 7-month period. Inspection of Fig. 15 shows that the community in the dredged area became more similar to those in the surrounding deposits of the reference area and to those in the pre-dredged site, and also had a closer internal similarity to one another (S^2 reduced to 0.09) in the months following cessation of dredging. This shows that many of the commoner species present in the dredged area in March 1992 prior to dredging had recolonized by December 1992. The clear difference from both the reference site and the community prior to dredging suggests, however, that many of the rarer components of the community had not yet colonized the dredged area in the following 7 months.

The study was then extended to include data for a 2yr period following dredging. These results are reported by Kenny & Rees (1996). They showed that although recruitment of new species, especially r-selected species such as the barnacle *Balanus crenatus* and the ascidian, *Dendrodoa grossularia* had occurred by December 1992, even at the end of a 2-yr period both the average species abundance and biomass for the dredged area were lower than those in the reference site.

It is also clear from their work that the community composition in the dredged area was not restored even 2yr after dredging, Inspection of Figure 16 shows the tightly clustered samples from the reference site and from the pre-dredged experimental site in March 1992. The marked shift in community composition and the increased variation between samples taken in May 1992 shortly after dredging is shown, as well as data collected in May 1993, 1 yr post-dredging and in May 1994, 2 yr after dredging. It is apparent from Figure 16 that despite the significant recolonization that had evidently occurred within 7 months of dredging, the community in the dredged area remained distinct from that in the reference area and from that in the deposits prior to dredging, even after 2yr. Whether this reflects residual differences in the nature of the deposits following dredging, or the long time period required for establishment of the rarer components of the original community is not yet known.

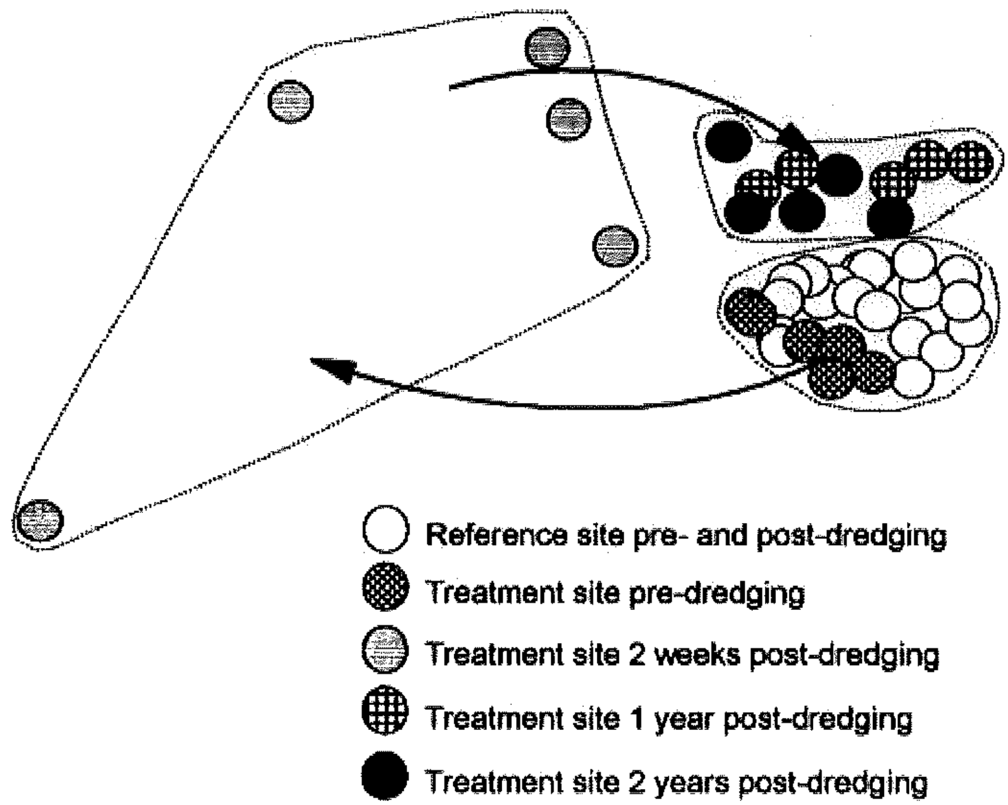


Figure 16 Two-dimensional multidimensional scaling (MDS) ordination for the benthic communities in a survey area off Norfolk in March 1992, and for following 2yr post-dredging. Note that despite the increasing similarity of the community in the dredged area to those in the surrounding sediments over the 2yr post-dredging period, recovery had not been fully accomplished even after 2 yr. (After Kenny & Rees 1996).

The results that have been reviewed above thus show that the process of recolonization involves two distinct phases; first, recolonization of species composition and population density by settlement of small individuals as larvae and juveniles; secondly, a period of growth during which the biomass approaches that in the undisturbed deposits. Inspection of Figure 16 shows, however, that in the gravel deposits of the southern North Sea this process had only entered its initial phase of partial restoration of community structure in the 7-month period that followed cessation of dredging, and that full recovery may take several years, much as would be anticipated for typical equilibrium communities on the seabed (see Figure 4, p. 13).

The rate of recovery of biological resources

The rates of recovery of biological resources following capital and maintenance dredging, disposal of dredged spoils and marine aggregate dredging have been widely studied in other habitats and conform with the general principles of ecological succession shown in Figures 2 and 3. That is, communities that inhabit fine semi-liquid and disturbed muds comprise opportunistic r-selected species that have a high rate of recolonization and which can reach high population densities within weeks or months of a catastrophic mortality. Conversely, communities that inhabit less disturbed deposits of deeper waters or coarse substrata have complex associations and are characterized by large slow-growing species that are selected for maximum competitive advantage in a habitat where space is already crowded. These large, slow-growing, K-selected equilibrium species recolonize only slowly following disturbance and may take several (or many) years for recovery of full species composition and biomass.

Table 5 shows the rates of recovery of the benthic fauna following dredging in various habitats. We have included semi-liquid muds from freshwater tidal areas and have arranged the data along a gradient of increasing environmental stability and predictability through estuarine and coastal muds to sands and gravels and coral reef assemblages. Inspection of the data summarized in Table 5 shows that recovery of the benthic fauna in highly disturbed semi-liquid muds can occur within weeks. This is associated with an ability for species such as *Limnodrilus* spp., *Ilyodrilus, Coelotanypus* sp. and *Procladius* to migrate through the surrounding deposits and to recolonize disturbed muds as adults.

Locality	Habitat type	Recovery time	Source
James River, Virginia	Freshwater semi-liquid muds	±3 wk	Diaz 1994
Coos Bay, Oregon	Disturbed muds	4 wk	McCauley et al. 1977
Gulf of Cagliari, Sardinia	Channel muds	6 months	Pagliai et al. 1985
Mobile Bay, Alabama	Channel muds	6 months	Clarke et al. 1990
Chesapeake Bay	Muds-sands	18 months	Pfitzenmeyer, 1970
Goose Creek, Long Island, NY	Lagoon muds	>11 months	Kaplan et al. 1975
Klaver Bank, Dutch Sector, North Sea	Sands-gravels	1–2 yr (ex-bivalves)	van Moorsel 1994
Dieppe, France	Sands-gravels	>2 yr	Desprez 1992
Lowestoft, Norfolk, UK	Gravels	>2 yr	Kenny & Rees 1994, 1996
Dutch Coastal Waters	Sands	3 yr	de Groot 1979, 1986
Tampa Bay, Florida	Oyster shell (complete defaunation)	>4 yr	US Army Corps of Engineers 1974
Tampa Bay, Florida	Oyster shell (incomplete defaunation)	6–12 months	Conner & Simon 1979
Boca Ciega Bay, Florida	Shells-sands	10 yr	Taylor & Saloman 1968
Beaufort Sea	Sands-gravels	12 yr	Wright 1977
Florida	Coral reefs	>7 yr	Courtenay et al. 1972
Hawaii	Coral reefs	>5 yr	Maragos 1979

Table 5 Table showing the rates of recovery of the benthic fauna following dredging in various habitats. Note that highly disturbed sediments in tidal fresh waters and estuaries that are dominated mainly by opportunistic (r-strategist) species have a rapid rate of recovery. Recovery times increase in stable habitats of gravels and coral reefs that are dominated by long-lived components with complex biological interactions controlling community structure. Longevity and slow growth are also associated with slow recolonization rates in sub-arctic seas. Examples have been arranged along a gradient from disturbed muds of freshwater-tidal estuarine conditions to stable reef assemblages.

A similar recolonization of disturbed deposits in dredged channels may also account for the relatively fast recolonization of some muds and sands in near-shore waters, especially those where tidal currents may transport juveniles into the dredged area (see Hall 1994). Inspection of the recolonization rates reported in the literature and summarized in

Table 5 suggest that a period of 2-4yr is a realistic estimate of the time required for recovery in gravels and sands, but that this time may be increased to more than 5 yr in coarser deposits, including coral reef areas. Interestingly, the data for areas in Tampa Bay, Florida that had been dredged for oyster shell, suggest that a period of as much as 1Oyr may be required for recovery following complete defaunation whereas a recovery time of only 612 months is required for recovery following partial dredging and incomplete defaunation (see Benefield 1976, Conner & Simon 1979). This suggests that areas of undisturbed deposits between dredged furrows may provide an important source of colonizing species that enable a faster recovery than might occur solely by larval settlement and growth (see also van Moorsel 1993, 1994).

Other more complex environmental factors also evidently affect the rate of recovery of dredged areas. Studies in the Dutch Wadden Sea by van der Veer et al. (1985) show that the recovery of species composition and biomass of benthic organisms was related to the speed of infilling of dredged pits. These data are summarized in Table 6, which shows that even 16yr after cessation of dredging no recovery of the benthos had occurred on a tidal flat at Terschelling Sand. On a tidal watershed at Oosterbierum a partial recovery of 85% of the species and 39% of the biomass had occurred after 4 years. This is typical of recolonization by small individuals that were in the process of growth towards the original biomass levels of the undisturbed deposits, a process which would clearly take several more years.

In the tidal channels, both the rate of infill and recolonization were related to the speed of currents. A partial recovery of 57% of the species and 67% of the biomass was recorded after 3 yr in a tidal channel at Paesensrede (see Table 6), with greater recovery and shorter time periods being recorded in areas of faster current. Even then, it will be noted that the species composition had not recovered and that the biomass evidently became dominated by fewer species of relatively large size compared with those in the surrounding deposits.

The likely recolonization rates for the benthic community of estuarine muds, sands, gravels and reef areas have been superimposed onto a generalized colonization succession in Figure 17, which allows some predictions to be made on the rates of recovery of deposits following dredging. The fine muds that characterize coastal embayments, estuaries and lagoons are likely to be colonized by large populations of a

Table 6 Table showing the percentage recovery recorded in a variety of habitats in the estuarine Dutch Wadden Sea following dredging up to 15yr previously. Based on van der Veer et al. 1985.

Area	Habitat	Time interval since dredging	% Recovery	
			Species	Biomass
Terschelling sand	Tidal flat	16 yr	0	0
Oosterbierum	Tidal watershed	4 yr	85	39
Paesensrede	Tidal channel	3 yr	57	67
Holwerderbalg	Tidal channel	2 yr	64	100
Kikkertgat	Tidal channel	1 yr	88	116

relatively restricted variety of opportunistic r-selected species, which are capable of rapid colonization within months of space being made available for colonization and growth. Because such deposits are subject to regular disturbance under natural conditions prior to dredging, the ecological succession recovers to the colonization phase shown in Figure 17, but does not proceed to the development of K-selected slow-growing equilibrium species within the community. Recovery of the "normal" community in disturbed deposits such as muds, therefore, can be achieved within months of cessation of dredging, or disposal of spoils.

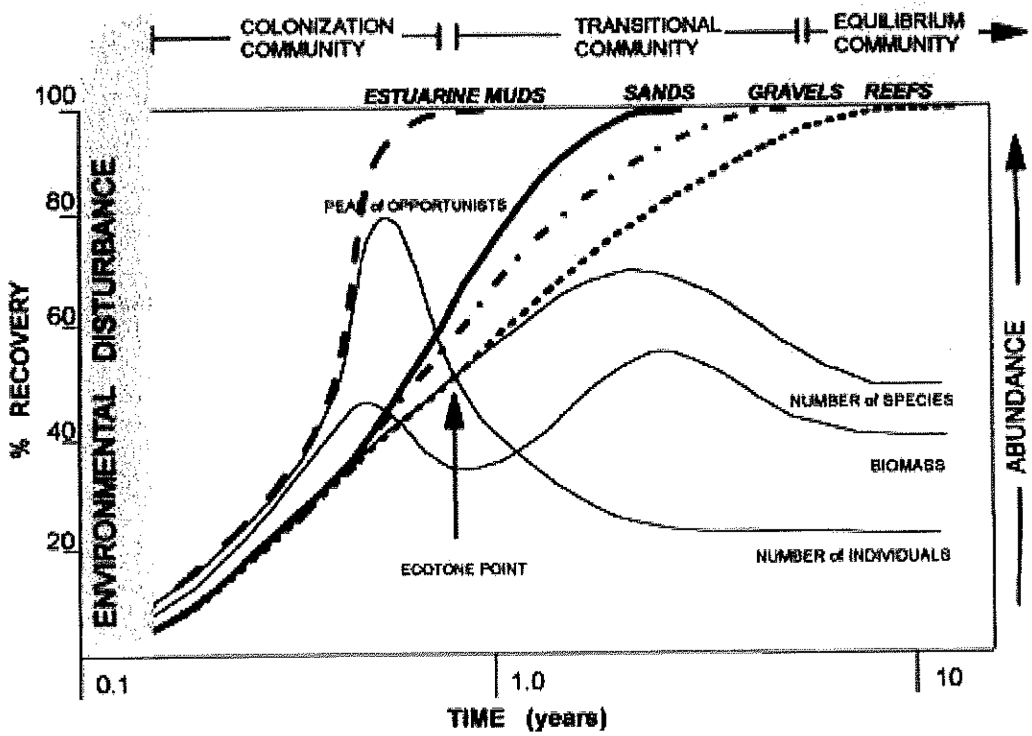


Figure 17 Schematic diagram showing the likely recolonization rates for the benthic community of estuarine muds, sands and reef areas. The curves for recovery have been superimposed onto a generalized colonization succession and allows some predictions to be made on the rates of recovery of deposits following dredging. Note that the fine muds that characterize coastal embayments, estuaries and lagoons are likely to be recolonized by a relatively restricted variety of opportunistic r-selected species within months of space being made available for recolonization and growth. Because such deposits are subject to regular disturbance, the succession recovers to the colonization phase, but does not proceed to the development of long-lived slow-growing K-selected species. The natural communities of gravels and sands, however; contain varying proportions of slow-growing K-selected equilibrium species depending on the degree of disturbance by waves and currents. These communities are held in a transitional state by natural environmental disturbance and are likely to recover within a period of 2-3yr after cessation of dredging. Finally, the recovery curve for reef communities indicates that a period of 8-l0yr may be required for the long process of establishment and growth of the long-lived and slow-growing K-selected species characteristic of equilibrium communities.

The natural communities of gravel and sand deposits, however, contain varying proportions of slow-growing, K-selected equilibrium species, depending, among other factors, on the degree of disturbance by waves and the speed of tidal currents. In this case, the tail of the sigmoid recovery curve becomes more pronounced because the rarer components of the equilibrium community may take several years to recolonize the deposits, even after the main components of the community have become established. Where the deposits are sandy, periodic mortality of the long-lived components may result in major seasonal changes in community composition such as occurs in the North Sea on the Klaver Bank (van Moorsel 1994) and as has been reported for the sediments of Liverpool Bay by Eagle (1975). Under these conditions, the community will be held in a transitional state by natural environmental disturbance, and is likely to recover within 2-3 yr after cessation of dredging.

There is good evidence that disturbance of the deposits by man may result in a shift from the equilibrium community characteristic of undisturbed deposits towards the transitional community, which characterizes deposits in areas of natural environmental disturbance. Studies by de Groot (1984) suggest, for example, that the increasingly heavy bottom gear used by trawlers has been associated with a shift in community composition of the benthos of the North Sea, and this also applies to the benthos ofthe Wadden Sea.

As might be anticipated from the successional sequence shown in Figure 17, long-lived components such as molluscs and larger crustaceans in near-shore waters, such as the Wadden Sea, have decreased in numbers and diversity over the years and have been replaced by larger populations of rapidly growing polychaete species (Reise 1982, Riesen & Reise 1982, Reise & Schubert 1987).

Finally, the community recovery curve for reef communities indicates that a period of 8-10yr may be required for the process of establishment and growth of the long-lived and slow-growing K-selected equilibrium species and for the development of the biological interactions that are familiar to those who have observed the immense diversity and complexity of life on undisturbed reef structures. This long process of establishment of an equilibrium community reflects partly the time required for colonization by rarer components of the community, but is also influenced by the nature and stability of the substratum following cessation of dredging, and the time required for complex stabilization processes involving both physical compaction and biological interactions. The relationship between biological community structure, sediment composition and seabed stability is considered in more detail below.

Community composition and seabed stability

The influence of sediment composition in controlling the nature of communities of animals that live on the sea bed has been widely recognized since the pioneer studies of Petersen (1913), Thorson (1957) and Sanders (1958). Most recent evidence suggests, however, that the precise relationship between biological community composition and specific properties of the sediments is poorly understood. In some estuaries and shallow water coastal embayments, fine grained and silty deposits clearly support an entirely distinct community compared with those from mobile sands or on stable sub-strata such as rocks and boulders.

On the other hand it is a matter of common observation that although very fine mobile muds may be dominated by opportunistic species such as the amphipod *Ampelisca brevicornis* or the polychaete *Lagis koreni,* the same silts can become consolidated into clays and then support long-lived and sedentary equilibrium species such as the boring piddock bivalves *Pholas dactylus* and *Barnea parva* as well as an epifauna of hydroids, ascidians and other species more characteristic of reefs. Clearly, the stability of the sediment, rather than particle size itself, is of importance in controlling community structure. In other instances it is clear that the deposits on the seabed undergo a complex process of consolidation or "armouring " that allows the establishment of communities that are more typical of rocks and reefs reflecting the complex relationships between the physical deposits and biological activities of the animals themselves.

The relationship between community composition and sediment type in deeper waters of the continental shelf is less well documented than that for estuaries and lagoons. Some early studies suggest that macrobenthic communities can be distinguished on a basis of sediment granulometry (Gltmarec 1973, Buchanan et al. 1978, Flint 1981) but other studies have shown little correlation (Buchanan 1963, Day et al. 1971). Efforts to identify what physical properties are of greatest importance in controlling the structure of marine communities are often frustrated by the fact that most of the sediment variables obtained from conventional sorting methods are interdependent since they are expressed as a percentage of the total sample (see Weston 1988). A high percentage of silt, for example, is inversely related to the percentage of the other sediment components. Again, many of the physical properties of sediments are linked with other features such as depth of disturbance by wave action, strength and duration of currents, and may themselves be linked with complex biological interactions including the surface area available for microbial food components, and the presence of species that can exclude potential competitors.

Partly for this reason, most recent studies have concluded that the complexity of soft-bottom communities defies any simple paradigm relating to a single factor, and that there should be a shift towards understanding relationships between the distribution of organisms in terms of a dynamic relationship between the sediments and their hydrodynamic environment. According to this view, complex shear forces at the sediment-water interface are considered to play a dominant role in controlling food availability, settlement of larvae, microbial food availability, pore water flow and other environmental features that affect the benthic organisms that inhabit marine deposits. It is therefore considered unlikely that any one factor alone, or even a combination of single granulometric properties, can account for the distribution of animals in most sedimentary habitats (for review, see Snelgrove & Butman 1994).

Despite this emerging view that sediment granulometry itself is unlikely to control the composition and distribution of biological communities on the sea bed, concern has been expressed that dredging for marine aggregates can result in significant changes in sediment composition. Studies off Dieppe, France have shown, for example, a large increase in the proportion of fine sand in deposits that have been intensively worked for marine aggregates (see Desprez 1992, ICES 1992, 1993). Again, the infill of pits and grooves from dredging for marine aggregates is commonly dominated by the fine deposits which are capable of mobilization by shear stress induced by waves and tidal currents (Dickson & Lee 1972, Shelton & Rolfe 1972, Millner et al. 1977).

If sediment composition were of importance in controlling biological community composition, such changes following dredging could potentially prevent subsequent recolonization by communities that were similar to those that occurred in the deposits prior to dredging (see Windom 1976) and could by implication affect the nature and abundance of food organisms for commercial fish stocks.

We have analyzed the relationship between biological community composition and the sediment granulometry in undredged coastal deposits in the English Channel and southern North Sea and find that both biological communities and the sediments fall into relatively distinct groups or communities when analyzed by multivariate techniques (Newell & Seiderer 1997d). However, there is little evidence of any correspondence between the distribution of different sediment types and biological communities in the survey areas. Analysis of the Spearman rank correlation between the similarity of biological communities and any one, or a combination of, particle size indices show that granulometric properties of the sediments are likely to account for a maximum of 45% of the variability of the biological component, leaving approximately 55% determined by other environmental factors.

The conclusion to be drawn from these results is that they support recent views that biological community composition is not controlled by any one, or a combination of simple granulometric properties of the sediments such as particle size distribution. It is considered more likely that biological community composition is controlled by an array of environmental variables, many of them reflecting an interaction between particle mobility at the sediment-water interface and complex associations of chemical and biological factors operating over long periods.

Such interactions are not easily measured or analyzed, but the results clearly suggest that restoration of sediment composition after completion of dredging for marine aggregates is not, within broad limits, a prerequisite for the establishment of marine communities that are comparable with those that occurred in the deposits prior to dredging. What is possibly of more importance in controlling the time course of recovery of an equilibrium community characteristic of undisturbed deposits is the process of compaction and stabilization. This will reflect changes in sediment composition, but is also in equilibrium with seabed disturbance from tidal currents and wave action, both of which show spatial variations and interactions with water depth. The processes associated with compaction and stability of seabed deposits may therefore largely control the establishment of long-lived components of equilibrium communities and account for the dominance of opportunistic species in the initial stages of colonization of recently sedimented material in unconsolidated deposits after the cessation of dredging.

Conclusions

At the outset of this review, we assessed the importance of the benthic community to fisheries production and outlined our intention of providing an ecological framework within which the impact of dredging can be understood. We have shown that systems models for shelf waters such as the North Sea suggest that the flow of materials from primary production by the phytoplankton passes partly through planktonic grazers, but that 20-50% sinks to the sea-bed either from dead and decaying phytoplankton cells, or as faecal material derived from the feeding activities of the grazing zooplankton (Steele 1974, Joiris et al. 1982, Newell et al. 1988). Such material then passes into the benthic food web, whose production in turn forms an important food resource for demersal fish.

It has been estimated from empirical models developed for the North Sea that as much as 30% of total fisheries yield to man is derived from benthic resources (see Fig. 1, p. 3). Production by the benthos is therefore important, not only as a resource in itself, but as a key food resource for demersal fish stocks. It becomes an increasingly important component of the marine food web in near-shore waters where primary production by larger macrophytes and seagrasses living on the seabed largely replaces that from the phytoplankton in the water column (for review, see Mann 1982).

From this it is clear that reclamation of large areas of coastal wetlands, coastal embayments or estuaries can have a potentially important effect on the supply of materials and energy to marine food webs, and that even in plankton-based deeper water ecosystems such as the North Sea, fish yields based on benthic production are sufficiently large to warrant proper conservation of benthic resources. Our review has concentrated, therefore, on the nature of benthic communities, their susceptibility to disturbance by dredging and land reclamation works, and on the evidence that is available for the recovery times required for the re-establishment of community structure following dredging or spoils disposal.

Our review of the literature shows that the communities of near-shore habitats are characterized by large populations of a relatively restricted variety of species that are well-adapted to exploit space that has become newly available by episodic catastrophic mortality. Such species are generally small, often mobile, and are selected for maximum rate of population increase, with high fecundity, dense settlement, rapid growth and rather a short life cycle. Such species have been designated "r-strategists" (see MacArthur & Wilson 1967, Pianka 1970) and have been referred to in our review as opportunists. Their population characteristics allow a rapid recovery of the initial community structure in deposits that are naturally subjected to high levels of environmental disturbance. It is, not surprising, therefore, to find that there are frequent reports in the literature of community recovery times that range from a few weeks to several months for disturbed deposits such as semi-liquid muds in tidal fresh waters, estuaries, lagoons and dredged channels (see Table 5, p. 36 and Fig. 17, p. 38).

In deeper waters, or where the substratum is sufficiently stable to allow the long-term survival of benthic organisms, the habitat tends to be crowded. Under these conditions, organisms have an "equilibrium strategy" and are selected for maximum competitive ability in an environment in which space for colonization and subsequent growth is limiting. Such species have been designated "K-strategists" and devote a larger proportion of their resources to non-reproductive processes such as growth, predator avoidance, and investment in larger adults (MacArthur & Wilson 1967, Gadgil & Bossert 1970). Because the K-selected equilibrium species live longer, they tend to have wider limits of physiological tolerance, which allows them to survive those variations in environmental conditions that occur in their habitat. Many have active site selection phases that include chemical recognition of the presence of adults of the same species. a strategy which ensures that environmental conditions have been within the limits of tolerance for long enough to allow survival of other members of the same species (for review, see Newell 1979).

Such K-selected equilibrium species develop complex biological associations with other long-lived components of the community, and may alter the environment in such a way as to both allow the presence of many other species that would not otherwise occur, and also inhibit other potential competitors for space. Biological interactions between the components of equilibrium communities that are characteristic of stable substrata thus lead to the development of complex communities that may take many years, or decades, to re-establish following destruction. It is therefore not surprising to find that as one moves along a gradient of increasing sediment stability from muds through sands to gravels and reefs, there is a corresponding increase in the times reported for recovery of community structure (Table 5, p. 36).

Knowledge of the components that comprise the benthic community on the sea bed, whether these are r-selected opportunistic species or K-selected equilibrium species, thus gives important information not only on key resources that may require protection, but on the likely rate of recovery following dredging. Inspection of the schematic colonization succession shown in Figure 17 (p. 38) suggests that a recovery time of 6-8 months is characteristic for many estuarine muds whereas sands and gravels may take from 2-3yr depending on the proportion of sand and the local disturbance by waves and currents. As the deposits become coarser, estimates of 5-10yr are probably realistic for the development of the complex biological associations between the slow-growing components of equilibrium communities characteristic of reef structures.

Our review suggests that processes associated with compaction and stabilization of seabed deposits may largely control the time-course of recovery of these long-lived components of equilibrium communities and account for the dominance of opportunistic species in the initial stages of colonization of recently sedimented material in unconsolidated deposits following the cessation of dredging.

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BENTHIC INFAUNA AND MAINTENANCE DREDGING: A CASE STUDY

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Abstract—Monitoring studies of a small maintenance dredging operation in Coos Bay, Oregon, showed that significant decreases of benthic infaunal abundance immediately after dredging extended at least 100 m from the site of actual dredging. The infauna re-adjusted to pre-dredging conditions within 28 days in the dredged area and within 14 days in the adjacent areas. At the spoil site a similar decrease was followed by a 2-week recovery period. The authors suggest that an area subjected to maintenance dredging is also subjected to frequent disturbances from ship movements and other harbor activities and that the infauna is well adapted to this. Thus, maintenance dredging is a relatively normal event and should not be expected to have catastrophic effects.

INTRODUCTION

A dredging operation in Coos Bay, Oregon, on October 4, 1972, provided an opportunity to study the acute effects of hopper dredging and spoiling on the benthic invertebrate community of a previously dredged estuary. Although the dredging operation was small, removing approximately 8000 yd^3, it was possible immediately afterwards to delineate significant dredge-induced changes in the total abundance and diversity of the benthic infaunal community.

Benthic invertebrates, have frequently been used as indicators of water quality (Gaufin & Tarzwell, 1952; Reish, 1960; Wass, 1967; and McNulty, 1970). The infaunal components, of primary concern in this study, are strongly dependent upon the biological, physical, and chemical characteristics of the surrounding substrate. This dependence combined with low mobility makes infauna particularly sensitive to disruptions associated with dredging and spoiling.

Previous investigations have shown significant declines in faunal abundances at dredge and spoil sites followed by numerical recovery; the rate of recovery dependent upon specific characteristics of the dredge operation and the affected community (Harrison *et al.*, 1964; Pfitzenmeyer, 1970; Saila *et al.*, 1972; Stickney, 1973). Although the broad, biological consequences of dredging activity are generally well known, localized biological and physical mechanisms responsible for these biotic repercussions are not. Intensive study of a minor hopper dredging incident allowed us to: (1) measure the removal of benthic infauna; (2) monitor rate of numerical recovery; and (3) delineate disruptive biological and physical mechanisms associated with hopper dredging and mid-channel spoiling.

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METHODS

The dredge site was located at the mouth of Isthmus Slough, a small arm of Coos Bay (Fig. 1) bordered by wood processing mills and log storage areas and located 26 km from the Pacific Ocean. Continual buildup of silt necessitates periodic maintenance dredging; five times in the last 10 y, most recently in 1971 2 y before the study (Slotta, *et al.*, 1973). The spoil site was located 0.5 km downstream in mid-channel. Both sites experience extensive shipping activity, and water quality is poor due to industrial, domestic, and shipping wastes (U.S.D.I., 1971).

The study was conducted during a period of minimum rainfall and low fresh water runoff. Bottom salinity ranged between 11.9 and 20.2‰. Tidal flushing generated most current activity; maximum current velocities observed two feet off the bottom exceeded 45 cm/sec (Slotta, *et al.*, 1973).

Six stations, approximately 33 m apart, were established on a cross-channel transect perpendicular to the proposed dredging channel (Fig. 1). The dredge passed over two of the stations (2 and 3) but did not pass over the other four (1, 4, 5, and 6).

Three stations (10, 11, and 12) in the spoil area were similarly defined. Two stations (10 and 11) had spoil material dropped directly over them, but the third (12) did not.

Four Shipek (1/25 m^2) grab samples were taken 3–6 days before dredging at all stations, and six samples were taken at each dredge station within 24 h after dredging. At each spoil station two samples were taken within 24 h. These 78 samples allowed us to measure immediate effects. Recovery studies were based on subsequent duplicate Shipek samples from each station 7, 14, 28, and 56 days after dredging.

Samples were measured volumetrically and preserved in 10% formalin. In the laboratory they were sieved with a 0·50 mm mesh screen, subsampled,

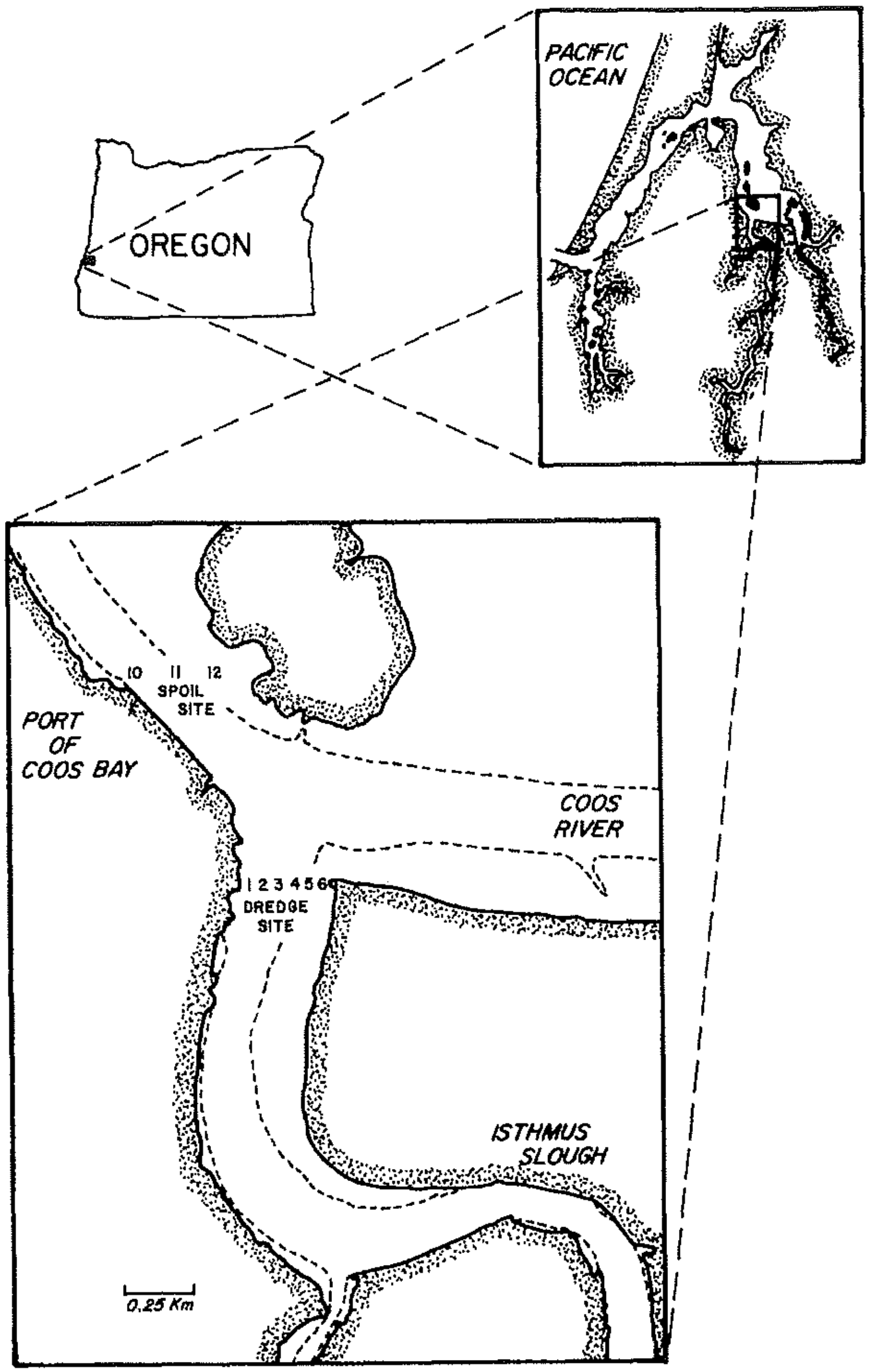

Fig. 1. Location map, Coos Bay, Oregon.

stained with Rose Bengal, hand sorted under a stero-microscope, and identified. Results were normalized to $1000\,cm^3$ sediment samples. Volumetric reporting for accuracy was chosen over areal because of the high density of meiofauna and great variability in sediment volume collected on different sediments.

Total abundance and taxa diversity were investigated. Total abundance refers to the number of individuals of all taxa collected by the grab. Taxa diversity was measured using the Shannon index, H' (Shannon & Weaver, 1963). Taxa diversity is referred to in this study rather than species diversity because we were unable to identify some organisms to species level (e.g., marine oligochaetes). The use of taxa in place of species does not affect H' if consistently recognizable and discrete taxa are compared (Wilhm & Dorris, 1966). Values for H' have been shown by Lloyd & Ghelardi (1964) to be sensitive to both species (taxa) richness and evenness (relative abundance of individuals within each taxa). Taxa richness was estimated by $TR = t - 1/\log_n N$, where t is the number of taxa and N the number of individuals in a collection (adapted from Margelef, 1958). Evenness was computed as $J' = H'/\log_n t$ (adapted from Pielou, 1969). Caution must be used in comparing diversity values because numerical measurements of diversity are highly dependent upon artificial factors such as sampling technique and taxonomic identification. Great care was taken to ensure that identical methods were applied to pre- and post-dredging samples and that diversity values were compared only within discrete, well defined stations.

RESULTS

Water quality

Water quality before and during dredge and spoil operations was monitored by the Ocean Engineering Department of Oregon State University. Before operations, dissolved oxygen measurements near the sediment surface ranged from 7.7 to 8.6 mg/l. Although sporadic, localized declines in dissolved oxygen to levels below 2.0 mg/l were recorded during dredging and spoiling activities, most measurements ranged from 6.0 to 8.0 mg/l (Slotta *et al.*, 1973). The lack of widespread, intensive oxygen depletion is believed to be the result of flushing induced by river and tidal currents and the small size of the dredging operation.

Although sediment conditions appeared favorable for moderate sulfate reduction (ample amounts of volatile solids, organic nitrogen, and sulfates), measurable free sulfides (HS^- and $S^=$) were absent in interstitial and overlying waters both before and during dredge operations. The presence of total sulfides (i.e., FeS) within the sediment suggests that sulfate reduction had occurred. Bella (1972) has hypothesized that periodic sediment disruption may oxidize total sulfides, recycling metal ions (most probably Fe^{2+}) which act to tie up free sulfides in insoluble compounds (FeS). Natural scour and marine traffic in shallow waters may also disturb the sediment. Lack of measurable free sulfides in an environment favorable for their formation is a strong indication that periodic sediment turnover is common within the study area.

Sediment characteristics

After the sediment was screened from each sample, coarse material >0.50 mm remained, consisting of benthic fauna, vegetation, shells, wood chips, and wood debris. Before dredge operations, assorted vegetation and small wood chips predominated at Stations 1 and 2; small wood chips at Stations 3, 5, 10, 11, and 12; large wood chips and dense wood debris at Station 4; and shell and wood chips at Station 6. Although the basic sediment types (sand, silt) did not change after dredging operations, statistical increases of dense wood debris were found at Stations 5 and 11 within 24 h. This post-operational increase in dense wood debris was easily detected by visual inspection of the grab samples. The dense wood debris and the significant elevation of the percentage of material >0.50 mm persisted at Station 5 throughout the rest of the study (56 days). At Station 11 similar alterations in sediment character were recorded but were less persistent; pre-spoiling sediment conditions returned after 3 weeks.

Benthic fauna

Both dredge and spoil sites contained a wide variety of benthic invertebrates before and after dredging operations. Similar taxa were found at both sites. The most frequently encountered organisms were the small polychaetes *S. benedicti*, *Pseudopolydora kempi*, *Polydora ligni*, *Etone lighti*, *Capitella* (*capitata*) *ovincola*, *Notamastus* (*Clistomastus*) *tenuis*, and *Glycinde armigera*. Bivalves included *Macoma inconspicua*, *Clinocardium nuttallii*, *Mya arenaria*, and *Modiolus* sp. Amphipods included *Corophium salmonis*, *Corophium spinicorne*, and *Anisogammarus ramellus*.

Cumaceans and oligochaetes were also present at both sites in lesser numbers. Cumaceans were represented primarily by the families Leuconidae and Nannastracidae, although members of the families Diastylidae and Cumidae were also present. The taxonomy of marine oligochaetes is extremely difficult, but previous authors (Jones, 1961; Sanders, *et al.*, 1965) have approached the problem by setting up personal categories within the oligochaetes sampled. These categories are not as satisfactory as specific determinations but they make it possible to count and differentiate types which may be used to calculate taxa diversity. The Coos Bay samples included two marine oligochaetes. Type "A" had a relatively short body (<4 mm) with the anterior body region only slightly wider than the rest of the body and terminating in a nose-like protrusion; posteriorly, the body terminated in a flattened disk. Type "B" had a relatively long (>4 mm) body which was distinctly wider at the anterior end; posteriorly, the body was elongated and progressively tapered.

Harpacticoid copepods, nematodes, and ostracods were also present but most passed through the 0.50 mm sieve; data were not quantitative, and these groups were not further considered.

Mean total abundance of meiofanual organisms ranged from 37 organisms per 1000 cm^3 of sediment at Station 11 to 2043 at Station 6. Immediately after dredging and spoiling there was a decrease at all stations (Fig. 2). This was statistically significant (5%) at all dredged stations except Station 4. We did not have enough post-spoiling samples to confirm the significance at spoil stations.

The decrease was greatest at those stations that were actively dredged, but decreases were noted at stations approximately 100 m from the dredging activity. The dredging efficiency appears to be directly proportional to the higher number of passes over Station 2 than over Station 3.

Changes in diversity, evenness, and taxa richness are reported in Table 1. Although these changes may

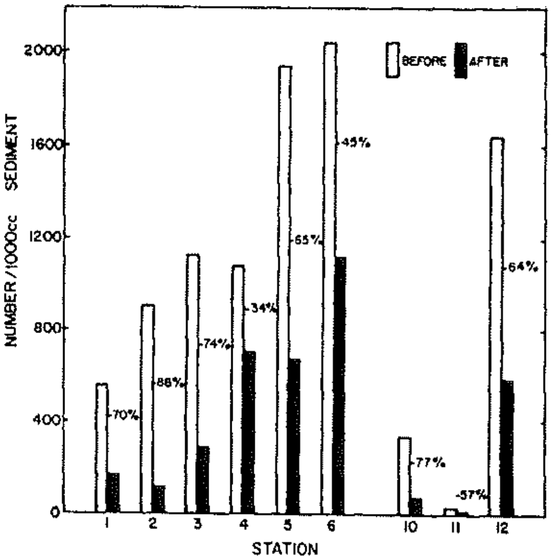

Fig. 2. Total numbers of organisms before and after. Dredging—stations 1–6. Spoiling stations 10–12.

not always be significant there tends to be a wider range among replicates after dredging than before.

Although more than 75% of the infaunal population had been removed by the dredging operation, the total abundance had readjusted to pre-dredging levels at Station 2 within 14 days and at Station 3 within 28 days. Most of the resurgent population was adult, suggesting that the initial adjustment was due primarily to an influx from adjacent areas or the emergence of adults initially buried by dredge-induced siltation.

Adjacent to the dredge areas, readjustment of total abundance was 7 days at Station 1, and 14 days at Station 6. Since Station 4 was not significantly decreased by dredging, readjustment did not occur. Station 5 failed to readjust to pre-dredging levels by the end of the study (56 days).

At the spoil stations an initial decrease in total abundances was followed by readjustment within 7 days.

At dredging Stations 1 and 2 and spoiling stations 10, 11 and 12 only diversity was temporarily increased immediately after dredging.

DISCUSSION

In order to interpret these results it is helpful to know something about hopper dredging, the natural processes of sedimentation and hydrodynamics within an estuary, and to know the changes in sedimentation and circulation in Coos Bay induced by this dredging operation. Hopper dredging, described in detail by O'Neal & Sceva (1971), involves a self-propelled vessel designed for hydraulic dredging and transportation of spoil to a disposal area. Two large suction pipes hinged on the sides of the ship and lowered or raised by cables have suction heads which remove sediment. The surrounding sediment is mechanically disturbed and thrown into suspension, settling out in areas of reduced turbulence. The limited width of the suction heads (approximately 2 m across) necessitates many trips over the same course to attain desired depth and width of the channel.

Table 1. Ranges of taxa diversity (*H'*), evenness (*J'*), and taxa richness (*TR*) at dredge and spoil sites before and after dredge operations

	Dredge site stations					
H'	1	2	3	4	5	6
Before	0.362–0.689	0.379–0.733	0.538–0.697	0.696–0.912	0.416–0.716	0.874–0.972
24 h after	0.939–1.665	1.274–2.110	0.360–1.286	0.534–1.098	0.317–1.166	0.630–1.701
7 days after	0.604–0.614	0.575–0.728	0.604–0.713	0.507–0.568	0.669–0.798	0.761–0.797
J'						
Before	0.157–0.269	0.165–0.318	0.234–0.299	0.302–0.509	0.174–0.326	0.335–0.366
24 h after	0.391–0.758	0.458–0.916	0.236–0.518	0.255–0.528	0.197–0.531	0.227–0.709
7 days after	0.223–0.227	0.238–0.453	0.262–0.287	0.237–0.231	0.322–0.346	0.288–0.302
TR						
Before	1.422–2.049	1.220–1.414	0.874–1.711	0.772–1.855	1.033–1.435	1.440–2.012
24 h after	1.665–2.162	1.400–3.998	0.936–2.323	1.083–1.676	0.6095–1.750	1.594–2.087
7 days after	2.161–2.251	1.033–1.645	1.467–1.803	1.295–1.502	1.007–1.294	1.845–1.910

	Spoil site stations		
H'	10	11	12
Before	0.640–0.679	1.412–1.669	0.307–0.569
24 h after	0.595–1.156	0.561–1.604	0.580–0.975
7 days after	0.356–0.476	0.362–0.756	0.440–0.564
J'			
Before	0.357–0.379	0.788–0.858	0.124–0.229
24 h after	0.248–0.618	0.785–0.917	0.252–0.417
7 days after	0.171–0.207	0.362–0.756	0.172–0.220
TR			
Before	0.925–0.950	1.138–1.674	1.445–1.515
24 h after	1.097–2.013	0.858–2.041	1.229–1.883
7 days after	0.986–1.260	0.458–0.614	1.643–1.673

The concentrated slurry of substrate, water and bottom debris sucked into the hopper bins is released as the ship moves over the spoil site. The operation takes only a few minutes. Material released from the surface will not fall directly to the bottom but will be transported horizontally by water movements as it falls through the water column (Postma, 1967). "Surface sheer during descent and impact-induced mixing at the bottom resuspends a portion of the material and fine material may be transported from the site" (Slotta *et al.*, 1973, p. 12). Dense, consolidated spoil material (bottom debris) will settle relatively fast and be deposited closer to the point of discharge while lighter materials (silt) may be transported far from the spoil site.

The distribution of sediments within an estuary is the result of complicated and interrelated processes of erosion, transportation, and deposition (Postma, 1967). Currents will affect the ultimate sediment pattern of an estuary by selectively eroding, transporting, and depositing various sediment types depending upon a multitude of hydrodynamic factors. Grain size, although by no means the only characteristic influencing these processes, is of prime importance. In general, fine-grained sediments (silt) will be eroded, transported easily, and ultimately deposited in areas of relatively low current velocity. Coarser grained sediments (sand, gravel), requiring relatively high current velocity to be transported, will be deposited where finer sediments would fail to be deposited.

Bottom contours reflect the long term net effects of erosion and deposition and are thus related to current velocities. Shoaling of fine sediments suggests a low energy environment having low current velocities, while a deep channel consisting of coarse sediments suggests a higher energy environment with relatively higher current velocities.

Although systematic and detailed bottom current measurements were not attainable during this study, generalized current patterns and relative current velocities are suggested from pre-dredge and pre-spoil sediment patterns and channel contours. Cross sectional diagrams depicting this sediment–current relationship are seen in Figs. 3 and 4.

The study site receives sediments from Isthmus Slough and the Coos River, and natural and persistent turbidity occurs. Shoaling at Stations 1, 2, and 3 is a response to a low energy environment, while minimum shoaling (deeper channel) and coarse sediments at Station 4 implies maximum current velocities. During the study period tidal oscillations were the most probable source of water movement because Isthmus Slough is a cul-de-sac and lacks significant fresh water inflow. The constant influx of suspended sediments and the low current activity creates an area of deposition—hence the need for maintenance dredging.

Stations 10 and 12 are also low energy environments, while Station 11 with a coarser sand substrate appeared to be a higher energy environment. Tidal oscillations and river runoff combine to contribute to increased current velocities. Station 11 was close to the spoil site and had a persistent high energy environment; natural scour and channel depth were

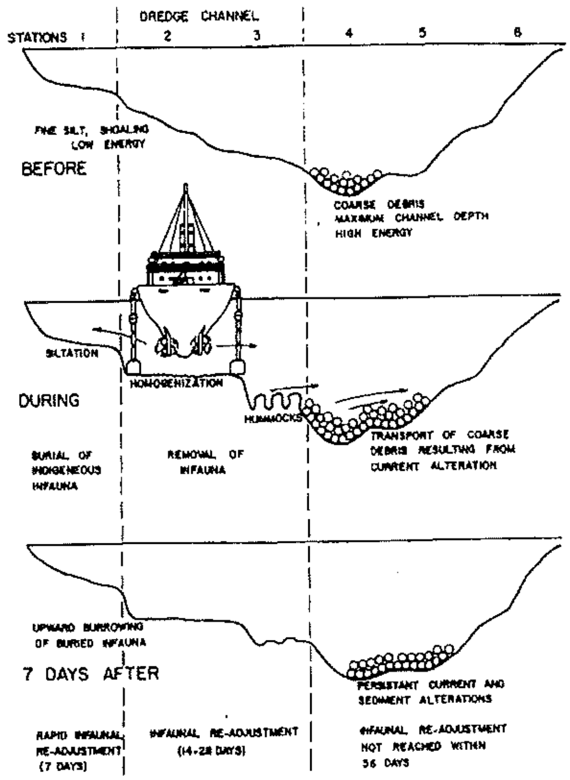

Fig. 3. Cross-section at dredge site to show changes.

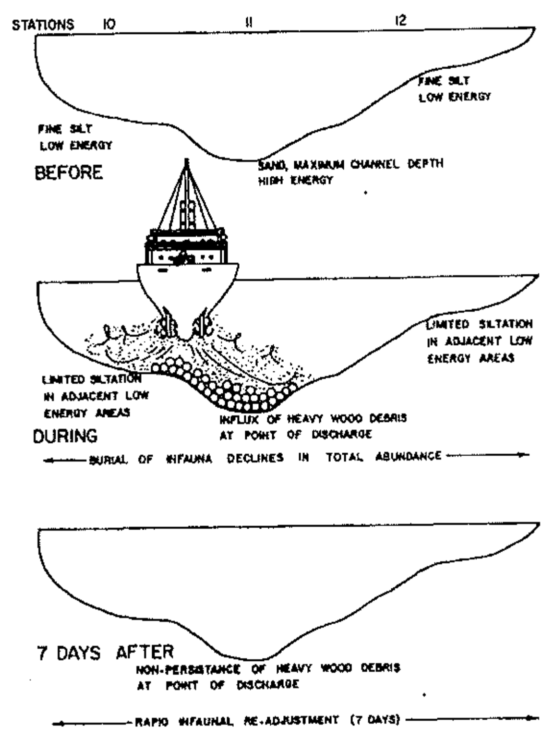

Fig. 4. Cross-section at spoil site to show changes.

expected to prevent spoiled material from becoming a hindrance to future navigation.

Within confined channels, even limited alterations of the bottom contour may have immediate and profound impacts on the hydrological characteristics of the area. Changes in current patterns may be followed by alterations of sediment distributions.

Changes in bottom contour resulting from removal of sediment at Stations 2 and 3 appear to have altered current patterns so that dense debris from Station 4 was transported towards Station 5 (Fig. 3(b)). Wood debris at Station 5 immediately after dredging and its persistence during the rest of the study period (56 days) suggests that: (1) large volumes of dense material were transported and deposited rapidly and (2) that ensuing natural siltation was limited. Current velocity and sediment debris are interrelated; higher velocities allow for the deposition of only denser materials.

Dredge-induced alterations of channel configuration may modify current patterns to de-stabilize the delicate balance between sediment erosion, transportation, and deposition. Ultimate changes in bottom contour are likely to result. Bathymetric charts prepared 2 months before, 1 day after, and 7 months after dredging showed altered bottom profiles near Stations 4 and 5 after 7 months (Slotta *et al.*, 1973). Although these stations were not actively dredged, bottom contours were altered by current actions responding to dredging nearby. Thus, the effects of a single dredging event appear to be more widespread than the mere removal of sediment from the dredge channel. While the removal of sediment itself is an immediate and localized impact of dredging, the alteration of current patterns may be more chronic and widespread.

At the spoil site the discharge of spoil through the water column resulted in a mechanical sorting of the spoil. Dense debris settled near the point of maximum discharge (Station 11), but fine silt and less dense materials appeared to be winnowed away in prevailing currents (Fig. 4(b)). Although heavy wood debris made up only a small fraction of the total spoil volume, it predominated at the sediment surface of Station 11 after spoiling. Since denser material will settle to the bottom in the hopper bins and fall through the water column faster than lighter materials it should be deposited first. The fact that dense debris was not covered over by the subsequent settling of the more abundant fine debris implies that the fine debris was transported away from the original point of spoil release to places where lowered current velocities allowed deposition.

After 3 weeks, the percentage of coarse material in each grab from Station 11 was reduced to pre-spoiling levels; the natural scour was sufficient to remove most of the spoil (Fig. 4(c)). Bathymetric charts prepared seven months after spoiling showed no significant shoaling within the area (Slotta *et al.*, 1973). The spoil site thus appears to be a persistent deep basin. Hence, for this particular dredging operation spoiling resulted in only the temporary deposition of denser spoil material at the spoil site. The ultimate fate of this material is unknown.

For practical reasons spoil will be dumped only in basins of sufficient water depth to avoid navigational interference. In the upper reaches of most estuaries, naturally occurring basins generally persist due to the action of relatively high and persistent current regimes. The long-term fate of spoil material dumped in these areas will probably be in low-energy areas perhaps less suited both economically and environmentally for additional sediment accretion. While in-bay spoiling may solve the immediate problem of spoil removal, the spoil material remains within the system, possibly resulting in the need for future dredging of nearby low-energy areas.

Benthic biological effects at the dredge and spoil site

Before the biological impact of a particular dredging operation can be assessed it is necessary to mention certain factors: history and frequency of dredging, harbor activities such as frequency and magnitude of shipping operations and industrial pollution, size and duration of the dredge operation, size of the shipping channel, and draft size of the dredge vessel.

Periodic dredging and heavy ship traffic within the study site are environmental factors to which the benthic community must adapt. The study site was dredged 2 y before the present study. During 1970, 175 vessels having drafts exceeding 8.5 m put in at the Port of Coos Bay (Slotta *et al.*, 1973). With the shallow-water depth of the study site (pre-dredging mean for all stations equalled 8 m) the sediment surface and associated benthic fauna probably experience extensive prop wash from marine traffic. Dragging of large anchors for stability during mooring is common and further disrupts the benthic environment.

The lack of measurable free sulfides in the Coos Bay dredge sediments is indicative of periodic sediment overturn. While some of this overturn is the result of natural processes, the man-made disturbances undoubtedly contribute. Only taxa capable of adjusting to these frequent disruptions will be abundant.

The bottom fauna of the Coos Bay dredge and spoil sites contained many species reported to be indicators of pollution. *Streblospio benedicti*, *Capitella (capitata) ovincola*, *Polydora ligni*, *Nereis* sp., *Scoloplos* sp., and *Mya arenaria* are examples (Reish, 1960; Richardson, 1971; and Boesch, 1971). *Streblospio benedicti*, *C. ovincola* and *P. ligni* have been compared to "certain weeds which proliferate over broad areas of man's disclimaxes" (Wass, 1967, p. 275). *Macoma inconspicua* and *Achelia nudiuscula* are also commonly found in polluted waters (Felice, 1959; Rickets, *et al.*, 1968). Different taxa have different ranges of tolerance to pollution. Although the above taxa are sometimes present in unpolluted environments, their high tolerance to domestic and industrial pollution and their great reproductive potential allows them to flourish in the stressed environment of the Port of Coos Bay. In polluted environments these taxa are less exposed to the pressures of biological competition and predation from less tolerant taxa (McNulty, 1970; Boesch, 1971) and hence the ambient pollution offers them a chance to become dominant.

The narrow width and depth of the channel at the dredge site (215 m maximum width; 11 m maximum depth) and the physical size of the dredge vessel *Chester Harding* (94 m length, 17 m width and 4–6 m draft range) are important factors which influenced the benthic disturbances resulting from this particular dredging operation. Hydromechanical forces resulting from the action of the dredge heads and the prop wash of the dredge vessel appear to be responsible for benthic disturbances both within and adjacent to the dredge channel. Hypothetical dredge-induced mechanisms responsible for these impacts are depicted in Figs. 3 and 4.

Observation from the bridge of the *Chester Harding* during dredge operations revealed surface turbidity resulting from: (1) hydromechanical disruption of the sediment surface by the suction heads; and more importantly, violent sediment disruption resulting from the repeated passage of a deep-drafted vessel over a shallow, fine-sedimented bottom. The large propellers of the *Chester Harding* were no more than 2 m from the sediment bottom at Station 2. Within the dredge channel, several interesting effects emerged from this situation. The prop wash was thought to thoroughly homogenize the top sediment layers of fine silt (Fig. 3(b)). The naturally-occurring horizontal and vertical patchiness of the benthic infauna was grossly altered. Before dredging, the patchiness was demonstrated by a high standard deviation of 287 in total abundance. Immediately following dredging this dropped to 99 implying that the numerical distribution of organisms between grabs became more even.

Station 3 differed from Station 2 by: (1) having increased water depth; and (2) being passed over less frequently, thus reducing the amount of prop wash. The change in variability of total abundance among pre- and post-dredged grabs is diametrically opposed to that observed at Station 2 (standard deviation before = 52; after = 258) suggesting increased faunal patchiness immediately after dredging. These rapid (24 h) changes in the distributional patterns of essentially non-motile infauna resulted from a number of factors. First, hopper dredging does not remove sediment uniformly; each suction head cuts a furrow approximately two meters wide on each side of the ship. Owing to the relatively small area of the suction heads, width of the ship, imprecision of ship navigation, and low number of passes, patches of sediment were left behind. In the absence of strong prop wash, which would have resulted in sediment homogenization, a mosaic pattern of dredged and undredged sections resulted. Forward motion of the vessel through the dredge channel resulted in furrows of vacated dredged material and relatively undisturbed hummocks of undredged material (Fig. 3b). The dramatic increases in post dredging sample variation at Station 3 seems to result from the grab randomly falling on dredged furrows or undisturbed hummocks. As an example of this variation, one post-dredging grab revealed 6 organisms/1000 cc sediment while its replicate showed 937 organisms/1000 cc sediment. It is obvious that unnatural gradients in the distribution of benthic populations have been created.

The limited prop wash and fewer passes of the dredge allowing the formation of hummocks of undredged material may be of biological significance in the eventual re-adjustment of the indigenous benthic community within the dredge area by (1) leaving behind viable adult organisms capable of repopulating the dredge channel by direct physical dispersion through migration or sediment slumping or (2) leaving behind adult reproductively viable organisms, which could lead to resurgent populations within the dredge channel by the dispersion of gametes or larvae.

The duration of these hummocks is not precisely known, but we suspect that due to slumping of the fine sediments, the action of diurnal tidal currents, and turbulence from ship traffic it is on the order of days. This is further supported by the dominance of adults in the post-dredging samples. Although the physical presence of these mechanically induced refugia may be highly transitory, they may have beneficial and long lasting results on the benthic infaunal community by providing "seed" areas for eventual re-establishment of the benthic community. Previous dredging studies have noted a fairly rapid increases in the abundance of infaunal organisms within dredge and spoil areas and have concluded that recovery of the infaunal populations is a fairly rapid process (Harrison *et al.*, 1964; Flemer *et al.*, 1968).

Because of the time period of this study and our knowledge of what constitutes the "normal" community, we feel that the term "recovery" should be avoided. Recovery implies not only a return to prior abundance levels, but moreover a return to ecological pathways within the community which may have taken years to develop. These ecological pathways involve a multitude of biological, chemical, and physical mechanisms having synergistic effects which are little understood, but are believed to be essential to the stability of the infaunal community. Drastic changes induced by dredging may alter these pathways, and the resulting community may never return to predredging structure and internal integrity although abundance levels may return to predredging levels. For instance, although the actual number of individuals within a dredged channel may return to former levels quite rapidly, these individuals may no longer reproduce and the stability of the community may be in jeopardy. Furthermore, hydrodynamic changes in channel contours and current patterns may result in altered physical and chemical parameters which may prevent the long term re-establishment of the benthic community as it existed before.

Since only a few community parameters (faunal abundance, taxa abundance, taxa diversity, evenness, and taxa richness) were examined within a short time period (56 days), we feel that the biological processes recorded reflect the readjustment of the benthic community to dredge and spoil induced alterations. Hence, we speak in terms of readjustment rates. This term recognizes the fact that the indigenous benthic community is reacting to dredge induced stimuli but does not connotatively predict the long-term outcome.

The proximity to adjacent non-dredged populations may affect the rate of readjustment. Station 3 where refugial areas on hummocks were hypothesized approached readjustment twice as fast as Station 2 which was more isolated from undisturbed areas. A relationship between distance from the dredge channel to adjacent areas and readjustment period may exist. On the other hand the slower readjustment rates at Station 2 may have resulted from a more thorough removal of organisms at the time of dredging. Samples taken seven days after dredging showed diversity, and evenness, values within the range of pre-dredging values. It is believed that the total homogenization of the sediment surface destroyed the natural patchiness of the remaining infauna, and produced temporary, but unrealistic increases in diversity and evenness.

At Station 3 where little homogenization of the sediment surface is hypothesized, ranges of diversity and evenness were similar before and after dredging.

Widespread, dredge-induced alterations in the abundance, and diversity of benthic infauna in adjacent areas appear to result from ensuing siltation and gross changes in sediment type resulting from altered channel configurations.

At Station 1, 33 m from intensive dredging, turbidity resulted in the siltation of the sediment surface (Fig. 3(b)). Suspended silt, broadcast from Station 2, settled out upon reaching the relatively undisturbed waters of Station 1. As Station 2 was progressively dredged removing biologically active surface sediments, the suspended silt resulting from prop wash was more abiotic. Covering the animal-rich sediment surface at Station 1 with abiotic sediments which produced an apparent immediate decrease in the total number of organisms/unit volume as sampled by the Shipek grab. The indigenous infaunal community at Station 1 remained in place but was diluted with the abiotic overlayer and was not efficiently sampled.

Diversity values were temporarily enhanced resulting from increased evenness. Within 7 days, however, these values also returned to predredging ranges.

Although infaunal organisms are essentially nonmotile, organisms buried by silt will begin to burrow upward to regain preferential positions near the sediment surface. Saila *et al.*, (1972) found that *Streblospio benedicti* could regain the surface within 24 h after being buried 6 cm. Other small polychaetes and oligochaetes can be expected to have similar rates of upward burrowing. Infaunal bivalves must be able to move rapidly toward the surface if sediment is deposited over them to prevent their life-supporting siphons from being covered (Reineck, 1967). The capability of bivalves to burrow upward after burial has been documented by Shulenberger (1970). Rates of burrowing upward vary with taxa. The rate of burrowing of bivalves within the study area may appreciably exceed that of small annelids due to: (1) the large size of bivalves (> 12 mm) compared to annelids (< 5 mm); and (2) the ability of bivalves to detect the need to start burrowing upward as soon as silt covers their siphons, while annelids living below the sediment surface may take longer to sense that burial is taking place.

If grab samples were taken before all taxa had regained former depth habitats, it would appear that: (1) the faster burrowing bivalves had increased in relative abundance, and (2) the slower-burrowing annelids had decreased in relative abundance. Since annelids (particularly *S. benedicti*) made up the overwhelmingly dominant taxa, sampling before preferred depths were reached would tend to: (1) show a marked reduction in total abundance, (2) increase diversity and evenness by equalizing the relative abundance of taxa. After all taxa have completed burrowing, spatial distributions with depth would be re-established and samples would resemble pre-dredging levels in abundance, diversity, and evenness. Predictably, these results were obtained in sampling 1 week later. On the other hand, declines in abundance resulting from the gross displacement or death of organisms would not readjust abundance, diversity, and evenness values to closely match pre-dredging values after only one week since these parameters are long-term adaptive characteristics. It appears that violent prop wash at Station 2 resulted in siltation and temporary burial of the indigenous community at Station 1.

Station 4 was the only station which did not show a significant (5%) decline in total abundance immediately after dredging. Since Station 4 was immediately adjacent to active dredging at Station 3 this occurrence is perplexing. The combination of increased channel depth and a relatively high energy environment apparently prevented dredge induced siltation at Station 4. Increased water depth acted to lessen sediment disruption produced by the close proximity of the dredge, while a more vigorous current regime prevented the deposition of fine silt.

Significant (5%) declines in faunal abundances at Stations 5 and 6 suggest that disruptive processes extend for at least 100 m from the dredge. Recalling the sediment data discussed earlier it appears that the mass movement of sediment and debris along the channel bottom resulted from altered current patterns due to dredge-induced changes in channel contours.

Station 5 was the only station which did not readjust to former abundance levels during the course of the study. While the immediate removal of organisms by dredging and siltation in adjacent areas appears to result in temporary declines in abundances, dredge-induced changes in current patterns and sediment type have longer-lasting effects. Readjustment of faunal abundance at Station 6 took 14 days.

The biological effects of this dredging operation on the benthic infauna appear to be related to: (1) siltation in adjacent areas caused by prop wash of the dredge; (2) removal of benthic organisms by the suction heads of the dredge with the dredge channel; and (3) alteration of current patterns and sediment distributions due to changes in hydrological characteristics of the dredge channel.

While dredging is a recurring but infrequent disturbance to the benthic environment, prop wash from passing ships occurs almost daily. These mechanical effects in a small or narrow estuary have not been adequately studied but they must be substantial. Prop wash from small boats in shallow water has been linked to violent disruptions to seed clams leading to their eventual death by crowding and smothering (Godcharles, 1971). Cashin (1956) remarked that tugs and ships operating in shallow waters can cause considerable sediment disruption. It is logical that daily disruption by marine traffic may have a substantial effect on the type of community which survives in harbor environments. Successful taxa are able to cope with persistent sediment instability and other pollution stresses related to a commercial shipping port.

Mechanisms at the spoil site (*Fig. 4*)

Analysis of the sediment from Stations 10 and 11 immediately after spoiling revealed an increase in coarse-sediment debris (large wood chips, bark), and faunal declines appear to be related to covering by spoil (Fig. 4(b)). Although no spoil was dumped over Station 12, declines in faunal abundance were probably related to siltation caused by spoiling 50 m away.

Faunal abundances became readjusted within seven days at all spoil stations (Fig. 4(c)) suggesting that most individuals were not grossly impaired. However, the direct effects of spoiling in this instance may be lost amid disturbances from other sources: Natural scouring and heavy shipping activity combined to limit the initial abundance of organisms at Station 11, the main disposal point. Large ships towed stern first by tugboats drag anchors for control of momentum. This practice was done over Station 11 several days before spoiling and collections taken after the anchor dragging had lower total abundances than immediately after spoiling (mean abundance after anchor dragging = 12 organisms/1000 cc sediment; after spoiling = 17).

Transport of organisms from the dredge site to spoil site within the spoil is difficult to assess. Both sites have similar fauna. An examination of the spoil taken directly from the dredge hoppers revealed very low abundances, however. This situation arises because the suction heads cut well below the biotic region so that dredged organisms were diluted with abiotic sediments.

Although diversity and evenness values at the spoil site did not rise as markedly as at Stations 1 where burial was hypothesized, values taken immediately after spoiling were generally higher (Table 1). The lack of uniform, temporary, increases of these values as seen at Stations 2 may be related to the non-uniform distribution of spoil material on the bottom. Slotta *et al.* (1973) found that the deposition of spoil material was very irregular, with closely located sampling points receiving widely different types and amounts of spoil. Uneven burial of organisms within stations therefore would contribute to disparate changes in diversity and evenness.

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AN ABSTRACT OF THE THESIS OF

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Title: SEASONAL VARIATIONS IN TIDAL DYNAMICS, WATER QUALITY, AND SEDIMENTS IN THE COOS BAY ESTUARY

Redacted for Privacy

Abstract approved: Larry S. Slotta

Data was collected during 1973 and 1974 to determine seasonal variations in tidal dynamics, water quality, and sediments of the Coos Bay Estuary. A brief survey of the historical development of the area was made; navigational improvements as well as other important physical alterations to the estuary, both existing and proposed, were summarized.

Tidal ranges and times of high and low water were measured at five locations during periods of various stages of river flow. NOAA tide predictions for the entrance and the city of Coos Bay were evaluated for their accuracy; the predicted times of tidal heights at Coos Bay were found to be significantly in error. Amplification of the tidal wave was examined, and was found to vary according to river flow. Lag of the tidal wave progression upstream was also determined to depend on river flow.

Seasonal flow measurements were made at three locations. Phase relationships between maximum ebb and flood flows and maximum and minimum tidal heights were determined. Goodwin's computer model, which is described in his Ph. D. thesis, "Estuarine Tidal Hydraulics: One Dimensional Model and Predictive Algorithm" (1974), was run to compare with the measured tidal ranges.

Water quality samples were collected seasonally at high and low tides, including the following parameters: salinity, temperature, dissolved oxygen, turbidity, and pH. The estuary was classified on a seasonal basis using the longitudinal salinity profiles. The quantitative methods of Simmons and Burt and McAlister were also used to classify the estuary. Flushing rates using a range of seasonal river flows were determined by using: the fraction of fresh water method, the tidal prism method, and the modified tidal prism method.

Sediment samples following the dry season and the season of maximum precipitation were analyzed for grain size distribution, volatile solids, and porosity. Sediment samples were primarily taken at the same locations as those for water quality sampling. The mode of sediment transport was determined and realms of sediment deposition within the estuary were approximated.

Seasonal Variations in Tidal Dynamics,
Water Quality, and Sediments in the
Coos Bay Estuary

by

Robert Jeffrey Arneson

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LIST OF SYMBOLS

C = wave celerity

g = gravitational force

h = mean water depth

x = longitudinal distance measured from the mouth

Q_T = total flow

Q_m = flow of the West Fork Millicoma River

A_m = area of the West Fork Millicoma drainage basin

A_n = incremental precipitation areas

R_n = average annual precipitations

R_m = mean rainfall in the West Fork Millicoma drainage basin

μ = damping modulus

Kx = phase change

ϕ = dissipation coefficient

π = 3.14159

f = fractional fresh water concentration

S_s = undiluted seawater salinity

S_n = mean salinity of any portion of the estuary

Q = accumulated volume of fresh water

V = volume of the segment

R = river flow

T = flushing time

List of Symbols, continued:

V_L = low tide volume of the estuary

P = tidal prism

r_n = exchange ratio

η_{XH} = range at upstream stations

η_{OH} = range at the mouth

σ_{t_H} = time angle at upstream stations

SI-ENGLISH CONVERSION FACTORS

To convert	To	Multiply by
centimeters (cm)	inches (in)	0.3937
meters (m)	feet (ft)	3.2808
kilometers (km)	statute miles (miles)	0.6214
square meters (m^2)	square feet (sq ft)	10.7639
square kilometers (km^2)	acres (acres)	247.1054
cubic meters (m^3)	cubic feet (cu ft)	35.3147
cubic meters (m^3)	cubic yards (cu yd)	1.3080
cubic meters (m^3)	acre-feet (acre-ft)	8.1071×10^{-4}
meters/seconds (m/sec)	knots	1.9439

SEASONAL VARIATIONS IN TIDAL DYNAMICS, WATER QUALITY, AND SEDIMENTS IN THE COOS BAY ESTUARY

I. INTRODUCTION

This study was designed to provide information to enable coastal planners to intelligently manage the Coos Bay estuary and its environs. The information comprises seasonal variations of various hydraulic, chemical, and physical estuarine characteristics including: tidal ranges and currents, fresh water inflows, salinity, temperature, dissolved oxygen, turbidity, pH, and bottom sediments. In order to compare Coos Bay with other estuaries it was classified using several quantitative methods.

One thing necessary in achieving an understanding of estuaries is obtaining a satisfactory definition for the word "estuary." Pritchard (1967b) gives the most widely used definition. An estuary is a "semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage." This definition accurately described Coos Bay throughout the entire year. Even in the summer when the fresh water flow is small, the sea water within the bay is still significantly diluted. There is shoaling at the mouth that is quite heavy at various times during the year, but the entrance continually remains open. Upon examining a chart of the area (Figure 1),

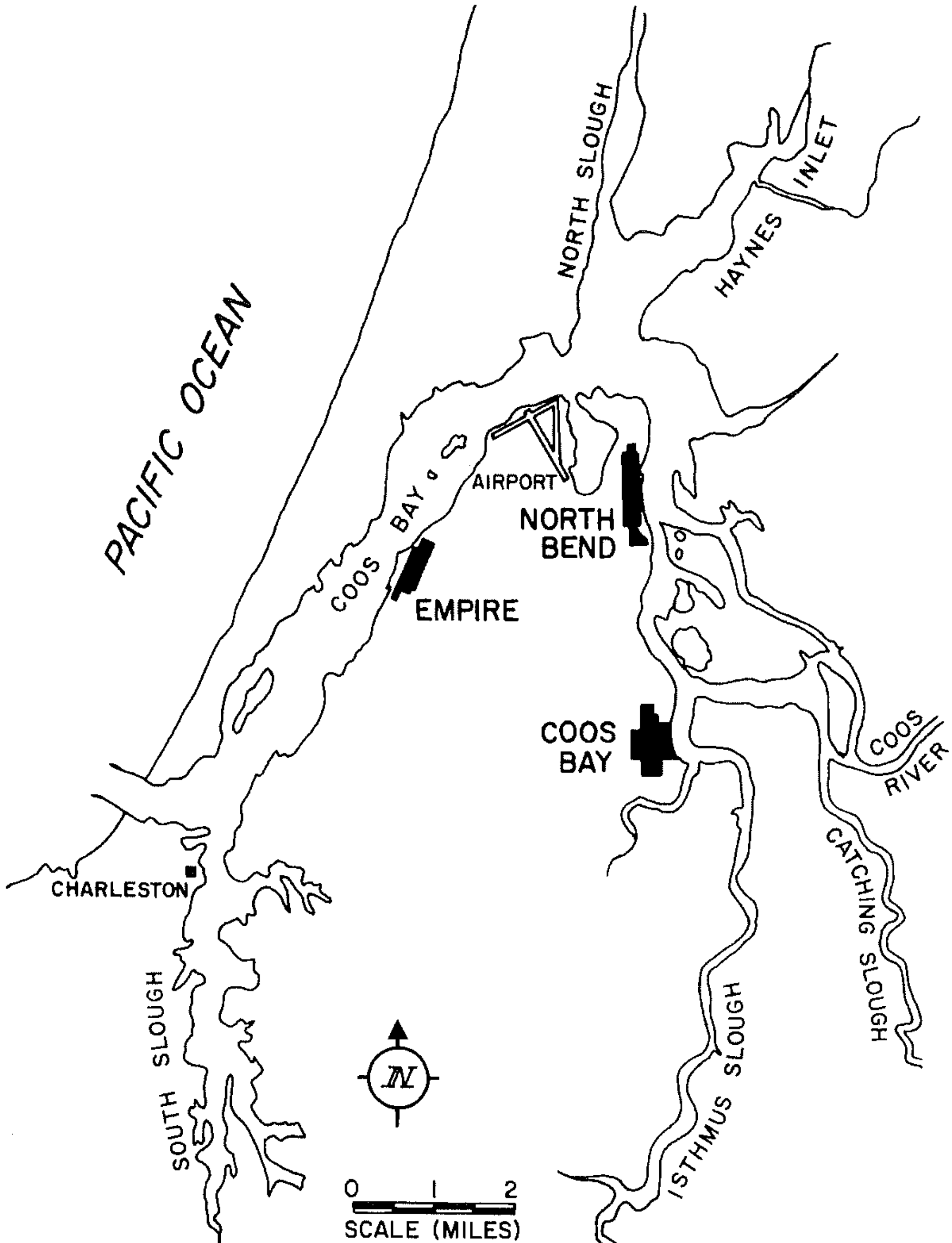


Figure 1. Map of Coos Bay Estuary, Coos County, Oregon

it is obvious that Coos Bay meets the other two criteria of the definition; it is indeed semi-enclosed, and it receives land drainage from the Coos drainage basin.

Estuaries are of the utmost importance to man's utilization of marine resources. They have been acclaimed one of the most naturally fertile areas in the world. The species that inhabit the estuary are unique in that they can exist in the dynamic conditions of changing salinity, temperature, and currents (Natural Resources, Ecological Aspects, 1971). Coos Bay is a migration area for salmon, steelhead, and shad. The anadromous carnivores feed on the smaller fish which are supported by the crustaceans found in the vast tidal flat areas. The tidal flats and marshes are also responsible for the production of clams and oysters. They provide a continuous supply of plankton and organic matter for the clams and oysters to feed upon.

Even though the estuarine species are adaptable, there is a fine balance which must be maintained in order for this ecosystem to survive. The basis of the food chain in the estuary is the plankton along with other nutrients which may be brought in by the tides and the fresh water inflow. If the plankton population is reduced by means such as herbicides or toxic wood products waste liquor, then the entire food chain would be adversely affected (Natural Resources, Ecological Aspects, 1971).

A management plan must be developed to insure that the fragile estuarine ecosystem balance is not upset in a way to be destroyed. This study does not cover all areas necessary to make complex coastal management decisions. It does, however, provide valuable quantitative descriptions of the Coos Bay estuary which may influence planning when combined with information which reflect other aspects of the estuary.

II. HISTORY

The original inhabitants of the Coos Bay area were the Coos Indians and the Coos were supposedly quite peaceful and helpful to the early pioneers. In contrast, the Rogue River Indians to the south were more warlike. The Coos Indians did not venture far from the bay in search of food as their major sustenance consisted of fish and berries, and infrequently some deer, elk, or bear (Dodge, 1898).

Probably the first white men to travel to the Coos Bay region were the fur trappers in 1826; these men were transients and did not start a permanent settlement. People began to settle in the early 1850's who were attracted by the possibility of finding gold while others were interested in coal. There was not much gold, but the volume of coal deposits was significant.

The coal field was approximately thirty-five miles long and eleven miles wide. The boundaries of the field were from North Slough, Coos Bay to Lampa Creek on the lower Coquille River. Even though the coal was a low grade subbituminous coal, mining was a leading industry in Coos Bay in the 19th Century. Production was between 40,000 and 75,000 tons per year from 1880 to 1890 (Beckham, 1973).

The other major industry which brought people to Coos Bay was lumbering. Vast stands of timber in the area included fir, hemlock, spruce and cedar. The first sawmill was established in 1865; twenty years later Coos Bay had the greatest number of sawmills of any of the Oregon coast communities. Transportation of the wood products created another new industry on the bay, that of shipbuilding. Between 1856 and 1881, fifty-three vessels were built (Beckham, 1973). Components for construction were also sent to other cities for assembly. Perhaps the most interesting of these were ship knees. The knees were formed by fir trees with taproots at approximate right angles and subsequently were used to construct the ribs of wooden ships since they were much stronger than steamed or bent timbers (Mahaffy, 1965).

The first town established on Coos Bay was Empire City (1853); it had a sawmill and shipyard and was the county seat. It was a major port and was one of the leading settlements on the estuary until the 1880's. People gradually moved away to be closer to the larger number of mills and the coal mines of the upper bay. The city of Marshfield (now Coos Bay) gradually gained predominance. It became the shipping center between Coos Bay and San Francisco. Marshfield was the first settlement to be incorporated in 1873 (Beckham, 1973). North Bend developed just north of Marshfield; it was also a location of shipping and lumber production. Although it was estalbished for almost 40 years, it did not become incorporated until 1903 (Coos Bay EIS Supplement, 1975).

The production of coal declined around the turn of the century and ceased to be excavated entirely around 1940. Considerable deposits still remain, but due to its low quality it is doubtful that it will again be mined for domestic use until higher grade petrochemical reserves are exhausted (Population Trends, 1963). The cessation of coal mining did not seem to be detrimental to the Coos Bay economy. The economy continued to prosper due to the rapidly expanding wood products industry. Port facilities for exportation of lumber continued to grow. Improved roads and the introduction of the railroad in 1893 aided Coos Bay to become the major economic and population center on the southern Oregon coast. Completion of U. S. Highway 101 in 1932 provided improved access from many of the outlying areas.

At the present time (1975) Coos Bay maintains its position as a major port for lumber shipping. The city claims to be the "world's largest lumber shipping center." The initiation of wood chip exportation in 1965 has increased the vessel traffic to the area. The number of vessels calling on the port with drafts greater than 20 feet climbed from 379 in 1965 to 650 in 1968. These figures represent the total number of ships, not just those engaged in the transport of wood products (Coos Bay EIS Supplement, 1975).

In a span of approximately 100 years, Coos Bay has changed from waters only traveled by Indian canoes to a highly industrialized port visited by numerous large merchant ships. Coos Bay, as all of

Oregon, owes its prosperity to timber and all industry related to its processing. The gold of Coos Bay first sought by the prospectors was actually to be found in the wood of the dense forests.

III. PHYSICAL DESCRIPTION

A. Location and Dimensions

The Coos Bay estuary is located on the southern Oregon Coast. It is approximately 341 kilometers (212 miles) south of the Columbia River and 702 kilometers (436 miles) north of San Francisco Bay (Coos Bay, Oregon, A Literature Survey (CBOALS), 1955). It is the second largest estuary in Oregon; only the Columbia River estuary is larger (Coos Bay EIS Supplement, Backgound Information (CBEISBI), 1975).

The bay extends approximately 21 kilometers (13 miles) from the mouth with an average width of 366 meters (1200 feet) at low tide. The surface area is 44.4 square kilometers (10,973 acres) at high tide and 23.5 square kilometers (5,810 acres) at low tide (Coos Bay EIS Supplement (CBEISS), 1975). Tidelands cover approximately 18.5 square kilometers (4,569 acres). The mouth of the estuary is 628 meters (2,060 feet) wide with an average depth of 8.8 meters (29 feet) (Percy et al., 1973).

B. Tides

The tide in Coos Bay is described as a mixed, semi-diurnal tide. The mean range at the entrance is 2.04 meters (6.7 feet). At the city of Coos Bay it is 2.10 meters (6.9 feet). It is estimated that the extreme range is 3.2 meters (10.5 feet). The delay time of high tide between the entrance and the city of Coos Bay as estimated by the Army Corps of Engineers is approximately 90 minutes (CBEISBI, 1975); however, the data from this study showed the average lag time to be 38.5 minutes from the entrance to the Corps of Engineers Dock in Coos Bay.

Tidal current velocities at the entrance average 1.0 meters per second (2.0 knots). Ebb currents have been measured as high as 2.6 meters per second (5.0 knots) at Guano Rock. Maximum flood currents are approximately 1.8 meters per second (3.5 knots) (CBOALS, 1955). The maximum ebb current recorded during this study was 1.22 meters per second (2.4 knots).

More inclusive information describing the tides is contained in Chapter IV.

C. Climate

The Coos Bay area experiences wet winters with dryer summers. Temperatures tend to be relatively mild (8.1 °C, 46.5 °F) in the winter and cool in the summer (14.7 °C, 58.5 °F) for the latitude of the region. This can be attributed to the strong influence of the marine weather systems (CBOALS, 1955).

Records of the thirty year period from 1933-1963 maintained by the U. S. Department of Commerce, Weather Bureau, for North

Bend indicate that the wettest month averaging 25.1 centimeters (9.9 inches) of precipitation is January and the month of least precipitation is July, averaging 0.97 centimeters (0.38 inches) of precipitation. January is also the coldest month (averaging 7.3°C, 45.2°F) and August the warmest (averaging 15.3°C, 59.6°F). The prevailing wind direction is north-northwest for June through September (averaging 5.2 m/sec, 11.6 mph). It is south-southeast in January (averaging 5.5 m/sec, 12.3 mph) and southeast (averaging 4.6 m/sec, 10.2 mph) the remaining months of the year (CBEISBI, 1975).

Fog is a dominant meteorlogical condition affecting the estuary. The summer and fall have the most foggy days; there were 163 hours of fog per month for July through November in the period 1951-1954. The remainder of the year only averaged 33 hours per month (CBOALS, 1955).

D. Drainage Basin

Measurements for this study resulted in an area of 1,502 square kilometers (580 square miles); further details regarding these measurements are included in Chapter IV, Section C of this report. According to Percy et al. (1973), the Coos Bay drainage basin covers an area of approximately 1,567 square kilometers (605 square miles). Approximately 88% of the drainage basin is forested. Croplands and rangelands only account for 2% and 1%, respectively.

The average yearly runoff for the basin is 2.7×10^9 cubic meters (2.2×10^6 acre-feet). Annually the average precipitation ranges from 127 centimeters (50 inches) near the coast to 254 centimeters (100 inches) farther inland (Percy et al., 1973). The seasonal runoff creates a large variation in the fresh water flowing into Coos Bay. Fresh water inflow in the summer may dip to as low as 2.83 cubic meters per second (CMS) (100 cubic feet per second (CFS)); in contrast the freshets of winter and spring may cause a flow in the range of 2,832 CMS (100,000 CFS) (CBEISBI, 1975). Flow extremes during the period of this study were 1.0 CMS (35.3 CFS) in September and 208 CMS (7349 CFS) in December.

There are numerous tributaries which enter Coos Bay. The main one is the Coos River which drains approximately 70% of the entire basin. It is formed by the South Fork Coos River and the Millicoma River approximately 8.9 kilometers (5.5 miles) from the point where it enters the bay. The Millicoma River is formed by the East Fork Millicoma and the West Fork Millicoma 14.0 kilometers (8.7 miles) from the bay. The gaging station from which flow rates into Coos Bay were extrapolated for this study is located on the West Fork Millicoma. The extrapolation method is discussed in Chapter IV, Section C of this report.

E. Physical Alterations

Numerous man-made alterations have been made to Coos Bay. Most have been done to increase channel dimensions for navigational purposes. Other sizable alterations such as the land fill for the North Bend Airport have taken place. A complete listing of modifications completed by the Army Corps of Engineers is given in Descriptions and Information Sources for Oregon Estuaries (Percy et al., 1973). Figure 2 developed by the Department of the Interior (Natural Resource, Ecological Aspects, 1971) shows the tidelands change between 1920 and 1970.

Because of the significant effect on the hydraulic response of the estuary, a summary of the major changes accomplished for navigational improvement are included in this study. Before any alterations the channel crossing the bar was 3.0 meters (10 feet) deep and 61.0 meters (200 feet) wide. The controlling depth to North Bend was 3.4 meters (11 feet) with a minimum width of 61.0 meters (200 feet). From North Bend to Coos Bay it gradually became narrower and more shallow. At Coos Bay the channel was only 1.8 meters (6 feet) deep and 15.2 meters (50 feet) wide. Shoals which limited use of the bay to small coastal vessels were present at a number of places in the channel (CBEISS, 1975).

Improvements to the channel began around 1880. The south and

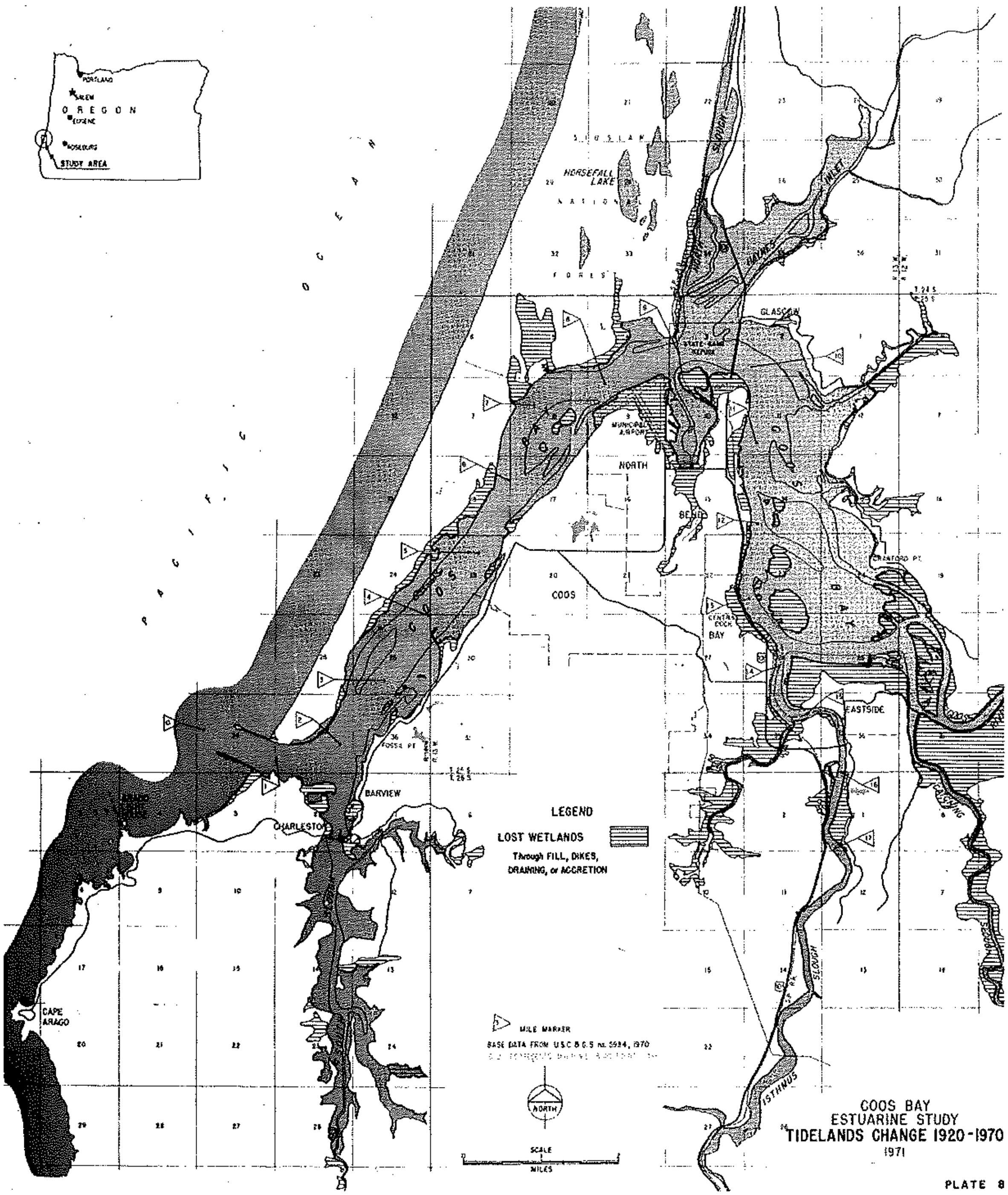


Figure 2. Tidelands change in Coos Bay, 1920-1970

north jetties were completed in 1928 and 1929, respectively. The south jetty is 1,190 meters (3,900 feet) long and the north jetty is 2,926 meters (9,600 feet) long. The entrance channel is presently maintained to a depth of 12.2 meters (40 feet). As one proceeds up the estuary, the dimensions gradually reduce to 9.1 meters (30 feet) deep and 91.4 meters (300 feet) wide at Guano Rock. The average annual amount of material dredged to maintain the entrance is approximately 650,000 cubic meters (850,000 cubic yards). The channel is maintained from Guano Rock to the upstream point in Isthmus Slough, which is 24.1 kilometers (15.0 miles) from the entrance, to 9.1 meters (30 feet) deep and 91.4 meters (300 feet) wide. A channel (6.7 meters - 22 feet-deep and 45.7 meters - 150 feet - wide) extends 3.2 kilometers (2.0 miles) up Isthmus Slough to Millington. The Coos River has a dredged channel 1.5 meters (5 feet) deep and 15.2 meters (50 feet) wide from the point of entry to the bay to the junction of the Millicoma River and the South Fork Coos River, a distance of 8.8 kilometers (5.5 miles). In addition to the main channel dredging, two turning basins, one in North Bend and one opposite Coalbank Slough, also require dredging. The turning basins are 9.1 meters (30 feet) deep, 183 meters (600 feet) wide, and 305 meters (1,000 feet) long (CBEISBI, 1975).

Although it is not a specific improvement to navigation, a large dredging project worthy of note is the Charleston small boat basin.

The basin was completed in 1956. The basin itself is 3.0 meters (10 feet) deep, 152 meters (500 feet) wide, and 274 meters (900 feet) long. The project includes a connecting channel to the bay which is 3.0 meters (10 feet) deep and 45.7 meters (150 feet) wide. A channel of the same dimensions extends southward to the highway bridge over South Slough (CBEISBI, 1975).

At present (1975) the Army Corps of Engineers has proposed a new deep draft navigation project. The major modifications would include increasing the depth over the bar to 13.7 meters (45 feet). The inner channel extending 24.1 kilometers (15.0 miles) would be increased to 10.7 meters (40 feet). The channel width would be widened to 122 meters (400 feet) between 14.5 kilometers (9.0 miles) and 24.1 kilometers (15.0 miles) from the entrance. The depth of the turning basins would be increased to conform to the channel depth. The North Bend basin would be widened to 244 meters (800 feet), and the one at Coalbank Slough to 213 meters (700 feet). There is also a proposed anchorage area 8.8 kilometers (5.5 miles) from the entrance. It would be the same size as the turning basin in North Bend (CBEISS, 1975).

Another significant proposed project (1975) is expansion of the North Bend Municipal Airport. The project would include extensive fill west of the airport to extend an existing runway approximately 580 meters. The fill would connect the island west of the airport

(Figure 2) to the shore. Also included in the proposed expansion is some fill of Pony Slough (due east of the airport, Figure 2) for fixed base operations (Hancock, 1975).

IV. TIDAL DYNAMICS

A. Introduction

Tidal forces tend to dominate the physical characteristics of an estuary, that is the river flow has a minor influence for most times of the year. A study of the dynamics of these tidal forces is necessary to determine natural behavior of the estuary and the responses to human interference. Concern about man-made alterations are the major impetus for tidal dynamic studies at the present; often an attempt to predict and evaluate the results of an alteration is made before an alteration is allowed. This study was conducted to describe the tidal action and flow characteristics observed in Coos Bay on a seasonal basis. The results may be used to calibrate computer models which subsequently would be used to predict conditions other than those reported in the study and those conditions which might occur following alterations to the estuary. The application of Goodwin's model described at the end of this chapter is an example of such a use.

Tides are produced by the gravitational effects of the sun and the moon. Even though the sun has much greater mass, due to its extreme distance from the earth, it exhibits tidal forces only 46% as large as the moon. A diurnal tide is one in which there is one maximum and one minimum in a day. A semi-diurnal tide has two maxima and two minima in a day. Whether a diurnal, semi-diurnal, or a combination of the two is present is a function of latitude and the declination of the moon. The tide at Coos Bay can be described as a mixed, semi-diurnal tide; this is a semi-diurnal tide with unequal highs and lows. The normal progression is low low water to low high water, low high water to high low water, high low water to high high water, and high high water to low low water. The normal tidal period is approximately 12.42 hours.

A monthly tidal variation is caused by the combined effects of the sun and moon. During the new and full moon the forces of the sun and moon are additive and produce greater tidal ranges. During the first and last quarters of the moon the forces of the sun and moon oppose each other to produce smaller tidal ranges. The larger ranges are called spring tides and the smaller ones neap tides. This cycle occurs twice during a month (Dean, 1966).

There are a number of other factors, both constant and variable, which govern tidal height and period. One constant factor is the geometry of the basin in which the tide is generated. Another one to be considered is Coriolis force. Variations generally occur due to meteorological conditions; storms may bring high winds and also changes in the barometric pressure. These factors may cause tidal heights and storm surges to be either adding to or subtracting from average conditions according to their magnitude and direction.

Due to the size of estuaries in comparison to the volume contained in the ocean it is generally assumed that local tides are not generated within the estuary. The estuarine tide is produced by the forcing function at the mouth, which is the ocean tide. The tide causes a large amount of seawater to be stored in the estuary during high tide and drained back into the ocean on the low tide. The volume of the water exchanged is defined as the tidal prism. The tidal prism is generally an order of magnitude greater than the volume of fresh water inflow during a tidal cycle. Tidal flow velocities are also far greater than those of the fresh water flow (Ippen, 1966b).

Two types of waves may ideally occur in estuaries; these are the progressive and standing waves. A progressive wave is characterized by having maximum height and maximum current occurring simultaneously; wave amplitude and velocity are considered to be in phase. A standing wave is one in which wave amplitude and velocity are 90° out of phase; when maximum wave height occurs the current is zero, the maximum current occurs mid-way between maximum and minimum height. Perfect standing waves rarely occur but partial standing waves of varying degree are not uncommon in short confined estuaries. Progressive waves may be found in very long estuaries with no physical obstructions and a small bottom slope (Harleman, 1966).

Because Coos Bay is a narrow estuary the effects of Coriolis force on tidal action are not important. The geometry of the estuary, however, greatly affects the tidal wave. Amplitude of the wave tends to increase as the estuary converges. If this convergence is rapid, rather than a gradual narrowing, reflection from the sides of the estuary can cause a decrease in wave amplitude. Another factor causing a reduction in amplitude is boundary friction (Harleman, 1966). The energy dissipation caused by boundary friction must be quantified in order to quantitatively define diffusion within the estuary.

If the geometry of an estuary is such that the wave amplitude gradually decays to zero upstream, then the tidal wave may be a damped progressive wave. The frictionless celerity, C, of this wave is

$$C = \sqrt{gh_{(x)}} \qquad (1)$$

where g is the gravitational force. The mean water depth, h, may vary as a function of x, the longitudinal position along the estuary. It is rare for an estuary to have a tidal wave that is either a true progressive wave or a standing wave; it usually exhibits characteristics somewhere between these two extremes. There may be reflection of the tidal wave at the head of the estuary caused by a dam or by shallow water which is below critical depth at all phases of the tide. Reflection of the wave is imperfect due to partial transmission and or dissipation of the barrier. As the imperfect reflected waves move seaward they are affected by the geometry of the estuary, similar to the generating incident wave. The reflected wave is superimposed on the incident wave causing the tidal motion of the estuary to be the sum of these two waves. Tidal motion of this form is defined as a cooscillating tide. This tide occurs at progressively later times as it moves upstream, but it usually requires less time between two stations than a progressive wave (Harleman, 1966). The tidal motion of Coos Bay appears to be that of a cooscillating tide.

In order to develop an understanding of the magnitude and duration of ebb and flood tidal flows, the equation for shallow water wave celerity, $C = \sqrt{gh_{(x)}}$ is used. It can be shown that on the flood tide, when water level is increasing from low to high tide, the greater mean depth causes the flooding tidal wave to travel faster than the ebb. That is celerity, C, increases as the mean depth, h, increases. Since the flood tide travels faster, lag times of high tide between two stations on the estuary should be less than low tide lag times.

Even though the magnitude of river flow is usually small compared to tidal flow, it must be considered when discussing lag times. Intuitively, river flow opposes a flood tide and therefore causes greater high tide lag times. Theory indicates that river flow increases mean depth resulting in increased celerity. It seems, however, that the opposition to flow more than offsets the effect of increased depth, and that high flows should create greater high tide lag times. River flow moves in the same direction as the ebb tide and tends to decrease low tide lag times as flow increases. Meteorological conditions previously dicussed could also alter lag times, but due to the size of the estuary they are neglected.

Tidal flows are also affected by whether the tidal ranges are spring or neap. The greater ranges of the spring tides usually produce greater currents and flows than the neap tides. The mixed semi-diurnal tide experienced in Coos Bay causes an interesting sequence of flow conditions. The two rising ranges are nearly equal in magnitude and consequently the flooding currents are quite similar. However, the two falling ranges usually differ significantly. The range between high high water and low low water is larger and generates greater ebbing currents than the range between low high water and high low water.

B. Tidal Measurements

Tidal measurements were made during the four seasonal periods. Measurement dates were September 11, 1973 - September 26, 1973; December 16, 1973 - December 25, 1973; March 11, 1974 - April 2, 1974; and June 3, 1974 - June 18, 1974 which represented seasonal conditions: summer, fall, winter, and spring, respectively. The dates of current measurements and water quality sampling were conducted to fall within the periods of tidal measurement.

Range and times were measured at five locations as indicated on Figure 3. The location nearest the entrance, Station 1, was at the Coast Guard boat house in Charleston, 4.63 kilometers (2.88 miles) from the entrance. Station 2 was at the Roseburg Lumber Company Dock, 12.73 kilometers (7.91 miles) from the entrance. Station 3 was at the Corps of Engineers dock, 21.23 kilometers (13.19 miles) from the entrance. Station 4 was at the point where Shinglehouse Slough enters Isthmus Slough 28.87 kilometers (17.94 miles) from the entrance. Station 5 was at the highway swing bridge over Catching Slough, 25.70 kilometers (15.97 miles) from the entrance.

Water Level Recorders (Leupold and Stevens, Type F) were used at Station 3, Station 4, and Station 5 for all seasons. One was also used at Station 2 for summer and fall. The recorder uses a 24-hour clock and therefore requires daily servicing. Daily servicing was sometimes difficult due to inclement weather and limited daylight conditions. Daily servicing did afford the opportunity to correct recorder malfunctions and continue tide recording minimizing loss of data. The Stevens recorder is a float and chain type device; the float moves inside a stilling well which dampens oscillations. The chain moves with the float and drives a pen in the recorder. The recorder measures the tide to within five minutes in time and 0.03 meters (0.1 feet) in range.

A Bristol Bubbler Tide Gauge was substituted for the Stevens

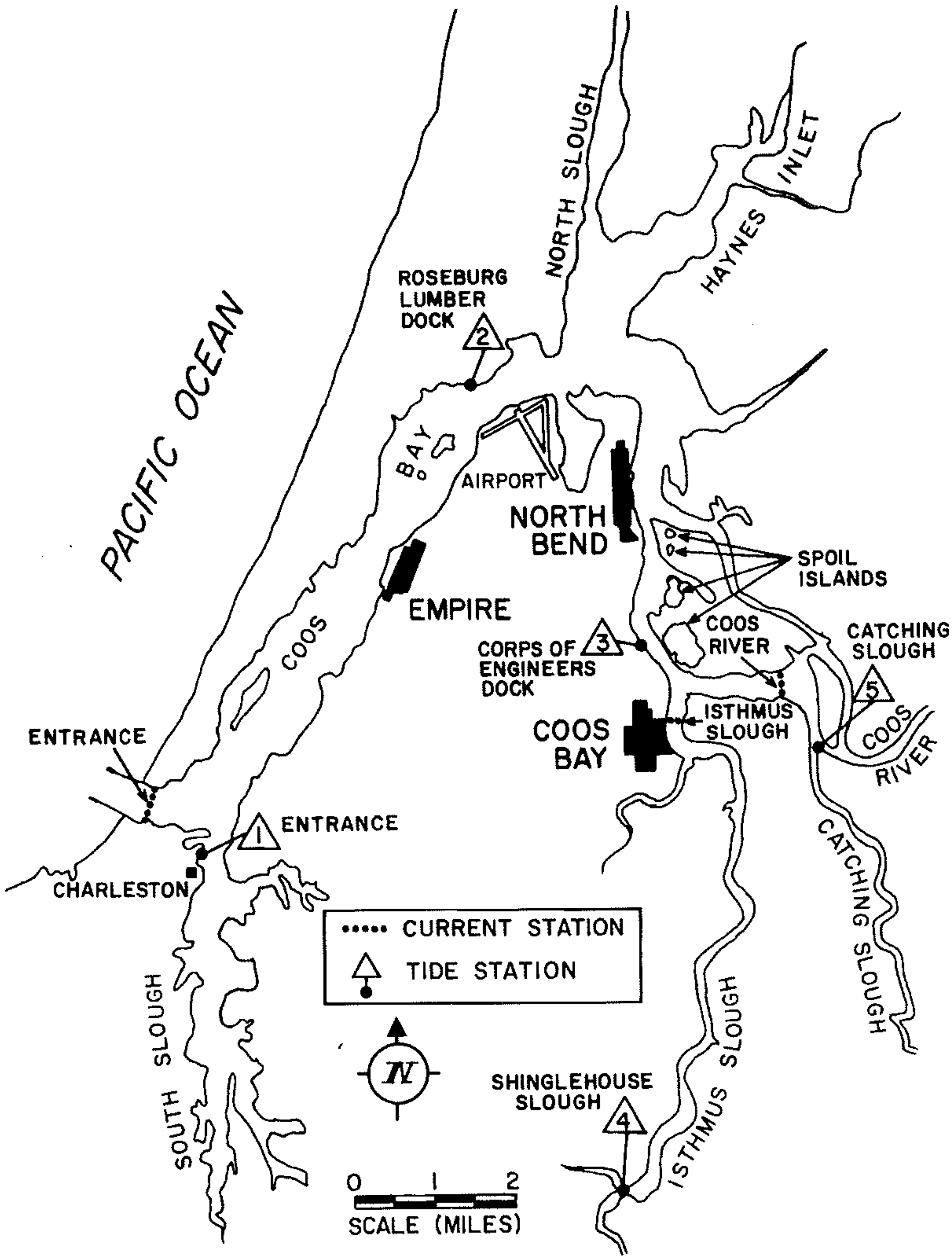


Figure 3. Location of tidal and current measurement stations, Coos Bay, 1973-1974

recorder at Station 2 for the winter and spring seasons. This gauge is on loan to Oregon State University from the National Ocean and Atmospheric Administration (NOAA). This substitution was made after one Stevens recorder stilling well was lost and another severely damaged due to collisions by floating debris and logs. The bubbler gauge does not use a stilling well; it is a pressure sensing device. An orifice with a constant supply of nitrogen is placed underwater so that it remains submerged at all stages of the tide. The water pressure at the orifice is transmitted through a nitrogen gas line to a temperature compensating bellows which drives the recording pen. The bubbler has a continuous strip chart recorder which should be serviced weekly. The bubbler gauge is accurate to within five minutes in time and 0.03 meters (0.1 feet) in range.

Tidal measurements at Station 1 were supplied by Henry Pittock, Oregon State University, School of Oceanography, in cooperation with NOAA, National Ocean Survey (NOAA, NOS). These measurements were made with a Fischer and Porter analog-to-digital recorder. This recorder uses a counterweighted float inside a stilling well to transmit the level of the tide. It has a digital readout at six minute intervals. The recorder is accurate to within six minutes in time and 0.03 meters (0.1 feet) in range.

C. Flow and Velocity Measurements

Current measurements were made during the four seasonal periods on the day preceding water quality sampling. The dates currents were measured on were September 12, 1973, December 18, 1973, March 22, 1974, and June 11, 1974 which represented seasonal flow conditions for summer, fall, winter, and spring, respectively. The dates were chosen to have similar tidal ranges of approximately 1.8 meters (6.0 feet). Similar ranges were chosen in an attempt to have similar tidal flows for the different seasons. Of course, ranges of equal magnitude do not insure equal flows since there may be a difference in height above mean lower low water.

Locations of the current stations were chosen to record tidal flow to and from the estuary at the mouth and points of major input upstream. The station at the mouth was located perpendicular to the channel at Coos Head, 1.71 kilometers (1.06 miles) from the entrance. Measurements were conducted at this location each season except in the fall. Measurements were taken farther upstream in the fall since there were breaking waves at Coos Head and entering the channel. The Fall location was upstream of the submerged end of the North Jetty, 3.11 kilometers (1.93 miles) from the entrance and perpendicular to the channel. The two upstream current stations were positioned in the same locations for all seasons. One was on the east end of the Marshfield Channel, perpendicular to the channel and 24.16 kilometers (15.01 miles) from the entrance. Another station, located on Isthmus Slough at the Public Dock, was perpendicular to the channel and 22.90 kilometers (14.23 miles) from the entrance. Locations of these stations are shown on Figure 3.

In order to have the necessary current data for calculating the total flow, currents were measured in more than one position across the channel. Four equidistant floats were positioned across the channel to establish locations for taking the vertical current profiles. In order to determine the exact position of each float, a perpendicular baseline was established on the shore. Baseline angles to the floats were then measured and the depth at the floats were recorded at this same time. Two to ten current measurements of equal intermediate depths were made for the vertical profiles. The number of profile points varied according to the total depth at the float. Vertical profiles were obtained at each float. Once the fourth profile was completed, a second pass was begun at the first float. This process was repeated continuously during the sampling period.

During this study two types of current meters were employed. These were both the old (No. 622-AA) and new (No. 665E) models of the Price-type Gurley Salt Water current meter and a Hydro-Products current Speed sensor. The Price meter is a cup anemometer-type measuring device. The old model has a digital counter; counts were measured for 30 second intervals and then converted to meters per second. The new model has a direct reading unit in either feet per second or meters per second. The only direction information available from the Price meter is if the sensor is visible when submerged. The Hydro-Products meter has a Savonius rotor which senses current and also a vane gives indication of the direction of flow; the direct reading unit indicates speed in knots and direction in degrees. In general, a Price meter was used at the mouth. A Price meter was also used at one of the upstream stations with the Hydro-Products meter at the other.

It was the objective to obtain sufficient current data to establish the phase relationships between flow and velocity and the tidal heights. To accomplish this, currents were measured during the period approximately two to three hours before maximum flow and one hour after maximum flow. Sufficient data was not always collected due to incorrect tidal prediction, darkness, and equipment malfunction. Fall current measurements were unsatisfactory due to an inordinate amount of equipment problems. For the next two seasons, after two new Price meters were received there was a standby meter available for use in craft making the upstream and downstream measurements. Even this equipment redundancy was not sufficient to prevent missing some measurements caused by equipment malfunction during the Spring.

For data reduction, the current and bathymetry data were input into a computer program developed by C. I. Rauw (1975). The program was modified by the author to accept data as read from the new Price current meters. The output of the computer program gave results for each measurement pass. The results obtained from the computer were average flow rate, average velocity, cross-sectional area, and the time of the pass.

Since there is no gaging station on the Coos River, fresh water flows were extrapolated from the flows measured on the West Fork Millicoma River (Geological Survey, 1974). The drainage areas of the Coos River, Isthmus Slough, and Coos Bay were measured by planimeter. Incremental areas of the different average annual precipitations within these areas were also measured (South Coast Basin, 1963). A ratio of the precipitation multiplied by the drainage areas and the known flow was used to determine the flows of each precipitation area. These were then summed to give the total fresh water flow at the mouth of the Coos River, Isthmus Slough, and Coos Bay. It was assumed that different amounts of precipitation would result in proportional amounts of fresh water flow in all areas. The equation used for the flow calculations to compute data for Table I was

$$Q_T = \frac{Q_m R_1 A_1}{R_m A_m} + \frac{Q_m R_2 A_2}{R_m A_m} + \ldots + \frac{Q_m R_n A_n}{R_m A_m} \qquad (2)$$

Table I. Seasonal Flows and Drainage Areas in the Coos Bay Drainage Basin

Date	Coos Bay Entrance (CMS)	Coos River (CMS)	Isthmus Slough (CMS)	West Fork Millicoma River (CMS)
Sept. 12, 1973	1.1	0.8	0.04	0.12
Sept. 13, 1973	1.0	0.8	0.04	0.12
Dec. 18, 1973	208.1	159.9	8.6	23.3
Dec. 19, 1973	140.8	108.3	6.3	15.8
Mar. 22, 1974	45.5	35.0	1.9	5.1
Mar. 23, 1974	39.7	30.5	1.8	4.4
June 11, 1974	18.0	13.8	0.74	2.0
June 12, 1974	15.9	12.2	0.71	1.8
Drainage area (sq. km.)	1502	1077	83	137

where Q_T = total flow,

R_m = mean rainfal in the West Fork Millicoma drainage basin,

Q_m = flow of the West Fork Millicoma River,

A_m = area of the West Fork Millicoma drainage basin,

R_n = average annual precipitations,

A_n = incremental precipitation areas.

D. Tidal Dynamic Results

The following discussion of the tidal dynamic results is based on the graphical presentation of the data of the included figures. A comprehensive listing of the measured tidal data is in Appendix A. Predicted tidal data used for figures was obtained from the U. S. Department of Commerce, NOAA tide tables for the West Coast of North and South America.

1. Flow

The seasonal average flows and velocities are plotted on Figures 4 through 9. The mean river flows were included as a comparison to the tidal flows. The river flows were so small when compared to the tidal flows that in most of the figures river flow appears essentially zero. The tidal waves plotted on the figures are a relative tidal height. No datum ties were made to the tide recorders;

thus no absolute water elevations were measured. Therefore, the relative heights were referenced to the lower low water for that day, which was defined as zero elevation. Exeptions are the tidal heights plotted for the entrance. These are true heights referenced to mean lower low water as computed by NOAA. Measurement of the entrance tidal heights were made at a location 2.9 kilometers (1.8 miles) farther from the mouth than the current profiles. Tidal heights plotted on the figures for the Coos River and Isthmus Slough were measured at the Corps of Engineers dock. The current measurement station in the Coos River was approximately 2.9 kilometers (1.8 miles) upstream from the tidal measurement. The current measurement station in Isthmus Slough was approximately 1.7 kilometers (1.04 miles) upstream from the tidal measurement. These distances were considered small enough for satisfactory correlation between heights and flows.

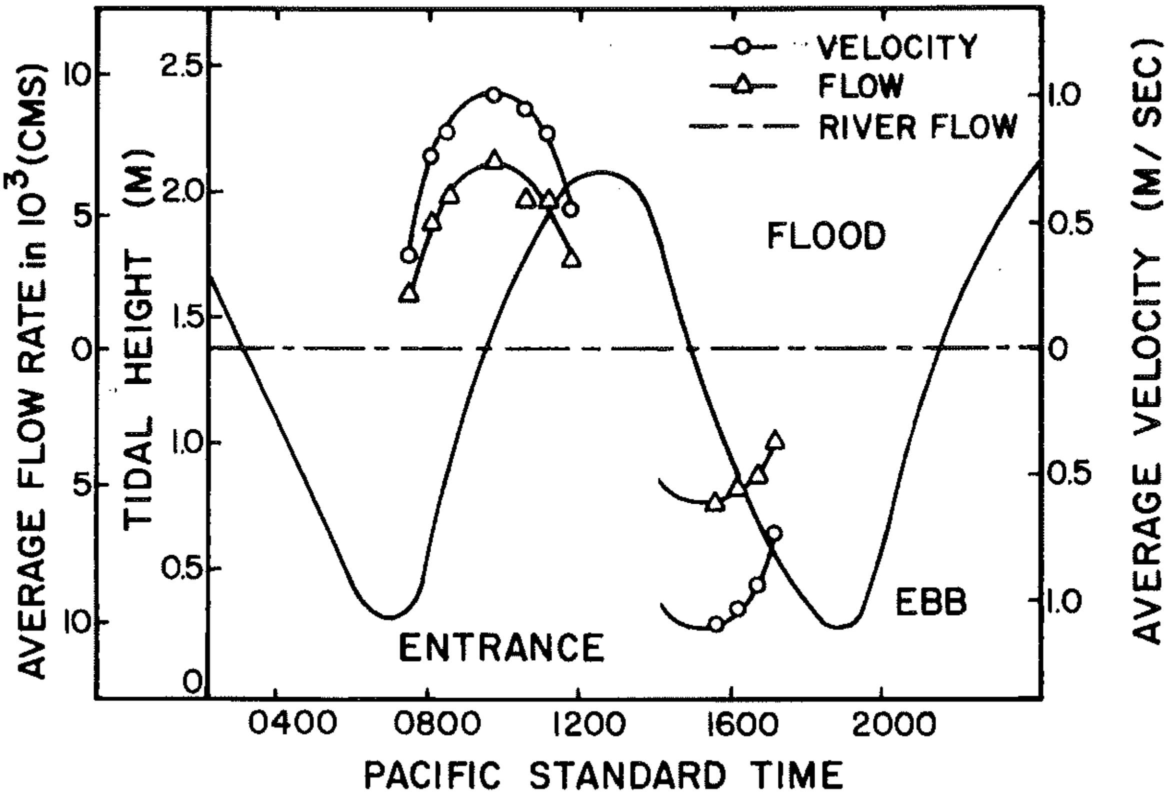
Table II provides a summary of the phase results obtained from Figures 4 through 9. Phase lags on the flood tide were measured from the time of low tide to the times of maximum flow and velocity. Phase lags on the ebb tide were measured from the time of high tide to the times of maximum flow and velocity. The phase lags were measured in this manner since the tide at the mouth was considered the forcing function. The flows and velocities were then viewed as lagging the effect that was producing them. The phase differences

Table II. Flow and Velocity Phase Results

Date	Tide	Phase Lag Following Low or High Water						Range
		Entrance (RK-1.71)		Coos River (RK-24.16)		Isthmus Slough (RK-22.90)		
		Flow	Velocity	Flow	Velocity	Flow	Velocity	(m)
Sept. 12, 1973 (Summer)	Flood	78°	78°	148°	126°	156°	129°	1.79
	Ebb	87°	81°	100°	130°	--	--	-1.82
Dec. 18, 1973 (Fall)	Flood	--	--	--	--	--	--	1.33
	Ebb	81°	87°	--	--	90°	49°	-2.14
Mar. 22, 1974 (Winter)	Flood	--	--	113°	95°	128°	--	1.71
	Ebb	84°	78°	124°	156°	92°	112°	-1.89
June 11, 1974 (Spring)	Flood	114°	127°	168°	122°	--	--	1.71
	Ebb	88°	90°	168°	162°	88°	74°	-1.07

are recorded in degrees. One tidal cycle is approximately 12.42 hours (44,712 seconds, 745.2 minutes) and is defined as moving through 360 degrees. Each degree is therefore equal to 2.07 minutes.

Tide and flow data for December 18, 1973 was not obtained because of equipment malfunctions during that field trip. It is noted that no maximums were observed on the ebb flow in Isthmus Slough (Figure 5) on September 12, 1973 due to late commencement of data taking by research personnel. On March 22, 1974 in Isthmus Slough (Figure 5) no velocity maximum was recorded on the flood tide. Even though flow increased and reached a maximum, all velocity values were equal. A velocity increase probably would not have been observed even if additional passes had been made since the last pass indicated a decreasing flow. Perhaps the constant velocity recorded was the maximum and lower values occurred before and after data was taken. No maximum flow or velocity was recorded on the flood tide at the entrance on March 22, 1974 (Figure 7) due to equipment malfunction. Times of maximum flows on both tides in the Coos River on June 11, 1974 (Figure 8) might be questioned. On the ebb, flow was seen to increase, decrease, and then increase again before decreasing on the last pass. The second maximum was slightly greater so it was designated as the time of maximum flow. The velocity maximum that day also occurred closer to the second maximum flow. On the flood tide, even though velocity had already



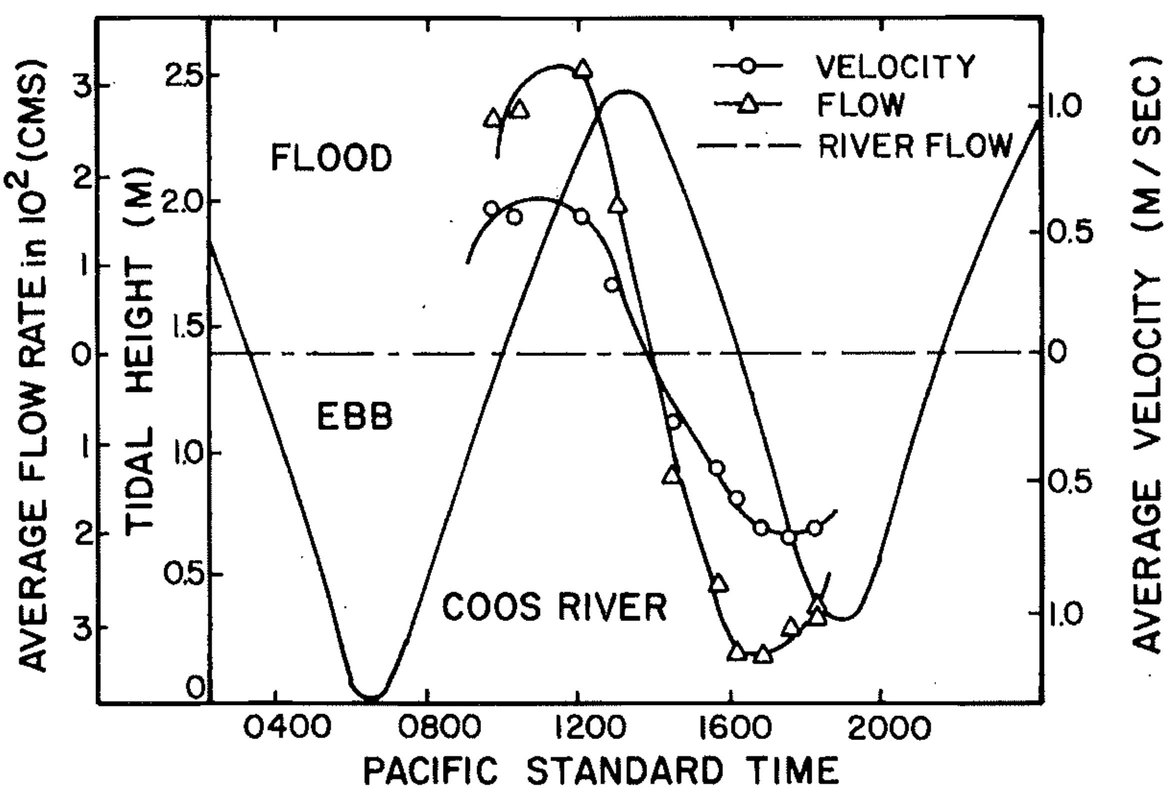


Figure 4. Average flow and velocity profiles, Coos Bay, September 12, 1973

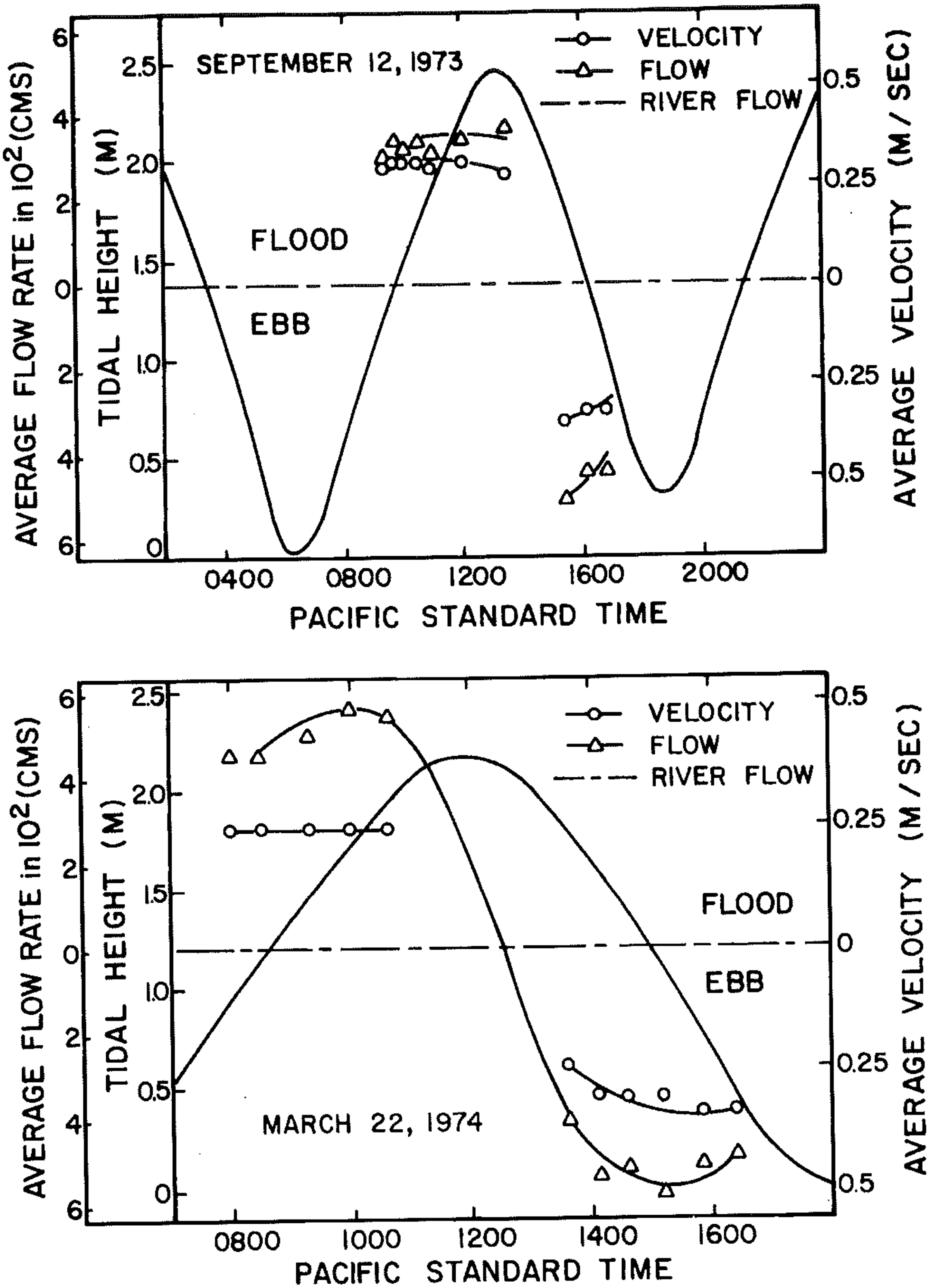
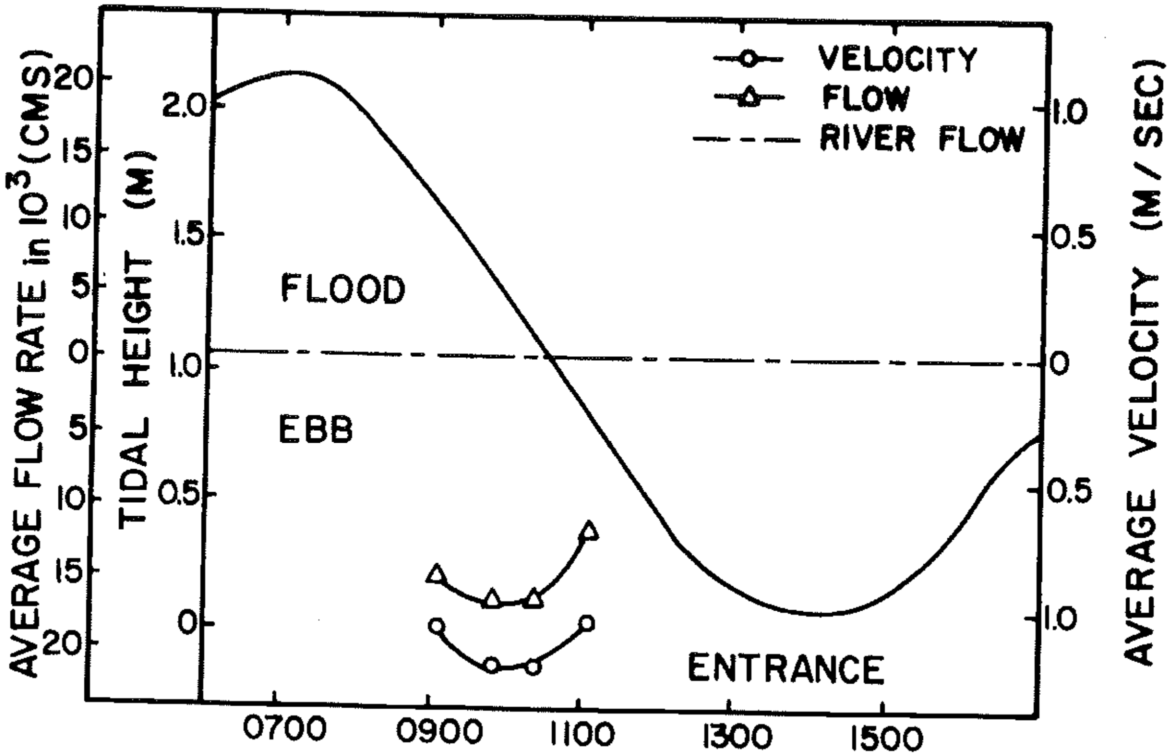


Figure 5. Average flow and velocity profiles, Isthmus Slough, Coos Bay, September 12, 1973 and March 22, 1974



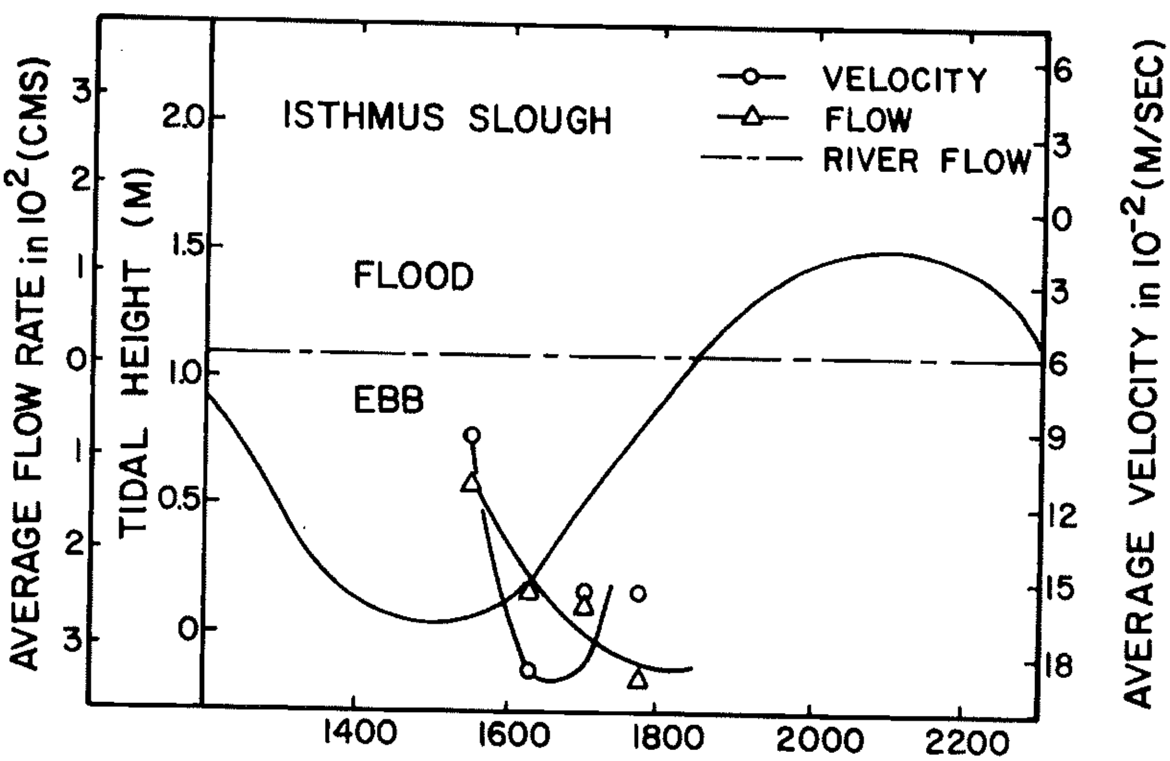


Figure 6. Average flow and velocity profiles, Coos Bay, December 18, 1973

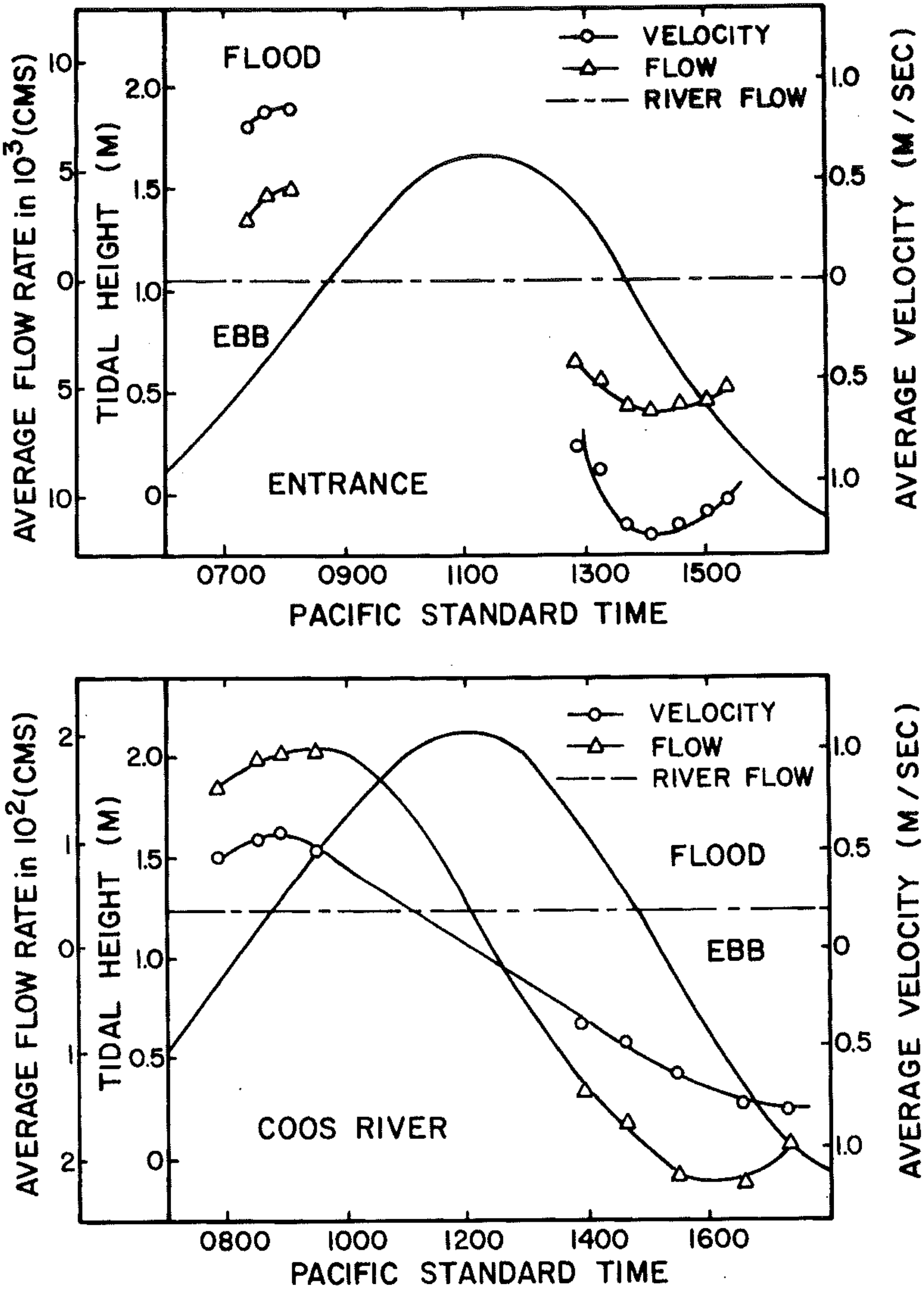
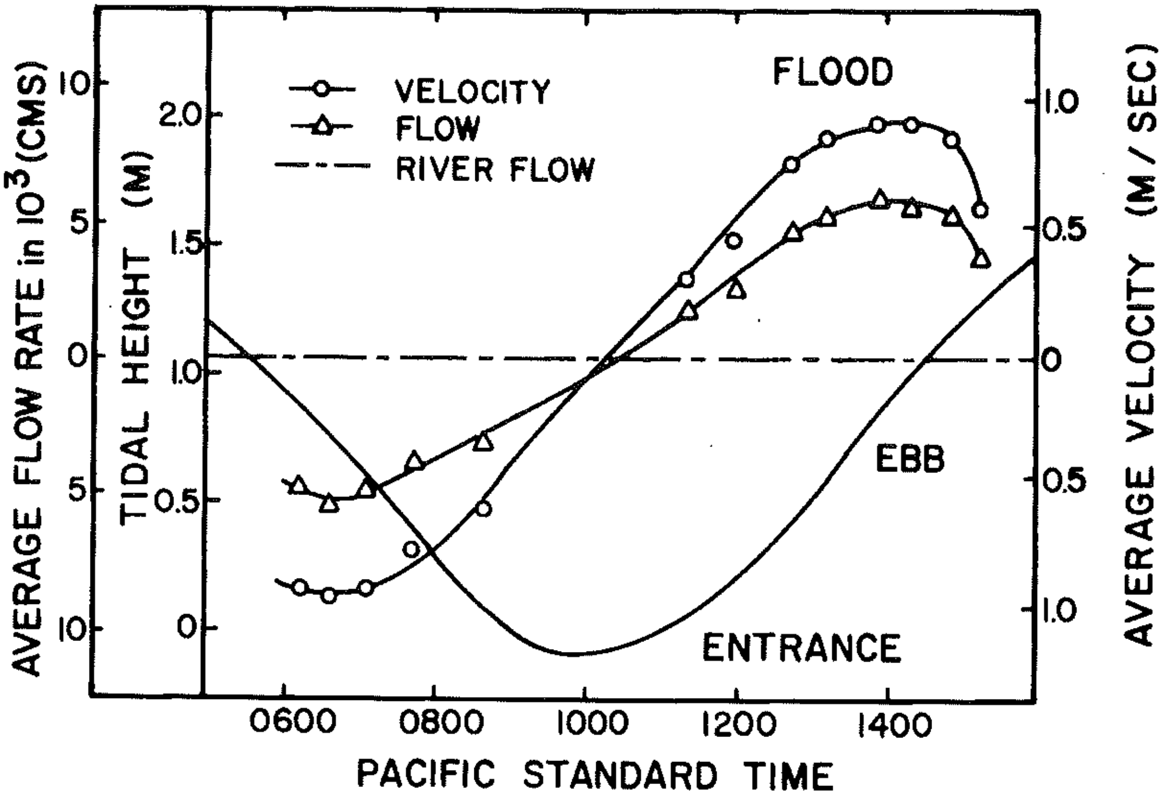


Figure 7. Average flow and velocity profiles, Coos Bay, March 22, 1974



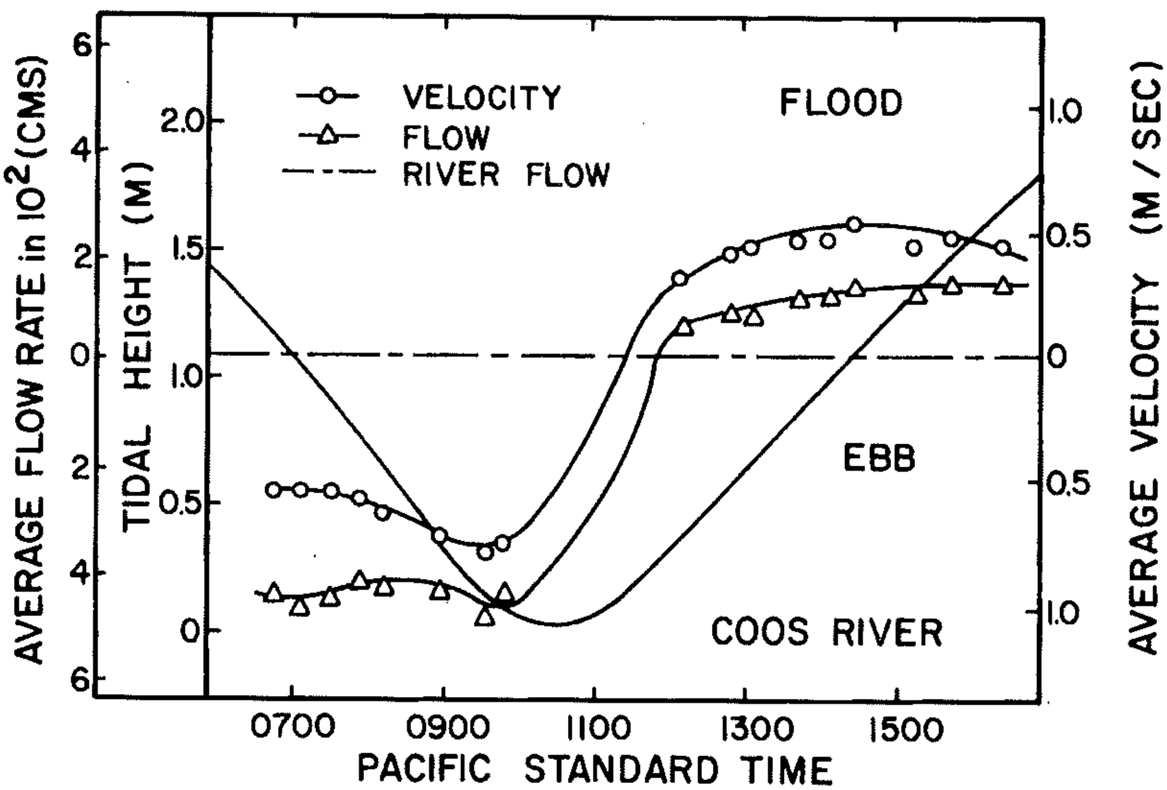


Figure 8. Average flow and velocity profiles, Coos Bay, June 11, 1974

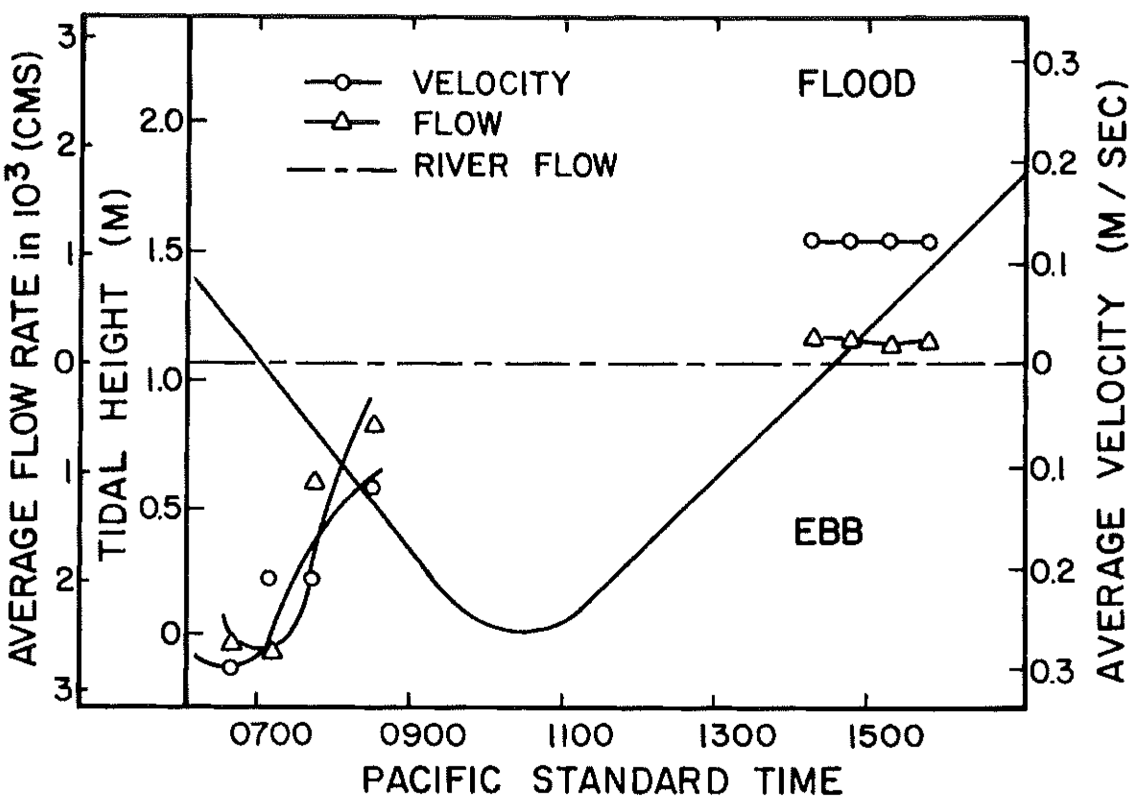


Figure 9. Average flow and velocity profiles, Isthmus Slough, Coos Bay, June 11, 1974

peaked, flow seemed to be leveling off and it was not discernible if the true maximum was reached while data recordings were being made. Velocity again displayed a constant value in Isthmus Slough on June 11, 1974 (Figure 9) on the flood tide. During this period flow decreased and then increased, but to a lesser value than its previous high indicating a maximum may have occurred before measurements were started.

2. Flow Data Interpretation

Phase lags at the entrance on the flood tides were appreciably smaller in the summer than in the spring. This could have been caused by the fresh water flow, which was an order of magnitude greater in the spring. This larger fresh water flow may have impeded the flood tide creating later peaks in the flow and velocity. It would have been easier to confirm this if more data had been retrieved on the flood tides in the fall and winter. Phase lags on the ebb tides did not show as much variance as the flood tides. From this data there appears to be no seasonal dependence on either river flow or tidal range as evidenced by no consistent trend in data results.

Phase relationships in the Coos River appeared entirely different than those at the entrance. Velocity lags on the flood tides were less than those on the ebb tides for each of the seasons. This was just opposite of conditions at the mouth in the spring. The summer season is not used for comparison since it was discerned that there was no significant difference in the velocity phase lags for that season. The probable reason for the phase relationship phenomena can be explained by the relative changes in cross-sectional areas during the tidal cycle. The variation in cross-sectional area is at least twice as great in the Coos River as it is at the entrance. In the spring the cross-section at the Coos River changed by almost 80 percent, whereas the change at the entrance was approximately only 20 percent. This extreme change in cross-section seems to have a greater effect on the velocity than the magnitude of the river flow. At the Coos River during the flood tide the velocity peaked before flow while the water was traveling through the more narrow channel. On the ebb, with the exception of the spring season, the velocity peaked after flow. The velocity did not peak until the cross-section again became small. From this standpoint, it can be seen that the velocity peak should occur sooner following low tide than following high tide. Range and absolute tidal heights also affect cross-sectional areas, but it is thought that they were sufficiently similar to neglect any changes they may have caused. Comparison of the phase lags of flood and ebb flows were not as consistent as those of velocity. The flood lag was longer in summer, shorter in winter, and equal to the ebb lag in the spring. There is no apparent explanation for this behavior.

There was less current data for comparison at Isthmus Slough than at either of the other two current stations. There was also a large degree of variability in the data which was recovered. For these reasons it was difficult to establish any definite relationships in the phase results at Isthmus Slough. Since there is no riverine flow into Isthmus Slough, the current could be expected to behave differently than either the entrance or Coos River. If cross-sectional area is in fact a more dominant influence than the river flow at the Coos River station, then tidal phase results in Isthmus Slough could tend to resemble those of the Coos River. This would be attributed to the significant change in cross-sectional area which also occurs at Isthmus Slough. Both of these stations have wide, shallow-sloping tidal flats on one bank. There is, however, no data concerning the relative influence of cross-sectional area versus river flow to substantiate this assumption.

3. Evaluation of NOAA Tide Predictions

The evaluation of the tide predictions published annually by NOAA was one of the intended purposes of this report. NOAA predictions are made for three locations on Coos Bay, which are the entrance, Empire, and Coos Bay. Accuracy of the predictions was evaluated in this study at the entrance and Coos Bay.

NOAA predictions are based on data which was taken over forty years ago. The measurement station at the entrance was the old Coast Guard boathouse, 2.26 kilometers (1.4 miles) from the entrance. The entrance tidal data for this study was measured at the existing Coast Guard boat house, 4.63 kilometers (2.88 miles) from the entrance. The NOAA measurement station in Coos Bay was located 20.77 kilometers (12.91 miles) from the entrance. Coos Bay data for this study was measured at the Corps of Engineers Dock, 21.23 kilometers (13.19 miles) from the entrance. Although not located in exactly the same locations, it was felt that these measurement stations were sufficiently close for good tidal comparisons.

In order to evaluate the accuracy of the predicted tidal heights, plots were made of predicted range vs. measured range or the ebb tide at each station. Figure 10 shows the comparison at the entrance and Figure 11 that of Coos Bay.

On Figures 10 and 11 the 45° diagonal line represents equal predicted and measured ranges. The dashed lines represent a 15% error in the predicted tide. Exceptions to these error boundaries occur on the summer (September 12, 1973 - September 26, 1973) and winter (March 11, 1974 - March 27, 1974) plots at Coos Bay. On these plots the dashed lines represent 20% error.

The plot at the entrance for summer (September 12, 1973 - September 26, 1973) on Figure 10 indicates that with only several exceptions measured ranges were greater than the predicted ranges.

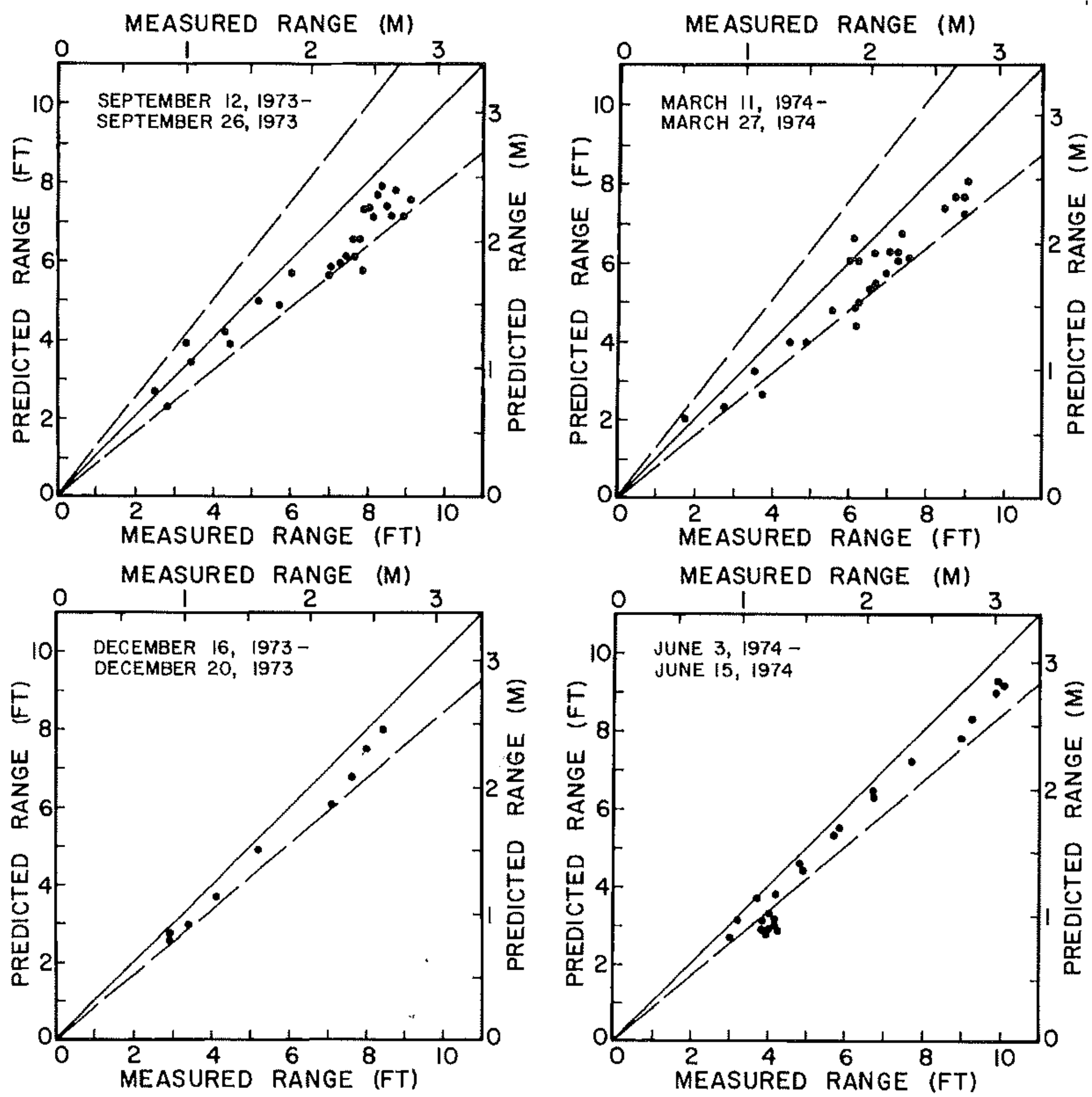


Figure 10. Predicted vs. measured tidal range, Entrance, Coos Bay, 1973-1974

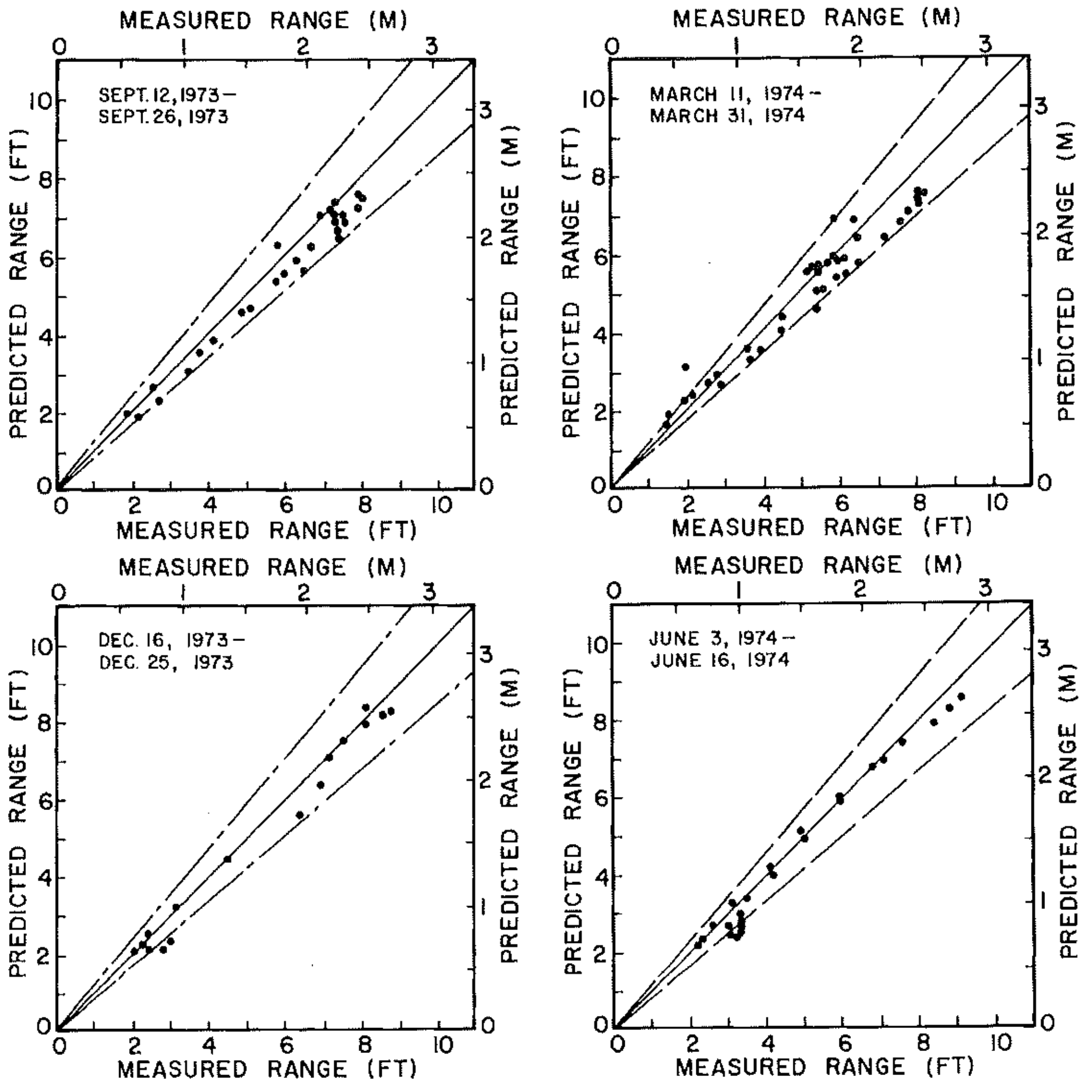


Figure 11. Predicted vs. measured tidal range, Corps of Engineers Dock, Coos Bay, 1973-1974

There were no points which fell outside of the fifteen percent error lines. On the Fall plot (December 16, 1973 - December 25, 1973) only two points plotted below the fifteen percent error range. There did not seem to be any radical change in river flow which may have caused these larger measured ranges. Even though fewer points were plotted, larger measured ranges than predicted ranges were predominant for this season also. The plot for Winter (March 11, 1974 - March 31, 1974) again shows the large majority of measured ranges were greater than the predicted ranges. Only two ranges fell outside of the 15% error lines. Neither of these points appeared dependent on either abnormally high or low river flows. On the Spring plot (June 3, 1974 - June 16, 1974) there were five points with greater than 15% error. None of these appeared dependent on river flow, but each occurrence was during a period of spring tides. The underestimated predicted ranges were all on the tide between low high water and high low water.

The four seasonal graphs at Coos Bay (Figure 11) indicate that predicted range was consistently less than measured range. A combined total of only four data points for all seasons was observed with predicted range greater than measured. The one point on the Summer plot (September 12, 1973 - September 26, 1973) which had an error greater than 20% appeared to have been the result of a very high river flow. The points on the Spring plot (June 3, 1974 - June 15, 1974) which were below the 15% error line occurred during the same period of spring tides and on the same tidal excursions as the low predictions for the entrance (Figure 10).

It is felt that the predominance of larger measured ranges than predicted ranges resulted from the tremendous amount of fill which has been placed within Coos Bay since the measurements were made on which the tidal predictions were based. The initial tidal measurements were made in 1933 and 1934. Beginning in Fiscal year 1937 tidelands in the upper bay were used for spoil islands (18.5 kilometers (11.5 miles) to 21.7 kilometers (13.5 miles) from the entrance) covering approximately 0.34 square kilometers (85 acres) of tidelands (Management of Dredge Spoils in Coos Bay, 1972). Large fills have also been placed in areas near the airport and Eastside. There were numerous other small fill areas as shown on Figure 2. The reduction in tidelands and channel area by these fills appears to be the cause of the higher measured than predicted ranges. It is realized that channel depths have been increased by two to three meters during this same period of time, which could have caused a decrease in measured ranges due to increased cross-sectional areas. It appears, however, that the combination of filling of the shallow tidelands and deepening of the navigation channels has produced a more hydraulically efficient cross-section for the tidal wave to propagate through. Thus, less dampening takes place resulting in an increase in tidal range.

In order to evaluate the accuracy of the times of predicted high and low tides, histograms of the time error of the predicted tides were constructed as shown on Figures 12 and 13. A positive error indicates a predicted tide occurred later than the measured tide. A negative error indicates a predicted tide occurred earlier than the measured tide. The histograms include data from all seasons.

The histograms for the entrance both exhibit a normal distribution although neither were centered around zero. The high tide errors were negatively skewed with 62% of the predicted times early while only 19% were late. Nineteen percent of the times were in the zero interval; that is they occurred between five minutes early and five minutes late. Seventy-nine percent of the predicted times occurred within twenty minutes of the actual times. The low tide errors were also negatively skewed. Positive errors totaled 34% and negative errors totaled 42%. The frequency of zero error was 24%. Eighty-one percent of the predicted times occurred within twenty minutes of the actual times.

The histograms at Coos Bay were not normally distributed as those at the mouth were. On both the high and low tides predicted times were later than those measured. There was a frequency of 1% in the zero interval on the high tide which was in fact only one occurrence. On the high tide 41% of the predicted times occurred

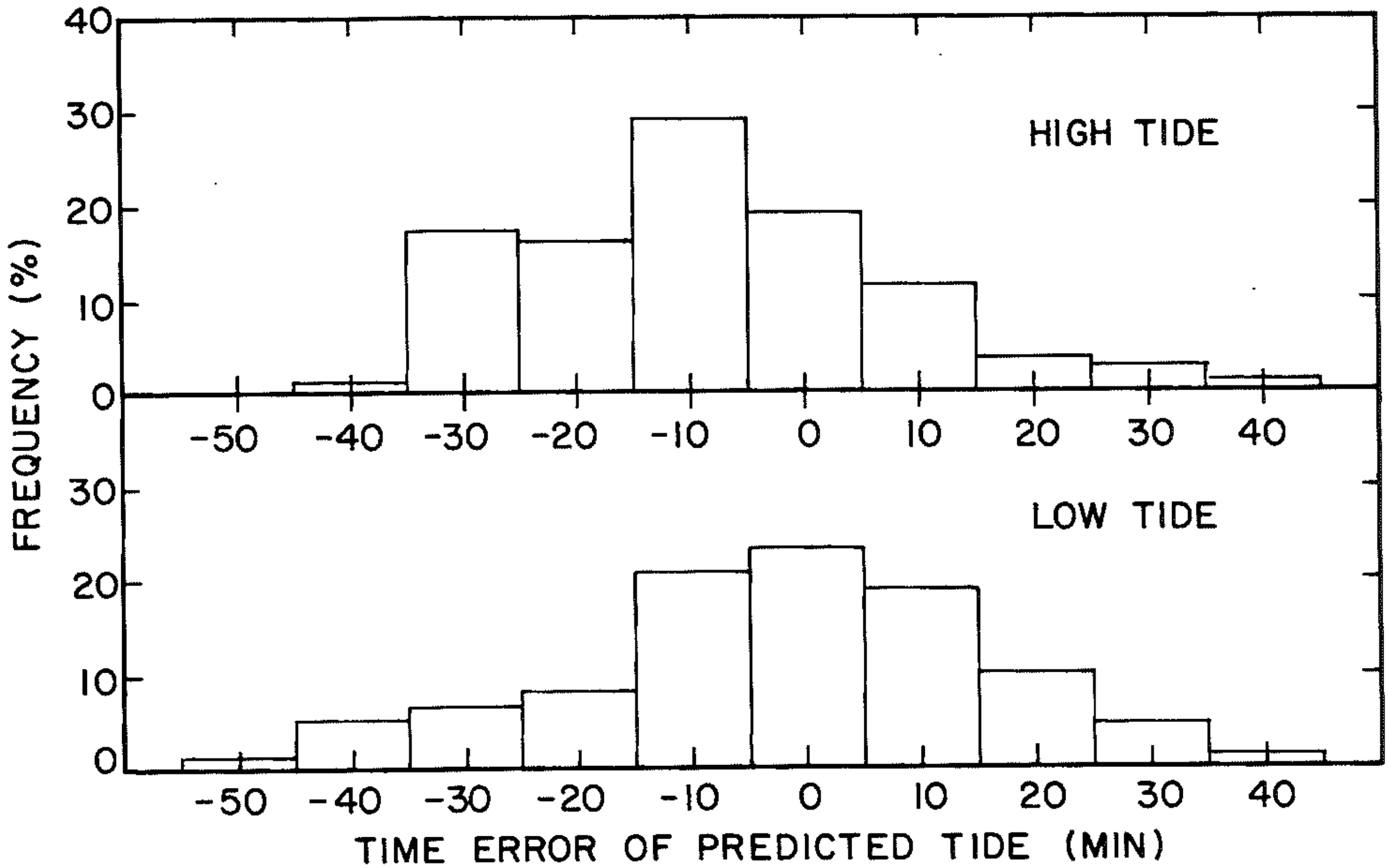


Figure 12. Histogram of time error of predicted tides, Entrance, Coos Bay, 1973-1974

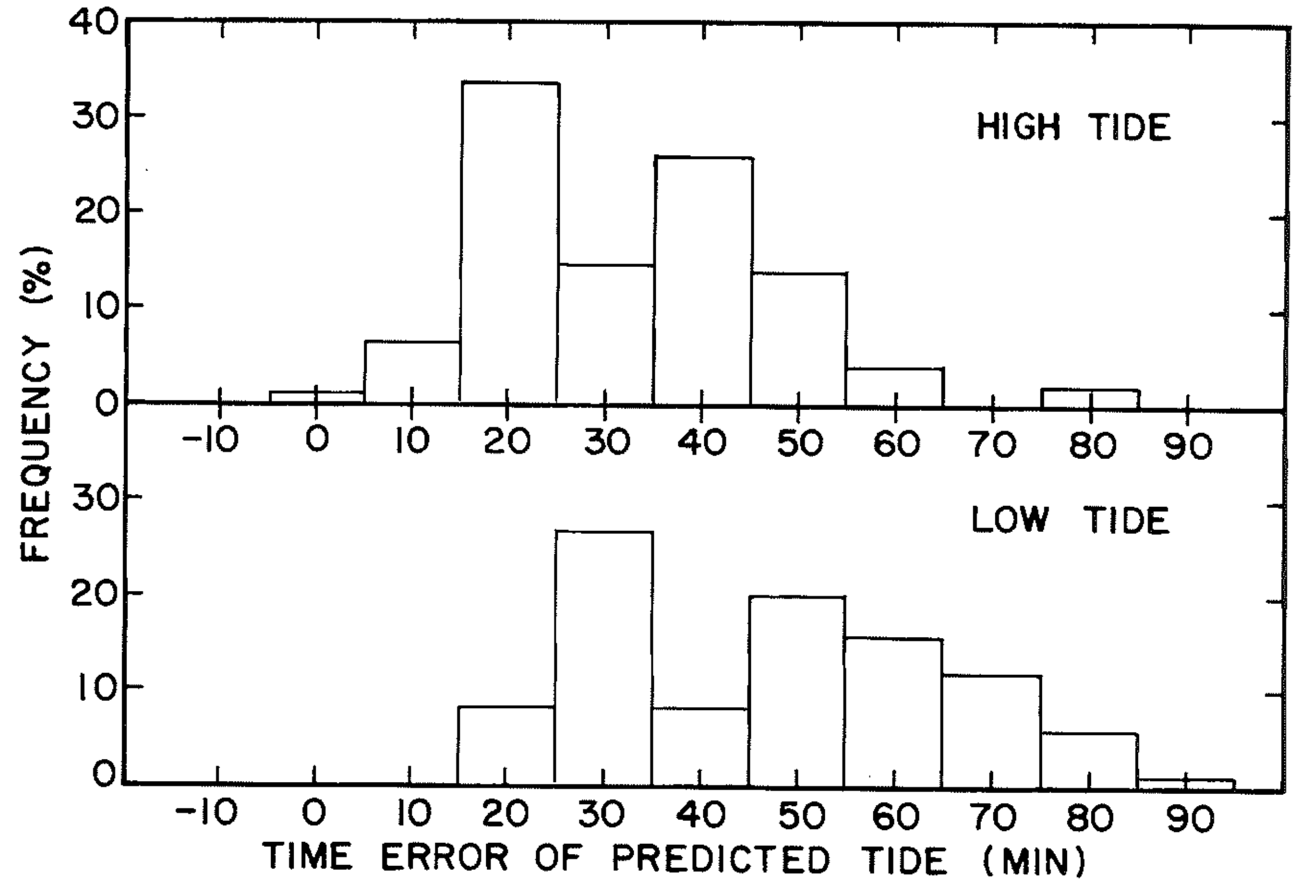


Figure 13. Histogram of time error of predicted tides, Corps of Engineers Dock, Coos Bay, 1973-1974

within twenty minutes of the actual times while only 8% were within this range on the low tide.

There was a great difference in the accuracy of the NOAA predicted tidal times between the entrance and the Coos Bay locations. At the entrance the average of high and low tides correctly predicted within twenty minutes was 80% compared to only 25% at Coos Bay. Apparently the alterations in the estuary have not significantly affected the time predictions at the entrance. This is further evidenced by the normally distributed histograms, even though they are somewhat negatively skewed. At Coos Bay the measured tides occurred earlier than those predicted; this is logical due to the increase in the mean channel depth after the measurements for predictions were made. The tidal wave now travels faster in the deeper water according to shallow water wave theory. As previously explained, the celerity increases as the mean depth increases. Another contributing factor to measured heights occurring earlier than predicted is the extensive fills. The fills have created a smaller estuarine volume which allows the tide to fill and empty it more quickly than it did when the volume was larger.

Upon evaluation of the predicted tidal range and times, it is evident that NOAA should revise its predictions. The errors in range are not extreme, but the time errors, especially at Coos Bay are unsatisfactory. Times of maximum tides are very important to the large commercial ships. A high tide error of an hour or more could be inconvenient and hazardous when getting underway on one of the deep draft vessels. Running aground in the estuary would be quite possible at a lower than expected stage of the tide.

4. Lag

Seasonal plots were constructed of measured ranges vs. measured lags on the high and low tides for each of the upstream tidal recording stations. The lag times computed are the difference of maximum and minimum tidal heights between the upstream stations and the station at the entrance. These lag times indicate the time it takes the tidal wave to travel to the different locations in the estuary. Variation in lag times was investigated to determine a seasonal influence, differences between high and low tide, or a dependence on range.

Figure 14 shows the data from the Roseburg Lumber Dock. The average high tide lag was longer than the low tide lag for all seasons. From this data it appears that the lag times definitely do not follow the shallow water wave theory which would predict less lag time on the high tide. The fall season (Dec. 24-Dec. 25) exhibited the longest average high tide lag time. This was expected at high flow due to the effects of river flow impeding the tide. Summer (Sept. 12 - Sept. 26), which was the season of least river flow, did not have the

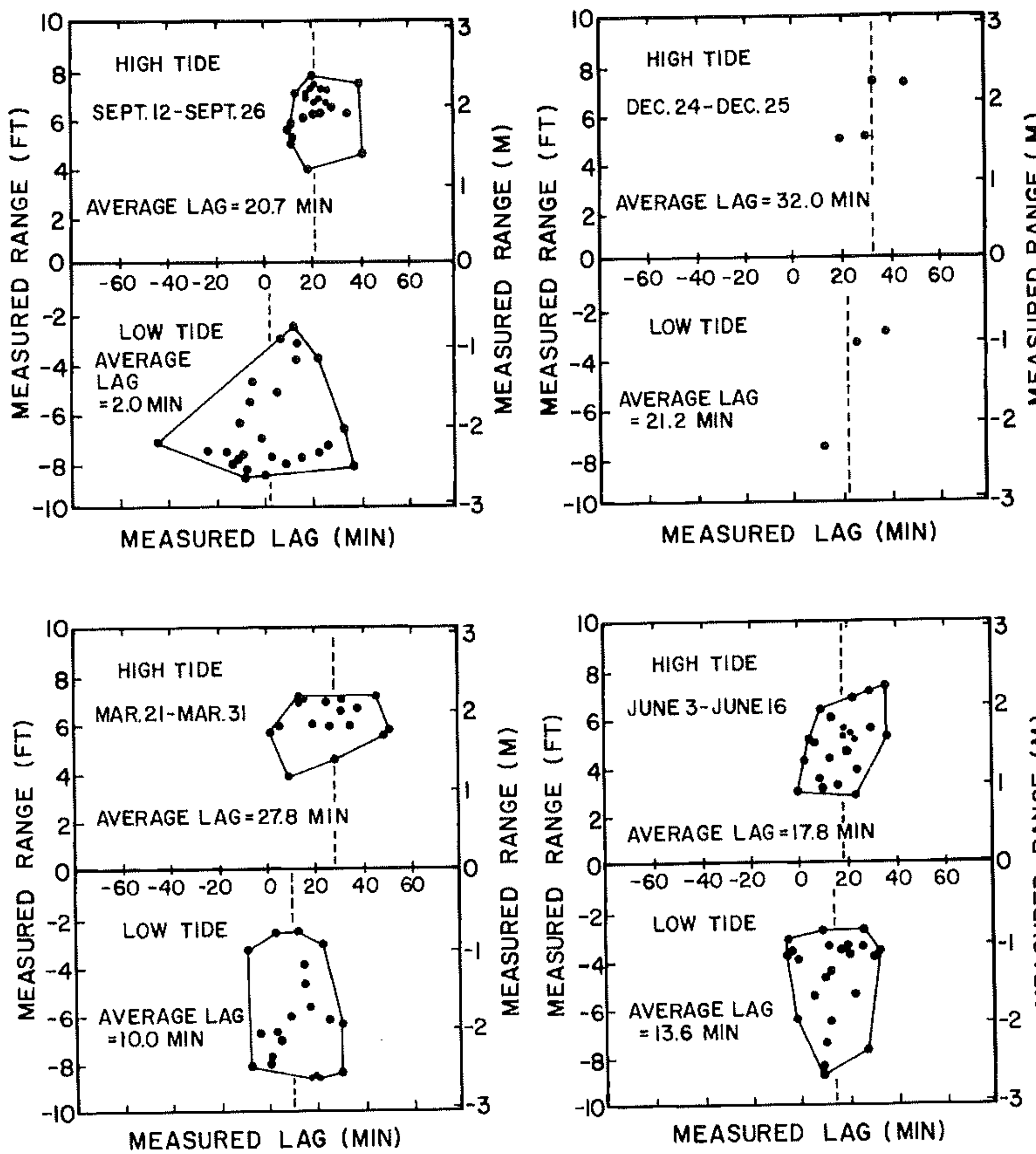


Figure 14. Measured range vs. measured lag, Roseburg Lumber Dock, Coos Bay, 1973-1974.

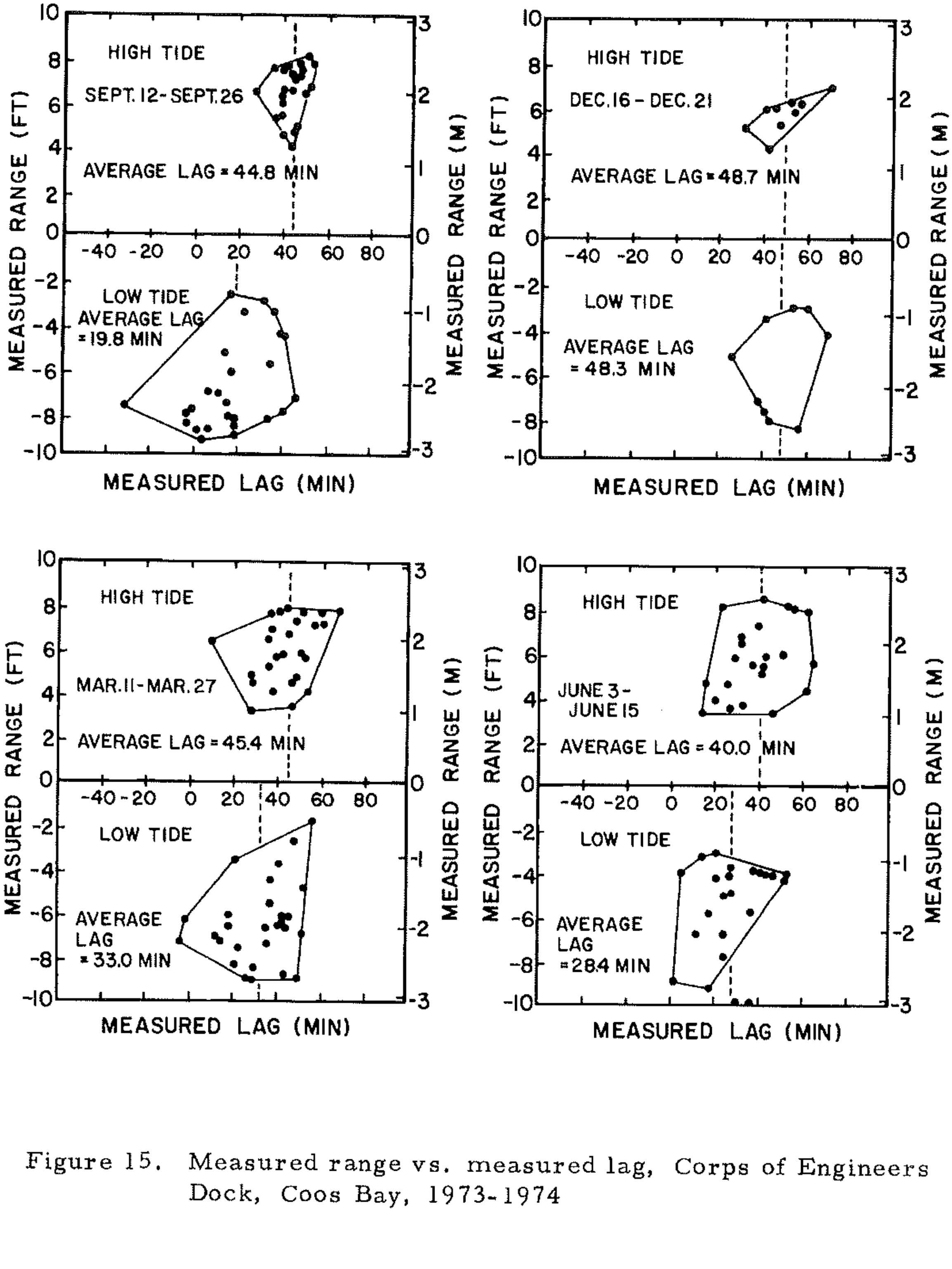


Figure 15. Measured range vs. measured lag, Corps of Engineers Dock, Coos Bay, 1973-1974

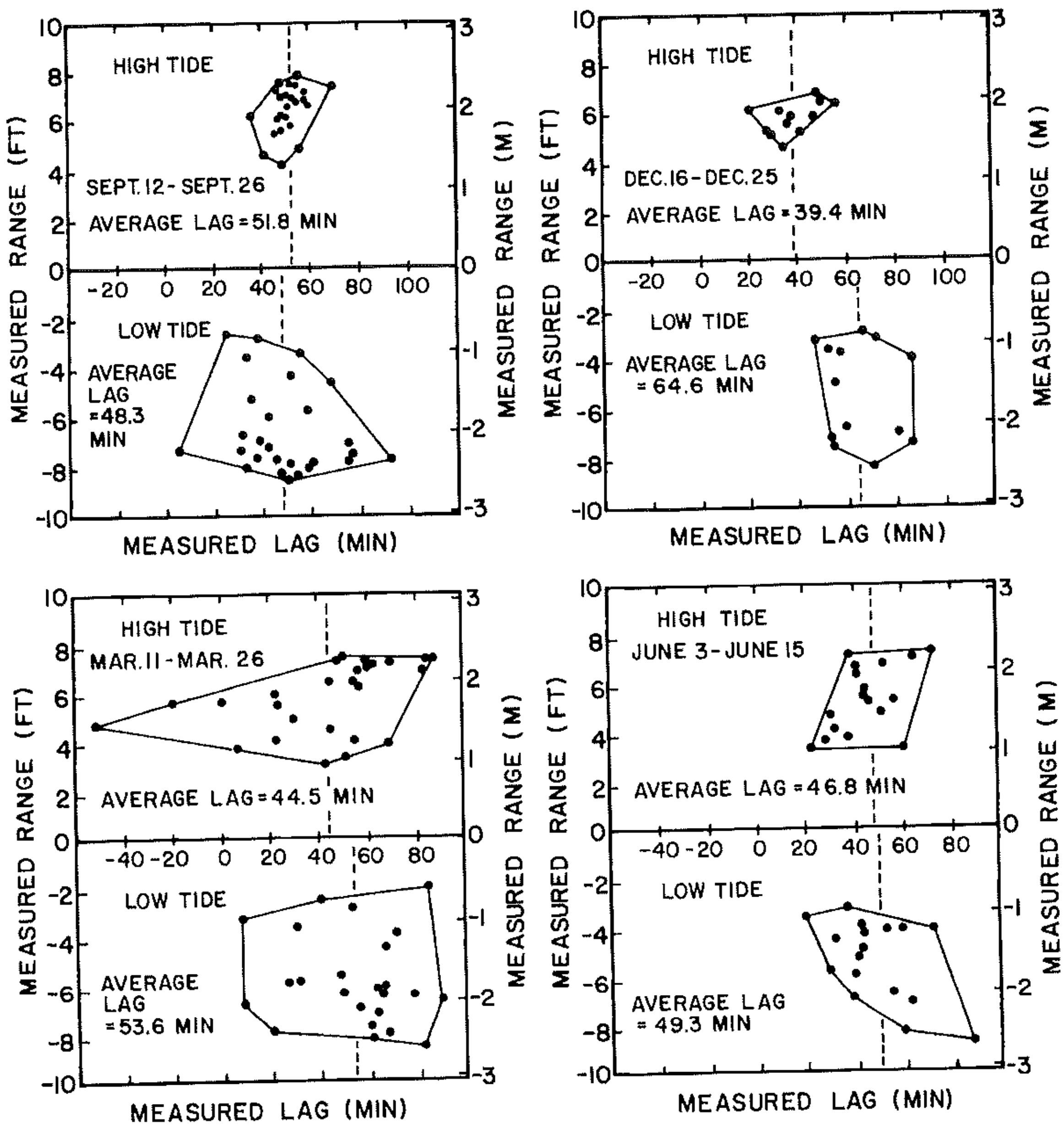


Figure 16. Measured range vs. measured lag, Catching Clough, Coos Bay, 1973-1974

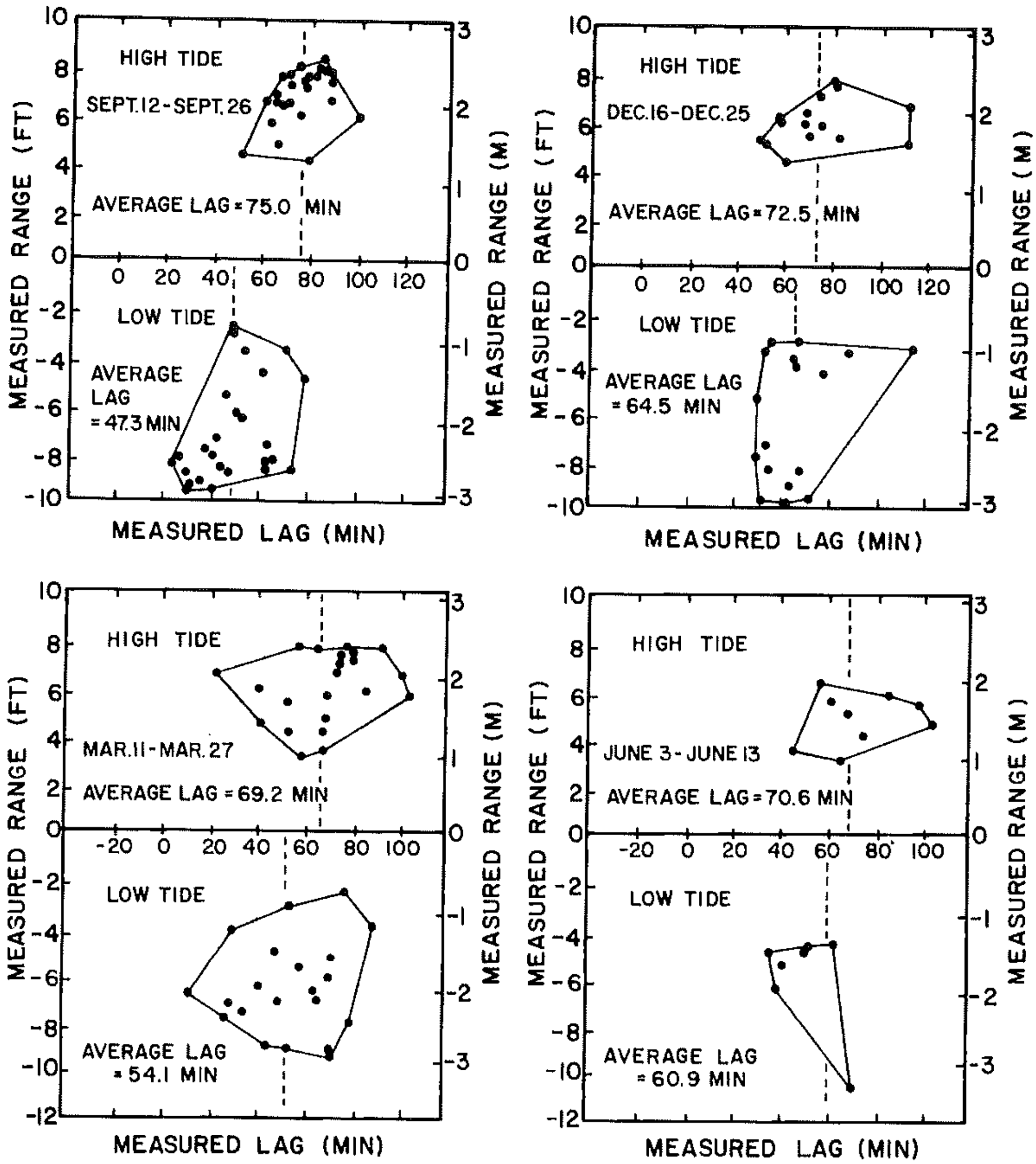


Figure 17. Measured range vs. measured lag, Shinglehouse Slough, Coos Bay, 1973-1974

shortest lag time. It was only three minutes longer than spring (June 3 - June 16), however, and this variation could be attributed to data scatter. The trend of decreasing high tide lag time with decreasing seasonal river flow still seemed to exist. Low tide average lag times did not follow any seasonal pattern. These varied from 2.0 minutes in the summer to 21.2 minutes in the fall. The times were more widely dispersed on low tide than on high tide. There did not appear to be any dependence of the low tide lag times on range. The high tide lags appeared longer for greater ranges. If the estuary fills similar to a reservoir, then large ranges could cause longer lags due to the increased volume of water being transferred during the tidal cycle.

Oregon State University data plots (1975) from measurements taken at the Corps of Engineers Dock (Figure 15) followed the same trend as the data at the Roseburg Lumber Dock with the high tide average lags being longer than the low tide average lags. The high tide average lags were very similar for all seasons and did not appear dependent on river flow. The high tide lags did show range dependence. The longer lags were exhibited on the higher ranges. Low tide average lags appeared seasonally dependent on river flows. Longer lags occurred during the seasons of higher flow rates. The result is predictable if the effect of the river is that of a source rather than an inertial force. The higher flow rate tends to place more water in the estuary during flood tide making it necessary to drain more water on an ebb tide. This means that higher flow rates can cause longer low tide lag times. Low tide lags did not appear to be range dependent.

Figure 16 shows the data which was gathered at the entrance to Catching Slough. With the exception of summer (Sept. 12 - Sept. 26) the difference in high and low tide average lag times seems to fit the shallow water wave theory, that is, high tide lags are less than those of low tide. The summer difference was only several minutes with widely scattered results on low tide which may have caused the shorter average lag. Seasonal influence of the river as a source was experienced on both the high and low tide at this station. During the fall season (Dec. 16 - Dec. 25) which, as previously stated, was the season of highest river flow, the average high tide lag time was the shortest. For this season the average low tide lag time was the longest. As the seasonal river flows decreased the average lag times for high and low tide increased and decreased, respectively. Seasonal river flows are summarized in Table I. There was a moderate trend on the high tides for longer lag times with higher ranges. No trend of this type was visible on the low tides.

Figure 17 shows the plots of data from the station at Shinglehouse Slough. Average high tide lag times were longer than low tide as they were at the Roseburg Lumber Dock and the Corps of

Engineers Dock. There was no seasonal river flow influence. This was expected since there is no direct river flow in Isthmus Slough. Neither the high nor low tide lags indicated a dependence on tidal range.

From the lag time results at these four stations, it can be seen that the tidal phenomenon within Coos Bay is very complicated. The disparity of the inertial force and source explanations for changes in lag times are difficult to resolve since these two theories give opposite results. It is felt that both are applicable, only in different situations. They are dependent on the volume of the estuary, the tidal prism, and the magnitude of river flow. The effect of increasing channel depth and placing fill within the estuary should again be considered. The increased channel depth causes the speed of the tidal wave to increase; filling the estuary decreases its volume and allows the tide to fill and empty the estuary more rapidly. Both of the explanations for the changes in lag times also appear to depend on whether a measurement station is located in the embayment or riverine portion of the estuary. From this study, it is not possible to say which factor is dominant or is the proper explanation, but only to conclude that lag times are extremely variable and would be difficult to predict at different locations in the estuary.

5. Amplification and Damping

Figures 18 through 21 have been included to display the effect of river flow on tidal damping. A comparison of the range ratios for a given flow rate can also be made between locations to determine the amplification or damping of the tidal wave as it moves upstream. The range ratio is the tidal range at the local station divided by the range at the entrance; this ratio has been defined as the amplification factor (Goodwin, Emmett, and Glenne, 1970). Flow rates plotted on these figures are those which were extrapolated as previously described. The data was compiled from all seasons.

It can be seen from Figures 18 through 21 that the amplification factor was greater than 1.0 at each station for all recorded flow rates. This indicates that there was tidal amplification present at all times during this study. Only three of the stations were compared to determine longitudinal amplification in the estuary. These were Roseburg Lumber Dock, Corps of Engineers Dock, and Catching Slough. Isthmus Slough was not used since it is not affected by direct river flow.

For flow rates of approximately 1.0 cubic meter per second (CMS), the amplification factor was seen to increase from the Roseburg Lumber Dock to the Corps of Engineers Dock, and then decrease again at Catching Slough. These changes could be explained by a

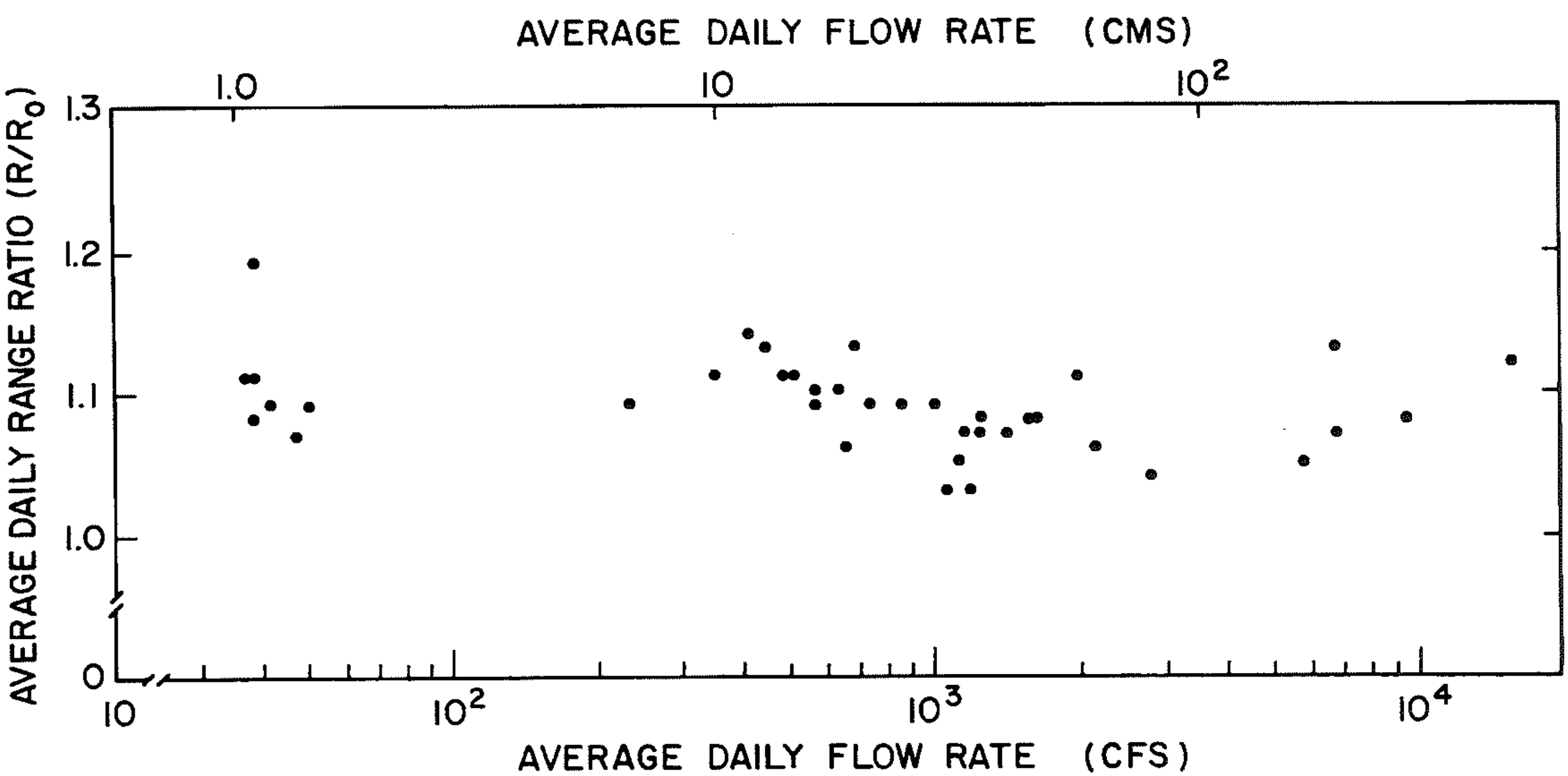


Figure 18. Average daily range ratio vs. average daily river flow, Roseburg Lumber Dock, Coos Bay, 1973-1974

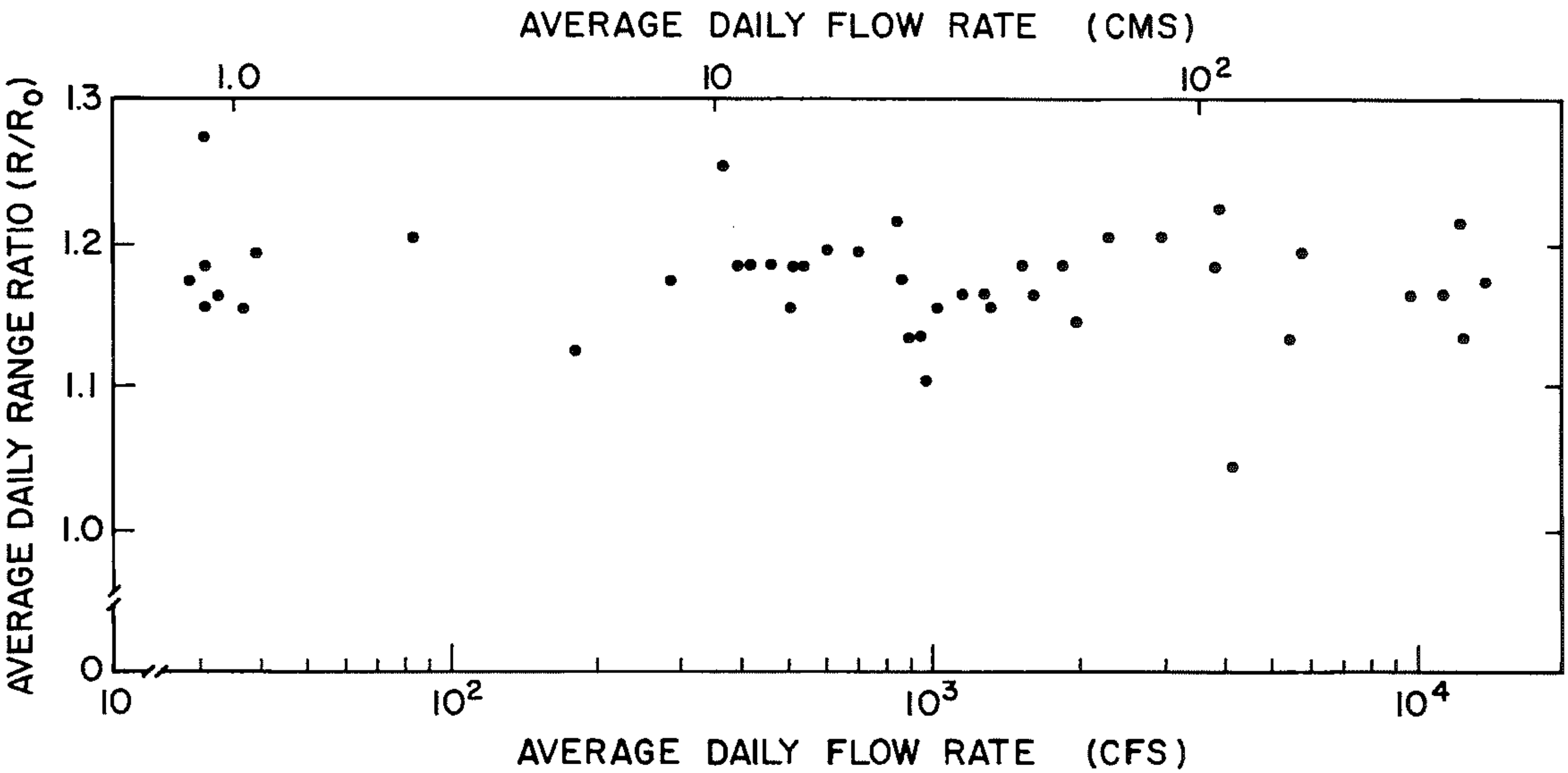


Figure 19. Average daily range ratio vs. average daily river flow, Corps of Engineers Dock, Coos Bay, 1973-1974

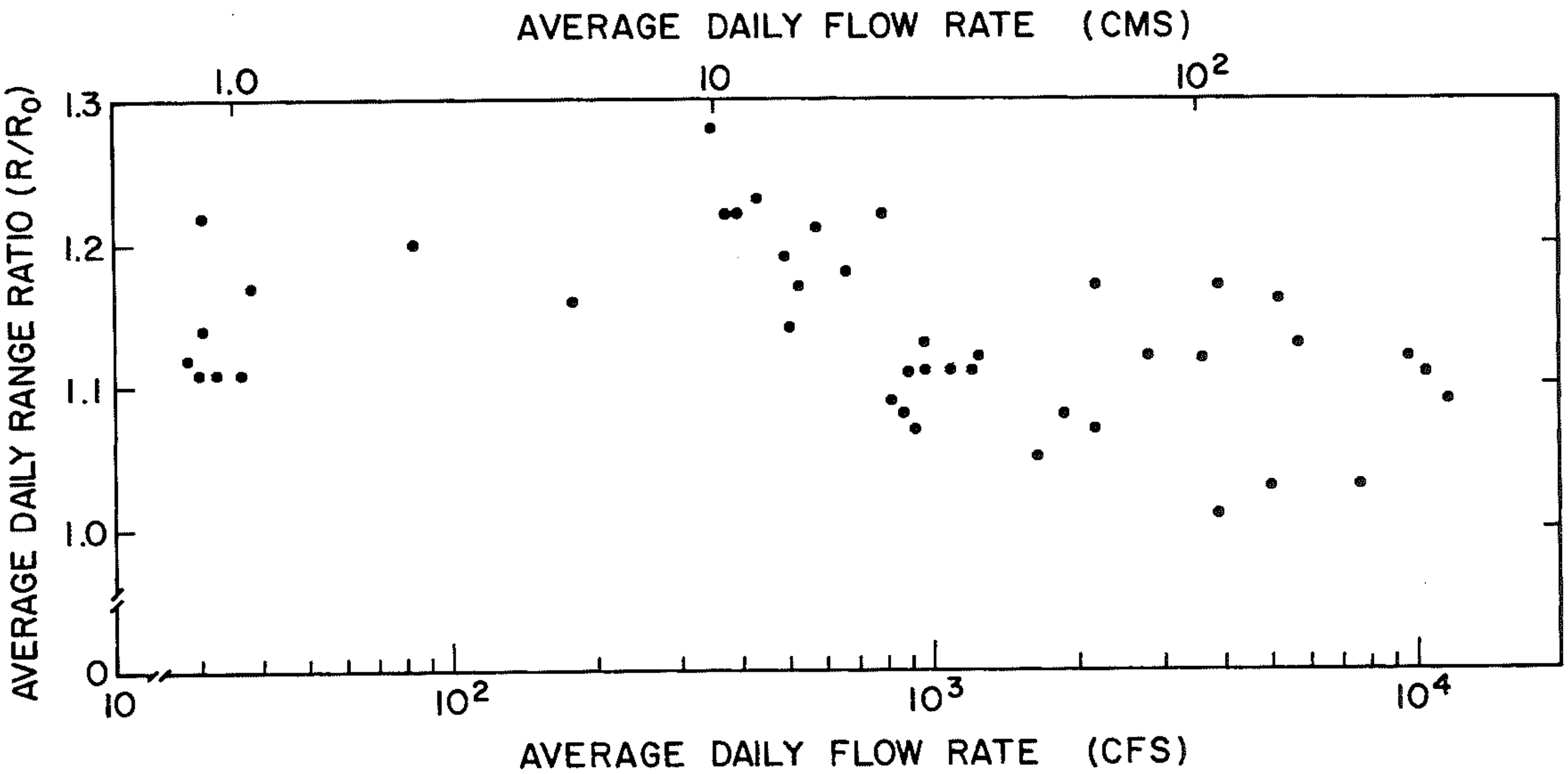


Figure 20. Average daily range ratio vs. average daily river flow, Catching Slough, Coos Bay, 1973-1974

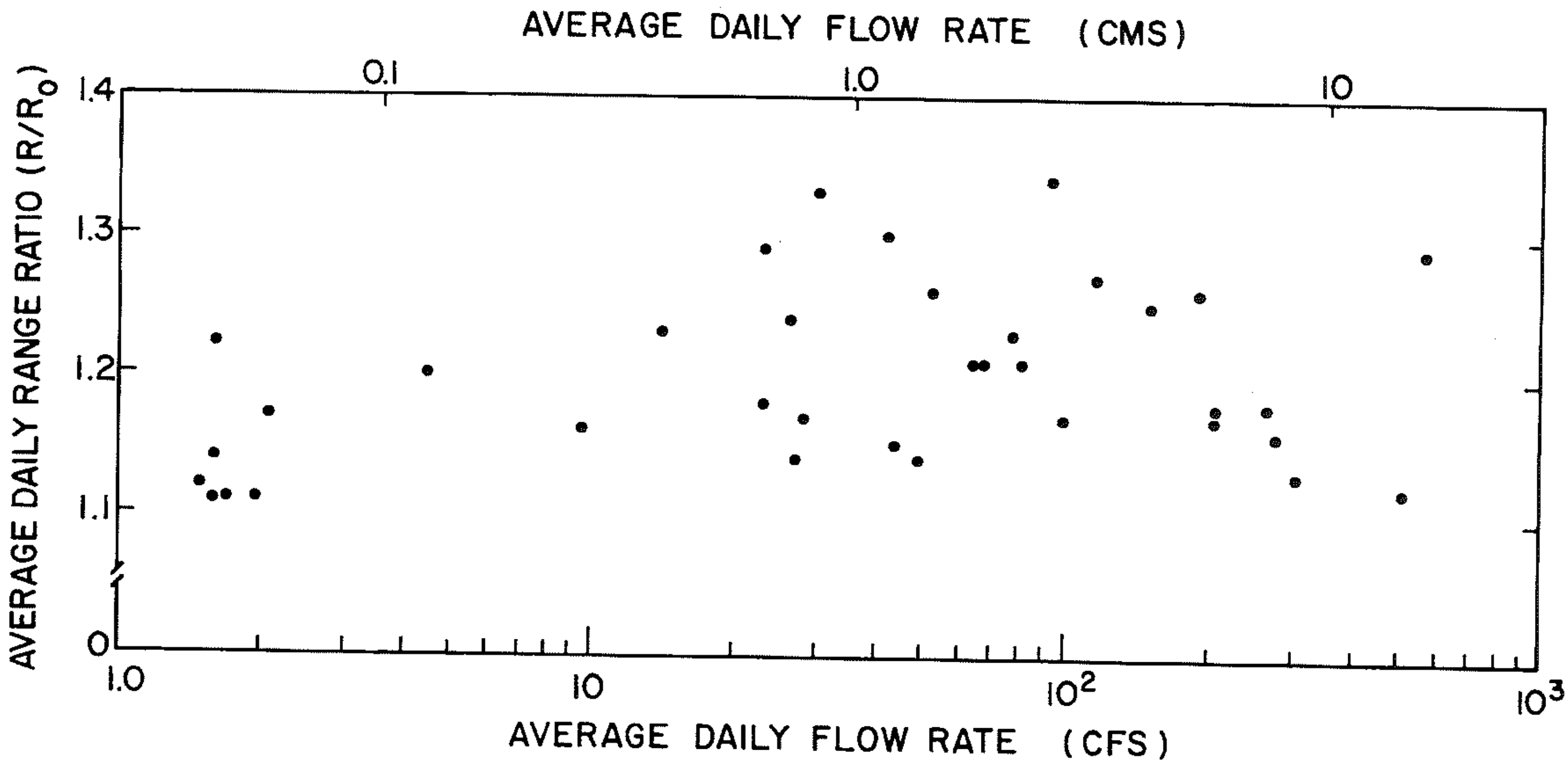


Figure 21. Average daily range ratio vs. average daily river flow, Shinglehouse Slough, Coos Bay, 1973-1974

convergence followed by a divergence of the estuary without considering boundary friction. Between flow rates of 1.0 CMS and approximately 10.0 CMS, amplification seems to continually increase proceeding upstream. At flow rates greater than 10.0 CMS there is still amplification between the Roseburg Lumber Dock and the Corps of Engineers Dock. At this point at Catching Slough, however, there was an exponential decrease in the amplification factor. At the Roseburg Lumber Dock and the Corps of Engineers Dock there was a slight decrease for the entire range of increasing flows. No trend was discernible for the small amount of data below 10 CMS at Catching Slough. Boundary friction is the factor which causes the decreases at all three stations. The probable reason for the sharp decrease of amplification factor at Catching Slough was that at this critical flow rate the water spread out onto the shallower-sloped tidal flats where it encountered much greater boundary friction. The great difference in boundary friction caused the rapid reduction in amplification factor. The divergence caused by the wider channel may have also contributed to the decreasing amplification factor. This same trend of a rapid exponential decrease at some critical flow rate was also reported to occur by Rauw (1975) and Utt (1974) on the Siletz and Siuslaw estuaries, respectively.

The range ratios at Shinglehouse Slough were included to show that amplification occurs at that location. Because of the magnitude of data scatter it was not possible to detect any dependence on flow rate. It should again be remembered that runoff is the extrapolated flow at this station, and it is not Coos River flow.

6. Cooscillating Tide

As it has been previously stated, the tidal motion of Coos Bay was thought to exhibit the characteristics of a cooscillating tide. A cooscillating tide in an estuary can be thought of as a first order spring mass damper system. Slotta and Hudspeth (1975) developed a method for using the cooscillating tidal theory which references upstream ranges to the ranges at the mouth. The previous method (Harleman, 1966) necessitated establishing a head of tide, which is quite difficult to precisely accomplish. It is believed that using the mouth as a reference point is a much more accurate method. Computer printouts (Slotta and Hudspeth, 1975) were used to construct Figure 22.

The plots shown on Figure 22 are the ratios of the ranges at upstream stations divided by the corresponding ranges at the mouth, $\frac{\eta_H}{\eta_{OH}}$, versus the time angle, σ_{t_H}, at the upstream stations. Two plots were made, one with falling tide ranges and one with rising tide ranges. The data was recorded at Roseburg Lumber Dock, the Corps of Engineers Dock, and Catching Slough. The time angles are

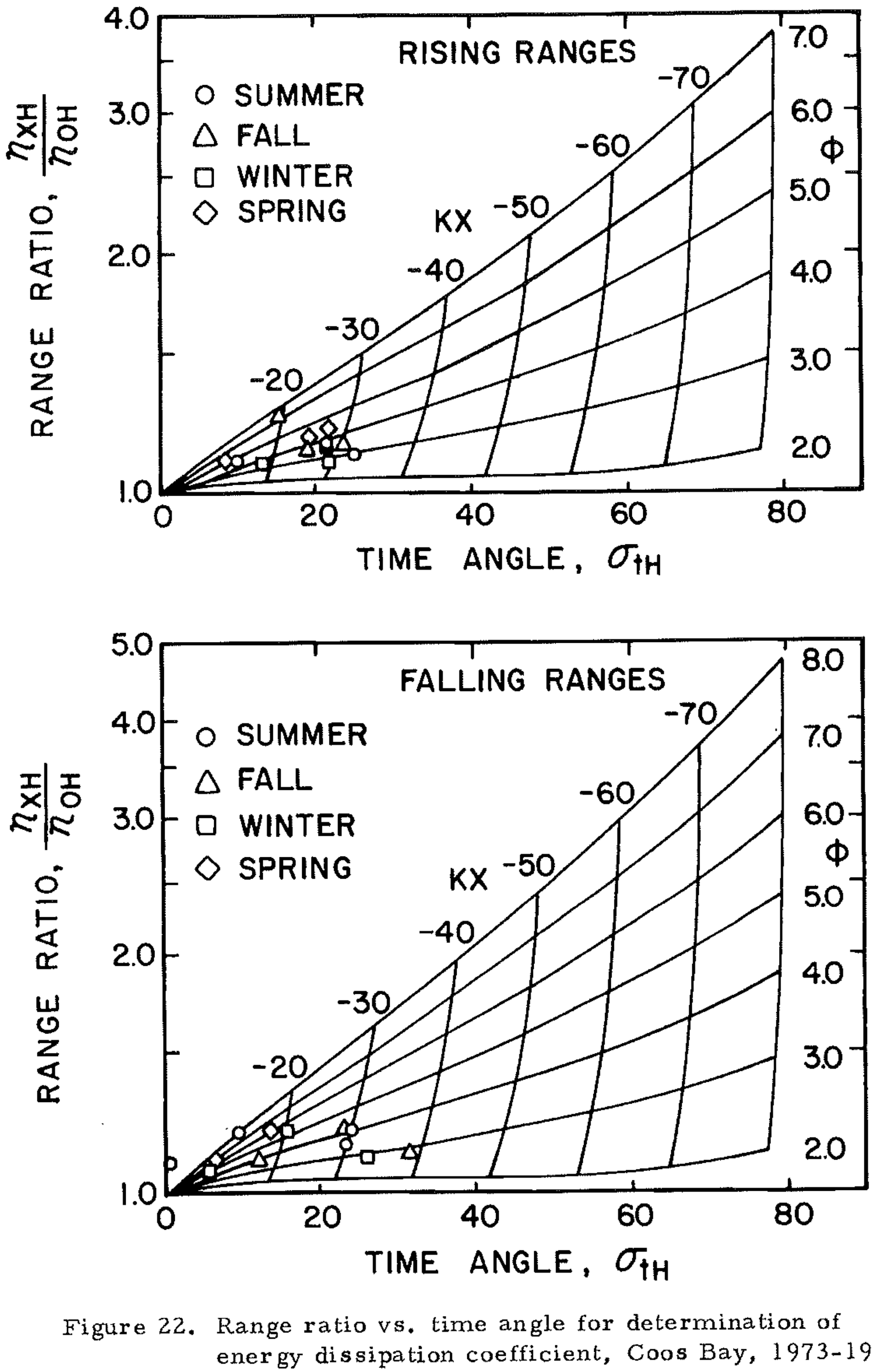


Figure 22. Range ratio vs. time angle for determination of energy dissipation coefficient, Coos Bay, 1973-1974

the measured lag times of high and low water at the upstream stations which were converted to degrees. ϕ is defined as the dissipation coefficient and Kx is the phase change.

Cooscillating tide theory indicates that ϕ is constant for a given estuary. If ϕ is known then the damping modulus, μ, can be determined from the following relationship (Ippen, 1966b):

$$\mu x = Kx \frac{\phi}{2\pi} \qquad (3)$$

The distance upstream is defined by x. By knowing μ, k, and ϕ, the tidal velocity at any point in the estuary can be calculated. If the estuary behaves according to this theory, tidal predictions are relatively simple since there is no need to choose a friction coefficient as with other methods of analysis. Tidal elevations and times, which are all that is needed for the plots are usually readily available (Harleman, 1966).

Figure 22 shows that the Coos Bay tide is not strictly defined by the cooscillation theory. Only one season had a relatively constant ϕ. ϕ was approximately 4.5 in the spring on the rising range plot. The other data on the rising plot were quite scattered. All of the seasons on the falling range plot followed the same trend. There was, however, no constant ϕ. It is thought that a satisfactory model of the estuary could not be made on the basis of the cooscillating tidal theory. This is due to the fact that the estuary does not have either a nearly rectangular geometry or an exponentially varying width from the mouth to the head of the tide. These are the two unique geometries which can be closely approximated with the cooscillating theory (Harleman, 1966).

Blanton (1963) calculated the energy dissipation of Coos Bay by taking the difference of energy transported between sections. His calculations were based on $\phi = 2.5$. Although it is not stated, it is assumed from Blanton's figures that a reflective coefficient of 1.0 was used on the nomograph from which he determined ϕ. In comparison the reflective coefficient used to plot Figure 22 was 0.25. Blanton's range ratios indicated damping of the tidal wave as it moved upstream, whereas those of this study were amplified. The amplification necessitated using the smaller reflective coefficient in order to fit the data on the plot. As the reflective coefficient decreases, the values of ϕ rotate counterclockwise. It is felt that changes to the estuary in the last ten years have not been of sufficient magnitude to cause such drastic changes to the tidal response. Therefore, Blanton's value for ϕ appears to be in error. This is highly possible due to the minimal amount of tidal data on which it was based. The data was only recorded for a period of eight hours, which seems quite unsatisfactory for determining characteristics of the tidal wave. In contrast, the data used to plot Figure 22 represents approximately eight weeks of recording tidal heights.

7. Application of Goodwin's Model

In the past several years there have been numerous numerical models developed for estuaries. A catalog of many of the models was published by Gordon and Spaulding (1974). Application of these models is contingent upon availability of the necessary data for computer input. In order to have this data, the model to be used should be chosen before a study is begun. In doing so, field research can be conducted to retrieve the desired data.

When this study was started, no specific model was selected for the simulation and prediction of estuarine characteristics. After analyzing the available data, a model by Goodwin (1974) was selected for prediction of tidal ranges. A complete description of Goodwin's model can be found in his Ph.D. thesis "Estuarine Tidal Hydraulics: One Dimensional Model and Predictive Algorithm" (1974). In brief the model is one-dimensional and assumes a homogeneous fluid with negligible wind and Coriolis forces. Other important assumptions include: no inflow of tributaries along the estuary, flow to and from storage areas has no inertial effect on flow in the main channel, and the bottom of the channel is horizontal in each estuary segment (Farreras, 1975).

In order to use Goodwin's model, the estuary first had to be schematized; that is, divided into segments in which there is not significant variance in width, depth, and bottom slope. This was quite difficult with Coos Bay due to the vast difference between the dredged channel and the shallow-sloping tidal flats. However, approximations were made in order to construct segments of trapezoidal cross-section with equal side slopes. The schematization, including all the tabulated values for each segment needed as computer input, and other necessary data such as river inflow and ocean tidal amplitude were provided to Salvador Farreras who inserted it into Goodwin's program on the Oregon State University CDC 3300 computer. Computer output included: tidal surface displacement at the centroid of each segment and flow and velocity at segment endpoints at selected time intervals. There was also a summary table of times of maximum and minimum displacements, maximum and minimum flow and velocity, slack water, and amplification factor at each segment. The surface displacements were used to construct Figure 23.

Figure 23 compares observed ranges with those predicted by the model. Even though the model was designed for best results when the estuary is well-mixed or partially-mixed, results were surprisingly good in all seasons including fall (December 19, 1973) when parts of the estuary were stratified. The deviations of 0.05 meters (0.16 feet) to 0.12 meters (0.39 feet) are comparable to Goodwin's (1974) results on the Yaquina, Siletz, and Alsea estuaries

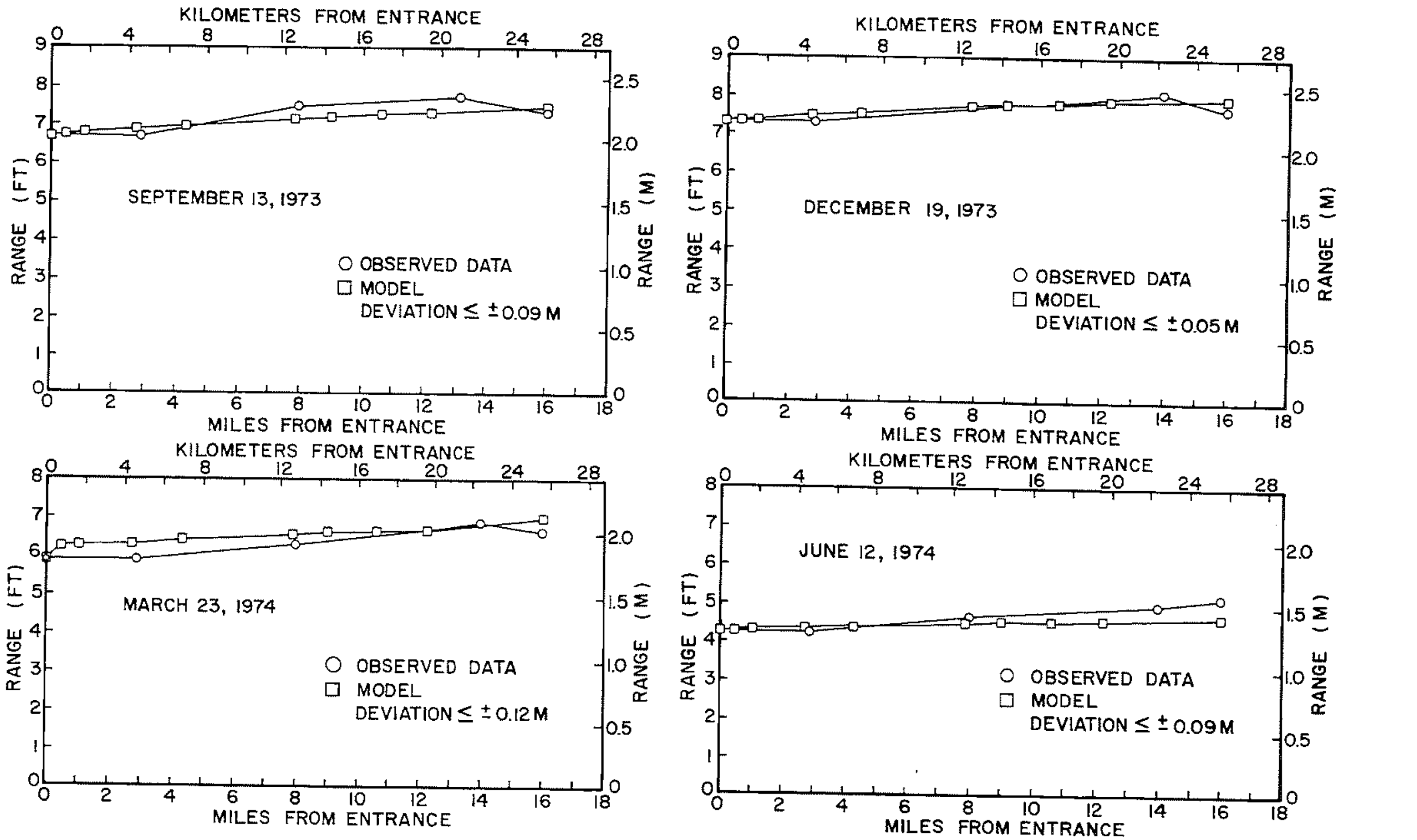


Figure 23. Comparison of measured and model predicted ranges, Coos Bay, 1973-1974

which were generally less than 0.06 meters (0.2 feet). The largest deviations which occurred was on March 23, 1974. There was no obvious reason for this deviation. It was possibly caused by wind or other factors not accounted for by the model.

A mean predicted amplification factor of all segments for the days plotted on Figure 23 was calculated to be 1.05. This validates the measured amplification factors of Figures 18 through 21 and shows that the tidal wave is indeed amplified within the estuary and not damped as previously reported by Blanton (1963).

It can be seen from Figure 23 that Goodwin's model can be used for satisfactory predictions of tidal ranges. There is, however, one inherent problem with the model which is not discernible from Figure 23. The program outputs a tidal wave which is a sinusoid, and does not simulate the semi-diurnal tide experienced in Oregon's estuaries. For this reason the tidal wave is closely approximated on one-half of the tidal cycle with the larger deviations occurring on the other half. Future work should be done to alter the program to simulate the semi-diurnal tide.

V. WATER QUALITY AND ESTUARINE CLASSIFICATIONS

A. Introduction

In the past estuarine waters have been thought of as picturesque places of beauty but in reality have been used as mere conveniences and sewers. They have served as thoroughfares for waterborne commerce, sites for large industrial complexes, and refuges for innumerable amounts of waste materials. There has been little concern for the quality of the estuarine water. Within the last decade realization has come to the forefront that gross misuse of these valuable assets must stop. In November 1969, the Federal Water Quality Administration submitted the National Estuarine Pollution Study, which was the first comprehensive study of estuarine pollution. In 1972 the Federal Water Pollution Control Act was amended to require that no pollutants be discharged from industrial plants by 1985 (Water Quality Criteria, 1968).

There is continually increasing emphasis on coastal zone management to provide maximum use of estuarine waters with a minimum damage to the environment. Pollution of the estuary is not dealt with directly in this study, but its effect on some water quality parameters has been included. The data may be useful to others for the prediction of effluent impact on the estuary.

Seasonal variations of water quality were the major interest of this study. These variations can be caused by changes in temperature, sedimentation, river flow rates, composition of seawater, and the biological cycles of the organisms that inhabit the estuary. Fluctuations in water quality also occur temporally and spatially within the estuary. Since data was gathered to study seasonal variations, a discussion of daily variations was not possible. Geographical variations were discussed along the length of the estuary, but not transversely at a given river distance.

The water quality parameters which were measured were salinity, temperature, dissolved oxygen, turbidity, and pH. The Oregon Department of Environmental Quality (DEQ) also measures these parameters and periodically takes samples at twenty-six locations in Coos Bay. Eleven of these locations are in South Slough (Percy et al., 1973).

B. Water Quality Measurements

Field research was conducted on September 13, 1973, December 19, 1973, March 23, 1974, and June 12, 1974. These dates represent the seasons summer, fall, winter, and spring, respectively. A listing of the tide range and river flow for these dates is given in Table III. On each of these days two sets of water quality measurements were taken, one at high tide and one at low tide. The locations

Table III. Flow and Tidal Conditions on Water Quality Measurement Dates

Date	Season	Tidal Range (m) Corps of Engineers Dock		River Flow (CMS)
		Rising	Falling	
Sept. 13, 1973	Summer	2.37	2.36	0.8
Dec. 19, 1973	Fall	1.82	2.45	108.3
Mar. 23, 1974	Winter	2.19	2.10	30.5
June 12, 1974	Spring	1.80	1.45	12.2

of water quality samples are shown on Figure 24 and described in Table IV. It was the objective to take measurements and samples at each location as near the time of slack water as possible. This was attempted by starting from South Slough slightly before slack tide and proceeding upstream with the tide. The water quality run by small craft took approximately three hours, whereas progression of the tide occurs in approximately one and one-half hours. Therefore, it was not possible to be at each location at precisely slack tide for sampling water quality without additional staff and equipment other than what was available.

Bottle samples for laboratory analysis and in situ measurements were collected at each of the sampling locations. The in situ measurements were made with a Hydrolab Model IIA portable water quality analyzer. The Hydrolab measured conductivity, temperature, dissolved oxygen, and pH. The conductivity was converted to salinity using the manufacturer's technical manual. The bottle samples were taken using an APHA type bottle sampler, the samples were collected near the surface, mid-depth, and bottom. The bottle samples were analyzed for salinity, dissolved oxygen, turbidity, and pH.

The Bisset-Berman Hytech Model 6220 Laboratory Salinometer was also used to determine salinity of water samples. Dissolved oxygen values were calculated using the Winkler titration method (Standard Methods, American Public Health Association, 1971).

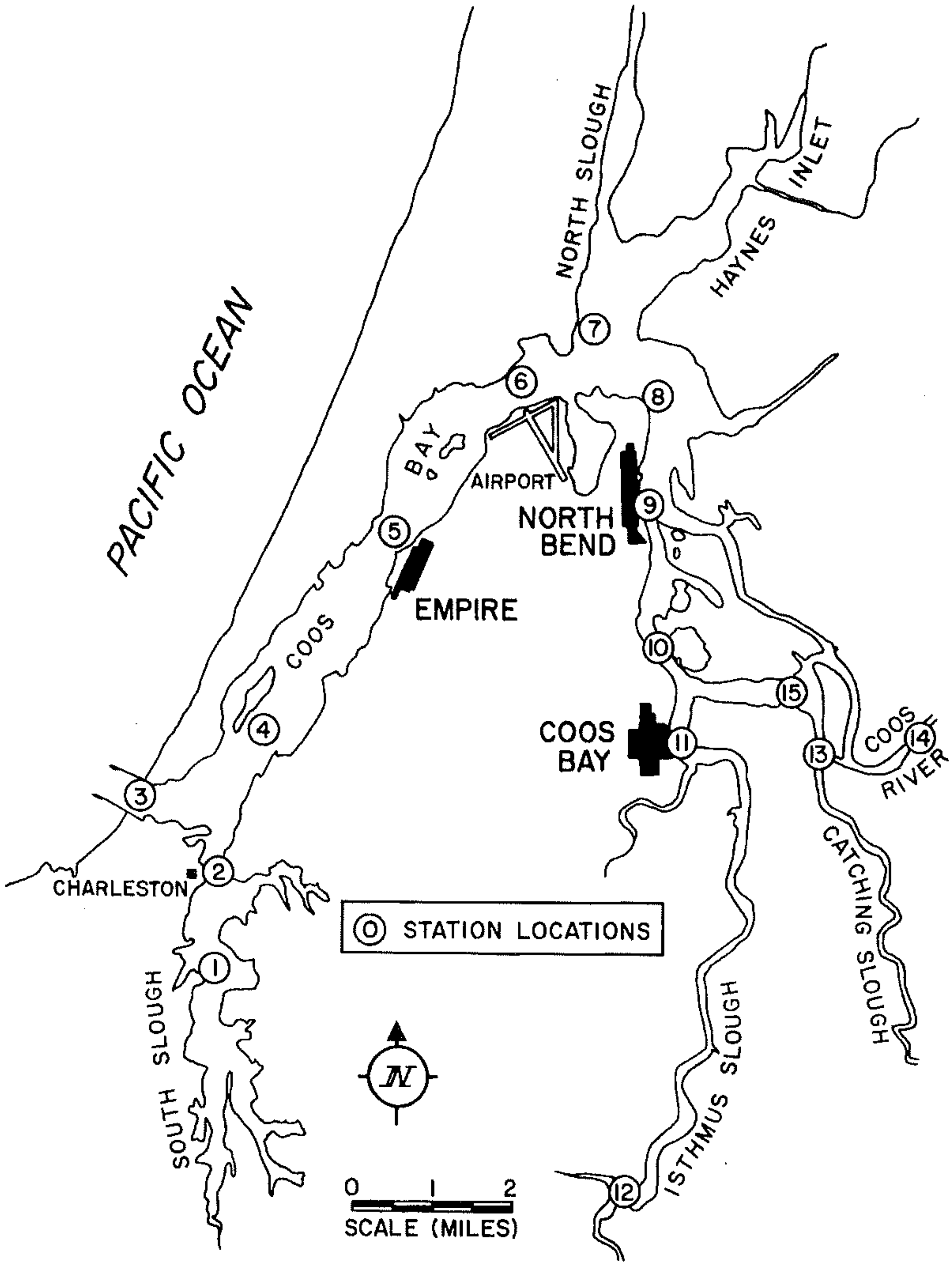


Figure 24. Location of water quality measurement stations, Coos Bay, 1973-1974

Table IV. Water Quality Sampling Locations

Station	Distance from entrance (km)	Distance from entrance (miles)	Description
1	7.07	4.39	Yonkers Point, South Slough, middle of channel
2	5.33	3.31	Charleston Highway bridge crossing South Slough
3	1.34	0.83	Navigation buoy #4
4	4.70	2.92	Navigation buoy #10
5	9.17	5.70	Navigation buoy #16
6	13.20	8.26	Navigation buoy #25
7	15.59	9.69	Haynes Inlet, Navigation marker #4
8	16.29	10.12	North Bend Range, lower marker
9	17.93	11.14	Navigation marker #36
10	21.23	13.19	Corps of Engineers Dock
11	23.19	14.41	Navigation marker #43
12	28.87	17.94	Isthmus Slough, middle of channel where Shinglehouse Slough flows into Isthmus Slough
13	26.62	16.54	Catching Slough, 820 meters south of the highway bridge where the first overhead power cables cross Catching Slough
14	27.89	17.33	Coos River Highway Bridge
15	24.16	15.01	Marshfield Channel, middle of channel on line between Marshfield Channel, front range and flashing green navigation marker #1

Turbidity was determined using a Hach Laboratory Turbidimeter, Model 1860-A. The pH was measured using a Corning pH meter.

C. Bathymetry

The depth of the water was measured at each water quality location on the high and low tide data gathering runs. This information is included to give an approximate view of the variation in depth in different portions of the estuary. It can be seen on Figures 25 and 26 that on several occasions the low tide depth at a station is greater than that at high tide. This is due to the inaccuracy in repositioning the boat when the depths were measured. Landmarks and navigational aids were used for visual positioning. The repeatability of the location was within approximately 20 meters. This was satisfactory for the water quality data but not for an accurate bathymetric picture.

D. Water Quality Results

The discussion of the water quality data results which follows is based on graphical representation of the data. A complete listing of the data attained from the Hydrolab and from bottle samples is in Appendix B.

1. Salinity

Salinity is the most useful water quality parameter for

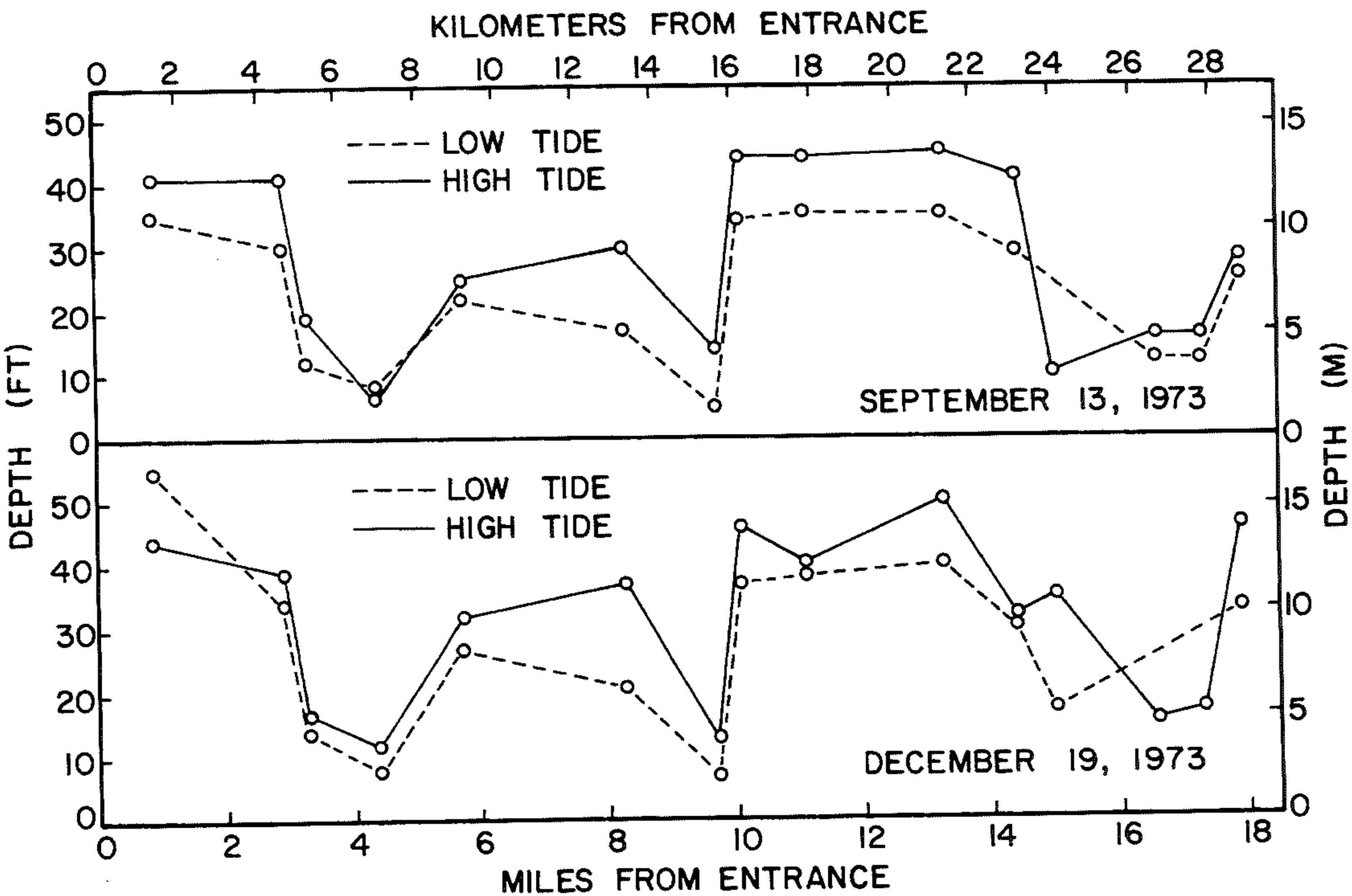


Figure 25. River depth at measurement station vs. distance from entrance, Coos Bay, September 13 and December 19, 1973

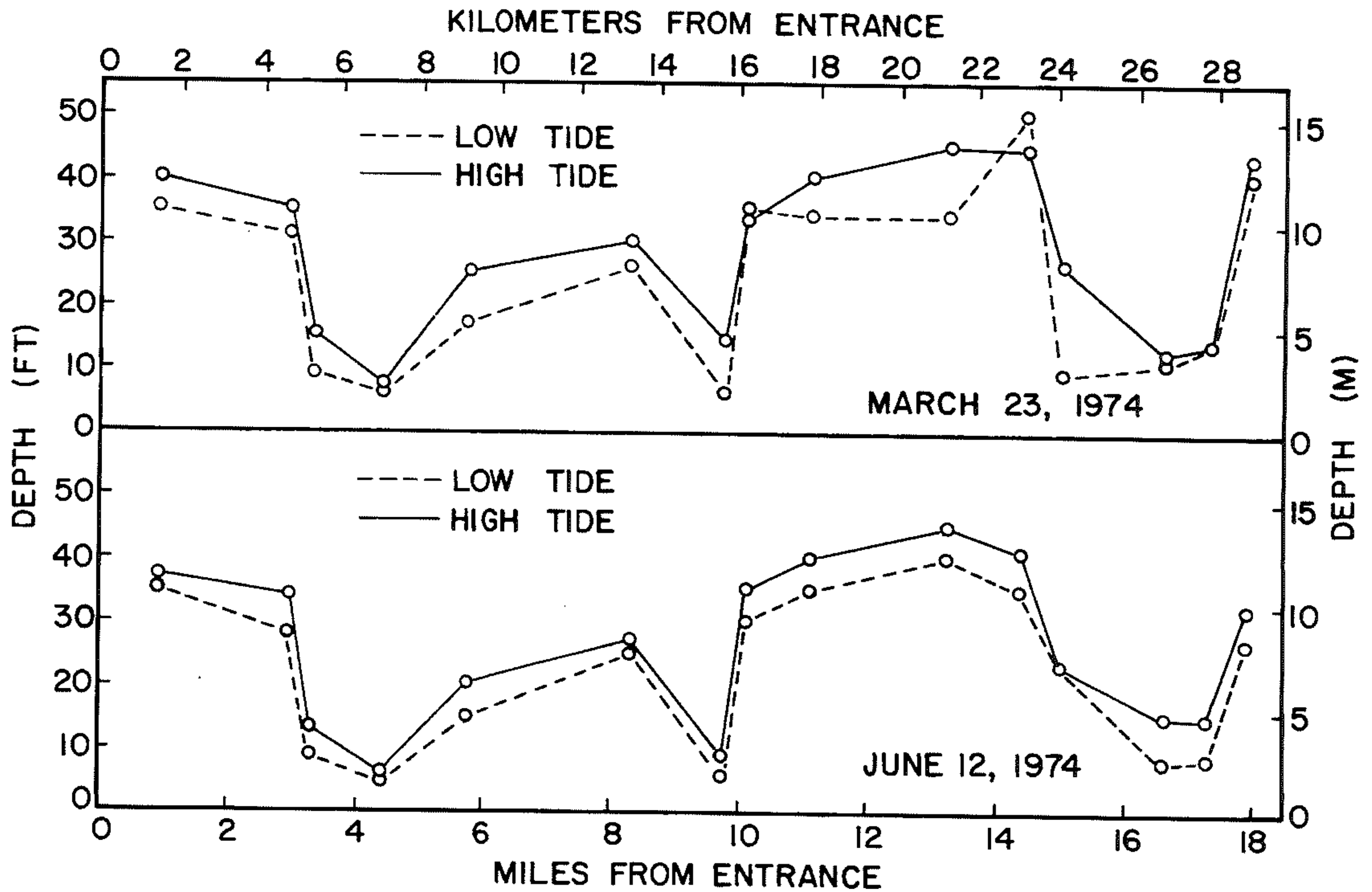


Figure 26. River depth at measurement stations vs. distance from entrance, Coos Bay, March 23 and June 12, 1974

classifying the estuary. The scheme of classification using salinity is discussed in Chapter V, Section E.

Salinity measurements are also important for purposes other than classifications. They may be used as a biological indicator to determine which species are able to exist in certain regions. They may also be used to calculate the flushing rate of the estuary (Mangelsdorf, 1967). Flushing rates are presented in Chapter V, Section F.

The estuarine salinity distribution is a function of the tidally driven salt water transport and the fresh water mixing processes which take place within the estuary. The water transport is affected by the fresh water inflow and the tidal currents. How these factors will interact is determined by their magnitude, by the Coriolis force, and the physical dimensions of the estuary (Bowden, 1967). Since Coos Bay is a relatively narrow estuary, the effect of Coriolis force is very small and can for our purposes be neglected. If the fresh water inflow dominates the tidal currents, the estuary will tend to be stratified. However, if the tidal force is dominant, the estuary will tend to be well-mixed. The amount of mixing within the estuary is affected by a number of variables. The strongest influence is usually the turbulence caused by the tidal currents (Bowden, 1967). Turbulence is also created by wind, river flow, and the ocean waves at the mouth. Density differences affect mixing. The density difference can be caused by temperature and to a greater extent, salinity. Pressure could also alter density but due to the shallow depths encountered in estuaries, the water is considered incompressible and therefore pressure has a negligible effect on density. Sediment concentration and effluents discharged into the estuary also affect the density of the water. Physical dimensions of the estuary are factors which affect mixing and transport patterns.

Salinity at the mouth was highest in June (33.876 parts per thousand (ppt)) and lowest in December (30.529 ppt). Bourke et al. (1971) found offshore surface salinities at Coos Bay to be higher (approximately 33.5 ppt) in the summer than in the winter (approximately 32.0 ppt). These salinities are elevated in the summer due to coastal upwelling and are decreased in the winter by the much greater river runoff and mixing at the mouth. These past observations are comparable to data gathered in this study.

Figures 27 through 29 are the salinity profiles for the dates indicated. The data used in preparing Figures 27, 29 were from the bottle samples using the laboratory salinometer rather than that from the Hydrolab as the results were thought to be more accurate. The laboratory salinometer was frequently calibrated during use; this was not practical with the Hydrolab. The salinities taken at the bottom, mid-depth, and surface for the high and low tides are joined by a straight line to emphasize the range of salinities which

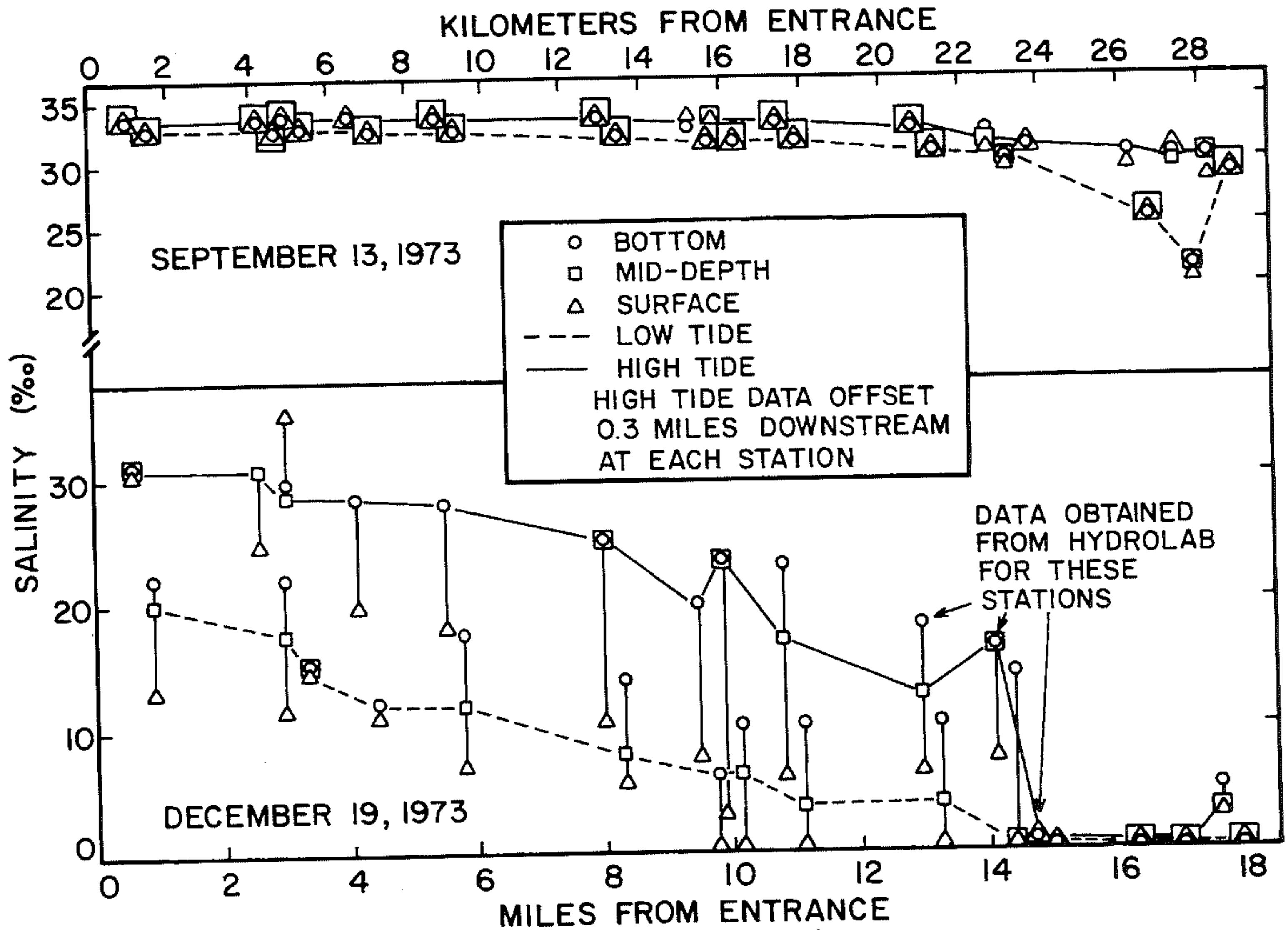


Figure 27. Salinity vs. distance from entrance, Coos Bay, September 13 and December 19, 1973

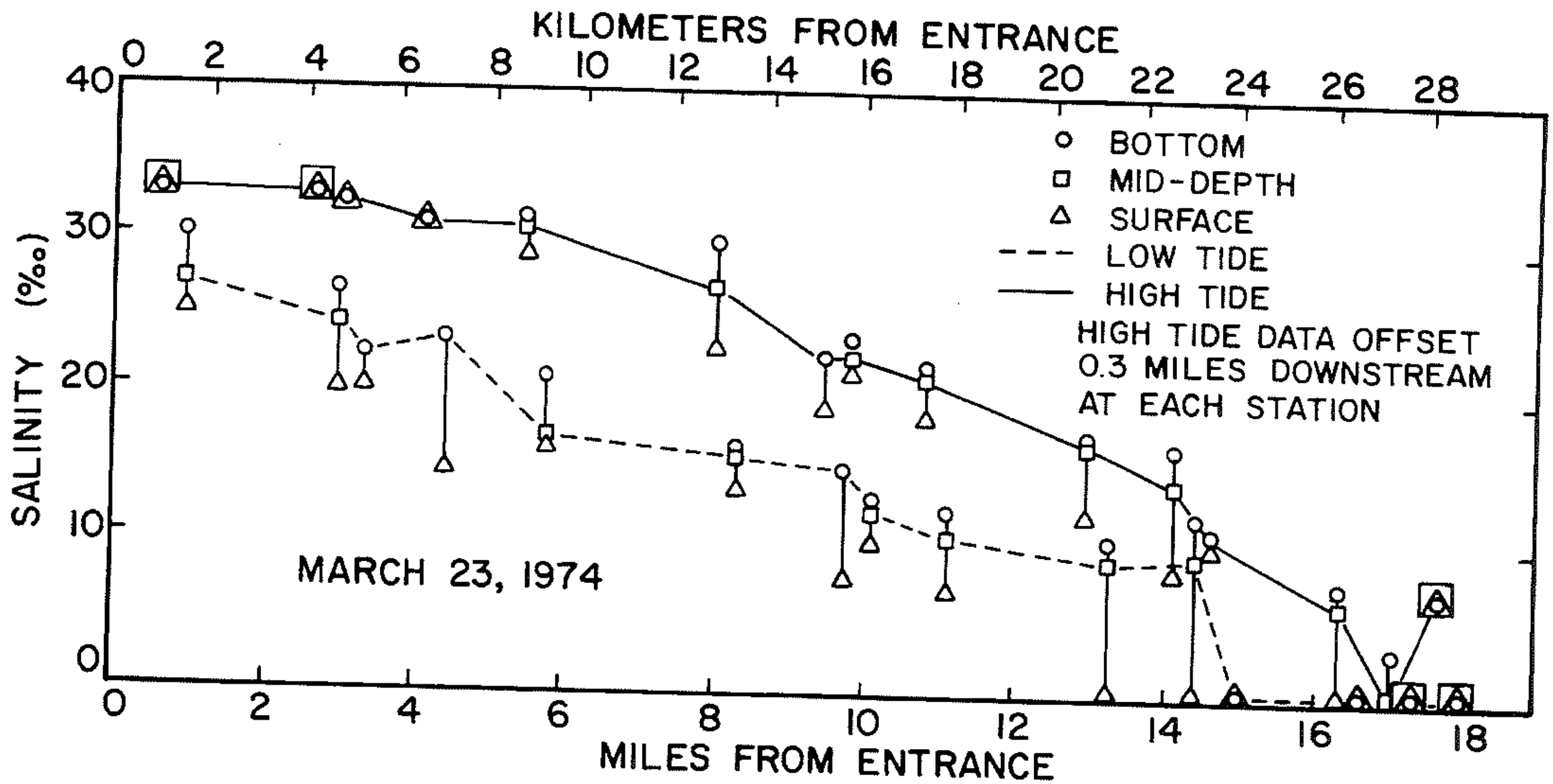


Figure 28. Salinity vs. distance from entrance, Coos Bay, March 23, 1974

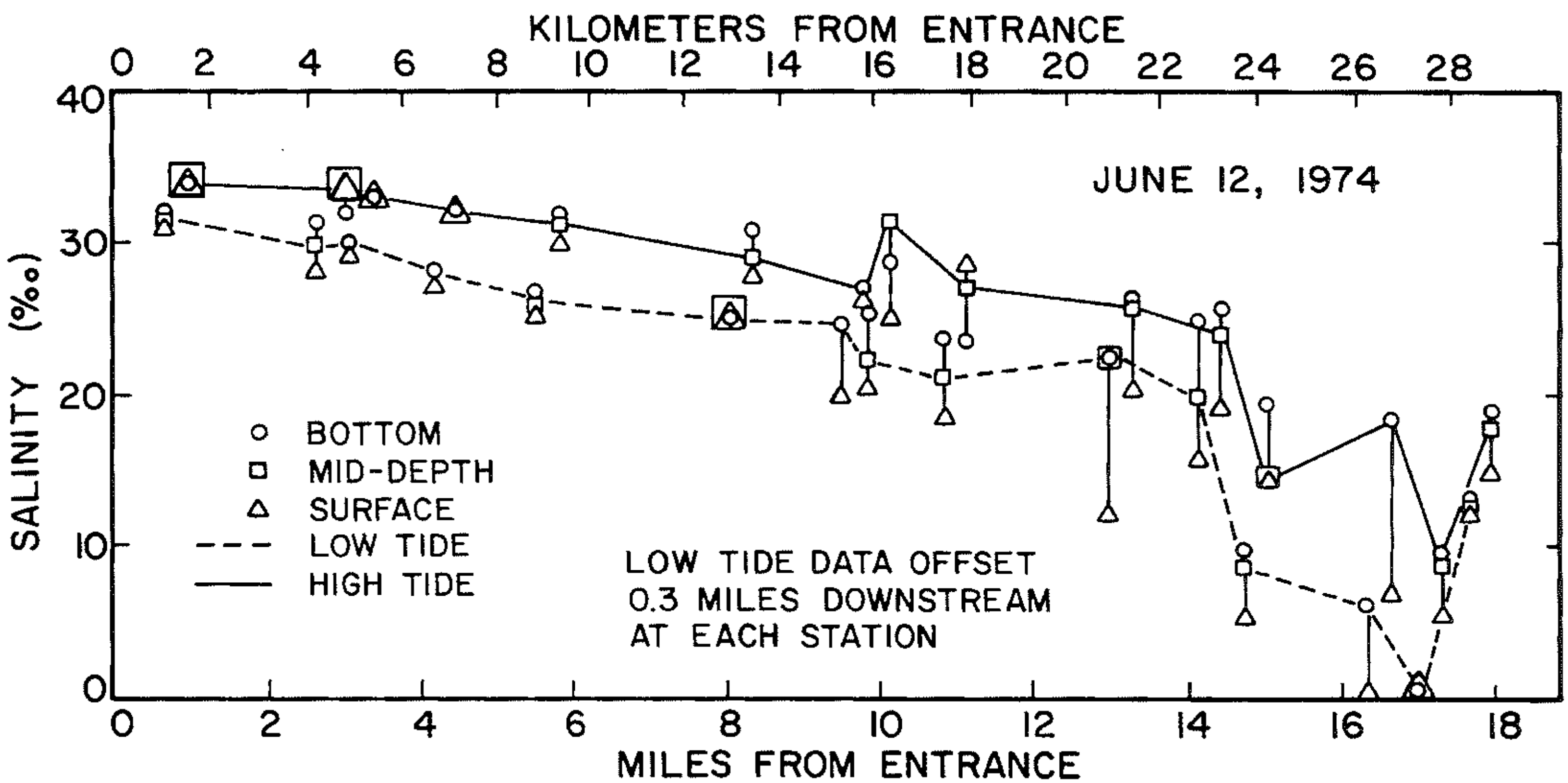


Figure 29. Salinity vs. distance from entrance, Coos Bay, June 12, 1974

repeatedly occur within the estuary.

The Summer salinity profiles (September 13, 1973) on Figure 27 indicate that the estuary is well-mixed on both the high and low tide. The fresh water flow for this season as listed in Table III was the lowest measured during this study. The low flows had very little effect on decreasing the salinity of the estuary. The influence of the fresh water flow becomes more evident at approximately 24.0 kilometers from the entrance on the low tide profile. It may appear inconsistent to see the marked increase in salinity between the stations 28.0 and 29.0 kilometers from the entrance on the low tide profile (see Figure 27, September profile). When the locations of the stations are noted it is not inconsistent. The station 28.0 kilometers from the entrance (Station 14) is in the Coos River where it is directly influenced by the fresh water inflow. The station 29.0 kilometers from the entrance (Station 12) is in Isthmus Slough where there is no river inflow. The high tide salinity at Station 12 is less than that at Station 14 by approximately 2 ppt. This is due to less salinity intrusion at a distance farther from the mouth of the estuary and the fact that the tidal current dominated the effect of river flow.

The Fall salinity profiles (December 19, 1973) on Figure 27 show a distinct difference between the high and low tides. The low tide exhibits the characteristics of a partially-mixed estuary to approximately 14.0 miles from the entrance. This does not include the stations in South Slough, Station 1 and Station 2. These stations are 5.33 and 7.07 kilometers from the entrance, respectively. Station 1 and Station 2 appear to be well-mixed. This is expected since there is no substantial fresh water flowing directly into South Slough. The flow is runoff and tidally driven water from the bay. Station 11 (23.19 kilometers from the entrance) has a bottom salinity 4.0 ppt greater than Station 10, which is approximately 2.0 kilometers closer to the mouth. In this case the data could be erroneous or a salt water lens may be present in the deeper water at Station 11. At distances farther from the entrance than Station 11, the water is essentially fresh. The high tide salinity profile is that of a stratified estuary. Station 3 (1.34 kilometers from the entrance) is essentially all seawater (34 ppt). Up to Station 8 (16.29 kilometers from the entrance) the bottom and mid-depth salinities are approximately the same with the lower salinity water flowing over the top of this wedge. The surface salinities increase consistently indicating the continual mixing with the progression toward the mouth. The surface salinity value at Station 2 appears to be an anomaly since it is greater than that at the mouth. There is no reason to expect an increase in salinity there unless South Slough is filled with ocean water while the channel experiences some dilution with river flow. Between 17.7 and 23.3 kilometers from the entrance the estuary tends to be partially-mixed. Upstream from that point it basically is fresh water.

The exception is Station 12 in Isthmus Slough. Some of the higher salinity water there appears to have been trapped at this point and not flushed out. The depth measured at this station (from Figure 25) shows a hole which would contain the more dense saline water and shelter it from flushing. It is approximately 4.3 meters (14.0 feet) deeper than the channel farther downstream. It should be noted from Table III that the river flow measured for this season was the greatest measured during this study.

The Winter (March 23, 1974) high and low tide salinity profiles on Figure 28 again show differing characteristics from those in the Fall. The low tide profile shows a partially-mixed estuary up to approximately 23.3 kilometers from the entrance. Upstream from that point the water is essentially fresh. On the high tide the estuary tends to be more well-mixed to approximately 12.9 kilometers from the entrance. Upstream from 12.9 kilometers the estuary appears to be partially-mixed. An obvious excpetion again is Station 12 in Isthmus Slough. This station is well-mixed with the more saline water remaining in Isthmus Slough instead of being flushed out.

The Spring salinity profiles (June 12, 1974) for the high and low tides are quite similar to one another. As Figure 29 indicates, the low tide salinities are of course lower but the changes in magnitude from one station to the next are nearly identical for both tides. The estuary is well-mixed to approximately 14.5 kilometers from the entrance. It is then partially-mixed for several kilometers and is somewhat stratified from river kilometer 21.0 upstream. On the low tide Station 12 in Isthmus Slough and Station 14 in the Coos River are exceptions. Station 12 exhibits the characteristics previously noted, which is well-mixed water of higher salinity trapped there due to the greater depth. Station 14 is upstream of the salinity intrusion and is fresh water. This is also found to be the case on the high tide. The saline wedge appears to end at approximately river kilometer 26.5 on the low tide.

From the descriptions of the seasonal salinity profiles it is evident that a consistent region for changing mixing patterns occurs approximately 22.5 to 24.1 kilometers from the entrance. This is logical since this is the Marshfield channel where the river can be considered to end and the bay begin. Downstream of this location there are large tidal flats which are covered only at high tide and are highly susceptible to mixing caused by the wind. The seasonal salinity data is in agreement with that of McAlister and Blanton (1963). They found Coos Bay to be well-mixed during periods of low runoff and a partially-mixed estuary during periods of maximum runoff. This corresponds to the Summer and Fall seasons of this 1973, 1974 OSU study.

2. Temperature

Temperature is another water quality parameter which may be used for estuary classification. The writer prefers to use it only as a comparison with salinity rather than a primary source for classification. This is due to the fact that during some seasonal periods fresh water and seawater temperatures in Coos Bay are almost identical or only differ by a few degrees. Accordingly, this makes it very difficult to determine mixing characteristics based on temperature profiles. Fresh water inflow and tidal currents are the major factors affecting the temperature distribution just as they were for the salinity distribution. It is for this reason that the seasonal profiles of these two parameters should be similar. They are not in all cases, however, due to the previously mentioned factor of only small differences in fresh water and seawater temperatures in some seasons.

The coldest mean monthly surface temperature offshore from Coos Bay was reported by Bourke et al. (1971) to be 8.46°C in June. Coastal upwelling had a significant effect on this temperature as it did on salinity. The warmest temperatures were in September and October, 13.24°C and 13.46°C, respectively. These temperatures were taken from a three year sampling effort which included: May and June, 1967; April through September, 1968; and July through

September, 1969. Table V lists the mean monthly surface temperatures offshore from Coos Bay reported by Bourke et al. (1971). Also listed are mean monthly temperatures of the West Fork Millicoma River measured by the Geological Survey from 1965 to 1970 (Water Resources Data for Oregon). The months listed in Table V are representative of the seasonal data of this study. The measuring station is approximately 11.0 kilometers upstream from the point where the Coos River enters the bay and is considered to be a satisfactory source of fresh water temperature.

Table V. Mean Monthly Temperatures (°C)

Location \ Month	September	December	March	June
Surface Offshore Coos Bay Area (Bourke et al., 1971)	13.24	10.44	10.10	8.46
West Fork Millicoma River (Water Resource Data for Oregon, 1965-1970)	17.2	7.2	8.9	18.3

During the high runoff seasons of fall and winter, the estuary would be expected to be partially mixed or stratified. These seasons are indicated by the months December and March on Table V. The temperature difference between fresh water and seawater for these two months is much less than that for September and June and could tend toward an isothermal profile rather than stratified. The lower runoff seasons of summer and spring (September and June on Table V) should represent a well-mixed estuary. Since these seasons have the larger temperature differences, the profiles could exhibit a more partially-mixed appearance. This would be more likely for the spring season since the river flow, and its influence, is a factor of ten greater than that for summer.

Figures 30 and 31 present the plots of temperature versus distance from the entrance. These data were the in situ measurements recorded on the Hydrolab at the surface, mid-depth, and bottom during the high and low tides. The seawater temperature referred to in the following discussion is that measured on the bottom at high tide at the station closest to the mouth (river kilometer 1.34). The fresh water temperature is that measured on the surface at low tide at the most upstream station in the river (river kilometer 27.89). It is assumed that these temperatures are close approximations of the offshore seawater and undiluted fresh water temperatures and can be compared with those of Table V.

The Summer temperature profiles (September 13, 1973) on Figure 30 show a large longitudinal variation. The seawater temperature was 10.0°C and the fresh water temperature was 18.7°C. Even

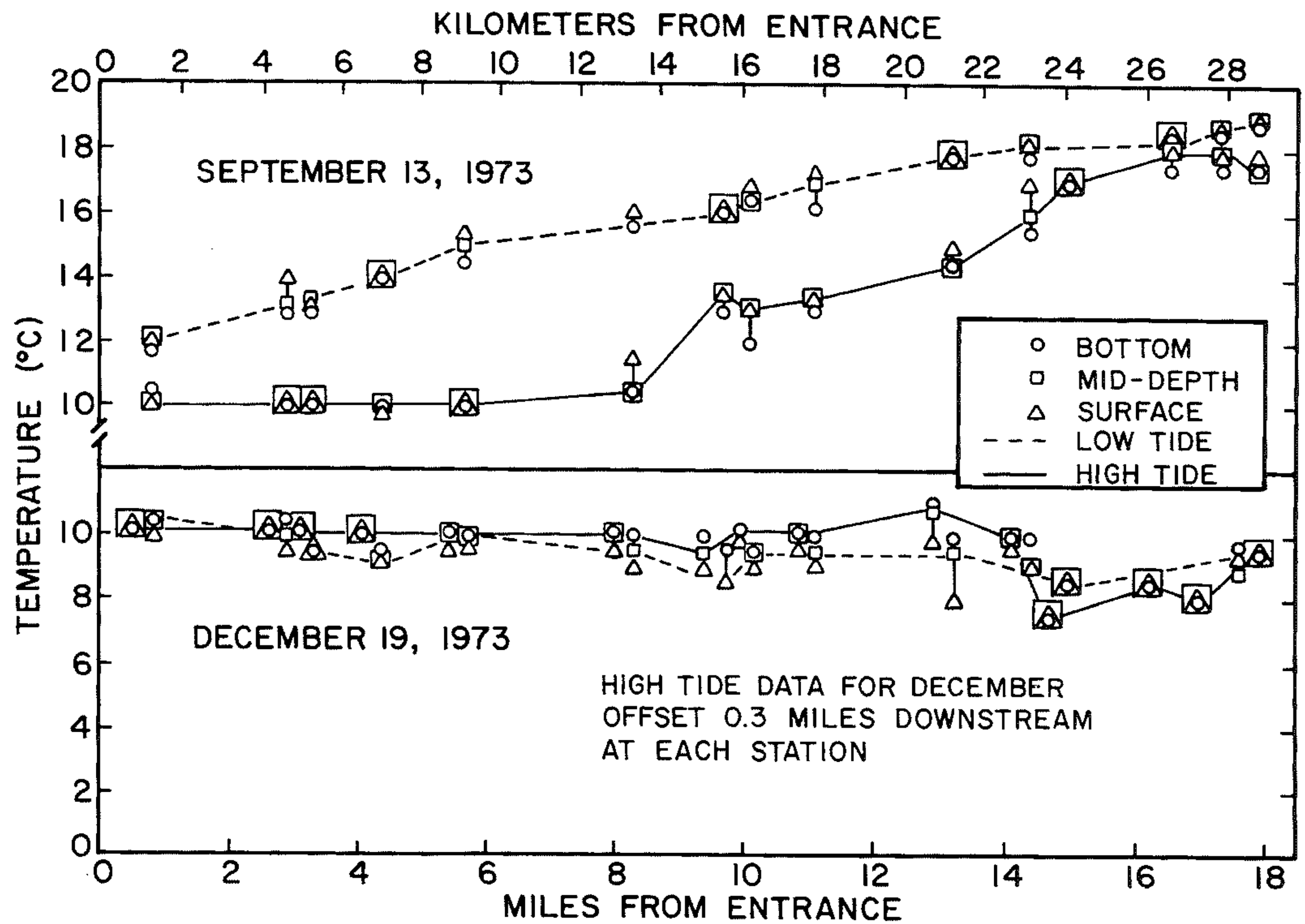


Figure 30. Temperature vs. distance from entrance, Coos Bay, September 13 and December 19, 1973

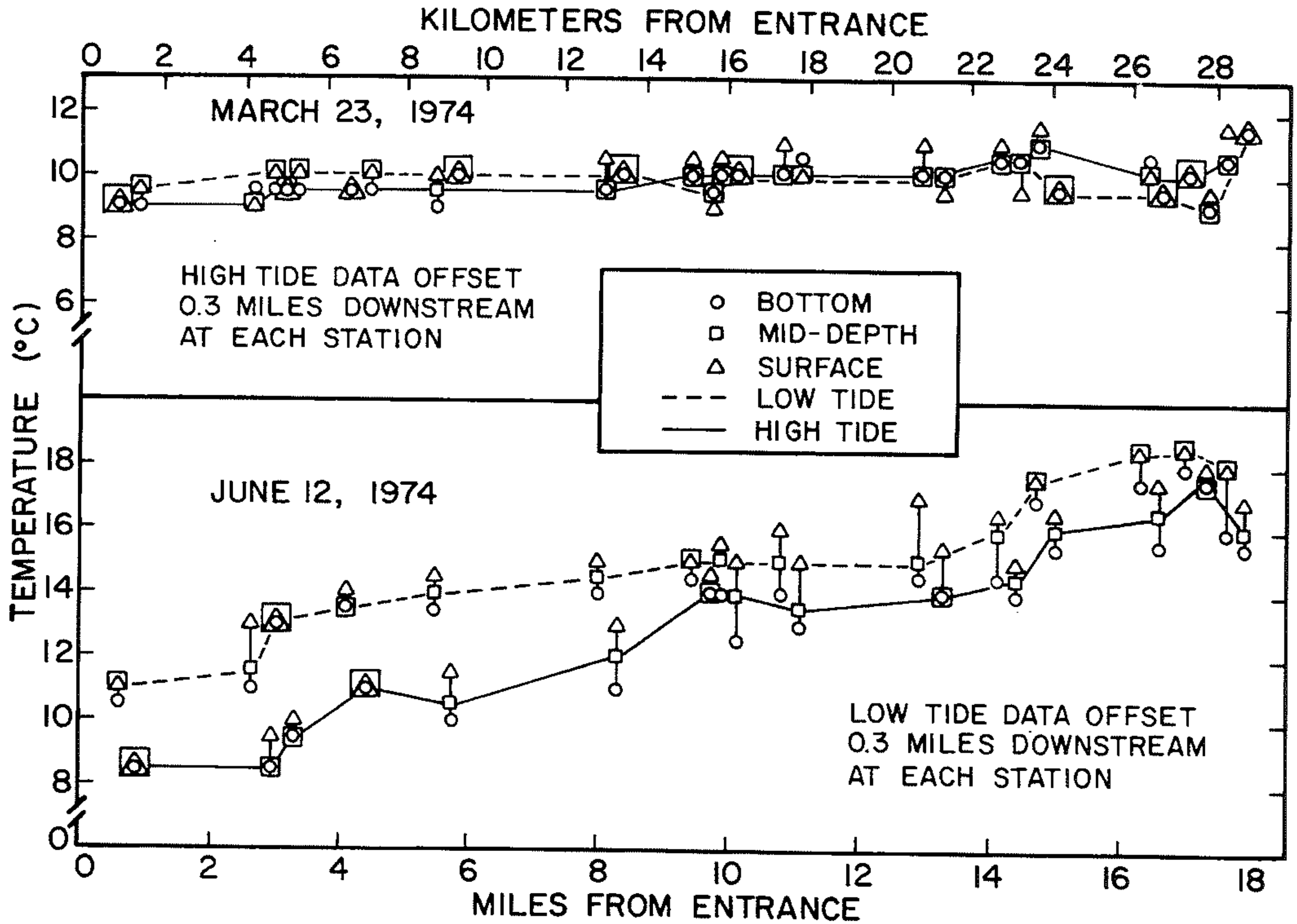


Figure 31. Temperature vs. distance from entrance, Coos Bay, March 23 and June 12, 1974

though the fresh water flow was minimal, due to the large temperature difference, it significantly warmed the estuarine water as did solar heating in the shallow estuarine waters. The dominance of the tidal currents was responsible for the estuary being well-mixed in most areas on both the high and low tides. The temperature was nearly constant (10°C) to river kilometer 9.7 on the high tide which corresponded essentially to the seawater limit explained in earlier discussions. Upstream of river kilometer 9.6 the warming influence of the fresh water is easily discernible. The low tide profile exhibits approximately a constant slope. However, the high tide profile has a sharp discontinuity between river kilometer 13.0 and 16.0. At 13.0 kilometers there is nearly a 3.0 degree increase in the temperature. This may be thought to be the end of major tidal influence. In comparison, however, from the salinity profile for this date (Figure 27) it is evident that the tidal influence is felt much farther upstream than 13.0 kilometers. A possible reason for the discontinuity is the existence of large exposures of tidal flat areas from river kilometer 13.0 to 24.0. These shallow areas could possibly account for a large amount of solar heating elevating the temperature higher in this region than it would be by the fresh water inflow alone.

The Fall temperature profiles (December 19, 1973) on Figure 30 are nearly isothermal. The seawater temperature was 10.1°C and the fresh water temperature was 8.5°C. This fresh water temperature, unlike those referred to for the other seasonal periods, was measured at river kilometer 24.2. (It was not possible to take measurements farther upstream on the low tide due to operation limitations; i.e., darkness.) The Fall season low tide temperatures were in general somewhat lower than those on the high tide. This trend is reversed upstream of river kilometer 22.5, This initially appears inconsistent since the fresh water is the colder input into the estuary. However, this area was sampled in mid-afternoon and the diurnal warming during daylight hours is possibly the cause for these higher temperatures.

The Winter temperature profiles (March 23, 1974) on Figure 31 are approximately isothermal as were those from the Fall season. There was very little difference in the seawater and fresh water temperatures; seawater was 9.0°C with the fresh water being 9.5°C. Because of this factor it is not possible to determine any mixing characteristics from these profiles.

The Spring temperature profiles (June 12, 1974) on Figure 31 have both vertical and longitudinal gradients. The seawater temperature was 8.5°C and the fresh water temperature was 18.0°C. Based on the temperature profiles the estuary appears to be partially-mixed on both the high and low tides. The low tide profile is not as constant as the one seen in Summer, but the discontinuity on the high tide is present as it was on the summer profile, again indicating the possible influence of increased solar heating in the tidal flat area. A distinct difference should be noted between the high tide profiles of Spring and Summer. The Spring profile appears isothermal only at the mouth as compared to a distance of approximately 9.7 kilometers in the Summer. This is due to the much greater fresh water flow in the spring (approximately ten times larger). The larger flow is also responsible for the estuary being partially-mixed instead of well-mixed as it was in summer. The decrease in temperature at the station 28.9 kilometers from the entrance on both tides in the spring is due to its location in Isthmus Slough. It does not receive the warm fresh water directly, but is significantly mixed by the tidal currents.

The seasonal fresh water and seawater temperature variations of this study closely approximate those listed on Table V. Thus, it is possible to predict the mixing characteristics for Coos Bay. Summer and Spring temperatures were as expected and can be compared favorably with inferences made regarding salinity profiles (see Figures 27 and 29). The Fall and Winter profiles were nearly isothermal with negligible vertical or longitudinal gradients; these were not satisfactory for purposes of classification or comparison and verification of the salinity results of Figures 27 and 28. These results point out that salinity profiles are generally much more useful than temperature profiles for classifying an estuary.

3. Dissolved Oxygen

In the previous discussion, significance was placed on using salinity and temperature parameters as tools for estuary classification. Because dissolved oxygen is not a conservative parameter it cannot be used for this purpose. However, dissolved oxygen (DO) concentration is of the utmost importance for determining what organisms can exist in the estuary. In the Oregon estuaries, DO affects the passage of anadromous fish (Water Quality and Pollution Control, 1971). Tests indicate that five to eight parts per million (ppm) of DO is satisfactory for all species of fish for good growth and health, even though they can live at lower levels. Most marine species die when subjected to DO levels below 1.25 ppm for more than a few hours (Water Quality Criteria, 1968).

DO levels of one to two ppm have been reported for Coos Bay during the late Summer and early Fall. Depressed DO levels during these periods have been attributed to low fresh water inflow and large waste loading. The major waste problem has been from the pulp and paper mills and domestic sewage (Percy et al., 1973). The upwelling which occurs in the vicinity of Coos Bay is also believed to contribute to the lower DO levels (Water Quality and Pollution Control, 1971). Studies by Reid show that upwelling off the Oregon Coast is most likely to occur in August and early September (Burt et al., 1959) and is supported by data of Wyatt and Kujala (1962) taken five miles offshore from Coos Bay. This data ranged from 8.6 ppm to 11.2 ppm. The lowest DO levels in the estuary reported by the Department of Environmental Quality (1973) were taken in Isthmus Slough south of Millington. From 1960 to 1973 the DO levels ranged from 2.2 ppm to 8.3 ppm (Water quality data on Coos Bay, 1973).

DO concentration is increased by two principal sources: reaeration and photosynthesis. Reaeration is the result of the transfer of oxygen across the air-water interface. This transfer may take place in either direction depending on the relative partial pressures of oxygen in the air and water (Bella, 1970). Once the oxygen has gone into solution in the surface layer it may be transported to lower layers by diffusion (Phelps, 1944). The solubility of oxygen in water is inversely proportional to both temperature and salinity concentration (Horne, 1969). Oxygen is produced by green plants during daylight by photosynthesis. According to Bella (1970) the amount of photosynthesis depends on the quality of light, temperature, nutrients in water, and the quantity of green plants in the water.

As previously noted, industrial wastes, especially those releases from the adjacent pulp and paper mills decrease the amount of DO in the estuary. DO is also reduced by the reduction of the organic matter in sewage by bacteria. If this organic load is sufficiently large then all of the DO in the water may be depleted (Clark and Viessman, 1966). Other possible inputs of organic matter in Coos Bay are seafood industry wastes, logs, and the bark from the logs. It has been determined that bark deposits remove a small, but measurable, amount of oxygen from the water. However, if bark loss to the storage water is minimized, log storage and transport on the estuary is not a major water quality problem (Schaumburg, 1973). Other loads on the DO concentration are the respiration of the plants, fish, and animal life that reside in the estuary.

Since DO is inversely proportional to both temperature and salinity concentration, it would be expected that DO levels in the summer and spring would be lower than those of the fall and winter. The higher salinity and temperature of summer and spring than those of fall and winter should cause this effect. The greater flows of fall and winter provide more flushing which would also contribute to higher DO levels.

Figures 32 through 35 represent the seasonal profiles of dissolved oxygen versus distance from the entrance for the high and low tides. The results shown are taken from analysis of bottle samples taken at the bottom, mid-depth, and the surface. These values are compared with the surface saturation value on each plot. The saturation values were obtained from Appendix C of Wastewater Engineering: Collection, Treatment, and Disposal using the

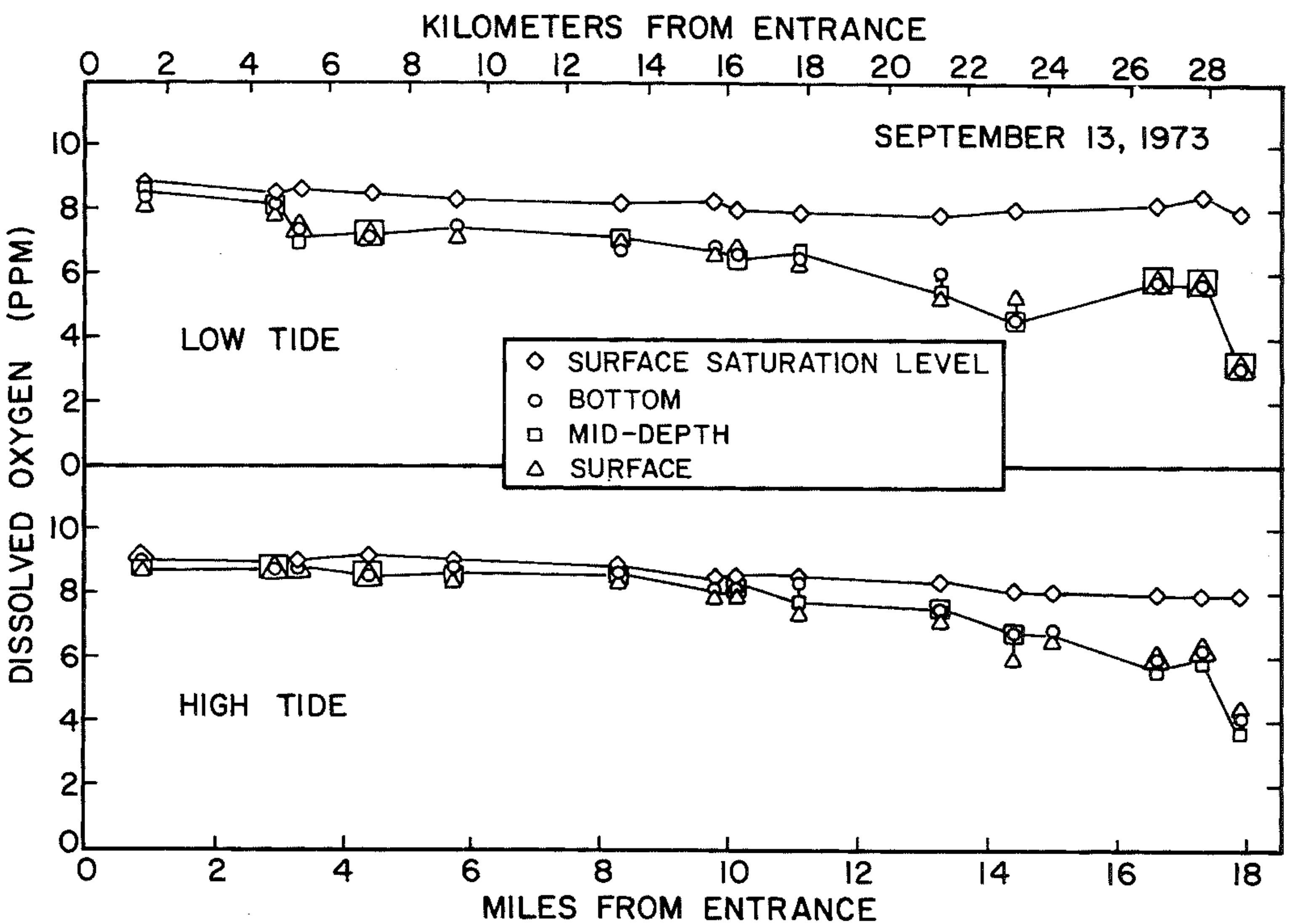


Figure 32. Dissolved oxygen vs. distance from entrance, Coos Bay, September 13, 1973

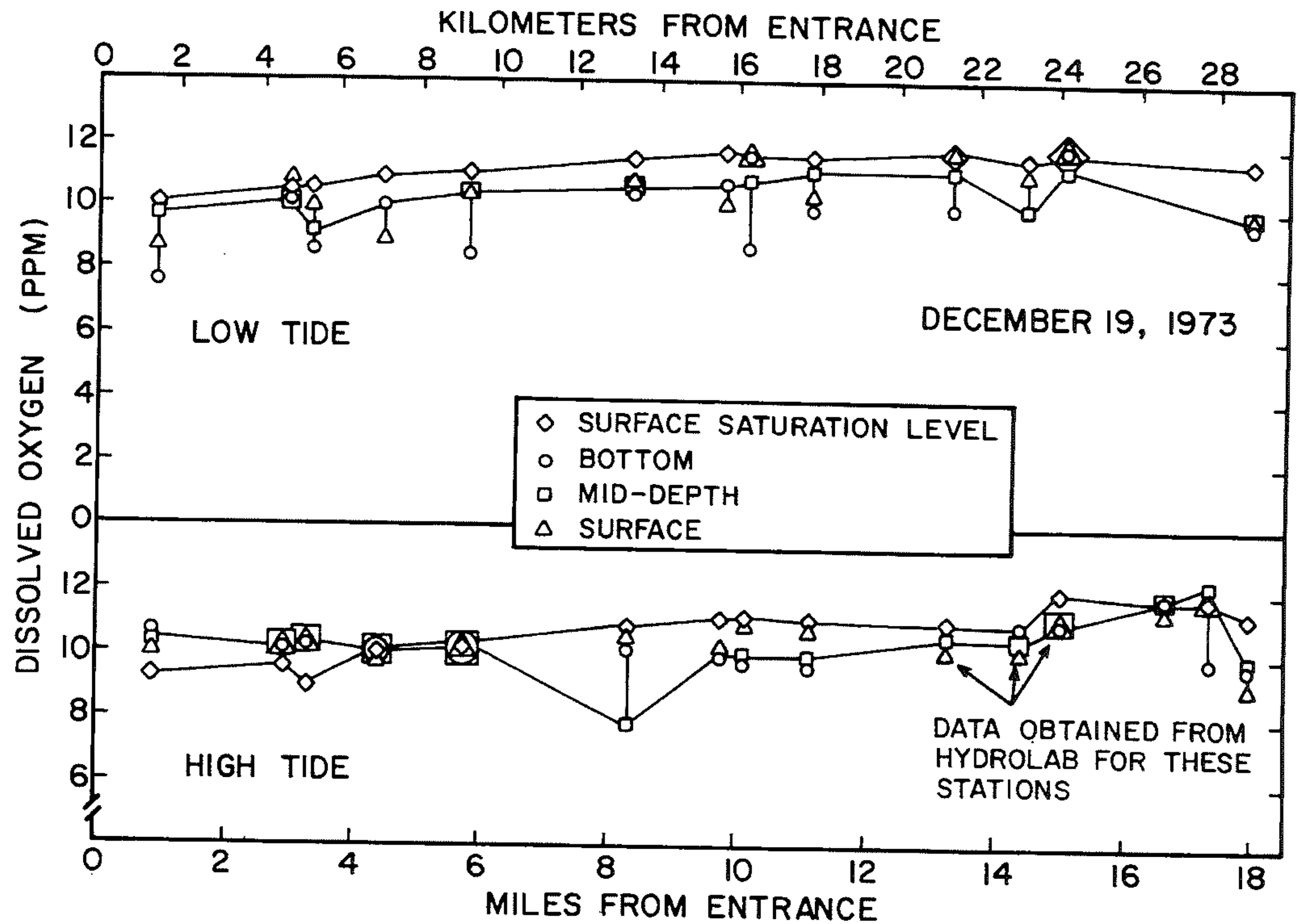


Figure 33. Dissolved oxygen vs. distance from entrance, Coos Bay, December 19, 1973

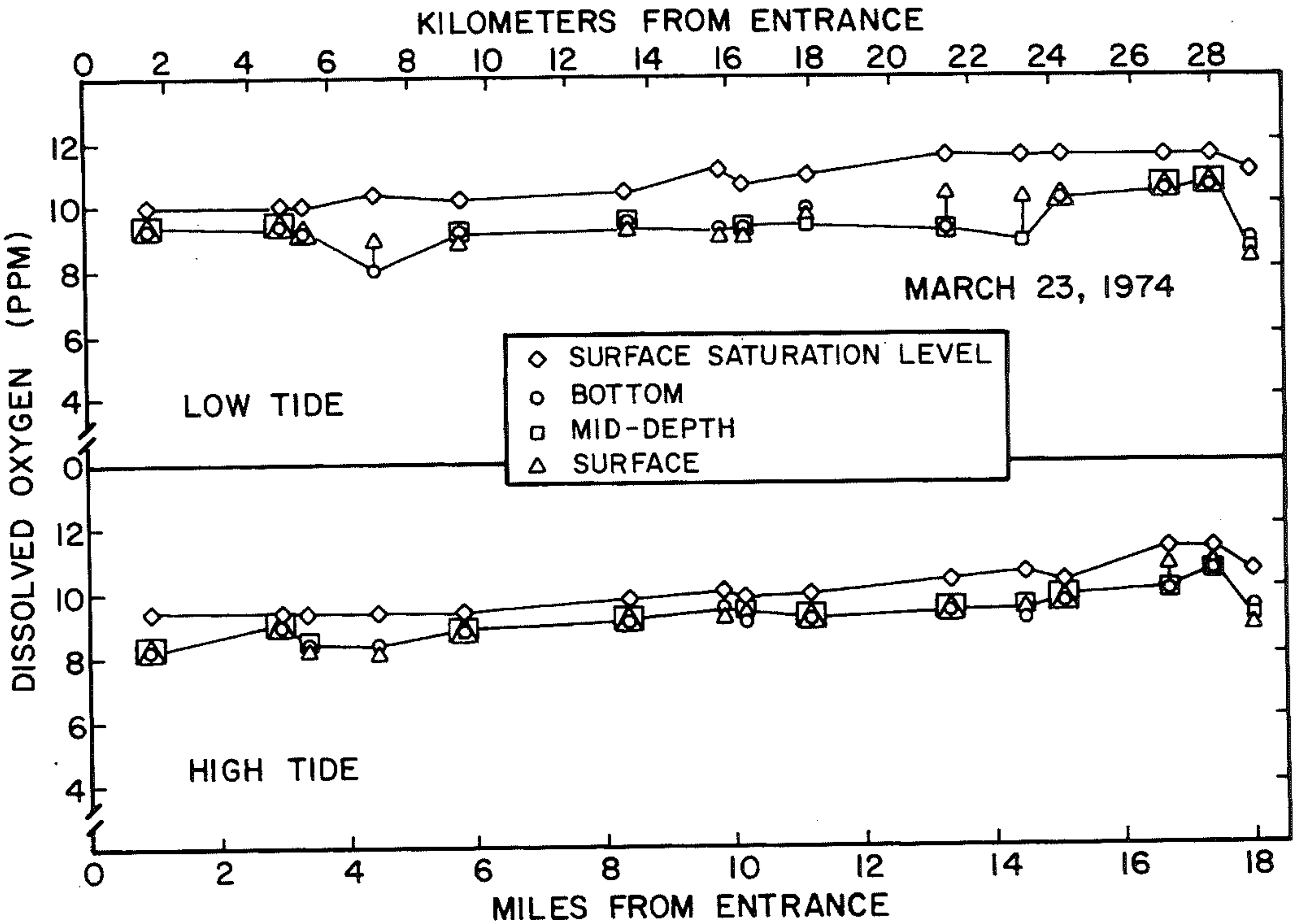


Figure 34. Dissolved oxygen vs. distance from entrance, Coos Bay, March 23, 1974

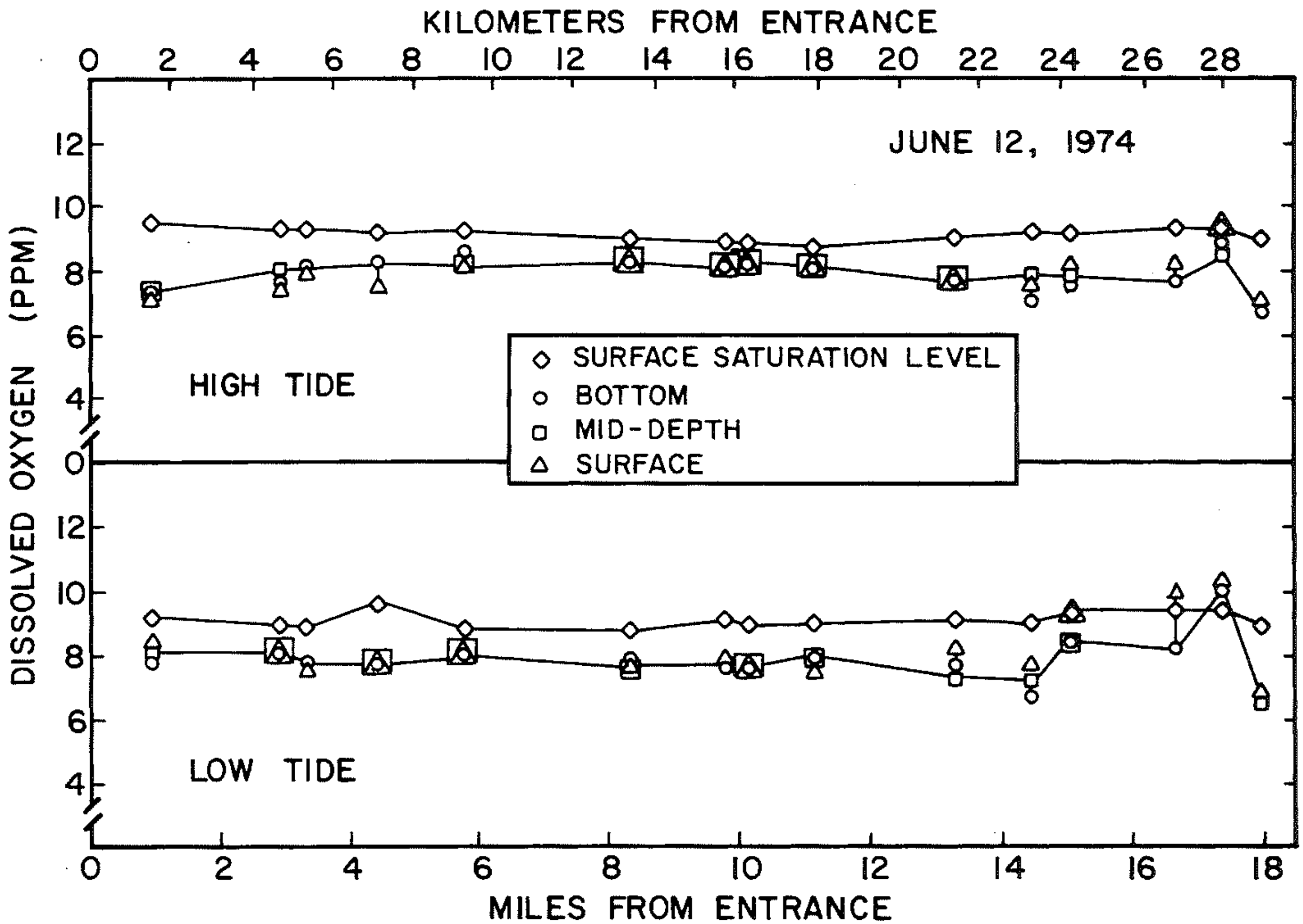


Figure 35. Dissolved oxygen vs. distance from entrance, Coos Bay, June 12, 1974

measured salinity and temperature data and assuming standard barometric pressure.

The Summer DO profiles (September 13, 1973) on Figure 32 are very similar on both the high and low tide. They are both quite close to saturation values at the mouth. The high tide profile remains nearly saturated until approximately river kilometer 16.0, whereas the low tide profile does so to only river kilometer 4.8. The high tide profile remains closer to the saturated value farther upstream since it is mostly seawater that has not been depleted by the loads of the estuary. There is virtually no vertical gradient on either tide. This is expected from the salinity results which indicated a well-mixed estuary for both tides. The only area which showed serious DO depression was the most upstream station, Station 12 in Isthmus Slough. The 1973 high tide sample (Station 12) is only 1.0 ppm greater than that at low tide indicating a minimal amount of flushing.

The Fall low tide DO profile (December 19, 1973) on Figure 33 shows a steady increase in concentration from the mouth upstream with a few exceptions. This longitudinal rise in the profile is probably caused by entering of colder fresh water. The first decrease in DO is seen at river kilometer 5.3 (Charleston Bridge). This depression is possibly due to release of seafood plant wastes in that area. Another reduction of DO was observed at river kilometer 23.2, which is near the turning basin in Isthmus Slough. This is a location where there is no green plant growth; there is probably also a significant uptake of DO by the free sulfides of the large tidal flats. The station at river kilometer 28.9 located upstream in Isthmus Slough again indicates there is very little flushing. The station at river kilometer 4.7 indicated supersaturation at the surface. This anomaly is questioned since there does not appear to be any reason for increased production, and the stations on either side are not supersaturated. On the high tide profile the estuary has supersaturated DO levels to approximately river kilometer 6.4. This was caused by the extreme breaking surf at the mouth significantly aiding reaeration. The bar conditions on the day of Fall observations were extremely rough. The low mid-depth DO value at river kilometer 13.3 is unexplainable and is possibly a data error.

The Winter DO profiles (March 23, 1974) on Figure 34 show no significant longitudinal or vertical gradients. The DO is slightly higher upstream in the Coos River than it is at the mouth. This difference is approximately 1.0 ppm on the low tide and 2.3 ppm on the high tide. The DO profiles follow those of the saturation levels to a large extent. The only large depressions occur at 7.07, 23.19, and 28.87 kilometers from the entrance on the low tide. These locations are Yonkers Point in South Slough and the two locations in Isthmus Slough which have been previously specified.

The spring DO profiles (June 12, 1974) on Figure 34 resemble those of the winter in that the saturation level profiles are closely followed. The low value at the mouth on the high tide is possibly due to some early seasonal upwelling. The Coos River station at river kilometer 27.89 is supersaturated at the surface on both tides. The sample in Catching Slough (26.62 kilometers from the entrance) was supersaturated at the surface on the low tide. These appear to be valid data results due the sunny weather favoring increased photosynthesis. The lowest DO levels for this season were at the upstream station in Isthmus Slough.

The seasonal DO results were as expected with concentrations slightly higher in fall and winter than in summer and spring. The upstream Isthmus Slough samples were consistently low and on the Summer sampling day reached 4.0 ppm which was out of the range for good growth and health of fish. This was the season of lowest fresh water flow recorded during this study. The turning basin in Isthmus Slough was slightly less than 5.0 ppm in the Summer (1974) which indicates Isthmus Slough to be an unsuitable habitat for fish in the summer. All other portions of the estuary appear to have DO levels suitable for maintaining a healthy fish environment throughout the year.

4. Turbidity

Turbidity is a measurement of the optical property of the water.

It is determined by the scattering and absorbing of light by the particles present in the water. Turbidity does not indicate an equivalent amount of suspended material in the water since it is dependent on the size, shape, and refractive indices of the particles.

The unit used as a measure of turbidity in this study is the Jackson Turbidity Unit (JTU). The JTU originated from the first equipment used for turbidity standardization which was the Jackson candle turbidimeter. A more accurate calibration is now being used since the Jackson type meters lack sensitivity below 25 JTU (Hach Water Analysis Handbook, 1973).

The suspended material in the water which causes the turbidity may be clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms (Clark and Viessman, 1966). The principal cause of turbidity in many estuaries is the sediment carried by the entering rivers (Water Quality Criteria, 1968). The amount of sediment carried is dependent on the river flow and the bank activity which supplies the material. These activities include such things as logging, farming, and sewage treatment.

Water traditionally has not been considered aesthetically pleasing if it is not clear. However, it does not necessarily need to be considered polluted or harmful because it is highly turbid. The limit recommended for drinking water by the U. S. Public Health Service is 5 JTU's. Most public water utilities supply water that is less than 1 JTU (Clark and Viessman, 1966). This is low compared to some areas sampled in Coos Bay, but the estuary waters are not highly turbid when compared to other Oregon rivers and streams which may have turbidity levels reach several thousand JTU's. One negative effect of high turbidity is reduced primary productivity. Decrease in photosynthesis is due to the reduced light attenuation of turbid water while the respiration rate of plants and animals remains essentially the same (Water Quality Criteria, 1968).

Turbidity versus distance from the entrance for the surface and mid-depth on the high and low tides is plotted on Figures 36 and 37. Most of the profiles indicate a high degree of variability. This could in part be attributed to the inaccuracy of the Hach turbidimeter, which is the Jackson type previously noted for lack of sensitivity below 25 JTU's; the mid-depth and surface samples taken in Coos Bay were all within this range.

The low tide turbidities, with exceptions only at scattered stations, are greater than the high tides values for all seasons. Based on this observation, Coos Bay resembles many other estuaries with sediment from the fresh water inflow being the principal cause of turbidity. The low tide turbidities are directly influenced by river flow. The highest turbidities in Coos Bay occurred in the fall (December 19, 1973) which was the period of greatest fresh water flow during these observations. High tide turbidities at the mouth

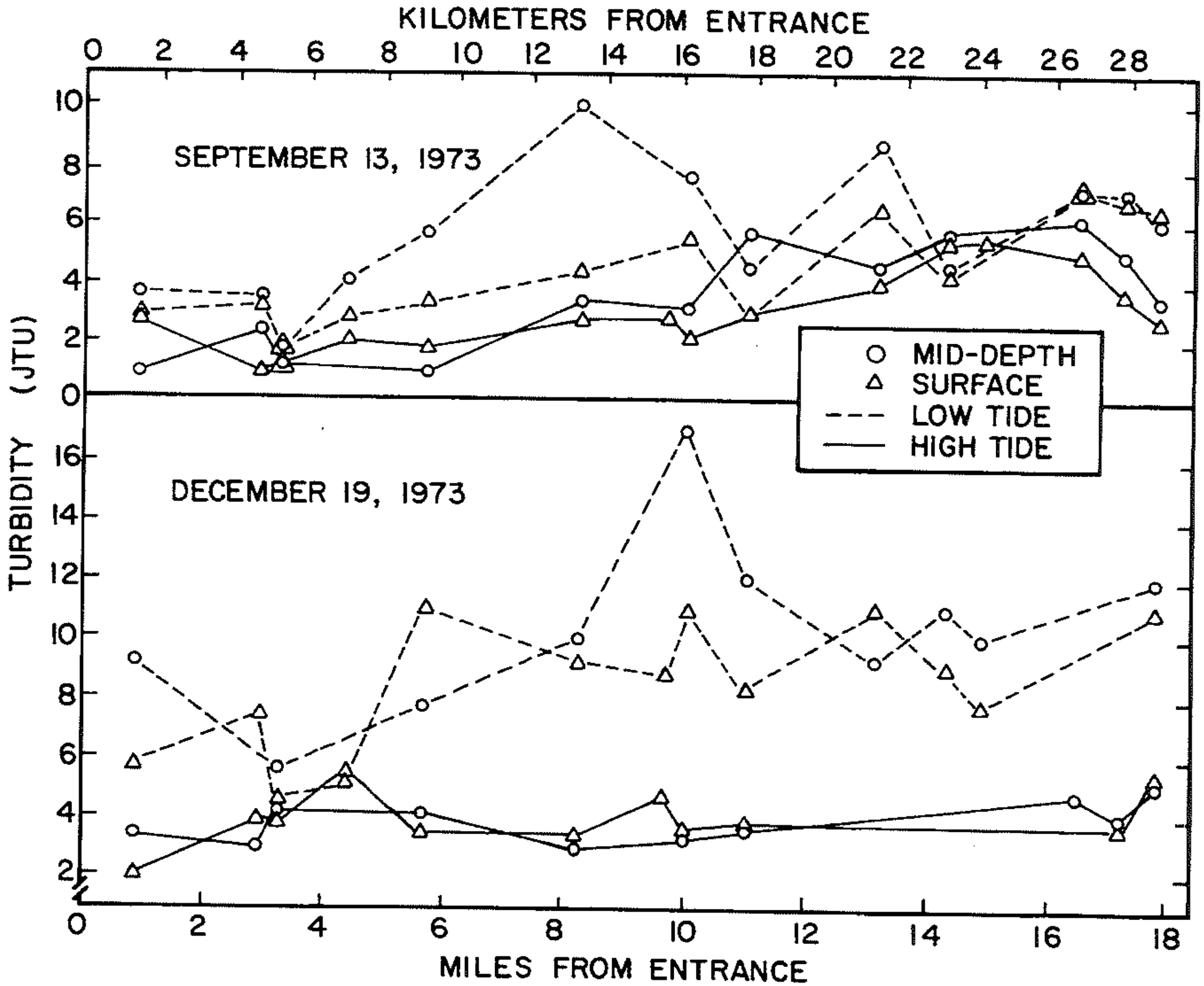


Figure 36. Turbidity vs. distance from entrance, Coos Bay, September 13 and December 19, 1973

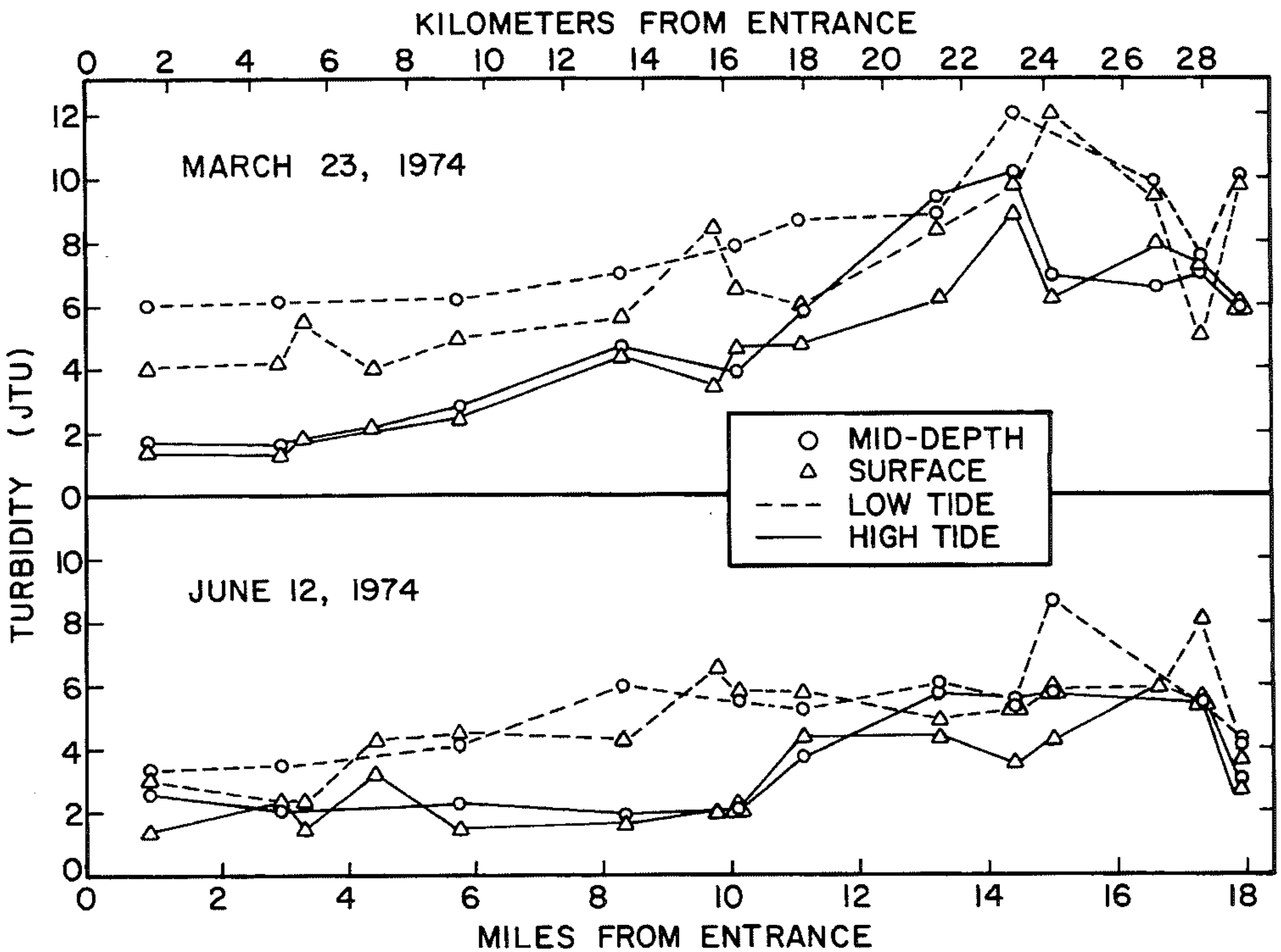


Figure 37. Turbidity vs. distance from entrance, Coos Bay, March 23 and June 12, 1974

are approximately the same for each season. The high tide profiles increase from the mouth proceeding upstream. This increase is almost negligible in the Fall which had the least amount of mixing during this study. Where mixing did occur, the saline water caused flocculation maintaining the lower turbidity. It should be noted from Figure 28 that the salinity difference of the high and low tides becomes significant at approximately river kilometer 24.0. This is the same region where there is a marked drop in the high tide turbidity (Figure 37).

The turbidity profiles indicated expected trends in seasonal changes. For more definitive results, however, it is recommended that a more accurate turbidimeter be used in future studies. This would hopefully reduce some of the scatter of data which might cause confusion in evaluation.

5. pH

pH is a chemical property of liquids which describes whether the substance is acidic or basic; the range of pH measurement is a scale of 0 to 14. A pH of 0 is very acidic and 14 is very basic. Pure water at 25°C has a pH of 7 (Hach Water Analysis Handbook, 1973).

pH can be affected by many factors such as the amount of dissolved CO_2 in the water, photosynthetic activity, and solar radiation.

High pH can occur at the surface due to CO_2 being in equilibrium with the atmosphere. Acidic values can be found in basins and tidal flat areas where hydrogen sulfide (H_2S) is produced (Horne, 1969). If small changes in pH are observed, it could indicate that the buffering system of the water has been altered. This could cause a CO_2 imbalance with a harmful and potentially lethal effect on marine life. Changes in pH can also influence the toxicity of other materials in the water (Water Quality Criteria, 1968).

The pH of seawater is usually found in the range of 7.5 to 8.4 (Horne, 1969). Samples reported at the intersection of Isthmus Slough and Marshfield Range had a range of pH between 7.2 and 8.4. Samples taken near the mouth during the same period ranged from 7.5 to 8.4 (DEQ, 1973). Similarity of these pH ranges does not imply that seawater is normally present at both locations.

Appendix B contains the pH data collected in this study. Since there were no significant trends or mixing characteristics to be derived from it, the data are not presented in graphical form. In general the seawater was more basic than the fresh water from the Coos River. The greatest range occurred in the Fall season with seawater a pH of 7.9 and entering fresh water being 6.4. These values and those following were obtained from analyzing bottle samples. In the spring there was little difference between the sea-water and entering fresh water values which were 7.4 and 7.2, respectively. In the winter a fresh water sample with a pH of 8.3 was collected. This appears erroneous since it does not correspond with the Hydrolab readings. The Hydrolab was consistently higher than the bottle samples and the Hydrolab reading at this point was only 7.2. The pH's recorded in Isthmus Slough were usually slightly lower than those in the Coos River. This could possibly have been caused by the reaction of the large amount of log storage in Isthmus Slough combined with a lower amount of flushing than in the river.

E. Classification of the Estuary

Estuary classification is a subject which has been approached using several different methods. The two most common consider the geomorphology of the estuary and the mixing characteristics of the estuary. Variations of these and other distinct methods will be discussed.

Pritchard (1967a) defined four types of estuaries using the geomorphological approach:

(1) Drowned river valleys

(2) Fjord-type estuaries

(3) Bar-built estuaries

(4) Estuaries produced by tectonic processes

Drowned river valleys are most commonly found where there is a relatively wide coastal plain. For this reason they are usually referred to as coastal plain estuaries in the United States. This type of estuary was formed some time following the glacial period when sea level rose and flooded the valleys.

Fjords were carved by glaciers and generally have a U-shaped cross section. Fjords commonly have a shallow sill which was formed at its mouth by glacial deposits. Beyond this sill there is a very deep basin which may reach a depth of several hundred meters. In some fjords with very shallow sills, estuarine features are exhibited only down to the sill. Below this depth, deep basin waters remain stagnant for long periods. In other fjords with deeper sills, the estuarine layers do not extend as deep as the sill and there is a slow exchange of the deep basin waters.

Bar-built estuaries are formed by sand islands and spits being built above sea level and extending between headlands. These can be broken by one or more inlets. Bar-built estuaries are usually shallow and are fed by more than one river.

Estuaries produced by tectonic processes is not a clearly defined classification. This category includes all the estuaries which are not covered specifically in the first three categories.

Coos Bay is classified as a drowned river valley or coastal plain estuary. Within this category the estuary can further be described by its mixing characteristics and circulation patterns. Pritchard (1967b) describes three major classes using this scheme of classification. These classes are the highly stratified estuary, the moderately stratified estuary, and the vertically homogeneous estuary. These are now more commonly referred to as a salt wedge estuary, a partially-mixed estuary, and a well-mixed estuary, respectively. The well-mixed estuary is subdivided into those estuaries with lateral variation in salinity and a laterally homogeneous estuary. This study was only concerned with longitudinal and vertical characteristics. Lateral variations were not investigated.

A theoretical salt wedge estuary can be described assuming that there is no tidal action and no friction at the interface between the seawater and fresh water. The salt wedge extends along the bottom to some point where the surface of the river is approximately sea level. The fresh water flows over the top of the salt wedge. If the effect of friction at the interface is considered, transfer of salt water to the upper fresh water layer will occur. This transfer is essentially only in the one direction causing the upper layer salinity to increase toward the mouth of the estuary. As the salt water is entrained in the fresh water, the upstream tip of the salt wedge is forced downstream. With larger river flows there is more friction and entrainment causing the wedge to move farther downstream. Even though the salt wedge estuary with no tidal action is a hypothetical model, it does approximate one type of naturally occurring estuary. This is one in which the influence of river flow is much greater than that of the tides. The classical example of this type of estuary is the mouth of the Mississippi River.

Tidal action is included in the theoretical model of a partially-mixed estuary. Tidal action, rather than friction at the interface of the seawater and fresh water, is the dominant mixing force. The tidal force and its turbulent eddies cause salt water to be transfered upward and fresh water to be transfered downward. The salinity of both the upper and lower layers increases seaward as a result of this mixing; however, the bottom layer still maintains the higher salinity. Due to the salt water transfered to the upper layer, there is increased flow in this layer. This affect must be balanced by a larger lower layer flow in the upstream direction.

The well-mixed estuary results when the tidal action is strong enough to cause any vertical stratification to disappear. Pritchard (1967b) emphasizes that there may be no truly vertically homogeneous estuary. Instrumentation may not be sensitive enough to detect the minor differences which could occur. In a well-mixed estuary the tidal flow is of a much greater rate than that of the river flow.

There are several important variables which govern the circulation pattern of the estuary. These are the width and depth of the estuary, the fresh water inflow, and the tidal currents. Width and depth remain fairly constant on a seasonal basis at Coos Bay. Due to the large tidal flat area both these parameters change appreciably in some areas between the high and low tides. The rate of fresh water inflow can change by a factor of one thousand between the rainy and dry seasons. The range of the tide varies with the period of the moon, but for the purposes of this study the seasonal data was taken on days exhibiting similar ranges. From this discussion, it can be seen that the major influence affecting seasonal changes in the circulation pattern of Coos Bay, is the fresh water inflow.

A method of quantifying the circulation pattern classification was developed by Simmons (Dyer, 1973). The ratio of river flow per tidal cycle to the tidal prism is calculated. When this ratio is greater than or equal to 1.0, the estuary is highly stratified (salt wedge type). If the ratio is about 0.25 the estuary is partially-mixed and when it is less than 0.1 it is well-mixed. Coos Bay is seasonally classified using this method on Table VI. The tidal prisms were calculated using the surface areas reported by Johnson (Percy et al., 1973). The river flows from Table I were used in these calculations.

Burt and McAlister (1959) devised another method of classification using the circulation pattern. This classification is based on the salinity gradient on the high tide at the location in the estuary where the mean salinity sampled is closest to 17 ppt. If the difference between the surface and bottom salinities is greater than or equal to 20 ppt, the estuary is stratified. A difference between 19 ppt and 4 ppt indicates a partially-mixed estuary. When the difference is less than or equal to 3 ppt, the estuary is well-mixed. Seasonal classification using this method is listed on Table VI. Burt and McAlister (1959) found Coos Bay to be well-mixed during all months except November when the estuary was partially-mixed. For several months two classifications were made by Burt and McAlister. The second classification indicated the estuary to be partially-mixed. These months were January, March, and June. Although it is not specified, those could have been made after storms which caused a high runoff and changed the mixing pattern of the estuary.

There is no salinity gradient or river distance listed for September 13, 1973 in Table VI. This is because salinity less than 27.0 ppt was not found in the estuary; it was well-mixed beyond river kilometer 27.9. Table VI shows March 23, 1974 and June 12, 1974 to be well-mixed according to Simmons classification scheme and partially-mixed according to that of Burt and McAlister. There is no significant disagreement here since the salinity gradients of 5.3 ppt and 5.1 ppt are very near the 3 ppt border for classification as well-mixed.

The classifications on Table VI using Simmons' and Burt and McAlister's methods compare favorably with the author's observations of the estuary using the seasonal salinity profiles. It must be remembered that in many cases it is not possible to place the entire estuary into one class. Since the salinity gradient method uses the

Table VI. Classification of the Estuary by the Flow Ratio and Salinity Gradient Methods

Date	Simmons		Burt and McAlister			
	Flow Ratio	Classification	Salinity Gradient (‰)	River Distance (km)	River Distance (mile)	Classification
Sept. 13, 1973	0.0006	Well-mixed	--	--	--	Well-mixed
Dec. 19, 1973	0.108	Partially-mixed	15.3	13.29	8.26	Partially-mixed
Mar. 23, 1974	0.024	Well-mixed	5.3	21.23	13.19	Partially-mixed
June 12, 1974	0.020	Well-mixed	5.1	24.16	15.01	Partially-mixed

high tide at a specific river mile, only the high tide is used for comparison. The estuary was observed to be well-mixed in the summer (Sept. 13, 1973). For this season both of the classification methods of Table VI also describe the estuary as well-mixed. In the fall (Dec. 19, 1973) the salinity profile showed a stratified estuary to river kilometer 17.7 and partially-mixed for the next several kilometers. The salinity gradient method defines the estuary as partially-mixed at river kilometer 13.29. The gradient of 15.3 is, however, high in the range of the partially-mixed class tending toward a two-layered (stratified) system. The flow ratio method also defined the estuary as partially-mixed for this season. In the winter (March 23, 1974) both classification methods are consistent, but for different portions of the estuary. The flow ratio method indicates a well-mixed estuary which can be observed on the salinity profile to approximately 13.0 kilometers from the mouth. At river kilometer 21.23 the salinity gradient method indicates a partially-mixed estuary which was the classification found by the writer for this location by using information regarding salinity profiles. In the spring (June 12, 1974) the flow ratio method again showed the estuary to be classified as well-mixed. The well-mixed classification held to approximately river kilometer 14.5 where it would be given a classification of partially-mixed, and subsequently was declared as stratified from river kilometer 21.0 upstream. The salinity gradient method defines the estuary as partially-mixed at river kilometer 24.16.

From the previous discussion it should be obvious that a classification of the entire estuary is not necessarily an accurate description of all portions of an estuary the size of Coos Bay. For this reason the writer believes the salinity profiles give the clearest picture for evaluation of the estuary along its longitudinal axis. The flow ratio method and salinity gradient method are convenient classification tools but at times can be misleading.

Ippen and Harleman (1966) developed another classification method. This method uses a stratification number, G/J, to classify the estuary. G/J is the ratio of the rate of energy dissipation per unit mass of water to the ratio of potential energy gain per unit mass of water. G is a function only of the tidal energy of the estuary and J is a function only of the fresh water inflow. A small value for the stratification number indicates a highly stratified estuary. An estuary with a large stratification number is considered to be well-mixed. Data collected in this study was not sufficient for a calculation of the stratification number. However, Blanton (1963) previously calculated a stratification number of 530 for Coos Bay. This value indicates that the estuary was well-mixed. Blanton's calculations were made from data gathered in the summer; the well-mixed result coincides with the summer classification of 1973.

F. Flushing Rates

Calculating the flushing time of an estuary is important for estimating the duration of a pollutant within the estuary. Dyer (1973) defines the flushing time as that time necessary to replace the fresh water within the estuary at a rate that is equal to the discharge of the river. Dyer also points out that as river discharge increases there is a more rapid mixing of fresh water and seawater but less proportionate mixing may occur. While this statement is true, it must be remembered that river flow is not the only factor affecting the flushing rate. The range of the tide which alters the tidal prism is also of major importance.

There are several methods for calculating the flushing rate. The first method is the fraction of fresh water method. The flushing rate of any portion or the entire estuary is determined by calculating the mean fractional fresh water concentration, f. The equation for f is:

$$f = \frac{S_s - S_n}{S_s} \qquad (4)$$

where

S_s = undiluted seawater salinity,

S_n = mean salinity of any portion of the estuary (Dyer, 1973).

The accumulated volume of fresh water, Q, is found by multiplying f by the volume of the segment of interest, V. The river flow, R, is then used in the following equation to determine the flushing time, T, in seconds (Dyer, 1973):

$$T = \frac{Q}{R} \quad (5)$$

Flushing rates calculated by this method are found in Table VII. The estuary was considered to extend to river kilometer 27.89 for these calculations. This was the most extreme upstream point of salinity samples used determining the mean salinity.

A second method for calculating flushing rates is the tidal prism method. This method assumes complete mixing of the entering fresh water and seawater and the water within the estuary on each tidal cycle. The flushing time, T, in tidal cycles, is determined by the equation:

$$T = \frac{V_L + P}{P} \quad (6)$$

where

V_L = low tide volume of the estuary,

P = tidal prism (Dyer, 1973).

The tidal prism method is considered to be an unsatisfactory approximation of the flushing rate because of the assumption of complete mixing. The results are generally much lower than those computed using other methods. Table VII shows this quite clearly.

Another method for determining the flushing rate was developed

Table VII. Calculated Flushing Rates

A. Fraction of Fresh Water Method

Date	Salinity (‰) Ocean	Salinity (‰) Mean	f	$Q \times 10^{-6}$ (cubic meters)	R (CMS)	Flushing Time (Days)
Sept. 13, 1973	33.7	32.9	0.023	2.12	0.79	30.9
Dec. 19, 1973	31.1	20.7	0.335	3.11	108	3.3
Mar. 23, 1974	33.0	22.6	0.314	29.25	30.5	11.1
June 12, 1974	33.9	26.7	0.212	19.77	12.2	18.7

B. Modified Tidal Prism Method

Date	Tidal Range (m)	R (CMS)	Flushing Time in Days: Distance (miles) 7.6 (kilometers) 12.2	Distance (miles) 17.3 (kilometers) 27.8	Distance (miles) 27.0 (kilometers) 43.5
Sept. 13, 1973	2.4	0.79	9.7	22.9	40.3
Dec. 19, 1973	1.8	108	6.2	11.8	13.4
Mar. 23, 1974	2.2	30.5	8.2	14.4	15.9
June 12, 1974	1.0	12.2	19.0	41.3	48.5

Table VII. Continued

C. Tidal Prism Method

Date	$V \times 10^{-7}$ (cubic meters)	$P \times 10^{-7}$ (cubic meters)	Flushing Time (Days)
Sept. 13, 1973	7.82	8.04	1.02
Dec. 19, 1973	7.82	5.55	1.24
Mar. 23, 1974	7.82	7.25	1.07
June 12, 1974	7.82	3.31	1.74

by Ketchum (Dyer, 1973). This method is known as the modified tidal prism method. The estuary is divided into segments. The length of each segment is determined by the distance that a particle of water will travel during the tide. The upstream boundary of the first segment is the head of the tide. The downstream boundary of this segment can be positioned by two methods. It may be located at the point where salinity intrusion ends or at the cross-section which encloses a tidal prism, P_1, from the head of tide, equal to the river flow, R. For this study the downstream location of the first segment was found using salinity intrusion for the fall and winter seasons and the river flow for spring and summer. The river flow method was used in spring and summer since there was no measured end of salinity intrusion.

After the size of the first segment is determined, the downstream segment sizes are calculated progressively. The low tide volume, V_{L_2}, of the second segment is equal to the high tide volume, V_{L_1}, of the first segment. V_{H_1} equals the sum of V_{L_1} and P_1. The general equation is as follows:

$$V_{L_n} = V_{L_{n-1}} + P_{n-1} \qquad (7)$$

Once segmentation of the entire estuary is complete, the exchange ratio, r_n, of each segment is calculated:

$$r_n = \frac{P_n}{P_n + V_{L_n}} \quad (8)$$

The flushing time of each segment is the inverse of the exchange ratio. The flushing rate of the estuary is equal to the sum of the flushing rates of each segment. Results of calculations using this method are found in Table VII. The flushing rates were calculated for several locations within the estuary for each season. The modified tidal prism method has been found to be a good approximation when the estuary is well-mixed, when a large number of segments are used, and if the cross-sectional area of the estuary increases rapidly downstream.

Even though Coos Bay does not have a rapidly increasing cross-section as one moves downstream, since the estuary was well-mixed and a large number of segments were used in the calculations, best results from the modified tidal prism method should have been obtained for Summer (Sept. 13, 1973). The effect of using a small range for calculation of flushing time can be seen in the long flushing time of June 12, 1974. This flushing time is not realistic since the small range would not be continuous for the entire duration of the flushing. The fraction of fresh water method and modified tidal prism method compare favorably on September 13, 1973 and March 23, 1974. This writer urges use of the most conservative flushing rate for pollutant transfer calculations.

VI. SEDIMENTS

A. Introduction

A thorough understanding of estuarine sediments is vitally important since a large majority of these sediments remain within the estuary under normal conditions (Ippen, 1966c). A knowledge of sediment types and their origins is desirable. This knowledge is extremely useful for an estuary such as Coos Bay where there is continuous annual maintenance dredging. Data concerning the sediment and sedimentation patterns is useful for evaluating the effects of proposed landfill, dredging, and spoiling activities within the estuary.

Outside sources provide the major contribution of sediments to the estuary. These sources include the ocean and the rivers and streams which empty into the estuary. There is also a significant input from sources within the estuary. Examples of these are: materials eroded from tidal flats and spoil islands by wave action, materials disturbed by dredging and propeller wash, industrial and sewage discharges, and particles blown into the estuary by the wind (Ippen, 1966c; Slotta et al., 1973). The magnitude of the contirubutions of these sources is governed by independent and varying factors such as tidal currents, river flow, ship traffic, and weather conditions.

Littoral drift transports sediment to the entrance of the estuary where it is then acted on by the estuarine tidal currents. The sediment is usually sand of the same type as found on nearby beaches (Kulm and Byrne, 1966). The littoral drift on the Pacific coast at Coos Bay is generally southerly in the summer and northerly in the winter with an annual net southerly transport (Percy et al., 1973). The littoral drift combined with low water flow tends to cause a large amount of shoaling at the bay's entrance in August and September. Significant shoaling also occurs during winter storm periods and when freshets are diminishing in the spring (Coos Bay EIS Supplement, 1975).

Tidal currents carry the marine sediments into the estuary. There is some suspended sediment but most travels as bed load. The extent of transport is a function of the magnitude of the tidal flow and river flow which determine the mixing classification of the estuary. A stratified estuary should carry marine sediment to the tip of the saline wedge. The transport mechanism is the bottom current in the saline wedge. Conversely, a well-mixed system has a net non-tidal flow that is outward at all depths and impedes the intrusion of marine sediment (Kulm and Byrne, 1966). From the classification results of this study it is suspected that most of the marine sediments are deposited in the estuary in the fall and winter. These were the seasons when the estuary was only partially-mixed. Quantitative results also indicated that the estuary was partially-mixed in the spring, but observation of salinity profiles indicated that it tended more toward being well-mixed than the winter season.

Fluviatile sediments are transported to the estuary by the fresh water inflow. Average conditions reveal that approximately 80% travels in suspension with the remainder being bed load. In most United States estuaries fluviatile sediment is the main source of shoaling material. The size range usually includes silt and clay (Ippen, 1966c). Because of its chemical composition, clay has the ability to flocculate. That is, when its negative potential charge is reduced below a certain critical value, the clay conglomerates and due to the larger size begins to settle. The reduction of the charge is caused when the particles come into contact with the intruding salt water (Postma, 1967).

The amount of fluviatile sediment transported into Coos Bay is estimated to be 72,000 tons annually (Percy et al., 1973). This amount is a function of the river flow. Assuming constant seasonal availability of sediment, this study shows that the maximum amount of fluviatile material should have been transported into the estuary in the Fall, during the season of greatest river flow.

The deposition of fluviatile sediment is affected by the mixing classification of the estuary as was the sediment of marine origin. In a stratified estuary the tip of the salt wedge usually marks the area of maximum shoaling of fluviatile sediment. In a well-mixed estuary the pattern of shoaling tends to be more widely distributed (Ippen, 1966c).

Kulm and Byrne (1966) found that an estuary could be divided into three major realms of deposition. Their study of Yaquina Bay, Oregon, showed the estuary had a marine realm, a fluviatile realm, and a transition realm classified as marine-fluviatile. From the limited sediment data in this study (with no analysis of mineral content) it is difficult to define these realms of deposition in Coos Bay. It is assumed that the realms do exist, however, since marine sediments are traditionally found close to the mouth, fluviatile sediments near the head of the estuary, and a mixture of the two in between. Results of studies conducted by the Corps of Engineers seem to indicate three deposition regions (Coos Bay EIS Supplement, 1975). The sediment of lower Coos Bay from the entrance to the Highway 101 bridge is predominantly sand. This would be classified as the marine realm. From the Highway 101 bridge to approximately kilometer 16.9 (mile 10.5) the bottom consists of a large amount of shell deposits. From kilometer 16.9 to kilometer 20.1 (mile 12.5) the bottom is silt. These regions could be considered the transition realm. For the next several hundred meters the bottom is rock, hard clay, and silt. It then returns to mainly silt to approximately kilometer 21.9 (mile 13.6). It appears that the region beginning at kilometer 20.1 and going upstream could be defined as the fluviatile realm.

Estuarine sediments are transported as bed load and suspended load. Bed load will occur as long as the specific entrainment velocities are exceeded. Suspended load is a function of both turbulent diffusion and vertical settling. Particle settling velocities must be exceeded or they will sink to the bottom. Both of these transport mechanisms are influenced by changing velocities due to tidal fluctuations. Alternate deposition and scour result from the tidal action. Net transport, however, follows the direction of the net velocity. As previously stated, predominant net velocities are such that most sediment transported into an estuary remains within the estuary (Ippen, 1966c).

Visher (1969) developed a method for classifying the modes of transport within an individual grain size distribution. The modes described are suspension, saltation, and traction. Characteristic profiles on log-probability curves of grain size distributions can be used to identify specific sedimentation processes. Visher identified seven processes including currents, swash and backwash, waves, tidal channels, fallout from suspension, turbidity currents, and aeolian dunes. An example of a grain size distribution from the lower swash zone is shown on Figure 38 (Visher, 1969). It should be noted that the plot was constructed using percent coarser by weight instead of percent finer by weight as in this study. Classification of

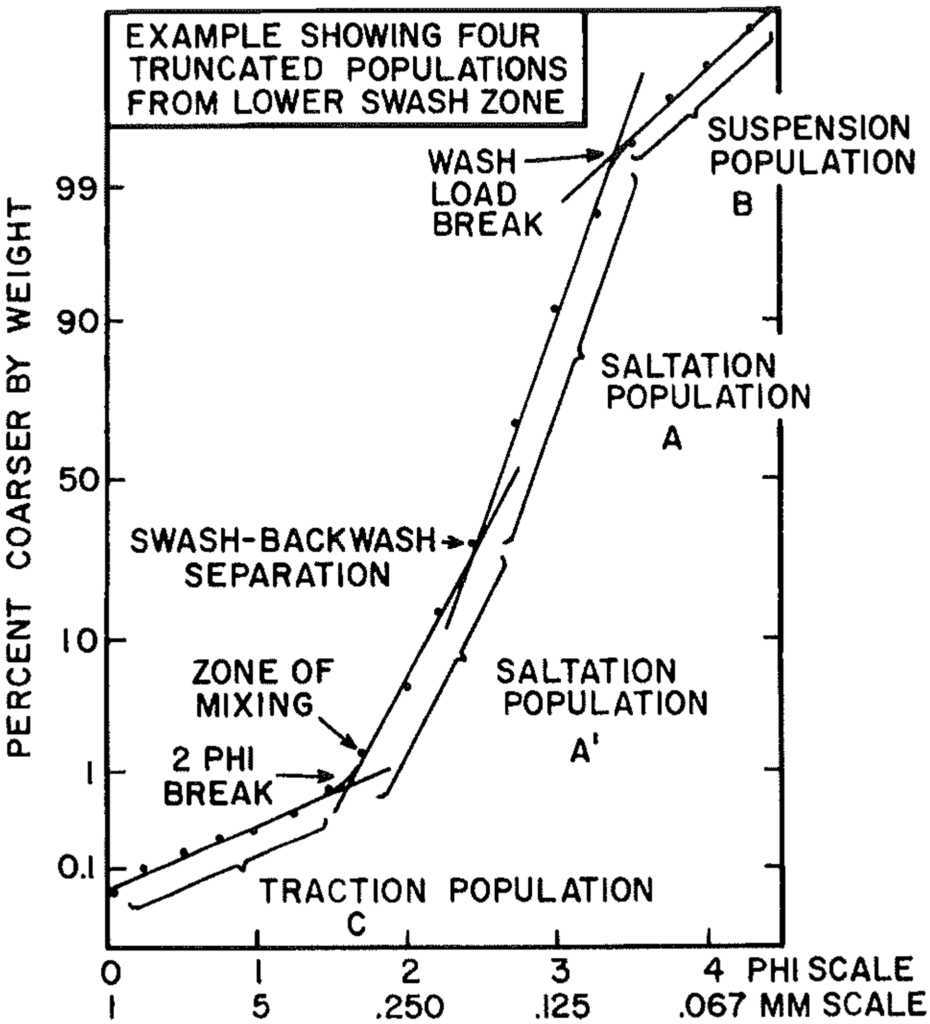


Figure 38. Grain size distribution indicating transport populations and truncation points (Visher, 1969)

transport modes and sedimentation processes is useful in determining the origin of sediments and what factors influenced their deposition. Due to the complexity of Coos Bay and the numerous factors affecting sedimentation, classification of the estuarine sediments by Visher's methods could produce a variety of results.

B. Sediment Measurements

Sediment samples were taken on September 25, 1973 and April 23, 1974. These dates were chosen to represent the end of the periods of low precipitation and runoff and high precipitation and runoff, respectively. The locations from which core samples were obtained are shown on Figure 39. These locations were the sites where water quality samples were taken with several exceptions. Station 3 was at channel buoy number 5 instead of number 4. Station 15 was an additional station at the junction of the Coos River and Isthmus Slough. Station 16 was at the same location as water quality Station 15.

The core samples were collected in transparent acrylic tubes. Samples from Station 1 through Station 8 were taken manually by scuba divers. The remainder of the samples were taken using a gravity coring device positioned on a catamaran. All samples were sealed and returned to Oregon State University for analysis. The samples were extruded from the acrylic tubes in 10 centimeter

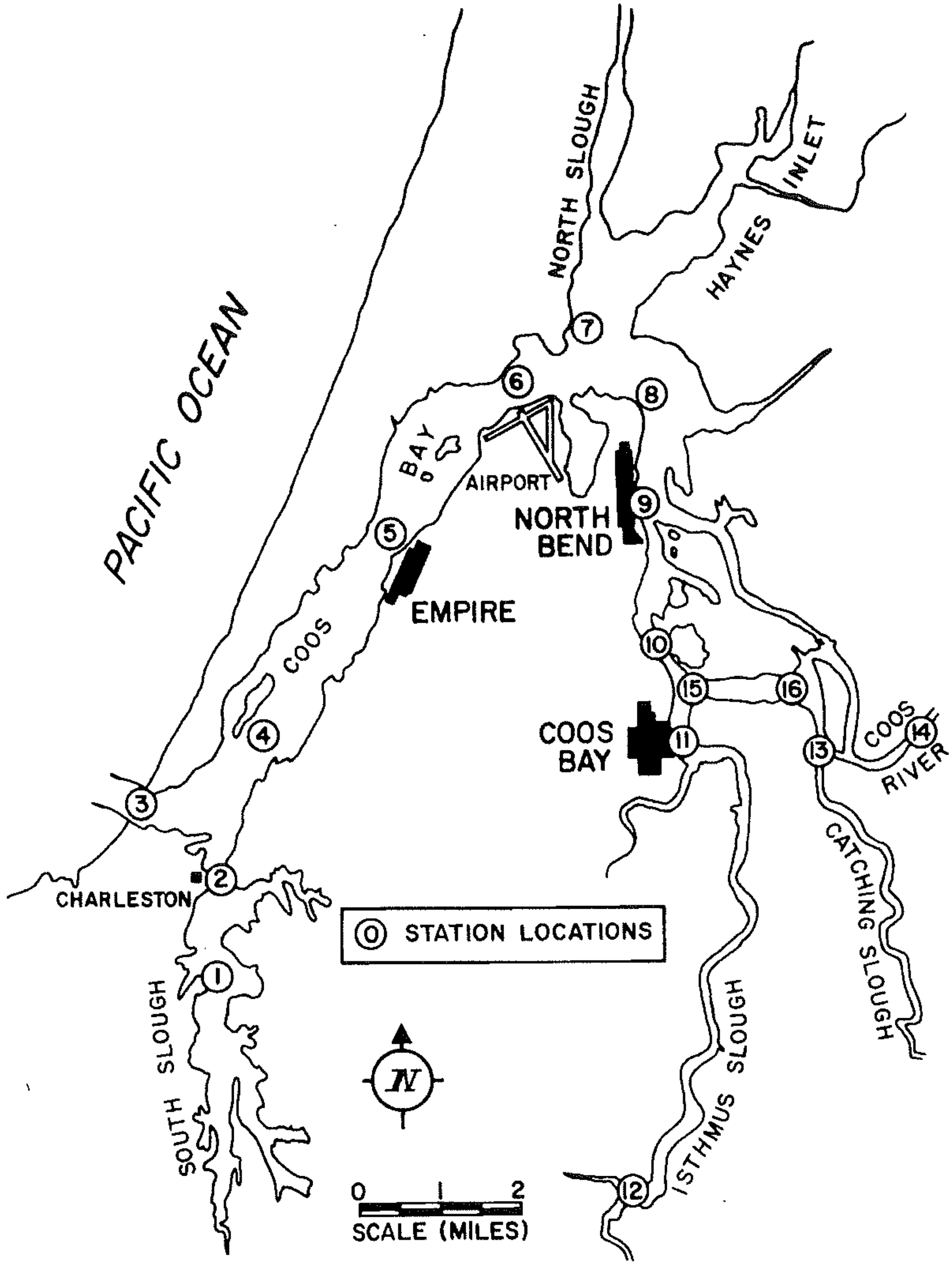


Figure 39. Sediment sample locations, Coos Bay, 1973-1974

lengths. The segmented lengths were air dried and weighed. Only the top 10.0 centimeters were analyzed in order to determine the near surface characteristics. This surface layer has been shown to be the most important sediment region for dependent biological activity and water quality.

The segments were separated for analysis of grain size, volatile solids, and specific gravity. Analysis of the grain size was conducted using hydrometer technique and sieving in accordance with American Society for Testing and Materials (ASTM) standards (Procedure for Testing Soils, 1964). Volatile solids (a measure of the organic constituents) samples were oven dried at 110°C to remove hygroscopic moisture and then burned at 600°C to oxidize any volatile materials present. The samples were weighed after each of these procedures. The volatile solids contents were then expressed in percent of the oven dried weight. Specific gravity of samples was determined according to ASTM standards using a pre-calibrated pyncnometer. Porosity was then calculated using the volume, air dried weight and specific gravity.

C. Sediment Results

Grain size distributions and a listing of sediment data are included in Appendix C. The figures contained in this section form the analytical base from which the sediment results were derived.

Profiles described as the Main Channel depict all locations except those in Isthmus Slough. Isthmus Slough was plotted separately to emphasize the sediment differences between the slough and the Coos River. Maintenance dredging using a pipeline suction dredge was being conducted in the area of the Corps of Engineers Dock on April 23, 1974. Since the dredge was working directly over the sample site, there were two sample taken, one downstream and one upstream from the dredge. It was thought that there might be some discernible differences in the two sample results. The positions of sampling at this station were noted on Figures 40 through 43.

1. Median Grain Size

The upper ten centimeters of each sediment sample was analyzed to determine the median grain size. Figure 40 depicts median grain size as it varied longitudinally in the estuary. Only several stations had any significant seasonal variations. In September the median grain size was relatively constant for the entire estuary. It varied from 0.2 mm to 0.3 mm with the exception of the two stations in Isthmus Slough. Particles in this range are classified as fine sand. The two stations in Isthmus Slough, located 23.2 kilometers and 28.9 kilometers from the entrance, had median grain sizes classified as silt. These were 0.020 mm and 0.015 mm, respectively. The finer grain sizes found in Isthmus Slough were expected since

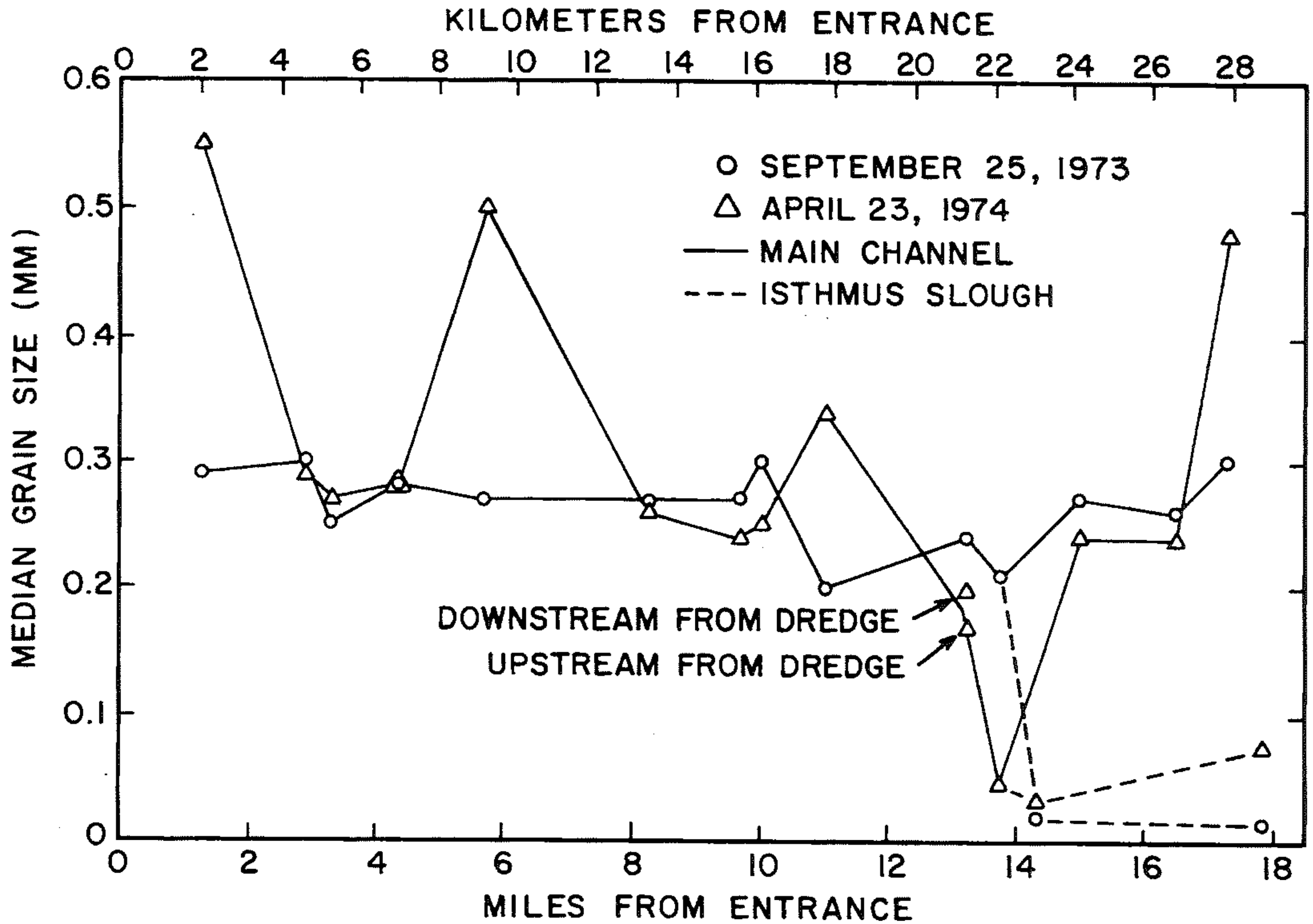


Figure 40. Median grain size vs. distance from entrance, Coos Bay, September 25, 1973 and April 23, 1974

there is no direct fresh water flow at these locations to flush the fines away. The tidal currents measured in Isthmus Slough were less than those measured in the Coos River which would also account for the deposition of the finer sediments. The results of the April data were predictable except for the sample 9.2 kilometers from the entrance. This station had a median grain size approximately 0.2 mm greater than the adjacent upstream and downstream stations which was probably due to shell fragments in the sample. The coarse median grain size (0.55 mm) near the mouth is due to the high velocity current experienced there. Only the larger particles do not become entrained and carried away. At a distance of 27.9 kilometers the influence of the high velocity of the greater seasonal river flow is indicated; the median grain size was 0.48 mm in April compared to 0.30 mm in September. The river flow on April 23, 1974 was 23.3 CMS (824 CFS) and the flow on September 25, 1973 was 46.2 CMS (1633 CFS).

The two samples taken 21.2 kilometers (13.2 miles) from the entrance were the ones taken downstream and upstream from the maintenance dredge. The difference of 0.03 mm between the two samples was minimal. The difference between these samples and the sample at this location in September was also very small. A station which did show considerable change, however, was the next one upstream, 22.2 kilometers (13.7 miles) from the entrance. This station is located where Isthmus Slough joins the Coos River. It appears that the dredge removed the coarse sediment of the upper layer and left the silt which is typical of Isthmus Slough. Apparently the layer of coarse sediment was not as thick at this location as it was further downstream.

2. Uniformity Coefficient

Figure 41 presents the uniformity coefficient versus the distance from the entrance. The uniformity coefficient represents the variation in particle size of the sample. It is defined as the ratio of D_{60} divided by D_{10}. D_{60} is the particle diameter of which 60% of the sample, by weight is finer; 10% of the sample is finer than D_{10}. A sample with a uniformity coefficient less than two is classified as uniform and considered to be well sorted. A sample with a coefficient greater than ten is non-uniform and poorly sorted (McKenzie, 1975).

The samples for both seasons were fairly uniform and displayed similar values to a distance of approximately 16.0 kilometers (10.0 miles) from the entrance. Data for the next four upstream locations were widely scattered. The large increase at 21.2 kilometers (13.2 miles) in September was due to wood chips and shell fragments being present throughout the sample which was fine sand and silt. Plant fibers and wood chips possibly accounted for the non-uniformity of the samples 23.2 kilometers (14.4 miles) and 28.9 kilometers (17.3 miles) from the entrance. The wood chips are debris from the wood

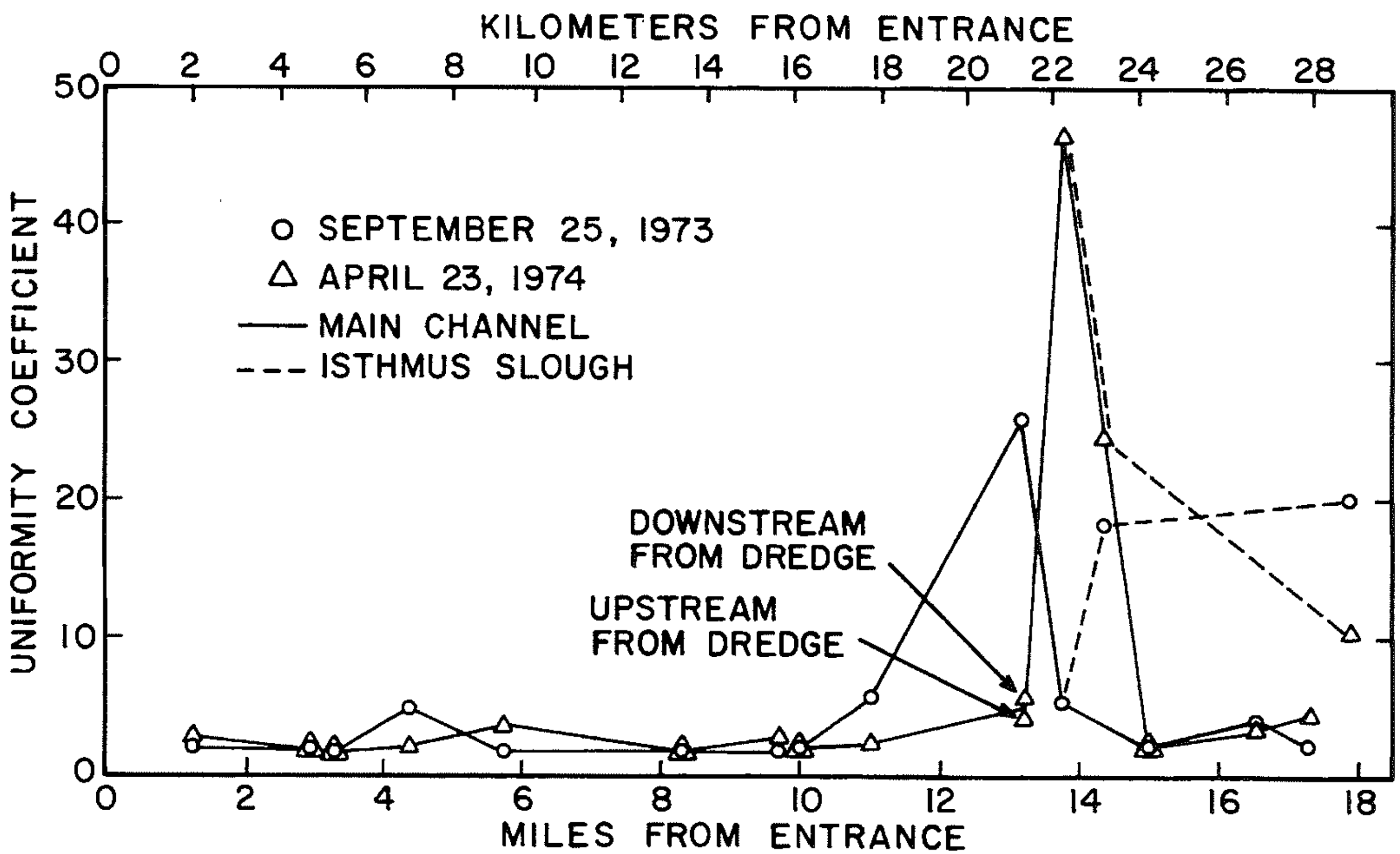


Figure 41. Uniformity coefficient vs. distance from entrance, Coos Bay, September 25, 1973 and April 23, 1974

products industries on Isthmus Slough and from the large amounts of log storage adjacent to the banks of Isthmus Slough. The large degree of non-uniformity (46.4) which occurred in April at the station 22.1 kilometers (13.7 miles) from the entrance could be explained by its location at the confluence of Isthmus Slough and Coos River. The fluviatile sediments could be settling due to the decrease in velocity at the bend. They would then be mixed with the finer sediments of Isthmus Slough. The most upstream station in Isthmus Slough (28.9 kilometers) displayed non-uniformity in April as it did in September. Wood fragments were again present. There was essentially no difference in the samples taken downstream and upstream from the dredge (Station 10, 21.2 kilometers). The uniformity coefficient was approximately 5.0 on April 23, 1974 compared to 26.0 on September 25, 1973. This could have been due to removal by the dredge of the non-uniform layers. The samples were generally well sorted with the exception of Isthmus Slough. The samples in Isthmus Slough were poorly sorted since the currents were too small to selectively remove the fines.

3. Volatile Solids

The results of the volatile solids analysis are shown on Figure 42. There was not much variation in September up to approximately 16.0 kilometers (10.0 miles) from the entrance where a rising trend

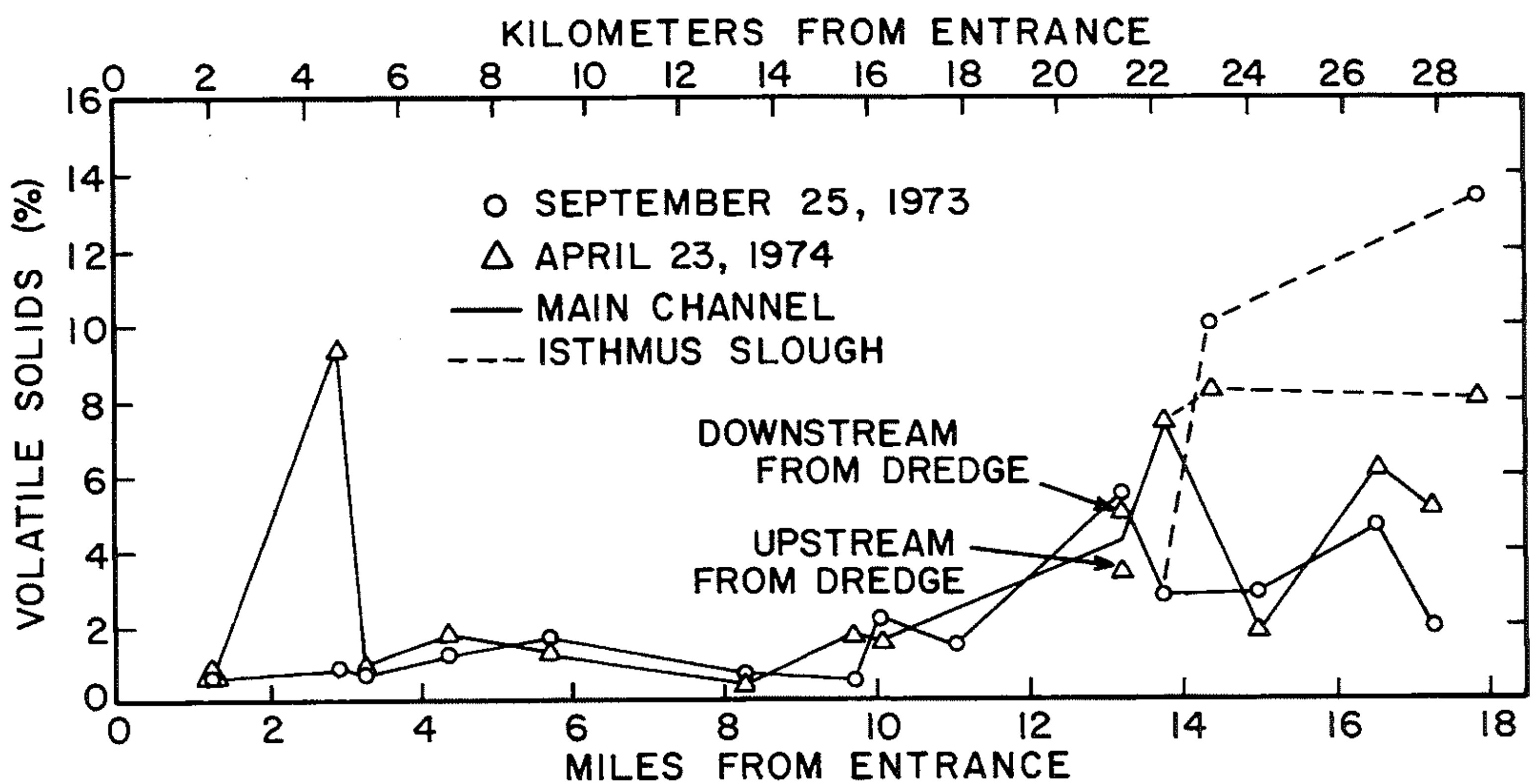


Figure 42. Volatile solids vs. distance from entrance, Coos Bay, September 25, 1973 and April 23, 1974

began. This characteristic break point was also noted on the plot of uniformity coefficient. There were two large peaks at 23.2 kilometers (14.4 miles) and 28.9 kilometers (17.9 miles). These were the two stations in Isthmus Slough which had samples previously described as containing numerous wood fragments. These fragments were the primary cause of the high volatile solids content. The rising trend which began at the break point could be attributed to the decreasing influence of the tidal flow transporting oceanic sediments. The fluviatile sediments are usually higher in organic content and their presence would cause the increase in volatile solids which occurred.

The April 23, 1974 volatile solids plot closely followed the pattern of the September 25, 1973 profile. The only distinct dissimilarity was the value of 9.4% for the sample 4.7 kilometers (2.9 miles) from the entrance. There was no visual indication to determine why this sample had such a high volatile solids content. There was no large difference in the samples taken downstream and upstream from the dredge's operation.

4. Porosity

The plot of porosity versus the distance from the entrance on Figure 43 was constructed to analyze the longitudinal variation in the porosity of the sediment within the estuary. Porosity is the ratio of the pore volume to the total volume of the sediment (Linsley and

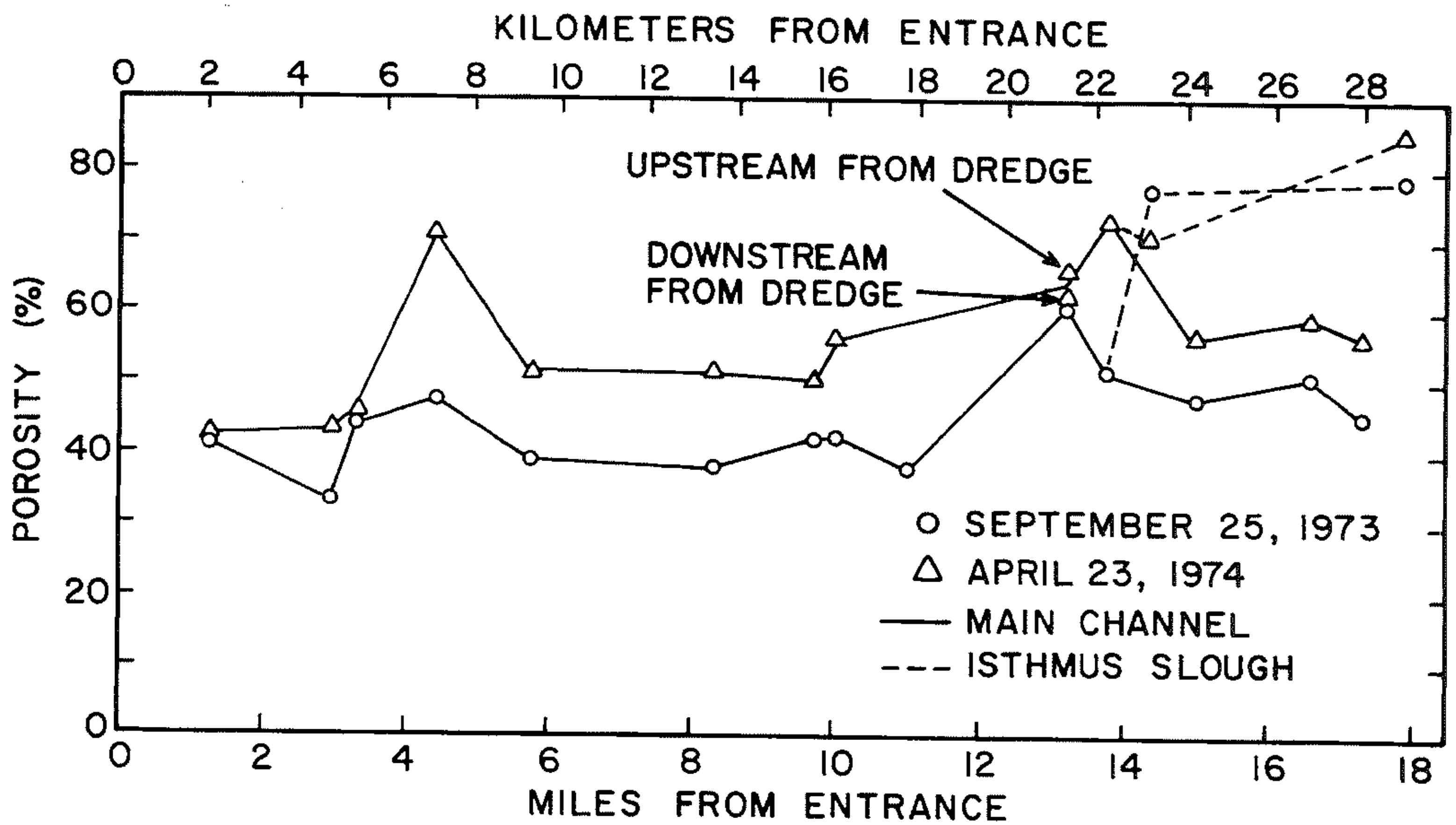


Figure 43. Porosity vs. distance from entrance, Coos Bay, September 25, 1973 and April 23, 1974

Franzini, 1964). The porosity is a measure of the compactness of the sediment. Turbulent areas with low net currents generally have sediments that are highly porous. This is due to the constant mixing with no opportunity for consolidation. Sand is usually a good example of a non-porous sediment because of its tendency to compact.

Both seasonal profiles on Figure 43 have an increasing trend proceeding upstream. With the exception of one sampling location, the April 23, 1974 profile exhibited higher porosities. This is thought to be due to the greater mixing of the sediments caused by the corresponding or preceeding higher flows and runoffs of this season. The higher flows also carry larger particles which create a less compact sediment as long as all the smaller particles are not washed away.

In September the profile (Figure 43) was relatively constant up to a distance of approximately 17.9 kilometers (11.1 miles). This is nearly the same area where large variations began on the plots of uniformity coefficient and volatile solids. It is possible that the volatile solids analysis influenced the porosity data. Since the porosity was determined by finding the specific gravity of the inorganic material, the volatile solids burned off could have decreased the density and thus indicated an increase in the porosity of the inorganic material. This tendency was seen as a high porosity at some of the same stations where there was high volatile solids.

Assuming no dependence on volatile solids the high porosity for both seasons in Isthmus Slough (samples taken 23.2 kilometers and 28.9 kilometers from the entrance) was caused by the constant mixing of the silt by tidal action. The higher porosity at the confluence of Isthmus Slough and the Coos River (22.1 kilometers) on April 23, 1974 was probably caused by the addition of the larger particles to the fine sediment. There apparently was sufficient fine sediment present that it was not all washed away allowing the larger particles to compact. The reason for the increase in porosity to 71% at Yonkers Point in South Slough (7.1 kilometers) was probably increased seasonal runoff carrying larger particles into the slough and tidal action creating mixing. There was no significant difference between the samples taken downstream and upstream from the dredge.

5. Interpretation of Grain Size Distributions

Four selected grain size distributions were plotted on Figures 44 through 47. All of the samples were taken on the same day, September 25, 1973. These samples were selected because they were the extremes of the locations sampled. The remainder of the grain size distributions are presented in Appendix C for the reader's interpretation.

The grain size distributions were plotted on arithmetic probability paper with percent finer by weight versus phi following Visher's

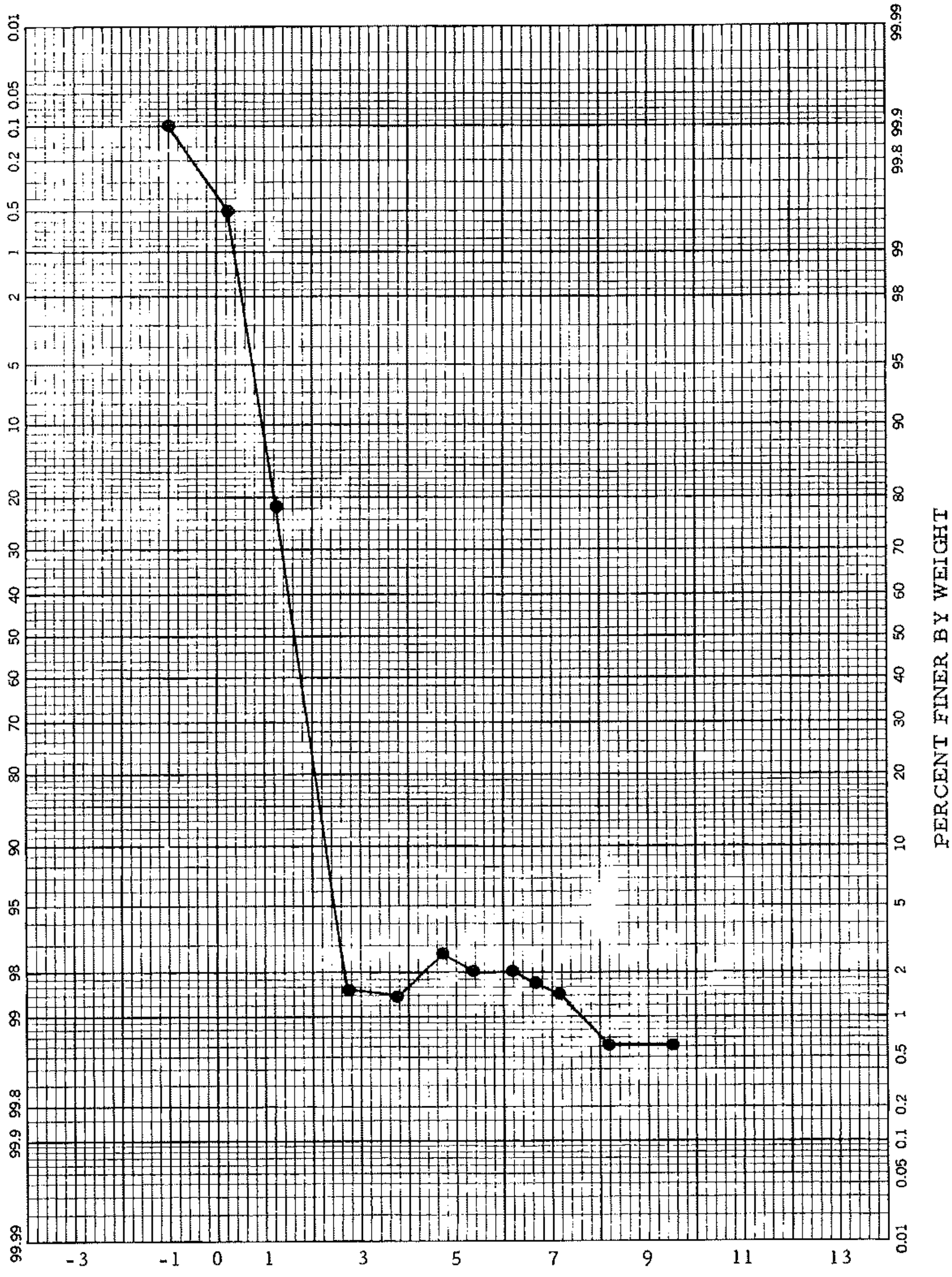


Figure 44. Grain size distribution at navigation buoy #5, Coos Bay, September 25, 1973

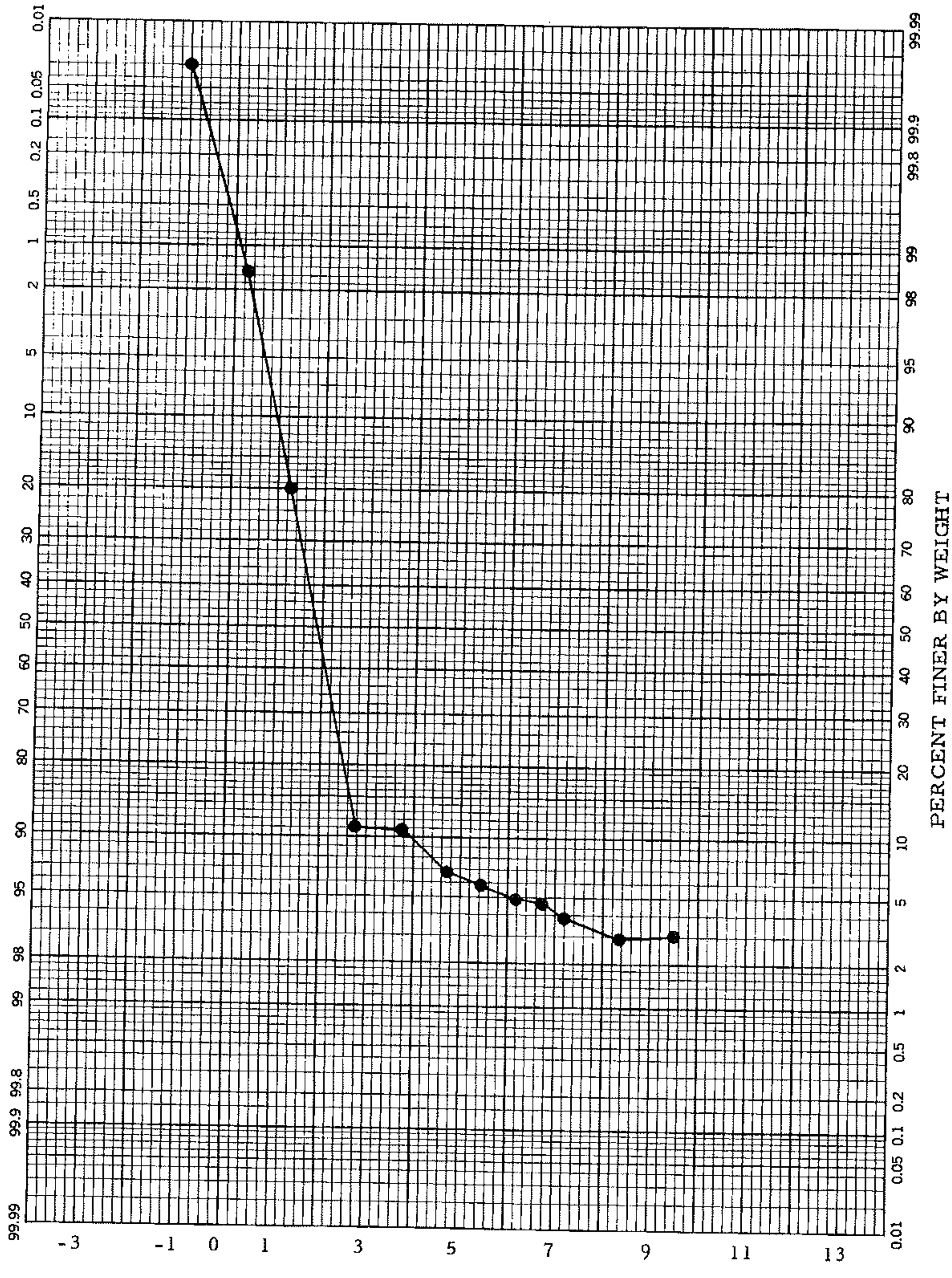


Figure 45. Grain size distribution at Yonkers Point, South Slough, Coos Bay, September 25, 1973

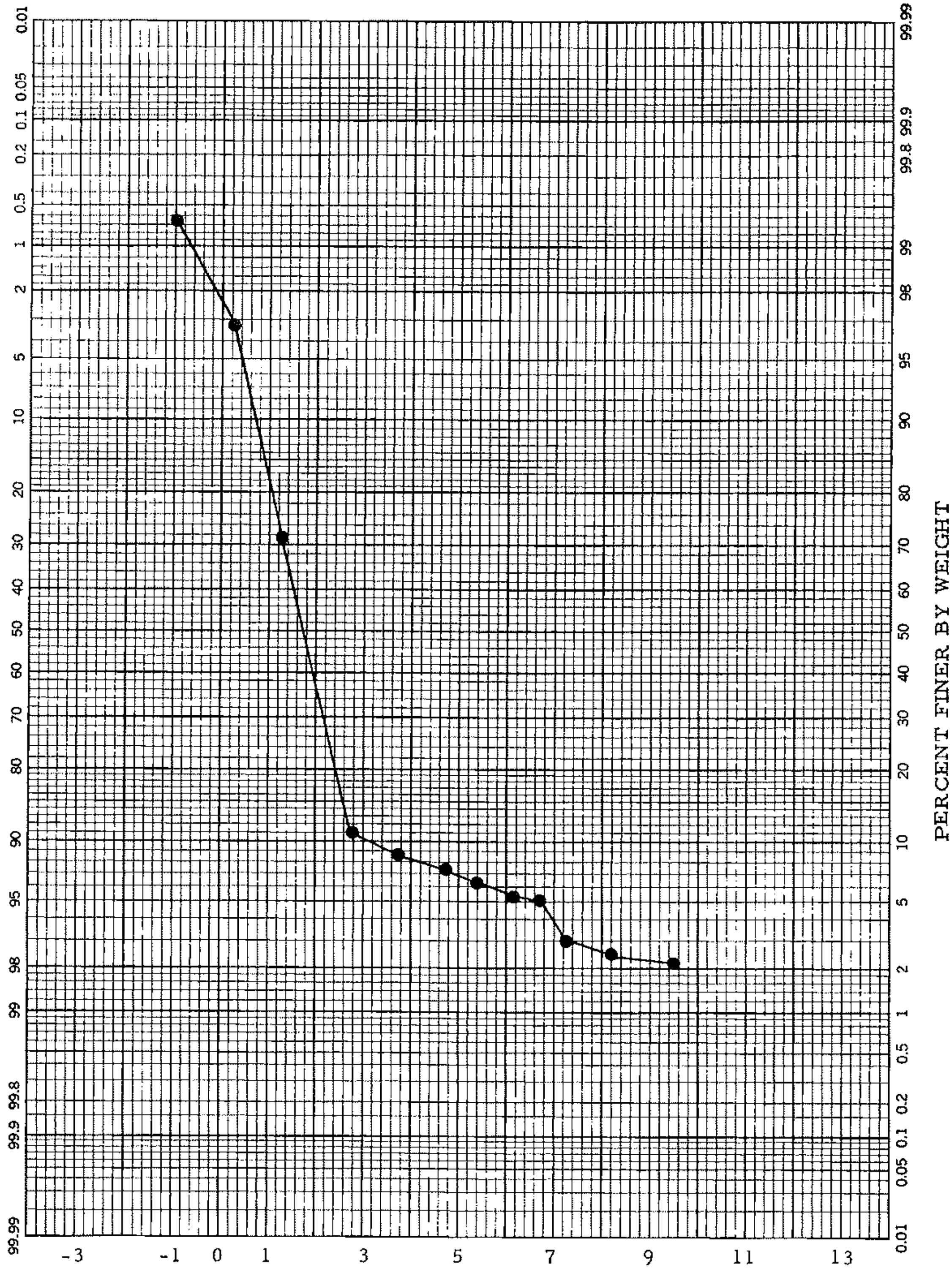


Figure 46. Grain size distribution at Coos River Highway bridge, river kilometer 27.89 (mile 17.33), Coos Bay, September 25, 1973

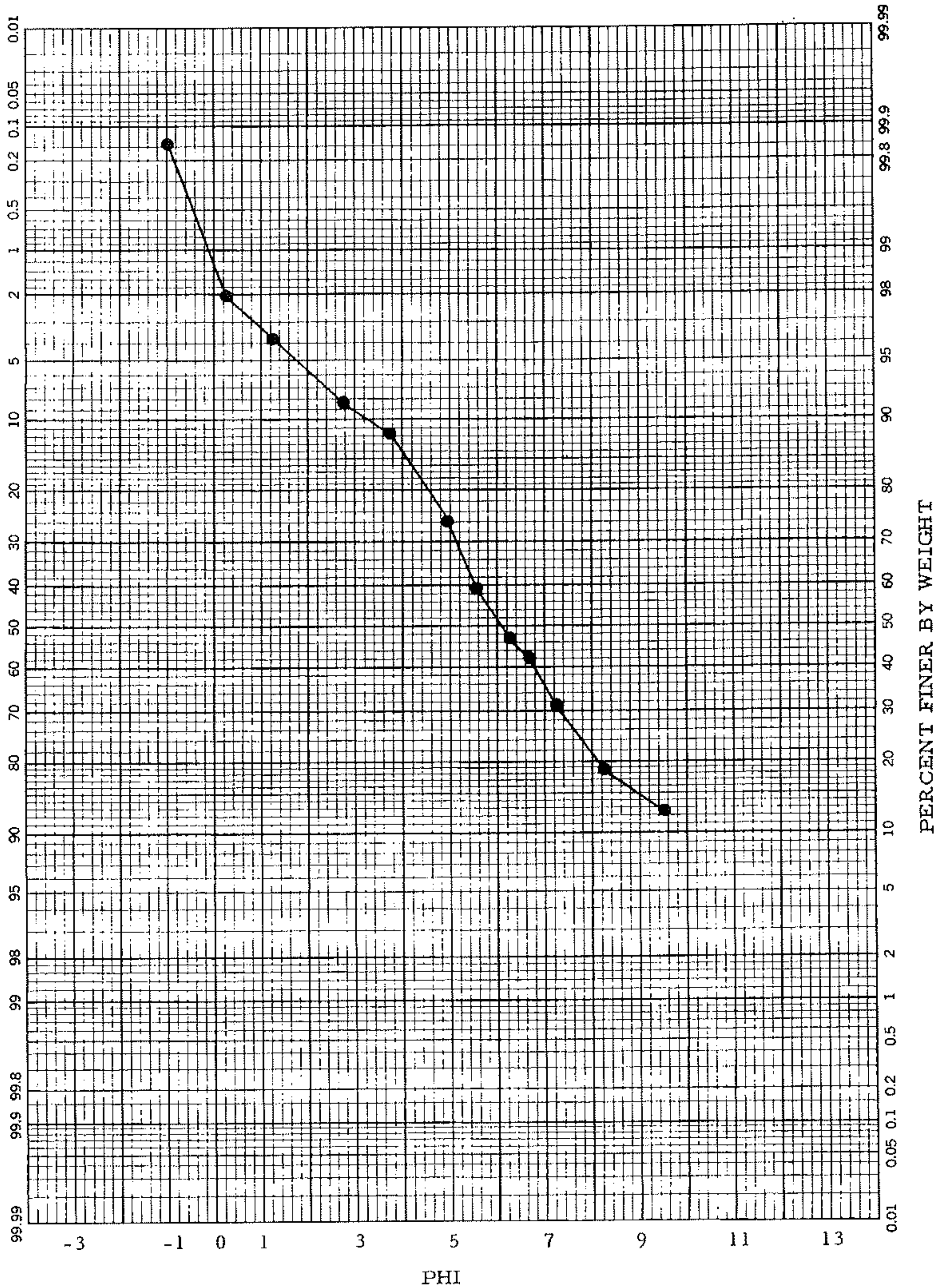


Figure 47. Grain size distribution at junction of Shinglehouse Slough and Isthmus Slough, Coos Bay, September 25, 1973

(1969) method for classifying the modes of transport. There was no attempt made to identify the specific sedimentation processes due the small number of samples and the widespread area over which they were collected. Figure 44 of the entrance clearly shows the three modes of transport: traction, saltation and suspension. The truncation point between traction and saltation occurred at 0.25 phi. The truncation point separating the saltation population from that of suspension was at 2.75 phi. Approximately 98% of the distribution was transported by saltation. This was as expected since the median grain size indicated the sample to be fine sand. The uniformity coefficient of this sample indicated it to be well-sorted. This was also deduced from Figure 42. The sharp, almost vertical, slope of the saltation population indicated that it was well-sorted. In contrast, the shallow slope of the suspension population indicated poor sorting. The discontinuity which occurred on Figure 44 at approximately 4.0 phi was the division of sieve and hydrometer analysis. There was apparently a small error in one of the analysis techniques. The slope of the lines on the plots were not approximated. Data points were connected to avoid possible misinterpretation of the results.

Figure 45 does not have a traction population as easily discerned as Figure 44. There was only a small slope change at 0.25 phi indicating possibly that the traction population had approximately the same sorting characteristics as the saltation population or that there was no transport by traction. There were not enough samples for comparison to determine which case occurred at this location. A larger suspension population for Yonkers Point in South Slough (Figure 45) was found as compared to results for the bay entrance. This is due to the lower velocity in South Slough which allowed more of the fines to settle.

Figure 46 shows the sample taken at Station 14 in the Coos River, 27.9 kilometers from the entrance. As with Figure 44, three transport modes were again indicated. The saltation population was not as well-sorted as the sample at the entrance. This was probably caused by the availability of varied sediments in the river whereas the entrance receives mostly marine sands.

Figure 47 showed the most variance when compared to the other three samples. This was as expected since Isthmus Slough is the area of lowest tidal currents and receives no riverine flow. It appears that traction occurred and the truncation point separating it from saltation was at 0.25 phi. It was very difficult to determine a truncation point between saltation and suspension. It appears that it occurred at 3.75 phi. It is evident from Figure 47 that previous currents were much lower at this location which allowed more fines to settle. Approximately 75% of the distribution had a phi value of greater than 4.0. This compared with the other locations which ranged from approximately 2% to 8% of the distribution greater than 4.0 phi.

Plots of grain size distribution (Figures 44, 47) had truncation points which fell within the ranges of the truncation points given by Custer and Ingram (1974) indicating that Visher's (1969) method is a valuable and generally accurate tool for analyzing the modes of sediment transport in Coos Bay.

VII. SUMMARY AND CONCLUSIONS

The Coos Bay Estuary is a highly industrialized area which has received a great deal of use and abuse throughout its history. The wood products industry has been mainly responsible for the growth of Coos Bay; it has become the world's largest lumber shipping center. Extensive dredging has taken place to enlarge and maintain the navigation channel for commercial ship traffic; these dredge and fill operations have changed the dynamic response of the estuary.

NOAA tidal predictions were evaluated at the entrance and the U. S. Army Corps of Engineers dock in the city of Coos Bay. Measured ranges were predominantly higher than predicted ranges at both locations. The predicted values were generally within 15% of the measured values. There was a large degree of variance in the accuracy of the time predictions between the two locations. At the entrance 80% of the predicted times were within twenty minutes of the measured ones. Only 25% were within twenty minutes at Coos Bay. There was a normal distribution of the time error at the entrance which was slightly negatively skewed. The time error at Coos Bay was not normally distributed with almost all the measured tides occurring earlier than the predicted ones.

Much of the fill of the estuary (see Figure 2) has taken place after the measurements for the NOAA tide predictions made in 1933 and 1934. It is thought that the fill is responsible for creating the larger measured ranges than those predicted. The fill decreased the volume of the estuary allowing the forcing tide to cause greater ranges. Channel dredging after 1934 significantly affected the accuracy of the time predictions at Coos Bay. Main channel dredging to 7.3 meters (24 feet) was completed in 1937. Channel depth was increased to 9.1 meters (30 feet) in 1951. The deeper channel has caused the tidal wave to move faster with the result that the measured times of tidal heights are earlier than those predicted. The predictions at the entrance are still fairly accurate since the tidal wave does not travel very far to this location. It is only 4.63 kilometers from the mouth compared to 21.23 kilometers to the Corps of Engineers dock.

Because of the large time errors at Coos Bay, NOAA predictions should be revised. Unknown times of tidal heights can be extremely hazardous to navigation. The large vessels which service the port could possibly run aground or be unable to get underway without accurately knowing the stage of the tide.

Phase relationships between maximum ebb and flood velocities and maximum and minimum tidal heights were different at the entrance and at the Marshfield Channel in the Coos River. Velocity lags on flood tides were less than those for the ebb tides for all seasons in the Coos River. In the spring the conditions at the entrance were exactly opposite. The difference is apparently due to the magnitude of the cross-sectional area change at each location between the high and low tides. The ratio of the difference in cross-sectional areas to the cross-section at high tide was at least twice as great in the Coos River as compared to the entrance. At the entrance the cross-sectional area change was not significant and river flow was the dominant effect on lag time causing it to be less on the ebb than the flood tide. In the Coos River on the flood tide the small cross-section caused velocity to peak very soon, but on the ebb it took much longer to peak since the water level had to reach the smaller cross-section before maximum velocity occurred.

Comparison of high and low tide lag times at the measured locations within the estuary were extremely variable. There was a tendency for high tide lags to be range dependent. River flow influenced the lag times at the Corps of Engineers dock and the entrance to Catching Slough.

By comparing the range at the mouth to the range at the upstream measurement stations it was found that the tidal wave was amplified at each location for all seasons. Amplification factor decreased with increasing river flows. At the entrance to Catching Slough there was an exponential decrease in the amplification factor at flow rates greater than 10 CMS. This is thought to be due to the increased boundary friction over the tidal flats and greater divergence caused by the wider channel.

Salinity profiles which were constructed from the water quality data indicated mixing characteristics that changed with the seasonal river flows. In the season of lowest flow, the summer, the estuary was well-mixed. It was also well-mixed in the spring. In the seasons of higher flow, the fall and winter, there was significant difference of the mixing pattern on the high and low tides. In the fall, which was the season of highest flow, the estuary was partially-mixed on the low tide and stratified on the high tide. In the winter the low tide again exhibited a partially-mixed characteristic. On the high tide, the estuary was well-mixed to approximately 12.9 kilometers from the entrance and partially-mixed from there upstream.

Classification of the mixing characteristics using temperature profiles was not as conclusive as the salinity profile results. Difficulties arose when the fresh water and seawater temperatures were nearly equal. The profiles were nearly isothermal which were useless for the purpose of classification. When there was significant difference in the temperatures the profiles were comparable to those of salinity.

Two quantitative methods were used to classify the circulation pattern of the estuary. Using Simmons' flow ratio method, Coos Bay was found to be well-mixed except for the fall season when it was partially-mixed. Using Burt and McAlister's salinity gradient method, the estuary was partially-mixed except for the summer season when it was well-mixed. Even though these classification schemes are quite useful, because circulation patterns are not the same for all portions of the estuary they can be misleading. It is for this reason that thewriter feels salinity profiles provide the clearest picture of the mixing characteristics.

Flushing rates were calculated for each season using several different methods. Ketchum's modified tidal prism method provided the most conservative estimates of the flushing rates which were dependent on the river flow. The rates ranged from 13.4 days in the fall (season of highest river flow) to 48.5 days in the spring. These rates were calculated for a flushing distance of 43.5 kilometers from the entrance. Spring was not the season of lowest flow during this study, but the range on the measurement day was less than half of the range in summer (season of lowest flow). Although the river flow was over ten times larger in the spring than in the summer, tidal range appeared to be the dominant factor accounting for the Spring flushing rate being approximately eight days longer than the Summer flushing rate.

Dissolved oxygen levels closely followed saturation values in the fall and winter. They were somewhat lower in the spring and summer, but the only serious depression occurred in Isthmus Slough in the summer (1974). DO levels reached 4.0 ppm which was below the range for maintaining good growth and health of fish. The low values of DO in Isthmus Slough appear to have been caused by the minimal flushing and small amount of fresh water input combined with the reduction of DO by wood products wastes and bark deposits from the extensive log storage areas.

Turbidity was directly influenced by river flow as were all of the water quality parameters. Low tide turbidites showed the greatest influence and were consistently higher than the high tide values. The highest turbidites were experienced in the fall at the time of greatest river flow. Coos Bay resembles many other estuaries in this respect with sediments from the river being the principal cause of turbidity.

The sediment samples were analyzed for grain-size distribution, uniformity coefficient, volatile solids, and porosity during two seasonal periods. The samples did not exhibit any large degree of seasonal variation. Porosity of sediments, however, was higher in the season of higher runoff; this was probably due to greater mixing caused by the previous high flows. The high flows also transported larger particles creating a less compact sediment providing the smaller particles weren't washed away. The finest grain sizes were found in Isthmus Slough, finer than in any other portion of the estuary. This was due to the smaller tidal currents and no rapid fresh water flow to transport the larger fluviatile sediments.

Isthmus Slough samples also displayed poor sorting. The currents were thought to be too small to selectively remove the fines.

Three realms of sediment deposition were thought to be present in sections of Coos Bay. Marine sediments were found predominant to approximately 16.0 kilometers from the entrance. A transition realm of marine and fluviatile sediments appeared to exist for the next several kilometers. The fluviatile realm began approximately 20.0 kilometers from the entrance and continued upstream. This region is also the area where the embayment ends and the river begins.

In a special report submitted by the U. S. Department of the Interior in June, 1971 (Natural Resources, Ecological Aspects, 1971), in the interest of protecting the resources and uses of Coos Bay it was recommended that hydrologic studies of the estuary be conducted for several reasons. These included determining "circulation and tidal transport patterns, ... flushing patterns and rates" and improving the "understanding of interrelationships between fresh water and salt water." This study has been directed toward meeting the requirements of these recommendations.

Future studies of Coos Bay should be more narrow in scope than this report. Areas covered here can serve as a baseline for more detailed work in one certain area. One interesting subject for further study would be determining the magnitude of fresh water flow rates necessary to change the mixing pattern of the estuary. This was not possible in this study since data was taken on only four days with a large variability in fresh water flows. Many more days of data would be needed or perhaps a computer program could be devised to simulate numerous varying inputs.

Computer modeling of the estuary is the key to intelligent use of the resources of Coos Bay. Goodwin's model was the only predictive program used in this study. The results of this model were surprisingly good considering it was not planned for use prior to any field research. Such models can be extremely useful in predicting the effects of proposed changes to the estuary. Coastal planners can then evaluate the desirability of the change before it takes place.

Although Coos Bay is highly industrialized compared to most of Oregon's estuaries, it is felt that the need to protect and improve its resources has been recognized. The quality of life of this estuary can continue to improve as long as a comprehensive management and development plan is intelligently employed. It is hoped that this study will provide necessary information to those responsible for implementing the plan.

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APPENDICES

APPENDIX A. Daily Measured Tidal Data

Date 1973	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
9/11	0.9	L	1800		1759		1	1815		15						
				1.71		1.89			1.99							
9/12	0.8	H	2336		0011		35	0027		51				0030		54
				-1.75		-2.20			-2.32						-2.24	
		L	0700		0615		-45	0630		-30				0705		5
				1.79					2.47						2.28	
		H	1218					1310		52				1310		52
				-1.82					-2.13						-2.11	
		L	1842		1834		-8	1855		13	1910		28	1920		38
				1.84		2.06			2.18			2.28			2.12	
9/13	0.8	H	0042		0047		23	0110		46	0135		71	0117		53
				-1.93		-2.13			-2.26			-2.36			-2.18	
		L	0648		0647		-1	0705		17	0725		37	0730		42
				2.04		2.23			2.37			2.47			2.29	
		H	1242		1302		20	1330		48	1405		83	1336		54
				-2.05		-2.28			-2.36			-2.44			-2.24	
		L	1930		1907		-23	1930		0	1956		26	2000		30
				1.87		2.10			2.24			2.34			2.13	
9/14	0.9	H	0100		0118		18	0145		45	0217		77	0148		48
				-1.77		-1.97			-2.09			-2.19			-2.03	
		L	0724		0714		-10	0732		8	0805		41	0755		31
				2.01		2.17			2.33			2.43			2.28	
		H	1312		1325		13	1355		43	1440		88	1400		48
				-2.31		-2.47			-2.62			-2.72			-2.48	
		L	2000		1947		-13	2008		8	2035		35	2047		47
				1.98		2.14			2.30			2.41			2.15	
9/15	0.8	H	0154		0207		13	0230		36	0305		71	0245		51
				-1.56		-1.69			-1.84			-1.94			-1.82	
		L	0748		0742		-6	0807		19	0840		52	0830		42
				1.95		2.05			2.22			2.32			2.21	

APPENDIX A. Continued

Date 1973	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
9/15	0.8	H	1342		1403		21	1430		48	1510		88	1429		47
				-2.42		-2.60			-2.72			-2.84			-2.52	
		L	2035		2035		0	2055		20	2115		40	2129		54
				1.95		2.15			2.28			2.38			2.10	
9/16	0.8	H	0242		0300		18	0323		41	0350		68	0334		52
				-1.27		-1.47			-1.57			-1.66			-1.58	
		L	0830		0825		-5	0845		15	0915		45	0905		35
				1.76		1.95			2.08			2.09			2.08	
		H	1412		1440		28	1505		53	1540		88	1507		55
				-2.45		-2.63			-2.78			-2.80			-2.60	
		L	2130		2122		-8	2135		5	2200		30	2220		50
				1.87		2.04			2.18			2.29			2.01	
9/17	1.0	H	0330		0352		22	0415		45	0440		70	0430		60
				-1.07		-1.18			-1.30			-1.39			-1.32	
		L	0854		0907		13	0935		41	0955		61	0945		51
				1.62		1.69			1.84			1.89			1.86	
		H	1500		1510		10	1540		40	1640		100	1547		47
				-2.40		-2.54			-2.66			-2.88			-2.41	
		L	2218		2210		-8	2221		3	2247		29	2305		47
				1.75		1.88			2.02			2.13			1.88	
9/18	1.1	H	0430		0453		23	0511		41	0535		65	0518		48
				-0.83		-0.93			-1.05			-1.13			-1.07	
		L	0942		0948		6	1006		24	1035		53	1015		33
				1.44		1.52			1.65			1.80			1.69	
		H	1554		1606		12	1631		37	1657		63	1610		46
				-2.23		-2.40			-2.53			-2.62			-2.44	
		L	2324		2313		-11	2322		-2	2353		29	2357		33
				1.67		1.84			1.98			2.07			1.89	
9/19	2.3	H	0554		0611		17	0622		28	0655		61	0630		36
				-0.57					-0.75			-0.84			-0.78	

APPENDIX A. Continued

Date 1973	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
9/19	2.3	L	1042					1100		18	1130		48	1107		25
				1.22					1.39			1.40			1.42	
		H	1654		1656		2	1735		41	1745		51	1735		41
				-2.19		-2.33			-2.50			-2.45			-2.36	
9/20	5.1	L	0030		0021		-9	0050		20	0110		40	0115		45
				1.58		1.73			1.54			1.90			1.76	
		H	0700		0711		11	0747		47	0815		75	0752		52
				-0.67		-0.76			-0.84			-0.91			-0.87	
		L	1212		1224		12	1245		33	1300		48	1250		38
				1.11		1.18			1.25			1.35			1.28	
		H	1806		1824		18	1851		45	1915		79	1855		49
				-2.21		-2.37			-2.45			-2.55			-2.36	
9/21	14.8	L	0136		0139		3	0153		17	0217		43	0227		51
				1.72		1.87			1.97			2.06			1.88	
		H	0818		0839		21	0900		40	0925		65	0910		50
				-0.81		-0.98			-1.01			-1.09			-1.04	
		L	1330		1344		14	1408		38	1440		70	1425		55
				1.26		1.38			1.45			1.53			1.50	
		H	1924		2005		41	2010		46	2030		66	2020		56
				-2.09		-2.30			-2.41			-2.52			-2.33	
9/22	14.2	L	0300		0244		-16	0258		-2	0323		23	0337		37
				1.94		2.15			2.26			2.37			2.18	
		H	0912		0939		27	1000		48	1030		78	1010		58
				-1.15		-1.17			-1.34			-1.45			-1.39	
		L	1442		1505		23	1525		43	1600		78	1550		68
				1.47		1.56			1.67			2.02			1.72	
		H	2042		2054		12	2122		40	2150		68	2130		48
				-2.30		-2.42			-2.56			-2.60			-2.45	
9/23	25.1	L	0348		0357		9	0408		20	0435		47	0447		59
				2.04		2.18			2.32			2.41			2.23	

APPENDIX A. Continued

Date 1973	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
9/23	25.1	H	1006		1030		24	1055		49	1128		82	1103		57
				-1.50		-1.58			-1.73			-1.90			-1.74	
		L	1600		1605		5	1636		36	1650		50	1658		58
				1.80		1.92			2.01			2.04			2.03	
		H	2200		2223		23	2245		45	2310		70	2251		51
				-2.25		-2.38			-2.47			-2.49			-2.38	
9/24	60.6	L	0430		0445		15	0505		35	0632		62	0530		60
				2.17		2.25			2.38			2.46			2.30	
		H	1036		1057		21	1130		54	1202		86	1130		54
				-1.98		-2.03			-2.18			-2.27			-2.15	
		L	1642		1715		33	1730		48	1745		63	1757		75
				1.94		2.00						2.25			2.11	
		H	2242		2308		26				2400		78	2340		58
				-2.27		-2.36						-2.60			-2.37	
9/25	46.3	L	0500		0523		23				0613		73	0615		75
				2.27		2.34						2.60			2.37	
		H	1118		1138		20				1243		85	1213		55
				-2.27		-2.50						-2.55			-2.36	
		L	1718		1755		37	1808		50	1820		62	1850		92
				2.14		2.25			2.37			2.49			2.26	
9/26	21.0	H	2330		0010		40	0025		55	0045		75	0040		70
				-2.15		-2.27			-2.39			-2.47			-2.27	
		L	0536		0602		26	0618		42	0640		64	0652		76

APPENDIX A. Continued

Date 1973	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
12/16	208	H	1718					1800		42	1825		67	1810		52
				-1.40					-1.59			-1.66			-1.52	
		L	2324					2350		26	0013		49	0019		55
				1.96					2.14			2.23			2.08	
12/17	270	H	0606					0717		71	0720		74	0654		48
				-1.94					-2.14			-2.24			-2.04	
		L	1306					1345		39	1358		52	1405		59
				1.09					1.28			1.38				
		H	1836		1904		28	1919		43	1936		60	1915		39
				-0.98					-1.24			-1.31			-1.20	
		L	2354					0104		70	0111		77	0120		86
				1.73					1.92			2.00			1.87	
12/18	160	H	0712					0804		52	0821		69	0745		33
				-2.14					-2.30			-2.38			-2.18	
		L	1412					1454		42	1501		49	1505		53
				1.33					1.55			1.61			1.42	
		H	2018					2050		32	2110		52	2052		34
				-0.76					-1.02			-1.07			-0.98	
12/19	108	L	0118					0200		42	0210		52	0205		47
				1.59					1.82			1.87			1.78	
		H	0754					0840		46	0902		68	0832		38
				-2.21					-2.45			-2.53			-2.33	
		L	1506					1550		44	1600		54	1600		54
				1.55					1.82			1.89			1.70	
		H	2124		2150		26	2205		41	2222		58	2200		36
				-0.62					-0.89			-0.94			-0.88	
12/20	385	L	0154					0255		61	0300		66	0300		66
				1.50					1.77			1.83			1.79	
		H	0830		0912		42	0925		55	0945		75	0917		47
				-2.33					-2.55			-2.58			-2.27	

APPENDIX A. Continued

Date 1973	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
12/20	385	L	1548					1645		57	1655		67	1715		87
				1.70					1.89			1.91				
		H	2230					2327		57	2327		57			
				-0.69					-0.90			-0.94				
12/21	412	L	0318					0412		54	0413		55			
				1.37					1.62			1.68				
		H	0930					1018		48	1019		49			
				-2.51								-2.74				
		L	1642								1745		63			
				1.84								2.09				
		H	2318								0110		112			
				-0.77								-1.04				
12/22	249	L	0406								0600		114			
				1.34								1.60				
		H	1006								1157		111			
				-2.63								-2.92				
		L	1724								1835		71	1830		66
				1.96								1.86			1.86	
12/23	214	H	2400								0107		67	0020		20
				-0.88								-1.17			-1.09	
		L	0448								0552		64	0540		52
				1.41								1.70			1.61	
		H	1042								1152		70	1110		28
				-2.68								-3.03			-2.12	
		L	1754		1805		11				1855		61	1915		81
				2.05		2.23						2.42			1.96	
12/24	145	H	0030		0103		33				0150		80	0120		50
				-0.73		-0.92						-1.07			-0.99	
		L	0518		0555		37				0645		87	0630		72
				1.26		1.52						1.68			1.59	

APPENDIX A. Continued

Date 1973	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
12/24	145	H	1118		1148		30				1240		82	1200		47
				-2.48		-2.33						-2.96			-2.52	
		L	1848		1900		12				1938		50	1958		70
				1.98		2.16						2.34			1.96	
12/25	155	H	0054		0140		46				0215		81	0150		56
				-0.94		-1.02						-1.20			-1.12	
		L	0600		0625		25				0705		65	0657		57
				0.94		1.49									1.58	
		H	1206		1225		19							1235		29

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
3/11	52	H	1436					1530		54	1551		75	1540		64
				-1.65					-1.90			-1.97			-1.83	
		L	2012					2055		43	2118		66	2118		66
				2.09					2.34			2.42			2.19	
3/12	109	H	0218					0310		52	0336		78	0318		60
				-2.46					-2.64			-2.71			-2.41	
		L	0906					0950		44	1019		73	1013		67
				1.84					1.36			2.19			1.90	
		H	1518					1605		47	1633		75	1615		57
				-1.21					-1.48			-1.54			-1.14	
		L	2042					2135		53	2155		73	2153		71
				1.56					1.73			1.81			1.67	
3/13	100	H	0300					0340		40	0410		70	0323		23
				-2.30					-2.71			-2.69			-2.37	
		L	0948					1015		27	1013		55	1008		20
				1.65								2.06			1.72	
		H	1618								1800		102	1558		-20
				-0.80								-1.10			-0.98	
		L	2100					2137		37	2230		90	2108		8
				1.44					1.72			1.79			1.71	
3/14	321	H	0330					0422		52	0515		105	0330		0
				-1.99					-2.23						-2.05	
		L	1036					1112		36				1045		9
				1.37					1.60						1.42	
		H	1706					1742		36				1615		-51
				-0.61					-0.82						-0.73	
		L	2154					2242		48	2253		59	2234		40
				1.06					1.25			1.30			1.16	
3/15	293	H	0424					0502		38	0518		54	0431		7
				-1.77					-2.00			-2.08			-1.78	

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
3/19	60	H	0848					0942		54	0957		69	0943		55
				-1.73					-2.00			-2.09			-1.88	
		L	1536					1555		19	1607		31	1625		49
				1.66					1.94			2.06			1.84	
		H	2248					2258		10	2312		24	2310		22
				-1.09					-1.35			-1.44			-1.35	
3/20	49	L	0336					0413		37	0426		50	0442		66
				1.25					1.50			1.90			1.51	
		H	1000					1028		28	1012		42	1030		30
				-1.83					-2.13			-2.24				
		L	1612					1625		13	1649		37			
				1.80					2.12							
		H	2254					2332		38	0006		72			
				-1.41					-1.69			-1.78				
3/21	41	L	0430					0507		37	0539		72			
				1.50					1.78			1.86				
		H	1036					1117		51	1152		86			
				-1.87					-2.20			-2.30				
		L	1712		1700		-12	1708		-4	1741		29	1743		31
				1.91		2.04			2.23			2.32			2.11	
		H	2312		2350		38	0001		49	0028		76	0008		56
				-1.70		-1.86			-2.00			-2.09			-1.93	
3/22	35	L	0500		0525		25	0544		44	0608		68	0618		78
				1.70		1.83			1.99						1.94	
		H	1130		1136		6	1206		36	1236		66	1225		55
				-1.88		-2.01			-2.20			-2.26			-2.09	
		L	1736		1739		3	1751		15	1821		45	1832		56
				1.97		2.13			2.15			2.35			2.16	
		H	2342		0007		25	0039		57	0103		81	0045		63
				-1.98		-2.13			-2.29			-2.36			-2.18	

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
3/23	30	L	0600		0605		5	0623		23	0619		49	0703		63
				1.90		2.01			2.19						2.10	
		H	1154		1225		31	1254		60				1317		83
				-1.80		-1.92			-2.10						-2.02	
		L	1736		1807		31	1828		52	1850		74	1905		89
				2.01		2.16			2.35						2.23	
3/24	27	H	0006		0037		31	0106		60				0113		67
				-2.19		-2.35			-2.54						-2.35	
		L	0642		0641		-1	0703		21	0725		43	0743		61
				2.02		2.19			2.39						2.23	
		H	1254		1309		15	1338		44				1403		69
				-1.66		-1.83			-1.99						-1.91	
		L	1830		1839		9	1911		41	1932		63	1935		66
				2.05		2.16			2.33			2.39			2.27	
3/25	26	H	0054		0107		13	0134		40	0200		66	0145		51
				-2.37		-2.41			-2.57			-2.65			-2.46	
		L	0724		0724		0	0754		30	0810		46	0825		61
				2.16		2.19			2.32			2.41			2.23	
		H	1342		1355		13	1419		37	1440		48	1430		48
				-1.64		-1.71			-1.86			-1.94			-1.85	
		L	1906		1923		17	1952		46	2012		66	2009		63
				1.97		2.04			2.21			2.26			2.17	
3/26	23	H	0106		0139		33	0207		61	0227		81	0207		61
				-2.46		-2.53			-2.72			-2.76			-2.58	
		L	0742		0812		30	0832		50	0855		73	0904		82
				2.09		2.19			2.35			2.41			2.25	
		H	1354		1440		46	1502		68	1527		93	1519		85
				-1.37		-1.40			-1.85			-1.63			-1.58	
		L	1942		1957		15	2025		43	2042		60	2038		56
				1.85		1.86			2.03			2.09			1.98	

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
3/27	24	H	0148		0207		19	0233		45	0302		74	0233		45
				-2.48		-2.59			-2.76						-2.61	
		L	0836		0853		17	0905		29				0948		72
				2.04		2.19			2.35						2.24	
		H	1442		1527		45	1550		68				1608		86
				-1.14		-1.16										
		L	2018		2032		14									
				1.63		1.71										
3/28	117	H	0206		0255		49									
				-2.46		-2.59										
		L	0936		0957		21									
				1.73		1.77										
		H	1524		1615		51									
				-0.90		-0.98										
		L	2124		2115		-9									
				1.57		1.65										
3/29	145	H	0254		0335		41									
				-2.47		-2.56										
		L	1024		1042		18									
				1.74		1.83										
		H	1648		1723		35									
				-0.67		-0.76										
		L	2154		2157		3									
				1.34		1.40										
3/30	332	H	0348		0416		28									
				-2.39		-2.47										
		L	1148		1141		-7									
				1.57		1.74										
		H	1824		1825		1									
				-0.62		-0.76										

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
3/30	332	L	2306		2318		12									
				1.03		1.19										
3/31	202	H	0518		0529		9									
				-1.94		-2.04										
		L	1242		1238		-4									
				1.68		1.83										
		H	1918		1944		26									
				-0.78		-0.91										

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Rosebrug Lumber Time (PST)	Rosebrug Lumber Range (m)	Rosebrug Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
6/3	8	H	1142		1218		36	1251		69	1307		85	1304		82
				-1.01		-1.13			-1.26			-1.35			-1.25	
		L	1712		1708		-6	1739		27	1804		52	1755		43
				1.55		1.71			1.81			1.88				
		H	2248		2317		29	2339		51	0014		86			
				-2.76					-3.03			-3.11				
6/4	12	L	0542		0608		26	0618		36	0654		72			
				2.27					2.58							
		H	1248		1304		16	1330		42						
				-1.00		-1.13			-1.25							
		L	1736		1756		20	1823		47	1845		69			
				1.15		1.62			1.72			1.78				
		H	2318		2354		36	0023		65	0057		99			
				-2.79					-3.04							
6/5	43	L	0630		0651		21	0703		33						
				2.25					2.51							
		H	1318		1346		28	1411		53						
				-1.01		-1.16			-1.27							
		L	1806		1836		30	1858		52	1927		81	1923		77
				1.48		1.58			1.73			1.79			1.74	
6/6	34	H	0030		0034		4	0059		29	0132		62	0115		45
				-2.69					-2.97						-2.66	
		L	0706		0726		20	0736		30				0833		87
				2.22					2.48						2.21	
		H	1424		1423		-1	1446		23				1501		38
				-0.97		-1.07			-1.22						-1.23	
		L	1842		1914		32	1935		53	1955		73	1953		71
				1.36		1.43			1.56			1.65			1.62	
6/7	27	H	0054		0114		20	0135		41	0203		69	0140		46
				-2.58		-2.65			-2.80						-2.50	

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
6/7	27	L	0754		0803		99	0812		18				0853		59
				2.17		2.26			2.41						2.21	
		H	1424		1500		36	1526		62				1536		72
				-0.97		-1.07			-1.18						-1.25	
		L	2000		1956		-4	2005		5	2126		86	2042		42
				1.2		1.34			1.42			1.51			1.47	
6/8	22	H	0136		0149		13	0152		16	0521		105	0227		51
				-2.33		-2.53			-2.72						-2.37	
		L	0818		0827		9	0820		2				0927		69
				2.03		2.16			2.43						2.12	
		H	1512		1541		29	1608		56	1623		71	1616		64
				-0.93		-1.01			-1.17			-1.25			-1.22	
		L	2024		2035		11	2103		39	2128		64	2116		52
				1.09		1.22			1.30			1.37			1.64	
6/9	18	H	0206		0230		24	0308		62	0321		75	0302		56
				-2.07		-2.26			-2.35						-2.21	
		L	0848		0858		10	0913		25				0950		62
				1.91		2.07			2.22						2.08	
		H	1600		1822		22	1640		40	1705		65	1652		52
				-0.92		-1.01			-1.14						-1.20	
		L	2054		2119		25	2135		41				2152		58
				0.99		1.10			1.19						1.24	
6/10	16	H	0300		0309		9	0320		20				0332		32
				-1.79		-1.95			-2.03						-2.00	
		L	0918		0930		12	0942		24				1012		54
				1.82		1.95			2.07						2.05	
		H	1642		1651		9	1714		32	1730		48	1722		40
				-0.99		-1.07			-1.22			-1.30			-1.28	
		L	2200		2217		17	2244		44	2253		53	2245		45
				0.86		0.98			1.08			1.16			1.12	

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
6/11	14	H	0342		0352		10	0409		27	0428		46	0410		28
				-1.48		-1.65			-1.75			-1.84			-1.74	
		L	1006		1011		5	1024		18	0146		40	1035		29
				1.69		1.86			1.96			2.05			1.94	
		H	1718		1732		14	1750		32	1815		57	1759		41
				-1.08		-1.19			-1.29			-1.37			-1.33	
		L	2318		2317		-1	2339		21	2355		37	2349		31
				0.80		0.88			0.99			1.07			1.02	
6/12	12	H	0424		0447		23	0510		46	0530		66	0524		60
				-1.24		-1.34			-1.45			-1.53			-1.47	
		L	1042		1053		11	1110		28	1225		43	1124		42
				1.6		1.71			1.80							
		H	1754		1813		19	1837		43				1847		53
				-1.27		-1.40			-1.49						-1.55	
6/13	11	L	0012		0022		10	0037		25				0052		40
				0.80		0.91			0.99						1.05	
		H	0600		0600		0	0614		14				0622		22
				-0.94		-1.04			-1.13						-1.18	
		L	1124		1143		19	1152		28				1207		42
				1.49		1.62			1.67						1.74	
		H	1836		1854		18	1913		37	2030		54	1920		44
				-1.51		-1.65			-1.75						-1.77	
6/14	11	L	0106		0128		22	0143		37				0145		39
				0.91		1.01			1.13						1.16	
		H	0700		0716		16	0733		33				0737		37
				-0.80		-0.91			-0.99						-1.03	
		L	1236		1231		-5	1251		15				1255		19
				1.44		1.58			1.63						1.69	
		H	1918		1941		23	2000		42				2002		44
				-1.81		-1.95			-2.05						-2.07	

APPENDIX A. Continued

Date 1974	River Flow (CMS)	Tide H-high L-low	Entrance Time (PST)	Entrance Range (m)	Roseburg Lumber Time (PST)	Roseburg Lumber Range (m)	Roseburg Lumber Lag (min)	Corps Dock Time (PST)	Corps Dock Range (m)	Corps Dock Lag (min)	Shinglehouse Slough Time (PST)	Shinglehouse Slough Range (m)	Shinglehouse Slough Lag (min)	Catching Slough Time (PST)	Catching Slough Range (m)	Catching Slough Lag (min)
6/15	10	L	0224		0222		-2	0236		12				0302		38
				1.18		1.31			1.42						1.42	
		H	0842		0845		3	0908		26				0912		30
				-0.69		-0.82			-0.90						-0.94	
		L	1324		1333		9	1345		21				1400		36
				1.44		1.55										
		H	2018		2024		6									
				-2.16		-2.35										
6/16	9	L	0248		0315		27									
				1.48		1.65										
		H	0924		0955		21									
				-0.69		-0.79										
		L	1406		1432		26									
						1.58										
		H			2104											
						-2.59										
6/17	8	L			0402											
						1.95										
		H			1059											
						-0.88										
		L			1531											
						1.71										
		H			2157											
						-2.93										
6/18	8	L			0457											
						2.23										
		H			1151											
						-0.94										
		L			1625											
						1.77										
		H			2240											

APPENDIX B. Water Quality Data

Station	Time (PST)	Hydrolab Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Bottle Samples Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
September 13, 1973												
LOW TIDE												
1	0655	2.4	8	14.0	8.0	28.3		BOT	7.2	7.6	5.2	32.608
		1.2	4	14.0	7.9	27.8		MID	7.2	7.6	4.1	32.508
		0.3	1	14.0	8.0	26.9		SUR	7.1	7.6	2.8	32.542
2	0707	3.7	12	13.0	7.6	28.6		BOT	7.4	7.6	5.4	32.977
		2.7	9	13.3	7.9	28.7		MID	7.1	7.6	1.8	33.007
		1.8	6	13.3	8.1	28.4		SUR	7.3	7.6	1.8	32.911
		0.3	1	13.2	8.2	27.3						
3	0721	10.7	35	11.75	9.0	29.9						
		9.1	30	11.25	9.1	29.9		BOT	8.4	7.7	4.5	33.189
		6.1	20	12.0	9.3	29.9		MID	8.6	7.7	3.7	33.354
		3.1	10	12.0	9.4	29.9		SUR	8.2	7.8	2.8	33.264
		1.5	5	12.0	9.4	29.5						
		0.3	1	12.0	9.5	29.0						

Note: Depths for bottle samples are indicated as follows:

BOT = Bottom
MID = Mid-depth
SUR = Surface

Salinity of bottle samples <2.8‰ are indicated as F: fresh water.

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Hydrolab Depth (ft)	Hydrolab Temp. (°C)	Hydrolab DO (ppm)	Hydrolab SAL (‰)	Hydrolab pH	Bottle Samples Depth	Bottle Samples DO (ppm)	Bottle Samples pH	Bottle Samples TUR (JTU)	Bottle Samples SAL (‰)
4	0732	9.1	30	13.0	8.8	29.9		BOT	8.1	7.6	4.1	33.010
		7.6	25	13.2	8.9	29.9		MID	8.2	7.6	3.5	32.979
		4.6	15	13.2	8.9	26.6		SUR	7.8	7.7	3.3	32.91
		1.5	5	14.0	8.9	29.9						
		0.3	1	14.0	9.0	29.8						
5	0746	6.7	22	14.5	8.5	29.0						
		5.5	18	14.5	8.5	29.0		BOT	7.5	7.7	5.5	32.517
		3.1	10	15.0	8.5	29.0		MID	--	7.6	5.7	32.518
		1.5	5	15.2	8.3	28.8		SUR	7.2	7.6	3.4	32.725
		0.3	1	15.2	8.4	28.7						
6	0803	5.2	17	15.6	8.5	28.6						
		4.3	14	15.75	8.4	28.7		BOT	6.8	7.6	15.0	32.271
		3.1	10	15.7	8.4	28.8		MID	7.2	7.6	10.0	32.236
		1.5	5	16.0	8.4	28.6		SUR	7.0	7.6	4.4	31.996
		0.3	1	16.0	8.4	28.5						
7	0811	1.5	5	16.0	8.9	26.8		BOT	6.8	7.6	28.0	31.686
		0.6	2	16.0	8.4	26.2		SUR	6.6	7.6	--	31.491
8	0817	10.4	34	16.5	8.6	27.8						
		9.1	30	16.7	8.4	28.0		BOT	6.6	7.6	10.0	31.727
		6.1	20	16.5	8.2	28.0		MID	6.5	7.5	7.6	31.784
		3.1	10	16.5	8.1	28.0		SUR	6.7	7.5	5.5	31.690
		1.5	5	16.7	8.0	28.0						
		0.3	1	16.7	7.9	28.0						

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Bottle Samples Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
9	0826	10.7	35	16.2	8.2	27.8						
		9.1	30	16.2	7.9	28.0		BOT	6.5	7.5	8.8	31.461
		6.1	20	16.2	7.8	27.8		MID	6.7	7.4	4.5	31.496
		3.1	10	17.0	7.8	28.0		SUR	6.4	7.4	3.0	31.525
		1.5	5	17.2	7.8	28.0						
		0.3	1	17.2	7.6	27.8						
10	0837	10.7	35	17.8	7.7	26.5						
		9.1	30	17.3	7.1	26.5		BOT	6.0	7.4	7.5	30.706
		6.1	20	17.8	8.7	26.8		MID	5.5	7.4	8.7	30.805
		3.1	10	17.8	6.4	26.5		SUR	5.3	7.3	6.5	30.807
		1.5	5	17.8	6.4	26.0						
		0.3	1	17.8	6.3	25.8						
11	0847	8.8	29	17.8	5.9	26.9						
		7.6	25	18.2	5.6	26.9		BOT	4.6	7.2	22.0	30.490
		4.6	15	18.2	5.2	26.4		MID	4.6	7.2	4.5	30.507
		1.5	5	18.0	5.0	26.2		SUR	5.3	7.3	4.3	29.774
		0.3	1	18.2	5.1	25.7						
12	0902	7.6	25	18.8	4.9	25.0						
		6.1	20	19.0	3.9	25.3		BOT	3.1	7.0	6.0	28.987
		3.1	10	19.0	3.6	24.8		MID	2.9	7.1	6.0	28.963
		1.5	5	19.0	3.4	24.0		SUR	2.9	7.1	6.5	28.989
		0.3	1	19.0	3.3	23.7						

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Hydrolab Depth (ft)	Hydrolab Temp. (°C)	Hydrolab DO (ppm)	Hydrolab SAL (‰)	Hydrolab pH	Bottle Samples Depth	Bottle Samples DO (ppm)	Bottle Samples pH	Bottle Samples TUR (JTU)	Bottle Samples SAL (‰)
13	0928	3.7	12	18.2	7.8	22.0						
		2.7	9	18.8	7.2	21.9		BOT	5.8	7.2	8.3	25.396
		1.5	5	18.3	6.9	21.9		MID	5.8	7.2	7.2	25.459
		0.3	1	18.5	6.8	21.3		SUR	5.7	7.2	7.1	25.283
14	0940	3.7	12	18.5	8.0	19.2						
		2.7	9	18.7	6.8	19.2		BOT	5.7	7.2	7.2	21.682
		1.5	5	18.7	6.9	19.2		MID	5.7	7.2	7.0	21.535
		0.3	1	18.7	6.8	19.0		SUR	5.5	7.2	6.8	20.516
September 13, 1973												
HIGH TIDE												
1	1222	1.8	6	10.5	9.2	29.9		BOT	8.6	7.5	2.8	33.669
		1.2	4	10.0	9.4	29.9		SUR	8.6	7.8	2.1	33.535
		0.6	2	10.0	9.4	29.9						
		0.3	1	10.0	9.4	29.9						
2	1229	5.8	19	10.0	8.7	31.3						
		4.6	15	10.0	9.2	31.3		BOT	8.9	7.9	1.0	33.454
		3.1	10	10.0	9.4	31.3		MID	8.9	7.8	1.2	33.463
		1.5	5	9.8	9.6	31.3		SUR	8.6	7.9	1.2	33.664
		0.3	1	10.0	9.6	30.5						
3	1248	12.5	41	10.0	9.1	29.9						
		9.1	30	10.0	9.6	30.6		BOT	9.0	7.9	2.5	33.591
		6.1	20	10.0	9.8	30.6		MID	8.7	7.9	1.0	33.631
		3.1	10	9.9	10.0	30.6		SUR	8.7	7.9	3.0	33.467
		0.3	1	9.9	10.0	30.6						

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Hydrolab Depth (ft)	Hydrolab Temp. (°C)	Hydrolab DO (ppm)	Hydrolab SAL (‰)	Hydrolab pH	Bottle Samples Depth	Bottle Samples DO (ppm)	Bottle Samples pH	Bottle Samples TUR (JTU)	Bottle Samples SAL (‰)
4	1253	12.5	41	10.0	8.8	29.9		BOT	8.8	7.9	2.0	33.511
		9.1	30	10.0	9.3	29.9		MID	8.8	7.9	2.4	33.566
		6.1	20	9.9	9.5	29.9		SUR	8.7	7.8	1.0	33.546
		3.1	10	9.9	9.7	29.9						
		0.3	1	9.8	9.8	29.9						
5	1305	7.6	25	10.0	8.9	29.9						
		5.5	18	10.0	9.4	29.9		BOT	8.9	7.8	1.5	33.501
		3.7	12	9.9	9.6	29.9		MID	8.7	7.8	1.0	33.612
		1.8	6	9.9	9.7	29.9		SUR	8.4	7.8	1.8	33.574
		0.3	1	9.9	9.7	29.9						
6	1323	9.1	30	10.5	9.4	29.9						
		6.1	20	10.5	9.6	29.9		BOT	8.7	7.9	2.7	33.511
		3.1	10	10.5	9.8	29.9		MID	8.7	7.8	3.4	33.402
		1.5	5	11.0	10.0	29.9		SUR	8.6	7.8	2.8	33.331
		0.3	1	11.5	10.1	29.9						
7	1331	4.3	14	13.0	9.1	29.9						
		3.1	10	13.0	9.1	29.9		BOT	8.2	7.7	4.0	32.714
		1.5	5	13.5	9.2	29.9		SUR	7.9	7.7	2.8	33.784
		0.3	1	13.5	9.4	29.9						
8	1339	13.4	44	12.0	9.2	29.0						
		10.7	35	12.0	9.2	29.0		BOT	8.3	7.7	4.6	33.164
		7.6	25	12.0	9.4	29.0		MID	8.5	7.7	3.2	33.225
		3.1	10	13.0	9.4	29.0		SUR	8.0	7.7	2.2	32.775
		1.5	5	13.0	9.4	28.3						
		0.3	1	13.0	9.6	28.3						

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Bottle Samples Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
9	1349	13.4	44	13.0	9.0	29.0		BOT	8.4	7.7	4.2	32.917
		10.7	35	13.0	9.0	29.0		MID	7.8	7.7	5.7	33.025
		7.6	25	13.4	9.0	29.0		SUR	7.5	7.6	3.0	33.202
		3.1	10	13.5	9.2	29.0						
		0.3	1	13.5	9.0	28.4						
10	1402	13.7	45	14.5	8.9	28.4						
		10.7	35	14.5	8.8	28.4		BOT	7.6	7.7	6.2	32.590
		7.6	25	14.5	8.8	28.4		MID	7.6	7.7	4.6	32.650
		3.1	10	15.0	8.8	28.4		SUR	7.2	7.6	4.0	32.482
		0.3	1	15.0	8.7	27.7						
11	1411	12.5	41	15.5	8.8	29.0						
		9.1	30	16.0	8.6	29.0		BOT	6.8	7.6	5.7	31.779
		6.1	20	16.0	8.4	29.0		MID	6.9	7.5	5.7	31.424
		3.1	10	16.5	8.0	28.4		SUR	6.0	7.7	5.4	30.994
		0.3	1	17.0	7.2	27.7						
12	1430	8.5	28	17.5	4.8	26.2						
		5.5	18	17.5	2.4	26.2		BOT	4.1	7.2	14.0	30.121
		3.1	10	17.5	2.3	26.2		MID	3.7	7.2	3.5	30.242
		1.5	5	17.5	2.2	26.2		SUR	4.4	6.7	2.8	28.542
		0.3	1	17.8	2.1	26.2						
13	1525	4.9	16	17.5	6.8	26.9						
		3.7	12	18.0	6.6	26.9		BOT	6.0	--	3.9	30.521
		2.4	8	18.0	6.4	26.9		MID	5.7	7.5	6.2	30.631
		1.2	4	18.0	6.4	26.9		SUR	6.1	7.5	5.0	30.293
		0.3	1	18.0	6.5	26.9						

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
14	1538	4.9	16	17.5	7.1	26.5						
		3.7	12	18.0	6.9	26.9		BOT	6.2	7.5	5.8	30.446
		2.4	8	18.0	6.7	26.9		MID	6.0	7.4	5.0	30.059
		1.2	4	18.0	6.8	26.9		SUR	6.3	7.1	3.7	30.479
		0.3	1	18.0	6.7	26.9						
15	1557	3.1	10	17.0	7.8	27.7						
		1.5	5	17.0	7.6	27.7		BOT	6.8	7.4	6.5	31.074
		0.3	1	17.0	7.5	27.7		SUR	6.6	7.4	5.5	31.090
December 19, 1973												
LOW TIDE												
1	1439	2.4	8	9.5	10.1	9.5	7.7	BOT	10.0	7.2	7.5	12.187
		1.5	5	9.0	10.0	9.1	7.6	SUR	8.9	7.0	5.1	10.993
		0.6	2	9.0	9.9	9.1	7.6					
2	1455	4.3	14	9.5	9.8	12.7	7.9	BOT	8.6	6.3	6.9	15.173
		3.1	10	9.5	9.8	11.8	7.9	MID	9.1	7.6	5.6	14.639
		1.5	5	9.5	9.8	11.4	7.9	SUR	9.9	7.6	4.6	14.373
		0.6	2	9.5	9.9	11.8	7.8					
3	1505	16.8	55	10.5	10.8	17.8	8.2					
		12.2	40	10.5	10.6	16.5	8.1	BOT	7.6	7.9	13.0	22.062
		9.1	30	10.5	10.6	14.4	8.1	MID	9.7	8.2	9.2	19.823
		6.1	20	10.0	10.6	15.8	8.1	SUR	8.7	7.8	5.7	13.029
		3.1	10	10.0	10.4	14.4	8.1					
		1.2	4	10.0	10.4	11.8	8.1					

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Hydrolab Depth (ft)	Hydrolab Temp. (°C)	Hydrolab DO (ppm)	Hydrolab SAL (‰)	Hydrolab pH	Bottle Samples Depth	Bottle Samples DO (ppm)	Bottle Samples pH	Bottle Samples TUR (JTU)	Bottle Samples SAL (‰)
4	1518	10.4	34	10.5	10.8	20.6	8.1	BOT	10.1	8.2	8.3	21.764
		7.6	25	10.5	10.6	17.8	8.1	MID	10.1	8.1	7.4	17.643
		4.6	15	10.0	10.6	14.4	8.1	SUR	10.8	7.6	7.4	11.560
		1.5	5	9.5	10.4	10.5	8.0					
		0.9	3	9.5	10.4	9.8	7.9					
5	1538	8.2	27	10.0	10.4	15.8	8.1	BOT	8.5	7.6	12.0	17.452
		4.6	15	10.0	10.4	11.1	8.0	MID	10.4	7.6	7.7	11.876
		3.1	10	10.0	10.2	9.2	7.9	SUR	10.4	7.3	11.0	6.995
		0.9	3	9.5	10.2	6.5	7.7					
6	1553	6.4	21	10.0	10.4	11.8	7.9	BOT	10.4	7.2	10.0	13.773
		4.6	15	9.5	10.1	7.3	7.7	MID	10.6	7.3	10.0	7.878
		3.1	10	9.5	10.0	5.6	7.5	SUR	10.8	7.1	9.2	5.704
		0.6	2	9.0	10.0	5.2	7.4					
7	1605	2.1	7	9.5	9.8	5.5	7.3	BOT	10.7	3.0	11.0	6.841
		0.6	2	8.5	9.6	3.4	7.2	SUR	10.0	6.7	8.8	F
8	1620	11.3	37	9.5	10.3	11.1	7.8					
		9.1	30	9.5	10.4	5.6	7.5	BOT	8.7	7.0	12.0	10.156
		6.1	20	9.5	10.6	5.1	7.3	MID	10.9	6.6	17.0	6.432
		3.1	10	9.0	10.6	4.3	7.3	SUR	11.7	7.4	11.0	F
		0.6	2	9.0	10.6	2.8	7.4					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
9	1632	11.6	38	10.0	10.6	11.1	7.8					
		9.1	30	9.5	10.4	9.2	7.7	BOT	9.9	6.9	18.0	10.346
		6.1	20	9.5	10.2	3.2	7.4	MID	11.2	6.8	12.0	3.868
		3.1	10	9.0	10.6	1.8	7.3	SUR	10.4	6.9	8.3	F
		0.6	2	9.0	10.6	1.8	7.2					
10	1648	12.2	40	10.0	10.0	9.8	7.7					
		9.1	30	10.0	9.8	8.0	7.5	BOT	10.0	6.9	15.0	10.353
		6.1	20	9.5	9.6	5.0	7.3	MID	11.2	6.9	9.3	4.067
		3.1	10	8.0	10.6	5.0	7.1	SUR	11.9	6.7	11.0	F
		0.6	2	8.0	10.5	2.2	7.1					
11	1706	9.1	30	10.0	10.2	14.4	7.9	BOT	--	6.8	22.0	14.209
		6.1	20	9.0	9.9	5.0	7.1	MID	10.0	6.0	11.0	F
		3.1	10	9.0	9.4	2.3	7.0	SUR	11.1	6.8	9.0	F
		0.6	2	9.0	9.9	0.5	7.0					
12	1745	10.1	33	9.5	8.4	6.2	6.8	BOT	9.6	6.8	14.0	F
		6.1	20	9.5	8.4	6.0	6.8	MID	9.8	5.8	12.0	F
		3.1	10	9.5	8.4	5.6	6.8	SUR	9.8	6.5	11.0	F
		0.6	2	9.5	8.4	5.6	6.8					
15	1840	5.2	17	8.5	10.6	0	7.2	BOT	11.9	7.0	10.0	F
		3.1	10	8.5	10.8	0	7.1	MID	11.3	6.7	10.0	F
		1.5	5	8.5	11.0	0	6.9	SUR	11.8	6.7	7.7	F
		0.6	2	8.5	11.1	0	6.9					

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Hydrolab Depth (ft)	Hydrolab Temp. (°C)	Hydrolab DO (ppm)	Hydrolab SAL (‰)	Hydrolab pH	Bottle Samples Depth	Bottle Samples DO (ppm)	Bottle Samples pH	Bottle Samples TUR (JTU)	Bottle Samples SAL (‰)
December 19, 1973												
HIGH TIDE												
1	0810	3.7	12	10.0	11.8	25.0	8.0	BOT	10.1	7.6	4.3	28.373
		2.7	9	10.0	11.4	24.8	8.1	SUR	9.8	7.7	5.6	19.580
		1.5	5	10.1	11.2	24.0	8.1					
		0.6	2	10.0	10.4	18.5	8.1					
2	0827	5.2	17	10.1	11.8	26.9	8.1	BOT	10.2	7.9	2.9	29.725
		3.7	12	10.2	11.4	26.5	8.1	MID	10.3	7.4	4.2	28.682
		2.1	7	10.1	11.2	26.2	8.1	SUR	10.3	7.8	3.9	35.007
		0.6	2	10.1	10.8	21.3	8.1					
3	0841	13.4	44	10.1	11.6	26.2	8.0					
		9.1	30	10.1	11.2	26.2	8.1	BOT	10.6	7.1	4.0	31.087
		6.1	20	10.2	11.2	26.5	8.1	MID	10.4	7.9	3.4	30.914
		3.1	10	10.1	11.2	25.8	8.1	SUR	10.1	8.0	2.1	30.529
		0.6	2	10.2	11.0	24.8	8.1					
4	0853	11.9	39	10.1	11.6	26.2	8.1					
		9.1	30	10.1	11.2	26.2	8.1	BOT	10.1	8.3	2.7	30.872
		6.1	20	10.1	11.0	25.5	8.1	MID	10.1	8.1	3.0	30.829
		3.1	10	10.2	11.0	25.5	8.1	SUR	10.1	7.8	3.9	24.735
		0.6	2	10.2	11.0	24.0	8.1					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
5	0907	9.8	32	10.0	11.6	25.0	8.1	BOT	10.3	7.2	5.2	27.945
		6.1	20	10.1	11.4	25.0	8.1	MID	10.4	8.1	4.1	27.979
		3.1	10	10.1	11.0	22.0	8.1	SUR	10.2	7.7	3.5	18.115
		0.6	2	9.5	10.4	11.9	8.0					
6	0933	11.3	37	10.1	11.6	24.4	8.1					
		9.1	30	10.2	11.2	24.4	8.1	BOT	10.2	7.8	7.7	25.614
		6.1	20	10.1	11.0	21.5	8.1	MID	7.9	7.9	3.0	25.163
		3.1	10	10.1	10.4	15.0	8.1	SUR	10.6	7.3	3.4	10.323
		0.6	2	9.5	10.2	10.7	8.0					
7	0950	4.0	13	10.0	11.2	17.0	8.1	BOT	10.0	7.8	9.0	19.783
		2.1	7	9.5	10.4	10.7	8.0	SUR	10.3	7.0	4.7	7.677
		0.6	2	9.0	10.1	13.0	7.7					
8	0957	14.0	46	10.0	11.3	20.9	8.1					
		9.1	30	10.1	10.8	20.6	8.1	BOT	9.8	7.8	4.7	23.294
		6.1	20	10.1	10.8	19.2	8.1	MID	10.0	8.1	3.3	23.459
		3.1	10	10.0	10.3	10.7	8.0	SUR	11.1	7.1	3.6	3.155
		0.6	2	9.8	10.0	4.6	7.7					
9	1012	12.2	40	10.1	11.0	20.6	8.1					
		9.1	30	10.1	10.8	19.9	8.0	BOT	9.7	7.7	4.2	22.805
		6.1	20	10.1	10.5	16.5	8.1	MID	10.0	7.8	3.6	16.973
		3.1	10	10.1	10.3	11.1	8.0	SUR	10.8	7.3	3.8	6.131
		0.6	2	9.5	10.0	5.6	7.6					

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Bottle Samples Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
10	1030	15.2	50	11.0	11.0	18.3	8.1					
		12.2	40	10.8	10.9	17.8	8.1					
		9.1	30	10.8	10.8	16.0	8.1					
		6.1	20	10.0	10.6	12.0	8.1					
		3.1	10	10.0	10.5	10.3	7.9					
		0.6	2	9.8	10.2	6.4	7.6					
11	1040	9.8	32	10.0	10.8	16.4	8.1					
		6.1	20	10.5	10.6	16.8	8.0					
		3.1	10	10.0	10.4	8.5	7.8					
		0.6	2	9.6	10.1	7.3	7.6					
12	1057	14.0	46	9.8	9.6	6.0	7.4	BOT	9.7	6.9	5.3	5.086
		9.1	30	9.5	9.0	3.0	7.2	MID	9.9	7.1	5.1	3.251
		6.1	20	9.0	8.8	3.0	7.1	SUR	9.1	6.2	5.4	2.891
		3.1	10	9.5	8.6	3.0	7.1					
		0.6	2	9.5	8.6	3.0	7.1					
13	1132	4.6	15	8.5	10.9	0	7.4					
		3.1	10	8.5	10.8	0	7.3	BOT	11.9	7.2	5.7	F
		1.5	5	8.5	10.8	0	7.2	SUR	11.6	6.6	4.8	F
		0.6	2	8.5	10.8	0	7.2					
14	1144	5.2	17	8.0	11.1	0	7.6	BOT	9.9	6.6	6.4	F
		3.7	12	8.0	11.1	0	7.4	MID	12.3	6.7	4.0	F
		2.1	7	8.0	11.0	0	7.2	SUR	11.7	6.4	3.7	F
		0.6	2	8.0	10.9	0	7.1					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
15	1123	10.7	35	7.5	11.0	1.0	7.4					
		6.1	20	7.5	11.0	0.9	7.3					
		3.1	10	7.3	11.0	1.0	7.2					
		0.6	2	7.5	10.9	1.8	7.2					
March 23, 1974												
LOW TIDE												
1	0608	2.1	7	9.5	10.2	15.5	7.8	BOT	8.0	7.1	8.8	23.471
		1.2	4	10.0	10.2	11.8	7.8	SUR	9.0	7.2	4.0	14.343
		0.3	1	10.0	10.0	11.1	7.8					
2	0620	2.7	9	9.5	12.2	18.5	7.9					
		1.5	5	10.0	10.8	17.7	7.9	BOT	9.2	7.2	5.0	22.478
		0.3	1	10.0	10.4	16.5	7.9	SUR	9.2	7.1	5.5	20.131
3	0630	10.7	35	9.0	11.4	24.4	8.0					
		9.1	30	9.5	11.2	23.0	8.0					
		7.6	25	9.5	11.2	22.7	8.0	BOT	9.3	7.5	12.0	30.232
		6.1	20	9.5	11.2	22.0	8.0	MID	9.3	7.5	6.0	26.909
		4.6	15	9.5	11.0	21.2	8.0	SUR	9.4	7.5	4.0	25.199
		3.1	10	9.5	10.8	20.5	8.0					
		1.5	5	9.5	10.8	19.8	8.0					
		0.6	2	9.5	10.6	19.8	8.0					
4	0641	9.4	31	9.5	11.4	21.2	8.0					
		7.6	25	9.5	11.2	19.8	8.0					
		6.1	20	9.5	11.0	19.2	8.0	BOT	9.4	7.7	9.2	26.770

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Bottle Samples Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
4	0641	1.5	15	10.0	10.8	19.2	8.0	MID	9.3	7.3	6.1	24.323
		3.1	10	10.0	10.6	17.8	8.0	SUR	9.3	7.4	4.2	20.047
		1.5	5	10.0	10.4	17.0	8.0					
		0.3	1	10.0	10.2	16.5	8.0					
5	0655	5.2	17	10.0	11.6	17.0	7.9					
		3.7	12	10.0	11.0	15.0	7.9					
		2.1	7	10.0	10.8	13.8	7.9	BOT	9.2	7.4	7.7	20.945
		1.2	4	10.0	10.2	13.8	7.8	MID	9.2	7.3	6.2	17.008
		0.3	1	10.0	10.2	13.8	7.8	SUR	8.8	7.3	4.9	16.185
6	0707	7.9	26	10.0	11.6	14.4	7.9					
		6.1	20	10.0	11.0	13.8	7.8					
		4.6	15	10.0	10.6	12.7	7.8	BOT	9.5	7.2	9.3	16.429
		3.1	10	10.0	10.5	11.8	7.8	MID	9.3	7.2	7.0	15.779
		1.5	5	10.0	10.3	11.1	7.7	SUR	9.3	7.2	5.6	13.665
		0.3	1	10.0	10.2	11.1	7.7					
7	0716	1.8	6	9.5	11.2	13.0	7.8					
		0.9	3	9.5	10.6	11.5	7.7	BOT	9.1	7.1	22.0	15.012
		0.3	1	9.0	10.0	5.6	7.5	SUR	9.0	7.1	8.4	7.694
8	0723	10.7	35	10.0	10.6	12.4	7.7					
		9.1	30	10.0	10.4	11.1	7.7	BOT	9.3	7.0	14.0	13.046
		7.6	25	10.5	10.4	10.5	7.4	MID	9.4	7.2	7.8	12.071
		6.1	20	10.0	10.4	10.5	7.6	SUR	9.0	7.1	6.5	10.152
		4.6	15	10.5	10.2	10.1	7.6					
		3.1	10	10.0	10.2	9.9	7.6					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
8	0723	1.5	5	10.0	10.1	9.1	7.5					
		0.3	1	10.0	10.0	7.3	7.5					
9	0732	10.4	34	10.5	10.8	13.0	7.7					
		9.1	30	10.5	10.5	12.7	7.7					
		7.6	25	10.5	10.4	9.8	7.6	BOT	9.9	7.1	22.0	12.196
		6.1	20	10.0	10.2	8.6	7.5	MID	9.4	7.1	8.7	10.550
		4.6	15	10.0	10.2	8.0	8.5	SUR	9.6	7.1	5.9	6.781
		3.1	10	10.0	10.2	8.0	7.5					
		1.5	5	10.0	10.0	6.8	7.4					
		0.3	1	10.0	9.8	5.6	7.4					
10	0745	10.4	34	10.0	10.6	8.9	7.5					
		9.1	30	10.2	10.2	8.6	7.5					
		7.6	25	10.0	10.2	8.0	7.4	BOT	9.2	7.1	17.0	10.350
		6.1	20	10.0	10.2	8.0	7.4	MID	9.2	7.1	8.8	9.188
		4.6	15	10.0	10.0	7.3	7.4	SUR	10.3	7.05	8.4	F
		3.1	10	10.0	9.8	6.2	7.3					
		1.5	5	9.5	9.8	3.0	7.3					
		0.3	1	9.5	10.0	2.4	7.4					
11	0758	15.2	50	10.5	6.9	8.6	7.4					
		12.2	40	10.5	9.8	10.5	7.5					
		9.1	30	11.5	10.0	9.8	7.5	BOT	--	7.0	8.7	11.992
		6.1	20	10.5	9.2	8.2	7.4	MID	8.9	7.2	12.0	9.384
		3.1	10	10.0	9.3	7.3	7.3	SUR	10.2	7.4	9.7	F
		1.5	5	10.0	9.3	5.6	7.4					
		0.3	1	9.5	9.8	5.5	7.4					

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Bottle Samples Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
12	0820	12.2	40	11.5	9.1	2.3	7.0					
		9.1	30	11.5	9.1	2.3	7.0	BOT	8.8	7.3	11.0	F
		6.1	20	11.5	9.0	2.3	7.0	MID	8.6	7.2	10.0	F
		3.1	10	11.5	8.9	2.2	6.9	SUR	8.4	7.2	9.7	F
		1.5	5	11.5	8.9	2.2	6.9					
		0.3	1	11.5	8.8	2.2	6.9					
15	0856	2.7	9	9.5	10.6	1.8	7.2					
		1.8	6	9.5	10.6	1.4	7.1	BOT	10.2	7.2	16.0	F
		0.9	3	9.0	10.4	1.0	7.2	SUR	10.1	7.2	12.0	F
		0.3	1	9.5	10.3	0.8	7.2					
13	0904	3.4	11	9.5	10.6	0	7.5	BOT	10.3	7.5	11.0	F
		2.1	7	9.5	10.5	0	7.2	MID	10.4	7.5	9.9	F
		0.9	3	9.5	10.6	0	7.0	SUR	10.4	7.3	9.4	F
		0.3	1	9.5	10.6	0	7.0					
14	0917	4.3	14	9.0	10.6	0	7.5					
		3.1	10	9.0	10.8	0	7.2	BOT	10.5	7.3	6.9	F
		2.1	7	9.0	10.9	0	7.1	MID	10.7	7.2	6.9	F
		1.2	4	9.0	10.8	0	7.0	SUR	10.5	7.1	5.0	F
		0.3	1	9.5	10.8	0	7.0					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
March 23, 1974												
HIGH TIDE												
1	1144	1.8	6	9.5	10.2	25.5	8.0	BOT	8.4	7.5	5.5	31.248
		0.9	3	9.5	10.4	25.8	8.1	SUR	8.2	7.7	2.2	30.840
		0.3	1	9.5	10.4	26.2	8.1					
2	1152	4.6	15	9.5	9.8	29.5	8.0					
		3.1	10	9.5	10.0	29.0	8.0	BOT	8.4	7.8	1.7	32.453
		1.5	5	9.0	10.1	29.9	8.0	MID	8.5	7.7	1.6	--
		0.3	1	9.5	10.1	29.9	8.1	SUR	8.3	7.7	1.8	31.905
3	1203	12.2	40	9.0	9.6	29.9	8.0					
		9.1	30	9.0	9.7	30.5	8.0	BOT	8.3	7.6	1.8	32.966
		6.1	20	9.0	9.7	29.9	8.0	MID	8.3	7.6	1.7	32.928
		3.1	10	9.0	9.7	29.9	8.1	SUR	8.2	7.6	1.4	32.620
		1.5	5	8.5	9.7	29.9	8.0					
		0.6	2	9.0	9.8	29.9	8.1					
4	1216	10.7	35	9.5	9.8	29.9	8.0					
		9.1	30	9.0	10.0	30.5	8.1					
		7.6	25	9.0	10.0	29.9	8.1	BOT	9.0	7.7	1.4	32.831
		6.1	20	9.0	10.0	29.9	8.0	MID	8.9	7.7	1.5	32.845
		4.6	15	9.0	10.0	29.9	8.1	SUR	9.0	7.7	1.3	32.399
		3.1	10	9.0	10.0	29.0	8.1					
		1.5	5	9.0	10.0	29.0	8.0					
		0.6	2	9.0	10.0	28.3	8.1					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
5	1232	7.6	25	9.0	10.2	29.9	8.0	BOT	8.7	7.8	2.4	31.304
		6.1	20	9.0	10.2	29.9	8.0	MID	8.8	7.5	2.8	30.916
		4.6	15	9.0	10.3	29.9	8.0	SUR	8.8	7.4	2.4	28.959
		3.1	10	9.5	10.6	28.3	8.1					
		1.5	5	9.5	10.8	26.2	8.1					
		0.6	2	10.0	10.8	24.8	8.1					
6	1250	9.1	30	9.5	10.1	27.8	8.0					
		7.6	25	9.5	10.2	28.0	8.0	BOT	9.0	7.6	7.0	29.879
		6.1	20	9.0	10.2	28.3	8.0	MID	9.1	7.7	4.6	26.994
		4.6	15	9.5	10.4	26.9	8.0	SUR	9.2	7.6	4.4	22.838
		3.1	10	10.0	10.7	23.3	8.0					
		1.5	5	10.0	10.6	21.2	8.0					
		0.3	1	10.5	10.7	20.2	8.0					
7	1258	4.3	14	10.0	10.4	20.6	8.0					
		3.1	10	10.0	10.4	20.6	8.0	BOT	9.5	7.6	7.2	22.543
		1.5	5	10.0	10.4	19.2	8.0	SUR	9.2	7.6	3.4	18.939
		0.3	1	10.5	10.2	16.5	7.9					
8	1304	10.1	33	10.0	10.1	22.0	7.9					
		7.6	25	10.0	10.0	22.0	8.0					
		6.1	20	10.0	10.1	20.5	8.0	BOT	9.1	7.5	7.3	23.678
		4.6	15	10.0	10.1	20.5	8.0	MID	9.4	7.5	3.9	22.522
		3.1	10	10.0	10.1	20.5	7.9	SUR	9.3	7.2	4.6	21.289
		1.5	5	10.5	10.2	19.8	8.0					
		0.6	2	10.5	10.2	19.2	7.9					

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Hydrolab Depth (ft)	Hydrolab Temp. (°C)	Hydrolab DO (ppm)	Hydrolab SAL (‰)	Hydrolab pH	Bottle Samples Depth	Bottle Samples DO (ppm)	Bottle Samples pH	Bottle Samples TUR (JTU)	Bottle Samples SAL (‰)
9	1312	12.2	40	10.0	10.0	19.8	8.0					
		9.1	30	10.0	10.2	20.2	8.0	BOT	9.1	7.3	8.7	21.971
		6.1	20	10.0	10.1	19.8	7.9	MID	9.2	7.3	5.8	21.193
		3.1	10	10.5	10.3	17.8	8.0	SUR	9.1	7.3	4.7	18.500
		1.5	5	10.5	10.4	17.8	7.9					
		0.3	1	11.0	10.4	16.9	7.9					
10	1325	13.7	45	10.0	10.1	17.0	7.9					
		10.7	35	10.0	10.0	17.0	7.9	BOT	9.3	7.3	10.0	17.313
		7.6	25	10.0	10.0	16.9	7.9	MID	9.4	7.3	9.4	17.005
		4.6	15	10.5	10.0	14.8	7.9	SUR	9.3	7.0	6.2	12.028
		1.5	5	11.0	10.2	11.8	7.8					
		0.3	1	11.0	10.3	10.4	7.7					
11	1341	13.7	45	10.5	9.7	15.0	7.8					
		10.7	35	10.5	9.8	19.2	7.8	BOT	9.1	6.9	46.0	16.586
		7.6	25	10.5	9.9	13.0	7.8	MID	9.4	7.1	10.0	14.337
		4.6	15	10.5	9.9	12.4	7.7	SUR	9.4	7.1	8.8	8.287
		1.5	5	10.5	9.8	10.1	7.6					
		0.3	1	11.0	10.0	7.0	7.5					
12	1356	13.1	43	10.5	9.2	6.5	7.4	BOT	9.4	7.0	11.0	7.448
		10.7	35	10.5	9.1	6.2	7.3	MID	9.2	6.9	5.0	7.135
		7.6	25	10.5	9.2	6.2	7.3	SUR	8.9	6.9	5.9	7.126
		4.6	15	10.5	9.2	6.2	7.3					
		1.5	5	11.0	9.3	6.0	7.2					
		0.3	1	11.5	9.3	5.7	7.2					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
15	1420	7.9	26	11.0	9.7	9.8	7.6					
		6.1	20	11.0	9.7	6.8	7.6	BOT	9.6	6.9	7.0	11.076
		4.6	15	11.0	10.0	9.2	7.6	MID	9.8	7.0	6.9	10.871
		3.1	10	11.0	10.1	8.6	7.6	SUR	9.8	7.0	6.2	10.067
		1.5	5	11.5	10.2	8.6	7.6					
		0.3	1	11.5	10.1	8.3	7.6					
13	1431	3.7	12	10.5	9.3	6.2	7.4					
		3.1	10	10.1	9.4	6.8	7.4	BOT	10.0	6.9	9.9	7.517
		2.4	8	10.1	9.4	6.8	7.4	MID	10.1	6.9	6.5	6.298
		1.8	6	10.1	9.6	5.7	7.3	SUR	10.7	7.0	7.8	F
		1.2	4	10.1	9.8	3.8	7.3					
		0.6	2	10.0	10.2	2.2	7.3					
14	1443	4.3	14	10.0	9.9	2.9	7.4	BOT	10.6	7.4	7.7	3.371
		3.1	10	10.0	9.9	1.9	7.4	MID	10.6	7.8	7.5	F
		1.5	5	10.0	10.3	1.8	7.3	SUR	10.8	8.3	7.3	F
		0.3	1	10.0	10.3	0.7	7.2					
June 12, 1974												
HIGH TIDE												
1	0447	1.8	6	11.0	8.9	27.4	8.0	BOT	8.2	7.5	4.1	32.125
		0.9	3	11.0	9.0	27.3	8.1	SUR	7.4	7.3	3.3	31.725
		0.3	1	11.0	8.8	27.3	8.0					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
2	0503	4.0	13	9.5	8.1	28.7	8.1					
		2.4	8	9.5	8.3	28.3	8.1	BOT	8.0	7.1	3.0	33.005
		1.2	4	9.5	8.4	28.0	8.1	SUR	7.8	7.1	1.5	32.786
		0.3	1	10.0	8.8	28.0	8.1					
3	0513	11.3	37	8.5	6.6	29.8	8.0					
		9.1	30	8.5	6.7	29.8	8.0					
		7.6	25	8.5	6.8	29.8	8.1	BOT	7.3	7.4	2.6	33.937
		6.1	20	8.5	7.2	29.8	8.1	MID	7.6	7.1	2.6	33.929
		4.6	15	8.5	8.0	29.8	8.1	SUR	7.1	7.1	1.4	33.876
		3.1	10	8.5	8.2	29.8	8.1					
		1.5	5	8.5	8.3	29.4	8.1					
		0.3	1	8.5	8.4	29.8	8.1					
4	0525	10.4	34	8.5	8.0	29.8	8.1					
		9.1	30	8.5	7.9	29.8	8.1					
		7.6	25	8.5	8.0	29.8	8.1					
		6.1	20	8.5	8.1	29.8	8.1	BOT	7.5	7.0	1.3	31.957
		4.6	15	8.5	8.2	29.8	8.1	MID	8.0	7.1	2.1	33.469
		3.1	10	8.5	8.4	29.4	8.1	SUR	7.4	7.1	2.3	33.489
		1.5	5	8.5	8.7	29.4	8.1					
		0.3	1	9.5	9.2	28.3	8.1					
5	0537	6.1	20	10.0	8.8	28.3	8.0					
		4.6	15	10.5	8.8	27.7	8.1	BOT	8.5	7.5	4.6	31.759
		3.1	10	10.5	9.2	27.3	8.1	MID	8.1	7.1	2.3	31.408
		1.5	5	11.0	9.3	26.9	8.1	SUR	8.0	7.0	1.5	29.894
		0.3	1	11.5	9.3	25.8	8.1					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
6	0552	8.2	27	11.0	9.6	26.9	8.1					
		6.1	20	11.5	9.6	26.9	8.1	BOT	8.1	7.2	5.8	30.944
		4.6	15	12.0	9.5	25.5	8.1	MID	8.2	7.2	1.9	29.051
		3.1	10	12.5	9.7	24.8	8.1	SUR	8.2	7.0	1.7	27.821
		1.5	5	12.5	9.6	24.8	8.1					
		0.3	1	13.0	9.6	24.0	8.1					
7	0602	2.7	9	14.0	9.7	23.3	8.1	BOT	8.0	7.2	3.2	27.084
		1.8	6	14.0	9.3	22.7	8.1	SUR	8.1	7.0	2.0	26.187
		0.9	3	14.0	9.2	22.7	8.0					
		0.3	1	14.5	9.0	22.7	8.0					
8	0609	10.7	35	12.5	9.5	25.5	8.0					
		9.1	30	12.5	9.3	25.5	8.1					
		7.6	25	12.5	9.4	25.5	8.1	BOT	8.2	6.9	3.5	28.864
		6.1	20	12.5	9.4	24.8	8.1	MID	8.5	7.2	2.1	31.677
		4.6	15	14.0	9.5	24.0	8.1	SUR	8.1	7.2	2.3	25.084
		3.1	10	14.0	9.6	23.0	8.1					
		1.5	5	14.5	9.6	21.9	8.0					
		0.3	1	15.0	9.3	21.2	8.0					
9	0617	12.2	40	13.0	9.4	25.0	8.1					
		9.1	30	13.0	9.4	24.8	8.1	BOT	8.0	6.7	3.3	23.691
		6.1	20	13.5	9.3	24.0	8.1	MID	8.2	7.4	3.7	27.198
		3.1	10	14.5	9.4	22.7	8.0	SUR	8.2	7.3	4.3	28.637
		1.5	5	14.5	9.3	21.9	8.0					
		0.3	1	15.0	9.3	20.6	8.0					

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Hydrolab Depth (ft)	Hydrolab Temp. (°C)	Hydrolab DO (ppm)	Hydrolab SAL (‰)	Hydrolab pH	Bottle Samples Depth	Bottle Samples DO (ppm)	Bottle Samples pH	Bottle Samples TUR (JTU)	Bottle Samples SAL (‰)
10	0629	13.7	45	14.0	9.1	22.7	8.0					
		10.7	35	14.0	8.9	22.7	8.0	BOT	7.6	7.3	27.0	26.343
		7.6	25	14.0	8.9	22.7	8.0	MID	7.7	7.2	5.7	26.143
		4.6	15	14.5	8.7	22.3	8.0	SUR	7.7	7.2	4.3	20.346
		1.5	5	15.0	9.0	20.6	8.0					
		0.3	1	15.5	8.8	17.8	7.9					
11	0640	12.5	41	14.0	8.6	18.1	7.9					
		9.1	30	14.0	8.5	18.5	8.0	BOT	7.0	7.1	63.0	25.869
		6.1	20	14.5	8.5	18.5	7.9	MID	7.9	7.5	5.5	24.278
		3.1	10	14.5	8.6	18.5	7.9	SUR	7.5	7.2	3.5	19.164
		1.5	5	15.0	8.5	18.1	7.9					
		0.3	1	15.0	8.3	17.5	7.8					
12	0656	9.8	32	15.5	7.6	17.2	7.7					
		7.6	25	16.0	7.4	17.2	7.6	BOT	6.6	7.2	7.5	19.043
		4.6	15	16.0	7.3	16.0	7.6	MID	6.7	7.1	4.1	18.105
		1.5	5	16.5	7.1	13.7	7.5	SUR	7.0	7.2	2.7	15.015
		0.3	1	17.0	6.9	13.0	7.5					
15	0721	7.0	23	15.5	9.0	18.1	7.9	BOT	7.6	7.4	5.8	19.648
		4.6	15	15.5	8.7	16.5	7.8	MID	7.8	7.4	5.7	14.411
		3.1	10	16.0	8.7	15.8	7.8	SUR	8.1	7.2	4.3	14.530
		1.5	5	16.5	8.8	13.0	7.8					
		0.3	1	16.5	8.8	13.0	7.8					

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Bottle Samples Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
13	0731	4.6	15	15.5	9.1	16.5	7.8	BOT	7.6	7.3	6.3	18.588
		3.1	10	16.0	8.7	15.0	7.8	SUR	8.2	7.4	6.0	6.856
		1.5	5	17.0	8.9	11.8	7.7					
		0.3	1	17.5	9.1	6.1	7.7					
14	0740	4.6	15	17.5	10.0	9.2	7.7					
		3.7	12	17.5	9.4	7.8	7.6	BOT	8.8	7.2	6.2	9.700
		2.7	9	17.5	9.2	7.2	7.6	MID	8.5	7.2	5.4	9.145
		1.8	6	17.5	9.2	6.8	7.6	SUR	9.4	7.3	5.5	5.697
		0.9	3	18.0	9.3	5.7	7.6					
		0.3	1	18.0	9.3	5.0	7.6					
June 12, 1974												
LOW TIDE												
1	1011	1.5	5	13.5	9.8	24.8	8.1	BOT	7.7	7.4	5.1	28.068
		0.9	3	13.5	9.2	24.0	8.1	SUR	7.7	7.0	4.3	27.025
		0.3	1	14.0	9.0	24.0	8.1					
2	1017	2.7	9	13.0	9.2	26.2	8.1					
		1.8	6	13.0	8.9	26.2	8.1	BOT	7.7	7.4	2.7	29.975
		0.9	3	13.0	8.7	26.2	8.1	SUR	7.5	7.4	2.4	29.233
		0.3	1	13.0	8.7	26.2	8.1					
3	1026	10.7	35	10.5	8.7	27.7	8.1					
		9.1	30	10.5	8.7	27.7	8.1					
		7.6	25	10.5	8.8	27.7	8.1	BOT	7.8	7.4	4.9	32.061
		6.1	20	10.5	9.0	27.3	8.1	MID	8.1	7.45	3.3	31.728
		4.6	15	11.0	9.0	26.9	8.1	SUR	8.4	7.3	3.0	31.132

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
3	1026	3.1	10	11.0	9.1	26.9	8.1					
		1.5	5	11.0	9.4	25.5	8.1					
		0.3	1	11.0	9.6	15.5	8.1					
4	1037	8.5	28	11.0	9.1	27.7	8.1					
		6.1	20	11.5	9.2	26.5	8.1					
		4.6	15	11.5	9.2	26.2	8.1	BOT	8.0	7.5	2.8	31.252
		3.1	10	12.0	9.5	25.8	8.1	MID	8.1	7.5	3.5	29.807
		1.5	5	12.5	9.6	25.5	8.1	SUR	8.1	7.4	2.4	28.042
		0.3	1	13.0	9.9	24.0	8.1					
5	1050	4.6	15	13.5	9.2	24.0	8.1	BOT	8.0	7.4	4.3	26.824
		3.1	10	13.5	9.2	23.7	8.1	MID	8.0	7.4	4.1	26.315
		1.5	5	14.5	9.4	21.9	8.0	SUR	7.9	7.4	4.5	25.408
		0.3	1	14.5	9.3	21.9	8.0					
6	1100	7.6	25	14.0	9.3	22.7	8.0					
		6.1	20	14.0	8.8	22.3	8.0	BOT	7.9	7.4	6.3	25.544
		4.6	15	14.5	8.8	21.9	8.0	MID	7.6	7.4	6.0	24.950
		3.1	10	15.0	8.7	21.2	8.0	SUR	7.7	7.3	4.3	25.074
		1.5	5	15.0	8.6	20.6	8.0					
		0.3	1	15.0	8.6	19.9	8.0					
7	1110	1.8	6	14.5	9.4	21.2	8.1	BOT	7.6	7.4	8.6	24.825
		0.9	3	15.0	9.1	19.9	8.0	SUR	7.9	7.3	6.5	19.678
		0.3	1	15.0	8.9	18.5	8.0					

APPENDIX B. Continued

Station	Time (PST)	Hydrolab Depth (m)	Hydrolab Depth (ft)	Hydrolab Temp. (°C)	Hydrolab DO (ppm)	Hydrolab SAL (‰)	Hydrolab pH	Bottle Samples Depth	Bottle Samples DO (ppm)	Bottle Samples pH	Bottle Samples TUR (JTU)	Bottle Samples SAL (‰)
8	1117	9.1	30	14.0	8.7	22.7	8.0					
		7.6	25	14.5	8.5	22.3	8.0	BOT	7.5	7.4	15.0	25.622
		6.1	20	14.5	8.5	21.2	8.0	MID	7.6	7.4	5.5	22.364
		4.6	15	15.0	8.6	19.2	7.9	SUR	7.6	7.2	5.8	20.472
		3.1	10	15.0	8.2	19.2	7.9					
		1.5	5	15.0	8.2	18.1	7.9					
		0.3	1	15.5	8.1	17.5	7.9					
9	1123	10.7	35	14.0	8.8	22.7	8.0					
		9.1	30	14.5	8.6	22.3	8.0					
		7.6	25	14.5	8.4	21.9	8.0					
		6.1	20	14.0	8.5	19.9	7.9	BOT	7.9	7.3	6.2	23.826
		4.6	15	15.0	8.4	19.2	7.9	MID	8.0	7.2	5.2	21.287
		3.1	10	15.5	8.3	17.8	7.9	SUR	7.5	7.3	5.7	18.623
		1.5	5	15.5	8.3	17.2	7.9					
		0.3	1	16.0	8.2	15.8	7.8					
10	1133	12.2	40	14.5	8.3	21.9	8.0					
		10.7	35	14.5	8.2	21.9	8.0					
		9.1	30	14.5	8.2	20.6	7.9	BOT	7.7	7.2	14.0	22.716
		7.6	25	15.0	7.7	19.9	7.9	MID	7.3	7.2	6.0	22.730
		6.1	20	15.0	7.7	18.5	7.8	SUR	8.2	7.2	4.8	12.117
		4.6	15	15.5	7.8	17.5	7.8					
		3.1	10	15.5	7.8	14.4	7.8					
		1.5	5	16.5	8.4	11.4	7.8					
		0.3	1	17.0	8.5	10.4	7.7					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
11	1143	10.7	35	14.5	7.8	17.8	7.8					
		9.1	30	14.5	7.9	17.8	8.0					
		7.6	25	15.0	8.0	17.2	7.9					
		6.1	20	15.5	7.7	15.8	7.7	BOT	6.7	7.1	34.0	24.950
		4.6	15	16.0	7.4	15.0	7.6	MID	7.2	7.2	5.2	20.009
		3.1	10	16.0	7.3	15.0	7.7	SUR	7.7	7.2	5.2	15.785
		1.5	5	16.0	7.5	14.8	7.7					
		0.3	1	16.5	8.4	12.4	7.7					
12	1205	8.2	27	16.0	7.3	15.0	7.7					
		6.1	20	17.5	7.1	11.4	7.4	BOT	6.4	7.0	9.3	13.138
		4.6	15	18.0	6.9	11.4	7.4	MID	6.5	7.0	4.3	13.355
		3.1	10	18.0	6.8	11.1	7.4	SUR	6.7	7.0	3.6	12.548
		1.5	5	18.0	6.7	11.1	7.4					
		0.3	1	18.0	6.7	11.1	7.4					
15	1224	7.0	23	17.0	8.9	10.4	7.7					
		4.6	15	17.5	8.6	8.9	7.7	BOT	8.4	7.1	9.3	9.919
		3.1	10	17.5	8.5	8.2	7.7	MID	8.4	7.05	8.6	8.994
		1.5	5	17.5	8.5	7.7	7.7	SUR	9.3	7.15	5.7	5.371
		0.3	1	17.5	8.7	5.7	7.7					
13	1234	2.4	8	17.5	9.4	5.3	7.7					
		1.5	5	18.5	9.3	3.6	7.7	BOT	8.2	7.0	11.0	6.425
		0.9	3	18.5	9.6	3.1	7.7	SUR	9.9	7.2	5.8	F
		0.3	1	18.5	9.7	2.2	7.7					

APPENDIX B. Continued

		Hydrolab						Bottle Samples				
Station	Time (PST)	Depth (m)	Depth (ft)	Temp. (°C)	DO (ppm)	SAL (‰)	pH	Depth	DO (ppm)	pH	TUR (JTU)	SAL (‰)
14	1343	2.7	9	18.0	9.5	0.6	7.8					
		1.8	6	18.0	9.4	0.6	7.7	BOT	10.0	7.15	10.0	F
		0.9	3	18.5	9.4	0.5	7.7	SUR	10.3	7.25	8.0	F
		0.3	1	18.5	9.5	0.6	7.6					

APPENDIX C. Sediment Grain Size Data and Grain Size Distribution Plots

Sample*	River Distance (km)	River Distance (mile)	D_{50} (mm)	Uniformity (D_{60}/D_{10})	Porosity (%)	Volatile Solids (% by wt.)
1S	7.1	4.4	0.28	4.92	47.7	1.22
2S	5.3	3.3	0.25	1.75	43.8	0.70
3S	2.0	1.2	0.29	2.06	41.4	0.62
4S	4.7	2.9	0.30	1.89	33.1	0.83
5S	9.2	5.7	0.27	1.76	39.0	1.67
6S	13.2	8.3	0.27	1.82	37.9	0.61
7S	15.6	9.7	0.27	1.71	42.1	0.47
8S	16.3	10.1	0.30	2.00	42.2	2.17
9S	17.9	11.2	0.20	5.62	37.9	1.44

---

* Sample Identification

** Sieve analysis only due to predominance of mollusk shells.

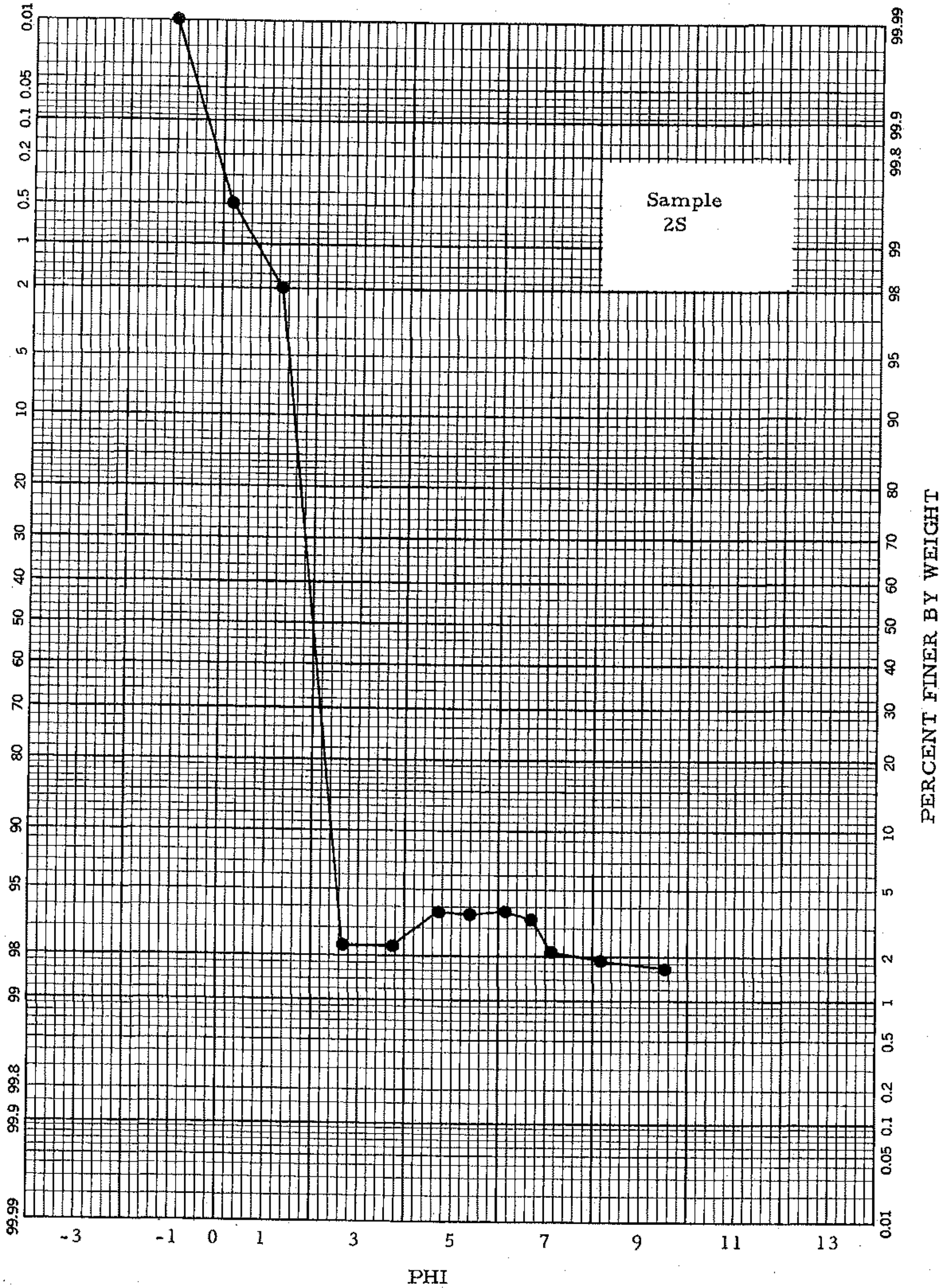
Code:
(1) Number refers to sample location (Figure 38).
(2) Letters S and A refer to September and April sampling dates, respectively.
(3) Letters F and B refer to in front of and behind the dredge, respectively.
(4) Same designations are used on the grain size distribution plots.

APPENDIX C. Continued

Sample*	River Distance (km)	(mile)	D_{50} (mm)	Uniformity (D_{60}/D_{10})	Porosity (%)	Volatile Solids (% by wt.)
10S	21.2	13.2	0.24	26.00	60.5	5.39
11S	23.2	14.4	0.02	18.82	77.1	10.01
12S	28.9	17.9	0.02	20.00	78.8	13.30
13S	26.6	16.5	0.26	3.73	50.9	4.58
14S	27.9	17.3	0.30	2.00	45.5	1.90
15S	22.2	13.7	0.21	5.19	51.5	2.77
16S	24.2	15.0	0.27	2.00	47.7	2.80
1A	7.1	4.4	0.28	2.06	70.9	3.69
2A	5.3	3.3	0.27	1.76	45.2	0.94
3A	2.0	1.2	0.55	2.58	42.1	0.67
4A	4.7	2.9	0.29	1.94	43.3	9.42
5A	9.2	5.7	0.50	3.58	51.4	1.29
6A	13.2	8.3	0.26	1.76	51.3	0.50
7A	15.6	9.7	0.24	2.70	50.3	1.68
8A	16.3	10.1	0.25	1.93	56.0	1.58
9A**	17.9	11.2	0.34	--	--	--

APPENDIX C. Continued

Sample*	River Distance (km)	River Distance (mile)	D_{50} (mm)	Uniformity (D_{60}/D_{10})	Porosity (%)	Volatile Solids (% by wt.)
10AB	21.2	13.2	0.17	4.20	65.8	3.42
10AF	21.2	13.2	0.20	5.75	62.4	4.99
11A	23.2	14.4	0.03	24.44	70.3	8.18
12A	28.9	17.9	0.08	10.31	84.8	7.98
13A	26.6	16.5	0.24	3.38	59.5	6.19
14A	27.9	17.3	0.48	4.38	56.7	5.11
15A	22.2	13.7	0.05	46.43	73.0	7.40
16A	24.2	15.0	0.24	2.08	56.2	1.80



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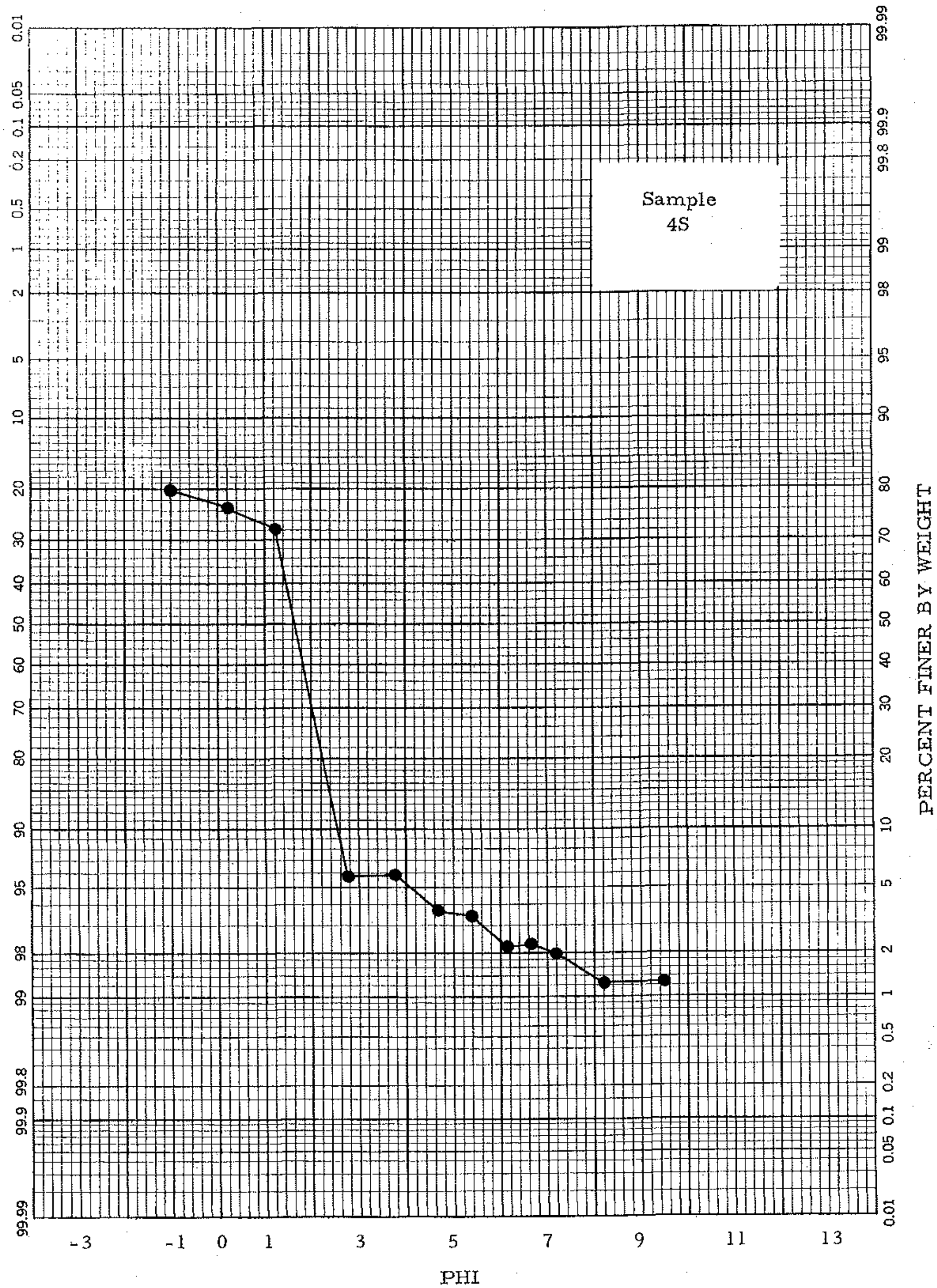
PHI
-3
-1
0
1
3
5
7
9
11
13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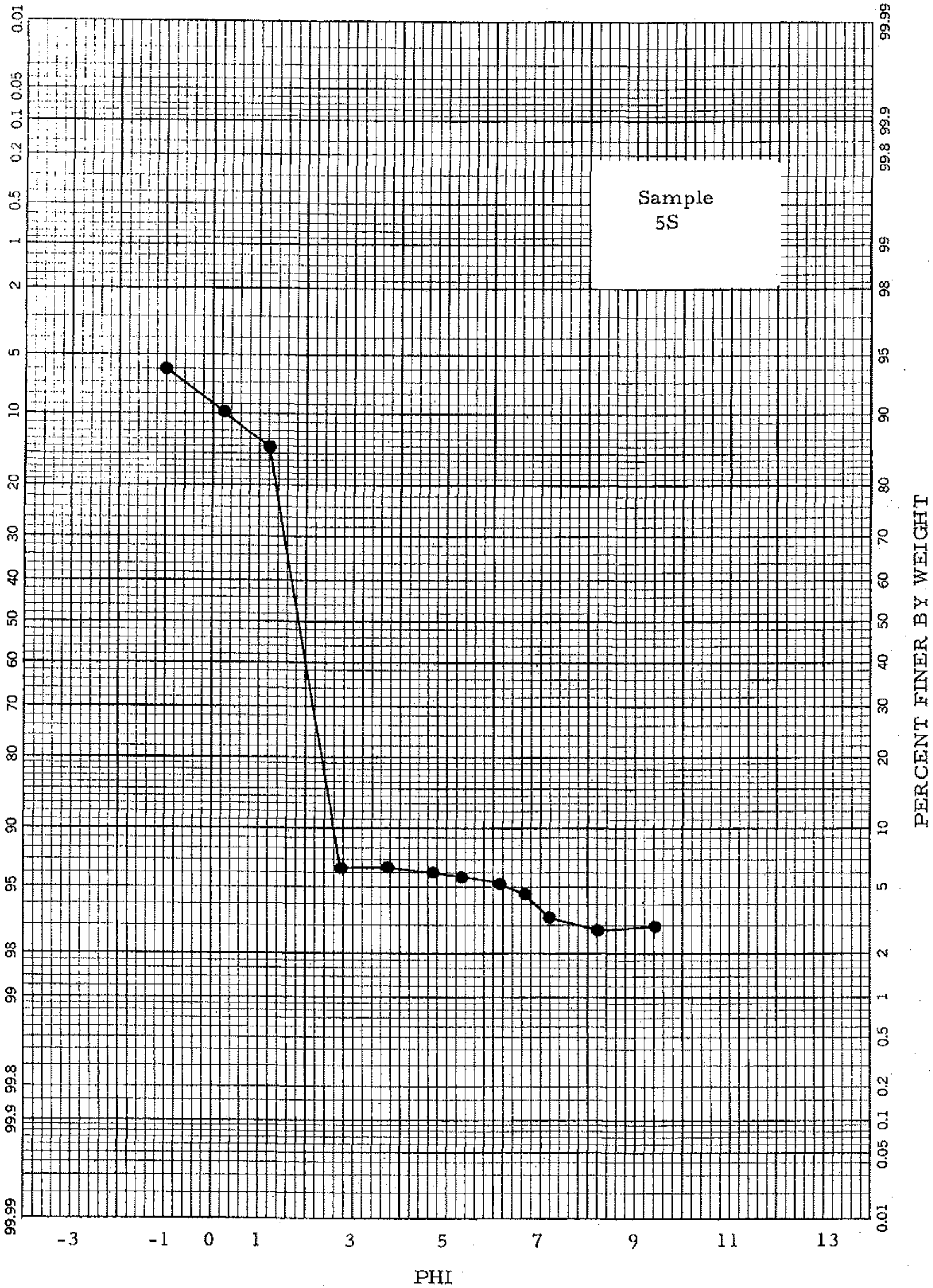
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0.1
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0.5
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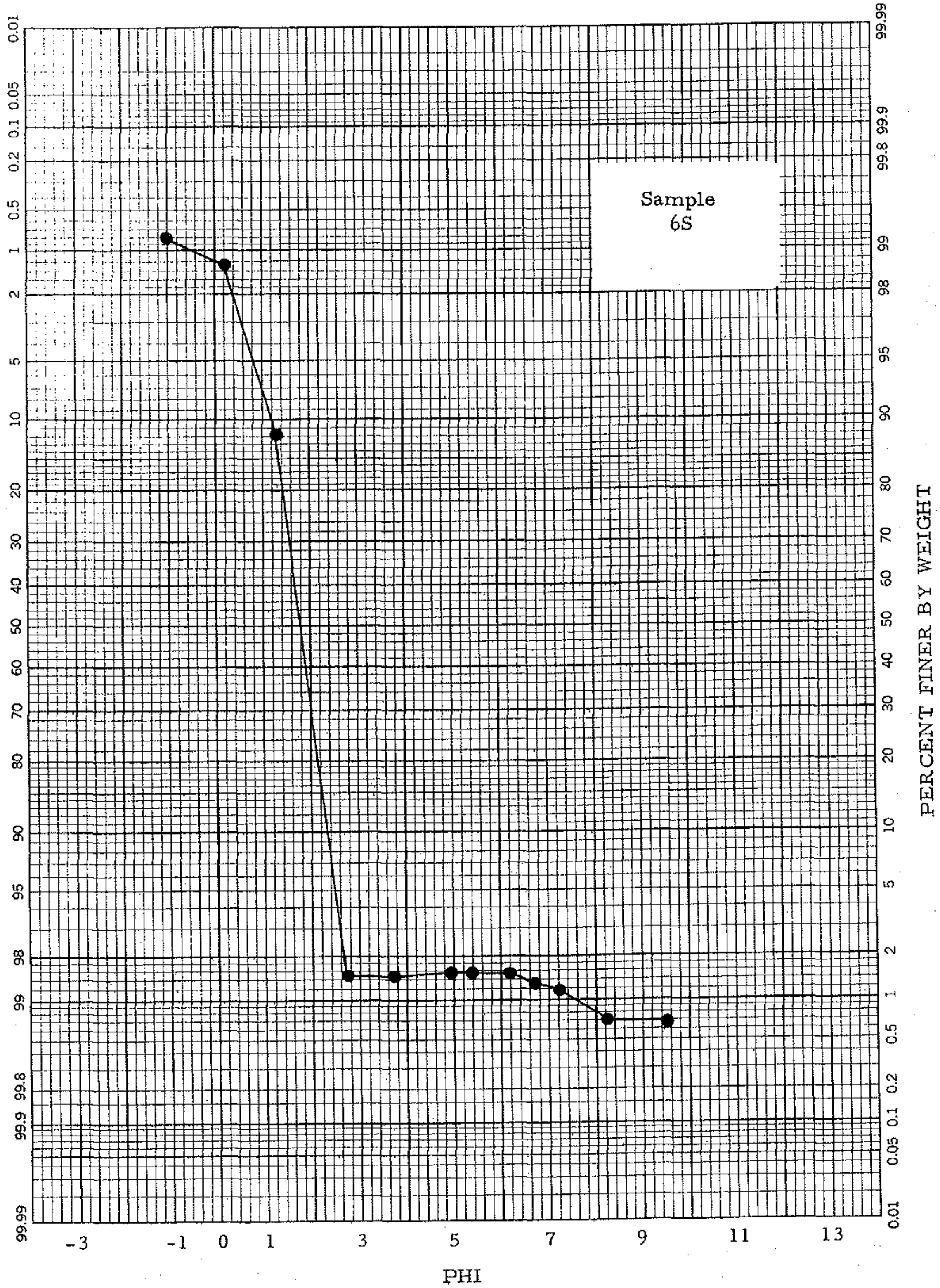
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11
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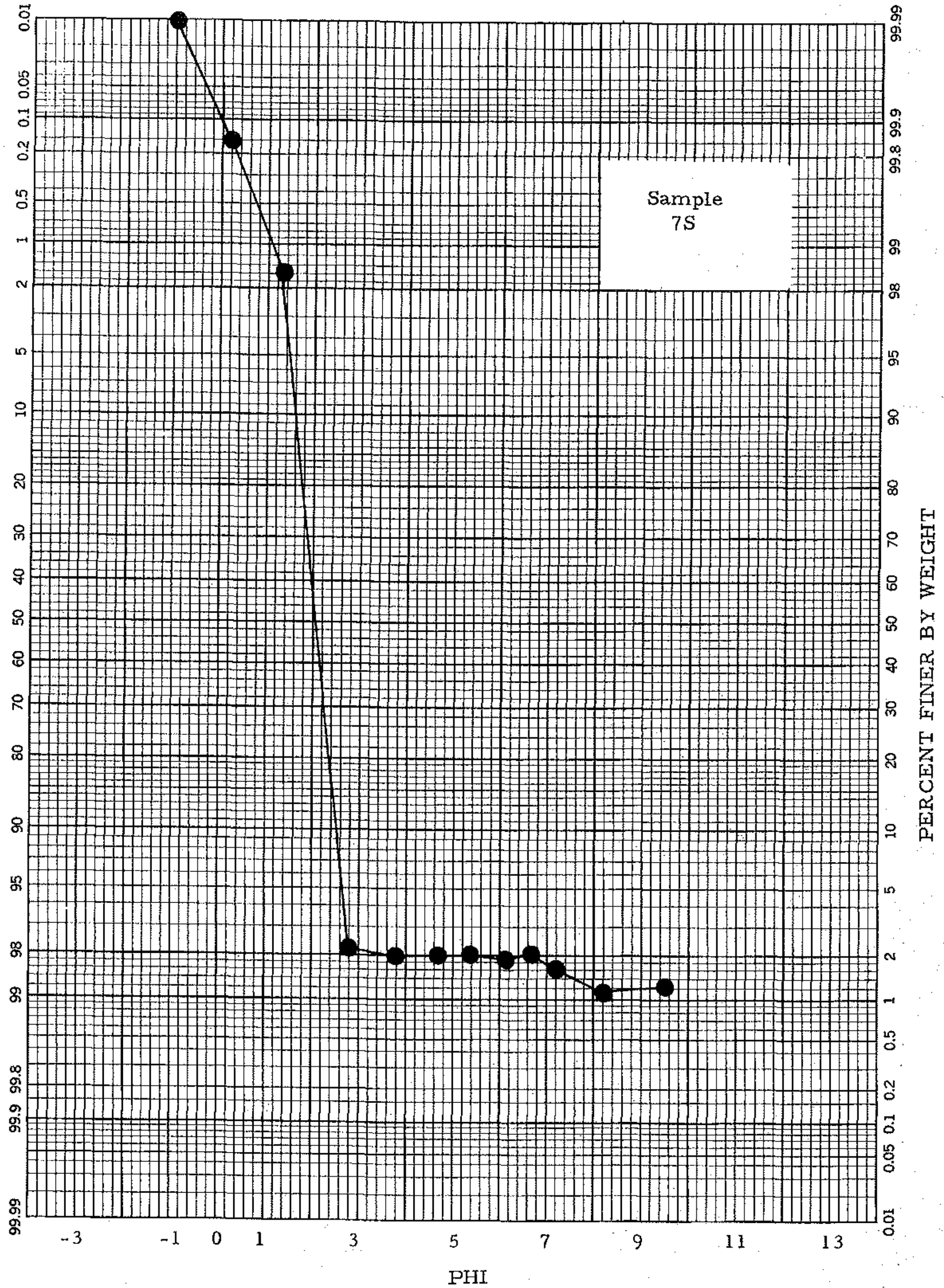
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0.1
0.2
0.5
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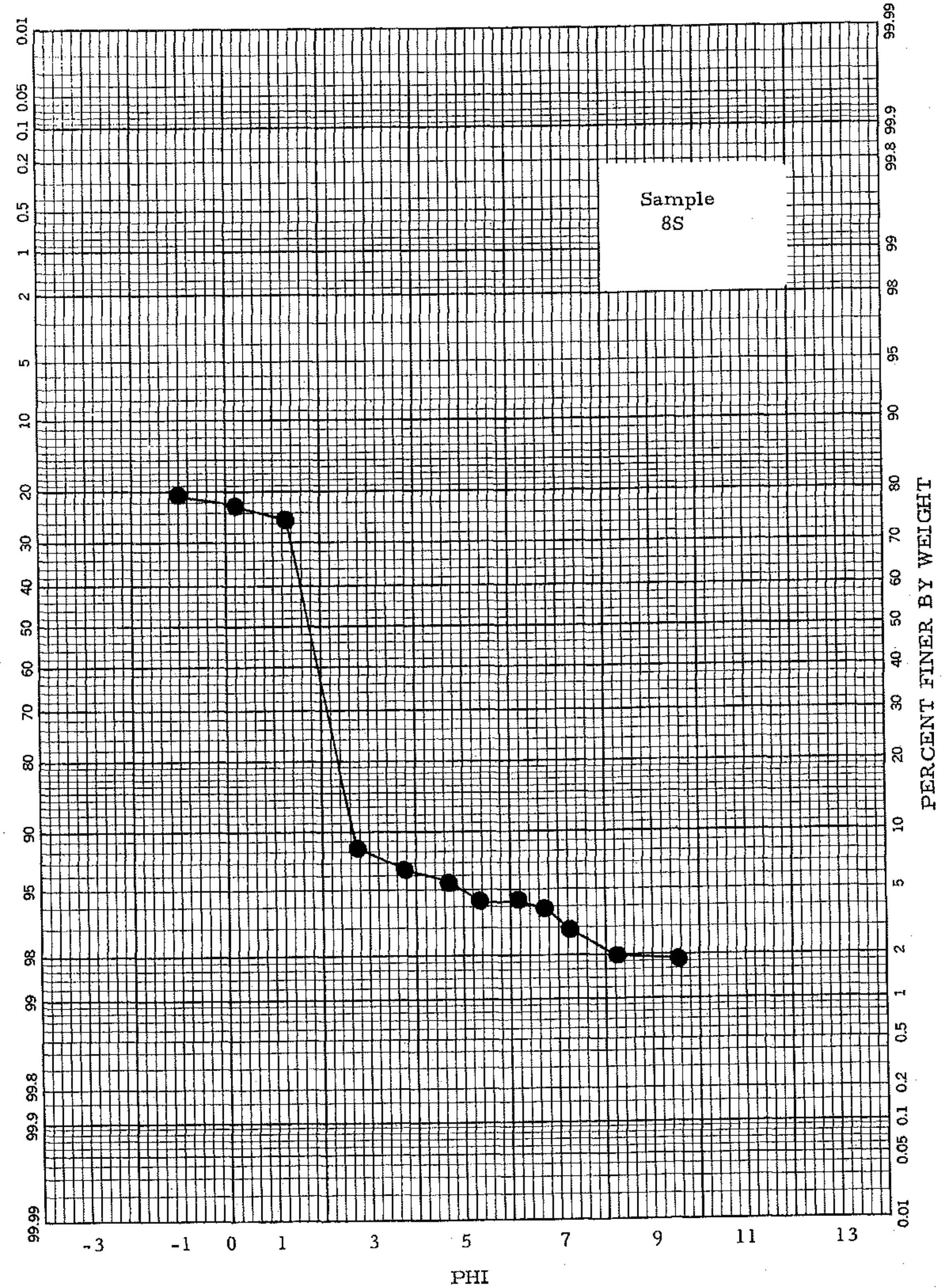
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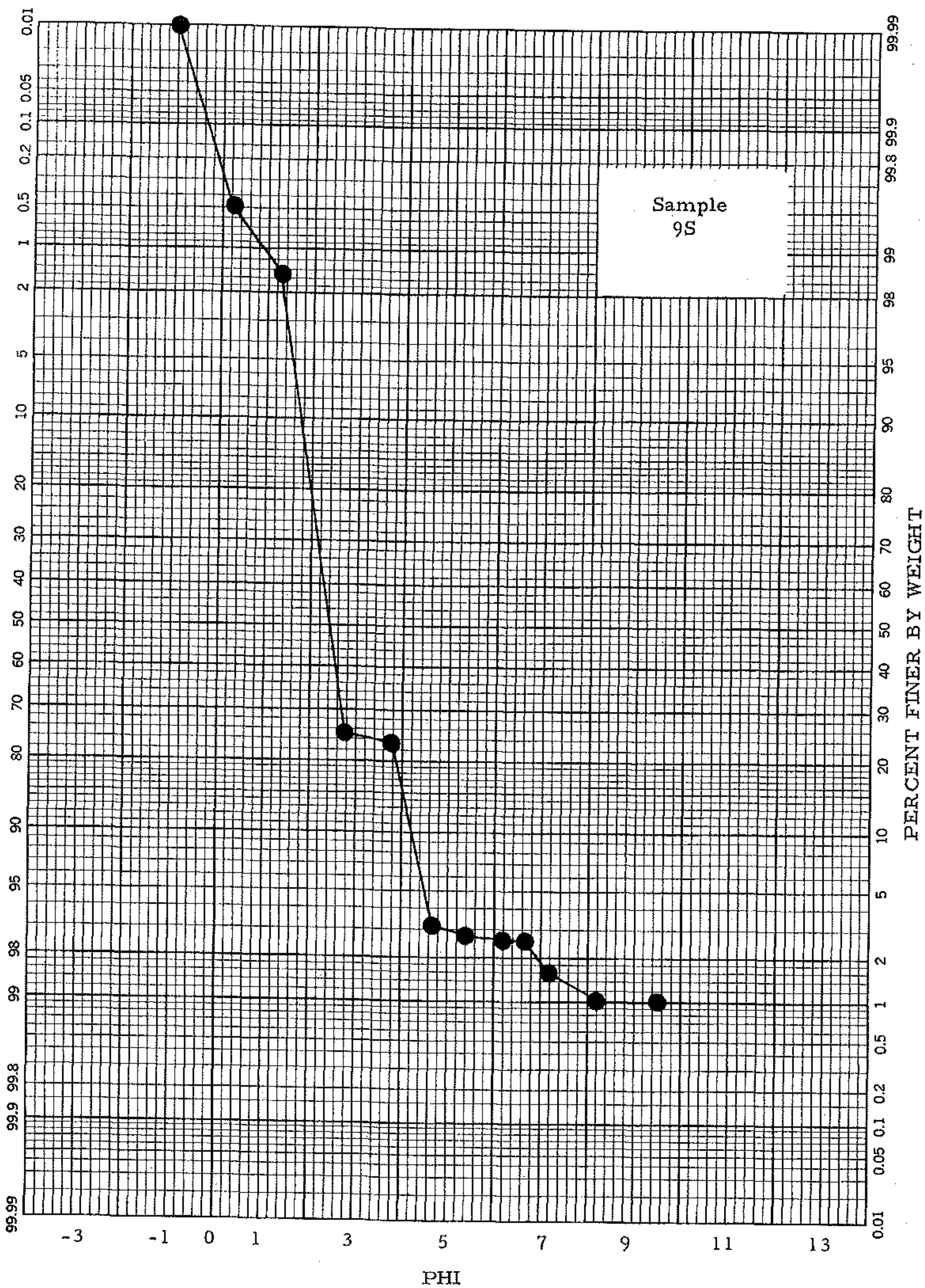
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11
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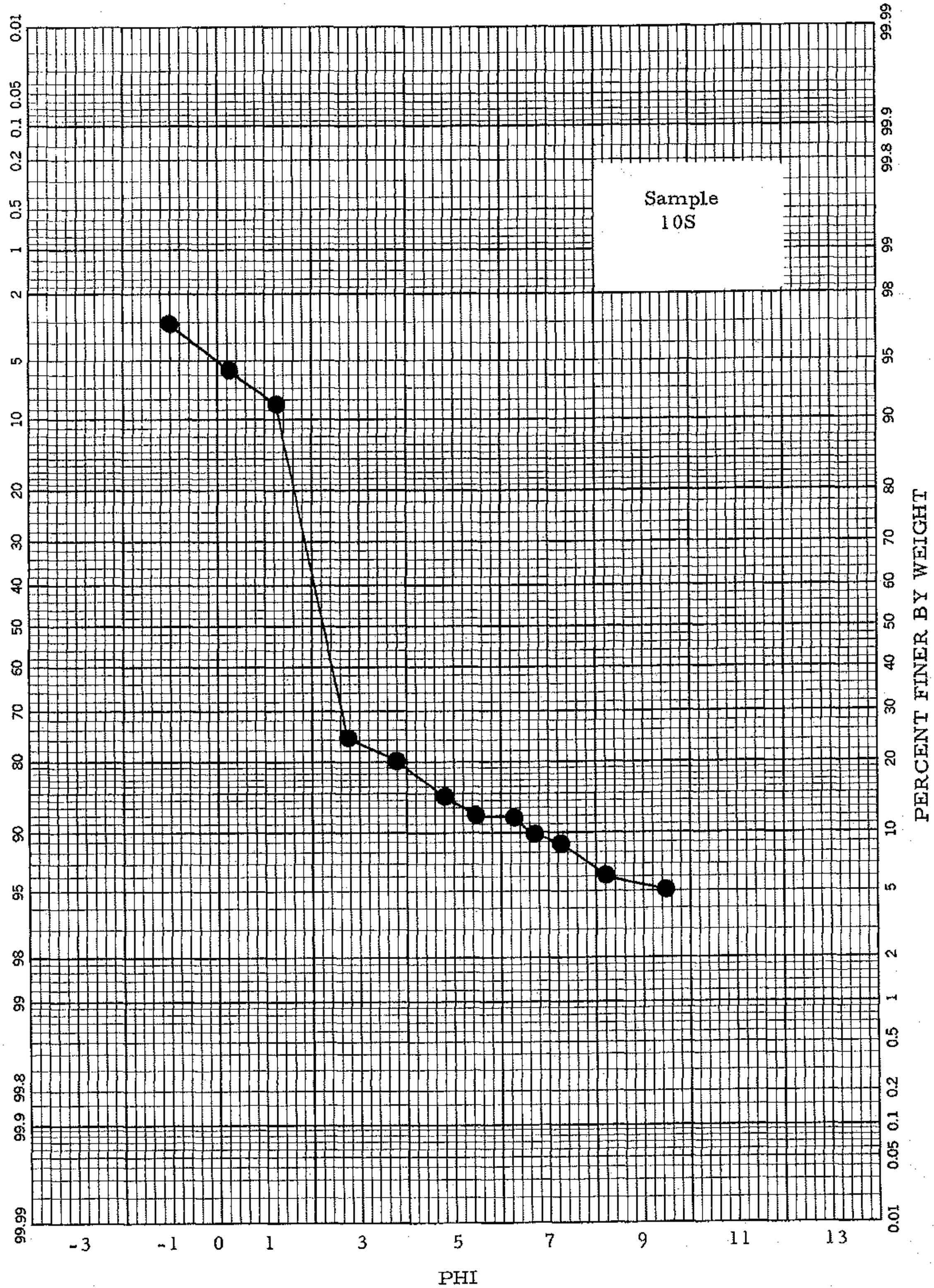
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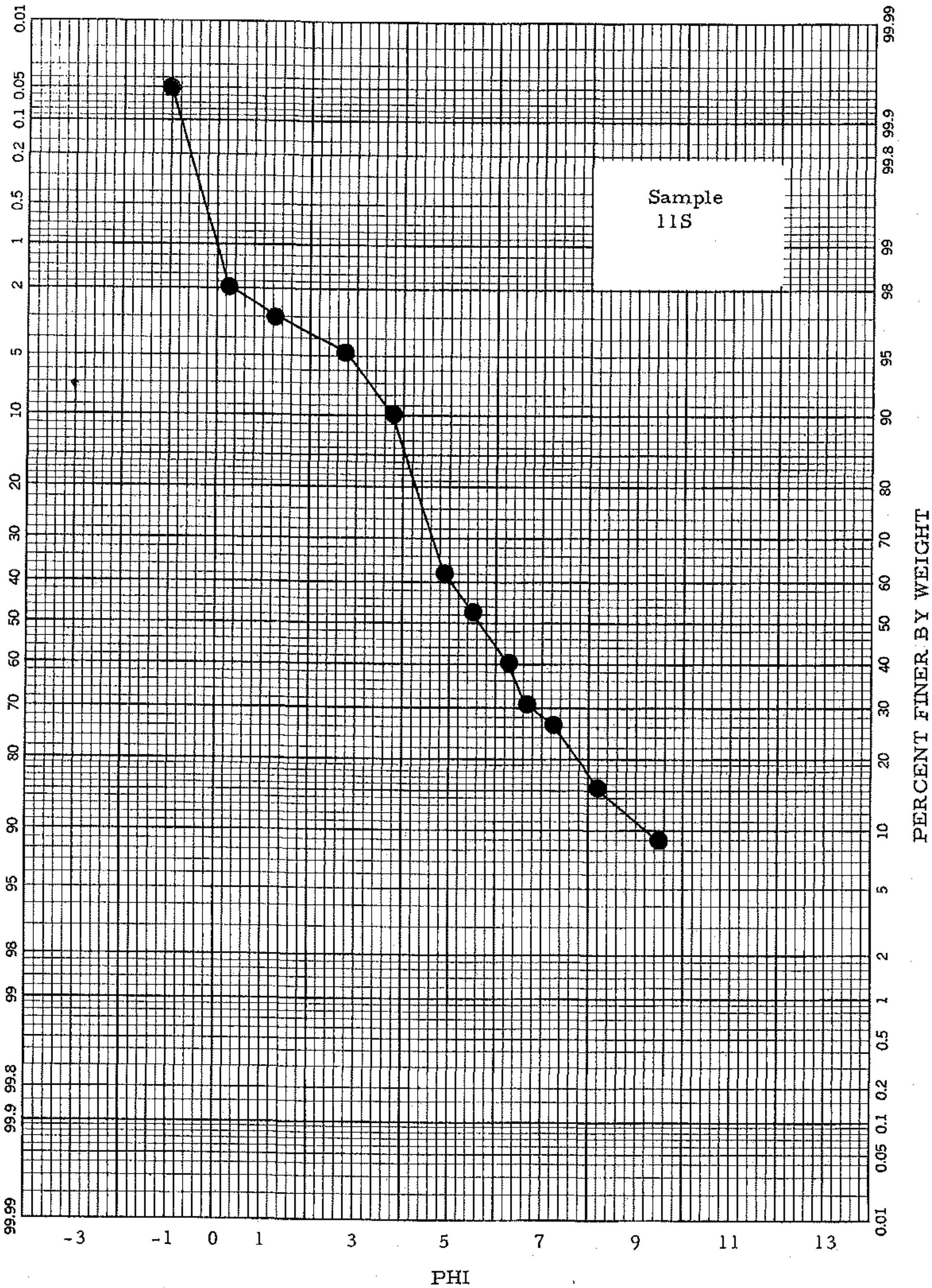
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0
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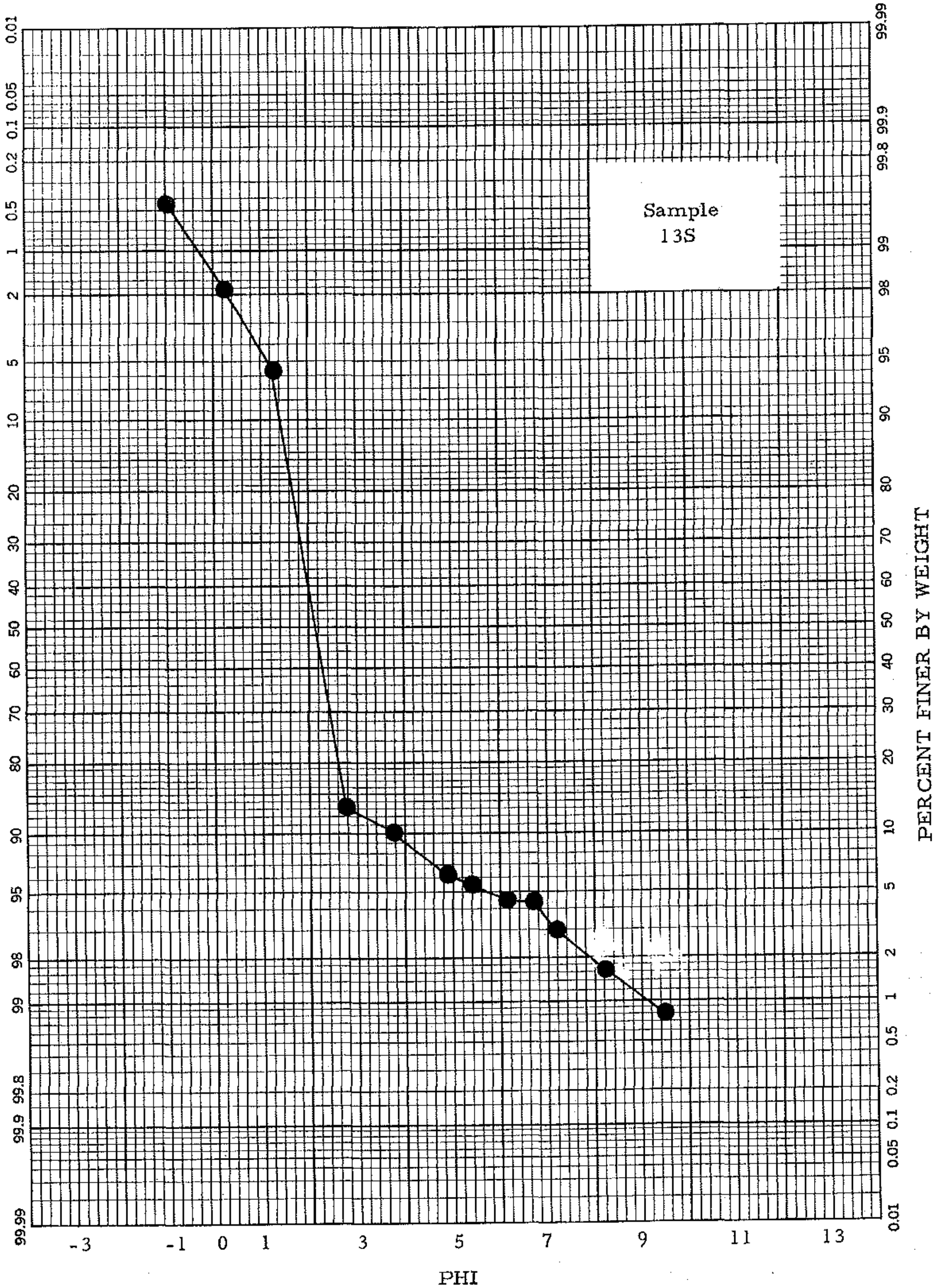
3
5
7
9
11
13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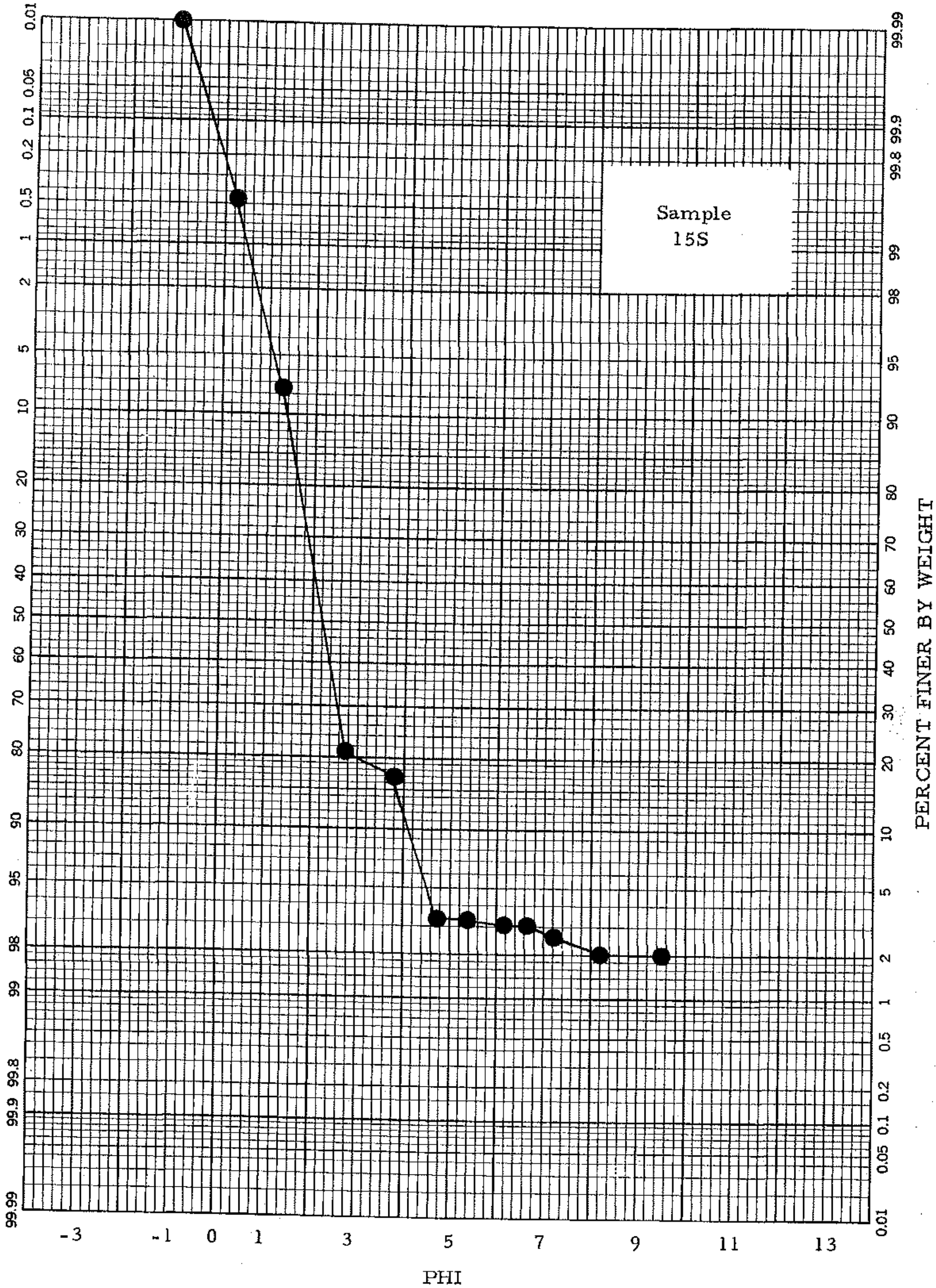
11
13
PHI
PERCENT FINER BY WEIGHT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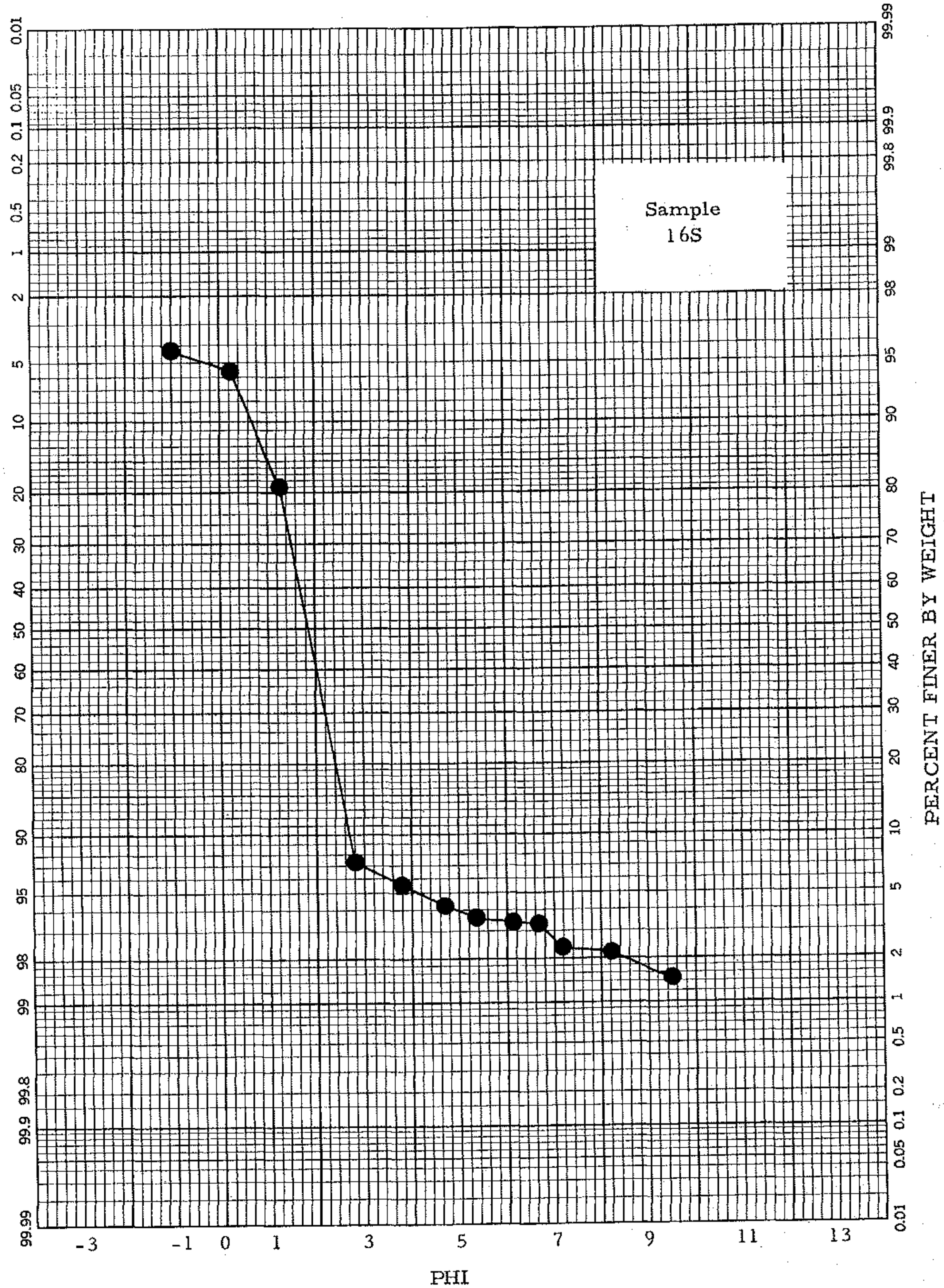
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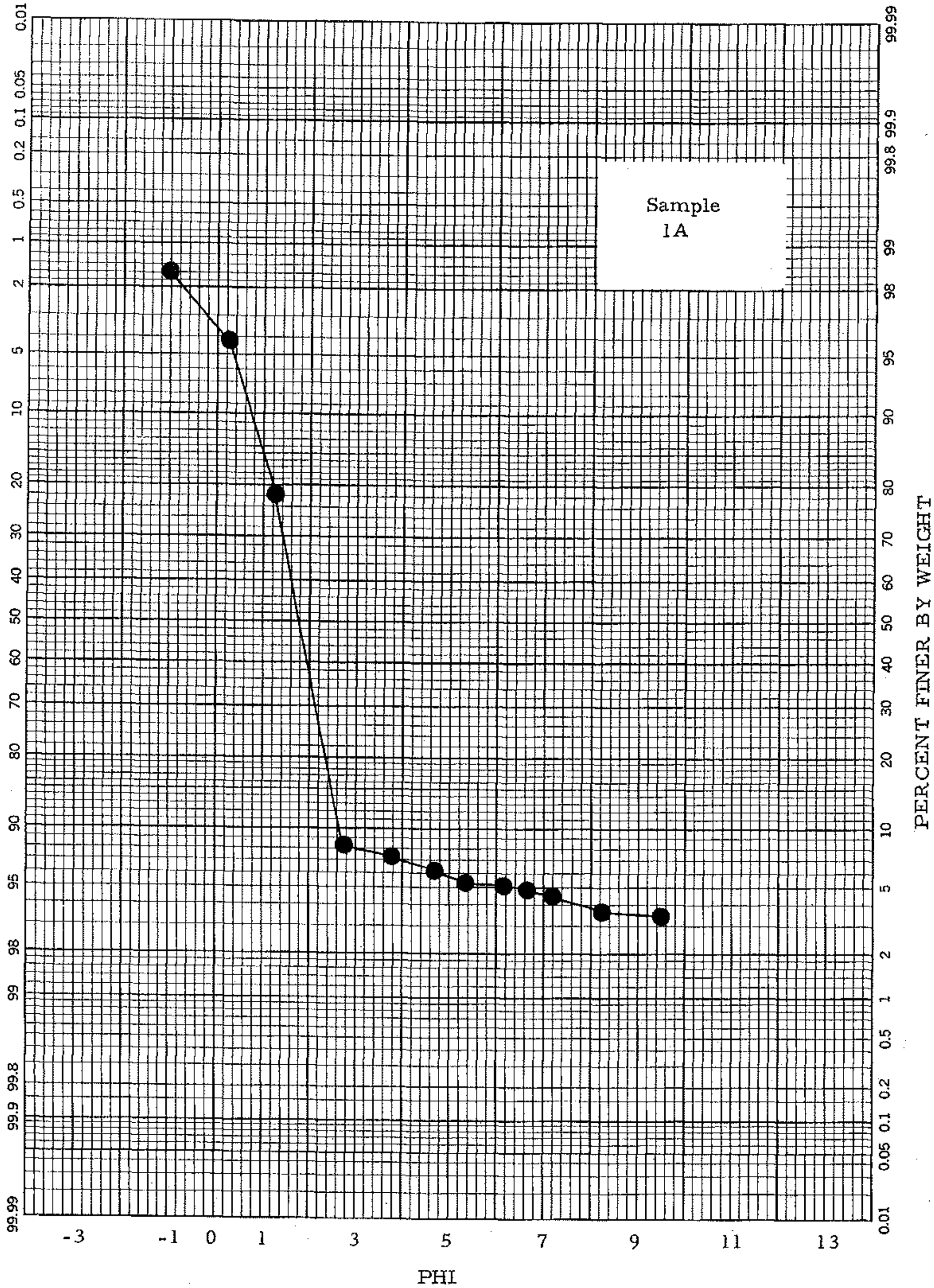
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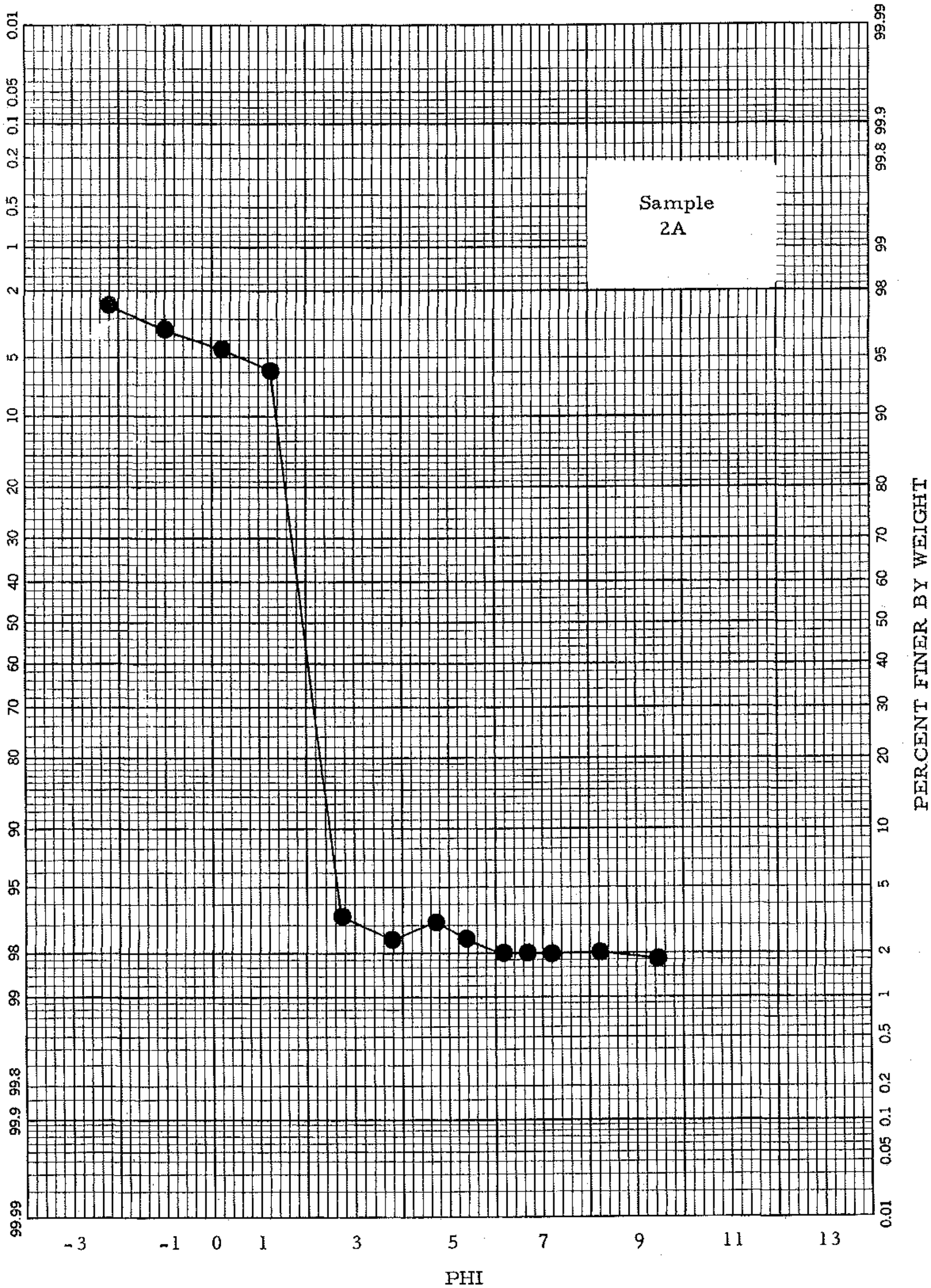
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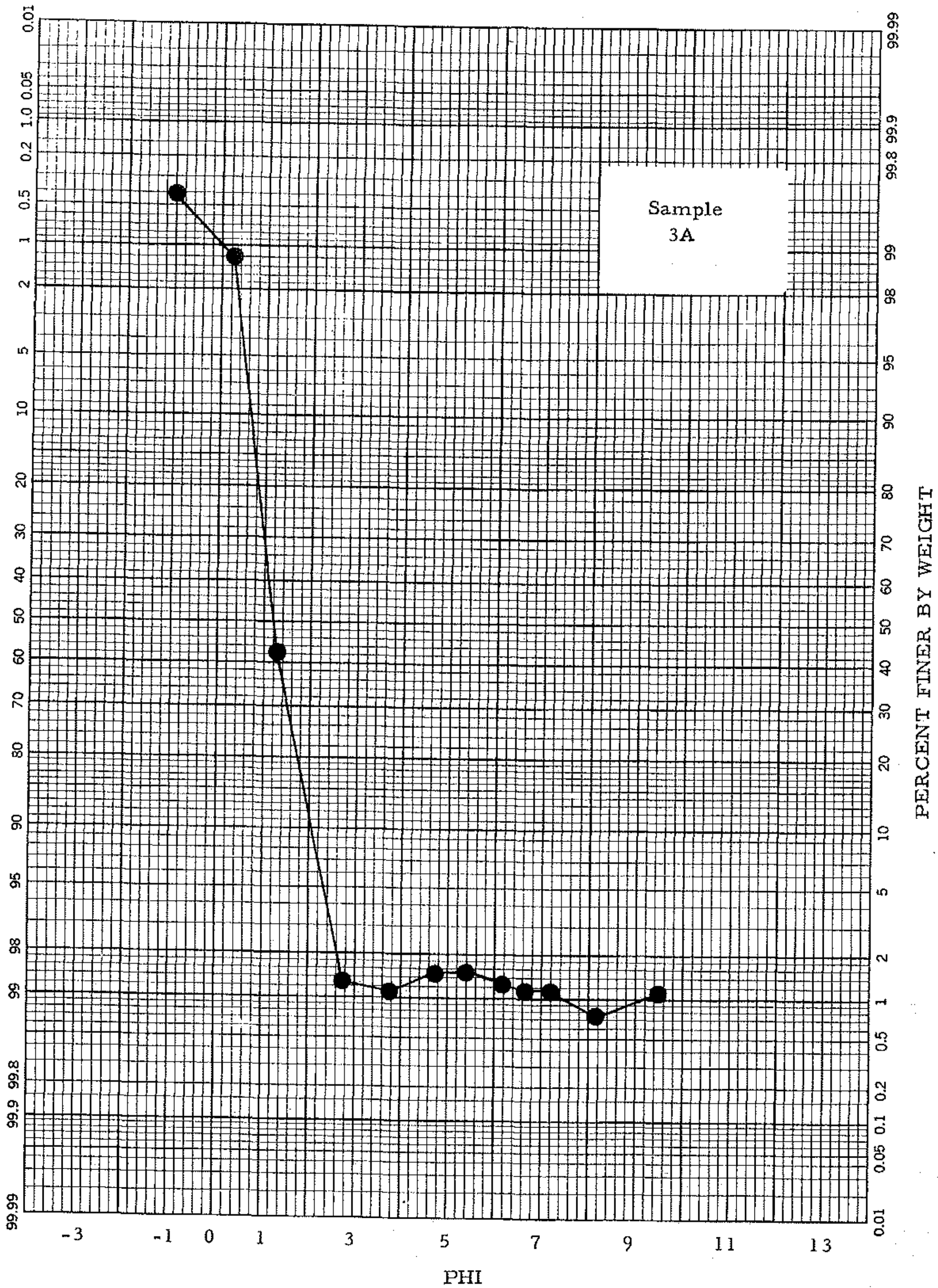
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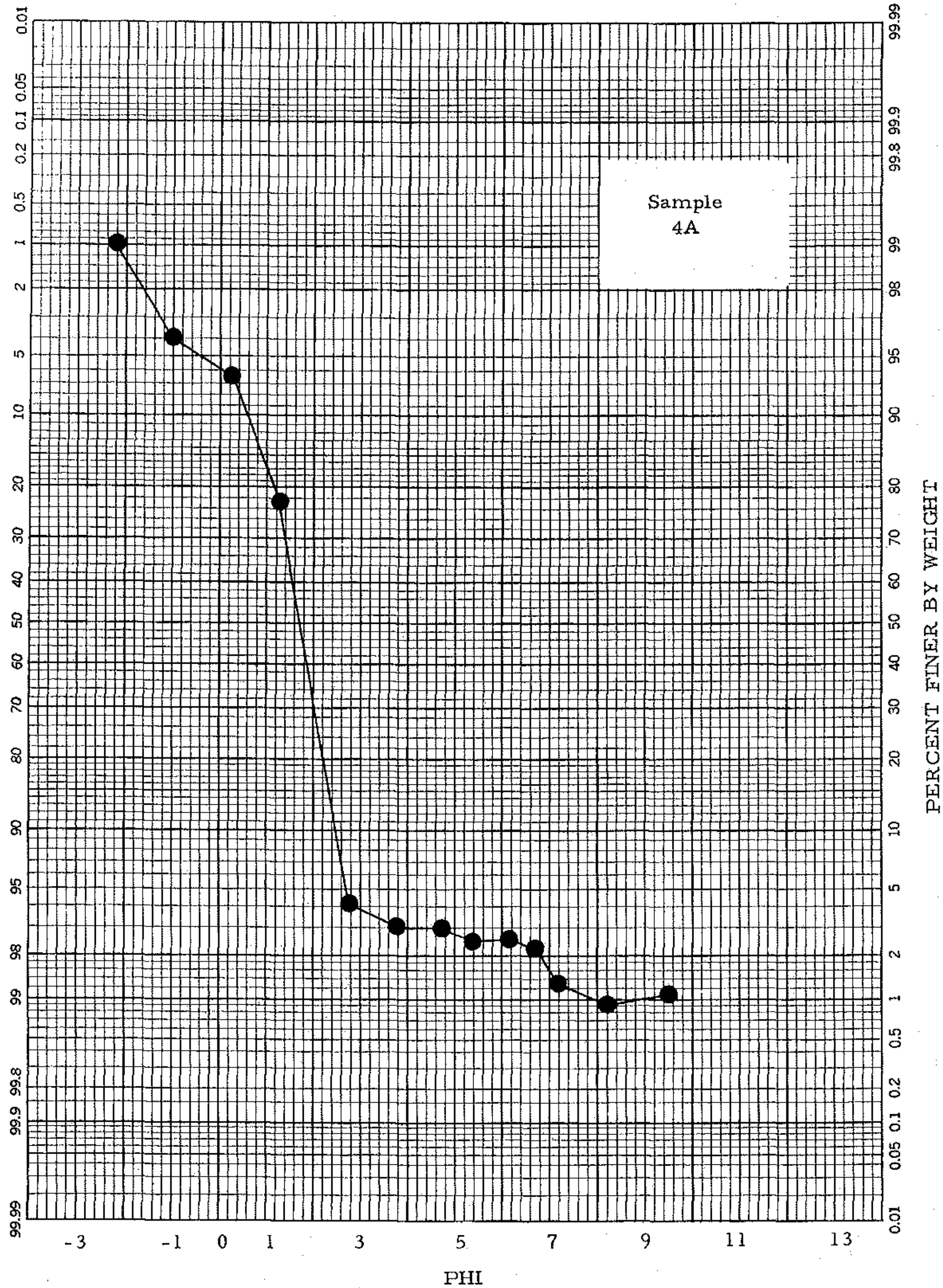

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PHI
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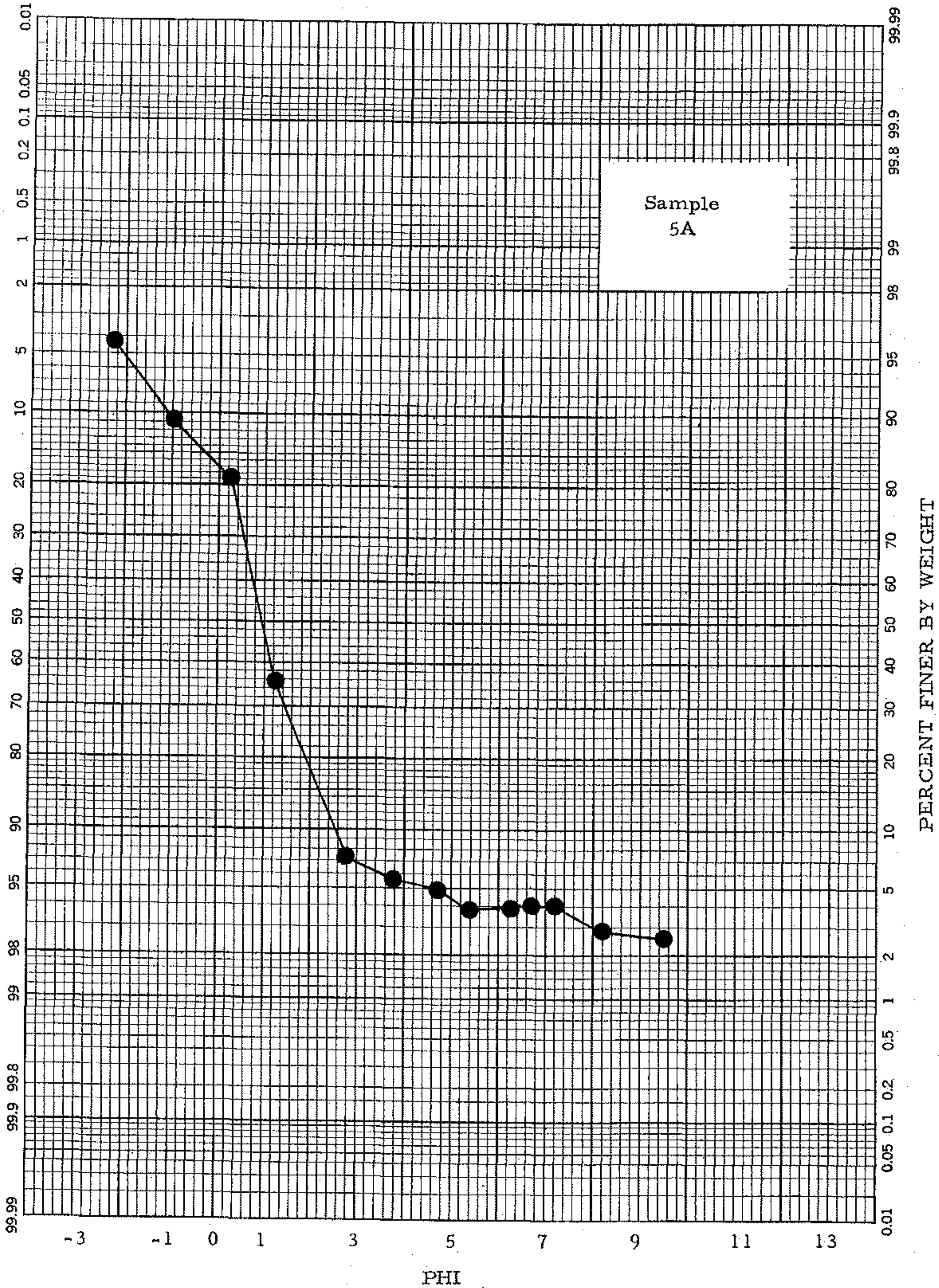
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0.1
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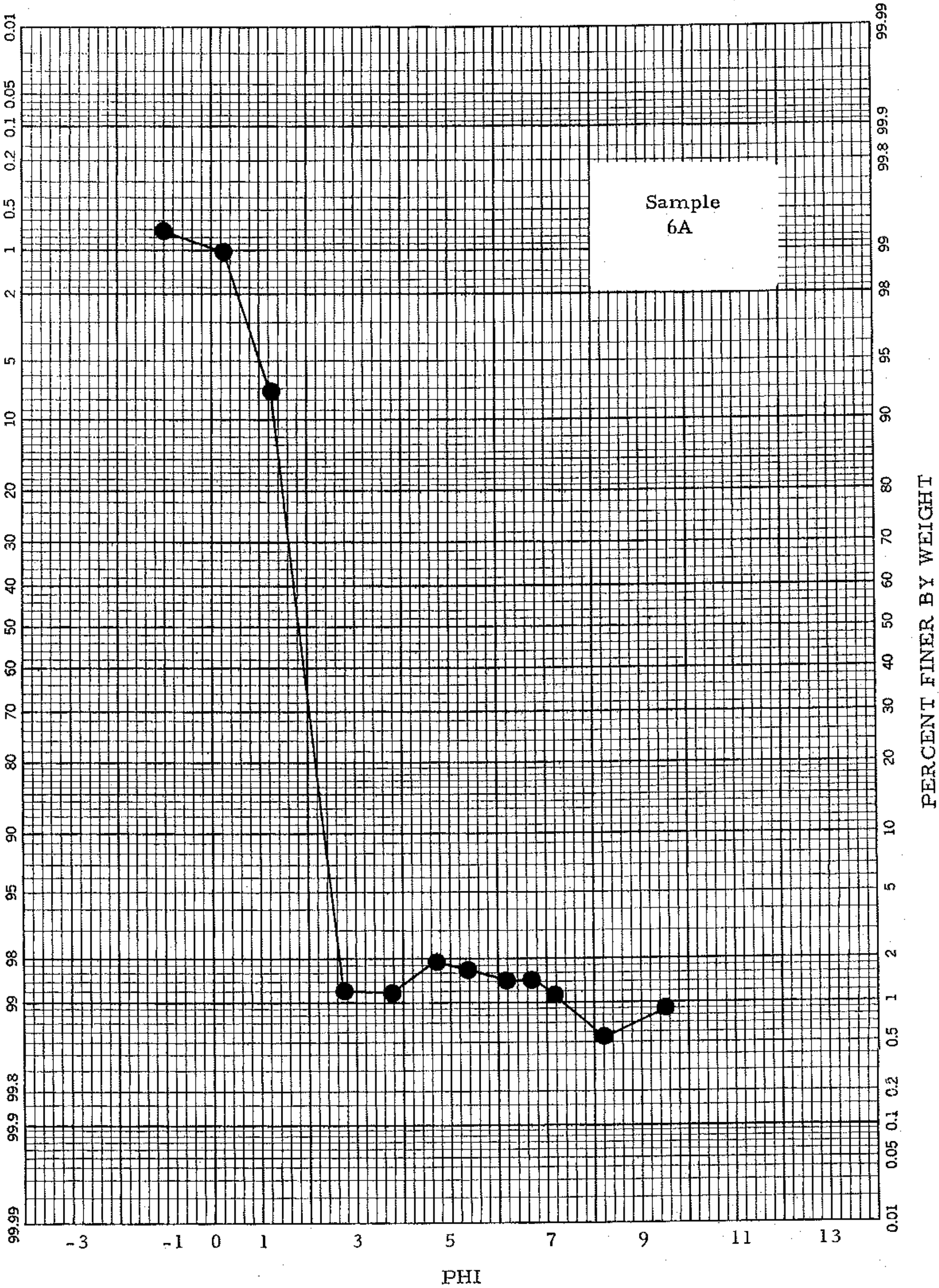

Sample
6A
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0.5
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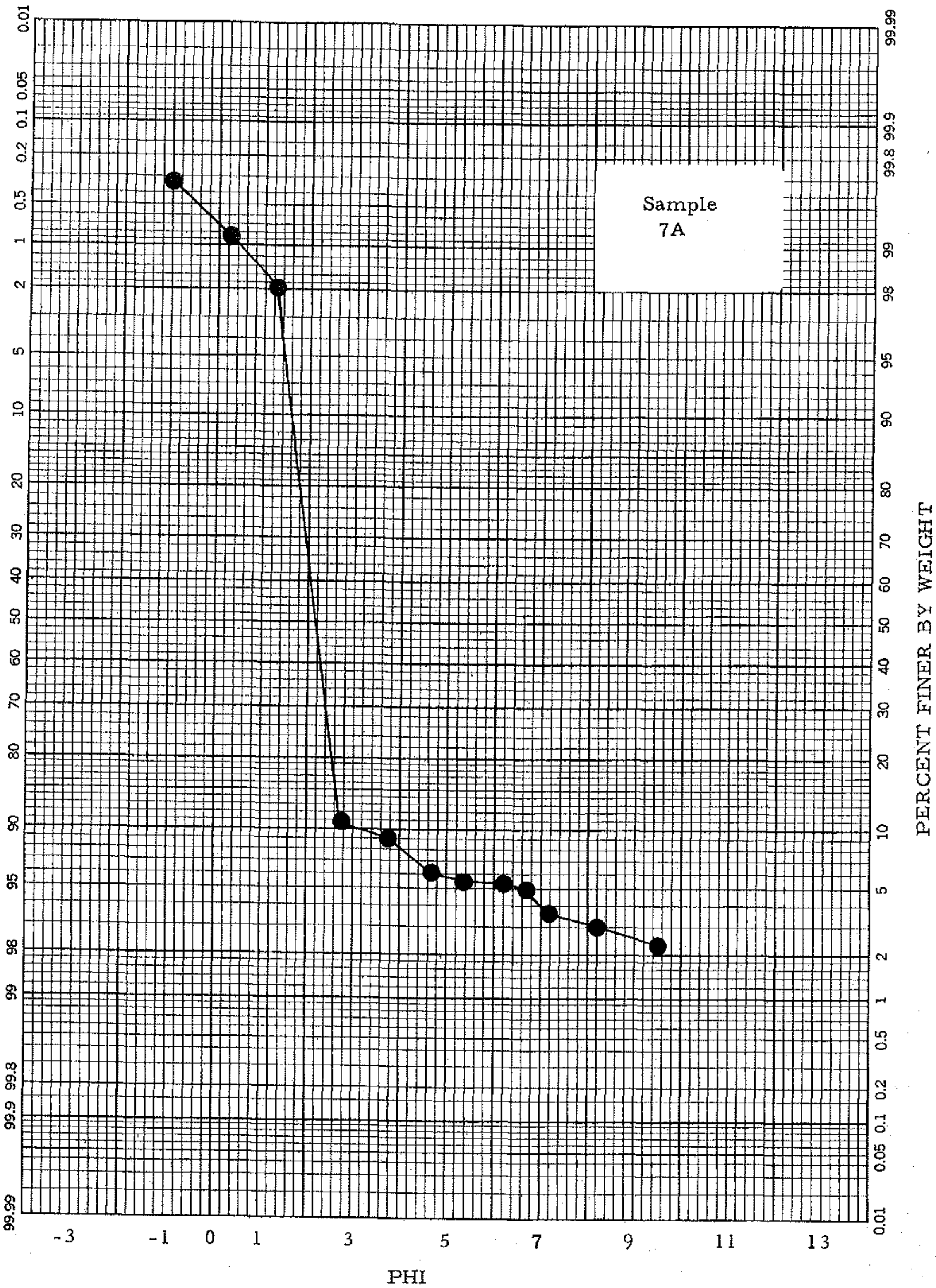
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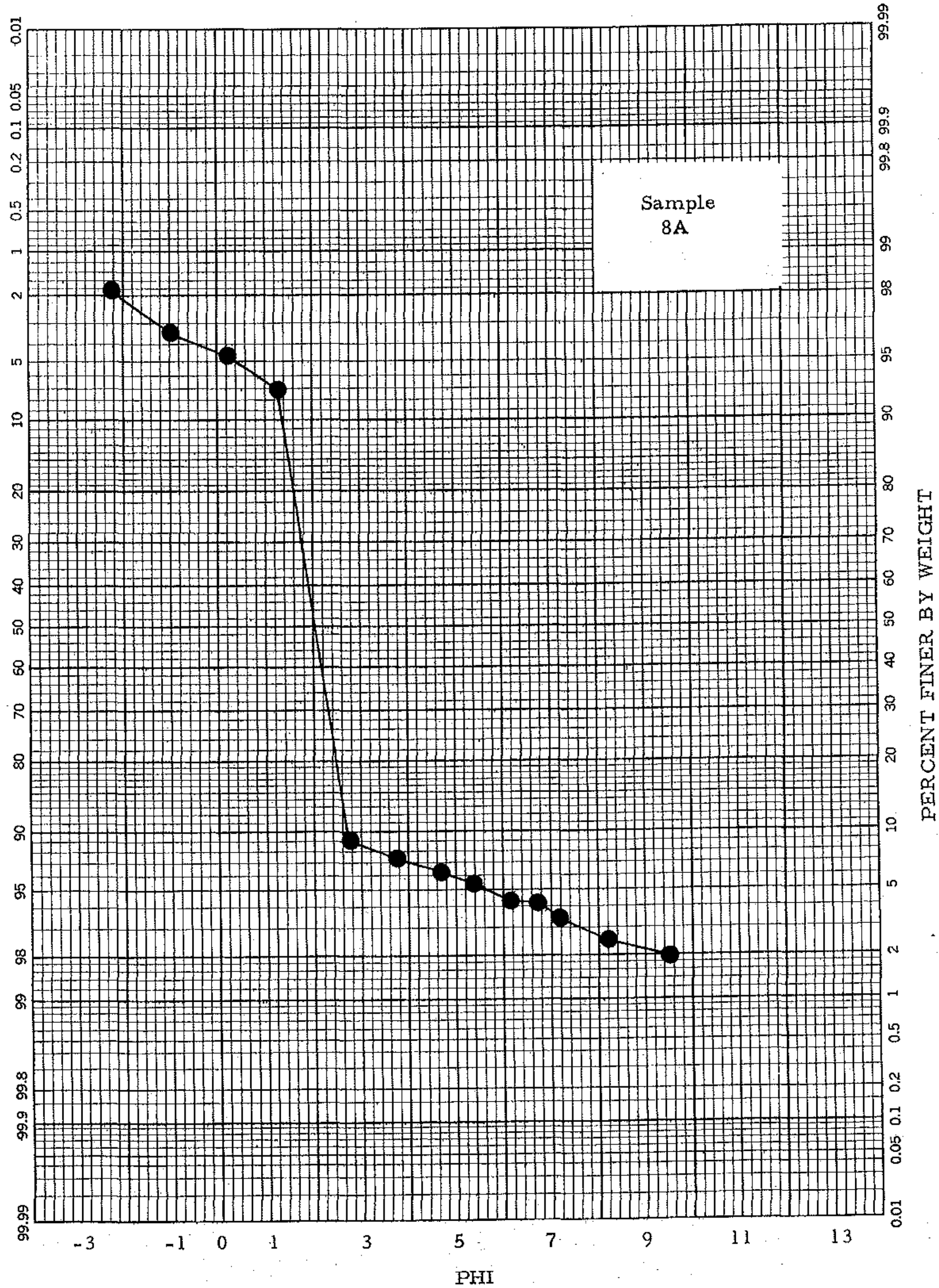
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0.1
0.2
0.5
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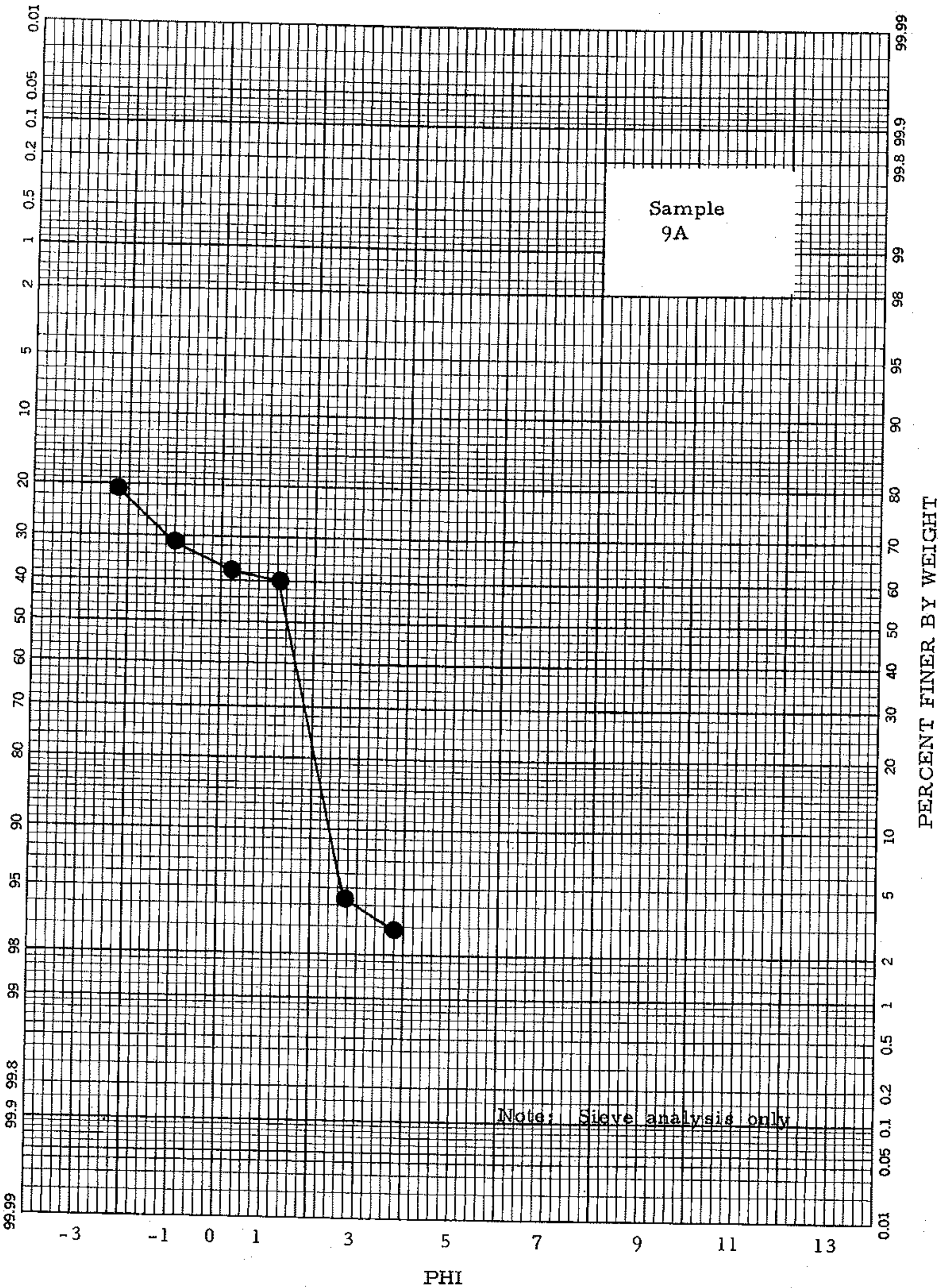
99.99


Sample
9A
Note: Sieve analysis only
-3
-1
0
1
3
5
7
9
11
13
PHI
PERCENT FINER BY WEIGHT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
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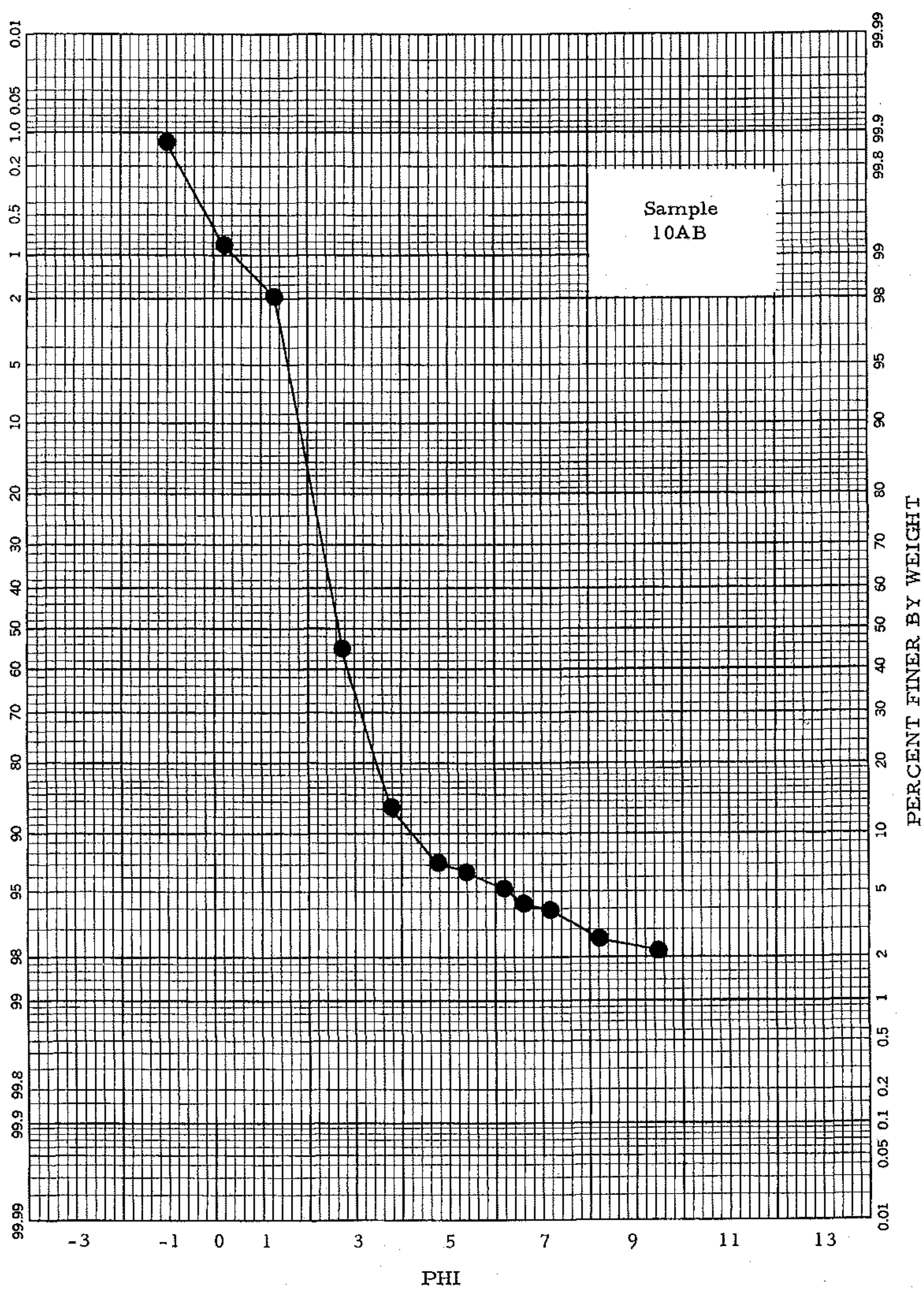
9F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11
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0.05
0.1
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0.5
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95
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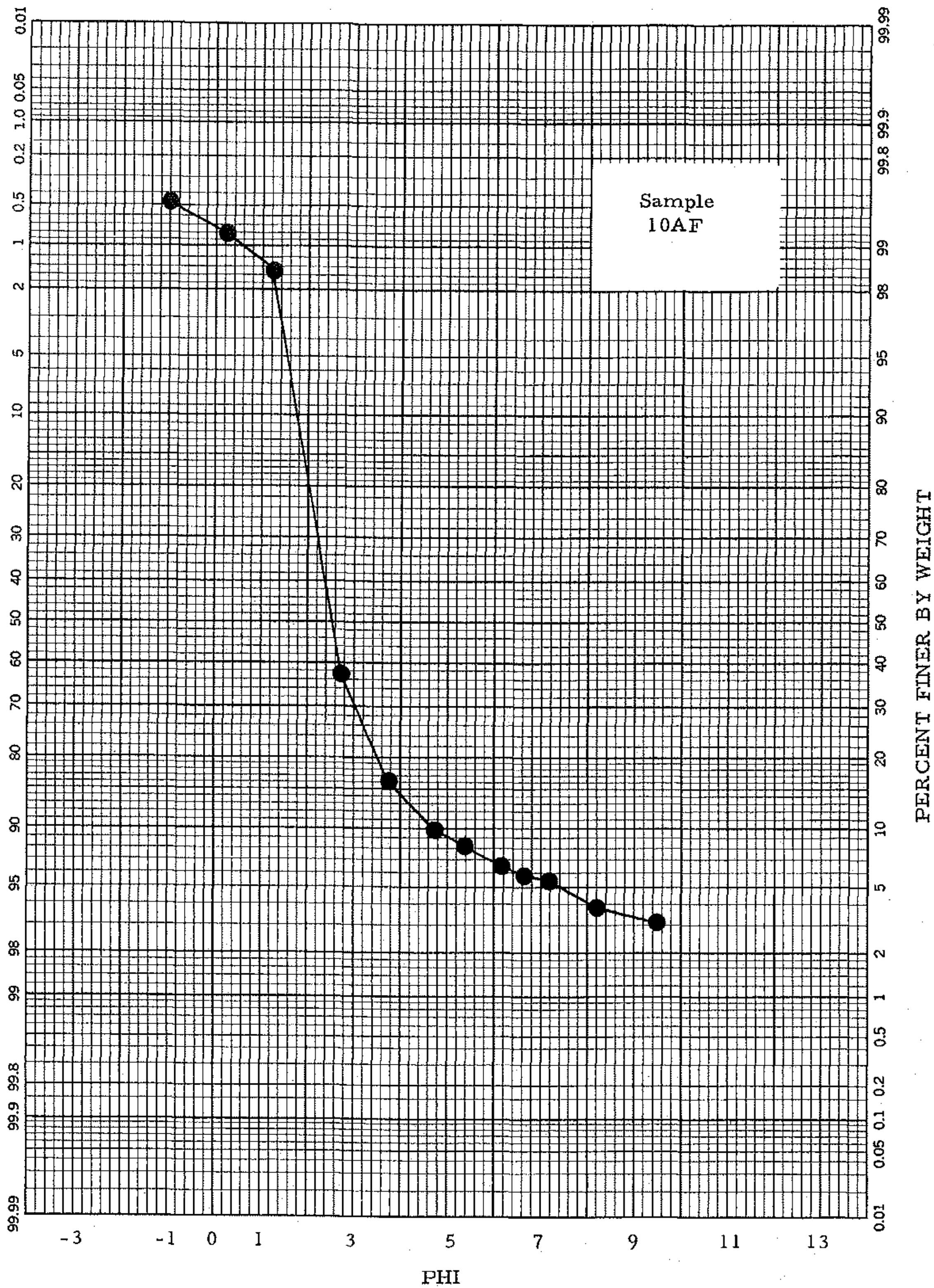
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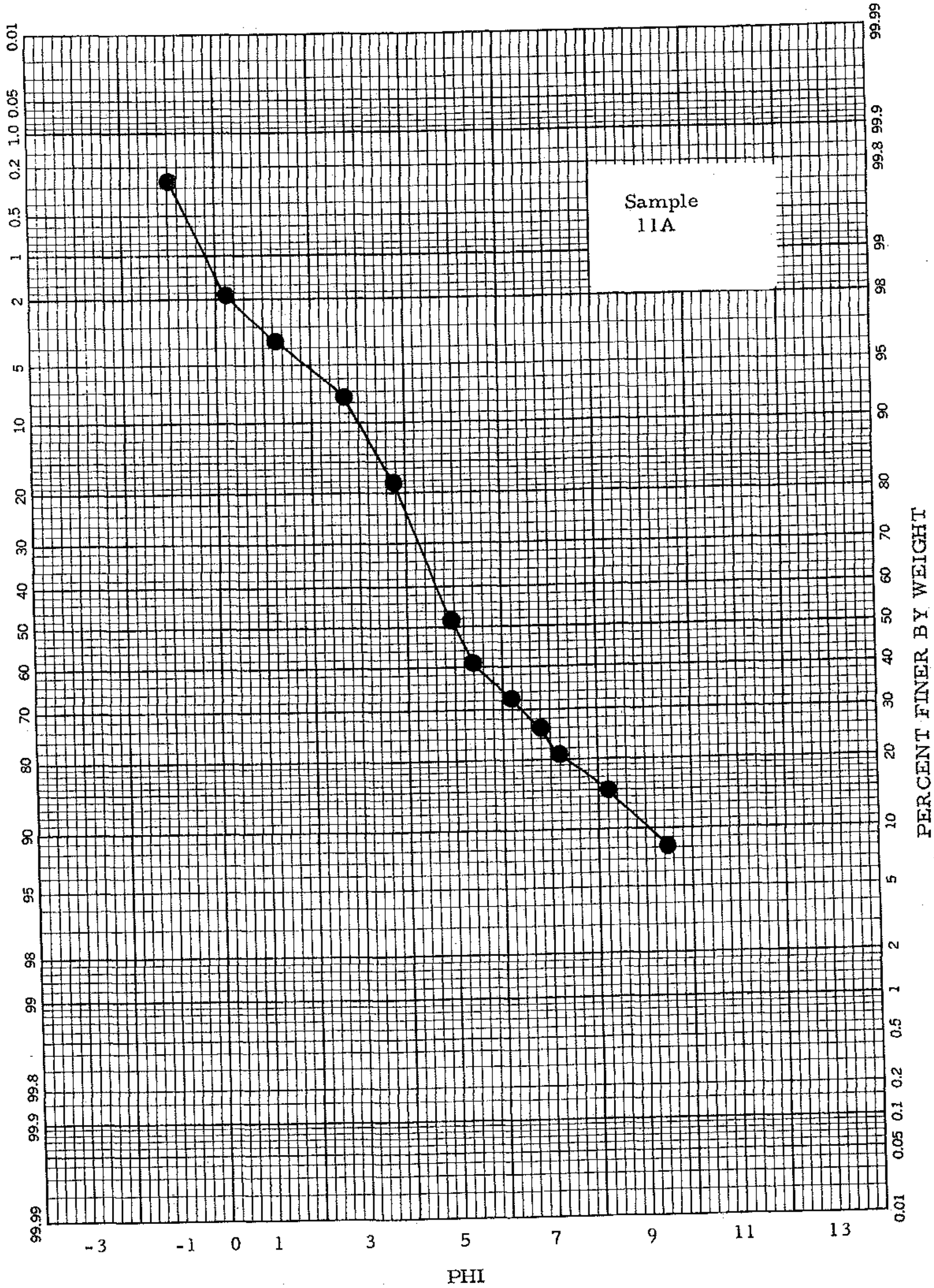
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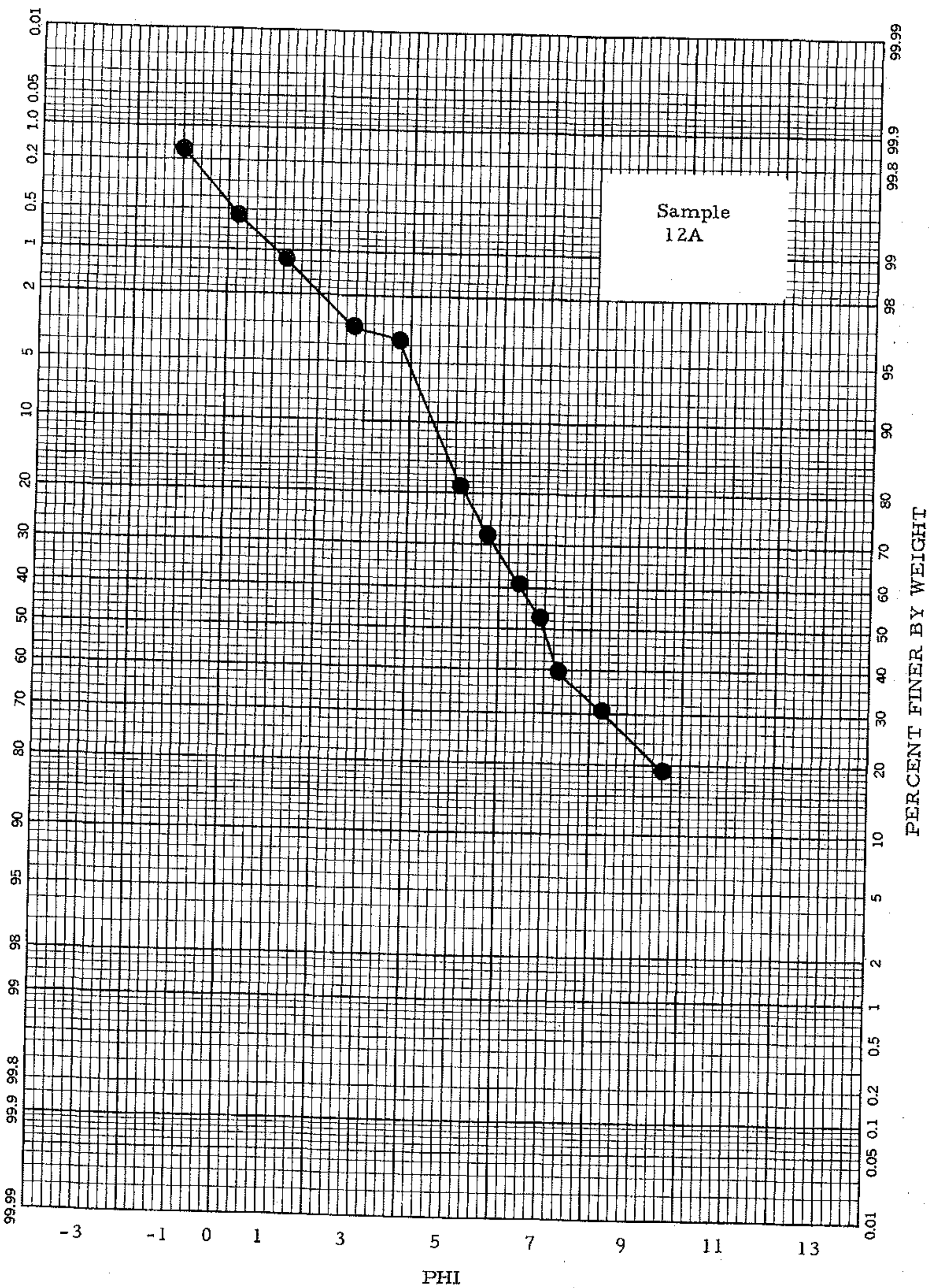
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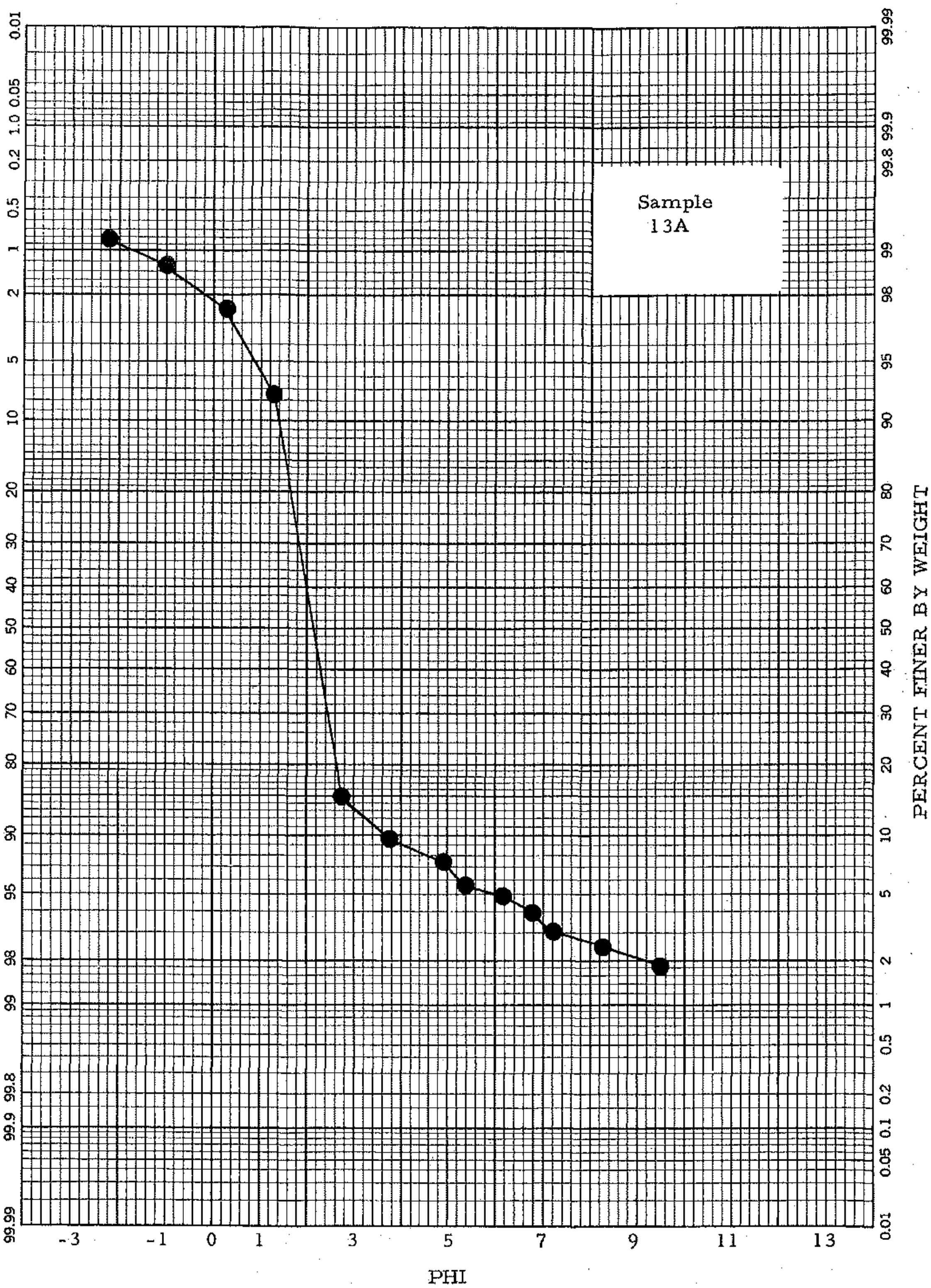
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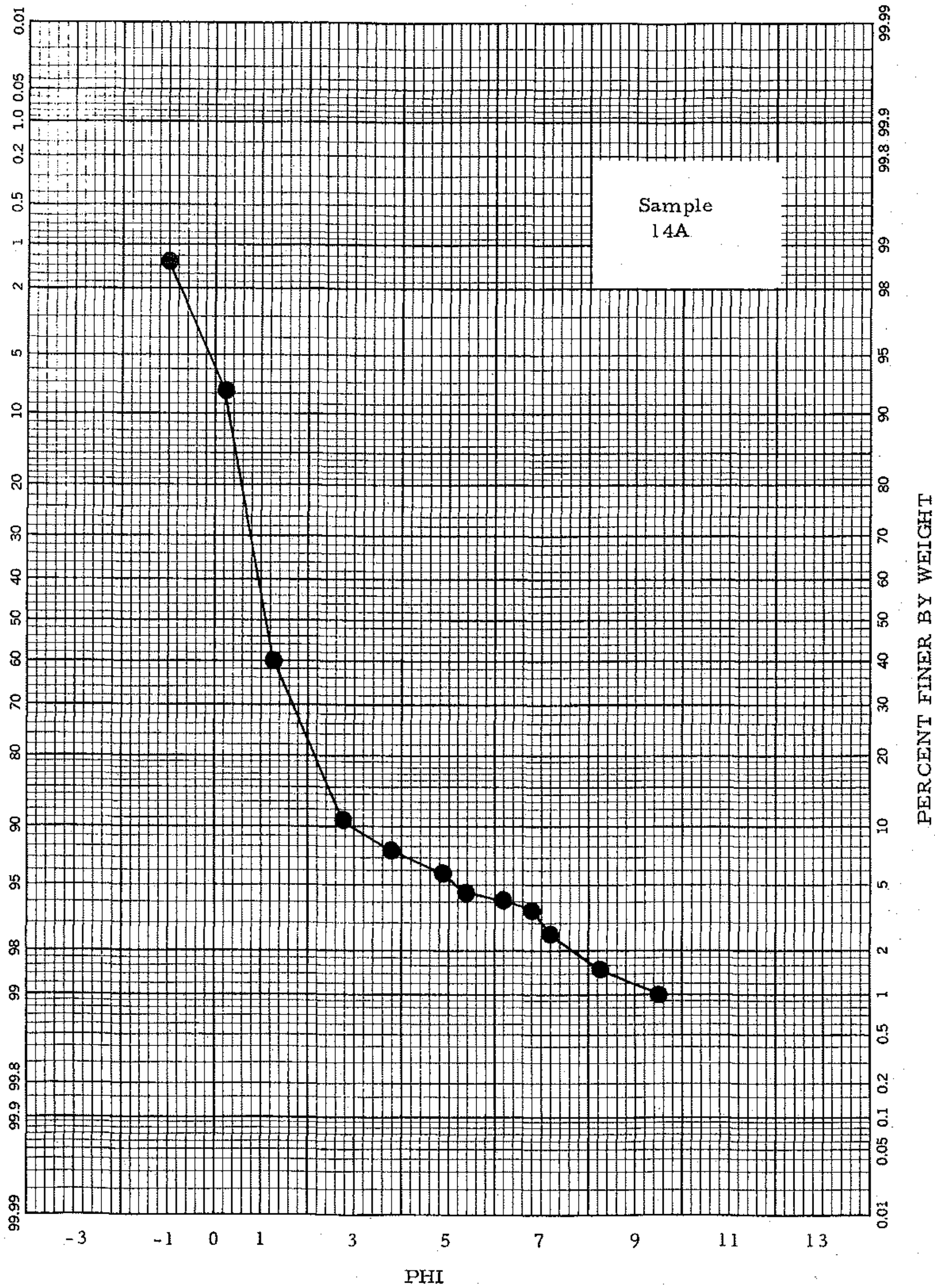
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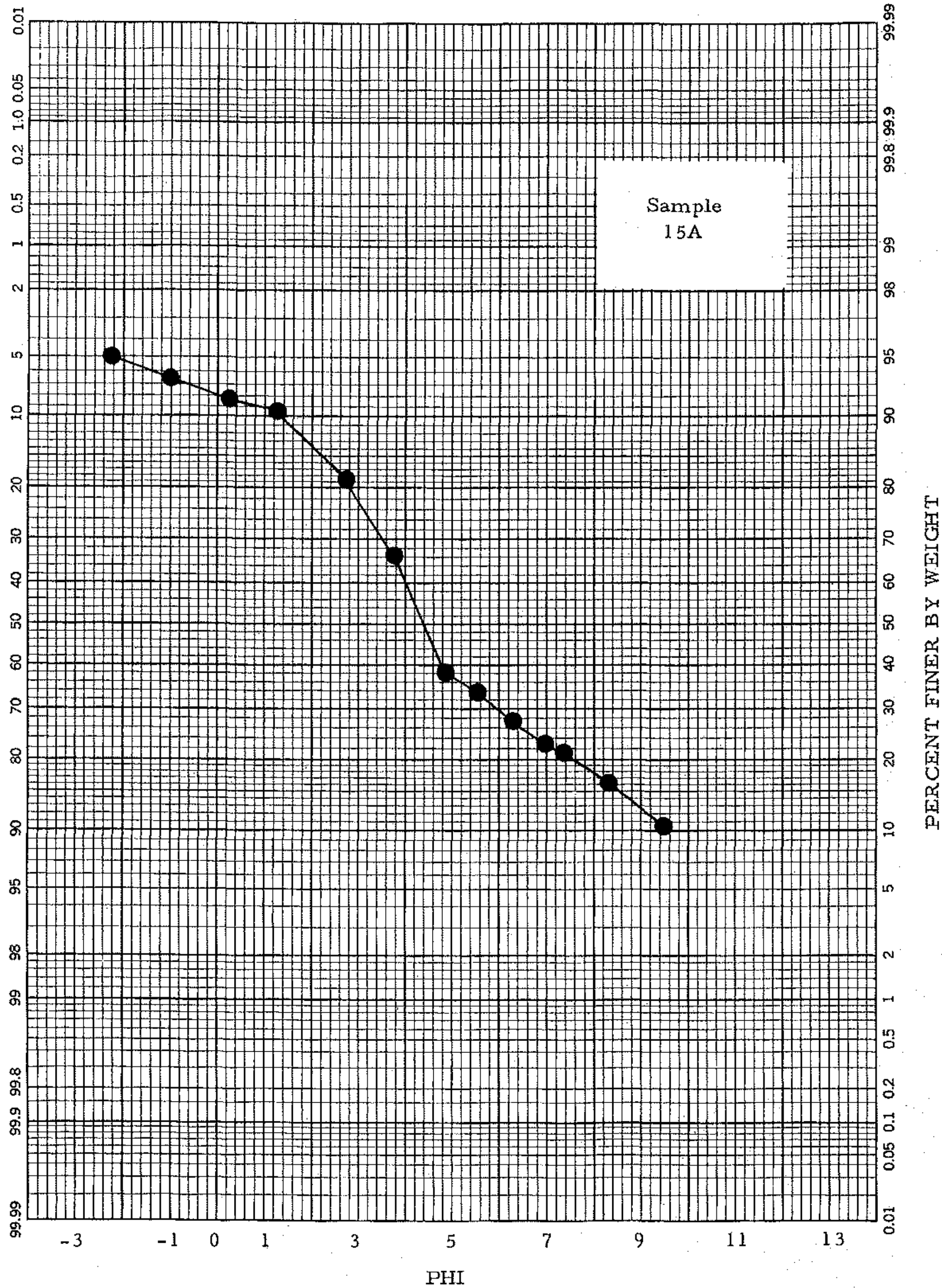
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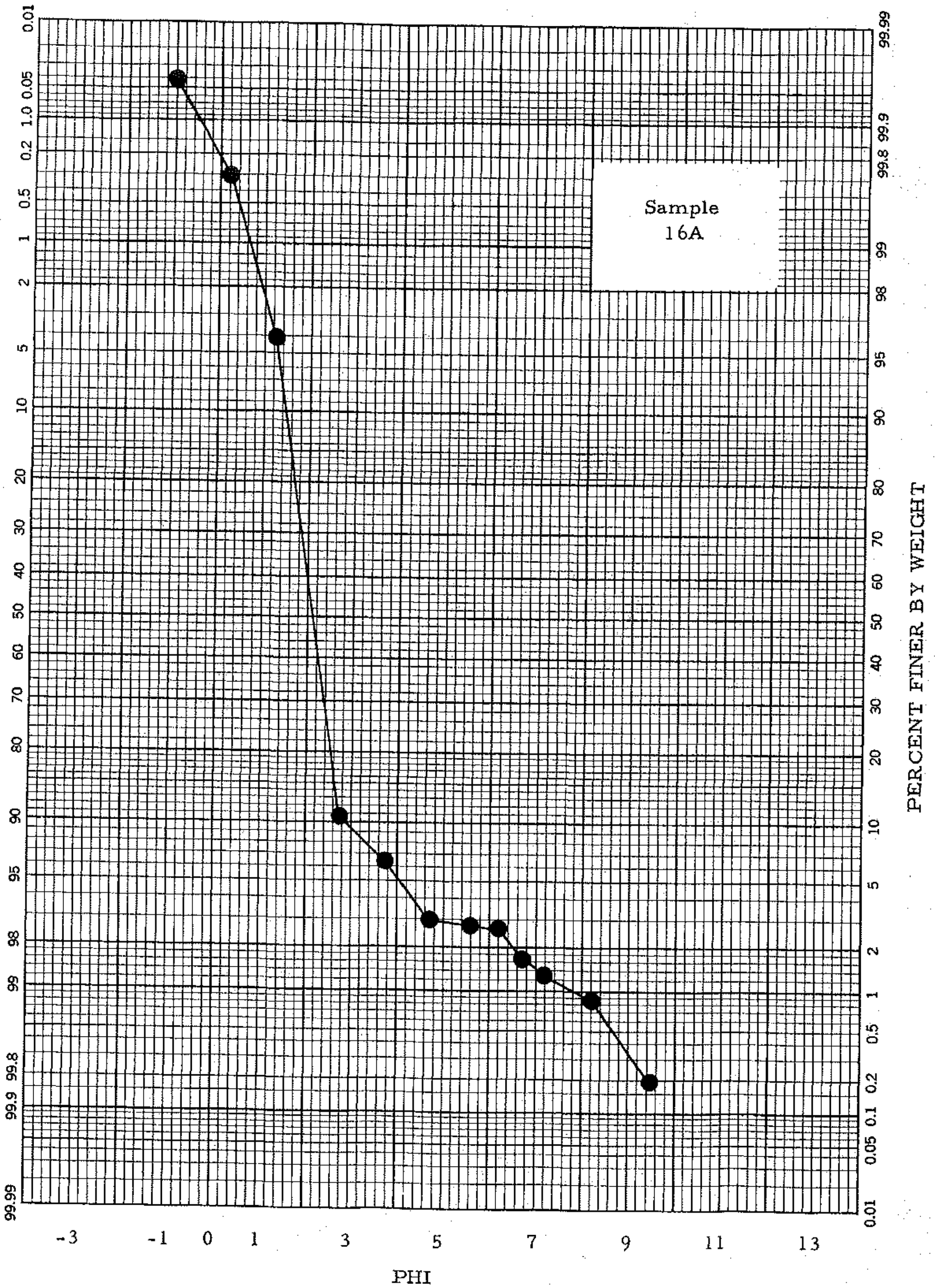
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BEFORE THE LAND USE HEARINGS OFFICER
FOR THE CITY OF WARRENTON, OREGON

In the matter of a Type III application for the Oregon LNG Bidirectional Terminal and approximately 3-miles of an LNG Bidirectional Pipeline within the Corporate limits of the City of Warrenton, Oregon.	**CUP 14-3, VAR 14-1, CUP 14-4 & VAR 14-2** **FINAL ORDER**

This Order is the final decision of the Warrenton Land Use Hearings Officer denying this set of consolidated applications for a Bidirectional Liquefied Natural Gas (LNG) Terminal and approving the associated applications for a Bidirectional LNG Pipeline within the corporate limits of the City of Warrenton.

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I. Summary:

This Order addresses the following separate land use permit requests:

A. Bidirectional LNG Terminal.

- Site Design Review for a Large Scale Water-dependent Industrial Development
- Hardship variance for permanent impacts to locally significant wetlands
- Conditional Use Permit for wetland impact mitigation in the I-2 zone
- Conditional Use Permit for over-height tanks in the Airport Imaginary Surface
- Variance to maximum fence height

B. Bidirectional LNG Pipeline.

- Hardship variance for permanent impacts to locally significant wetlands
- Conditional Use Permit for wetland impact mitigation in the I-2 zone
- Conditional Use Permit for a pipeline under-crossing in the A-3 zone

II. Introduction to the Property and Applications:

Terminal Applicant.. LNG Development Company, LLC, dba Oregon LNG
Attn: Peter Hansen
8100 NE Parkway Drive, Suite 165
Vancouver, WA 98662

Terminal Property ... Legal Description: The LNG Terminal is proposed for the east bank of the Skipanon Peninsula (ESP) and will occupy all or part of the following parcels located in Sections 10, 14, 15 & 22 of Township 8 North, Range 10 West of the Willamette Meridian (~96 acres):

Tax Lot	Owner
810140000300	Oregon DSL
810140000380	Oregon DSL
81015D000100	Port of Astoria
81015D000101	Oregon DSL
81015D000200	Port of Astoria
81015D000300	Port of Astoria
81015D000700	Port of Astoria
81015D000800	Port of Astoria
81015D001900	James Neikes/Pinnacle Long LLC

Pipeline Applicant... LNG Pipeline Company, LLC, dba Oregon LNG
Attn: Peter Hansen
8100 NE Parkway Drive, Suite 165
Vancouver, WA 98662

Pipeline Property .... Legal Description: The approximately 3-mile portion of the LNG Pipeline that will be located within the corporate limits of Warrenton will occupy part of the following parcels located in Sections 15, 22, 23 & 26 of Township 8 North, Range 10 West of the Willamette Meridian:

Tax Lot	Owner
81015D000700	Port of Astoria
81015D001000	Port of Astoria
81015D001500	Port of Astoria
81015D001600	Port of Astoria
81022AB00100	Port of Astoria
81022AB00400	Port of Astoria
81022AA00200	Port of Astoria
81022AA00500	Port of Astoria
81022AB00500	Clatsop County
81022AA00400	Port of Astoria
81022AA00700	Port of Astoria
81023BC00100	Port of Astoria
81023BC00200	Port of Astoria
81023BC00300	Port of Astoria
81023BC00800	Port of Astoria
81023BC00700	Port of Astoria
81023BC01000	David & John Nygaard/Warrenton Fiber Co.
81023BD00600	David & John Nygaard/Warrenton Fiber Co.
81023BD00700	David & John Nygaard/Warrenton Fiber Co.
81023BD01500	Steadfast LLC
81023BD02002	Steadfast LLC
810230000200	Port of Astoria
810260000500	Port of Astoria
810250000500	Port of Astoria
810250000400	Port of Astoria

Laws Applicable to the Terminal: Warrenton Development Code (WDC), Ch. 16.12 Definitions; Ch. 16.64 Water-Dependent Industrial Shorelands District including 16.64.030; Ch. 16.72 Aquatic Development District; Ch. 16.88 Flood Hazard Overlay District; Ch. 16.92 Airport Hazard Overlay District including 16.92.040-.070; Ch. 16.96 Soils Hazard Overlay District; Ch. 16.104 Dredged Material Disposal Site Locations; Ch. 16.116 Design Standards; Ch. 16.120 Access and Circulation; Ch. 16.124 Landscaping, Street Trees, Fences and Walls including 16.124.050; Ch. 16.128 Vehicle and Bicycle Parking; Ch. 16.132 Clear Vision Areas; Ch. 16.136 Public Facilities Standards; Ch. 16.140 Stormwater and Surface Water Management; Ch. 16.144 Signs; Ch. 16.152, Grading, Excavating and Erosion Control Plans; Ch. 16.156 Wetland and Riparian Corridor Development Standards including 16.156.080; Ch. 16.160 Columbia River Estuary Shoreland and Aquatic Area Development Standards; Ch. 16.164 Impact Assessment and Resource Capability Determination; Ch. 16.192 Large-Scale Developments, including 16.192.020, .030,.040,.050, .070; Section 16.208.050 Type III Procedure –Quasi-Judicial; Ch. 16.212 Site Design Review including 16.212.040; Ch. 16.220 Conditional Use Permits; Ch. 16.244 Coastal Zone Consistency; Ch.16.256 Traffic Impact Study; Ch. 16.272 Variances, including 16.272.020, and the Warrenton Comprehensive Plan (WCP).

Laws Applicable to the Pipeline: Warrenton Development Code (WDC), Ch. 16.12 Definitions; Ch. 16.40 General Commercial District; Ch. 16.60 General Industrial District; Ch. 16.80 Aquatic Natural District; Ch. 16.84 Coastal Lake and Freshwater Wetlands District; Ch. 16.88 Flood Hazard Overlay District; Ch. 16.92 Airport Hazard Overlay District; Ch. 16.96 Soils Hazard Overlay District; Ch. 16.116 Design Standards; Ch. 16.120 Access and Circulation; Ch. 16.124 Landscaping, Street Trees, Fences and Walls; Ch. 16.128 Vehicle and Bicycle Parking; Ch. 16.132 Clear Vision Areas; Ch. 16.136 Public Facilities Standards; Ch. 16.140 Stormwater and Surface Water Management; Ch. 16.144 Signs; Ch. 16.152, Grading, Excavating and Erosion Control Plans; Ch. 16.156 Wetland and Riparian Corridor Development Standards; Ch. 16.160 Columbia River Estuary Shoreland and Aquatic Area Development Standards; Ch. 16.164 Impact Assessment and Resource Capability Determination; Ch. 16.192 Large-Scale Developments; Section 16.208.050 Type III Procedure –Quasi-Judicial; Ch. 16.220 Conditional Use Permits.

The underlying applications and this decision are divided into two parts, corresponding to the LNG terminal and the LNG pipeline. The LNG terminal includes a host of accessory uses, such as the marine facilities, LNG storage tanks, LNG vaporization facilities, natural gas liquefaction facilities and associated support facilities. The LNG pipeline is more limited and consists of a buried 36 inch (outside diameter) natural gas transmission pipeline and associated valves and pumping stations. The approximately 3-mile segment within the City of Warrenton that is the subject of this application is one end of an 86.8 mile pipeline that, at the other end, connects with an interstate gas pipeline in Woodland, Washington. The Officer is mindful that much of the argument and information in the record addresses the entire 86.6-mile pipeline and the larger project, *e.g.*, FERC's DEIS on the project issued Aug 2015. This decision, however, is limited to those portions of the project located in the corporate limits of the City of Warrenton, Oregon and impacts in the City and cognizable under the WDC and WCP.

The Federal Energy Regulatory Commission (FERC) has exclusive jurisdiction, pursuant to the Natural Gas Act (NGA) over the review, approval and operation of LNG terminals and pipelines, except where the Coastal Zone Management Act (CZMA) applies, the implementation of which is vested through each coastal state with local jurisdictions, such as the City of Warrenton. Because portions of Warrenton's land use regulations were adopted as local implementation of the CZMA, at least in theory, this applicant must demonstrate compliance with the city's land use regulations. See WDC ch. 16.244 (Coastal Zone Consistency). For that reason these applications are before the City. The applicant, however, makes clear that it disputes the City's authority to require local land use approval for any aspect of this project and reserves the right to dispute at a later date the City's authority if it so chooses.

The site proposed for the LNG terminal is composed of dredge spoils deposited by the US Army Corps of Engineers (USACE) over many years. Presently, the USACE holds an easement on the property to continue dredge spoil disposal, but the USACE is not an owner on title to any of the parcels involved in this application. These parcels, comprising 96 acres of the ESP, were the subject of a consolidated comprehensive plan and zone text amendment and interpretation in 2005 and 2006 by the City when Skipanon Natural Gas LLC, predecessor to Oregon LNG, sought to have the land expressly designated for an LNG import terminal, as a use allowed outright. The proposal was approved by the City Commission, which was affirmed on appeal by LUBA and the Oregon Court of Appeals.[1] LUBA's description of that proceeding is instructive historical background to the present applications which essentially seek the approval of the various city permits and other land use approvals to implement the development that was anticipated in 2006:

> The area subject to the challenged plan and zoning amendments is located in the Columbia River estuary, and consists of the East Skipanon Peninsula (ESP), a shoreland area created from dredge spoil deposits next to the Skipanon River, and a large area of adjoining estuarine waters to the north of the ESP. The ESP is part of Youngs Bay, and is located in close proximity to the Columbia River deep-draft navigation channel and the Skipanon River waterway. From 1979 to 2001, the ESP was designated and zoned for water-dependent industrial uses, but no industrial uses developed there during that period of time. In 2001, the city approved a request from the Port of Astoria to redesignate the ESP "other shorelands," and apply a "Conservation" plan designation, and a new Urban Resort and Recreation zone, in order to facilitate development of a proposed golf course. The golf course proposal did not come to fruition, however.
>
> In 2005, intervenor applied to the city to redesignate 96 acres of the ESP as Especially Suited for Water-Dependent (ESWD) shorelands and

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[1] See *People for Responsible Prosperity, et al. v. City of Warrenton*, 52 Or LUBA 181, *Aff'd w/out Opn.* 208 Or App 495, 143 P3d 775 (2006).
[2] *Id.* at 184-185 (citations omitted).
[3] See *Beck v. City of Tillamook*, 313 Or 148, 153, 831 P2d 678 (1992). The City's 2006 legislative action also imposed 2 transportation-related conditions on the development of the ESP for an LNG terminal suggested by ODOT in a 2005 comment letter on that application. Those conditions are incompatible with the current proposal and access configuration, and the applicant

rezone the same area as Water-Dependent Industrial Shorelands (I-2). The application also proposed redesignating approximately 370 acres of adjoining estuary as Aquatic Development and rezoning the same area Aquatic Development (A-1). In addition, intervenor requested that the city codify an earlier code interpretation that LNG importation, regasification and transfer is a permitted use in the I-2 zone. Intervenor did not seek permits for a particular use allowed in the I-2 zone, but it is undisputed that intervenor contemplates constructing an LNG terminal and regasification facility on the subject property, which will require federal, state and local permits. To address questions raised by the state Department of Land Conservation and Development intervenor submitted a conceptual plan of an LNG terminal. The plan depicts a 1500-foot ship berth and a large ship-turning basin in an A-1 zoned portion of Youngs Bay that is connected to the ESP via a 1000-foot dock and pipeline, with the proposed regasification and transfer facility located on the ESP.

The city planning commission recommended approval of the proposed plan and zoning map and text changes. After conducting a de novo hearing, the city commission voted to approve the requested amendments.[2]

To be clear, the City Commission's 2006 action did not approve the present applications, most notably this LNG terminal, but it was a legislative determination and a formal interpretation of the local code that an LNG terminal facility, as a matter of fact and law, is a use permitted outright in the City's A-1 and I-2 zones as a "marine cargo transfer facility" and as a "water dependent industrial use." This umbrella use category also includes its normal and customary accessory uses as allowed outright in the A-1 and I-2 zones. The City Commission in 2006 expressly stated, and LUBA affirmed, that any subsequent development proposal, such as this one, "will have to comply with numerous environmental impact avoidance, minimization and mitigation requirements imposed by the federal, state and local governmental permitting processes for in-water development in the Columbia River Estuary. Therefore, reclassification will also be consistent with the priority of maintaining the integrity of the estuarine ecosystem." Affirmances by LUBA and the Court of Appeals makes the City Commission's 2006 determination "law of the case" in the present proceeding with regard to whether the use proposed is allowed in the operative A-1 and I-2 zones.[3]

One change from the use at issue in the 2006 interpretation is that the current proposal is for a bidirectional terminal (export and import); whereas, the 2005 proposal was made before the current natural gas production boom and proposed only an import terminal. Several opponents have suggested that this difference is material and has the effect of making the 2006 decision not relevant to the present application. The Officer

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[2] *Id.* at 184-185 (citations omitted).

[3] See *Beck v. City of Tillamook*, 313 Or 148, 153, 831 P2d 678 (1992). The City's 2006 legislative action also imposed 2 transportation-related conditions on the development of the ESP for an LNG terminal suggested by ODOT in a 2005 comment letter on that application. Those conditions are incompatible with the current proposal and access configuration, and the applicant seeks their revision through a separate plan amendment and zone text change. The present applicant anticipates the approval of those changes.

disagrees. From a land use perspective, and as implicated by all of the applicable land use criteria, LNG import is not materially different from LNG export. Both relate to the City's land use regulations in exactly the same way, and the land use criteria do not make a material distinction between the two. Therefore, the Officer concludes that the City's 2006 decision has precedential relevance to the present application and the issues resolved in the 2006 proceeding will not be redecided here.

The LNG terminal application consists of two binders submitted June 2014 and revised in November 2014 that include a set of full-sized plans and supporting documentation. The LNG pipeline application consists of a single binder submitted June 2014 that includes a set of full-sized plans, maps and supporting documentation. Subsequently, the applicant submitted information related to seismic safety (Ex. 75), as well as additional argument and evidence as part of the public hearing process described in the next section (Exs. 138, 139, 140, 187, 191 & 193).

III. Summary of the Local Proceeding and the Record:

The applications in this case were submitted in June 2014 and subsequently revised (Nov 2014) and supplemented since then, and City planning staff produced two comprehensive reports corresponding to the two applications on August 26, 2015 recommending conditional approval of both. The City mailed notice of the applications and a September 3, 2015 hearing to the owners of the surrounding properties and interested parties who requested notice and published notice in *The Columbia Press* on August 21, 2015. At the commencement of the September 3rd hearing, the Officer explained the procedure and disclaimed any ex parte contacts, bias, or conflicts of interest. No one challenged the Officer or questioned him about potential ex parte contacts, bias or conflicts of interest or challenged the Officer's jurisdiction or his ability to decide the matter impartially. However, several witnesses objected to the adequacy of the city's notice and the venue selected for the hearing. In particular, these parties stated that the community meeting room was too small and that it was not clear from the city's notice that the hearing might be held over more than one day.

Present at the hearing was Skip Urling, Warrenton Community Development Director, who provided a verbal summary of the application, the process and the status of the record at that point in time. While no public agency representatives testified at the hearing, the following written communications were received from agencies:

- ODOT Region 2 comment letter (Ex. 5), Aug. 25, 2015
- ODFW comment letter (Ex. 21), Aug. 31, 2015
- Astoria City Council letter of opposition (Ex. 164), Sept. 10, 2015
- ODFW comments (Ex. 186), Sept 21, 2015

The applicant's design and consulting team, consisting of attorney Mike Connors, project manager from CH2M, Mark Bricker, geotechnical engineer, Don Anderson, transportation engineer, Terry Yuen, and environmental consultant, Jay Lorenz (collectively the "applicant"), each of whom presented different components of the project proposal through a PowerPoint overview (Ex. 138). The applicant also submitted the Draft EIS (DEIS) on the project recently released by FERC (Ex. 139) and a packet of supplemental information addressing specific approval criteria and factual issues (Ex.

140). The applicant's attorney expressed agreement with the staff reports and had no objections to staff's proposed conditions of approval.

Following the presentation by the applicant's design and consulting team, numerous members of the public spoke in favor of the project, followed by a few witnesses with neutral testimony or questions. Opponents to the project then testified, beginning with Loren Goldberg, representing Columbia RiverKeeper and others, testified and provided a written summary of her arguments along with supporting documentation (Ex. 44). Afterward, a significant number of individuals testified in opposition to the proposal. The Officer concluded public testimony at approximately 9:30 p.m. and continued the hearing to the following evening (September 4, 2015) beginning at 5:30 p.m. At the continued hearing, additional opponents to the project testified until no one else requested the opportunity to testify, after which the applicant's team provided a short oral rebuttal to the opponent testimony. The hearing concluded at approximately 10:30, at which time the Officer addressed requests to keep open the record.

Several opponents and the applicant requested that the record be kept open for concluding testimony, pursuant to which the Officer ordered the following open record schedule:

- September 18, 2015 - Submission of argument and evidence on any relevant topic by anyone.
- September 25, 2015 - Response to materials submitted on September 18th
- October 2, 2015 – Applicant's final rebuttal and closing arguments (no new evidence)

During this open record period, the following relevant documents were received into the record:

- Oregon LNG Written Evidentiary Submittal from Ch2m following September 3rd hearing (Ex. 187), Sept. 18, 2015; and
- RiverKeeper, et al., Testimony and exhibits (Ex. 83), Sept. 17, 2015
- Oregon LNG Response to Public Comments Received by September 18, 2015, submitted by Ch2m (Ex. 191), Sept. 25, 2015;
- RiverKeeper, et al., closing testimony (Ex. 188), Sept. 25, 2015
- Oregon LNG Closing Argument from Hathaway Koback & Connors (Ex. 193), Oct. 2, 2015.

The record closed with the applicant's October 2nd Closing Arguments, at which point the Officer took the matter under consideration.

IV. Findings:

Only issues and approval criteria raised in the course of the application, during the hearing and before the close of the record are discussed in this section. All approval criteria not raised by staff, the applicant or a party to the proceeding have been waived as contested issues and are not addressed in these findings.[4] The Officer concludes

[4] If this decision is appealed to the City Commission, the Commission has the discretion to allow new evidence or argument at the appeal hearing. WDC 16.208.050(H)(2)(b). If the Commission

that all uncontested approval criteria and issues addressed by the applicant and found to be met in the staff reports that are not challenged by any opponent to this proceeding are met. For those approval criteria and issues that are not challenged by any opponent to this proceeding, the Officer adopts as his own and incorporates herein by reference the corresponding findings from the staff reports. The Officer finds those criteria to be met, even though they are not specifically addressed in these findings. The Officer adopts the following findings in response to the approval criteria and issues that were challenged by focused testimony and argument by any opponent during the local process:

A. Procedural Objections:

In response to procedural objections voiced in public testimony, the Officer stated at the time, and reiterates here, that the city's notice was adequate and conformed to the requirements of ORS 197.763 and WDC 16.208.050 (procedures for Type III quasi judicial proceedings). The proof of that adequacy was the full hearing room and the lack of any objection by any party since then that they did not receive notice of the application or hearing. Those who complained about the notice were present at the hearing and did not also claim that any alleged defects in notice prevented them from preparing for the hearing. Absent any focused objection that would indicate that (1) the notice was defective in some material way relative to the legal requirements and (2) the person's ability to participate was prejudiced by those defects in a material way, the Officer concludes that the city's notice was adequate.

Regarding objections to the venue and the 2-day hearing, the Officer made sure that the hearing would be long enough to accommodate the testimony of everyone who wished to participate, and he took pains during the 2-day hearing to make sure that everyone that wanted to testify or submit written comments was invited and able to do so. At the end of the second day of hearing, the Officer closed the public testimony portion of the hearing after verifying that no one else wished to testify and kept open the record for subsequent submission of written materials. The Officer asked for objections, and no one objected to this process. On that basis, the Officer concludes that the venue was sufficient and a multi-day hearing only enhanced the public's opportunity to testify. The open-record period that ensued after the hearing was consistent with the requirements of ORS 197.763 pertaining to the submission of evidence and testimony after a public hearing. Therefore, everyone who wanted to participate had full opportunity to do so.

B. LNG Bidirectional Terminal Applications:

The terminal development requires multiple permits, which are subject to numerous sets of approval criteria contained in the WDC and WCP. Additionally, these permit applications are subject to numerous submission requirements, which take the form of information and documents required before an application can be deemed complete for purposes of processing. Many of the criteria for all of the permits are redundant, in that the same or very similar requirement applies to several of the permits. In the sections that follow, the Officer addresses the primary arguments of the main

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declines to allow new evidence or argument, failure to raise a particular issue before the close of the record by the Officer will preclude any argument based on that issue before the Commission in a subsequent appeal.

opponents, *i.e.,* RiverKeeper, et al., and the applicant's responses to those primary arguments. Then the Officer addresses the specific permit approvals these consolidated applications seek.

1. **Application requirements – ownership of the property WDC 16.208.070(D)(3) and the USACE dredge spoil disposal easement:**

RiverKeeper asserts that the application cannot be approved because one of the primary submission requirements for a land use application is authorization by owners of the property. In particular, WDC 16.208.070(D)(3) requires "signed written authorization of the property owner of record if the applicant is not the owner." The USACE holds a dredge spoil easement over the ESP, and RiverKeeper asserts that this interest equates to an ownership interest that is implicated in this submission requirement (Ex. 44, p 16-17; Ex. 83, p 4-6; Ex. 188, p 3-4). The terminal application does not include a signed authorization from the USACE. After the hearing, RiverKeeper raised four specific arguments based on this issue (Ex. 83, p 4-6). First, RiverKeeper argues that WDC 16.208.070(D)(3) requires USACE authorization because it is a "record owner" of the terminal site. Second, RiverKeeper asserts that, without USACE authorization, the terminal cannot be deemed a "reasonable and legal use" of the parcel under WDC 16.156.080(B)(1) for purposes of the wetland hardship variance. Third, RiverKeeper speculates that, if the applicant uses the ESP for an LNG terminal, thus making it unavailable for dredge spoil disposal by the USACE, the taxpayers of Warrenton are responsible for providing the USACE with an alternative disposal site. Finally, RiverKeeper argues that, because of the strong position taken by the federal government in litigation related to the easement and in a December 14, 2015 letter to FERC, the Officer must assume that the federal government will never relinquish its easement rights on the ESP.

RiverKeeper's argument is misplaced for several reasons. First, application requirements are not necessarily land use approval criteria.[5] Only if one of the relevant approval criteria requires a particular submission item can that item be deemed an approval requirement for the permit, *e.g.,* a complete site plan is a necessary prerequisite to determining compliance with the site plan approval criteria. In this case, RiverKeeper points to no permit approval standard that requires signed authorizations from all property owners. It appears that the requirement is attached only to the application completeness review. Second, the requirement is for the authorization by owners of record and does not implicate easement holders. The holder of an easement is not an "owner of record." Therefore, the Officer does not regard the applicant's failure to obtain USACE authorization for the application to be fatal to land use approval in this case, since the issue can be resolved through a condition of approval. Third, the Officer disagrees that the City of Warrenton may be responsible for obtaining an alternative dredge disposal site for the USACE. Even if that were the case, that does not relate to any of the approval criteria and cannot be a basis for denial. Finally, the Officer disagrees that the lack of USACE permission to use the property necessarily means the project is not a reasonable and legal use of the ESP for purposes of the wetland hardship variance. The applicant asserts that it will resolve the USACE dredge spoil

[5] *See e.g., LeRoux v. Malheur County,* 32 Or. LUBA 124 (1996); *Champion v. City of Portland,* 28 Or LUBA 618 (1995); *Wissusik v. Yamhill County,* 27 Or LUBA 94 (1994).

easement and will obtain clear title to the land for the project. The Officer takes that optimistic prediction at face value and a possible outcome. If that happens, the project proceeds; if not, the project is stopped and cannot proceed. The difference does not involve discretion and is a clear and objective determination of whether the USACE has relinquished its easement or not. Therefore, a condition of approval is warranted to the effect that the applicant shall obtain clear title to the entire site and that USACE must relinquish its easement before construction begins. <u>See</u> Terminal Condition 20.

2. <u>WDC 16.64.020 & 16.72.020</u>: Base Zone Requirements of the A-1 & I-2 Zones:

a) <u>Is the terminal a use allowed in I-2 Zone?</u> RiverKeeper asserts that the proposed use fails to comply with (violates) several provisions of WDC Ch. 16.64 and is therefore not a use allowed in the Water-Dependent Industrial Shoreland Zone. RiverKeeper begins by quoting the I-2 Zone purpose statement that "Uses of the [I-2 Zone] areas shall maintain the integrity of the estuary and coastal waters." RiverKeeper asserts that the development does not maintain the integrity of the estuary and coastal waters and therefore is not a use allowed in the I-2 Zone. This argument is misplaced for two reasons. First, purpose statements are not necessarily approval standards for individual permit decisions, and there is no indication that the City Commission intended these purpose statements to serve as approval criteria.[6] Second, the Officer interprets this purpose statement as being implemented by the numerous siting standards applicable to uses in the I-2 Zone, which necessarily means that the purpose statement does not serve as an independently applicable approval standard.[7] In other words, compliance with the substantive requirements of the I-2 Zone necessarily fulfills and complies with the zone's stated purpose.

b) <u>Compliance with the I-2 zone development standards.</u> RiverKeeper also points out that WDC 16.64.020 requires compliance with the WDC Ch. 16.64 and other applicable development standards and applicable comprehensive plan provisions. According to RiverKeeper, because the proposal does not comply with those development standards it is not a use allowed in the I-2 Zone. As a general proposition, this is a correct interpretation of the WDC, but it also presupposes that the project fails to comply with other substantive development standards. Compliance with those standards is addressed below.

c) <u>Is the terminal a Water-Dependent Industrial Use?</u> RiverKeeper and other opponents argued in a number of different ways that the use proposed did not qualify as a "Water-Dependent Industrial Use" under WDC 16.64.020. As a starting point, the terminal site is proposed for a site that is split zoned A-1 and I-2 and regulated by WDC chapters 16.72 and 16.64, respectively. Although the two zones use different phrasing, both zones allow outright water-dependent commercial or industrial uses. The I-2 zone imposes a number of different development standards in WDC 16.64.040, and the two zones have slightly different purpose statements.

The City Commission in 2005 and 2006 rendered a legislative interpretation of the A-1 and A-2 zoning regulations to the effect that an LNG import terminal is a water

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6 *See Anderson v. Peden*, 284 Or 313, 320, 587 P2d 59 (1978).

7 *See LO 138 LLC v. City of Lake Oswego*, slip op. LUBA No. 2014-092 April 15, 2015.

dependent industrial use as envisioned by the A-1 and I-2 zones. That decision was affirmed on appeal and is law of the case with regard to this proceeding. As the Officer has previously determined, import and export do not constitute a material difference for purposes of determining that such an LNG terminal is a water dependent industrial use as that term is used in the A-1 and I-2 zones. From the 2006 City Commission interpretation, the Officer concludes that the use is allowed in the A-1 and I-2 zones, and the balance of the siting and development standards simply dictate how the use looks and operates. Only if there is something in the siting and development standards that can't be met either outright, through conditions, or avoided through a variance will those serve as a basis for denial of an otherwise allowed use such as this.

d) **Applicability of purpose statements.** RiverKeeper asserts that the use and this project in particular are inconsistent with the purpose statements of the I-2 (Ex. 44, p 18) and A-1 (Ex. 44, p 22) zones. The Officer rejects this because purpose statements are not necessarily approval standards for individual permit decisions, and there is no indication that the City Commission intended this purpose statement to serve as an approval standard.[8]

e) **Lack of DEQ air quality permits.** RiverKeeper argues under WDC 16.64.040(E) that, because the applicant has not provided DEQ air quality permits and has not provided proof that the construction and operation of the terminal will comply with state noise standards, the application must be denied. The applicant responded that it is not required to obtain any of the many state and federal discretionary permits before local land use approval, and that it is legally sufficient to impose a condition of approval requiring the applicant to obtain all such state and federal permits prior to operation (Ex. 191, p 15-16 and Ex. 193, p 9-10).

The Officer disagrees with RiverKeeper's challenge on this point for two reasons. First, where a local criterion requires the applicant to obtain state or federal discretionary permits, it is sufficient to impose a condition of local land use approval that the permits be obtained prior to operation. Second, RiverKeeper's argument creates a chicken & egg conundrum for this and other applicants where state or federal permits are required, but those discretionary approvals also require some sort of local confirmation, *e.g.,* a land use compatibility statement, that the use is allowed under local zoning. Oregon cases on this point have held that a condition of local land use approval requiring the applicant to obtain the discretionary state or federal permit is appropriate where the record shows that obtaining those permits is feasible, and where nothing in the record shows that the applicant is precluded as a matter of law from obtaining them.[9] The Officer takes that approach here because RiverKeeper has not demonstrated that the applicant is precluded as a matter of law from obtaining a state air quality permit or really any other state or federal permit, and it appears quite feasible that the applicant will obtain these permits.[10] It is

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8 *Anderson v. Peden, supra.*

9 *See Wal-Mart Stores, Inc. v. City of Bend*, 52 Or. LUBA 261 (2006), citing *Bouman v. Jackson County*, 23 Or LUBA 626, 647 (1992) and *Skerpetos v. Jackson County*, 29 Or LUBA 193, 210 n 14 (1995).

10 As explained *infra*, the Officer does not make the same assumption about the NMFS Section 7 consultation under the federal Endangered Species Act or that the project can obtain a non-jeopardy biological opinion.

sufficient to impose a condition requiring those permits before construction begins. See Terminal Condition 21. If the applicant fails to obtain any required state or federal permit, it cannot begin construction.

f) **Gas flare heat and glare**. RiverKeeper also argues under WDC 16.64.040(N) that, because the application proposes periodic gas flares and the applicant admits that the gas flares will be visible from 4 of the 6 "key observation points" analyzed, the use violates the prohibition against exposed heat or glare in the A-2 zone (Ex. 44, p 2, 11, 20, 21). See WDC 16.64.040(N).[11] The Officer partly agrees and partly disagrees.

RiverKeeper correctly points out that there is no de minimus exception to the prohibition in WDC 16.64.040(N) against unenclosed industrial heat or glare sources. That said, the unenclosed gas flare problem is solved by imposition of a condition that the terminal operation shall not have any unenclosed gas flares. Gas flares certainly qualify as a heat source, which is subject to this siting standard. However, the Officer does not agree that an exposed gas flare necessarily constitutes a "glare," certainly not the way that a directed or focused spotlight at night causes glare on adjacent properties. Simply because a gas flare is visible at night, does not mean that it also glares. While the underlying purpose of this code requirement is not clear, it is simply worded, applies to this use, and on its face prohibits operations producing heat or glare that are not "conducted entirely within an enclosed building." Because the code does not provide for any de minimus exceptions to this requirement, it must be met, at least with regard to heat generated by the gas flare. See Terminal Condition 22.

3. **WDC Ch. 16.88: Flood Hazard Overlay requirements, is the site appropriate for this use, earthquake and tsunami risks:**

Portions of the terminal site are within the City's Flood Hazard Overlay (FHO) and Special Flood Hazard Area (SFHA) and subject to WDC Ch. 16.88, which imposes several limitations on development within its borders. RiverKeeper cites the FHO purposes from WDC 16.88.010 in conjunction with WDC 16.220.030(A)(5), one of the CUP approval standards, and asserts that the site is not appropriate for the proposed use because of the risk of damage or catastrophic loss from a tsunami or severe earthquake (Ex. 44, p 23-26).

As a water-dependent industrial use with marine port facilities, the use is tied to the Columbia River and thus areas encumbered by the FHO and SFHA. By definition, the use must be located in or near the FHO and, at times, within the SFHA. Given the firmness of this connection and the need for close proximity to deep water port facilities, the Officer concludes there is virtually no way to locate this facility outside the boundaries of a FHO district.

WDC 16.88.040(G)(2)(b) acknowledges this practical reality by prohibiting critical facilities from the SFHA "to the extent possible," *i.e.*, "unless no feasible alternative site is available." This code section describes requirements for siting critical facilities

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[11] WDC 16.64.040 provides specific development standards for the A-2 zone, including "Except for exterior lighting, operations producing heat or glare shall be conducted entirely within an enclosed building."

that must be located in the SFHA. Most notably, the facility "shall have the lowest floor elevated above [base flood elevation] or the height of the 500-year flood, whichever is higher." The applicant addresses this requirement by proposing an earthen berm around the facility to resist a storm surge and to prevent a flood or tsunami inundation. The applicant estimates the 500 year flood elevation at 13 feet, and the berm will be at elevation of 22 to 27 feet. The applicant's engineer quantified the degree to which the facility and the berm will displace floodwaters and calculates that displacement will not be more than 1 foot at any point and has modeled flooding and inundation from a tsunami (Ex. 138, p 30-31; Ex. 187, p 13-16; Ex. 193, p 16-18). RiverKeeper asserts that a berm 22 to 27 feet high is not sufficient to withstand a Fukushima size tsunami (Ex. 44, p 23-26). RiverKeeper also asserts that the terminal facility cannot withstand a high magnitude earthquake associated with the Cascadia Subduction Zone because the site is subject to soil subsidence and liquefaction. If a significant tsunami were to occur right after and in combination with a large earthquake, RiverKeeper asserts that this facility and its design and safety measures will not be sufficient to prevent significant damage or complete destruction of the terminal facility. Relying on testimony from geologist Tom Horning (Ex. 175), RiverKeeper asserts that the Columbia River Fault underlies the terminal site, and the risks and possible damage from movement of that fault were not evaluated.

In response to these challenges, the applicant provided a summary of its geotechnical investigations at the site and seismic evaluation, including the results of tsunami inundation modeling (Terminal Application App F; Ex. 138, p 22-37). The applicant provided additional responses and analysis of the seismic and tsunami risk factors after the September hearing (Ex. 187, p 9-16 and Ex. 191, p 9-15), including a response to Tom Horning's report on the Columbia River Fault (Ex. 175). In a nutshell, the applicant responded to the Horning Report with an evaluation of the Columbia River Fault from which it concluded the fault was too old and movement too remote a possibility (no more recent than 1.6 million years ago) for it to be considered relevant today (Ex. 187, p 10-13). These responses are in addition to the detailed engineering analysis and construction design in the application binders for the terminal facility to minimize flooding or damage due to flooding, including flooding due to a significant tsunami and earthquake.

While the issues involved in tsunami and earthquake prediction and damage that might result from a catastrophic event are complicated, and the magnitude of damage from design failure would be staggering, the resolution of the FHO requirements are not that difficult. At its core, the FHO regulations in WDC ch. 16.88 are basic FEMA requirements for construction and building design to minimize the degree of damage that might result from a flood event. WDC ch. 16.88 does not contain any absolute prohibitions or design/construction requirements that would preclude this facility. RiverKeeper's reliance on WDC 16.88.010 is misplaced because these purpose statements are not approval criteria, but, at most, articulate aspirational objectives of the FHO to minimize risk and the degree of damage from flooding. These purposes are implemented by the design requirements for buildings in the FHO. RiverKeeper's attempt to implicate WDC 16.220.030(A)(5) and assert that a site in the FHO is not appropriate for terminal facility is inconsistent with the Code's requirements because the only aspects of the terminal project that are subject to the CUP criteria are the wetland fill mitigation in the I-2 zone and the over-height storage tanks in the Airport Hazard Overlay zone. The CUP criteria are not applicable to the terminal facility as a whole because it is a use allowed outright in the A-1 and I-2 zones. In fact, the Officer concludes that only a site in the FHO district is likely to be appropriate for a marine industrial terminal such as this, and the applicant's foundation and other reinforced designs, including tsunami berm that are designed to minimize flood damage, are sufficient to satisfy the mandatory requirements of the FHO.

4. **WDC Ch. 16.96: Soils Hazard Overlay requirements:**

The site is underlain by Coquille-Clatsop complex and Tropopsamments soils, both of which qualify it for the City's Soil Hazard Overlay (SHO) regulations in WDC ch. 16.96. Also, the soils of the ESP are mapped as being moderate to highly compressible, and the site is almost entirely composed of old dredge spoils, all of which implicates the SHO regulations. RiverKeeper asserts that the site's location close to the Cascadia Subduction Zone fault and right on the Columbia River Fault make it inherently unsuitable and unreasonably dangerous for this use. RiverKeeper cites an August 2012 DOGAMI report *Earthquake Risk Study for Oregon's Critical Energy Infrastructure Hub* (Ex. 44, attachment 32) in support of its argument that this site is not appropriate for a major LNG terminal. Similar to its arguments under the FHO, however, RiverKeeper attempts to boot-strap the conditional use criteria, particularly WDC 16.220.030(A)(5) which requires that the site be appropriate for the use, into the SHO requirements of WDC ch. 16.96. While it is true that WDC 16.96.020(A) requires compliance with the other applicable development code standards, the CUP criteria in WDC 16.220.030 are not applicable to the terminal facility as a whole, but only to the wetland mitigation in the I-2 zone and the over-height storage tanks in the Airport Hazard Overlay zone, both of which are discussed *infra*.

Fairly read, the SHO regulations in WDC ch. 16.96 do not include a requirement that a site so encumbered be deemed "generally suitable." That requirement is found in the conditional use permit criteria of WDC ch. 16.220, but only applies to certain limited aspects of the development, not the terminal. Nonetheless, the soil suitability analysis for Large-Scale Development in WDC 16.192.030 is applicable and is addressed *infra*. As things stand, however, the requirements of the SHO for this development are not that stringent and largely discretionary:

> *16.96.040 Areas with Coquille Variation or Coquille-Clatsop Complex Soils. The City may require an on-site soil survey report and a report by a licensed engineer for large-scale commercial, industrial or governmental structures, multifamily residences, or other structures which would cause a heavy loading of soil in areas of the City with Coquille variant silt loam or Coquille-Clatsop complex soils.*
>
> *16.96.050 Additional Provisions.*
> *A. The City may charge the owner or developer a reasonable fee for the cost of reviewing the adequacy of the soil survey, the methods proposed to avoid soils hazards and the methods actually used to avoid these hazards.*
>
> *B. The City may require the owner or developer to post a performance bond to assure that adverse effects that may occur from a proposed development in the SH zone can be corrected. The size of the bond shall be*

no larger than necessary for correcting potential adverse effects. The bond shall be released when the City determines that performance pursuant to the applicant's approved engineered plan is satisfactory.

The SHO does not impose any particular performance or design standards on this development, only that the site's soils be investigated by a suitably qualified geotechnical engineer and that the results of that investigation be reflected in the design of foundations and structures. The applicant provided a thorough geotechnical investigation (Terminal Application App F) and addressed the SHO requirements (Terminal Application p 5-33 to 5-34). The application described engineering steps and foundation designs that, according to the applicant, would withstand earthquake damage (Ex. 138, p 32-34; Ex. 187, p 9-13; Ex. 191, p 9-15; Ex. 193, p 16-18). The applicant also analyzed the seismic and tsunami risk factors and provided design details of the 22-27 foot tall earthen berm around the plant that would reduce the risk of inundation from a major tsunami (Ex. 138, p 30-31, 35-36). After the September hearing the applicant provided an analysis of these issues including a response on the Cascadia Subduction Zone hazards and specifically addressed the implications of the site being underlain by the Columbia River Fault and a response to Tom Horning's report (Ex. 175). According to the applicant, the Columbia River Fault, while located basically under this site, was too old and movement too remote a possibility (no more recent than 1.6 million years ago) for it to be considered a relevant threat today (Ex. 187, p 10-13). There was no countervailing or comparably credible evidence that detracted from the applicant's geotechnical evidence, its engineering and foundation design, nor its response to these arguments about tsunami and earthquake risk. The Officer concludes that the applicant's geotechnical investigation (Terminal Application App F), related analyses and documentation, the specifically proposed ground improvements, and the deep foundation designs are sufficient to satisfy the requirements of SHO.

5. <u>WDC Ch. 16.156</u>: Wetland and Riparian Corridor Development standards:

The terminal project will result in 3.2 acres of temporary wetland impacts due to construction activities that will be restored and ~35 acres of permanent wetland impacts for the terminal improvements. <u>See</u> Terminal Application Figs 5-1 & 5-4, respectively and Terminal Application narrative 5-81 to 5-89. The wetlands that will be impacted are on the City's local Goal 5 inventory and are classified as Significant Wetlands. The same wetland areas are also encompassed within the City's acknowledged Goal 16 (Estuarine Resources) boundary, and most of the terminal site is within the City's acknowledged Goal 17 (Shoreline Resources) boundary. Oregon DSL reviewed and concurred with the applicant's wetland delineation (Terminal Application App. H). The temporary wetland impacts will be mitigated and restored in-place and in-kind (Terminal Application Fig 5-1).

The permanent wetland impacts are the subject of a separate removal and fill application to Oregon DSL and the USACE, neither of which have been approved. The City regulates wetland fills under WDC 16.156.030, for significant locally inventoried Goal 5 wetlands, such as these, by requiring Oregon DSL permit approval and a hardship variance issued pursuant to WDC 16.156.080. The applicant argues, however, that where resource areas are subject to both Goal 5 and Goals 16 and/or 17, OAR 660-023-0240(2) provides in pertinent part that "[t]he requirements of Goals 15, 16, 17, and 19 shall supersede requirements of [Goal 5] for natural resources that are also subject to and regulated under one or more of those goals." See also Warrenton Comprehensive Plan §4.100 referring to the administrative rule. Thus, according to the applicant, where wetlands, such as these, that are protected by Goals 5, 16 and 17, state law and the City's Comprehensive Plan specify that the Goal 16 and/or Goal 17 protection program controls the regulation of those wetlands, not Goal 5 or the local Goal 5 wetland regulations.

Notwithstanding Warrenton Comprehensive Plan §4.100 and OAR 660-023-0240(2), RiverKeeper argues that the ~35 acres of permanent wetland fill is subject to the City's Goal 5 wetland protections in WDC ch. 16.165 (Ex. 44, p 29-31). On this basis, RiverKeeper asserts that the applicant needs a hardship variance for this fill under WDC 16.165.080. In essence, RiverKeeper asserts that both Goal 5 and the Goal 16 & 17 protection schemes apply to this proposed wetland fill. In support of its argument, RiverKeeper points to references in the Comprehensive Plan (§5.100) and the I-2 Zone regulations in WDC 16.64.040(T), which reference WDC ch. 16.156.

Based on the pretty clear language in Warrenton Comprehensive Plan §4.100 and OAR 660-023-0240(2), the Officer concludes that the applicant's proposed filling of these significant Goal 5 wetlands is not subject to WDC ch. 16.156 and does not require a hardship variance, but rather is subject only to the City's Goal 16 and 17 protections in WDC ch. 16.160 (Columbia River Estuary Shoreland and Aquatic Area Development Standards) and ch. 16.164 (Impact Assessment and Resource Capability Determination). Otherwise, the applicant would have to obtain a variance for the ~35 acres of permanent wetland impacts under WDC 16.156.080. Therefore, the primary regulatory matrix for the proposed permanent fill of ~35 acres of locally significant wetlands, as well as the massive estuary impacts this project presents are addressed under WDC Chs. 16.160 and 16.164 which implement the CZMA and State-wide Planning Goals 16 and 17.

6. WDC 16.160.020: Columbia River Shoreland and Aquatic Area standards, Deep-Water Industrial Development:

As previously noted, the lead permitting agency for this project is FERC, pursuant to the Natural Gas Act, and the only regulatory connection to local land use criteria is the Coastal Zone Management Act (CZMA), which is implemented and administered by local governments pursuant to State-wide Planning Goals 16, 17, 18 & 19. The City Commission's 2006 decision expressly did not address, and it reserved for another day, consideration of Goals 16 and 17 – two of the four State-wide Planning Goals that implement the CZMA. In Warrenton, the CZMA and Goals 16 and 17 are implemented through the City's acknowledged Comprehensive Plan (portions of Articles 4, 5 and 6) and WDC Chs. 16.160 and 16.164. Consequently, the Officer concludes that an important legal function of this proceeding is to address CZMA consistency through the City's acknowledged comprehensive plan and land use regulations, pursuant to Goals 16 and 17. While the applicant generally disputes the applicability of local land use regulations to the project, it concedes that it is subject to CZMA regulations that are implemented locally, which in this case include WDC chs. 16.160 and 16.164 and WCP Articles 4, 5 and 6.

This project is a port industrial development with significant estuary and coastal shoreland impacts, including a 109-acre dredge area and a ~35-acre permanent wetland impact (fill) and construction of new pilings, docks and dolphins. Such activities in the A-

1 and I-2 zones must demonstrate compliance with the standards in WDC ch. 16.160, most notably WDC 16.160.020(B) and (C) – subsection (B) applies to dredging impacts and subsection (C) applies to the construction, installation and use of the piers, pilings and dolphins – both of which require findings of compliance with all of the following discretionary standards:

> *B. New or expanded facilities for deep-water navigation, port or industrial development requiring aquatic area dredging or filling may be allowed only if all of the following criteria are met:*
> 1. *The proposed use is required for navigation or other water-dependent use requiring an estuarine location, or is specifically allowed in the applicable aquatic zone; and*
> 2. *A need (i.e., a substantial public benefit) is demonstrated; and*
> 3. *The proposal does not unreasonably interfere with public trust rights; and*
> 4. *Feasible alternative upland locations do not exist; and*
> 5. *Potential adverse impacts are minimized.*
>
> *C. Deep-water navigation, port or industrial development requiring new piling or dolphin installation, construction of pile-supported structures, or other uses or activities which could alter the estuary may be permitted only if all of the following criteria are met:*
> 1. *A need (i.e., a substantial public benefit) is demonstrated; and*
> 2. *The proposal does not unreasonably interfere with public trust rights; and*
> 3. *Feasible alternative upland locations do not exist; and*
> 4. *Potential adverse impacts are minimized.*

a) **Need/substantial public benefit for the use.** The applicant provides extensive documentation about the global demand for natural gas and the importance of national and global energy markets and how this project will generate significant local and regional economic benefits in terms of jobs, wages and tax revenue. See Terminal Application at p 5-91 to 5-92, App. 5A, Exs. 69, 193, p 12-13 & 54-55. In addition to these economic analyses, the Officer heard compelling testimony from a substantial number of local and regional residents as to the importance of such economic drivers to create jobs and economic prosperity, especially following the collapse of the region's timber and fishing industries. While this industrial facility will not create the number of jobs anywhere comparable to the former timber and fishing industries, it is undeniable that this facility will create a significant number of jobs for the construction phase and a smaller number for operation of the facility going forward.

RiverKeeper and other witnesses argue that there is no (or at least not a sufficient) public need or benefit for the natural gas that will be exported or imported through this facility (Ex. 44, p 36-39). Under current market and production conditions, it is clear that this will be an export terminal for the foreseeable future. RiverKeeper cites to a number of research and economic reports that discuss the current and future market for natural gas (Ex. 44, p 36-39 and references cited therein). RiverKeeper and other opponents point out that the small number of long-term operational jobs undercuts the applicant's claims of an economic boon to the region.

The Officer takes a slightly different view than either party. First, the facility in question is an LNG import/export terminal, and the Officer is tasked with evaluating these conflicting claims of economic benefit/detriment in the context of the local land use criteria. This is not a debate about world or regional natural gas markets or the advisability of the world's reliance on fossil fuels, but rather an application to site a terminal facility in Warrenton's shoreline area and estuary. Second, the question under WDC 16.160.020(B) & (C) is not whether there is a public need for natural gas, but whether there is a public need or benefit in constructing this terminal facility in this shorelands location. The Officer takes at face value the applicant's assertions that there is a regional and global market demand for natural gas, and he declines to decide whether that is a good thing or not. The applicant's significant investment in this facility is prima facie evidence of the strength and optimism of the global gas market. The Officer declines RiverKeeper's invitation to evaluate the fluctuations of global gas consumption or the wisdom of relying on carbon fuels. Such an economic analysis is beyond the scope of these local land use criteria, and the Officer concludes it is not contemplated in this criterion. The locational question under WDC 16.160.020(B) & (C), therefore, is more simple than that: is there a public need for this deep water industrial port facility to be located in the shoreline area? The objective of the code section appears to be the prohibition of superfluous port facilities, docks and piers that don't necessarily have to be situated in Warrenton's estuary and shoreland area. The Officer concludes that such a need and connection exists here because the particular use proposed requires close and immediate access to a deep water marine port. This is a use that must be sited in an estuary and near-shore area, and cannot be sited in upland areas away from an estuary.

Almost by definition, this industrial marine terminal plus its docks, pilings and piers must be located close to deep water port and marine areas that deep draft vessels can access. Such would not be the case, and there may not be a public need for a shoreland or estuary location, if this were anything but a deep-water marine industrial terminal development. It would be extremely inefficient and illogical for the City to create an aquatic industrial zone and then determine that a marine port terminal does not need to be situated in a shoreland or estuary area such as this one that is specifically zoned for that use. The only conclusion to be drawn from the City's creation of the A-1 and I-2 zones, application of those zones to the ESP and implication of WDC ch. 16.160 is that the City Commission specifically wanted this sort of use to occur and that it be located in close proximity to the shore and estuary. The fact that the City Commission has zoned areas for this use is compelling evidence of a need and public benefit for precisely this sort of use in this location. The applicant's evidence of job creation, albeit, not equivalent to previous resource job numbers, and the economic significance of the proposed operation are compelling evidence of a public benefit. The evidence of future tax revenues (Ex. 69) compounds this evidence, as do arguments for strengthening of an energy distribution network. This conclusion is confirmed by the Commission's 2006 interpretation that deep water port facilities and water-dependent industrial uses such as this one are allowed in the A-1 and I-2 Zones and therefore must be located in shoreline areas and estuaries. On this basis, the Officer concludes that a preponderance of evidence in the record demonstrates a sufficient need and substantial public benefit to locating this terminal in this location.

b) **Does the use unreasonably interfere with public trust rights?** WDC 16.160.020(B)(3) requires a finding, based on a preponderance of evidence in the record, that the proposed use will not unreasonably interfere with public trust rights. The application spends little time addressing the public trust impacts of the proposal and essentially limits the discussion to explaining why and how fishing will not be unduly inconvenienced as a result of the exclusion zones. See Terminal Application p 5-92. The applicant's hearing submissions (Ex. 138 & 140) provide some acknowledgement of recreational and commercial fishing in and around the terminal basin and some explanation as to how these public trust activities would be impacted by the terminal operations (Ex. 140, p 6-7). For example, the applicant acknowledges for the first time a 500-yard exclusion zone for LNG vessels while in transit, a 200-yard exclusion zone for LNG vessels moored at dock, and a 50-yard exclusion zone from the dock facilities with no vessels present. The applicant also discusses possible impacts to popular Buoy 10 fishing and offers vaguely to minimize impacts by "restrict[ing] LNG marine carrier arrivals and departures to nighttime periods or when the number of fishermen has decreased during the Buoy 10 fishing season" (Ex. 140, p 7).

Not until its second post-hearing submission does the applicant acknowledge other elements and programs in the lower Columbia River and Youngs Bay designed to preserve dwindling salmon and steelhead stocks and which affect recreational and commercial fishing (Ex. 187, p 25-29). The applicant discusses for the first time the closure of Young's Bay off-channel area to recreational fishing and the Select Area Fisheries Enhancement (SAFE) site in Youngs Bay, which was established as one of the reasonable and prudent alternatives directed by NMFS as mitigation in its Biological Opinion (BiOp) for the Federal Columbia River Power System (FCRPS).[12] In short, the applicant takes the position that, because of these existing fishing restrictions, local fishers are, or should be, accustomed to restrictions similar to what will be imposed by the operation of the LNG terminal facility (Ex. 187, p 27-29). From this, the applicant concludes that fishing restrictions caused by this project will have little or no practical impact on local fishing.

The applicant's third post-hearing submission offers little more discussion (Ex. 191, p 4-5), but it provides a comprehensive summary in its closing argument of the project's impacts on fishing (Ex. 193, p 31-33) and other public trust rights (Ex. 193, p 56-57). The applicant asserts that the area to be impacted by dredging, construction of the marine facilities, and on-going vessel operations has "minimal biological significance," citing findings adopted in 2006 by the City Commission in support of its zone change decision for the ESP (Ex. 193, p 57). It also asserts that the limitations that might be imposed on fishing by LNG terminal operations are dwarfed by the more onerous restrictions imposed on fishing by the Young's Bay Closure Zone and the Young's Bay SAFE area designation. From this the applicant concludes that the terminal facility will have

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[12] The FCRPS is a collaborative program of the US Army Corps of Engineers, the Bonneville Power Administration and the Bureau of Reclamation for the operation of 31 federal hydroelectric dams on the Columbia River and its major tributaries. NMFS issued its BiOp in 2008, which was supplemented in 2010 and 2014.

some impacts on public trust rights, but will not unreasonably interfere with those rights.

While the applicant acknowledges that the scope of the Public Trust Doctrine (PTD) encompasses aquatic habitat for fish, it asserts that the state has ample authority to allow the dredge and removal of estuary fish habitat, even for non-water related uses (Ex. 193, p 56-57). The applicant also argues that the estuary habitat that would be lost to the 109-acre dredge (1.2 million cy) for the vessel turning basin, would not eliminate or impact significant fish habitat, at least significant fish habitat that is in short supply. *Id.* The applicant relies in part on the A-1 zoning and the City's 2006 code interpretation as conclusive determinations that the City Commission has already taken this habitat loss into account and found it acceptable because of the estuary's "minimal biological significance" (Ex. 193, p 23 & 57).

RiverKeeper and other opponents similarly spend a lot of time arguing that the exclusion zones present a significant and unreasonable interference with public trust rights because they would preclude fishing access to significant areas for significant amounts of time, as does the exclusion of the public from the ESP (Ex. 44, p 40-44; Ex. 83, p 15-18; Ex. 183, p 11-15). RiverKeeper also relies on agency comments from Oregon Department of Fish and Wildlife to the USACE in January 2015 (Ex. 44, attachment 63), an August 29, 2015 ODFW comment to City of Warrenton (Ex. 21), and a September 21, 2015 ODFW comment to Warrenton (Ex. 186). RiverKeeper also focuses on the broader scope of the PTD to include wildlife and fish and the critical habitat identified as necessary for the sustainability of those populations in trust for the people of the State, including setting fishing limits and protecting habitat to prevent the extinction of those species (Ex. 44, p 42-44; Ex. 188, p 15).

The starting point for addressing this criterion is the language of the standard: "the proposed use does not unreasonably interfere with public trust rights." The applicant correctly notes that the standard expressly allows some degree of infringement and does not preclude all interference with public trust rights, only unreasonable interference. Quite clearly, a new marine port facility and the passage of these LNG ships will temporarily exclude boat-based fishing for 500 yards on either side of an LNG vessel while ships are in passage. A longer temporary 200-yard exclusion will apply while vessels are at dock, and a permanent 50-yard exclusion will apply around the dock facilities when vessels are not present. The Officer heard testimony that these exclusion zones also apply to the large ocean-going commercial passenger vessels, not just LNG vessels, but there was testimony that these are significant limitations on both commercial and recreational fishing that are already heavily-constrained by other exclusions, temporal and spatial limitations.

The Officer finds the evolution of ODFW comments on this project from January 2015 to late September 2015 are compelling evidence of the project's impacts on fish, fishing, fish habitat, on-going fish recovery efforts, and thus public trust rights. The testimony of affected fishing organizations and individual fishers is also compelling and credible evidence that these impacts are real and that they significantly (unreasonably) impact public trust rights (Exs. 4, 7, 9, 25, 43, 48, 51, 80, 96, 103, 108, 118, 119 & 123). ODFW's final comment letter (Ex. 186), submitted just before the record closed, is most telling:

> 1) The Applicant suggests that ODFW's failure to raise issues other than those expressed in our August 29, 2015 letter to the City of Warrenton [Ex. 21] is an indication that our other concerns (such as those raised in our response to the Corp's Joint Permit Application [Ex. 44, attachment 63]) had been resolved... We can assure Warrenton that ODFW continues to have substantial issues with the project proposal ranging from the adequacy of proposed compensatory mitigation to the potential impacts of fish entrainment in ballast and cooling water intakes.
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> 3) The Applicant states that the presence of the Young's Bay Control Zone (YBCZ) already restricts recreational fishing access, therefore safety zones will not further impact recreational fishing in the area. Warrenton should be aware that the YBCZ only restricts angling for a portion of the year, while the proposed security zones are effective the entire year. Further, Warrenton should also be aware that the Department is currently evaluating the area at the mouth of Young's Bay for potential expansion of the Young's Bay terminal commercial fishery. The expected east boundary for the expanded fishing area would be adjacent to the proposed OLNG terminal, and therefore, commercial fishing activity in this area could be impacted by security zones around docked and marine carriers in transit and maneuvering in the turning basin.
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> In addition, it is also important to point out that recreational vessels will be periodically prohibited (about 250 times each year) from movement in and out of the Skipanon River during the times that the LNG marine carriers travel between the berth and the federal navigation channel. These safety closures will permanently prohibit recreational fishing and crabbing from a 100 acre area at the marine terminal, and will prohibit transit through the turning basin area over a period of about 125 hours each year.
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> Given the potential impacts to recreational and commercial fisheries listed above, the Department suggests that the Applicant should be providing more detail characterizing the local importance of the commercial recreational fisheries and how those fisheries will (or may) be affected during construction and operation of the OLNG terminal, berthing dock, and other facilities. We also suggest that the Applicant include a detailed description of proposed mitigation actions designed to offset any losses of recreational and/or commercial boating and fishing opportunities that result from adherence to the proposed Oregon LNG safety/security zones. (Ex. 186, emphasis added)

Echoing these concerns, in its scoping comments on the project, NMFS requested, among other things, "[a]n estimation of potential monetary losses incurred by both commercial and recreational fisheries and fishing communities due to the proposed project as well as other existing and foreseeable LNG projects within the same geographic area" (Ex. 44, attachment 5).

The Officer does not view the applicant's response to ODFW comment letters or NMFS scoping comments to be adequate. The Officer finds that the applicant has not adequately characterized and quantified the impact of its operations on commercial and recreational fishing, nor has it demonstrated that these impacts will not be unreasonable. These impacts to fishing and where fishing vessels can go is a direct result of the construction, installation and operation of the pilings, piers and docks as anticipated by WDC 16.160.020(C) – mostly the operation and less so the construction/installation. It is not sufficient to simply state that the impacts are of the same type that local fishing already experiences with other large vessel traffic and closures due to the YBCZ and Young's Bay SAFE Area restrictions. These preexisting fishing restrictions are significant and do not subsume the LNG terminal's impacts within their temporal or geographic scope. The YBCZ and Young's Bay SAFE Area restrictions are designed to preserve and help recover the estuary's dwindling and endangered fish populations, not to provide industrial operations, such as this LNG terminal, with greater latitude to degrade fish habitat and impact fish populations. The existing restricted fishing areas and periods are intended to help endangered and diminished fish populations recover to the point that fishing can again expand. It appears from ODFW's comments that the agency either believes that the LNG terminal operation will work against those recovery efforts by causing unacceptable habitat impacts, or that the applicant has not provided enough detailed information for ODFW to determine that it won't have that adverse effect. Either way, ODFW is the state agency with expertise in this area, and at the time the record closed, it was not satisfied with the project's analysis of the magnitude of impacts, the proposed mitigation or both. On this basis, the Officer finds that this application falls short of the mark under WDC 16.160.020(C), from which the Officer concludes that operation of the piers, docks and other in-water constructed elements will (or is likely to) unreasonably interfere with these public trust rights. As discussed in more detail in response to WDC ch. 16.164 (Impact Assessment and Resource Capability Determination), the Officer concludes that the mitigating measures are not sufficient to prevent unacceptable losses, irreversible damage, unacceptable degradation or reduction in estuary resources from this project, all of which affects public trust rights.

The Officer reaches a similar conclusion with regard to the project's impact on fish habitat, caused by 109 acres of estuary dredging (1.2 million cy) and ~35 acres of permanent wetland impacts, which is a recognized resource within the scope of the public trust doctrine (PTD) and thus a public trust right. As a starting point, Oregon's view of the PTD is broad and encompasses public ownership in the state's fish and wildlife resources[13] and wetlands.[14] Oregon's Supreme Court has upheld state authority to regulate fish harvests so that fish "may have an opportunity to propagate their species, and be preserved from

[13] *Simpson v. Department of Fish and Wildlife*, 242 Or.App. 287, 255 P3d 565, 569-73 (2011).
[14] *See Morse v. Oregon Div. State Lands*, 34 Or App 853, 581 P2d 520, *aff'd* 285 Or 197, 590 P2d 709 (1979).

extermination."[15] The Court subsequently reiterated that the state holds "migratory fish in the navigable waters ... in its sovereign capacity in trust for all its citizens ... and as an incident of the assumed ownership, the legislative assembly may enact such laws as tend to protect the species from injury by human means and from extinction by exhaustive methods of capture."[16] On this basis, the Officer takes a similarly expansive view of the PTD and protected public trust rights under WDC 16.160.020(B)(3) and (C)(2) to include fish habitat within the lower Columbia River, its estuary and related estuary tidal wetlands.[17]

The record contains credible, compelling evidence that the Lower Columbia River Estuary, which includes the area proposed for the LNG turning basin and dock facilities, is habitat for ~76 fish species, 16 of which are federally listed as threatened or endangered and 3 of which are listed Species of Concern by Oregon (Terminal Application App G, Table 3-1; Ex. 44, attachment 5). The Officer views the Williams Report (Ex. 44, attachment 1) as credible and compelling evidence of use of the terminal area and Young's Bay by juvenile endangered salmon and steelhead. The Officer notes the applicant's concession that its consultants did not take into consideration several of the sources cited by the Williams Report because they were published after the applicant's Biological Assessment was prepared (Ex. 187, p 33-35; Ex. 193, p 29). The applicant states, however, that the studies evaluated in its Biological Assessment considered data that were used in the later studies cited in the Williams Report. The Officer is not convinced by the applicant's statements that it has sufficiently considered the Williams Report, the sources it cites, nor the damage to estuary habitat used by ESA-listed salmonids.

With regard to impacts to listed salmon and steelhead, the application states that it will take certain steps to minimize potential impacts to listed fish species by curbing its dredging activities (Terminal Application p 5-135 to 5-136, App G, p 3-74 to 3-87, terminal staff report at 211) including the following:

- Dredging will be conducted during ODFW approved in-water work periods (Nov 1 to Feb 28) to "minimize potential impacts to listed fish species through the avoidance of vulnerable salmonid life stages and peak migration periods.

- Dredging will occur in relatively deep water areas and, therefore, should 'avoid' areas where subyearling Chinook and chum salmon are present. Dredging may also be performed with a clamshell bucket dredge, which is unlikely to entrain salmonids or other ESA-listed or proposed species.

- If at any time during dredging activities, listed salmonids are observed in distress or a listed salmonid is killed, operations will cease and NMFS will be notified.

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[15] *State v. McGuire*, 24 Or. 366, 33 P. 666 (1893).
[16] *State v. Hume*, 52 Or. 1, 5-6, 95 P. 808 (1908)
[17] *See generally* Michael C. Blumm & Erika Doot, *Oregon's Public Trust Doctrine: Public Rights in Waters, Wildlife, and Beaches*, 42 Envt'l Law 375 (2012) - attachment 78 to Ex. 44.

The applicant concludes in its Columbia River Estuary Impact Assessment (Terminal Application App G) that, while the terminal project and operations going forward "represents a potential degradation or reduction of estuarine resources," these along with the other mitigation measures it proposes are sufficient to "eliminate or minimize to an acceptable level" the expected adverse impacts (Terminal Application p 5-141).

RiverKeeper and numerous other opponents disagree that the project's impacts to estuary resources, especially habitat for listed fish species, are as de minimus as the applicant claims or that the mitigation measures will reduce those impacts to acceptable levels. ODFW appears to agree with the opponents, and in its final comment letter on September 21, 2015 (Ex. 186) ODFW incorporated its prior concerns and comments about the project (Ex. 21; Ex. 44, attachment 63) and maintained the following relevant concerns:

> 4) As indicated above, Warrenton should also be aware that ODFW has concerns regarding the Applicant's proposal to withdraw water from the Columbia River for OLNG carrier ballast and cooling water. Our review of OLNG's proposal to not provide fish screens on these intakes has raised some concerns about potential negative effects to hatchery fish reared in the Young's Bay SAFE area. Should our concerns regarding fish screening not be satisfactorily addressed, we will be recommending mitigation for the potential loss of those and other fish.
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> 5) Lastly, ODFW has concerns that the proposed Young's River Mitigation site will not adequately mitigate for impacts to estuarine wetland habitat at the proposed OLNG terminal and marine facility site. Specifically, we do not believe that the proposal is consistent with ODFW's Habitat Mitigation policy (OAR 635-415-000 through 0025) which governs the Department's provision of biological advice and recommendations concerning mitigation for losses of fish and wildlife habitat caused by development actions. ODFW considers the estuarine wetland habitat at the terminal site to be Category 3 Habitat per the Habitat Mitigation Policy. For this habitat category, ODFW recommends (1) no net loss of either habitat quantity or quality; (2) avoidance of impacts through alternatives to the proposed development action; or (3) mitigation of impacts, if unavoidable, through reliable in-kind, in-proximity habitat mitigation to achieve no net loss in either pre-development habitat quantity or quality. The primary issue with the Applicant's proposal is that: (1) mitigating loss of tidal saltmarsh habitat with restoration of freshwater marsh habitat would be considered by ODFW to be out-of kind habitat mitigation; and (2) the assemblage species impacted at the terminal site would not be the same as those benefitting from the restoration of the Young's River site and would therefore be considered out-of-proximity mitigation. If the mitigation standard is not met, per OAR 635-415-0025(3)(c) the "Department shall recommend against or shall not authorize the proposed development action." (Ex. 186)

RiverKeeper provided several studies that analyzed the use of the Lower Columbia River Estuary, Young's Bay and the terminal site by listed fish species and the value of these areas as fish habitat (Ex. 44, attachments 1 & 2 and sources cited therein). The most relevant and compelling conclusion about the importance of these areas and the project's impact on ESA-listed salmonids that are supposed to be protected here, is the summary of impacts from the Williams' report (Ex. 44, attachment 1):

> Based on these results, it is clear that construction and operation of the proposed Oregon LNG project would negatively impact ESA-listed salmonids of a variety of species and life stages throughout the entire year. The habitats surrounding the proposed Oregon LNG site, both shallow water and deeper water, are used extensively by salmonids including fry for rearing, by juvenile salmonids for rearing and outmigration, and by returning adult salmon. Impacts would likely be greatest for fry-stage juvenile subyearling Chinook and chum salmon, which use the shallow water habitats of the Lower Columbia River estuary extensively for rearing and growth prior to outmigration.
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> While the importance of LCRE habitats for salmon production in general is increasingly recognized, the LCRE's Reach A may be an especially important nursery, rearing, and transitional stage for aggregated production from the lower Columbia River and its tributaries, particularly for the Youngs Bay watershed and for coho and chum salmon recovery efforts in the lower river. The fry migrant life history type (i.e., subyearling) contributes to Chinook salmon spawner success in the Columbia River basin, especially to the lower-river populations. For example, chum salmon are predominantly fry migrants and historically comprised a large biomass of adults returning to the lower Columbia River basin (Johnson et al. 1997). Both of these ESA-listed species (chum and fall Chinook) are dependent upon utilizing shallow water habitats for extended periods that conflict with the construction and operation of the proposed OLNG project.
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> Impacts to nearshore habitats from turbidity and sedimentation associated with project construction and dredging will have long-term negative effects on these species and their recovery. Similarly, construction of the OLNG project site immediately adjacent and downstream of significant restoration efforts involving a suite of stakeholders (and large investments) that include federal, state, tribal and local constituents does not seem wise. (Ex. 44, attachment 1).

Evidence in the record shows that the Lower Columbia River Estuary, and Young's Bay in particular, play a critical role in the 2008 BiOp for the FCRPS and the two subsequent Supplemental BiOps (2010 and 2014), which identify funding for the Youngs Bay SAFE Area and others as a Reasonable and Prudent Alternative, *i.e.,* as mitigation for impacts to ESA-listed fish species caused by operation of the federal hydro dam system. The fact that the FCRPS BiOp is a "jeopardy opinion" and specifically identifies Youngs Bay for mitigation projects, that it is designated as a SAFE Area, that there is a designated closure zone that includes the terminal area, and that the area is identified by credible scientific studies as habitat for several ESA-listed salmonids at different times of the year for different lengths of time, is strong evidence of a significant and unreasonable impact on this important public trust resource. The ODFW comments demonstrate to the Officer that maintaining the integrity of these fish protection areas and the ESA-listed species they harbor is very important, that the applicant has not addressed those or other impacts sufficiently, and that the mitigation measures offered are not sufficient. The fact that the FCRPS BiOp includes Youngs Bay as part of the mitigation for the likely take of ESA-listed species and the size and scale of the impact this project will have on salmonid habitat in the Lower Columbia River Estuary strongly suggests to the Officer that the NMFS BiOp that will be issued for this project in the future will also be a jeopardy opinion.[18] The Officer regards ODFW and NMFS to be the two agencies with primary credible expertise in evaluating impacts of projects such as this one on salmonid habitat and the effectiveness of mitigation to prevent or minimize those impacts.

The Officer expressly rejects the applicant's suggestion (Ex. 193, p 57) that the portion of the Lower Columbia River Estuary that will be impacted by the 135-acre turning basin, the 109-acre dredge area or the 35-acre permanent wetland fill has "minimal biological significance," simply because the City Commission reached that conclusion in 2006 in support of its zone change decision for the ESP. That 2006 proceeding and that general non-specific finding was no substitute for this specific estuary impact inquiry under Goals 16 and 17, as LUBA so found. More to the point, the City Commission found in the 2006 proceeding, and LUBA agreed, that Goal 16 compliance would be determined, along with any required mitigation needed to meet Goal 16's estuary protection requirements in the subsequent development permit process.[19] The Officer reaches the same conclusion about the 35-acre permanent wetland impact (fill).[20] The present process is the one that LUBA was referring to in its 2006 opinion,

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[18] To date, the NMFS has not issued a BiOp for the Oregon LNG project, for which FERC is the lead federal agency. As explained under WDC ch. 16.164 *infra*, evidence and argument in the record from ODFW (Ex. 21 & 186, Ex. 44, attachment 63) and protections for Youngs Bay imposed by the FCRPS jeopardy BiOp as mitigation for take caused by the FCRPS operations, strongly suggests that a jeopardy opinion from NMFS is likely in the present case. Either that or there is simply not enough credible evidence in this record for the Officer to conclude that the project's impacts to the Lower Columbia River Estuary resources are acceptable or will be mitigated to acceptable level.

[19] In its affirmance of the City in the 2006 proceeding, LUBA held that "the development standards applied during federal, state and local permitting processes are sufficient to ensure that any [estuary resource] loss is mitigated. While the city did not impose a specific condition requiring mitigation, it did require in condition 2 that any subsequent development proposal comply with all applicable local laws, including code provisions implementing Goal 16 that appear to require that loss of significant habitat be mitigated. We agree with intervenor that Goal 16 does not require more in the context of the present plan and zoning amendments." *People for Responsible Prosperity, et al., v. City of Warrenton*, 52 Or LUBA at 204.

[20] As the Officer already concluded, the 35-acre permanent wetland impact is analyzed under Goal 16 *infra* and not Goal 5 *supra*. According to LUBA's affirmance of the City Commission's 2006 decision, the Goal 16 analysis under WDC ch. 16.164 was not conducted in 2006, but is conducted today in light of the present spate of land use permits and documentation of the project's anticipated impacts to these Goal 16 resources. The 35-acre permanent wetland fill also poses unresolved and therefore unreasonable impacts on this public trust right, as confirmed by ODFW's most recent comment letter (Ex. 186).

and the Officer now determines this project's compliance with Goals 16 and 17 *infra* under the WDC ch. 16.164 discussion.

On this basis, the Officer concludes that the project will unreasonably interfere with significant public trust rights in the form of adverse impacts to fish habitat in this portion of the Lower Columbia River Estuary and by impacting habitat that is a state and federally acknowledged as important mitigation area for ESA-listed salmonids that use this and near-by shallow water and medium depth habitat.[21] This conclusion relates to the 109-acre dredge footprint and the ~35-acre permanent wetland impact. The Officer agrees with the arguments asserted by RiverKeeper in this regard (Ex. 44, p 40-44; Ex. 83, p 16-18; Ex. 188, p 11-16), and the concerns expressed by ODFW (Exs. 21 & 186; Ex. 44, attachment 63) and finds the opponents' evidence compelling and credible (Ex. 44, attachments 1, 2 & 3).

c) **Feasible alternative upland locations do not exist**. WDC 16.160.020(B) and (C) require a demonstration that feasible alternative upland locations do not exist for the proposed facility. The applicant asserts that, as a water-dependent industrial use, locations for the LNG terminal are limited to shorelands with deep water access and appropriate industrial zoning (Terminal Application at 5-92). The applicant also points out that it considered alternative locations and arrangements to achieve the stated purpose and need for this project. See DEIS §3.0 (Alternatives), especially §3.3 (LNG Terminal Alternatives). The applicant asserts that the DEIS alternatives analysis satisfies this criterion (Ex. 187, p 52-56). In its alternative sites analysis, the applicant identified multiple upland locations for the terminal, but rejected each one for a variety of reasons related to legal obstacles, logistical problems, distance in-land, number of bridges that would have to be underpassed to get to them, and the like (DEIS §3.3.2).[22] Only the preferred site, however, was encumbered by Warrenton's Columbia River Estuary Shoreland and Aquatic Area regulations, and none of the applicant's reasons for rejecting these alternative upland sites were related to concerns listed in WDC ch. 16.160.

RiverKeeper and other opponents assert that the applicant has failed to carry its burden of proof with regard to this criterion (Ex. 44, p 44). According to RiverKeeper, to the extent the proposal is basically a liquefaction facility, it could be located elsewhere away from the Lower Columbia River Estuary, and the

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[21] The Officer recognizes that the majority of the dredge area for the terminal is not shallow water habitat. However, the record shows that the area is still out of the main shipping channel and is medium depth habitat for several ESA-listed salmonids during several life stages, throughout most of the year and for differing durations depending on the species (Ex. 44, attachment 1).

[22] In the DEIS the applicant says it considered and reject alternative sites in the Puget Sound area for the terminal due to likely legal challenges. It also states that alternative sites in Coos Bay Oregon and Grays Harbor Washington were considered and rejected due to inadequate shipping channel depth (DEIS p 3-13). The applicant goes on to state that "Eight locations along the lower Columbia River with reasonable access to the Portland metro area were initially considered as potential terminal locations." *Id.* All of these are feasible upland locations for the LNG terminal in that they are outside of the Columbia River Estuary Shoreland and Aquatic Area regulated by WDC ch. 16.160.

liquid super-cold natural gas could be piped to ships in the estuary. In support of its argument that this is a feasible arrangement, RiverKeeper cites one example from Maryland (Ex. 44, p 44).

As a general proposition, RiverKeeper is correct that this facility could be designed similarly to the Dominion Cove Point LNG terminal in Maryland, where the liquefaction plant is about one mile from the coast and loading terminal. In that sense, there are almost a limitless number of suitable upland alternatives, but the Officer interprets this criterion to require alternatives that are consistent with the project's stated purpose and need (DEIS p 1-8). It is also true that WDC 16.160.020(B)(4) and (C)(3) do not articulate an alternatives analysis type requirement; rather, WDC ch. 16.160 requires the applicant to prove that "feasible alternative upland locations do not exist for the proposed facility." This is a relatively high standard that basically requires the applicant to prove a negative. In that light the Officer does not believe that DEIS §3.3 alternative sites analysis satisfies the city's criterion.

The unique aspect of the applicant's preferred location is that the entire site was zoned A-1 and I-2 for this specific purpose, where the liquefaction facility can be situated in conjunction with a loading terminal. This is a lot of the applicant's justification under this criterion (Ex. 187, p 54). However, the first criterion in WDC 16.160.020(B) requires that the new industrial use be water dependent or specifically allowed in the applicable aquatic zone. The unique nature of the zoning therefore is already taken into account in these criteria and cannot be used basically to invalidate the "feasible alternative upland location" criterion. The objective of WDC ch. 16.160 appears to be to ensure that uses that don't have to be sited in the Columbia River Estuary will not be approved there, thus the relatively high burden of proof which this standard imposes on an applicant. Again, WDC ch. 16.160 appears to be one of those Goal 16 siting standards that was not addressed in the 2006 proceeding in which the A-1 and I-2 zones were applied to the ESP. It is applied here for the first time to this specific project.

The record shows that multiple alternative upland locations exist for this LNG terminal – 8 of them in the Lower Columbia River, but not necessarily in the LCRE, and all with reasonable access to Portland (DEIS p 3-13). The applicant rejected all of those, except the preferred site, for reasons unrelated to Warrenton's protections of the Lower Columbia River Estuary under WDC ch. 16.160. Even though the applicant asserts that alternative sites farther up-stream from the ESP would require more dredging (Terminal Application at 5-87), many of those sites are not in the Lower Columbia River Estuary, and none are in Warrenton's Goal 16 Estuary and Shorelands Area. From this, the Officer concludes that Warrenton has placed a high priority on the preservation of its estuary and shoreland areas, and that preservation objective should be given a higher priority in the list of considerations for alternative sites than appears to have happened here. In that light, the alternative sites identified by the applicant in the DEIS were rejected for reasons unrelated to Goal 16 considerations or Warrenton's Estuary and Shoreland Area protections; therefore, none of those reasons render these alternative sites infeasible in the context of WDC ch. 16.160. All or most of these alternative sites are upland relative to the preferred site, and the Officer concludes they are still feasible for purposes of avoiding impacts to Warrenton's Columbia River Estuary Shoreland and Aquatic Area.

From this, the Officer concludes that the applicant has not met its burden of proof under WDC 16.160.020(B)(4).

With regard to WDC 16.160.020(C)(3) and whether there are suitable alternative upland locations for the in-water constructed elements, i.e., pilings, piers and docks, the Officer reaches a different conclusion. Unlike the terminal plant as a whole, for which there are other alternative upland locations outside of Warrenton's Goal 16 and 17 protected areas, docks, piers and pilings really have no other alternative location. It might seem to be a trite conclusion, but docks, piers and pilings, as a general proposition, can only be sited in estuary areas, and the structure of WDC 16.160.020 appears to require a separate analysis of the terminal facility as a whole versus the docks, piers and pilings. Thus, the Officer concludes that such a need exists because this particular proposed use requires close and immediate access to a deep water marine port. This is a use that must be sited in an estuary or near-shore area and cannot be sited in upland areas away from an estuary. This is the same analysis but a different conclusion than the Officer reached regarding the same criterion and the LNG terminal facility as a whole because of the narrow focus of WDC 16.160.020(C) on the in-water and over-water pier and piling elements.

d) **Does the proposal minimize potential adverse impacts as required by WDC 16.160.020(B) & (C)?** The applicant describes its potential mitigation measures for the project impacts to estuary resources in its Impact Assessment (Terminal Application, App G, §3.2.3; Terminal Application p 5-93 to 5-94). The Officer notes that these measures are "potential," because the Impact Assessment expressly states that "Oregon LNG has not determined the exact type [of dredge technology] to be used." (Terminal Application, App G, p 3-75). As NMFS said in its NEPA scoping comments on this project, the specific dredging technology and methods matter and will dictate the precise extent of impact to fish that use the turning basin as habitat (Ex. 44, attachment 5). ODFW also described what it viewed as the impacts of the dredge proposal and questioned severely the lack of clarity on methods, timing and the efficacy of the mitigation measures (Ex. 44, attachment 63). The applicant responds to RiverKeeper's criticism by describing the many ways that it has "minimized" impacts to recognized resources and has responded to ODFW comments (Ex. 191, p 17-22) and NMFS scoping comments (Ex. 191, p 15-17).

The Officer's resolution of this criterion again turns on the precise wording of the standard, *viz.*, "[p]otential adverse impacts are minimized." The standard contains no qualifications such as "to the extent practicable" or otherwise. As with the previous standard, this one presents a relatively high burden of proof for the applicant. Given the Officer's conclusions regarding the project's unreasonable interference with acknowledged public trust rights, ODFW's continuing concerns about the project and its mitigation (Ex. 186) and the likelihood that NMFS will find jeopardy, the Officer concludes that the proffered mitigation (Terminal Application p 5-93 to 5-94; App G, §3.2.3; Ex. 191, p 15-22) does not meet the standard because there remain unreasonable impacts to protected public trust rights and the feasible alternative upland locations were rejected for reasons unrelated to Warrenton's Estuary protections in WDC 16.160. Therefore, the project impacts of the terminal as a whole do not appear to have been minimized as this criterion requires.

With regard to the piers, docks and pilings under WDC 16.160.020(C)(4), however, the Officer reaches a different conclusion than he did for the plant as a whole under WDC 16.160.020(B)(3). First, the impact of just these in-water and over-water constructed elements is far less than the 109-acre dredge and ~35-acre permanent wetland fill required for the larger terminal. Second, the unacceptable impact of the pilings, piers and docks is the significant exclusion zones imposed on other vessels by the Coast Guard. The Officer finds that the existence and size of these exclusion zones is out of the applicant's power to control. The Officer concludes that, arguably, the applicant has provided sufficient evidence that potential adverse impacts of the pilings, piers and docks are minimized because the exclusion zones associated with LNG vessels and the dock are imposed by the Coast Guard. Consequently, there does not appear to be anything the applicant can do to reduce these exclusion zones short of abandoning the project altogether. The Officer also believes that the applicant has taken sufficient steps to lessen and mitigate the harmful impacts of construction and installation of these in-water and over-water elements by the timing of construction, use of bubble curtains, vibratory pile drivers and other sound dampening techniques and construction methods (Terminal Application p. 5-135 to 5-136; DEIS p 4-85 to 4-91). The Officer is not overly convinced that these techniques will be enough or be deemed sufficient to satisfy NMFS. The Officer concludes from this evidence that other/different techniques will be required as reasonable and prudent alternatives in its BiOp, when it is issued.[23] For purposes of WDC 16.160.020(C)(4), however, the applicant has, over time, proposed an increasing number of construction techniques to reduce harmful impacts of the construction and installation of the in-water and over-water elements. The Officer concludes that the applicant has met this standard.

7. **WDC 16.160.040: Columbia River Shoreland and Aquatic Area standards, Dredging standards and Mitigation/Restoration standards:**

Another local land use provision implementing State-wide Planning Goals 16 and 17 is WDC 16.160.040 (Dredging and Dredged Material Disposal), which applies to dredging operations in the Columbia River Shoreland and Aquatic Area, and was not addressed by the City Commission in the 2006 proceeding.

a) **Need, interference with public trust rights, feasible alternative upland sites, potential adverse impacts minimized.** WDC 16.160.040(A), applicable to all estuary dredging and dredge disposal projects including this one, provides that:

> *Dredging in estuarine aquatic areas ... shall be allowed only if all of the following criteria are met:*
> 1. *Dredging is specifically allowed by the applicable aquatic zone ...*
> 2. *A need (i.e., a substantial public benefit) is demonstrated; and*

[23] NMFS provided original scoping comments on the harmful effects of underwater noise and concussion on sub-adult ESA-listed salmonids (Ex. 44, attachment 5, p 7), as did ODFW (Ex. 44, attachment 63, p 3). In-water construction techniques are common concerns of these agencies, who frequently impose permit conditions specifying how pile driving and dock construction shall be done. That will likely happen here when NMFS issues its BiOp for this project.

3. *The proposal does not unreasonably interfere with public trust rights; and*
4. *Feasible alternative upland locations do not exist; and*
5. *Potential adverse impacts are minimized.*

As a starting point, it is uncontested that the use is allowed pursuant to WDC 16.160.040(A)(1) as an "approved water dependent use of aquatic areas or adjacent shorelands that requires an estuarine location." With regard to the balance of the WDC 16.160.020(A) requirements, they restate the criteria from WDC 16.160.020(B) and (C), which the Officer addressed *supra*. Those findings with regard to those same criteria are incorporated herein by this reference. The Officer concludes, based on a preponderance of credible evidence in the whole record, that the application fails to demonstrate compliance with WDC 16.160.020(A)(3), (4) and (5). Beyond that, RiverKeeper asserts that this project fails to meet the standards in WDC 16.160.040(B), (C), (F) and (G), all of which are discussed next.

b) **Dredging shall be the minimum necessary to accomplish the proposed use.** WDC 16.160.040(B) requires that, *"[w]hen dredging is permitted, the dredging shall be the minimum necessary to accomplish the proposed use."* RiverKeeper claims the project fails to demonstrate compliance with WDC 16.160.040(B) because the applicant "does not evaluate designing the turning basin to accommodate smaller LNG vessels" (Ex. 44, p 48). The applicant responds that "80% of the LNG vessels will already be smaller vessels" (Ex. 193, p 60) and, besides, the applicant cannot restrict the LNG vessels serving the terminal to a specific size (*Id.*). The project's anticipated vessel sizes are discussed at Terminal Application p 2-2, 2-3 & 5-87. Alternative basin dredge footprints (anything less than 109 acres) do not appear to have been considered in the DEIS.

Resolution of this issue turns on whether there is a preponderance of credible evidence in the record to demonstrate that it is met. The applicant states that most (80%) of the vessels are of the smaller size, which presumably means that a turning basin smaller than 109 acres would suit. Beyond that, all the applicant says is that it can't restrict LNG vessels based on size. The Officer is aware of no legal basis for that statement and sees no evidence in the record that a smaller turning basin (anything smaller than 109 acres) was considered, despite the fact that most vessels do not appear to need a turning basin that big. The most that can be said is that the basin size and dredge volume are the smallest needed to accommodate the largest LNG vessel that is likely to serve the terminal. This does not address the requirement in WDC 16.160.040(B), and it does not appear that the applicant has sized the dredge volume to be the "minimum necessary to accomplish the proposed use." From this lack of evidence, the Officer concludes that the applicant has not met this standard.

c) **Undesirable erosion, sedimentation, increased flood hazard and other changes in circulation shall be avoided:** WDC 16.160.040(C) requires that *"[u]ndesirable erosion, sedimentation, increased flood hazard, and other changes in circulation shall be avoided at the dredging and disposal site and in adjacent areas."* This dredge criterion, implementing Goals 16 and 17, imposes another relatively strict standard with no qualifying language such as "to the extent practicable" or "to an acceptable level." Instead, the standard requires that the applicant demonstrate that "[u]ndesirable erosion, sedimentation, increased flood hazard, and other changes in circulation shall be avoided at the dredge and disposal site and in adjacent areas." RiverKeeper simply says (Ex. 44, p 48) that the standard is not met and cites to its §404 comments to the USACE on the dredge and fill permit (Ex. 44, attachment 70). The applicant responds that it provided extensive hydrodynamic modeling of the dredge operation and that the "DEIS addressed the impacts in detail and determined that they can be acceptably mitigated by the proposed mitigation measures." (Ex. 193, p 60-61). The staff report reiterates all of the modeling, studies and analyses that the applicant has undertaken and the mitigation measures it will employ to achieve this standard (staff report at 147-149) and concludes that the standard is met. The applicant also cites to the city's outside expert review (Staff report Ex. 2), and asserts that the consultant "reviewed and concurred with the Impact Assessment."

The Officer begins with the language of the standard that must be met, which is expressed in pretty mandatory terms without modifiers. Basically, WDC 16.160.040(C) requires that "undesirable" impacts "shall be avoided." The City Commission, for whatever reason, adopted a standard with little wiggle room for an applicant that proposes a project with <u>any</u> unavoidable undesirable dredge impacts. The applicant has provided abundant (a preponderance of) evidence that it has evaluated the dredge impacts, modeled those impacts and has minimized the impacts to the extent practicable, including mitigating conditions. However, the applicant does not claim that it will avoid all undesirable impacts of the dredge. The record has considerable information about the undesirable impacts of the dredge, beginning with the applicant's own expert studies (DEIS §4.1.5.2), including RiverKeeper's §404 comments to the USACE (Ex. 44, attachment 70, p 50-53), RiverKeeper's expert studies of the undesirable impacts of the dredge (Ex. 44, attachment 1, p 21-25), and ODFW's §404 comments to the USACE (Ex. 44, attachment 63, p 4-6). The most that can be said is that the applicant may have minimized the potential adverse impacts to the extent practicable (Terminal Application p 5-95 & 5-97), but the standard in WDC 16.160.040(C) is more demanding than that. Based on the strict language in WDC 16.160.040(C) and the applicant's own concession that there will be undesirable impacts from the dredge, the Officer cannot conclude that the standard is met.

d) **<u>Adverse short-term effects of dredging shall be minimized</u>:** WDC 16.160.040(F) requires that *"[a]dverse short-term effects of dredging and aquatic area disposal such as increased turbidity, release of organic and inorganic materials or toxic substances, depletion of dissolved oxygen, disruption of the food chain, loss of benthic productivity, and disturbance of fish runs and important localized biological communities shall be minimized."*

Unlike the standards discussed above, this standard is not expressed in absolute avoidance terms, but requires mere minimization. It is clear from the record that there will be adverse short-term impacts from the dredge operation. <u>See</u> impact citations in preceding section. However, the record does demonstrate with a preponderance of evidence that the applicant has taken significant measures to minimize those impacts (Staff Report p 151-152). As the applicant points out

(Ex. 193, p 61), a lot of the minimization measures it formulated happened after RiverKeeper's §404 comments to the USACE (Ex. 44, attachment 70, p 50-53) and therefore don't reflect the current/final proposal. Based on a preponderance of evidence, the Officer finds that the applicant has demonstrated compliance with this relatively flexible standard.

e) **Effects of initial and subsequent maintenance dredging shall be considered prior to approval:** WDC 16.160.040(G) requires that the "*effects of both initial and subsequent maintenance dredging, as well as dredging equipment marshaling and staging, shall be considered prior to approval of new projects or expansion of existing projects. Projects will not be approved unless disposal sites with adequate capacity to meet initial excavation dredging and at least five years of expected maintenance dredging requirements are available.*"

Again, this standard, WDC 16.160.040(G), is not expressed in mandatory and absolute terms, but requires that effects be considered and that the applicant demonstrate that its dredge spoil disposal site has at least 5 years of capacity. RiverKeeper claims the applicant has not made an adequate demonstration (Ex. 44, p 48-49), but cites only its §404 comments to the USACE (Ex. 44, attachment 70, p 50-53) from January 15, 2015. The applicant points out that RiverKeeper's January 2015 comments are stale (Ex. 193, p 61-62), and in any event, that it has demonstrated that it did consider both initial and subsequent maintenance dredging and that it has demonstrated 5-year capacity at its disposal site. Based on a preponderance of evidence, the Offer finds that the applicant has demonstrated compliance with this relatively flexible standard.

f) **Is mitigation and restoration for impacts from wetland fill and shallow to medium depth dredging adequate:** The last set of WDC ch. 16.160 criteria upon which RiverKeeper challenges the project is WDC 16.160.120, which requires specific project design mitigation actions and compensatory mitigation actions (Ex. 44, p 49) "*to ensure that the integrity of the estuary ecosystem is maintained" and that will "maintain the functional characteristics and processes of the estuary, such as its natural biological productivity, habitats, and species diversity, unique features and water quality.*" WDC 16.160.120(A) & (B). These are the fundamental discretionary approval criteria in WDC 16.160.120 governing mitigation for impacts to shoreland and estuary resources. The balance of the subsections do not provide discretionary approval standards so much as submittal requirements and mitigation plan elements.

RiverKeeper claims that the applicant's mitigation plan is not sufficient under these standards, citing the Williams and Bierly reports (Ex. 44, attachments 1 & 2) and its §404 comments to the USACE (Ex. 44, attachment 70). The applicant provides extensive discussion about this approval standard (Terminal Application 5-114 to 5-122 & 5-206), plus the mitigation discussion in the DEIS (DEIS §2.1.1.3), in post-hearing comments (Ex. 187, p 40-41, 44-46 & 60-61), and in closing arguments (Ex. 193, p 62-63). Staff concluded that the applicant's evidence and argument were sufficient to demonstrate that the standards in this section were met (Staff Report p 175-189).

The starting point, again, must be the specific language and requirements of the City's code standard. WDC 16.160.120 is aimed at the adequacy and efficacy of mitigation for estuary and shoreland impacts. Subsection (B)(1) provides a non-exclusive list of options for mitigation design elements, the object of which is to avoid, reduce or rectify the impact. If "after consideration of impact avoidance, reduction or rectification, there are still unavoidable impacts," the applicant must implement the Subsection (B)(2) compensatory mitigation options. Ultimately, the package of mitigation must achieve the functional requirements in WDC 16.160.120(A) & (B), *i.e.,* "to ensure that the integrity of the estuary ecosystem is maintained" and that it will "maintain the functional characteristics and processes of the estuary, such as its natural biological productivity, habitats, and species diversity, unique features and water quality." There must be a preponderance of credible evidence in the record that these discretionary standards are met.

The applicant provides the following compensatory mitigation measures, conceding that it cannot avoid, reduce or rectify impacts to estuary or shoreland (wetland) resources under Subsection (B)(1):

- enhancement of about 120 acres of estuarine wetland habitat on the Youngs River near its mouth at Youngs Bay, through dike breaching and access channel enhancement and creation;
- removal/replacement of eight road culverts that represent complete barriers to listed salmonids;
- creation and enhancement of wetlands in the floodplain of the Nehalem River;
- long-term protection (through either conservation lease or purchase) of mature riparian habitat along one or more reaches of high-quality salmonid waterbody habitat; and
- habitat acquisition to maintain and restore old-growth habitat for northern spotted owl and marbled murrelet

> "At this time the proposed compensatory mitigation is conceptual and is based on the input from the FWS, NMFS, and state agencies. However, Oregon LNG has stated that it is committed to implementing the minimum elements of compensatory mitigation measures described in this EIS if FERC authorizes the project. For undefined mitigation actions, such as locations of fish barrier removal, Oregon LNG would organize an interagency Adaptive Management Team consisting of representatives from FWS, NMFS, ODF, ODFW, and WDFW that would review specific mitigation projects prior to implementation to ensure their consistency with the mitigation commitments described in this EIS." (DEIS p. 2-17)

The applicant's closing arguments perhaps best sum-up its approach to mitigation (Ex. 193, p 62-63): enhancement of ~140 acres (or ~120 acres) of shallow-water estuarine wetland habitat in Youngs Bay near the mouth of Youngs River by breaching a mile-long dike at 2 or 3 points to allow tidal re-flooding of the area:

> "Construction and operation of the Terminal will require permanent and temporary aquatic area and wetland impacts. Thus, Oregon LNG identified approximately 120 acres situated on three existing parcels in rural Clatsop County at the mouth of the Youngs River to mitigate

> for permanent wetland impacts at the Terminal within the Lower Columbia Watershed [4th HUC]. The conceptual plan at the compensatory wetland mitigation site is to reconnect the historic floodplain that is behind a dike to tidal marsh habitat. This wetland enhancement will comply with the ODSL-recommended enhancement mitigation ratio of 3:1 (3 acres of enhancement for every 1 acre of impact). Thus, Oregon LNG will enhance approximately 105 acres of the 120-acre mitigation site as wetland to compensate for the approximately 34.9 acres (ODSL 3:1 enhancement ratio) of permanent wetland impacts within the Lower Columbia Watershed at the Terminal site. Oregon LNG has discussed the proposed mitigation site at the mouth of the Youngs River with ODSL and other state and federal agencies. While no formal approval commitments have been made, state and federal agencies indicated the location of the site and conceptual plan to reconnect the historic wetland floodplain with the estuary are consistent with state and federal requirements." (Terminal Application at 5-206)

From this, it is clear that the applicant has not yet firmed-up this mitigation with DSL, the USACE or a cooperating environmental organization to manage the project. Summarizing the mitigation benefits in its closing remarks, the applicant appears to increase the acreage from 120 to 140 acres, and reconfirms that the state (DSL), and federal (USACE) agencies have yet to review, ratify, permit or even endorse the applicant's proposed mitigation:

> "Oregon LNG responded to EPA and Bierly's comments on the mitigation site. Oregon LNG demonstrated that the Youngs River mitigation site would provide in-kind mitigation because the impacts are primary to freshwater wetlands and marshes with low salinities comparable to salinities at the mitigation site. Comparisons of site elevations show that elevations at the mitigation site are appropriate for restoration of vegetated low marsh habitat, the very type of fringe habitat that opponents have identified as being important for salmonids. Hydrodynamic modeling showed good water circulation throughout the mitigation site. Furthermore, at a mitigation ratio of 3 to 1, the mitigation site would provide a greater area of tidal marsh than the area of wetlands that would be impacted. Whereas diking has repeatedly been listed as a primary cause to loss of historic tidal wetland floodplain habitat, the proposed mitigation would contribute to reversing the cause of the historic loss of tidal floodplain. Oregon LNG also committed to coordinating with USACE and EPA, as commenting agency, in the development of the wetland mitigation plan to ensure compliance with Section 404(b)(1) guidelines." (Ex. 193, p 62-63)

In evaluating the feasibility or efficacy of proposed mitigation, the Officer must look to at least preliminary comments from reviewing agencies and outside experts who have reviewed the mitigation plans. In this regard, the Officer is persuaded by ODFW comments that the validity of the mitigation plan is far from settled (Ex. 186 & Ex. 44, attachment 63). Just before the record closed in this proceeding, ODFW reiterated its prior concerns about the applicant's proposed mitigation plan:

> "Lastly, ODFW has concerns that the proposed Young's River Mitigation site will not adequately mitigate for impacts to estuarine wetland habitat at the proposed OLNG terminal and marine facility site. Specifically, we do not believe that the proposal is consistent with ODFW's Habitat Mitigation policy (OAR 635-415-000 through 0025) which governs the Department's provision of biological advice and recommendations concerning mitigation for losses of fish and wildlife habitat caused by development actions. ODFW considers the estuarine wetland habitat at the terminal site to be Category 3 Habitat per the Habitat Mitigation Policy. For this habitat category, ODFW recommends (1) no net loss of either habitat quantity or quality; (2) avoidance of impacts through alternatives to the proposed development action; or (3) mitigation of impacts, if unavoidable, through reliable in-kind, in-proximity habitat mitigation to achieve no net loss in either pre-development habitat quantity or quality. The primary issue with the Applicant's proposal is that: (1) mitigating loss of tidal saltmarsh habitat with restoration of freshwater marsh habitat would be considered by ODFW to be out-of kind habitat mitigation; and (2) the assemblage species impacted at the terminal site would not be the same as those benefitting from the restoration of the Young's River site and would therefore be considered out-of-proximity mitigation. If the mitigation standard is not met, per OAR 635-415-0025(3)(c) the "Department shall recommend against or shall not authorize the proposed development action." (Ex. 186, p 3-4)

See also Ex. 44, attachment 63, p 15-16. This comment echoes the concerns expressed in the Bierly Report (Ex. 44, attachment 2, p 10-11):

> "The site proposed for Oregon LNG's development has been proposed for development multiple times in the past. The environmental studies of those proposals have been extensive (Slotta and Boley, 1975; Higley and Holton, 1975; Montagne & Associates, Inc., 1976). These analyses of the physical and biological conditions of the site and surrounding Youngs Bay ecosystem have been significantly updated with work done through the Lower Columbia River Estuary Partnership and others to provide a broader context of the significance of shallow intertidal marshes and flats to juvenile salmon and other ecosystem functions. Given the history of ecological alterations to the Youngs Bay shallow tidal areas and the growing understanding of the significance of these systems to juvenile salmon, further alteration cannot be considered insignificant.
>
> "The proposed development will impact some 35 acres of tidal marsh at the terminal site. Oregon LNG's assumption that the site meets ODFW Priority Habitat Category 5 is based on personal opinion and is not supported by subsequent evaluation of comparable marsh sites throughout the estuary (LCREP, 2013). The ecological evaluations of the East Skipanon Peninsula conducted for other development proposals have not resulted in the conclusion that the marshes of the

Skipanon are "degraded" or "non-essential". On the contrary, the tidal marshes of the site were considered to constitute a significant impact. The proposed terminal project will likely result in significant impacts to the tidal marshes at the mouth of the Lower Columbia River estuary.

"The proposed site lies in the area of the most significant historical loss of intertidal wetlands in the Lower Columbia River estuary. Nearly all the intertidal wetlands of the Skipanon and Alder Creek area have been diked and alienated from the estuary. Most of the remaining intertidal marshes in the reach have established on unconfined dredge material disposed more than eight decades earlier. Recent research on juvenile salmonid use of the estuary has documented extensive use of similar marshes established on disposal material (Thom et. al., 2012).

"The proposed mitigation site lies nearly 5 to 6 miles up Youngs River, a significantly different relationship to the Columbia River than the impact site. The proposed restoration action also raises questions about the functional benefits to juvenile salmon if the diked area is to be breached in only two or three locations. There is no biological basis for the proposal other than the results of the hydrological modeling that shows flooding of the entire site but has no evaluation of the biological outcomes from restoration."

To a certain extent the applicant successfully rebuts many specific statements in the Bierly Report regarding the technical aspects of the proposed mitigation in Youngs Bay (Ex. 187, p 41-47, Ex. 193, p 24-25, 29-30). The applicant even rebuts ODFW's comments (Ex. 193, p 28, Ex. 191, 17-21). But, the applicant fails to address the fundamental determination that the Officer must make, *i.e.,* that its mitigation will "ensure that the integrity of the estuary ecosystem is maintained" and will "maintain the functional characteristics and processes of the estuary, such as its natural biological productivity, habitats, and species diversity, unique features and water quality." WDC 16.160.120(A) & (B).

Based on all of the evidence in the record regarding the permanent wetland impact and whether the proposed mitigation is (or is likely to be) adequate, the Officer takes several lessons: (1) Historically, there has been a tremendous loss of prime tidal marsh wetland from the Lower Columbia River Estuary, from which 89% (9,100 acres) has been filled and drained, including ~6,000 acres of emergent tidal marsh wetland from the Skipanon and Youngs Bay area. These are biologically active areas that are vital to the ecological health of the estuary. (2) Mitigation wetlands, in this case a reclaimed pasture, often do not work because they do not replicate or replace the biological or ecological functions lost from the tidal wetlands that were filled. The near-by Astoria Airport mitigation area is cited as an example, and DSL's required 3:1 mitigation ratio is symptomatic of the problem. This does not mean that this mitigation plan will not work; however, it eliminates any presumption that the plan will work unless there is credible and relevant supporting biological and ecological evidence. (3) The applicant has not conducted any focused, systematic or quantitative analysis of the biological or ecological function (or likely function) of the proposed mitigation area (reclaimed pasture); the applicant conducted only hydrological modeling to determine that the area will flood at high tide. The applicant is depending solely upon the future review and hoped-for approval of state and federal resource agencies, *e.g.*, DSL, ODFW, USACE and USFW , to corroborate its unsupported statements that the mitigation area will function from an ecological perspective. While that could happen, credible and compelling evidence in the record leads the Officer to doubt that these agencies will simply ratify the applicant's proposal as-is. The Officer finds that the applicant has not successfully rebutted these points that are expressly stated in the Bierly Report and clearly reflected in ODFW comments.

From this, the Officer concludes that the record does not contain substantial evidence that the proposed mitigation for the permanent wetland impacts will function from an ecological or biological perspective, certainly there is no credible or convincing evidence that this 120 (or 140) acres of reclaimed pasture will function or replicate/replace the 35 acres of permanent wetland impact, which is an increasingly scarce and valuable resource in the Lower Columbia River Estuary. Absent some such credible evidence, the applicant has not demonstrated that the proposed mitigation will "ensure that the integrity of the estuary ecosystem is maintained" or that it will "maintain the functional characteristics and processes of the estuary, such as its natural biological productivity, habitats, and species diversity, unique features and water quality," as WDC 16.160.120(A) and (B)(2) require. Even though the state and federal resource agencies, upon whose future ratification the applicant depends (Ex. 193, p 62-63) might agree, there is no evidence that that is likely to happen.

This is not a situation controlled by *Gould*[24] or *Wetherell*,[25] where a condition that the applicant simply obtain a discretionary state or federal permit was sufficient and there were no corresponding local code criteria that had to be met. To be clear, the opponents have not demonstrated that the applicant is precluded as a matter of law from obtaining its DSL or USACE fill permits. Rather, this applicant has a substantial burden of proof under WDC 16.160.120, and it is promising to someday obtain discretionary state and federal permits as a substitute for demonstrating today that it complies with the local criteria implementing Goals 16 and 17.[26] If DSL or the USACE had already issued their fill permits based on the applicant's mitigation plan, after consultation with the state and federal wildlife agencies, that might be compelling evidence that the mitigation plan was

[24] *Gould v. Deschutes County*, 54 Or LUBA 205, 266 (2007). It is sufficient for the local government to require that the applicant obtain the discretionary state or federal permit as a condition of approval unless there is evidence that the applicant is precluded as a matter of law from obtaining those permits. Stated differently, the applicant need not prove compliance with the state and federal permit criteria as part of the local land use process and as a precondition for obtaining local land use approval. *See also Bouman v. Jackson County*, 23 Or LUBA 628, 647 (1992)], in which LUBA held in the context of water availability, that "a decision approving the subject application simply requires that there be substantial evidence in the record that [the applicant] *is not precluded from obtaining such state agency permits as a matter of law."*

[25] *Wetherell v. Douglas County*, 44 Or LUBA 754, 764 (2003), standing for the same proposition, but LUBA's holding was based, in part on the particular language of the Douglas County Code.

[26] As mentioned previously, the City's 2006 decision has no precedential relevance to this determination because the City Commission's findings in that earlier proceeding expressly stated that the local criteria implementing Goals 16 and 17 would be evaluated in the first instance in the context of a specific development proposal, which is now.

sufficient to meet the WDC 16.160.120 criteria. Absent any such permits, however, and with a preponderance of credible evidence in the record that the mitigation plan may be wholly illusory from a biological and ecological perspective, this application falls short of the mark.

8. WDC Ch. 16.164: Impact Assessment and Resource Capability Determination standards, Impact Assessment Conclusion and Resource Capability Determination:

WDC ch. 16.164 contains the fundamental Goal 16 and 17 evaluation and discretionary approval criteria for a project such as this, which presents significant impacts to the City's Goal 16 and 17 coastal and estuary resources. This chapter is also the focus of the natural resource evaluation for impacts to the City's Goal 5 inventoried wetlands that are also contained within the City's Goal 16 and 17 boundaries.[27] See OAR 660-023-0240(2) and WCP §4.100. This project's impacts to the City's Goal 16 and 17 resources include 35 acres of permanent wetland fill and 109-acres (1.2 million cy) of estuary dredge impact, plus associated construction of docks and placement of pilings. WDC ch. 16.164 requires a substantial amount of information and analysis by way of submission requirements (WDC 16.164.030) and provides the following relevant decisional options:

> *16.164.040 Impact Assessment Conclusion. Based on the information and analysis in Section 16.164.030, one of the following four conclusions shall be reached:*
>
> *A. The proposed uses and activities do not represent a potential degradation or reduction of estuarine resource.*
>
> *B. The proposed uses and activities represent a potential degradation or reduction of estuarine resources. The impact assessment identifies reasonable alterations or conditions that will eliminate or minimize to an acceptable level expected adverse impacts.*
>
> *C. The proposed uses and activities will result in unacceptable losses. The proposed development represents irreversible changes and actions and unacceptable degradation or reduction of estuarine resource properties will result.*
>
> *D. Available information is insufficient for predicting and evaluating potential impacts. More information is needed before the project can be approved.*
>
> *16.164.050 Resource Capability Determination. Some uses and activities may only be approved when consistent with the resource capabilities of the area and the purposes of the zone. This section describes procedures for making this determination. A completed resource capability determination consists of the following elements:*
>
> *A. Identification of the affected area's zone, and its purpose.*

[27] Wetlands of Warrenton, Oregon Technical Report Number 1, Wetland Conservation Plan Inventory, October 15, 1993. The ESP is identified as estuarine wetlands at p 295.

B. Identification of the types and extent of estuarine resources present and expected adverse impacts. This information is included in the impact assessment.

C. A determination of whether the use or activity is consistent with the resource capabilities of the affected zone. A use or activity is consistent with the resource capabilities of the area when either:

1. Impacts on estuarine resources are not significant; or

2. Resources of the area will be able to assimilate the use and activity and their effects and continue to function in a manner which:

a. In natural aquatic zones, protects significant wildlife habitats, natural biological productivity, and values for scientific research and education; or

b. In conservation aquatic zones, conserves long-term use of renewable resources, natural biological productivity, recreation and aesthetic values and aquaculture.

As a starting point, the items listed in WDC 16.164.030 (Information Needed for an Impact Assessment) appear to be submission requirements and are not expressed as approval criteria.[28] While it is questionable that the applicant has fully complied with item I (demonstration that the project's potential public benefits will equal or exceed expected adverse impacts), this application was deemed complete long ago, and the Officer finds that the applicant has achieved substantial compliance with all such submission requirements. For this reason, the Officer rejects RiverKeeper's assertion that the application should be denied simply because it believes that the applicant's submissions are insufficient relative to the list in WDC 16.164.030 (Ex. 44, p 51-54).

a) **Impact Assessment Conclusion:** WDC 16.164.040 requires a threshold decision to be made about the environmental (estuary and shoreland) impacts of the project by picking one of the following based on a preponderance of evidence in the record:

1) No potential degradation or reduction of estuarine resources; or
2) Potential degradation or reduction or estuarine resources, but alterations or conditions will eliminate or minimize impacts to an acceptable level; or
3) There will be unacceptable losses, irreversible changes and unacceptable degradation or reduction of estuarine resources; or
4) More information is needed before the determination can be made and the project approved.

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[28] *LeRoux v. Malheur County*, 32 Or. LUBA 124, 129 (1996), ("The fact that application requirements may not have been satisfied provides no basis for remand absent a showing that the failure to satisfy the requirements resulted in non-compliance with at least one mandatory approval criterion.") citing *Champion v. City of Portland*, 28 Or LUBA 618 (1995); *Wissusik v. Yamhill County*, 27 Or LUBA 94 (1994).

The applicant's Columbia River Estuary Impact Assessment is in Appendix G to the application and is further explained in the DEIS (DEIS §§4.1.4 & 4.1.5). On this basis, the applicant asserts that the project, as proposed, will eliminate or minimize impacts to an acceptable level (Terminal Application p 5-141). RiverKeeper and virtually all of the opponents assert that the estuary and shoreline impacts of the project are so severe that the project will result in "unacceptable losses," "irreversible changes" and "unacceptable degradation or reduction of estuarine resource properties" (Ex. 44, p 49- 50, Ex. 188, p 16-20). RiverKeeper relies on its own expert evaluations of the project and its impacts on estuary and shoreland resources by Bierly and Williams (Ex. 44, attachments 1 & 2). Additionally, RiverKeeper relies on comments it submitted on the §404 water quality certification (Ex. 44, attachment 70) as well as those of EPA (Ex. 44, attachment 64) and ODFW (Ex. 44, attachment 63). The Officer recognizes that the §404 comments were submitted at an early stage of the project (January 2015) and address the entire project, and not just the Warrenton components.

In response to these comments, the applicant has repeatedly emphasized that it has and continues to coordinate with state and federal agencies to refine and improve the project, reduce its impacts and perfect its mitigation for unavoidable impacts (Ex. 187, p 56-67; Ex. 191, p 15-22; Ex. 193, p 7-10). The applicant also has endeavored to respond point-by-point to the technical aspects of the opponents' arguments and agency comments (Ex. 187, p 60-67; Ex. 193, p 24-25, 28-33).

Again, the record on these issues is large and contains conflicting information and opinion about (1) the value of those resources as habitat in the ecology of the Lower Columbia River Estuary, (2) the magnitude of the project's impact on estuary and shoreland resources, and (3) the efficacy and adequacy of the proposed mitigation to restore the biological function of these resources. With regard to the first consideration, habitat value, the Officer views as credible ODFW's characterization of the estuary and wetland habitat values in its comments to the USACE. With regard to the habitat value of the portion of the 109-acre estuary dredge area, ODFW said the following:

> "3.3 Habitat and Species Use: Subtidal soft-sediment habitats provide a series of diverse, productive, and dynamic ecological functions and values in the LCR estuary. These ecological functions include (among others) provision of habitat for foraging by invertebrates, fish, birds, and marine mammals. In addition, some species of fish may use the soft-sediment habitat as a nursery area, and the subtidal zone provides an important source of detritus, which serves as a food source for a number of species. Soft-sediments also play an important role in the microbial and biogeochemical transformations of organic materials/compounds for nutrient cycling, and they typically serve as a sink or reservoir for the deposition of water-borne particles. In some benthic zones large quantities of nutrients (i.e. phosphorus) and organic material are essentially stored for a period and subsequently released in pulses with seasonal current and thermal variations. Diverse communities of motile, epifaunal, and infaunal invertebrates inhabit subtidal soft-sediments, and the communities of arthropods, annelids, cnidarians, mollusks, echinoderms, and other invertebrates are specifically adapted to survive,

feed, grow, and reproduce themselves in the unconsolidated sediments. Microbial activity and deposition of organic matter associated with fine-grained sediments together support a complex food web that includes resident (infaunal, epifaunal, motile) and transitory (seasonal, migratory) species. Mixed communities of shellfish, such as Dungeness crab, bay shrimp, seastars, gaper clams, butter clams, littleneck clams, softshell clams, cockles, and many other species may occur in the subtidal areas of Oregon estuaries, and many of these species may inhabit the proposed OLNG dredge impact area. Some of these shellfish are motile (e.g. crabs, shrimp, snails, seastars, etc.) and may inhabit or migrate through the subtidal zone, while others are sessile (e.g. cnidarians, bivalves, etc.) and remain in place over the duration of their adult lives. Ambient environmental conditions such as the composition and organic content of the substratum, salinity, depth, water temperature, depth of the aerobic layer, sedimentation rate, and degree of disturbance are often critical factors that determine the specific locations where shellfish occur. The mixed communities of living bivalves and the beds of their non- living shells (e.g., shell rubble or shell hash) function to help stabilize unconsolidated sediments and provide heterogeneous habitat for numerous species of adult and juvenile fishes, crabs, shrimp, amphipods, worms, and other estuarine organisms. In some cases, filter-feeding populations of bivalves play an important role in the removal of phytoplankton and smaller particulate materials, thereby decreasing turbidity and increasing light penetration throughout the water column.

"Several species of demersal fishes inhabit Oregon estuaries, and many of these (e.g., Starry flounder, English sole, sand sole, staghorn sculpins, sturgeon) are benthic feeders that utilize subtidal habitat to locate their prey, as well as for spawning and rearing. Subtidal habitat is also used by many species of migratory fishes such as fall Chinook salmon, coho salmon, steelhead, chum salmon, coastal cutthroat trout, eulachon, topsmelt, Pacific herring, longfin smelt, surf smelt, northern anchovy, etc., and other species (e.g., lingcod, greenling, rockfishes, gobies, sand lance, surfperches, threespine stickleback, Pacific tomcod, and sturgeons). As stated by the applicant (Section 4 / Description of Resources in Project Area) the OLNG terminal portion of the project could potentially impact salmonid rearing and migration habitat, lamprey migration habitat, eulachon rearing, spawning and migration habitat, and green sturgeon feeding habitat within the LCR estuary. As estuarine fish grow they typically move into deeper subtidal areas (often as their ability to avoid predation increases) to meet their survival needs. Species such as sole, sand lance, and sculpin create burrows in subtidal soft-sediments to escape predation and to forage for benthic food resources. Salmonids and other fish species also rear and migrate through subtidal soft-sediment habitats to access high energy, primary, or alternate food sources such as burrowing amphipods and other epibenthic or benthic invertebrates. Soft-sediment habitat is also utilized by numerous shallow-water fish (i.e., sculpins) during periods of low tide when they seek refuge in the deeper subtidal areas that are continuously under water. The subtidal habitat zone provides a critically important food source (e.g., epibenthic and infaunal invertebrates) for these species during low tides."

(Ex. 44, attachment 63, p 5-6)

With regard to the habitat value of the ~35 acres of wetland that will be impacted, ODFW said the following:

> Terminal Wetland Impacts Characterization: The proposed wetland impacts at the terminal and ancillary facilities consist of 3.15 acres of temporary impacts and approximately 34.92 acres of permanent impacts. ODFW's understanding is that DSL has reviewed and approved the OLNG terminal wetland delineation report. The proposed wetland impacts at the terminal occur primarily in estuarine intertidal emergent marsh habitat (29.35 ac.) which in this area ODFW considers to be Category 3 Habitat per the FWHMP. <u>This shallow-water habitat is critical for rearing habitat for several ESA-listed salmonids and is also used by a variety of other estuarine-dependent species</u>. For this habitat category, ODFW recommends (1) no net loss of either habitat quantity or quality; (2) avoidance of impacts through alternatives to the proposed development action; or (3) mitigation of impacts, if unavoidable, through reliable in-kind, in-proximity habitat mitigation to achieve no net loss in either pre-development habitat quantity or quality." (Ex. 44, attachment 63, p 15).

EPA provided general and preliminary §404 comments on the project, where in pertinent part it said:

> "EPA has some concerns that the proposed project will not provide the level or degree of economic benefit that the applicants and local governments are anticipating, but will instead contribute to further degradation of environmental conditions within the lower Columbia River estuary while eliminating or changing very valuable in-channel and near shore habitat conditions. ... EPA is concerned that while this project will add some ecological benefits to the overall system, it does not result in a net gain in wetland habitat in the estuary. Due to the many complexities associated with this mitigation proposal, EPA recommends that the Corps consider providing additional interagency review into the proposed CWMP to provide more detailed input towards its completion and approval." (Ex. 44, attachment 64, p 2 & 4).

While EPA's §404 comment pre-dates the applicant's full wetland mitigation plan, its Impact Assessment (Terminal Application App G) and the DEIS (released August 2015), EPA makes relevant and credible comments about the ecological and habitat value of the Lower Columbia River Estuary and the development site.

Collectively, these comments that describe the ecological importance of the habitats that stand to be affected by this project are mirrored in the literature review and descriptions provided in the Bierly Report on wetland impacts (Ex. 44, attachment 2, p 6-8) and the Williams Report on estuary impacts (Ex. 44, attachment 1, p 5-21). In its closing arguments, the applicant describes RiverKeeper's characterization of the estuary habitat as "bizarre" and claims that "the evidence demonstrates that the area is already deep water habitat and has 'minimal biological significance'," citing the City's findings from 2006 (Ex. 193, p 23 & 57). The Officer disagrees.

The Officer regards the ODFW description of the habitat value of the estuary and wetlands that will be impacted as credible and compelling evidence that is corroborated by EPA's 404 comments and the Bierly and Williams Reports, which are also credible and compelling. Granted, these are not the best estuary or wetland habitats, but in the Lower Columbia River Estuary, even suboptimal habitat is significant because so much has been lost over the years to filling, diking, dredging and diversions. In light of this history of habitat loss and extensive review of relevant ecological studies confirming use of these and near-by estuary and wetland habitat by many fish and invertebrate species, the Officer finds the applicant's rebuttal in Ex. 187 to be not credible. The applicant's rebuttal states that, while some of the more recent studies cited by Bierly and Williams post-date the applicant's Impact Assessment and the DEIS, the data used in those studies were considered (Ex. 187, p 33-39, 41-47). Bierly and Williams cited these papers for more than just the data they rely upon, but also their analysis of the data and their conclusions. Therefore, the Officer regards the Bierly and Williams Reports as more credible than the applicant's on the issue of habitat value and the severity of the project's impact on those habitats. For the applicant to claim that "the mere presence of ESA-listed fish in the vicinity of the proposed project does not necessarily imply negative impact" (Ex. 187, p 34) defies logic. To then rely upon relatively ill-defined and unproven mitigation measures to reduce or eliminate negative effects is similarly specious, especially in light of the removal of 1.2 million cy of sediment and a wetland mitigation plan that lacks sound biological and ecological evaluation and verification. The applicant's hydrologic modeling of the Youngs Bay mitigation area is no substitute for an ecological/biological evaluation. Thus, the Officer disagrees with the applicant's attempt to minimize the significance of the estuary and shoreland habitat that will be permanently impacted. A preponderance of the credible evidence shows the opposite.

Regarding the significance of the project's impact, again, the Officer cannot credit the applicant's attempts to minimize the impacts of the 109-acre dredge footprint and ~35-acre permanent wetland impact, which state and federal environmental agencies regarded as significant (Ex. 44, attachment 63, p 4-6 & 15; Exs. 21 & 186). The Officer regards a 109-acre dredge footprint and removal of 1.2 million cy of sediment to be significant, perhaps not when compared to the USACE's Columbia River channel deepening dredge program, but it is a significant loss when compared to any recent project in shallow to medium depth areas of the Lower Columbia River Estuary. The Officer is not persuaded that other dredge projects cited by the applicant (Ex. 187, p 30-33) are comparable to this one. In this regard, the Officer finds that RiverKeeper has persuasively rebutted the applicant's arguments (Ex. 188, p 16-18). The Port of Astoria dredging project of an initial 364,000 cy is far smaller than what is proposed here, especially when the DEIS states that the Youngs Bay impact will be 148 acres (DEIS, p ES-1). The Port Westward project does not appear to involve any dredging, so its relevance to this case is not apparent. Finally, while the Columbia River Channel Deeping Project involves a massive amount of dredging, all of that dredging will occur in the main shipping channel, which is a far different part of the estuary than the area at issue here.

Similarly, the Officer finds that a ~35-acre permanent wetland impact is also a significant loss of habitat in the context of the Lower Columbia River Estuary, which has seen big wetland losses since pre-settlement times (Ex. 44, attachment 2, p 2-5). The preponderance of credible evidence is against the applicant on this issue.

Finally, RiverKeeper indicts the applicant's dredge mitigation measures and its wetland fill mitigation plan. As discussed under WDC 16.160.120, the Officer has already determined that the wetland mitigation plan is unproven and unverified from a biological or ecological perspective. In light of the significance of the estuary and shoreland habitat loss that will occur, a mitigation plan with a sound and verified ecological evaluation is warranted. It is not sufficient to simply rely upon on-going agency review, a future evaluation of the plan and hoped-for ratification by state and federal agencies to validate the mitigation plan. As the Officer indicated in response to WDC 16.160.020, the Lower Columbia River Estuary, and Young's Bay in particular, play an important role in the 2008 BiOp for the FCRPS and the two subsequent Supplemental BiOps, which identify funding for the Youngs Bay SAFE Area and others as a Reasonable and Prudent Alternative. The fact that the FCRPS BiOp is a jeopardy opinion and identifies Youngs Bay for mitigation projects, that it is designated as a SAFE Area, that there is a designated closure zone that includes the terminal area, and that the area is identified by credible scientific studies as habitat for several ESA-listed salmonids at different times of the year for different lengths of time, is strong evidence that these will be deemed important habitats and the project's impact on these habitats will be significant. It is also strongly suggestive that USACE will not simply ratify the mitigation plan after consultation by NMFS and issuance of its BiOp on this project, which could well be a jeopardy opinion.

Based on the foregoing findings, the Officer cannot conclude there will be no potential for degradation or reduction of estuarine resources. Also, it is not possible to impose conditions of approval to rectify the above-mentioned deficiencies. The applicant has the burden of proving by a preponderance of evidence that all of the mandatory approval criteria are met or can be met through the imposition of conditions. Compliance with several mandatory approval criteria in WDC ch. 16.160 cannot be determined based on the existing record, and those discretionary determinations cannot be deferred through conditions to another time. Therefore, the question is whether the record demonstrates that those criteria are not and cannot be met, or whether, through the submission of additional evidence, could the applicant make the required demonstration.

The Officer concludes that it is theoretically possible, through the submission of more or different evidence, that the mandatory approval criteria could be met. In particular, given the lack of a biological or ecological assessment of the wetland mitigation site, the mitigation plan could be modified to overcome the above-noted deficiencies, especially if federal and state agencies provide positive substantive comments on the plan. For other criteria, rehabilitation is much less likely, but nonetheless possible. For that reason, the Officer concludes that the record is currently insufficient for him to determine there will be no unacceptable losses, irreversible changes or unacceptable degradation or reduction of estuarine resources. The record is insufficient, but more or different information could allow the Officer or City Commission to make that determination; although, that seems unlikely based on the fundamental nature of the project and the estuary and shorelands that will be impacted.

b) **Resource Capability Determination:** WDC 16.164.050 provides that some uses may only be approved when consistent with the resource capabilities of the area and the purposes of the zone. In this case, those limitations are the local implementation of State-wide Planning Goals 16 and 17, the substance of which have been discussed under the preceding sections corresponding to WDC ch. 16.160 and 16.164. To pass muster under this criterion, the record must be sufficient to support one of following alternative findings, with the implication that if neither determination can be made, the project cannot be approved:

1. *Impacts on estuarine resources are not significant; or*

2. *Resources of the area will be able to assimilate the use and activity and their effects and continue to function in a manner which:*

   a. *In natural aquatic zones, protects significant wildlife habitats, natural biological productivity, and values for scientific research and education; or*

   b. *In conservation aquatic zones, conserves long-term use of renewable resources, natural biological productivity, recreation and aesthetic values and aquaculture.*

Based on the Officer's conclusions under WDC 16.160.020(B) & (C) and 16.160.120, related to adverse impacts to estuary and shoreland resources, public trust rights and the application's failure to minimize those impacts, and similar findings under WDC 16.164.040, the Officer concludes that the project poses significant impacts on estuarine resources. The remaining question is whether the estuarine resources of the area will be able to assimilate the project's impacts (construction and operations) and still continue to function at an acceptable level. This is an evidentiary question, and the applicant bears the burden of proving with a preponderance of evidence in the record that WDC 16.164.050(C)(2)(b) is or can be met.

RiverKeeper claims that the impacts of the terminal construction on estuary resources are simply too traumatic, most notably the 109-acre (1.2 million cy) dredge and ~35 acre wetland fill, to pass muster under this standard (Ex. 44, p 54). In support of its argument, RiverKeeper relies on the Bierly and Williams Reports (Ex. 44, attachments 1 & 2) and EPA's §404 comments to the USACE from January 2015 (Ex. 44, attachment 63). The applicant has responded throughout the process by emphasizing its efforts to avoid and minimize the project's impact on estuary resources, reduce its dredge and wetland fill footprint, and to use construction methods and operational techniques that, according to the applicant, ensure that the estuary continues to function at acceptable levels (Terminal Application p 5-141 & 5-142 and App G; Ex. 193, p 68). The applicant simply states that the proposal is for a use allowed outright in the City's A-1 zone, the applicant has submitted all of the required materials and analyses, and Appendix G demonstrates compliance with the standard.

The Officer cannot decide this criterion based on EPA's §404 comments that were submitted at such a preliminary stage of the process (January 2015); however, as noted earlier, EPA's comments contain a reliable description of the importance of the affected estuary resources in the ecology of the Lower Columbia River Estuary and the importance for maintaining their function. EPA's comments are strongly supported by the Bierly and Williams Reports and sources cited therein, and ODFW's comments (Exs. 21 & 186; Ex. 44, attachment 63) all of which the Officer finds to be credible and persuasive evidence on this issue. From this, the Officer concludes that the project's impact on the estuary and shoreland resources will be significant. The only question is whether the record is sufficient to demonstrate that the proposed mitigation will off-set those impacts sufficiently to allow the estuary resources to function at acceptable levels. The Officer concludes that it is not.

The Officer finds, based on a preponderance of evidence in the record, that the project's impacts have not been mitigated adequately, most notably the 109-acre dredge and 35-acre wetland fill. At least the record is not sufficient to demonstrate that the mitigation is adequate. The record clearly establishes the ecological importance of the remaining shallow to mid-depth habitat in the Lower Columbia River Estuary to ESA-listed salmonids and other fish and invertebrates. This status and ecological importance is confirmed by the 2008 FCRPS jeopardy BiOp and the two subsequent Supplemental BiOps, which identify funding for the Youngs Bay SAFE Area, among others, as Reasonable and Prudent Alternatives. The state's closure zone that includes Youngs Bay and the terminal area further demonstrate the importance of this estuary area as habitat. Similarly, a ~35-acre wetland fill will be a significant loss in the context of the massive loss of tidal wetlands in the Lower Columbia River Estuary over the past 30 to 40 years. The preponderance of evidence in the record demonstrates the ecological significance of the affected estuary resources and the significance of the project's impact on them.

What is missing from the record is any comparably credible evidence that the applicant's mitigation measures will work, much less, that the mitigation measures will make-up for these significant losses and allow the estuary resources to continue to function. As the Officer reads the application and record, however, Youngs Bay mitigation site where 120 acres (or 140 acres) of diked pasture will be reclaimed (flooded) is intended to mitigate for the ~35-acre wetland fill. There is no comparable mitigation area for the loss of 109-acres of benthic habitat removed by dredge and which will be re-dredged every 2 to 3 years thereafter. In this regard, the Officer agrees with RiverKeeper's conclusion that the 109-acre (1.2 million cy) dredge is a significant estuary habitat impact with little or no demonstrably sufficient mitigation (Ex. 44, p 45-47). No matter how carefully dredge operations are conducted, they still remove benthic habitat and still cause sedimentation and turbidity.[29] Granted, the 109-acre area to be dredged has only a small portion of shallow-water habitat, but the balance is mid-

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[29] The applicant has not determined how dredging will occur or by what method (Application App G, p 3-75). RiverKeeper notes this a significant omission since it affects the degree of impact so significantly (Ex. 44, p 45-47). The Officer agrees that the lack of detail is a significant omission because it affects the kind and degree of impact.

depth off-channel habitat, which the record shows is important resting habitat for ESA-listed salmonids. On this point, even EPA's and ODFW's preliminary §404 comments are relevant and valid. Where these comments are deficient is they lack an evaluation of the applicant's mitigation measures and plan, which was not released until after the comments but still lacks detail.

The basic wetland fill mitigation plan is to breach an existing mile-long dike in two or three places and allow tidal flooding of the area that has been used since the early 1900's as pasture land (Terminal Application App G, p 3-76 to 3-83). In support of its wetland mitigation plan, the applicant performed a hydrological modeling exercise to verify that the pasture area would flood. Conspicuously absent, however, is a biological or ecological evaluation of the pasture's recovery potential and whether the techniques proposed for this particular mitigation site will be sufficient, based on comparable and relevant data. The Officer concludes that it is impossible to determine the likely success and effectiveness of the mitigation plan without such an expert evaluation. Absent such an evaluation, the record is not sufficient to demonstrate that the estuary or shoreland impacts of the project will be assimilated to such as degree as to allow the estuary resources to continue to function as required by WDC 16.164.050(C)(2). Additionally, the record reflects a fundamental dispute between the applicant and ODFW as to whether the mitigation offered would be in-kind and in-proximity as required by Oregon's mitigation policy in OAR 635-415-0000 to 0025 (Ex. 186, p 3-4). Despite the applicant's adamant assertions that the mitigation is both in-kind and in-proximity (Ex. 193, p 25), the Officer finds the agency's position to be more credible and reliable until proven otherwise, which to it has not. As previously stated, absent from the conversation to date is an evaluation and opinion by NMFS of the applicant's biological assessment and the project's impact on ESA-listed fish. While a non-jeopardy opinion might be sufficient to validate the applicant's claims about the project's impacts and the effectiveness of its mitigation, the record is not currently sufficient to allow the Officer to make, in effect, such a non-jeopardy determination under the City's Goal 16 and 17 code requirements. As things stand, these evidentiary deficiencies are fatal to a finding of compliance with WDC 16.164.050.

9. <u>WDC Ch. 16.192</u>: Large-Scale Development standards, Soil Suitability and Utilities.

Large-scale developments, such as this one, must demonstrate compliance with the applicable provisions of WDC ch. 16.192. RiverKeeper has challenged the project only with regard to two of these standards: Soil Suitability under WDC 16.192.030, and Utilities under WDC 16.192.050 (Ex. 44, p 54-55). Each of these sections are addressed separately.

a) **<u>Soil Suitability under WDC 16.192.030</u>.** The site is underlain by Coquille-Clatsop complex and Tropopsamments soils, both of which qualify it for the City's Soil Hazard Overlay regulations in WDC ch. 16.96. While the project's compliance with these regulations is addressed above, WDC 16.192.030 requires that all Large-Scale Development provide a soil survey, additional geotechnical information and demonstrate that one of following is met:

1. *The detailed soil survey indicates that there is not a significant amount of hazardous soils on the portion of the site proposed for development; or*

2. *A method of eliminating hazards which could result from soils on the site prepared by a licensed geotechnical engineer and submitted to the City of Warrenton Planning and Building Department for review by a City-appointed engineer who will be paid by the developer and/or property owner.*

The applicant responds to the Soil Hazards Overlay requirements (Terminal Application p 5-33 to 5-34) and to the WDC 16.192.030 requirements (Terminal Application p 5-144 to 5-146) based upon a comprehensive geotechnical investigation (Terminal Application, App F). RiverKeeper asserts that the site's location close to the Cascadia Subduction Zone fault and right on the Columbia River Fault make it inherently unsuitable and unreasonably dangerous. RiverKeeper cites an August 2012 DOGAMI report *Earthquake Risk Study for Oregon's Critical Energy Infrastructure Hub* (Ex. 44, attachment 32) in support of its argument that this site is not appropriate for a major LNG terminal.

In response to these challenges, the applicant provided a summary of its geotechnical investigations at the site and seismic evaluation, including the results of tsunami inundation modeling (Terminal Application App F; Ex. 138, p 22-37). The applicant provided additional responses and analysis of the seismic and tsunami factors and risk after the September hearing (Ex. 187, p 9-16 and Ex. 191, p 9-15), including a response to Tom Horning's report on the Columbia River Fault (Ex. 175). The applicant concluded by stating that it has complied with all of the soil suitability requirements in WDC 16.192.030 (Ex.193, p 69).

Due to the prevalence of moderately to highly compressible soils on the ESP, the Officer concludes that the site is dominated by hazardous soils, thus eliminating the first criterion as a possibility. Therefore, the question is whether the applicant's geotechinical investigation (Terminal Application App F) and foundation and construction design measures (Terminal Application p 5-144 to 5-146) will be sufficient to eliminate the hazards that could result from soils on the site.

The subject of geotechnical investigations, soil suitability, foundation design and damage risk assessments are technical in nature. The only technical information in the record about this particular facility at this particular site and the risks of earthquake damage due to hazardous soils is provided by the applicant. None of the opponents have provided comparably credible, site-specific information on the subject. Even the 2012 DOGAMI report provides only basic advice to incorporate seismic reinforcement and mitigation into facility design and does not recommend against siting energy facilities in the region (Ex. 44, attachment 32, p 12-13).[30] The record is sufficient to convince the Officer that the applicant has

[30] DOGAMI's primary recommendation is that "Energy sector companies must pro-actively integrate seismic mitigation into their business practices for Oregon's energy sector to adequately recover from a magnitude 8.5 to 9 Cascadia earthquake in a reasonable time period." Additionally "Energy sector companies and the State of Oregon should build Oregon's seismic

done that. The applicant's geotechnical investigation appears to be sufficiently thorough and based on subsurface data from the site. From this factual information, the applicant has distilled a set of foundation and building design features that respond to the DOGAMI recommendations, in that they incorporate suitable seismic mitigation sufficient to withstand a significant earthquake, the primary result of which would be to cause liquefaction of the site's soil substrate. While general information about the risks and potential damage from a large Cascadia earthquake is unsettling, the apparent response recommended by DOGAMI involves thorough geotechnical investigations and appropriate foundation and building design. The preponderance of credible evidence in the record is sufficient to convince the Officer that the applicant has complied with WDC 16.192.030.

b) **Utilities under WDC 16.192.050**. WDC 16.192.050 requires a developer to provide complete information about the public utilities and facilities (water, sanitary sewer and transportation) needed to serve the project, at what levels and whether there is adequate existing capacity to serve the anticipated need. Pertinent to this project, this section requires:

> *The development will only be allowed if sufficient capacity exists or suitable evidence indicates it will exist prior to completion of the development construction. In deciding the sufficiency of capacity, consideration will be given to possible increases in flows resulting from activities of existing system users and from facilities which are likely to be built due to the proposed use, but are not part of the development.*

RiverKeeper's focus under this section is the amount of process water the terminal will require and whether the applicant has demonstrated that a sufficient supply is available (Ex. 44, p 55; Ex. 83, p 13-14). The application provided basic information about the terminal's process water demand and the available supply (Terminal Application p 5-147), and the applicant responded to RiverKeeper's challenge on the subject in its post-hearing submissions (Ex. 187, p 8; Ex. 191, p 7-9; Ex. 193, p 69-70).

The plain language of WDC 16.192.050 does not present a high bar to an applicant, but appears to require the applicant to evaluate (quantify) its public utility and service needs and verify that adequate supplies or capacity exists. This is not a demanding standard at this stage of the process, since it clearly anticipates that adequate supplies will not become available until the facility is ready for operation, *e.g.*, use of the standard "suitable evidence," setting a compliance deadline of "prior to completion of the development," and allowance for other users of the system. The record, especially the applicant's post-hearing submissions (Ex. 191, p 7-9), shows that this relatively low standard is or can be met prior to completion of the development with regard to water supply. While RiverKeeper correctly points out that water rights would be needed for some of

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resilience to a Cascadia earthquake. Adopting pro-active practices and a risk management approach will help achieve seismic resilience. Encouraging a culture of awareness and preparedness concerning the seismic vulnerability of the energy sector including long range energy planning should be conducted." (Ex. 44, attachment 32, p 12-13).

the excess process water anticipated by the application, the applicant has demonstrated with sufficient certainty that it can acquire the right to the necessary quantity of water in time. On this basis, the Officer concludes that the applicant has met its burden under WDC 16.192.050.

10. WDC Ch. 16.220: Conditional Use Permit (CUP) criteria.

The fundamental CUP review criteria are set forth in WDC 16.220.030 and require affirmative findings of the following, based on a preponderance of evidence in the whole record:[31]

1. *The proposed use is in conformance with the Comprehensive Plan.*
2. *The location, size, design and operating characteristics of the proposed use are such that the development will be compatible with, and have a minimal impact on, surrounding properties.*
3. *The use will not generate excessive traffic, when compared to traffic generated by uses permitted outright, and adjacent streets have the capacity to accommodate the traffic generated.*
4. *Public facilities and services are adequate to accommodate the proposed use.*
5. *The site's physical characteristics, in terms of topography, soils and other pertinent considerations, are appropriate for the use.*
6. *The site has an adequate area to accommodate the proposed use. The site layout has been designed to provide for appropriate access points, on-site drives, public areas, loading areas, storage facilities, setbacks and buffers, utilities or other facilities which are required by City ordinances or desired by the applicant.*

As previously stated, the LNG terminal use is allowed outright in the A-1 and I-2 zones; therefore, the CUP criteria do not apply generally to the terminal. Only two aspects of the proposal trigger the need for a CUP: (1) ~3.2 acres of temporary wetland impact mitigation in the I-2 zone associated with the terminal construction (illustrated on Terminal Application fig 4-40)[32] and (2) two 190-foot tall LNG storage tanks that will

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[31] The structure of WDC 16.220 is somewhat confusing. The CUP "review criteria" are set forth in WDC 16.220.030 (Review Criteria), and the Officer regards these as the primary mandatory approval standards for CUPs. However, WDC 16.220.020 (Authorization to Grant or Deny Conditional Uses) provides another and slightly different set of standards, about which the code ambiguously says "A new, enlarged or otherwise altered development listed in this Code as a conditional use shall be approved or denied by the Planning Commission under the procedure in this chapter. The Planning Commission shall base its decision on whether the use complies with: ..." The applicant generally addresses the WDC 16.220.020 in a perfunctory sort of way (Application, p 5-163 to 5-165), and RiverKeeper makes a similarly half-hearted argument based on WDC 16.220.020 (Ex. 44, p 56). Clearly the focus of the applicant's efforts and RiverKeeper's attack on the CUPs is under WDC 16.220.030 (Application, p 5-165 to 5-168; Ex. 44 p 56-59). In this Opinion, the Officer likewise focuses on WDC 16.220.030, in part because of the absence of any developed argument by the parties under WDC 16.220.020 and also because the Review Criteria in WDC 16.220.030 subsume all of the substantive criteria one could infer from WDC 16.220.020.

[32] The objective of the temporary wetland impact mitigation is to restore and replant with native wetland vegetation ~3.2 acres area around the terminal that will be disturbed by the terminal construction activities. See Application at p 5-83.

project above and into the airport imaginary surface associated with the Astoria Airport, situated on a horizontal plane 150 feet above the airport's primary runway surface and extending outward from the airport 10,000 feet.[33] No other element or aspect of the terminal is subject to the CUP criteria. The applicant objects to RiverKeeper's attempt to boot-strap in the entire terminal project and make it subject to the CUP criteria (Ex. 193, p 70). The Officer agrees. The only two aspects of the project that implicate the CUP criteria are addressed in a combined fashion as follows:

a) **Does the proposed use conform with the comprehensive plan?** General compliance with all applicable Comprehensive Plan provisions is required under this section. While many provisions are arguably applicable to the terminal generally, very few appear to be particularly relevant to the temporary wetland impact mitigation or the tall LNG storage tanks. RiverKeeper cites 11 specific plan provisions as applicable to the terminal generally (Ex. 44, p 62-69), but doesn't indicate any as being specifically applicable to the two conditional uses. Absent any reference by the applicant, opponents or staff to any specific comprehensive plan provisions relevant to the temporary wetland impact mitigation or the two over-height LNG storage tanks, the Officer concludes that both conditional uses are consistent with the comprehensive plan, to the extent any of its provisions are applicable.

b) **Are the location, size, design and operating characteristics of the use such that the development will the use be compatible with and have minimal impact on surrounding properties?** As a starting point, the ESP is surrounded on three sides by water. Because no party to this proceeding disputes that the temporary wetland impact mitigation is compatible with, and will have no impact on, surrounding properties, the Officer concludes that this criterion is met with regard to the temporary wetland impact mitigation.

   The over-height LNG storage tanks, however, have the potential of impacting aviation operations at the Astoria Airport. Several people testified to this possibility at the September hearing and argued that these two large LNG storage tanks did not meet this standard with regard to the airport property. As logical as that might seem, the Officer is more inclined to rely upon comments from the affected agencies, *i.e.*, the Port of Astoria, Oregon Division of Aeronautics (ODA) and the Federal Aviation Administration (FAA) as to whether the over-height tanks impact their airport operations. The applicant provided documentation of FAA's and ODA's positions (Terminal Application, App C). Absent any comparably credible evidence on this issue than statements from the affected aviation authorities, the Officer concludes that the applicant has met its burden with regard to this criterion and the two over-height LNG tanks.

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[33] Although the applicant did not raise the issue, there is some question as to whether imposition of an imaginary surface 150 above the runway of the Astoria Airport (an avigation easement) and extending out 10,000 to affect this property is lawful, or whether it affects an uncompensated taking in violation of the state and federal Constitutions. *See Barnes v. City of Hillsboro*, 61 Or LUBA 375, 392, *aff'd* 239 Or App 73, 243 P3d 139 (2010) (reversing the city and striking as an unconstitutional taking the imposition of a similar avigation easement around the Hillsboro Airport).

c) **Will the use generate excessive traffic?** The record of this matter doesn't ascribe any particular number of vehicle trips to the temporary wetland impact mitigation project, nor to the two LNG storage tanks. Absent any such evidence or argument that either aspect of the project will generate any vehicle trips, the Officer concludes that this criterion is not relevant to either conditional use, and its requirements are met.[34]

d) **Are public facilities and services adequate to serve the use?** Similar to the trip generation/traffic issue discussed in the preceding section, this one does not appear to be relevant to the temporary wetland impact mitigation aspect of the project. The wetland mitigation should not have any particular demand for public services and facilities.

RiverKeeper and many other opponents, however, argued throughout the local process that the applicant needed to provide a credible emergency response plan for the whole terminal project and asserted that local emergency responders (fire & life safety) and local medical facilities would be significantly deficient if they had to respond to a major explosion, fire or chemical/LNG leak from the facility. These opponents fashion this argument in the context of this CUP criterion, asserting that the over-height LNG storage tanks pose a public safety risk from explosion, fire or chemical/LNG leak for which the City of Warrenton is not prepared (Ex. 44, p 57-58 & attachment 70, p 107-109). These witnesses argue that the lack of an emergency response plan, especially one sufficient to handle such a catastrophic event, warrants denial of the project as a whole, or at least the conditional use permit for the over-height LNG storage tanks. Implicit in these arguments is the notion that emergency services (fire & life safety) and medical facilities are essential public services and facilities that are required for the LNG tanks, given the explosion, fire hazard and chemical leak hazards they present. Otherwise, neither the WDC nor the WCP appear to have a comparable requirement applicable to any other aspect of this project. Put differently, given the specific land use permits this project must obtain from the City of Warrenton, the applicable land use approval criteria do not require any level of emergency planning or preparedness for this project other than this one CUP criterion applicable to the over-height LNG storage tanks. Additionally, the opponents' arguments implicate earthquake and tsunami safety concerns for the LNG storage tanks.

The application addresses in general terms how the terminal will impact public services and facilities (Terminal Application p 5-166; Terminal Application App I). The applicant has maintained all along that nothing in the WDC or WCP require an emergency response plan or demonstration that local emergency response services would be adequate in the event of a fire, explosion or LNG/chemical leak at the facility (Ex. 187, p 17; Ex. 193, p 20). Nonetheless, the applicant addressed the issue by submitting a relatively lengthy Resource Report on Reliability and Safety (Terminal Application, Resource Rpt 11) and responded specifically to these arguments in its post-hearing submissions (Ex. 187, p 17-19; Ex. 193, p 20-22). The thrust of the applicant's response is three-fold:

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[34] Trip generation and adequacy of the affected transportation system is addressed generally under WDC ch. 16.256 *infra*.

(1) The facility will be engineered, designed and constructed to ensure a high degree of safety that will minimize to the maximum degree possible the possibility of any fire, explosion or chemical/LNG leak (Ex. 138, p 32-37). Thus according to the applicant, the chance of any mishap is small.

(2) The applicant has or will submit to FERC an Emergency Response Plan that will be fully vetted, reviewed and possibly revised by FERC pursuant to its authority as the lead federal agency on the project under the Natural Gas Act. In partial fulfillment of this on-going emergency preparedness planning, the applicant provided a copy of the current Emergency Response Manual (Ex. 140, dated April 10, 2013) that includes a series of Emergency Response Procedures for a host of possible mishaps and serves to illustrate how emergencies would be handled at the plant; and

(3) The issue is addressed in the DEIS issued by FERC in August 2015 (DEIS §4.1.13.9 - Emergency Response and Evacuation), which requires as a mitigation measure (Mitigation Measure 52) that the applicant compile and submit an Emergency Response Plan that includes coordination with the Coast Guard, state, county and local emergency responders and emergency planning groups. In partial fulfillment of this on-going emergency planning coordination, the applicant provided a copy of Memorandum of Understanding with Oregon Department of Energy (Ex. 140, dated June 2009) that is designed to address the emergencies and procedures.

As a starting point on this issue, the Officer is reluctant to read into this CUP criterion a requirement for an emergency preparedness plan for the entire LNG terminal facility, for all operations, and for all possible emergencies, when no such requirement appears to exist in the WDC or WCP. That said, these 190-foot tall LNG storage tanks require a CUP, and to put it bluntly, if they were to blow-up for some reason, that event would trigger the need for emergency fire and life safety services and facilities. Thus, some planning for emergency preparedness arguably is required for this particular use under this CUP criterion. The Officer is also not willing to interpret this CUP criterion to duplicate WDC 16.88.040(G)(2)(b)'s prohibition against critical facilities in the Special Flood Hazard Area discussed *supra.*, and require a full assessment of tsunami and earthquake risks and the appropriateness of the site.[35] In response to the possibility that the LNG storage tanks could be inundated by a tsunami or other flood event, the applicant cited the tsunami flood modeling and related information in the record and emphasized the 22-27 foot tall earthen berm that will enclose the terminal facility and, essentially, make if flood proof (Terminal Application p 5-166 to 5-167). Thus, the applicant has provided a substantial amount of information on the subject of emergency preparedness generally. None of it, however, appears to relate to the capacity of local agencies to respond to the worst-case scenario catastrophic event.

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[35] In response to WDC 16.88.040 (Standards for Flood Hazard Reduction), the Officer was persuaded by the credible geotechnical information about the site (Application, App F; Ex. 138, p 22-29), the applicant's engineering steps and foundation design to prevent earthquake damage (Ex. 138, p 32-34; Ex. 187, p 9-13) and the risk of inundation from a major tsunami (Ex. 138, p 30-31, 35-36). There was no countervailing or comparably credible evidence that detracted from the applicant's evidence.

The Officer concludes that this local land use criterion is not intended to trigger a comprehensive emergency services and facilities evaluation for the worst case scenario, especially for the entire terminal operation.[36] The adequacy of emergency services and facilities is implicated only by the over-height LNG storage tanks intruding into the airport imaginary surface. The affected aeronautic agencies indicated their acceptance of this intrusion so long as there are warning lights on top of the tanks. The emergency preparedness and response that could be required if these tanks explode, burn or leak, in this context, is not specified by the local land use criteria, but is addressed by the Natural Gas Act, which is administered by FERC and other federal agencies. Therefore, to the extent that the City's CUP criterion applicable to the over-height LNG tanks requires some level of emergency service planning or response in the event of a catastrophe, the Officer does not conclude that it requires proof of emergency service and facility capacity to handle the worst-case catastrophic scenario engulfing the plant as whole. The Officer concludes that the record contains a substantial amount of credible evidence that this applicant has taken measures to address a reasonably significant event, has demonstrated that there would be adequate facilities and services, within limits, to respond to such an event, and that further planning and review and refinement of those plans will occur under FERC oversight. See 49 CFR 193 & 33 CFR 127. Also, the applicant asserts that the plant's design and construction have benefitted from past LNG terminal disasters which makes prior/other LNG plant disasters not particularly relevant or predictive of what might happen here. The Officer agrees, and in that relatively narrow light, concludes that this CUP criterion is met.

e) **Are the site's physical characteristics appropriate for the use?** Again, the Officer has little difficulty concluding that the site is appropriate for the applicant's proposed wetland impact mitigation. The object of the proposal is to restore, replant and recover ~3.2 acres of the site's wetlands that will be impacted by terminal construction activities. The impact will be temporary and the mitigation is on-site.

With regard to the over-height LNG storage tanks, the applicant provides basically the same information as previously mentioned, in which the applicant describes aspects of the site that are or will be suited to the LNG tanks (Terminal Application p 5-166 to 5-167; App I & Resource Rpt 11). Unlike the preceding CUP standard, the applicant's response to this one is more focused on the physical attributes of the site and how well-suited it is for the over-height LNG storage tanks. This necessarily is more oriented toward the opponents' claims that the site is inordinately subject to earthquake damage due to its location near the Cascadia Subduction Zone and the Columbia River Fault (Ex. 44, p 56-57 & attachment 70, p 107-109). As discussed *supra*, under WDC 16.88.040 (Standards for Flood Hazard Reduction) and WDC ch. 16.96 (Soils Hazard Overlay), the applicant provided credible geotechnical information about the site (Terminal Application, App F; Ex. 138, p 22-29), described engineering steps and

[36] For example, the Officer is not willing to interpret a CUP criterion applicable to the over-height LNG storage tanks as requiring the applicant to demonstrate emergency services and facilities sufficient to deal with an explosion or fire caused by LNG vessel loading or unloading, or some pressurization or refrigeration process unrelated to the storage tanks.

foundation designs that, according to the applicant, would withstand earthquake damage (Ex. 138, p 32-34; Ex. 187, p 9-13; Ex. 191, p 9-15; Ex. 193, p 16-18), and finally described the 22-27 foot tall earthen berm that would reduce the risk of inundation from a major tsunami (Ex. 138, p 30-31, 35-36), that, plus the site is 11+ river miles inland, up the Columbia River and thus much less susceptible to tsunami flooding. The applicant also addressed the arguments of Tom Horning (Ex. 175) that the site's situation right on the Columbia River Fault made it especially susceptible to, and likely to suffer, earthquake damage. According to the applicant, the Columbia River Fault, while located basically under this site, was too old and movement too remote a possibility (no more recent than 1.6 million years ago) for it to be considered relevant today (Ex. 187, p 10-13). There was no countervailing or comparably credible evidence that detracted from the applicant's geotechnical evidence, its engineering and foundation design, nor its response to these arguments about tsunami and earthquake risk. For that reason, the Officer concluded that the site was suitable for the proposed use, and for the same reasons does so again in the context of this CUP criterion.

f) **Does the site have an adequate area to accommodate the use?** Again, the Officer has no difficulty concluding that the site is appropriate for the applicant's proposed in-kind and on-site wetland impact mitigation. The opponents to not claim otherwise or challenge this aspect of the project.

   With regard to the over-height LNG storage tanks, the opponents offer little argument that the site's size is the problem. The two over-height LNG storage tanks take up little room and are not expansive, so long as they are not involved in a fire, explosion or chemical/LNG leak. The opponents' principal arguments are related to the explosion, fire and leak risk that the tanks and the terminal facility as a whole pose to the community and the lack of emergency services and facilities to handle a catastrophic disaster should the terminal catch fire, explode or leak. The Officer addressed those arguments in the preceding sections in response to the second, fourth and fifth criteria in WDC 16.220.030(A). Because the opponents offer no particular arguments based on this, the sixth, CUP standard, the Officer concludes that the applicant meets it with regard to the over-height LNG storage tanks intruding into the airport's imaginary horizontal surface 150 feet above the airport runway. With this, the Officer concludes that the applicant has demonstrated through a preponderance of credible evidence in the record that it meets all of the CUP criteria for both conditional use requests: the on-site temporary wetland impact mitigation in the I-2 Zone and the over-height LNG storage tanks intruding into the airport's imaginary horizontal surface.

11. WDC Ch. 16.256: Traffic Impact Study.

This chapter, designed to implement the Transportation Planning Rule (TPR) in OAR Div. 660-012, requires the compilation of a Traffic Impact Study (TIS) for developments that either involve a zone change/plan amendment or meet certain trip generation thresholds. The chapter provides no particular performance standards or approval criteria, only that, if a TIS is required, it must be prepared by a professional engineer in compliance with OAR 734-051-180 and WDC 16.232.060 (the city's implementation of the TPR).[37] The applicant addressed the criterion (Terminal Application p 5-174 to 5-177) and submitted a TIA for the terminal (Terminal Application, App E).[38] There is no dispute that the chapter applies to this development and requires production of a TIS, but the dispute involves scope and level of detail that is required of the TIS.

RiverKeeper and other opponents argue that the traffic and trip generation of the pipeline component of the project are significant and understated by the applicant's TIS (Ex. 44, p 59-61). In particular, RiverKeeper points to the recently released DEIS and argues that it describes significant traffic impacts with greater trip generation and impacts than revealed in the terminal application TIS, especially when pipeline construction overlaps with terminal construction. Thus, RiverKeeper faults the applicant's terminal TIS for failing to take into account pipeline construction traffic, which according to RiverKeeper will have an acute impact on the Cities of Astoria and Warrenton and the surrounding transportation infrastructure such as the Youngs Bay Bridge and Highway 101.

The applicant responds by also pointing to the DEIS and explaining that the DEIS assumes the peak day in the peak month of the expected construction traffic for the first segment (Spread 1) of the pipeline (Ex. 187, p 6). The applicant states that it did not prepare a TIS for the pipeline construction because none was required by WDC ch. 16.156 and the majority of pipeline construction would occur outside the Warrenton city limits, but that it subsequently submitted a TIS Addendum (dated May 20, 2015) that addressed the traffic expected from the 3-mile portion of Spread 1 construction within the City of Warrenton and how those trips would be coordinated and not overlap with terminal construction. Thus, according to the applicant, "the peak of Pipeline construction will be different than the peak of Terminal construction within Warrenton ... the peak Pipeline construction of the 3-mile segment within Warrenton will occur after the peak Terminal construction, [and] the total Pipeline and Terminal traffic impacts during the peak Pipeline construction period will be less than the peak Terminal construction period." (Ex. 187, p 7). Based on all of this, the applicant asserts that its TIS complies with the requirements of WDC ch. 16.256 and, with the May 2015 TIS Addendum, it demonstrates that traffic impacts of the terminal will not overlap or conflict with the construction of the 3-mile pipeline segment inside the city limits (Ex. 193, p 71-72).

RiverKeeper responds (Ex. 83, p 18-22) that the applicant should have provided a TIS Addendum that covered more than the 3-mile segment situated within Warrenton. RiverKeeper also asserts that ODOT has not concurred with the applicant's TIS or its traffic mitigation measures, citing an August 2015 letter (Ex. 5).

From all of this, the Officer finds that only traffic impacts from land use activities within the City of Warrenton are cognizable under WDC ch. 16.256, which includes traffic attributable to the terminal operations and construction and the traffic generated by construction of the 3-mile pipeline segment located within the city. ODOT does not appear to have any regulatory role in the terminal or pipeline, as it admits in its August 25, 2015 letter to the City (Ex. 5), but the Officer views ODOT's comments as credible

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[37] The reference to OAR 734-051-180 appears to be an outdated citation. The applicant's explanation appears to be plausible (Ex. 193, p 71, n. 11), *i.e.*, the rule and thus the code simply require a traffic impact study consistent with ODOT's requirements.
[38] The applicant did not submit a separate TIA for the pipeline component of this application.

expert testimony on the project's impacts that are cognizable under WDC ch. 16.256. Finally, the Officer finds that the applicant shored-up a lot of the 2014 TIS's deficiencies by submitting the May 20, 2015 TIS Addendum, such that ODOT's comments help focus the remaining issue as how to mitigate for construction-related traffic (Ex. 5, p 2-3). The Officer does not read ODOT's comments as RiverKeeper appears to, as being negative, but rather that ODOT's concerns can be addressed through mitigation. In fact, staff accepted ODOT's recommended conditions of approval and attached them as Conditions 6, 7, 8 & 9 (Terminal Staff Report, p 361-362).

From all of this, the Officer concludes that the applicant has met the requirements of WDC ch. 16.256, such as they are, by submitting the 2014 TIS (Terminal Application, App E), the May 20, 2015 TIS Addendum, and then explaining how the traffic impact concerns raised by the opponents would be addressed (Ex. 187, p 6-8; Ex. 193, p 71-72). Notwithstanding the logic of the concerns voiced by the opponents and ODOT, the WDC does not require more. This conclusion is based on the relative lack of any objective approval standards or substantive requirements for addressing traffic/transportation impacts in WDC ch. 16.256.[39]

12. Warrenton Comprehensive Plan (WCP) Consistency.

A potentially large number of comprehensive plan provisions have some applicability to some aspect of this project, but, in reality, very few are implicated in any meaningful way. The applicant addressed a significant number of Plan provisions that it believed were applicable, and RiverKeeper challenged the project based on a subset of those provisions as not being met by this proposal (Ex. 44, p 62-69). The Officer addresses each of the comprehensive plan provisions cited by RiverKeeper in the following findings. For those that neither RiverKeeper nor any other party asserts is applicable and not met, the Officer relies upon and incorporates by this reference the Terminal Staff Report.

As a general matter, the Officer takes the view that generally worded comprehensive plan policies have little relevance in quasi-judicial permit proceedings as approval criteria, but rather, comprehensive plan provisions are usually intended to guide the planning commission and governing body in fashioning land use regulations. This view is consistent with the following statement from the WCP's introduction: "The Plan functions as a legal framework that City officials will use to make decisions. It is a statement of how the City Commission and Planning Commission, though the zoning ordinances, subdivision regulations, public facility policies and other means, will direct and control growth and change for the benefit of the people of this community." (WCP Art 1). Certainly comprehensive plan provisions are not directly applicable as approval criteria to limited land use decisions, such as the site plan design review component of the terminal proposal, unless they are also incorporated into the zoning ordinance.[40]

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[39] In the event the City Commission approves this project on appeal, the Officer recommends inclusion of ODOT's recommended conditions of approval, as set forth in the staff report at p 361-62 (Conditions 6, 7, 8 & 9).

[40] See ORS 197.015(12) & 197.195(1); *LO 138 LLC v. City of Lake Oswego*, __ Or LUBA __ (LUBA No. 2014-092, slip op. April 15, 2015) ("Comprehensive plan standards may only be applied to limited land use decisions as approval standards if they have been incorporated into the city's land use regulations. ORS 197.195(1).")

The degree to which any particular WPC provision is applicable to this project as an approval standard, therefore, depends upon its precise wording and whether comprehensive plan compliance is required by the development code. At a minimum, WCP provisions appear to be approval criteria for the conditional use permits and variance components of this project. See WDC 16.220.030(A)(1) and 16.272.020(D), respectively. It is less clear that the WCP is a source of applicable approval criteria for any other aspect of this project. For example, the WCP does not appear to be implicated by wetland permitting under WDC ch. 16.156, or estuary and shoreland development under WDC chs. 16.160 and 16.164. Compliance with applicable comprehensive plan policies is required for uses allowed outright in the A-1 Zone, but not the I-2 Zone. See WDC 16.72.040(C) versus WDC 16.64.040.

a) **WCP 4.310 – Natural Features, soils.** This plan provision provides in pertinent part:

> *"(1) Hazards resulting from poor soils shall be minimized by using sound soils data and engineering principles to determine public and private development techniques and by requiring those developing property, when appropriate, to assume responsibility for certain hazard-related costs."*

RiverKeeper asserts that the project is inconsistent with this policy (Ex. 44, p 62) and incorporates by reference its arguments under the Soil Hazard Overlay from WDC ch. 16.96 (Ex. 44, p 26-29). The applicant provides a basic response to the WCP argument (Terminal Application, p 5-185 to 5-187), a geotechnical investigation and analysis (Terminal Application, App F) and a more detailed response to the opponents' assertions that the site's soils and geology make it unsuitable for this use. The application described engineering steps and foundation designs that, according to the applicant, would withstand earthquake damage (Ex. 138, p 32-34; Ex. 187, p 9-13; Ex. 191, p 9-15; Ex. 193, p 16-18). The applicant analyzed the seismic and tsunami risk factors and provided design details of the 22-27 foot tall earthen berm around the plant that would reduce the risk of inundation from a major tsunami (Ex. 138, p 30-31, 35-36). In these post-hearing submissions, the applicant provided an analysis of the geotechnical and tsunami risk, including the Cascadia Subduction Zone hazards, and specifically addressed the implications of the site being underlain by the Columbia River Fault and a response to Tom Horning's report (Ex. 175).

Given the generally worded "requirements" of WCP 4.310 that "hazards resulting from poor soils shall be minimized by using sound soils data and engineering principles…," and the lack of any focused and comparably credible expert evidence to rebut the applicant's investigation, analysis and engineering design measures, the Officer concludes that the applicant has satisfied the requirements of this policy. In support of this conclusion, the Officer incorporates herein by this reference his findings adopted in response to WDC chs. 16.88 and 16.96, WDC 16.192.030, 16.220.030(A) related to soils and geotechnical issues. Because these code chapters and sections related to soils and geological suitability are more specific and focused, the Officer concludes that they implement the generally worded WCP 4.310.

b) **<u>WCP 4.320 – Natural Features, flood hazards</u>.** This plan provision provides in pertinent part:

> *"(2) A flood hazard permit will be required for all types of development, including dredging and filling, in areas of special flood hazards identified by Federal Emergency Management Agency's (FEMA) Federal Insurance Rate Maps (FIRM). The FIRM maps were originally dated May 15, 1978 (as amended) and have been updated in March 2010 by FEMA."*

RiverKeeper argues that this plan provision requires the applicant to obtain a Flood Hazard Permit now, as part of the present consolidated proceeding (Ex. 44, p 62). The applicant responds that it will obtain a Floodplain Development Permit subsequent to this land use proceeding in conjunction with grading and site preparation applications, all of which are subject to a Type I process, not land use procedures (Terminal Application p 5-187 to 5-188; Ex. 193, p 73). Staff reports that it is typical to consolidate such Type I permits after the land use process is complete (Terminal staff report p 283-284). RiverKeeper asserts that the present consolidated proceeding must be denied unless and until the applicant applies for and obtains its Flood Hazard Permit.

The code, especially WDC ch. 16.88, is somewhat ambiguous about what a Flood Hazard Permit is or when it must be obtained in the overall development process. The Officer concludes from these ambiguities that a Floodplain Development Permit under WDC ch. 16.88 for development in a designated Area of Special Flood Hazard is the "Flood Hazard Permit" mentioned in WCP 4.320. WDC ch. 16.88 does not contain any special approval criteria for a Flood Hazard Permit, except for the informational submission requirements in WDC 16.88.030 (Administration) A-E and the design standards for development in the Area of Special Flood Hazard in WDC 16.88.040. These are discussed *supra*, and the Officer incorporates those findings here by this reference. While RiverKeeper raises substantive arguments in response to WDC 16.88 (Ex. 44, p 23-26), its argument under WCP 4.320 appears to be procedural, not substantive. In that light, the code provides a Type I process for Floodplain Development Permits (WDC Table 16.208.020) and does not require that they be obtained prior to or in conjunction with land use permits. For that reason, the Officer rejects this argument and imposes a requirement that the applicant obtain a Floodplain Development Permit before beginning any site preparation work. <u>See</u> Terminal Condition 23.

c) **<u>WCP 4.360 – Natural Features, air quality and noise</u>.** This plan provision provides in pertinent part:

> *(1) It is the City's policy to preserve air quality and minimize noise through compliance with applicable state and federal regulations, use of additional local requirements and other means.*
>
> *(2) Before building permits will be issued for large-scale, non-residential developments, suitable information shall be submitted which shows that the development will not violate state or federal air quality and noise regulations. When appropriate, such evidence may also be required*

before issuing building permits for uses which generate high levels of noise or substantial amounts of air pollution.

RiverKeeper argues that these plan provisions apply at this stage in the development process and the applicant has not yet met them (Ex. 44, p 63). The applicant responds that these plan provisions do not constitute mandatory approval criteria, and in any event, the developer will obtain all necessary state and federal air quality permits and will demonstrate compliance with applicable noise standards before building permits are issued, but cannot do so now (Terminal Application, p 5-191).

As a starting point, the Officer addressed similar arguments (lack of DEQ air quality permits and gas flare heat and glare) *supra* under the base zone requirements, and incorporates those findings here by this reference. Second, WCP 4.360 (Natural Features, air quality and noise) is not worded as a mandatory approval standard, but anticipates code criteria (WDC) and permitting procedures to implement its general requirements. As previously stated, the Officer concludes that RiverKeeper has not established that the applicant is legally precluded from obtaining these discretionary state and federal permits. For that reason, the record shows that it is feasible for this applicant to meet those state and federal standards and obtain those permits subsequent to the local land use process. It is sufficient, therefore, to impose a condition requiring those permits before construction (site preparation work) begins. See Terminal Condition 21. If the applicant fails to obtain any required state or federal permit, it cannot begin construction of the facility.

d) **WCP 5.305 – Columbia River Estuary, dredging**. This plan provision provides in pertinent part:

These policies are applicable to all estuarine dredging and dredged material disposal in the Columbia River Estuary, shall be allowed only: (1) If, allowed by the applicable zone and required for one or more of the following uses and activities:

(a) Navigation, navigational access, or an approved water- dependent use of aquatic areas or adjacent shorelands requiring an estuarine location; and

(b) A need (i.e., a substantial public benefit) is demonstrated and the use or alteration does not unreasonably interfere with public trust rights; and

(c) No feasible alternative upland locations exist; and

(d) Adverse impacts are minimized, avoided, and mitigated; and

(e) An approved restoration project; and

(f) Excavation necessary for approved bridge crossing support structures, pipeline, cable, or utility crossing; and

(g) Maintenance of existing tidegates and tidegate drainage channels where a Goal 16 exception has been approved; and

(h) Aquaculture facilities.

The plan policy then goes on to state numerous requirements for dredge and fill operations in the City's Goal 16 and 17 estuary and shoreland areas. RiverKeeper argues (Ex. 44, p 63) that this WCP section's requirements parallel the substantive requirements of WDC 16.160.020, and RiverKeeper incorporates by reference its arguments from that section (Ex. 44, p 35-47).

In response to this challenge, the applicant also takes the position that WCP 5.305 parallels the substantive requirements in WDC 16.160.020 and proceeds with a discussion of how the proposal meets those criteria (Terminal Application, p 5-198 to 5-203), relying primarily on its impact assessment (Terminal Application, App G) the DEIS and related supporting documents and the future biological opinion that NMFS will provide FERC as part of its Section 7 consultation under the Endangered Species Act.

As a starting point, the Officer agrees with the position of the parties that the requirements of WCP 5.305 are largely implemented through the specific substantive provisions and approval criteria of WDC 16.160.020 and 16.160.040. However, the plan policy provisions are worded as mandatory approval criteria, not as generally worded policy, and therefore appear to be approval criteria applicable to permits such as this, albeit identical to WDC 16.160.020 and 16.160.040. In that light, the Officer incorporates herein by this reference all of his findings *supra* related to WDC ch. 16.160 compliance. On this basis, the Officer concludes that, because the requirements of WDC ch. 16.160 are not met by the terminal proposal, so too the requirements of WCP 5.305 are not met.

e) **<u>WCP 5.307 – Columbia River Estuary, estuarine construction</u>.** This plan provision provides in pertinent part:

These policies apply to over-water and in-water structures such as docks, bulkheads, moorages, boat ramps, boat houses, jetties, pile dikes, breakwaters and other structures involving installation of piling or placement of riprap in Columbia River Estuary aquatic areas, and to excavation of shorelands for creation of new water surface area. This section does not apply to structures located entirely on shorelands or uplands, but does apply to structures, such as boat ramps, that are in both aquatic and shoreland designations. ...

(4) Piling or dolphin installation, structural shoreline stabilization, and other structures not involving dredge or fill, but which could alter the estuary may be allowed only if all of the following criteria are met:

(a) A substantial public benefit is demonstrated; and

(b) The proposed use does not unreasonably interfere with public trust rights; and

(c) Feasible alternative upland locations do not exist; and

(d) Potential adverse impacts, as identified in the impact assessment, are minimized.

RiverKeeper again asserts that this plan provision parallels and has the same substantive requirements as WDC 16.160.020(B) and (C), but with regard to over and in-water structures such as the docks, piers and pilings proposed here (Ex. 44, p 63). The applicant responds that the plan provision's requirements are met with regard to the in-water and over-water structures it proposes (Terminal Application p 5-203 to 5-205).

As a starting point, this plan provision is worded in mandatory terms as a permit approval standard, albeit identical to WDC 16.160.020(B) and (C). The Officer addressed previously the WDC ch. 16.160 criteria in the context of the in-water and over-water construction elements, which consist of piers, pilings and docks. See findings *supra* addressing WDC 16.160.020(C). This comprehensive plan provision applies just to "pilings or dolphin installation, structural shoreline stabilization, and other structures not involving dredge or fill, but which could alter the estuary." The Officer infers two important differences between the analysis required for WCP 5.307 and the prior analysis under WDC 16.160.020(B) related to estuary dredging, which employed basically the same criteria: (1) the docks, pilings and piers are relatively small and their installation, construction and operation will have a commensurately smaller impact on estuary resources as compared to the 109-acre dredge of 1.2 million cy of benthic substrate; and (2) the docks, piers and pilings are locationally dependent on the near-shore area adjacent to this A-1 and I-2 Zoned aquatic industrial parcel.

Regarding WCP 5.307(4)(a), the applicant claims a substantial public benefit in terms of economic benefits to the community and region and the global demand for natural gas that is driving this project. As previously discussed, the Officer does not interpret the need (substantial public benefit) criterion as calling for a global LNG market and demand analysis. Instead, the locational question under WCP 5.307(4)(a) is whether there a public need for these pilings, piers and dock facilities to be located in the shoreline area? The Officer concludes that such a need exists because this particular proposed use requires close and immediate access to a deep water marine port. This is a use that must be sited in an estuary or near-shore area and cannot be sited in upland areas away from an estuary. It is also dependent upon the aquatic industrial A-1 and I-2 zoning, which are on and adjacent to the estuary.

Along the same lines, under WCP 5.307(4)(c), the Officer concludes that the pier, dock and pilings that are needed to moor LNG transfer ships necessarily must be located in estuary areas such as this one. This is the same analysis but a different conclusion than the Officer reached regarding the same criterion and the LNG terminal facility as a whole because of the narrow focus of WCP 5.307(4) on the in-water and over-water pier and piling elements.

Regarding the public trust element in WCP 5.307(4)(b), the in-water and over-water elements of this facility certainly impact public trust rights, and present two primary impacts: (1) the construction and installation of the pilings, docks and piers and (2) operation of the dock and piers for LNG tanker moorage. When viewed in isolation, the Officer concludes that the impact of construction and installation may not be significant – certainly nothing compared to the impact of the 109-acre dredge. The operation of the docks and piers, however, involve berthing LNG tankers, which will impose a 500-yard exclusion zone from LNG vessels while in transit, a 200-yard exclusion zone for LNG vessels moored at dock, and a 50-yard permanent exclusion zone from the dock facilities with no vessels present. As with the same standard in WDC 16.160.020(B), the Officer concludes this is a significant and unreasonable interference with public trust rights. In reaching this conclusion, the Officer is persuaded by ODFW comments on this project from January 2015 to late September 2015 (Exs. 21 & 186; Ex. 44, attachment 63), which raised strong concerns about the project's impacts on fish, fishing, fish habitat, on-going fish recovery efforts, and thus public trust rights. The testimony of affected fishing organizations and individual fishers is also compelling and credible evidence that these impacts are real and significantly (unreasonably) impact public trust rights (Exs. 4, 7, 9, 25, 43, 48, 51, 80, 96, 103, 108, 118, 119 & 123). ODFW's final comment letter (Ex. 186), submitted just before the record closed, is most telling. Because the impact of the on-water and over-water elements of this proposal include these significant vessel exclusion zones, the Officer concludes that the applicant has failed to demonstrate compliance with WCP 5.307(4)(b).

Finally, with the requirement in WCP 5.307(4)(d) to minimize adverse impacts, the Officer concludes that, arguably, the applicant has provided sufficient evidence that potential adverse impacts are minimized because the exclusion zones associated with LNG vessels and the dock are imposed by the Coast Guard. It appears that the only way to make these exclusion zones smaller is to eliminate the docks, piers and pilings altogether. In that light, the impact of the in-water and over-water elements of the docks and piers are not self-imposed, but directly imposed by another agency. Consequently, there does not appear to be anything the applicant can do to reduce these exclusion zones short of abandoning the project altogether.

f) **<u>WCP 5.309 – Columbia River Estuary, fill</u>.** This plan provision provides in pertinent part:

> *These policies apply to the placement of fill material in the tidal wetlands and waters of the Columbia River Estuary. These policies also apply to fill in non-tidal wetlands in shoreland designations that are identified as "significant" non-tidal wetlands.*
>
> * * *
>
> *(5) Fill in estuarine m1ualic [sic] areas may be permitted only if all of the following criteria are met:*
> *(a) If required for navigation or for other water-dependent uses requiring an estuarine location, or if specifically allowed under the applicable aquatic zone; and*
> *(b) A substantial public benefit is demonstrated; and*
> *(c) The proposed fill does not unreasonably interfere with public trust rights; and*

(d) Feasible upland alternative locations do not exist; and
(e) Adverse impacts, as identified in the impact assessment, are minimized.

RiverKeeper claims this plan provision imposes the same requirements as WDC 16.160.020(B) and (C) and that the applicant has not demonstrated compliance with either one (Ex. 44, p 63). The applicant appears to agree that the provision is implemented through WDC 16.160.020 and provides similar responses to what it provided for these code requirements (Terminal Application, p 5-205 to 5-208). No one asserts that the comprehensive plan provision imposes any different requirements than what WDC 16.160.020 requires.

WCP 5.309(5), by its terms, is limited to impacts associated with construction, installation and operation of the in-water and over-water elements. This means the pilings, piers and docks. The specific required elements in this plan provision match those of WDC 16.160.020(C), which applies to "new piling or dolphin installation, construction of pile-supported structures," and the like. The Officer addressed these criteria in the context of the project's pilings, piers and docks in the discussion *supra* of WDC 16.160.020(C), and he incorporates by reference those findings here. In a nutshell, the Officer concluded that the pier, piling and dock elements (construction, installation and operation) meet the first criterion (need), third (feasible upland locations do not exist) and fourth (potential adverse impacts are minimized), but not the second (no unreasonable interference with public trust rights). The Officer reaches the same conclusions here with regard to WCP 5.309.

g) **WCP 5.311 – Columbia River Estuary, fish & wildlife habitat.** This plan provision provides in pertinent part:

> *These policies apply to uses and activities with potential adverse impacts on fish or wildlife habitat, both in Columbia River estuarine aquatic areas and in estuarine shorelands. (1) Endangered or threatened species habitat shall be protected from incompatible development.*

RiverKeeper focuses on the mandatory language of this policy ("habitat shall be protected") and argues that the project fails to protect the critical habitat of ESA-listed salmonids (Ex. 44, p 63). RiverKeeper relies on the Williams Report (Ex. 44, attachment 1) and its §404 comments (Ex. 44, attachment 70). The applicant responds to the issue by pointing to many years' worth of meetings with the affected state and federal agencies with jurisdiction over ESA-listed fish, how the project design has changed in response to those discussions and how NMFS and USFWS service will ensure final compliance with the federal Endangered Species Act when they issue their respective biological opinions (Terminal Application, p 5-208 to 5-209).

As a starting point, the Officer does not read this comprehensive plan provision to be a separate stand-alone approval criterion, but instead is implemented through the WDC, *viz.*, WDC ch. 16.160 and especially WDC ch. 16.164. However, while impacts to ESA-listed salmonids dominated the discussion from all sides, those chapters do not expressly mention endangered fish species. Nonetheless, RiverKeeper and the Officer (and arguably the applicant) have interpreted WDC chs. 16.160 and 16.164 to be the primary local mechanisms by which impacts to endangered fish species are addressed. For that reason, the Officer incorporates herein by this reference his findings *supra* that address ESA-listed salmonids under WDC chs. 16.160 and 16.164.

An additional point bears mentioning. The applicant has throughout this application and the local process emphasized how it must coordinate with a plethora of state and federal agencies with jurisdiction over many aspects of aquatic habitat, endangered species and water quality, with the implication that Warrenton should defer, to some degree, to those agencies on those subjects. To a certain extent, the applicant is right, in that these agencies have the technical, biological and ecological expertise to evaluate this project and its impacts and to fashion appropriate conditions to protect these resources. On that basis, the Officer has relied on comments on the project from ODFW[41] and NMFS.[42] However, this is not simply a situation where the local code requires the applicant to obtain discretionary state and federal permits and the local government is injecting itself into those state and federal permit proceedings and attempting to determine whether the applicant will be able to obtain those permits. Here, the local code has numerous substantive criteria that, while similar to the issues addressed by the state and federal agencies, are purely local land use approval criteria that implement the CZMA through state programs and the WCP and are reflected in land use criteria in the WDC. In that light, these criteria cannot be ignored, nor can the Officer simply defer to state and federal environmental agencies and trust that they will address these issues.

The Officer has made clear, especially under WDC ch. 16.164 that he believes that the impacts of this project on ESA-listed salmonids and their estuary and shoreland habitat are unacceptably great and not sufficiently mitigated. Also, the Officer is skeptical that NMFS will simply approve the project in its Section 7 consultation with FERC by issuing a non-jeopardy opinion. Comments in the record from ODFS and NMFS on this project and relevant portions of NMFS's 2008 jeopardy BiOp (and the 2010 and 2014 supplemental BiOps) on the FCRPS project lead the Officer to conclude that a jeopardy BiOp on this project is a real possibility, which would undermine any suggestion that the Officer simply defer a determination of the project's impacts on endangered species to a subsequent conclusion by state and federal agencies.[43]

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[41] See ODFW comments at Exs. 21 and 186 and Ex. 44, attachment 63.

[42] See NMFS §404 comments at Ex. 44, attachment 5.

[43] Another reason to not wait or defer to NMFS on a determination of whether this project will jeopardize ESA-listed salmonids through direct take or habitat impacts is that FERC, in the Bradwood Landing LNG case, approved that project before NMFS issued its biological opinion. While the opponents' challenge to FERC's decision on Bradwood Landing was subsequently dismissed by the Ninth Circuit as moot for other reasons, the fact that FERC did not wait for NMFS to issue its biological opinion on that project before issuing a decision concerns the Officer. *Oregon v. FERC*, 636 F.3d 1203 (2011). The sequence of decision making in the Bradwood Landing case, were it to be repeated here would appear to violate federal law and would also nullify consideration of Warrenton's CZMA criteria. For that reason as well as those stated *supra*, the Officer addresses now the project's impacts to endangered fish in the context of the city's local CZMA land use criteria, and concludes that the preponderance of evidence weighs against approval.

h) **<u>WCP 5.323 – Columbia River Estuary, public access</u>.** This plan provision provides in pertinent part:

> *These policies are applicable to uses and activities in Columbia River Estuary shoreland and aquatic areas which directly or indirectly affect public access. "Public access" is used broadly here to include direct physical access to estuary aquatic areas (boat ramps, for example), aesthetic access (viewing opportunities, for example), and other facilities that provide some degree of public access to Columbia River Estuary shorelands and aquatic areas.*
>
> *(1) Existing public ownerships, right-of-ways, and similar public easements in estuary shorelands which provide access to or along the estuary shall be retained or replaced if sold, exchanged or transferred. Right-of-ways may be vacated to permit redevelopment of shoreland areas provided public access across the affected site is retained.*
>
> *(3) Proposed major shoreline developments shall not, individually or cumulatively, exclude the public from shoreline access to areas traditionally used for fishing, hunting or other shoreline activities.*

RiverKeeper asserts that several aspects of the project violate this requirement (Ex. 44, p 64-68), which it summarizes as follows:

1. Public access to the terminal site will not be maintained because the shoreline will be fenced to exclude the public along the shore. Additionally the project anticipates that King Avenue will be vacated to the applicant, thus terminating public access via that public right-of-way.

2. The area covered by the Coast Guard's safety/security zone is significantly greater than the area covered by the aquatic land lease, and evidence demonstrates that the security zone will restrict public access.

3. Oregon LNG ignores the moving safety/security zones around LNG vessels (500-yards) as well as the fixed safety/security zone (200-yards) when LNG vessels are moored at the dock. The vessel-based security zones are also inconsistent with WCP 5.323(3).

4. The LNG berth, standing alone, excludes public access to an area traditionally used for fishing, hunting, and boating.

5. The size and duration of dredging excludes public access to areas traditionally used for fishing and water recreation. ODFW states: "OLNG's proposal to dredge the turning basin and berth in one 4-month in-water work window beginning in June 1, 2015, through September 30, 2016 is well outside the recommended in-water work window for the Area (November 1 to February 28) and has the potential to substantially interfere with recreational angling in the lower Columbia River (Buoy 10) salmon fishery."

The applicant addresses the public access issue in general terms (Terminal Application, p 5-217 to 5-218) and responds to RiverKeeper's WCP 5.323 challenge in its closing argument (Ex. 193, p 74-77).

As a starting point, there is a difference between public access over submerged and submersible lands where the public trust doctrine applies and where there is a tradition in Oregon for public access[44] versus private property that is not otherwise encumbered with any private or public access easements or common law traditions. A third issue is whether and how public right-of-way is vacated, which is a matter controlled by state statute.[45]

Regarding the first issue, the Officer has already concluded that the 50-yard permanent exclusion zone imposed on the docks and the 200-yard exclusion zone imposed on docked LNG vessels, appears to be an unreasonable infringement of public trust rights under WDC 16.160.020(B) and (C). At least, the applicant has not sufficiently analyzed (quantified) the precise nature and extent of those impacts on commercial and recreational fishing. For those reasons, too, the applicant has not demonstrated that there will not be acceptable losses, irreversible changes or unacceptable degradation or reduction of estuary resources under WDC 16.164.040.

RiverKeeper appears to assume that the exclusion zones extend onto land and don't encumber just water. The applicant, however, confirmed with the Coast Guard that the exclusion zones do not extend onto onshore areas (Ex. 191, p 4-5). The applicant explains that public access on the ESP will be blocked for only a small portion of the site right around the plant building (Ex. 193, p 74, citing Terminal Application figs. 1-3, 2-1, 2-2, 4-44 & 4-49). The applicant also points out that title to the properties making up the ESP do not reveal a public right-of-way dedication over much of the site. The "King Avenue right-of-way only extends onto a small portion of the far southern end of the Terminal site and does not currently provide access to or along the estuary..." (Ex. 193, p 75). From this, the Officer concludes that the balance of the ESP (everything outside of the fence) will be accessible by the public, something that warrants a condition. See Terminal Condition 24. The applicant then argues that any more public access than that would conflict with the underlying A-1 and I-2 zoning and the city's comprehensive plan policies encouraging and protecting industrially zoned lands for those purposes.

So far as the Officer can tell, the public currently has little legal right to access the onshore parts of the ESP, and this project will not have much of an impact on that access. Basically, the public will still have access to the ESP outside of the plant building perimeter fence, unless federal law dictates otherwise for such energy infrastructure facilities. The submerged and submersible portions of the site are still encumbered with public trust rights, which the Officer has already determined will be unreasonably infringed upon by this project. The King Avenue

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[44] See *State ex rel Thornton v. Hay*, 254 Or 584, 462 P2d 671 (1969), b*ut see also McDonald v. Halvorson*, 308 Or 340, 780 P2d 714 (1989).

[45] See ORS 271.080 to 271.230 – state law controlling the vacation of public rights-of-way. While this project proposal anticipates the vacation of King Avenue, the application does not include a vacation petition, nor is vacation approval sought in this proceeding.

public right-of-way exists where it exists according recorded dedication deeds. Thus, the Officer concludes that the project, even if approved, would not "exclude the public from shoreline access to areas traditionally used for fishing, hunting or other shoreline activities." Even if approved, this proceeding does not currently include a vacation request under ORS 271.080, et seq. The language of WCP 5.323(1) appears to apply to vacation requests and related proceedings, which this is not. Therefore, based on a preponderance of the evidence in the record, and as explained by the applicant (Ex. 193, p 74-77), the Officer concludes that the project meets (or at least does not violate) the requirements of WCP 5.323.

i) **WCP 5.327 – Columbia River Estuary, residential, commercial and industrial development.** This plan provision provides in pertinent part:

> *These policies apply to construction or expansion of residential, commercial or industrial facilities in Columbia River Estuary shoreland and aquatic areas. ... Industrial uses and activities include facilities for fabrication, assembly, storage, and processing, whether water-dependent, water-related or non-dependent non.- related.*
>
> * * *
>
> *(2) Residential, commercial or industrial development requiring new dredging or filling of aquatic areas may be permitted only if all of the following criteria are met:*
> *(a) The proposed use is required for navigation or other water-dependent use requiring an estuarine location, or if specifically allowed in the applicable aquatic zone; and*
> *(b) A substantial public benefit is demonstrated; and*
> *(c) The proposed use does not unreasonably interfere with public trust rights; and*
> *(d) Feasible alternative upland locations do not exist; and (e) Potential adverse impacts are minimized.*

RiverKeeper argues that the project violates this language for the same reasons that it violates WDC 16.160.020(B) and (C) (Ex. 44, p 68). The applicant provides a similar explanation to what it provided in response to WDC 16.160.020(B) and (C) (Terminal Application, p 5-218 to 5-222).

The Officer finds that this plan provision language applies to shoreland industrial development that involves dredging and filling. In that light, it is implemented by WDC 16.160.020(B) and (C), and the Officer incorporates herein by this reference his findings adopted *supra* in response to those code sections. On this basis, the Officer concludes that the terminal project violates this WCP provision.

j) **WCP 5.331 – Columbia River Estuary, significant areas.** This plan provision provides in pertinent part:

> *These policies are intended to protect certain shoreland and aquatic resources with estuary-wide significance. Significant shoreland resources are identified as such in the area and subarea description. Significant aquatic resources are found in Natural Aquatic areas. This subsection*

applies only to activities and uses that potentially affect significant shoreland or aquatic resources. Other resources without estuary-wide significance are not covered by this subsection. Only those resources identified as significant under Statewide Planning Goal 17 are covered by these policies and standards.

(1) Significant estuarine aquatic and shoreland resources shall be protected from degradation or destruction by conflicting uses and activities.

RiverKeeper argues that the project violates this provision for the same reasons it violates WDC 16.160.020(B) and (C) (Ex. 44, p 68). The applicant provides a similar explanation to what it provided in response to WDC 16.160.020(B) and (C) (Terminal Application, p 5-222 to 5-223).

The Officer notes that the language of this plan policy tracks more precisely (but not exactly) the requirements of the estuary impact assessment conclusion in WDC 16.164.040, and not so much WDC 16.160.020(B) and (C). From a comparison of the plan policy with the code requirements, the Officer concludes that WCP 5.331 is implemented by WDC ch. 16.164. For that reason, the Officer incorporates herein by this reference his findings adopted *supra* in response to WDC ch. 16.164 to conclude that the application does not achieve the requirements of this plan policy.

k) **WCP 5.347 – Columbia River Estuary, mouth of the Skipanon River Subarea.** This plan provision provides in pertinent part:

(3) The approximately 40 acre Holbrook Slough DMD / Mitigation site is reserved for mitigation of development impacts on the East Skipanon peninsula. Offsite mitigation may be considered as part of the required mitigation or in addition to this onsite mitigation. Acreage not used for mitigation would then become available for DMD or development, but not until the site is fully developed.

RiverKeeper faults the applicant for failing to implement this plan policy by using the Holbrook Slough for dredge material disposal (DMD) and mitigation for the ~35-acre permanent wetland impact proposed here (Ex. 44, p 69). The application explains that the applicant chose to not use the Holbrook Slough site for wetland impact mitigation because it is too small (Terminal Application, p 5-225 to 5-226). In closing arguments, the applicant further responds to RiverKeeper's argument (Ex. 193, p 77-78).

The Officer reads WCP 5.347 to provide Holbrook Slough as one of several possible mitigation sites for wetland impacts on the ESP, but not the sole or exclusive mitigation site for such impacts. The Officer agrees with the applicant's view and concludes that WCP 5.347 does not impose a mandatory or exclusive requirement on this project.

C. LNG Bidirectional Pipeline Applications:

Approximately three miles of the of the 86.8-mile LNG bidirectional pipeline will be located in Warrenton (Pipeline Application figs 4-1, 4-2 & 4-3). The pipeline will consist of a 36-inch (outside diameter) welded steel pipe within a 50-foot permanent easement. An additional 50-foot temporary construction easement will be used for upland areas and a 25-foot temporary construction easement in wetland areas. In Warrenton, the pipeline will pass through the following five base zones and three overlay zones:

Zone/Overlay Designation	Abbreviation	Distance	WDC Ch.
General Commercial	C-1	0.1 miles	16.40
General Industrial	I-1	1.6 miles	16.60
Water-Dependent Industrial Shorelands	I-2	0.4 miles	16.64
Aquatic Natural District	A-3	0.5 miles	16.80
Coastal Lake & Freshwater Wetlands	A-5	0.1 miles	16.84
Floodplain Hazard Overlay	FHO	2.0 miles	16.88
Soils Hazard Overlay	SHO	1.5 miles	16.96
Airport Hazard Overlay	AHO	underground	16.92

Specific land use approvals required for the pipeline and addressed in this decision are

- Conditional Use Permit for 0.5-mile segment in the A-3 Zone – WDC ch. 16.220
- Conditional Use Permit for wetland restoration in the I-2 Zone – WDC ch. 16.220
- Hardship variance for impacts to locally significant wetlands – WDC ch. 16.156
- Large-Scale Development Permit for the pipeline generally – WDC ch. 16.192

Approximately 2 miles of the pipeline's route in Warrenton is designated floodplain. There will be one stream crossing and several wetland and waterbody crossings, for which the applicant proposes specific crossing methods (Pipeline Application p 4-19 to 4-23).

Wetland crossing method 1 Standard trenching	This method will be used in dry wetlands where soils are stable enough to support equipment without sinking (for example, mineral hydric soils), or in wetlands that have already been disturbed. A reduced construction easement of 75 feet will be maintained and overland construction techniques will be used, unless exceptions are required by site conditions. Topsoil disturbed by trenching will be segregated, and no matting will be used if conditions are dry
Wetland crossing method 2 Standard trenching, heavy equipment on timber mats	This method will be used in wetlands where the soils are too wet to support Pipeline construction equipment. Timber mats will be used as necessary to support the construction equipment. A reduced construction easement of 75 feet will be maintained and overland construction techniques will be used, unless a variance has been granted. Topsoil disturbed by trenching will not be segregated
Wetland crossing method 4 Horizontal directional drilling	Horizontal Directional Drilling methods will be used for specialized Pipeline crossings of large wetland areas including Adairs Slough. Directional drilling is limited in

	application and dependent on critical wetland characteristics, including subsurface lithology, crossing length, burial depth, sediment composition, bank conditions, and access. Adverse environmental impacts that may result from drilling operations on waterway crossings would be related to discharge and transportation of drilling fluid; however, aside from turbidity effects, drilling fluid is a relatively environmentally benign substance. Mitigation of any adverse impact from drilling fluid would be by collection and cleanup of spilled material.
Waterbody crossing method 1 Dry crossing 0 to 30 feet	This method is applicable to perennial (with flow) or intermittent and ephemeral streams between 0-30 feet wide that are cold water fisheries and to perennial streams that may not be fish-bearing but are tributary to fish-bearing streams. Stream flow may be channeled into one or multiple flume pipes to convey water across the trench and maintain downstream flow. The trench will be excavated from under the flume pipe, the pipeline will be threaded under the flume, the trench will be backfilled, and the flume pipe will be removed to restore natural downstream flow. If no fish are present in the stream, the crossing method may be modified with a dam and pump arrangement to convey stream water around the construction area. If the stream is dry at the time of construction, Crossing Method 3, will be the crossing method
Waterbody crossing method 2 Horizontal directional drilling	In general, this method is applicable to major waterbodies (Application Table 4-5), and it minimizes impacts to these streams over traditional trenching methods. Preliminary site- specific HDD pipeline crossing plans are included in Appendix 1I to Resource Report 1. An HDD is planned across the Skipanon River for the water supply pipelines.
Waterbody crossing method 3 Open-cut trench	One intermittent stream crossing will occur at a small tributary to the Lewis and Clark River near MP 2.6. This crossing will be made using the open-cut trenched method. This method is applicable to intermittent and ephemeral streams that are not fish-bearing, and to fish-bearing intermittent or ephemeral streams if dry at the time of construction. Perennial streams that are minor, non-fish-bearing and not directly tributary to a fish-bearing stream may also use this crossing method. This method is allowable for the crossing of minor or intermediate waterbodies. The restrictions on in-stream work time (24 to 48 hours), restoration of preconstruction contours, limitations on equipment operating in the waterbody, or required bridging identified in the FERC process.

The applicant provided a single binder by way of application materials for the pipeline segment within the City of Warrenton, which includes a narrative and the following technical appendices that are uniquely tailored to the pipeline proposal:

- App A – Figures referenced in the narrative
- App B – Stormwater Management Plan
- App C – Columbia River Estuary Impact Assessment
- App D – Oregon DSL Wetland Delineation Concurrence Letter
- App E – Impact Study on Public Facilities and Services

During the local process the applicant provided a May 15, 2015 addendum to its Traffic Impact Study for the terminal (Terminal Application, App E) that specifically addressed the traffic attributable to the pipeline construction and operations.

The opponents, including RiverKeeper, provided abundant and detailed arguments and supporting documentation against the project, but very little of it focused on the pipeline, the specific permits and approvals required for the pipeline, or impacts uniquely attributable to the pipeline. The majority of the opposition arguments and documentation, arguably all of it, is focused on the terminal aspect of the project (Exs. 44, 83 & 188, and attachments to Ex. 44). The primary expert report provided by RiverKeeper that is focused on impacts of the pipeline is a report by Jonathan Rhodes ("Rhodes Report"), but this analysis addresses the entire 86-mile pipeline and its many impacts, only a small portion of which is relevant to the 3 miles within the boundaries of Warrenton.

1. Is the pipeline a use allowed in the C-1, I-1, I-2 and A-5 Zones:

Four of the five base zones through which the pipeline passes allow "pipelines" outright:

- C-1 Zone: WDC 16.40.020(A);
- I-1 Zone: WDC 16.60.020(M);
- I-2 Zone: WDC 16.64.020(J); and
- A-5 Zone: WDC 16.84.030(F)

Pipelines are conditionally allowed in the A-3 Zone. See WDC 16.80.030(E). No party disputes that the pipeline proposed here qualifies as a use allowed outright in the C-1, I-1, I-2 and A-5 Zones, and the Officer so concludes.

2. WDC Ch. 16.220 - Conditional use permit for pipeline in the A-3 Zone (0.5 miles) and for wetland restoration in the I-2 Zone (4.3 acres).

Two aspects of the pipeline segment within the city require conditional use permits (CUPs):

- 0.5 miles of the pipeline traverses the A-3 Zone, for which a CUP is required,
- 4.3 acres of wetland restoration is proposed for the I-2 Zone.

Approval of both CUPs requires a preponderance of evidence demonstrating compliance with the following criteria in WDC 16.220.030 (Review Criteria):

1. *The proposed use is in conformance with the Comprehensive Plan.*
2. *The location, size, design and operating characteristics of the proposed use are such that the development will be compatible with, and have a minimal impact on, surrounding properties.*

3. *The use will not generate excessive traffic, when compared to traffic generated by uses permitted outright, and adjacent streets have the capacity to accommodate the traffic generated.*

4. *Public facilities and services are adequate to accommodate the proposed use.*

5. *The site's physical characteristics, in terms of topography, soils and other pertinent considerations, are appropriate for the use.*

6. *The site has an adequate area to accommodate the proposed use. The site layout has been designed to provide for appropriate access points, on-site drives, public areas, loading areas, storage facilities, setbacks and buffers, utilities or other facilities which are required by City ordinances or desired by the applicant.*

The applicant addresses both pipeline CUPs in a consolidated fashion (Pipeline Application, p 5-74 to 5-78) as does staff in its report (Pipeline staff report at 111-117). The 0.5-mile segment of pipeline in the A-3 Zone will be buried. Construction of the 3 miles of pipeline in Warrenton will cause 25.7 acres of temporary wetland impacts,[46] mostly due to soil compaction and related construction damage, and 3.25 acres of permanent wetland impacts. Mitigation for the permanent wetland impacts will occur outside the city at the 120-acre restoration site and are discussed *supra* in the terminal section of this opinion. Mitigation for the temporary wetland impacts will occur on-site, in place and in-kind, as the applicant proposes to rehabilitate the construction areas after construction is complete, and 4.3 acres of that mitigation will occur in the I-2 Zone. The applicant describes the wetland impact restoration as consisting of the following actions:

> "Rectification and restoration of temporary impacts will involve the following actions, as needed: general site cleanup, ripping soil to counter the effects of compaction, and restoring/replanting vegetation. Native plant material will be provided for vegetation restoration. The species composition will vary depending on hydrologic characteristics at each location." (Pipeline application, p 5-74)

a. **<u>The use is in conformance with the Comprehensive Plan</u>.** The applicant addresses comprehensive plan compliance as a separate section to the application (Pipeline Application, p 5-78 to 5-110), but lists the following as applicable:

<u>Article 2</u> (Community Development), §2.310 Land and Water Use Classification
<u>Article 3</u> (Land and Water Use), §3.320 Commercial Lands, §3.330 Industrial Lands, §3.340 Agriculture, Forestry, Wetlands and Open Space.
<u>Article 4</u> (Natural Areas), §4.310 Soils, §4.320 Flood Hazards, §4.330 Drainage and Erosion, §4.340 Topography, §4.350 Water Quality, §4.360 Air Quality and Noise, §4.370 Fish and Wildlife, §4.380 Scenic and Historic Resources, §4.390 Energy Conservation.

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[46] The applicant misquotes DSL's definition of "temporary impacts" (Pipeline application, p 5-74). According to OAR 141-085-0510(90), temporary wetland impacts are "adverse impacts to waters of this state that are rectified within 24 months from the date of the initiation of the impact." Because of the applicant's apparent misunderstanding of the definition, a condition of approval is warranted to ensure that restoration occurs within 24 months from the date of the initiation of the impact so that they qualify as temporary. <u>See</u> Terminal Condition 25 & Pipeline Condition 10.

Article 5 (Columbia River Estuary and Estuary Shorelands), §5.150 Mouth of the Skipanon River Subarea Findings, §5.170 Airport and Vicinity Subarea Findings, §5.301 Deep-Water Navigation, Port and Industrial Development, §5.303 Diking, §5.305 Dredging and Dredged Material Disposal, §5.307 Estuarine Construction, §5.309 Fill, §5.311 Fish and Wildlife Habitat, §5.313 Fisheries and Aquaculture, §5.321 Mitigation and Restoration, §5.323 Public Access, §5.327 Residential, Commercial and Industrial Development, §5.331 Significant Areas, §5.333 Water Quality Maintenance, §5.335 Water-Dependent Development Areas, §5.339 Federal Consistency, §5.347 Mouth of the Skipanon River Subarea, §5.351 Airport and Vicinity Subarea.

Article 6 (Beach and Dune Shorelands)

Article 7 (Community Facilities and Services), §7.320 Water, Sewer and Storm Drainage/Flood Control, §7.330 Fire, Police, Recreation and Solid Waste Management.

Article 8 (Transportation), §8.320 Street Design, §8.330 Street Width, Access and Parking Design, §8.350 Multi-Mode Transportation.

Article 9 (Economy), §9.310 City Economy.

Like the applicant, the Officer will address these WCP policies *infra*.

b. **The location, size, design and operating characteristics of the use are such that it will be compatible with, and have a minimal impact on, surrounding properties.** The wetland restoration in the I-2 Zone is located entirely on the ESP where there is no current or proposed development, except for the terminal. The applicant's objective in the restoration is to return these wetland areas to their current status and condition. Accordingly, the Officer concludes that the 4.3-acre I-2 zoned wetland mitigation area meets this requirement. Similarly, the pipeline through the A-3 Zone will be completely buried, which, in the Officer's view, meets this criterion. The Officer adopts as his own and incorporates herein by this reference, the findings from the Pipeline Staff Report on this CUP criterion (Pipeline staff report, p 115).

c. **The use will not generate excessive traffic, when compared to traffic generated by uses permitted outright, and adjacent streets have the capacity to accommodate the traffic generated.** Neither of the two uses associated with the pipeline that require a CUP will generate traffic, except a modest amount associated with the actual installation of the buried pipeline in the A-3 Zoned segment and the wetland rehabilitation activities. The applicant provided a May 20, 2015 Traffic Study addendum addressing traffic attributable to pipeline construction and operations, but it did not differentiate the construction traffic attributable to this 0.5-mile segment from that of the other segments. In the absence of any arguments to the contrary from the opponents, the Officer concludes that construction traffic attributable to this 0.5-mile segment of the pipeline and the wetland restoration both are not excessive and therefore meet this criterion. The Officer adopts as his own and incorporates herein by this reference, the findings from the Pipeline Staff Report on this CUP criterion (Pipeline staff report, p 115).

d. **Public facilities and services are adequate to accommodate the use.** Similar to the preceding criterion, the Officer is hard pressed to identify what if any public facilities are specifically needed to construct or operate this 0.5-mile segment of the pipeline in the A-3 Zone or the 4.3-acre wetland rehabilitation area in the I-2 Zone. The opponents have raised a number of arguments about the need for emergency services (fire, life and safety) in the event of a catastrophic explosion at the terminal facility, either by itself, or in conjunction with an earthquake and/or tsunami. Those issues are addressed *supra* in the terminal portion of this opinion. The Officer, however, does not find those arguments credible in the context of this 0.5-mile segment of the pipeline and finds no credible argument that public facilities or services are lacking for the 4.3-acre wetland enhancement area in the I-2 Zone. From this, the Officer concludes that this criterion is met with regard to these two specific CUP requests. The Officer adopts as his own and incorporates herein by this reference, the findings from the Pipeline Staff Report on this CUP criterion (Pipeline staff report, p 115).

e. **<u>The site's physical characteristics, in terms of topography, soils and other pertinent considerations, are appropriate for the use</u>.** The 4.3-acre wetland restoration is proposed for the ESP precisely because its physical characteristics, topography, soils and other physical attributes are suitable for wetland restoration. With regard to this 0.5-mile segment of the pipeline in the A-3 Zone, the applicant asserts that "the topography is flat along the entire crossing of Warrenton, which greatly simplifies construction and installation of the Pipeline. The Pipeline is proposed through soils designated as part of the SHO zone; however, installation will be via trench or HDD, causing no significant increase in load to soil deposits. The Pipeline will not result in a significant increase in loading." (Pipeline application, p 5-77). The opponents do not contradict this statement or the evidence in the record that supports it. Therefore, the Officer concludes that both CUP requests meet this criterion. The Officer adopts as his own and incorporates herein by this reference, the findings from the Pipeline Staff Report on this CUP criterion (Pipeline staff report, p 116).

f. **<u>The site has an adequate area to accommodate the use. The site layout has been designed to provide for appropriate access points, on-site drives, public areas, loading areas, storage facilities, setbacks and buffers, utilities or other facilities which are required by City ordinances or desired by the applicant</u>.** As a starting point, and consistent with the preceding CUP criterion, the applicant asserts that the 4.3-acre wetland mitigation area is proposed for the ESP, zoned I-2, precisely because it is so well suited for wetland rehabilitation. The site is flat, currently jurisdictional inventoried wetlands and presumptively well suited for this work. The applicant asserts that "this restoration work will only occur where preexisting wetlands were located. Therefore, the proposal is to return these areas to preexisting conditions." This statement and evidence upon which it is based are unchallenged by the opponents. With regard to the 0.5-mile pipeline segment in the A-3 Zone, the applicant claims that the "completed underground Pipeline will not require onsite drives, public areas, loading areas, storage facilities, utilities, or other facilities for its entirety across Warrenton. The Pipeline route, including easements within the A-3 zone has adequate area to accommodate the proposed construction work and operation." (Pipeline Application, p 5-77). In light of the evidence supporting these statements and lack of any contradictory argument from the opponents, the Officer concludes that this criterion is met for both CUP requests. The Officer adopts as his own and incorporates herein by this reference, the findings from the Pipeline Staff Report on this CUP criterion (Pipeline staff report, p 116).

3. **<u>WDC 16.156</u>: Hardship variance for impacts to locally significant wetlands.**

Several segments of the pipeline within Warrenton will cause impacts to locally significant (Goal 5) wetlands. These wetlands appear to be outside the City's Goal 16 and 17 boundaries, and presumably for that reason, the applicant addressed these impacts under Goal 5 instead of Goals 16 and 17 as it did for the terminal's wetland impacts. As such, impacts to wetlands designated as locally significant under Goal 5 require a hardship variance pursuant to the criteria in WDC ch. 16.156.080, which requires affirmative findings based on a preponderance of evidence in the whole record that the following criteria are met:

1. *The proposed development represents a reasonable and legal use of the lot or parcel, considering the zoning.*
2. *Strict adherence to this chapter and other applicable standards would effectively preclude a use of the parcel that could be reasonably expected to occur in similarly zoned parcels.*
3. *The property owner would be precluded a substantial property right enjoyed by the majority of landowners in the vicinity.*
4. *The variance is the minimum necessary to retain use of the property.*
5. *Granting of the variance will not be materially detrimental to the public welfare or be injurious to property or improvements in the neighborhood of the premises.*
6. *The variance will be in general harmony with the intent and purpose of this chapter, and will not adversely affect any officially adopted Comprehensive Plan policy.*

a. **<u>The proposed development represents a reasonable and legal use of the lot or parcel, considering the zoning</u>.** The applicant asserts that the pipeline use is both legal and reasonable in each of the zones through which it passes because it is either allowed outright (C-1, I-1, I-2 & A-5 zones) or conditionally (A-3 zone) (Pipeline Application, p 5-39). Staff agreed with the applicant's argument and conclusion (Pipeline staff report, p 59-60). RiverKeeper focuses its argument under this criterion on the terminal and says nothing about whether the pipeline is a reasonable or legal use in the zones through which it passes (Ex. 44, p 32-33).

In contrast to the terminal which has impermissibly significant impacts on the estuary and shoreland resources, the pipeline appears to be just a pipeline, with no unusual, extraordinary or significant impacts. While not dispositive, the fact that the pipeline is allowed outright or conditionally in all of the city zones it crosses, and it conforms to the relatively standard notions of what a buried pipeline is and what it takes to install it, the Officer concludes that the pipeline is both a legal and a reasonable use. That would not be the case if its impacts were impermissibly great or significant on protected estuary or shoreland resources. Because the pipeline is mostly buried, frequently installed with HDD, and with no continuous above ground impacts, the Officer concludes it satisfies this criterion, and in support adopts and incorporates herein by this reference, the findings from the Pipeline Staff Report on this variance criterion (Pipeline staff report, p 59-60).

b. **<u>Strict adherence to this chapter and other applicable standards would effectively preclude a use of the parcel that could be reasonably expected to occur in similarly zoned parcels</u>.** The subject of this permit is the pipeline proposed to run through locally significant wetlands, for which a variance is required. The gist of this criterion is that the use would be allowable in the same zone elsewhere without the limitation that requires the variance. In other words, would the pipeline be reasonably expected to occur in these same zones were they located on other parcels not encumbered by wetlands? The applicant appears to take the same view and notes that pipelines are allowed outright in four of the zones and conditionally in the fifth zone. The only reason for a variance is the fact that the pipeline alignment is encumbered by wetlands for most of its path in Warrenton (Pipeline Application, p 5-39), and the staff seems to agree (Pipeline staff report, p 60). Again, the opponents don't seem to object to the pipeline under this criterion, only that the terminal does not meet it (Ex. 44, p 33). The Officer concludes that this criterion is met and in support adopts and incorporates herein by this reference, the findings from the Pipeline Staff Report on this variance criterion (Pipeline staff report, p 60).

c. **<u>The property owner would be precluded a substantial property right enjoyed by the majority of landowners in the vicinity</u>.** Similar to its response to the previous variance criterion, the applicant responds to this one by noting that a pipeline is a use allowed outright in all of the city base zones it crosses except the A-3 Zone, in which it is conditionally allowed. The applicant also points to the marine industrial zoning and the Especially Suited for Water Dependent Shorelands designation applied by the City Commission to the ESP in 2005 and the Commission's 2006 interpretation that an LNG terminal is a use allowed outright in that zone. From this the applicant concludes that, if the wetland protections of "WDC 16.156.030 were strictly enforced, ... Oregon LNG would be unable to site the Pipeline, a use that is allowed in the base zone and satisfies all of the applicable criteria." (Pipeline Application, p 5-39). Again, RiverKeeper does not really dispute any of these statements or conclusions about the pipeline (Ex. 44, p 33). As with the previous criterion, the Officer concludes that this criterion is met and in support adopts and incorporates herein by this reference, the findings from the Pipeline Staff Report (Pipeline Staff Report, p 60-61) on this variance criterion.

d. **<u>The variance is the minimum necessary to retain use of the property</u>.** The applicant asserts that it considered several other pipeline alignments, each with varying degrees of wetland impacts, and selected its preferred alignment because it minimized the impacts on wetlands, especially high value wetlands (Pipeline Application, p 5-39 to 5-40). According to the applicant, it employed the following measures to minimize wetland impacts:

- Horizontal directional drilling method will be used to install the Pipeline well below the surface of wetlands and streams in the vicinity of Adairs Slough.
- The Pipeline was aligned parallel to or within existing road right-of-way, utility corridors, or previously disturbed areas.

- The Pipeline route was aligned so that wetlands will be crossed at their narrowest point when possible.
- The Pipeline was aligned so that streams will be crossed at a right angle to their banks to minimize negative impacts to riparian areas and streambed.
- The width of the Pipeline right-of-way will be reduced to 75 feet when crossing nonagricultural wetlands to minimize the area of disturbance.
- Temporary workspace will be located in areas outside of wetlands to minimize the number of acres of disturbance.

The applicant concludes by saying that "[e]ven if the Pipeline could be microsited to avoid every wetland, this would increase the overall length of the Pipeline and period of active construction, which could result in more permanent impacts to the landscape and longer periods of temporary disturbance and active construction along the Pipeline route." (Pipeline Application, p. 5-40). Based on these measures and the applicant's arguments, staff agreed and concluded that "Given the limited site to locate a terminal and the proliferation of wetland areas within the city, the relief requested through the hardship variance application is the least amount necessary." (Pipeline staff report, p 62). RiverKeeper's arguments against this variance criterion are again, aimed primarily at the terminal (Ex. 44, p 34). RiverKeeper asserts that all of the applicant's alternatives assumed this terminal on the ESP and none considered a terminal somewhere else or a smaller terminal. Those arguments do not address the pipeline and the applicant's efforts to minimize wetland impacts through a different pipeline alignment or different construction techniques. As such, RiverKeeper does not really dispute any of the applicant's statements or conclusions about the pipeline. As with the previous criterion, the Officer concludes that this criterion is met because of the applicant's efforts to minimize or avoid wetland impacts. In support of this conclusion, the Officer adopts and incorporates herein by this reference, the findings from the Pipeline Staff Report (Pipeline Staff Report, p 62) on this variance criterion.

e. **Granting of the variance will not be materially detrimental to the public welfare or be injurious to property or improvements in the neighborhood of the premises.** The applicant estimates ~25.7 acres of temporary wetland impacts due to construction activities and 3.25 acres of permanent wetland impacts for above-ground facilities that will remain in place. The temporary wetland impacts will be mitigated by in-place and in-kind restoration, repair and enhancement, and the permanent impacts will be mitigated at the 120-acre mitigation site (Pipeline application, p 5-40 to 5-41). Staff agreed and concluded that:

> "permanent impacts to 3.25 acres of wetland and temporary impacts to 25.7 acres will not be harmful to the public welfare or injurious to nearby property or improvements. Most of the proposed corridor is sparsely developed and does not offer improvements that may be at risk. Temporary impacts will be mitigated with restoration of the site occurring immediately following construction and permanent impacts will be mitigated elsewhere in the watershed. Filling wetlands under these circumstances will not have direct adverse impacts to either property,

improvements or the general welfare of the community." (Pipeline staff report, p 63)

RiverKeeper's arguments are focused on the permanent wetland impacts of the terminal and do not specifically address anything particular to the pipeline (Ex. 44, p 34). From all of this, the Officer concludes there will certainly be detrimental impacts to the public welfare through temporary and permanent wetland impacts. However, the standard is material detriment, and the Officer concludes that the applicant has minimized the wetland impacts of the pipeline to the point of immateriality. There is no allegation of damage to property or improvements in the vicinity of the pipeline. In this light, the Officer concludes that this variance criterion is met (Pipeline staff report, p 62-63).

f. **The variance will be in general harmony with the intent and purpose of this chapter, and will not adversely affect any officially adopted Comprehensive Plan policy.** The applicant addresses this variance criterion in the same way it has responded to the rest, by pointing out the many ways in which it has endeavored to avoid and minimize the pipeline's wetland impacts (Pipeline Application, p 5-41). Staff reviewed and generally has agreed with the applicant's assertions and conclusions about the project's success in that regard (Pipeline staff report, p 63-64). Again, the opponents focus on the terminal's compliance with this variance standard (or lack thereof) and do not address whether the pipeline complies with it (Ex. 44, p 34-35).

As a starting point, the WDC ch. 16.156 purpose statement does not provide any useful objectives or aspirational goals for the City's wetland protection program. The Officer is left to assume that the intent and purpose of the chapter is to implement Goal 5's wetland preservation objectives. Moreover, the general harmony requirement for variances is an ambiguous one, but is not that difficult to apply to this pipeline proposal crossing Goal 5 wetlands. The applicant points out that it has considered several different alignments and construction methods to find a route that is least destructive to wetlands and has employed construction methods that minimize those impacts. Because the pipeline will be buried, there should be little if any impact to wetlands on the surface, and in that light the Officer concludes it is in general harmony with the presumed wetland preservation objectives of WDC ch. 16.156. The construction phase of the project will have the most significant impact to wetlands, but there the impacts are for the most part temporary. Because the overwhelming impact on wetlands from this project will be temporary and can, at least in theory, be restored, the Officer concludes that this pipeline project meets the final variance criterion (Pipeline staff report, p 63-64).

4. WDC Ch. 16.192: Large-scale development permit for the pipeline generally.

The pipeline segment within Warrenton qualifies as a "large-scale development," for which site plan review and approval is required under WDC Ch. 16.192. Despite the potentially broad scope of such a site plan review, only two aspects of the pipeline project arguably have been challenged by the opponents, *viz.*, soil suitability and adequacy of utilities under WDC 16.192.030 and 050, respectively.

a. **<u>Soil Suitability under WDC 16.192.030</u>.** Approximately 1.5 miles of the 3-mile pipeline alignment will be underlain by Coquille-Clatsop complex soils, which is highly compressible and also subjects those segments to the City's Soil Hazard Overlay regulations in WDC ch. 16.96. WDC 16.192.030 requires that all Large-Scale Developments provide a soil survey, additional geotechnical information and demonstrate that one of following is met:

1. *The detailed soil survey indicates that there is not a significant amount of hazardous soils on the portion of the site proposed for development; or*

2. *A method of eliminating hazards which could result from soils on the site prepared by a licensed geotechnical engineer and submitted to the City of Warrenton Planning and Building Department for review by a City-appointed engineer who will be paid by the developer and/or property owner.*

The primary implication with regard to these highly compressible soils is that the pipeline may float because it is either lighter than or only slightly more heavy than the soil that it replaces (Pipeline Application, p 5-69 to 5-70). To prevent the pipeline from floating during inundation, the applicant will place counterweights on and around those pipe segments. For portions that will be buried in trenches, the overburden to be removed will be back-filled on top of the pipe. While the applicant has provided a general soil survey for the area, particularly on the ESP, it argues that a detailed soil survey for the pipeline route is not necessary because of the construction, installation and pipeline design methods employed will eliminate any hazards that could result from the Coquille-Clatsop complex soils. In response to the suggestion that an LNG pipeline buried in these soils would be particularly hazardous if there were a significant seismic event, the applicant provided the following supplemental information:

> "Oregon LNG has committed to FERC to perform additional geotechnical explorations along the Pipeline and in the vicinity of HDDs and to perform additional geotechnical analyses as part of more detailed engineering design. It is anticipated that concrete coated pip will be installed in some areas to counteract the potential for floatation of the pipeline due to flooding or seismically induced liquefaction. A 3-inch thick coating of concrete will result in a pipeline with a weight that is approximately equal to the volume of saturated soil that is being displaced by the Pipeline. By compensating for the weight of displaced soil, the pipeline will not be subject to significant static settlement and will not undergo significant floatation during flooding or seismically induced liquefaction. The Pipeline design is consistent with applicable FERC regulations related to seismic liquefaction. However, if FERC requires additional seismic liquefaction mitigation for the portion of the Pipeline within the City of Warrenton, Oregon LNG will address this requirement in the detailed design phase of the Project." (Pipeline staff report, p 105)

The applicant's original design and additional explanation of seismic stressing of the LNG pipeline if a major event were to occur was reviewed by the City's geotechnical consultant, who found it to be acceptable (Pipeline staff report, Ex. 2). On this basis, staff concurred with the applicant's position (Pipeline staff report, p 105). In their arguments about the geotechnical risks involved in this project, the opponents did not differentiate the risk associated with the pipeline versus the rest of the terminal project (Ex. 44, p 54).

With regard to soil suitability, the Officer is left with the relatively modest requirements of WDC 16.192.030, the applicant's geotechnical information and pipeline design engineering and the review comments of the city's geotechnical consultant. From all of this, the Officer concludes that the applicant has made a sufficient demonstration that it will employ methods that will eliminate hazards that could result from the Coquille-Clatsop complex soils.

b. Utilities under WDC 16.192.050. WDC 16.192.050 requires a developer to provide complete information about what public utilities and facilities (water, sanitary sewer and transportation) are needed to serve a Large-scale Development, at what levels and whether there is adequate existing capacity to serve the anticipated need. Pertinent to this project, this section requires:

> *The development will only be allowed if sufficient capacity exists or suitable evidence indicates it will exist prior to completion of the development construction. In deciding the sufficiency of capacity, consideration will be given to possible increases in flows resulting from activities of existing system users and from facilities which are likely to be built due to the proposed use, but are not part of the development.*

Unlike the terminal, the applicant asserts that operation of the pipeline "will not require the use of any public utilities or services such as streets, water, sanitary sewer, or storm sewer" (Pipeline Application, p 5-71). The opponents again mount several arguments under this criterion (Ex. 44, p 55), but aimed exclusively at the terminal portion of the proposal. Staff tends to agree with the applicant's claims that no public services and facilities will be needed for the pipeline (Pipeline staff report, p 108 & 115). While the construction phase of the pipeline may have a different demand for public services and facilities than will the operational phase, there is no serious challenge to the applicant's position that few or no services/facilities are needed for either. Absent any such argument or evidence, the Officer takes at face value the applicant's arguments and concludes that this criterion is met (Pipeline staff report, p 63-64).

5. WDC Ch. 16.160: Columbia River Estuary Shoreland and Aquatic Area Development Standards.

A relatively short segment of the pipeline within Warrenton passes through zones that implement Goals 16 and/or 17. Of the five zones through which the pipeline passes, only the I-2 and A-3 Zones are within the City's estuary (Goal 16) or coastal and shoreland (Goal 17) protection areas. Consequently, the pipeline segments in the I-2 Zone (0.4 miles) and A-3 Zone (0.5 miles) are subject to review under WDC 16.160.020. In particular, Goal 16 is implicated where the pipeline crosses the mouth of the Holbrook Slough at Youngs Bay, Adairs Slough, and Vera Creek. Goal 17 is implicated where the pipeline crosses the first 50 feet adjacent to the sloughs and creek within these zones.

Because limited segments of the pipeline implicate Goals 16 and 17, the applicant must demonstrate compliance with all of the substantive subsections of WDC ch. 16.160, which includes the following:

- WDC 16.160.030, Diking
- WDC 16.160.040, Dredging and Dredge Material Disposal
- WDC 16.160.070, Filling of Aquatic Areas and Non Tidal Wetlands
- WDC 16.160.080, Fish and Wildlife Habitat
- WDC 16.160.090, Land Transportation Systems
- WDC 16.160.120, Mitigation and Restoration
- WDC 16.160.130, Public Access to the Estuary and its Shoreline
- WDC 16.160.150, Residential, Commercial and Industrial Development
- WDC 16.160.170, Significant Areas
- WDC 16.160.180, Water Quality Maintenance
- WDC 16.160.190, Water-Dependent and Water-Related Criteria

The applicant devoted an extensive amount of its narrative to addressing these Goal 16 and Goal 17 local land use criteria (Pipeline Application, p 5-42 to 5-61), and the staff report largely accepted and concurred with the applicant's proposed findings and supplemental findings (Pipeline Staff Report, p 65-92). As with the other aspects of the pipeline, the opponents did not provide any focused arguments that the pipeline application (as opposed to the terminal application) failed to meet these mandatory approval criteria (Ex. 44, p 35-49).

For several reasons the Officer concludes that all of the WDC ch. 16.160 criteria, which implement Goals 16 and 17, are met with regard to the pipeline aspect of this project in the I-2 and A-3 Zones. First and most importantly, the impacts to Goal 16 and 17 resources from the pipeline are far smaller, far less significant and of much shorter duration than were the terminal's impacts to Goal 16 and 17 resources under these same criteria. Only 0.4 acres are in the I-2 Zone, and only 0.5 acres are in the A-3 Zone. Thus, the net impact to Goal 16 and 17 areas is less than one acre. Moreover, the vast majority of wetland impacts (~25.7 acres) are temporary, and only 3.25 acres of wetland impact is permanent. All of the impact to areas subject to Goal 16 and 17 are supposedly temporary. This is significantly different than was the case for the terminal impacts to Goal 16 and 17 protected areas (109-acre dredge footprint and an ~35-acre permanent wetland fill).

Second, the applicant is able to and has taken many measures to avoid impacts to Goal 16 and 17 resources and to reduce those impacts that are unavoidable. This is largely due to the preferred route designed by the applicant, the fact that the pipeline is buried, and for several significant Goal 16 and 17 segments, it is installed using HDD.

Third, the opponents focus their arguments primarily against the terminal aspect of the project and far less so with regard to the pipeline component. While the opponents mount some significant arguments as to why the pipeline generally is not designed and will not be installed so as to avoid or reduce impacts to wetland, stream and riparian resources (Ex. 44, attachment 3), those arguments have little relevance to the 3-mile segment in the City of Warrenton. Still, the opponents' correctly point out that construction along the pipeline route in wetland areas will cause significant damage to the wetland soil substrate through compaction. The Officer agrees, but concludes that those impacts are relatively minor compared to other actual and potential wetland impacts, and they are the minimum required to install the pipeline. It is also theoretically possible to rehabilitate those impact areas and restore those damaged wetlands as the applicant proposes, so long as the restoration work is correctly executed.[47] See Terminal Condition 25 and Pipeline Condition 10.

In this way, the Officer reaches a different conclusion about the impact of the pipeline to Goal 16 and 17 resources under these local criteria than he did with the terminal impact to the same resources. In support of this conclusion that the pipeline complies with the WDC ch. 16.160 requirements, the Officer adopts as his own the findings from the Pipeline Staff Report (Pipeline Staff Report, p 65-92). In particular, the Officer adopts the staff report findings addressing the criteria in WDC 16.160.070, Filling of Aquatic Areas and Non-tidal Wetlands (Pipeline Staff Report, p 66-72), WDC 16.160.080, Fish and Wildlife Habitat (Pipeline Staff Report, p 72-76) and WDC 16.160.120, Mitigation and Restoration (Pipeline Staff Report, p 76-87).

6. WDC Ch. 16.164: Impact Assessment and Resource Capability Determination.

The other principal set of local land use regulations implementing Goal 16 are in WDC ch. 16.164. The pipeline passes through only two Goal 16 zones: the A-3 Zone for 0.5 miles and the A-5 Zone for 0.1 miles. As explained in findings addressing the same chapter for the terminal project, *supra*, WDC 16.164.030 (Information Needed for an Impact Assessment), appears to provide a list of information required for a complete application and are not approval standards. The Officer reiterates that interpretation and conclusion here. WDC 16.164.040 (Impact Assessment Conclusion) sets forth the important decisional requirement for the chapter:

Based on the information and analysis in Section 16.164.030, one of the following four conclusions shall be reached:

A. The proposed uses and activities do not represent a potential degradation or reduction of estuarine resource.

B. The proposed uses and activities represent a potential degradation or reduction of estuarine resources. The impact assessment identifies reasonable alterations or conditions that will eliminate or minimize to an acceptable level expected adverse impacts.

C. The proposed uses and activities will result in unacceptable losses. The proposed development represents irreversible changes and actions and unacceptable degradation or reduction of estuarine resource properties will result.

[47] Rehabilitation and restoration of wetland areas is theoretical in the sense that the mitigation measures must be implemented properly to limit damage and the restoration efforts must be executed properly. Absent the entire project complying fully with these measures, wetland restoration frequently does not work or does not work well. Failure is a common outcome in these projects.

D. Available information is insufficient for predicting and evaluating potential impacts. More information is needed before the project can be approved.

The applicant submitted an environmental assessment for the pipeline aspect of the project, at least the segment lying wholly within Warrenton (Pipeline Application, App. C) and addressed the submission requirements in WDC 16.164.030 (Pipeline Application, p 5-61 to 5-66). The applicant then addressed WDC 16.164.040 claiming that the "Pipeline proposed by Oregon LNG represents a potential degradation or reduction of estuarine resources. The impact assessment identifies reasonable alterations or conditions that will eliminate or minimize expected adverse impacts to an acceptable level." (Pipeline Application, p 5-66). Staff agreed with this conclusion (Pipeline Staff Report, p 99-100).

Based on the conclusions *supra* about impacts to protected Goal 16 and 17 resources from the portions of the pipeline that are zoned I-2 and A-3 (0.4 miles and 0.5 miles, respectively) and including the A-5 Zoned section (0.1 miles), the Officer agrees with staff and the applicant and concludes that the A-3 and A-5 Zoned segments of the pipeline qualify under WDC 16.164.040(B). While the pipeline represents a potential degradation or reduction of estuarine resources in the A-3 and A-5 Zones, the impact assessment identifies reasonable alterations or conditions that will eliminate or minimize expected adverse impacts to an acceptable level. In support of this conclusion that the pipeline complies with WDC 16.164.030(B), the Officer adopts as his own the findings from the Pipeline Staff Report (Pipeline Staff Report, p 92-100).

On the same basis, the Officer concludes that the sections of the pipeline zoned A-3 and A-5 comply with the requirements of WDC 16.164.050 (Resource Compatibility Determination)[48] which requires in pertinent part:

> *C. A determination of whether the use or activity is consistent with the resource capabilities of the affected zone. A use or activity is consistent with the resource capabilities of the area when either:*
>
> *1. Impacts on estuarine resources are not significant; or*
>
> *2. Resources of the area will be able to assimilate the use and activity and their effects and continue to function in a manner which:*
> *a. In natural aquatic zones, protects significant wildlife habitats, natural biological productivity, and values for scientific research and education; or*
> *b. In conservation aquatic zones, conserves long-term use of renewable resources, natural biological productivity, recreation and aesthetic values and aquaculture.*

---

[48] WDC 16.164.050 applies generally to the City's aquatic zones; it expressly states that it applies to the A-1, A-2 and A-3 Zones, but does not list the A-5 Zone. The applicant noted that the pipeline in the A-3 zone requires a resource compatibility determination because it is a conditional use; whereas, it is allowed outright in the A-5 Zone (Pipeline Application, p 5-66). Due to the apparent ambiguity and the likely impacts to A-5 estuary resources, the applicant addressed WDC 16.164.050 for the A-5 Zoned segment.

3. *For temporary alterations, the resource capability determination must also include:*
   a. *Determination that potential short-term damage to estuary and shoreland resources is consistent with the resource capabilities of the area; and*
   b. *Determination that the area and affected resources can be restored to their original condition.*

D. Determining Consistency with the Purpose of the Zone. Certain uses in the Aquatic Development (A-1), Aquatic Conservation (A-2), and Aquatic Natural (A-3) Zones may be permitted only if they are consistent with the purpose of the aquatic zone in which they occur. This determination is made as follows:

1. *Identification of the affected zone, and its purpose.*

2. *Description of the proposal's potential impact on the purposes of the affected zone.*

3. *Determination that the proposal is either:*
   a. *Consistent with the purpose of the affected zone; or*
   b. *Conditionally consistent with the purpose of the affected zone; or*
   c. *Inconsistent with the purpose of the affected zone.*

The applicant addressed these requirements in the application (Pipeline Application, p 5-66 to 5-69), and staff agreed with the applicant's proposed findings and conclusions (Pipeline Staff Report, p 100-103). As staff notes, the compatibility determination is contingent upon proper and complete restoration of the pipeline construction areas:

> "Rectification and restoration of temporary impacts will involve the following actions, as needed: general site cleanup, ripping soil to counter the effects of compaction, and restoring/replanting vegetation. Native plant material will be provided for vegetation restoration. The species composition will vary depending on hydrologic characteristics at each location." (Pipeline Staff Report, p 101).

See Pipeline Condition 10. A relatively short segment of the pipeline within Warrenton passes through the A-3 and A-5 Zones (total of 0.6 miles). The impacts associated with construction of the pipeline, and thus the pipeline use generally, can be made compatible with the A-3 and A-5 Zone purposes and thus the resources they are intended to protect so long as the restoration is properly and completely completed. In support of this conclusion that the pipeline complies with WDC 16.164.050, the Officer adopts as his own the findings from the Pipeline Staff Report (Pipeline Staff Report, p 100-103).

7. Warrenton Comprehensive Plan (WCP) Consistency.

The following comprehensive plan provisions appear to be applicable to the pipeline component of the project:

Article 2 (Community Development), §2.310 Land and Water Use Classification

Article 3 (Land and Water Use), §3.320 Commercial Lands, §3.330 Industrial Lands, §3.340 Agriculture, Forestry, Wetlands and Open Space.
Article 4 (Natural Areas), §4.310 Soils, §4.320 Flood Hazards, §4.330 Drainage and Erosion, §4.340 Topography, §4.350 Water Quality, §4.360 Air Quality and Noise, §4.370 Fish and Wildlife, §4.380 Scenic and Historic Resources, §4.390 Energy Conservation.
Article 5 (Columbia River Estuary and Estuary Shorelands), §5.150 Mouth of the Skipanon River Subarea Findings, §5.170 Airport and Vicinity Subarea Findings, §5.301 Deep-Water Navigation, Port and Industrial Development, §5.303 Diking, §5.305 Dredging and Dredged Material Disposal, §5.307 Estuarine Construction, §5.309 Fill, §5.311 Fish and Wildlife Habitat, §5.313 Fisheries and Aquaculture, §5.321 Mitigation and Restoration, §5.323 Public Access, §5.327 Residential, Commercial and Industrial Development, §5.331 Significant Areas, §5.333 Water Quality Maintenance, §5.335 Water-Dependent Development Areas, §5.339 Federal Consistency, §5.347 Mouth of the Skipanon River Subarea, §5.351 Airport and Vicinity Subarea.
Article 6 (Beach and Dune Shorelands)
Article 7 (Community Facilities and Services), §7.320 Water, Sewer and Storm Drainage/Flood Control, §7.330 Fire, Police, Recreation and Solid Waste Management.
Article 8 (Transportation), §8.320 Street Design, §8.330 Street Width, Access and Parking Design, §8.350 Multi-Mode Transportation.
Article 9 (Economy), §9.310 City Economy.

The applicant addressed these WCP provisions in the narrative (Pipeline Application, p 5-78 to 5-110), and staff concurred with this analysis and the applicant's conclusion that all of the requirements in these provisions were met (Pipeline Staff Report, p 118-168). RiverKeeper advances several arguments against the project based on the WCP (Ex. 44, p 62-69), but none relate to the pipeline, only to the terminal portion of the project. As a preliminary matter, the Officer takes the same position as he did under the terminal portion of the project that, generally speaking, the comprehensive plan is implemented through the city's land use regulations in the WDC and that the arguably applicable WCP do not apply directly to any quasi-judicial land use applications. The only WCP provisions that do apply directly are those expressed unambiguously in mandatory terms that, by their language, are directly applicable to quasi-judicial applications. In light of the absence of any focused argument that the pipeline component of the project fails to conform to or otherwise violates an express provision of the WCP, the Officer concludes that the pipeline meets and is consistent with the requirements of the WCP.

V. Decision and Conditions:

A. **The Bidirectional LNG Terminal** application is denied for failure to demonstrate compliance with the following:

WDC 16.160.020 (Columbia River Shoreland and Aquatic Area standards, Deep-Water Industrial Development)
WDC 16.160.040 (Columbia River Shoreland and Aquatic Area standards, Dredging standards and Mitigation/Restoration standards)
WDC Ch. 16.164 (Impact Assessment and Resource Capability Determination standards, Impact Assessment Conclusion and Resource Capability Determination)

WCP 5.305, 5.307, 5.309, 5.311, 5.327 and 5.331.

Although the Officer has determined that the conditional use permits for the temporary wetland impact mitigation in the I-2 Zone and over-height LNG storage tanks complied with the applicable approval criteria, as did the over-height fence variance, because those separate elements are dependent upon the terminal development site plan, which is denied, the Officer denies the entire bidirectional LNG terminal project, exclusive of the pipeline. Because this decision is without prejudice, all of the applications associated with the bidirectional LNG terminal may be refilled with new/additional supporting documentation and information. In the event this decision is appealed, and the City Commission decides to approve the terminal application, the Officer recommends the following conditions. Unless and until the City Commission so decides, the following conditions are merely advisory and do not imply project approval for the LNG terminal:

1. The applicant shall take weekly noise readings during construction and submit the results to the city to demonstrate that the construction noise is at or under the state and federal standards. Noise exceedances may require noise attenuation measures to be implemented.

2. Prior to commencing dredging, the applicant shall provide documentation to the city that it has obtained approval to use the DWS site or an alternative site with the capacity to receive the quantity of material specified in the application.

3. The applicant shall analyze the need for additional improvements to NE King Avenue to accommodate turning movements into the dental office at the intersection E Harbor Street and NE King Avenue, and implement improvements as appropriate, prior to commencing construction.

4. The applicant shall update the portion of the stormwater management plan for NE King Avenue to be consistent with the local road standard design.

5. NE King Avenue shall be designed and constructed to meet the requirements of a local road as described in WDC Table 16.136.010 City of Warrenton Street Design Standards.

6. Prior to issuance of a building permit and terminal construction, the applicant shall implement the mitigation measures described in Section 6 of the Updated February 2015 TIS, per ODOT approval. If the applicant has not obtained ODOT approval of the mitigation measures the applicant shall work with ODOT to finalize and approve the appropriate mitigation measures. ODOT, or the City of Warrenton may modify the means by which a mitigation measure will be implemented, as long as the alternative means ensure compliance with performance measures.

7. The applicant shall implement additional temporary mitigation measures as described in Section 7.1 of the TIS, and listed below, as needed and/or required by ODOT or the City at any time during construction of the facility. All mitigation measures listed below will require ODOT approval prior to implementation.

a. Establish temporary increases in lane capacity (by widening existing shoulders for bypass traffic).
b. Institute time-of-day restrictions for large, oversized construction vehicles.
c. Use flaggers, as necessary, to direct traffic when large equipment is exiting or entering public roads to minimize risk of accidents.
d. Provide advance warning and proper roadway signage along US 101, US 101 Bus, and US 30 to warn motorists of potential vehicles entering and exiting the roadway. Signage would include "Equipment on Road," "Truck Access," or "Road Crossings."
e. Use pilot vehicles when slow or oversized wide loads are being hauled.
f. Place appropriate detour plans and warning signage in advance of any planned traffic disturbances.
g. Maintain one travel lane on all roadways at all times, if possible.
h. If lane closures must occur, post adequate signage for potential detours or possible delays.

8. The applicant shall pay all costs required to fully implement all the mitigation measures stated above to the standards and approval of ODOT.

9. The applicant shall implement and pay all costs for any and all additional mitigation measures required by ODOT for impacts not fully identified or stated in the TIS, such as, but not limited to the following:

   a. Park and ride facilities outside the analysis area with direct state highway access.

10. Roadway improvements to be constructed by the applicant on East Harbor Street shall include curb, gutter & sidewalks along Harbor Street constructed adjacent to the limits of the Terminal Footprint/Outline as shown on Appendix A Figures 5-1, 5-3 & 5-5 (6/24/2014).

11. The applicant shall construct and install approximately 4,600 feet of curb/gutter, drainage and sidewalk on the south side of E. Harbor Street From NE Harbor Place to SE Neptune Drive per the standards and approval of ODOT.

12. Prior to the issuance of building permits, the applicant shall submit modeling of the water and sewer systems acceptable to the city engineer and construct such off-site improvements as determined to be necessary in the exercise of the city engineer's engineering judgment. Depending on the nature and location of such improvements, this may require a land use application or other permit application.

13. The applicant shall extend the City's potable water system by constructing an appropriate sized and looped main by connecting to an existing 18-inch main near SE 7th Street & Marlin Avenue through the LNG property and connecting per the submitted concept drawing Figure 4-32 (12/16/2013) to the City's 18-inch main near the intersection of NW Warrenton Drive and NE 5th Street.

14. The new water main to the SE 7th Street & Marlin main shall be 18 inches ID between a connection at the south end of the north-south waterline on NE King

Avenue and tie on to the existing 18-inch main on SE Marlin Avenue, in accordance with the City's current Water Master Plan.

15. The applicant shall ensure that all discharges to the City of Warrenton's shared outfall are in compliance with an approved National Discharge Elimination System (NPDES) Individual Industrial Permit issued by the Oregon Department of Environmental Quality (DEQ).

16. Non-industrial sewer discharges shall be transported to the City of Warrenton's Waste Water Treatment Plant (WWTP) via the existing sewer system with a point of connection to the 10-inch gravity sewer main on East Harbor Street, if discharges are within the existing capacity of the gravity system. Otherwise a larger gravity sewer main will need to be constructed to the nearest downstream sewer lift station, located at E Harbor Street & SE Heron Avenue.

17. Should construction activities impair well water production or quality, the applicant shall provide alternative sources of water or otherwise compensate the owner. Should permanent well damage from construction activities be substantiated, the applicant shall either compensate the well owner for damages or arrange for a new well to be installed.

18. The applicant shall not begin construction of facilities and/or use of staging, storage, or temporary work areas and new or to-be-improved access roads until it provides the city documentation of approval or compliance with all of the following:

    a. Proof that the applicant has filed the following with the FERC Secretary:
        (1) All remaining cultural resources survey reports and ethnographic studies;
        (2) All site evaluation reports, and avoidance or treatment plans, as required; and
        (3) All comments on the reports, studies and plans from the Oregon and Washington SHPOs and appropriate interested Indian tribes.

    b. Notice to the Advisory Council on Historic Preservation affording it an opportunity to comment if historic properties would be adversely affected; and

    c. FERC staff reviews and the FERC Director of Office of Energy Projects (OEP) approves the cultural resources reports, studies and plans, and notifies the applicant in writing that treatment measures (including archaeological data recover, if necessary) may be implemented and/or construction may proceed.

19. Prior to pipeline construction, the applicant shall file with the Secretary documentation that copies of the Discovery Plan were provided to the Washington Department of Archaeology and Historic Preservation and Oregon SHPO, together with their comments on the plan. If the state agencies do not find the plan acceptable, the applicant shall file a revised Discovery Plan that addresses the concerns, for review and written approval by the Director of OEP.

20. The applicant shall obtain clear title to the entire site and relinquishment by USACE of its dredge spoil disposal easement before commencement of any site preparation work or construction activities.

21. The applicant shall obtain all required state and federal permits before commencement of any site preparation work or construction activities. These include, but are not limited to permits from Oregon Department of Environmental Quality and Division of State Lands and Federal Energy Regulatory Commission, US Army Corps of Engineers.

22. The applicant shall enclose any gas flares and other heat producing operations entirely within a building or similar enclosed structure.

23. The applicant shall obtain a Floodplain Development Permit from the City of Warrenton before commencement of any site preparation work or construction activities.

24. All portions of the East Bank of the Skipanon River Peninsula (ESP) outside of the LNG terminal plant fence shall be accessible by and to the public.

25. The applicant shall complete all wetland mitigation, rehabilitation and restoration work in strict and full conformance with the mitigation plans provided to the City and to state and federal resource agencies and in compliance with the regulations of those agencies. The restoration work intended to be mitigation for the temporary wetland impacts shall occur within 24 months from the date of the initiation of the impact.

B. **The Bidirectional LNG Pipeline** applications, consisting of a wetland hardship variance for 25.7 acres of temporary wetland impacts and 3.25 acres of permanent wetland impacts as part of a large scale industrial development, and conditional use permits relating to wetland mitigation in the I-2 zoning district and a pipeline crossing under the A-3 zone, are approved in general conformance with the plans and application materials provided by the applicant. The pipeline component is approved as proposed, subject to the requirements that the pipeline applicant, owner or subsequent developer, including all contractors, consultants and subcontractors (collectively "Pipeline Developer") shall comply with all applicable code provisions, laws and standards and the following Conditions of Approval, which shall be interpreted and implemented consistently with the foregoing findings:

1. The Pipeline Developer shall conduct noise level testing at the beginning of each HDD construction activity and provide a report to the city within 1 day documenting that the construction noise complies with the state and federal standards. If the construction noise exceeds those standards, construction shall cease until the contractor can design and test a noise attention device or practice that lowers the noise levels at the receiving properties to meet those standards and provide written documentation to the city.

2. The Pipeline Developer shall fully restore to current city public works standards all streets, trails, drainage facilities and other public infrastructure disturbed by the installation of the pipeline.

3. All trenching construction areas shall have restoration begin immediately following the completion of construction of that segment of the trench. Revegetation planting shall occur at the first planting season following construction.

4. The Pipeline Developer shall submit authorizations/permits, including all mitigation plans, from all applicable state and federal agencies prior to the issuance of grading permits for the pipeline. These include but are not limited to ODSL, USACE and an NPDES 1200-C permit.

5. The Pipeline Developer shall consult with USFW concerning habitat categorization and mitigation for pipeline construction impacts, and provide the city the pertinent parts of the USFWS record of decision prior to the issuance of grading permits.

6. Prior to any site work, the Pipeline Developer shall submit the consent of all owners of record for the properties on which the pipeline will be located, easement agreements, court order granting possession or comparable documentation demonstrating legal authority to access each property for purposes of constructing the pipeline.

7. All monitoring reports from the ODSL required Environmental Inspectors shall be submitted to the City when submitted to ODSL.

8. The Pipeline Developer shall not begin construction of facilities and/or use of staging, storage, or temporary work areas and new or to-be-improved access roads until it provides documentation and approval of the following:

   a. The Pipeline Developer shall file the following with the FERC Secretary:
      (1) remaining cultural resources survey reports and ethnographic studies;
      (2) site evaluation reports, and avoidance or treatment plans, as required; and
      (3) comments on the reports, studies and plans from the Oregon and Washington SHPOs and appropriate interested Indian tribes;

   b. the Advisory Council on Historic Preservation is afforded an opportunity to comment if historic properties would be adversely affected; and

   c. FERC staff reviews and the Director of OEP approves the cultural resources reports, studies and plans, and notifies the Pipeline Developer in writing that treatment measures (including archaeological data recover, if necessary) may be implemented and/or construction may proceed.

9. Prior to pipeline construction, the Pipeline Developer shall file with the Secretary documentation that copies of the Discovery Plan were provided to the Washington Department of Archaeology and Historic Preservation and Oregon SHPO, together with their comments on the plan. If the state agencies do not find the plan acceptable, the Pipeline Developer shall file a revised Discovery Plan that addresses the concerns, for review and written approval by the Director of OEP.

10. The Pipeline Developer shall complete all wetland mitigation, rehabilitation and restoration work in strict and full conformance with the mitigation plans provided to the City and to state and federal resource agencies and in compliance with the regulations of those agencies. The restoration work intended to be mitigation for the temporary wetland impacts shall occur within 24 months from the date of the initiation of the impact.

Date of Decision: March 4 , 2016.

By: Daniel Kearns

Daniel Kearns,
Land Use Hearings Officer
City of Warrenton, Oregon

NOTE: Only the Decision and Conditions of Approval, if any, are binding on the applicant, owner or subsequent developer of the subject property as a result of this Order. Other parts of the final order are explanatory, illustrative or descriptive. There may be requirements of local, state or federal law or requirements which reflect the intent of the applicant, city staff, or the Hearings Officer, but they are not binding on the applicant as a result of this final order unless included as a condition of approval.

Notice of Appeal Rights

This is the Hearings Officer's final decision on these consolidated applications. Anyone with standing may appeal any aspect of the Hearings Officer's decision, to the Warrenton City Commission pursuant to WDC 16.208.050(H) by filing a notice of appeal with the Community Development Director within 14 days after the date the notice of this decision is mailed.

A floating temporary dredge line crossing the channel may be feasible depending on current forces and the need for anchoring. If a floating line is technically feasible, it would be flushed/drained and removed from the FNC to accommodate passage of large vessels. Passage of smaller, shallow draft vessels would be diverted around the section of floating line in an area with sufficient water depth appropriately marked and lighted. Figure 3-5 depicts potential locations for a floating temporary dredge line crossing at NRI Dredge Areas 2 and/or 3.

Sandy/silty dredge material from NRI Dredge Areas 2, 3 and 4 may be loaded into scows and transported to the disposal site where it would be hydraulically offloaded. This would require the temporary construction and use of a hydraulic unloader facility outside the FNC in close proximity to the APCO dredge material disposal site, and could extend the time necessary to complete dredging. Offloading rock dredged from NRI Dredge Areas 1 and 2 with a hydraulic unloader would pose operational difficulties because hydraulic unloaders do not function well with fractured rock and limited sediment. The temporary hydraulic unloader facility would be located sufficiently outside the FNC and appropriately lighted and marked to not cause a navigational safety issue.

3.6 MAINTENANCE DREDGING

Maintenance dredging will be completed by JCEP and is anticipated to occur about every three years (M&N 2017d) and will likely be completed with mechanical dredge equipment, with material transported by scow to a temporary hydraulic unloader for placement at the APCO site. Total maintenance dredge volume per three year dredge cycle is estimated at approximately 117,000 cubic yards combined for the four NRI Dredge Areas and the Access Channel. Maintenance dredging activities would follow the same protocol and procedures, and be under the same requirements as those discussed above for capital dredging. Tugs and scows transiting between the dredge and unloading facility will not be of sufficient draft or size to require special consideration beyond communication/coordination with the Coos Bay Pilots Association (Pilots) and U.S. Coast Guard (USCG) as necessary.

3.7 MITIGATION SITE DREDGING

Dredging will also occur at the Eelgrass Mitigation Site which is not adjacent to the FNC; dredging and scow loading operations will be fully outside the FNC and will not impact navigational servitude. Material unloading and hydraulic pipeline transport of dredge material to the Kentuck site will be fully outside the FNC and will not impact navigational servitude. Tugs and scows transiting to and from loading or unloading facilities will not be of sufficient draft or size to require special consideration beyond communication/coordination with the Pilots and U.S. Coast Guard (USCG) as necessary.

5-11-84

HENDERSON MARSH MITIGATION PLAN

This mitigation plan is the result of intensive work undertaken in 1979 by a special task force created through the Coos Bay Estuary Inter-Agency Task Force planning process. Two representatives each from Menasha Corporation, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and a coordinator from Wilsey and Ham, a consultant, developed the evaluations and mitigation actions presented here. Evaluations were made according to the Habitat Evaluation Procedures as developed by the U.S. Fish and Wildlife Service, and are based on field surveys for all identified areas. The mitigation plan was then presented to and ratified by the full Inter-Agency Task Force. (September 1979)

In 1981 Weyerhaeuser purchased Menasha's West Coast holdings and subsequent changes in this mitigation plan were undertaken by Weyerhaeuser Company and the agencies because of the need for rail within the planned road corridor. The changes were completed with the help of the original representatives on the special task force as well as representatives from the U.S. Army Corps of Engineers, U.S. Forest Service, Bureau of Land Management, Oregon Division of State Lands, Oregon Department of Land Conservation and Development, and the Coos County Planning Department.

The following is a detailed description of the elements of the Henderson Marsh Mitigation Plan. The Plan specifies that industrial development will remain south and east of the road corridor. First, there is a listing of the areas that will be filled, requiring the mitigation actions. Second, are listed the specific mitigation actions and their relative resource values. Third, are listed those wetlands not intended to be filled during the scope of this plan, but lie within the development area and are expected eventually to be filled. (See Paragraph 14 of Conditions) The specific areas referred to are shown on the attached drawing. (Figure 1)

Historically, Henderson Marsh was held under several private ownerships, and the uses were basically agricultural activities, such as grazing cattle and horses. Menasha Woodenware Corporation acquired the land and continued to lease the land to individuals for agricultural purposes. In 1959 Menasha Woodenware Corporation developed plans to build a paper mill on the Coos Bay estuary. Part of that plan was to use Henderson Marsh as a lagoon for waste-water effluent. Through the intervention of the Bureau of Sport Fisheries and Wildlife (now U.S. Fish & Wildlife Service), and the Oregon State Game Commission (now Oregon Department of Fish & Wildlife), negotiations began to displace the lagoon to another site, and temporarily replace the wildlife values that were being lost because of the project. Ultimately through negotiations it was decided to displace the lagoon into the deflation plain, with the agencies reasoning that the losses that would occur in the deflation plain would be less than those in Henderson Marsh. (See copies of correspondence attached, Pages A-1 through A-13.) It was also part of the negotiations that Menasha Woodenware Corporation would hold the lands in Henderson Marsh available for waterfowl management, subject to direction of the U.S. Bureau of Sport Fisheries and Wildlife, including public hunting, subject to the following; "It is envisioned that there will be industrial development along the northern edge of Coos Bay, and waterfront and tidelands fronting said corporation lands will be available for public hunting only insofar as public hunting is compatible with other use of the property." (See 1960 Memorandum of Understanding, attached)

Menasha Woodenware Corporation also agreed at its expense to construct and maintain dikes, spillways, tide gates, and aerial spray brush areas in wetland to improve waterfowl habitat on Henderson Marsh. However, only a portion of this work was done during the first two years of the agreement. Subsequently it became more and more difficult for Menasha Woodenware Corporation to get adequate direction from the agencies involved. The last correspondence that exists between Menasha Woodenware Corporation and the agencies was in March of 1964. No other contacts were made until in early 1978.

It can be seen on the attached photos (Figures 2 and 3) that wildlife habitat changes in Henderson Marsh were very minimal. However, in those same photos it is readily apparent that because the lagoon ultimately built only uses 250 of the intended 750 acres of the leasehold (placing the north containment dike 5,500' south of original plan) and the reverse tidegate system installed on Jarvis Creek caused significant changes in water retention on the deflation plain, wetland wildlife habitat on the deflation plain increased substantially. The original agreement, therefore, may be judged as a relatively good one in the interest of maintaining comparable acreages of wetland wildlife habitat, however, not by design.

In 1978, however, development pressures dictated that a significant portion of Henderson Marsh would have to be filled. Compensation for this loss is a mandatory requirement for the development project. The specific compensatory actions that must be undertaken are described in the detailed Henderson Marsh Mitigation Plan that follows. These active restoration actions have been found by the original special task force and Interagency Task Force to be consistent with the resource capabilities and protection of natural values of the area.

Utilizing the site for development purposes as described will require the filling of 162.32 acres of freshwater and saltwater wetlands. Filling these wetlands will have an adverse impact, however, the lost biologic value is compensated for by the mitigation actions described.

The site has unique characteristics that make it especially suited to a large industrial use with water dependent and/or related requirements. These unique characteristics are:

1. Location adjacent to the 35' deep draft channel.
2. Adjacent to the portion of the main channel that has favorable hydraulic conditions for low maintenance dredging requirements.
3. Location in the lower bay, below the railroad bridge. This area should be the prime area for future development because of the dredging and navigation constraints in the upper bay.
4. The largest flat and serviceable parcel of land on the entire Oregon south coast region that meets the above requirements.
5. The parcel's single ownership that enhances its usability for a large, integrated development.
6. On-site availability of a water source via the Coos Bay Dune Sheet.
7. A waste-water effluent lagoon that is adjacent to the site. In addition the lagoon has a deep-water ocean outfall which has additional capacity.

8. The location adjacent to existing heavy industrial facilities and the required industrial support services.
9. The location away from population centers and thus a minimum of use conflicts.
10. A favorable location in terms of air quality, wind pattern, and air shed replacement characteristics.

The zoning designations in the Coos Bay Estuary Plan which apply to the Henderson Marsh Mitigation Plan are compatible with the long-term future of this site to reserve it for an integrated industrial use that takes full advantage of the unique characteristics.

MITIGATION REQUIREMENTS

Site 1a - Willow (includes Site 20, Port
Road Fill)

- This site has a habitat evaluation of 5.11 and is 77.82 acres in size.

  Total HUV units lost - 397.66

Site 1c - Willow North of Workman's Yard (Port Road Fill)

- This site has a habitat evaluation of 5.11 and is 1.93 acres in size.

  Total HUV units lost - 9.86

Site 2 - Wet Meadow #1

- This site has a habitat evaluation of 5.66 and is 19.50 acres in size.

  Total HUV units lost - 110.37

Site 3 - Wet Meadow #2

- This site has a habitat evaluation of 6.77 and is 8.00 acres in size.

  Total HUV units lost - 54.16

Site 4a - Salt Marsh #1

- This site has a habitat evaluation of 5.44 and is 6.63 acres in size.

  Total HUV units lost - 36.07

Site 4b - Salt Marsh (Port Road Fill)

- This site has a habitat evaluation of 5.44 and is 0.33 acres in size.

  Total HUV units lost - 1.80

Site 4c - Salt Marsh #1 (Port Road Fill)

- This site has a habitat evaluation of 5.44 and is 0.40 acres in size.

  Total HUV units lost - 2.18

Site 5 - Meadow (60% wet=)

- This site has a habitat evaluation of 4.88 and is (60%=) 11.24 acres in size.

  Total HUV units lost - 54.85

Site 7 - Rush Meadow #2

- This site has a habitat evaluation of 4.00 and is 7.36 acres in size.

  Total HUV units lost - 29.44

Site 11 - Alder/Willow Corridor

- This site has a habitat evaluation of 4.75 and is 10.40 acres in size.

  Total HUV units lost - 49.40

Site 14 - Willow/Conifer (Road North of Roseburg - Port Road Fill)

- This site has a habitat evaluation of 4.55 and is 6.08 acres in size.

  Total HUV units lost - 27.66

Site 19a - North East Pond/Lily Pad (Port Road Fill)

- This site has a habitat evaluation of 4.07 and is 0.55 acres in size.

  Total HUV units lost - 2.24

Site 19c - North West Pond/Willow/Lily Pad (Port Road Fill)

- This site has a habitat evaluation of 4.85 and is 2.02 acres in size.

  Total HUV units lost - 9.80

Site 19d - South West Pond/Lily Pad/Willow (Port Road Fill)

- This site has a habitat evaluation of 4.63 and is 0.10 acres in size.

  Total HUV units lost - 0.46

Site 21 - Willow (Corps Spill)

- This site has a habitat evaluation of 5.11 and is 8.68 acres in size.

  Total HUV units lost - 44.35

Site 30 - Pocket Salt Marsh

- This site has a habitat evaluation of 3.80 and is 1.28 acres in size.

  Total HUV units lost - 4.86

162.32 ACRES OF WETLANDS ARE TO BE FILLED. THESE MITIGATION REQUIREMENTS ANTICIPATE THE NEED FOR REPLACEMENT OF 835.16 HUV UNITS TO BE LOST.

MITIGATION ACTIONS

Action 1 - Site 1b - Willow North of Port Road

- Had a beginning habitat evaluation of 5.11 before mitigation design.
- Develop drainage control structure at road to regulate aquatic regime.
- Develop pond areas averaging 1/2 acre in size, to range between 1/4 and 3/4 acre in size, to encompass a total of three acres of ponds.
- Connecting channels will be opened between the pond areas, to develop maximum edge effect.

Site Size = 26.60 AC
Unit Gain = 1.8

Total HUV achieved = 47.88

Action 2 - Site 1c - Willow North of Workman's Yard

- Had a beginning habitat evaluation of 5.11 before mitigation design.
- Develop drainage control structure at road to regulate aquatic regime.
- Develop 2 ponds, 1/2 acre in size or equivalent, to achieve one acre of ponds.
- Connecting channels will be developed between ponds to maximize edge effect.

Site Size = 5.21 AC
Unit Gain = 1.8

Total HUV achieved = 9.38

Action 3 - Site 12 - Wet Conifer North of Old Rookery

- Had a beginning habitat evaluation of 4.75 before mitigation design.
- Drainage control at south end to regulate aquatic regime and construction channel at south end to Site 1b if deemed appropriate by ODFW and USFWS.
- Develop pond areas, to a total of 2 acres of open water.
- Connecting channels will be developed to maximize edge effect.

Site Size = 20.40 AC
Unit Gain = 2.5

Total HUV achieved = 51.00

Action 4- Site 14 - Deflation Plain North of Roseburg's and Road Corridor

- Had a beginning habitat evaluation of 4.55 before mitigation design.
- Develop pond areas to total 4 acres of open water.
- Develop connecting channels as appropriate for edge effect.

Site Size = 31.78 AC
Unit Gain = 1.8

Total HUV achieved = 57.20

Action 5 - Site 4b - Salt Marsh, Site 13 - Dune Hummock, Site 10c - Low Fresh Marsh, Site 10d - Deflation Plain (Scrub/Shrub Wetland). SEE PARAGRAPH 14, CONDITIONS.

- Site 4b had a beginning habitat evaluation of 5.44, site 13 had a beginning habitat evaluation of 4.16, site 10c had a beginning habitat evaluation of 4.55, and site 10d had a beginning habitat evaluation of 4.55.
- Remove upper tidegates and two sand roads to increase tidal activity into the area. Also remove lower tidegates and install two 5-foot arch culverts to make the portion of Jarvis Creek east of the transportation corridor fully intertidal (open to the estuary).
- A weir and reverse tidegate system will be installed in upper Jarvis Creek across the opening of a proposed 84 inch culvert under the future access road in the transportation corridor.
- Grade and contour dune hummock areas to increase aggregate marshes to 38.4 acres.
- Contour adjacent dunes to maximize edge values.
- Salt marsh corridor between spoils disposal site on Henderson Marsh and road corridor will be 300' minimum width with buffer strips consisting of wetland and upland vegetation to top of road corridor and fill.
- A 400' wide zone on a line perpendicular to the center line of the channel on a centerline to the mouth of Jarvis Creek shall be designated to project estuarine values and give continuity to the mitigation action.

SITE 4b - LOW SALT MARSH BRACKISH
Site Size = 1.9
Unit Gain = 1.5
Total HUV = 2.85

SITE 13 - DUNE HUMMOCK
Site Size = 7.1
Unit Gain = 2.78
Total HUV = 19.74

SITE 10c - LOW FRESH MARSH
Site Size = 11.1
Unit Gain = 2.39
Total HUV = 26.53

SITE 10d - DEFLATION PLAIN (SCRUB/ SHRUB WETLAND)
Site Size = 18.3
Unit Gain = 2.39
Total HUV = 43.74

Total HUV achieved = 92.86

Action 6 - Site 10a - Deflation Plain North of Lagoon

- Had a beginning habitat evaluation of 4.55 before mitigation design.
- Develop ponds over 10% of the site ranging from 1/4 to 1 acre in size to achieve 26 acres of pond area.
- Contour excavated materials to maximize water-edge effect (on-site disposal is preferred and will be utilized when appropriate for enhancement).

Site Size = 230.60 AC
Unit Gain = 1.55

Total HUV achieved = 357.43

Action 7 - Site 10b - Deflation Plain South of Lagoon

- Had a beginning habitat evaluation of 4.55 before mitigation design.
- Develop ponds over 10% of the site that are 1/4 - 1/2 acre in size to achieve 1.5 acres of ponds.
- Contour excavated materials to maximize edge effect (on-site disposal is preferred and will be utilized when appropriate for habitat enhancement).

Site Size = 13.89 AC
Unit Gain = 1.55

Total HUV achieved = 21.53

Action 8 - Sites 7 and 11 - Channel and Rush Meadow West of Henderson Marsh

- Site 7 had a beginning habitat evaluation of 4.00, and Site 11 had a beginning habitat evaluation of 4.75 before mitigation design.
- Sites 7 and 11 were designated as areas to be filled, in subsequent design changes. See "MITIGATION REQUIREMENTS".

Action 9 - Site 15 - Menasha Lagoon

- Had a beginning habitat evaluation of 0.00 before mitigation design.
- Dike the southwest corner of the lagoon to create a freshwater marsh that is 48.67 acres in size.

Site Size = 48.67 AC
Unit Gain = 4.5

Total HUV achieved = 219.02

Action 10 - Site 9a - Ditch from Area 1b to Area 10a North of Road Corridor

- Had a beginning habitat evaluation of 4.16 before mitigation design.
- Create approximately 1 acre of open water and drainage ditches which will connect area 1b to area 10a, leaving a buffer strip which will be vegetated between the road corridor and the mitigation project.
- Project is to be designed to discourage intrusion into the wetlands fro~ the road corridor.
- Edge effect will be maximized.
- Drainage from this corridor and pond will then be channeled to the deflation plain.

Site Size = 4.59 AC
Unit Gain = .53

Total HUV achieved = 2.43

THESE MITIGATION ACTIONS ENCOMPASS 420.14 ACRES OF LAND. INCLUDED IN THIS ARE NEWLY CREATED WETLANDS TOTALLING 117.5 ACRES. THE TOTAL HUV ACHIEVED FOR THESE NINE ACTIONS IS 858.73 POINTS.

RECAP OF FILL SITES AND MITIGATION ACTIONS

MITIGATION REQUIREMENTS

Site	Acres	HUV	Loss
1a	77.82	5.11	397.66
1c	1.93	5.11	9.86
2	19.50	5.66	110.37
3	8.00	6.77	54.16
4a	6.63	5.44	36.07
4b	0.33	5.44	1.80
4c	0.40	5.44	2.18
5	11.24	4.88	54.85
7	7.36	4.00	29.44
11	10.40	4.75	49.40
14	6.08	4.55	27.66
* 19a	0.55	4.07	2.24
* 19c	2.02	4.85	9.80
* 19d	0.10	4.63	0.46
21	8.68	5.11	44.35
30	1.28	3.80	4.86
	162.32		835.16

MITIGATION ACTIONS

Nr.	Acres	HUV	Gain
1	26.60	1.80	47.88
2	5.21	1.80	9.38
3	20.40	2.50	51.00
4	31.78	1.80	57.20
5/4b	1.90	1.50	2.85
5/13	7.10	2.78	19.74
5/10c	11.10	2.39	26.53
5/10d	18.30	2.39	43.74
6	230.60	1.55	35[illegible]
7	13.89	1.55	
8	(action dropped)		
9	48.67	4.50	219.02
10	4.59	0.53	2.43
	420.14		858.73

* These actions concern areas of the identified units which will be impacted by the transportation corridor construction. The remainder of each site will be treated as per Condition 15.

ESTUARINE MITIGATION USING DSL RULE

Formula

AM = (RVd/RVm) (AD)

AM = Area of the Mitigation Site
AD = Area of the Development Site
RVd = Adjusted Relative Value of the Development Site
RVm = Adjusted Relative Value of the Mitigation Site

Mitigation Rule Standards (Selected for this discussion)

1. Director may adjust relative values 25%.
2. Surface area of a mitigation site may not be smaller than the surface area of the development site.
3. If a habitat is replaced by a better habitat, the ratio will be 1:1 under the conservation of surface area principle.

Estuarine area to be developed within the scope of the Henderson Marsh Agreement:

AREA	RVd	DESCRIPTION	ACRES
Site 17	3.0	Marine Intertidal	9.70
Sites 4c, 30, 4b	4.0	Marine High Salt Marsh/ Sand/Mud	2.01
Site 4a	5.0	Low Brackish Marsh/ Sand/Mud	6.63
			18.34

RVd weighted average for 18.34 Ac = 3.83

RVd increased by 25% = 4.79

MITIGATION AREAS PROPOSED

AREA	CURRENT DESCRIPTION	MITIGATED DESCRIPTION	RVm	ACRES
Site 4b	Low Brackish Marsh/ Sand/Mud	Low Marine Marsh/ Sand/Mud	1.0	1.9
Site 10c	Low Fresh Marsh/ Sand/Mud	Low Brackish Marsh/ Sand/Mud	5.0	11.1
Site 10d	Shrub/Scrub Fresh Wetland/Sand	Low Brackish Marsh/ Sand/Mud	5.0	18.3
Site 13 (West)	Dune Hummock	Low Brackish Marsh/ Sand/Mud	5.0	0.9
Site 13 (East)	Dune Hummock	Low Marine Marsh/ Sand/Mud	1.0	6.3
				38.5

RVm for total mitigation area = 4.15

RVm decreased by 25% = 3.11

Worst case AM Determination

AM.= (RVd/RVm) (AD)
= (4.79/3.11) (18.34)
= 28.25 Acres

Therefore, the proposal contained within this agreement exceeds that which would be required in a worst case analysis.

CONDITIONS

1. All habitat development construction activities described in this mitigation package will occur wherever practicable with on-site design assistance provided by ODFW and USFW. The following minimum requirements will apply to the individual actions before they will be considered complete.

   - Slopes established shall be stable and naturally revegetating, AND
   - pond mean water depth shall be 2 feet for the original pond area intended, AND
   - the minimum water depth shall be maintained for 6 months annually ending in June.

   If there is a demonstrated change in the natural rate of recession in the wetland areas of the Plan, during the nonregulated portions of the year, Weyerhaeuser will work with the appropriate agencies to define the problem and possible remedies.

2. Disposal of excavated materials associated with mitigation will occur on-site according to the agency specifications. Disposal of excavated materials that will not go into the fill areas should preferably be disposed of in the dune hummocks at toe of stabilized dune between Henderson Marsh and deflation plan.

3. Dredged material disposal will be utilized for fill whenever practicable.

4. The Oregon Department of Fish and Wildlife will take responsibility to maintain and manage the drainage control structures on current Weyerhaeuser properties that have been identified in several of the above items, as a part of their wildlife management program.

5. Any problems that may arise during the implementation of the above actions that would undermine the intentions of the mitigation action will require development of alternative actions to create opportunities for the intended habitat values with the agreement of ODFW, USFWS and Weyerhaeuser Company. Pursuant to the original intent for long range management, Weyerhaeuser will turn over responsibilities of the future management of all mitigation actions to ODFW and their designated agents or assigns. As an action or portion of an action, is identified for construction/implementation, Weyerhaeuser will notify ODFW and USFWS (and land manager if not on Weyerhaeuser property). Pre-design discussions or on-site design will be undertaken. Generally, actions will be constructed as single projects, though actions can be broken into discreet portions if previously agreed to by above parties.

When construction is completed, Weyerhaeuser will notify in writing ODFW and USFWS (and land manager if appropriate) that construction is complete and that the two year project monitoring program is to begin (Notice of Construction Completion). Unless notified in writing by ODFW and USFWS, the two year monitor period shall begin 30 days after date of notification (NCC). If there is objection to the initial construction the agency must outline the perceived problem(s) and recommend the action to be taken to resolve it in writing, within the 30 day Notice of Construction Completion period. This includes any request that the parties meet on-site to discuss the situation.

If no problems are identified, or problems are identified and consequently resolved, then a two year monitor period begins. This will consist of two calendar years from the close of the 30 day Notice of Construction Completion, whereby the action can be observed to determine if it meets the objectives as outlined in the mitigation plan.

At the end of the two year monitor period, Weyerhaeuser will notify in writing ODFW and USFWS (and land manager if appropriate) that the two year period has ended (Notice of Action Completion). The respective agencies then have 30 days in which to notify Weyerhaeuser of any deficiencies, problems, etc., with the particular action. If a problem is identified, Weyerhaeuser will correct the problem and all parties involved shall mutually determine if further monitoring is required.

If no problems are identified at the close of the 30 day final notice, then responsibility for the operation and maintenance of the mitigation action shifts to the ODFW (or land manager if appropriate).

6. In recognition of the DSL rule requiring five years of mitigation project monitoring, Weyerhaeuser will maintain responsibility for project success for five years. However, actual facilities maintenance and operations will be delegated to ODFW after two years, following the procedure outlined in the long-term responsibilities for Actions (Condition 5). If the causes for project deficiencies are difficult to determine, i.e., whether ODFW or Weyerhaeuser is responsible, then DSL will be asked to determine the responsible party and the appropriate corrective actions.

7. The Port and Corps will be required to mitigate for those fill actions that have occurred. Mitigation actions are a part of the above-described projects. Compensation is to be negotiated with Weyerhaeuser Company.

8. Weyerhaeuser Company has the right to develop an alternative site or action to achieve comparable objectives to the diking of the south part of the lagoon, if they determine that the existing Action No. 9 is inconsistent with their future lagoon use requirements. An alternative action must be developed with ODFW, USFWS, and the landowner.

Weyerhaeuser will remain responsible for all dikes that are necessary for the Lagoon's use for industrial wastewater treatment and containment. ODFW will be responsible for long-term maintenance (after two year monitor period) of that portion of Action 9 that does not include those dikes.

9. Weyerhaeuser-owned properties north of the port road, including Sites 1b, 1c, 9a, 10a, 12, and the ridges and timberlands adjacent to those sites will be deeded to the public (ODFW) for value (trade, sale or gift) after all conditions of this agreement have been met.

10. Interim management of the Henderson Marsh area is available to the resource agencies, as long as the management activities and consequent habitat changes do not alter the requirements for mitigation or jeopardize the filling schedule. Mitigation actions completed as per this plan will be turned over to ODFW for management subject to Condition 5.

11. Weyerhaeuser Company will be the responsible agent for all mitigation activity identified in this plan. Mitigation responsibilities assessed to the Corps of Engineers and the Port of Coos Bay for fill sites will be managed by Weyerhaeuser Company.

12. Phasing of these mitigation actions will be allowed in accord with the phasing of the filling of wetland areas and will be determined by the development program and permit requirement. Mitigation actions will occur prior to or concurrent with associated fills, except when engineering constraints prohibit this and Oregon Department of Fish and Wildlife and U.S. Fish and Wildlife Service agree to allow delaying the start of the mitigation project which shall be no longer than 9 months.

13. The items contained in this Plan are expected to be the same standards and mitigation requirements that will be stipulated in the state and federal permits necessary for the fill action.

14. Any net gains in freshwater HUV's resulting from the mitigation actions identified above will not be allowed for mitigation credits or "banking" outside this plan.

Concerning LCDC Goal 16 and ORS 541 requirements, approximately 18.34 acres of estuarine resource are expected to be lost which includes 11.71 acres of intertidal. Intertidal means from minus 3.5 to line (1983) of non-aquatic vegetation including lands north of bay front access road. Mitigation Action 5 (4b, 13, 10c, and 10d) would create approximately 36.5 acres of salt marsh.

A 400' wide buffer zone will be established at the entrance of Jarvis Creek to extend to the navigation channel to protect the estuarine values created by mitigation actions 5a and 5b.

15. With the exception of Sites 4b and 13, wetlands that are south and east of the planned Port Road and not included in the Henderson Marsh mitigation plan are listed below. If they eventually become industrial sites, mitigation for these wetlands will occur and will be provided for as supplements to this plan.

a. Site 16 - Jordan Lake

- This site has a habitat evaluation of 4.75 and is 2.85 acres in size.

b. Site 18 - Old Deflation Plain (Between Port Road and Roseburg Lumber)

- This site has a habitat evaluation of 4.55 and is 26.5 acres in size.

c. Site 19 - Lily Pad/Willow Complex

- This site is a wetland complex which is interconnected by culverts and empties into Jordan Cove. There are five distinct ponds which remain wet most of the year and are listed as follows:

19a) N. E. Pond, 1.65 acres, 4.07 HUV.
19b) S. E. Pond, 3.49 acres, 4.67 HUV.
19c) N. W. Pond, 11.75 acres, 4.85 HUV.
19d) S. W. Pond, 4.78 acres, 4.63 HUV.
19e) S. Pond, 8.08 acres, 3.55 HUV.

16. Estuarine intertidal areas between Roseburg Lumber Company and the mouth of Jarvis Creek have been evaluated as a part of the Henderson Marsh Mitigation Plan. However, only Site 17 has been designated for a specific project at this time (PACON project) with specific mitigation actions (Site 4b). Estuarine intertidal losses not already provided for in this plan will be handled on a project basis through the appropriate permit processes.

17. The evaluation of the habitats included in the Henderson Marsh mitigation plan will be treated as base data for all future discussions of changes or supplements as provided in Paragraphs 1, 5, 6, 8, 15, and 16 of these conditions.

The signators to this plan agree to respond promptly to any request provided for in these conditions and, if appropriate, assign individuals to represent their interests in clarification and/or resolution of problems that may arise during the implementation of this plan.

18. This plan recognizes the impending shift in stewardship on the North Spit from the Corps to BLM for certain lands where mitigation actions are proposed (Actions 5,6,7,9). This plan supports the BLM land use planning process that must be accomplished (as per change in control). It further encourages that planning process to fully recognize the rationale, need and agreed to management designs, that have been developed in the Henderson Marsh Mitigation Plan. If, for some reason, the BLM land use plan does not provide for the implementation of mitigation actions presented in this document, then mutually agreeable (Weyerhaeuser, ODFW, USFWS, and landowner [if not Weyerhaeuser]) alternative mitigation actions will be identified.

Accepted and agreed to this 11 day of May, 1984.

Vice President Western Oregon Region Weyerhaeuser Company	for Director Oregon Department of Fish and Wildlife	Asst. Regional Director United States Fish and Wildlife Service