THE RELATIONSHIP BETWEEN THE UPPER LIMIT OF COASTAL WETLANDS AND TIDAL DATUMS ALONG THE PACIFIC COAST

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PREFACE

In 1975, the National Ocean Survey (NOS) was requested by the U.S. Environmental Protection Agency to conduct a study relating to the use of tides to assist in determining the area of applicability of the Federal Water Pollution Control Act. Specifically, the request was to determine if there is a correlation between a tidal datum which is measured and recorded by NOS throughout the coastal United States as designated by vegetative analysis. Results of the pilot study led to the recommendation to conduct more detailed research into the possibility of defining coastal wetlands within a biogeographical region in terms of a tidal datum. In the interest of advancing knowledge of the intertidal areas of the west coast for our charting and coastal mapping function, NOS agreed to conduct the study, with the results embodied in this report. This study was assigned to the Oceanographic Division, Office of Marine Surveys and Maps, which under the 1979 reorganization became the Tides and Water Levels Division, Office of Oceanography.

Representing the Environmental Protection Agency as Project Manager was Dr. Harold Kibby. For the National Ocean Survey, Mr. Carroll I. Thurlow served as manager.

This report was written by Henry A. Debaugh, Jr. and A. Nicholas Bodnar, Jr. All field work was performed by employees of the Tides and Water Levels Branch, Oceanographic Division. They were LCDR A. Nicholas Bodnar, Jr., NOAA, Professional Engineer (California), Principal Engineer, Requirements and Facilities Section; Mark W. Allen, Oceanographer; William M. Stoney, Oceanographer; Stephen K. Gill, Oceanographer; Richard A. Hess, Oceanographer; and Henry A. Debaugh, Jr., Oceanographer/Biologist.

The preparation of this report could not have been accomplished without the support of the following individuals who contributed many long hours of work to the project: LCDR Don M. Spillman, Acting Chief, Tides and Water Levels Branch; Gina A. Morse; Mary M. Lamkin; James R. Hubbard, Chief, Datums and Information Section; Stephen D. Lyles; Briah K. Connor; Robert J. Leffler; Frederick Lindsey; Jack E. Fancher, Chief, Processing Section; Howard K. Kushner; Thomas F. Sheehan; Dale H. Deitemyer; Robert C. Nace; Donald C. Carrier, Chief, Requirements and Facilities Section; Robert J. McClain; David L. Porter; Richard F. Edwing; and Jill Meldon. Also, special thanks are extended to Dr. Ronald New and Dr. Stanley Alper of the Office of Marine Technology for their assistance with the statistical analysis of the data.

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ABSTRACT. The relationship between the upper limits of coastal wetlands and tidal datums as well as inundation levels was investigated for 17 marshes along the Pacific coast. Based on 8 marshes (10 samples per marsh) in Oregon and Washington a standard elevation for the upper limits of coastal marshes (in this region) was computed [0.46 meter (1.5 ft) above mean high water (MHW)]. However, this relationship does not apply in areas which progress from marsh to sand dune. Based on 5 marshes (10 samples per marsh) in south and central California a standard elevation for the upper limits of coastal marshes, in this region, was also computed [0.90 meter (3.0 ft) above MHW]. A method of computing the equivalent of 19-year mean frequency and duration of inundation tables at subordinate tide stations is described. An average percent frequency and duration of inundation at the upper limits of Oregon and Washington marshes (11.6 percent frequency, 2.0 percent duration) is shown. No inundation level was computed for south and central California because the upper limits of these marshes exceeded any inundation level.

I. INTRODUCTION

A. Purpose

This report represents the engineering portion of a larger research project, funded by the Environmental Protection Agency (EPA), to investigate the possibility of defining wetlands using vegetative criteria and/or tidal datums. The project's intent is to survey and document the elevations of the various tidal datums and how they relate to the transition zone between marsh and upland vegetation. The biological portion of this project will be reported by the respective consultants retained by EPA.

B. Background

Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) as interpreted by the United States District Court for the District of Columbia [National Resource Defense Council vs. Callaway et al. Civil Action N. 74-1242 (D.C.D.C. March 27, 1975)] required the Corps of Engineers, in cooperation with the EPA, to define wetlands contiguous to the navigable waters for regulatory purposes.

In May 1975 the National Ocean Survey (NOS) was requested by EPA, to conduct a pilot study to investigate the relationship between (1) tidal datums and upper coastal marsh vegetation, and (2) the frequency of inundation for elevations corresponding to the upper limits of the wetlands.

Results of the pilot study led to the recommendation that more investigations be conducted to determine whether the upper limit of coastal marshes could be adequately delimited based on either a constant value above the mean high water (MHW) datum or on a frequency of inundation level. A more intensive survey of the three biogeographical regions on the west coast was initiated in 1977. This report is a result of that survey.

On September 18, 1979, the EPA published proposed guidelines in the Federal Register (Vol. 44, No 182, pp. 54222-54251) for specification of disposal sites for dredged or fill material. In section 230.42, wetlands are defined as consisting of areas that are inundated or saturated by surface or ground water at a <u>frequency</u> and <u>duration</u> sufficient to support, and that under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

II. METHODS

A. Site Selection

Twenty-one marshes were selected—7 in California (Fig. 1), 11 in the Pacific Northwest (Fig. 2), and 3 in Alaska (Fig. 3). The criteria for selection were (1) availability of established local tidal datums, (2) suitable marsh areas, (3) lack of disturbance at the transition zone between wetland and uplands, and (4) economics. Criteria 1 and 4 were the most restrictive.

Several new tide stations were established to provide control for this project, especially in areas where no tidal data were available In some areas, tide stations established for other projects were utilized for this study. Finally, in other areas historic tide stations were reoccupied to provide control.

A list of marshes which met the vegetative criteria was presented to NOS by the biological consultants. NOS selected the marshes included in this study based on criteria 1 and 4.

B. Field Procedures

To determine the local tidal datums at each study site, a tide gage was installed in the vicinity of the MHW line within the study area. A minimum of three high waters were collected and reduced to mean values (1941-1959) by using simultaneous comparisons with measurements taken at a controlling tide station. These mean values were used to compute the local MHW datum (Marmer, 1951). As a check on these elevations, a third-order level connection was made between the study site gage and the controlling tide stations where feasible. Three temporary bench marks (TBM) were established in the vicinity of these study site gages to simplify future data collection. These bench marks are described in the separate appendix to this report.

Third-order levels were run between the study site gages and the temporary bench marks set near the transects established by the biological consultants. Profiles were then run along each transect and referenced to a common datum with the tide stations. The stationing and elevations were measured at all grade changes and at all stakes preset by the biological consultants. This information is presented in both tabular and graphic form in the separate appendix to this report. A generalized schematic of a typical marsh situation is illustrated in Fig. 4. The location of all transects in each marsh was selected by the biological consultants.

Figure 1 - STUDY SITE LOCATIONS (CALIFORNIA)

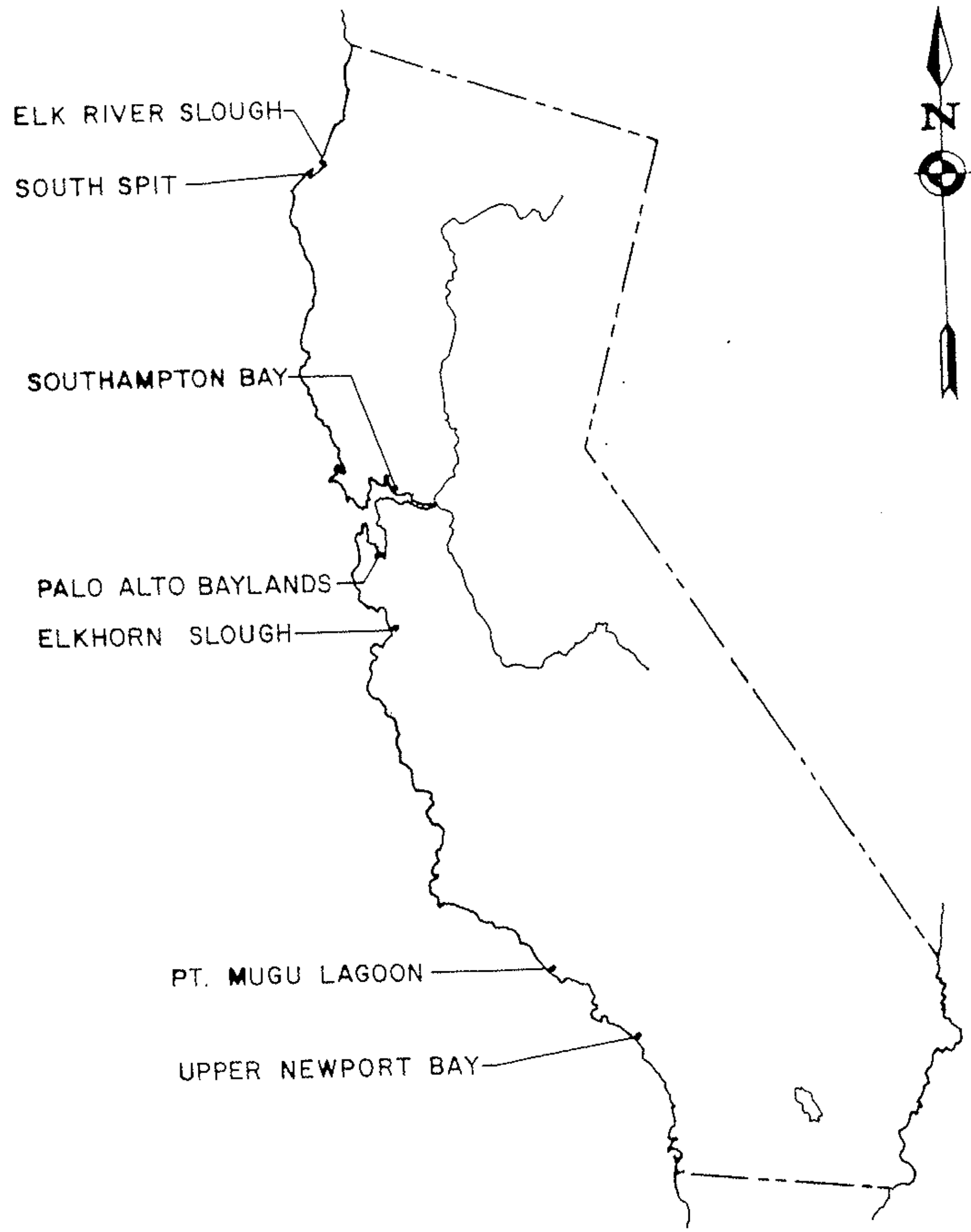


Figure 2– STUDY SITE LOCATIONS (PACIFIC NORTHWEST)

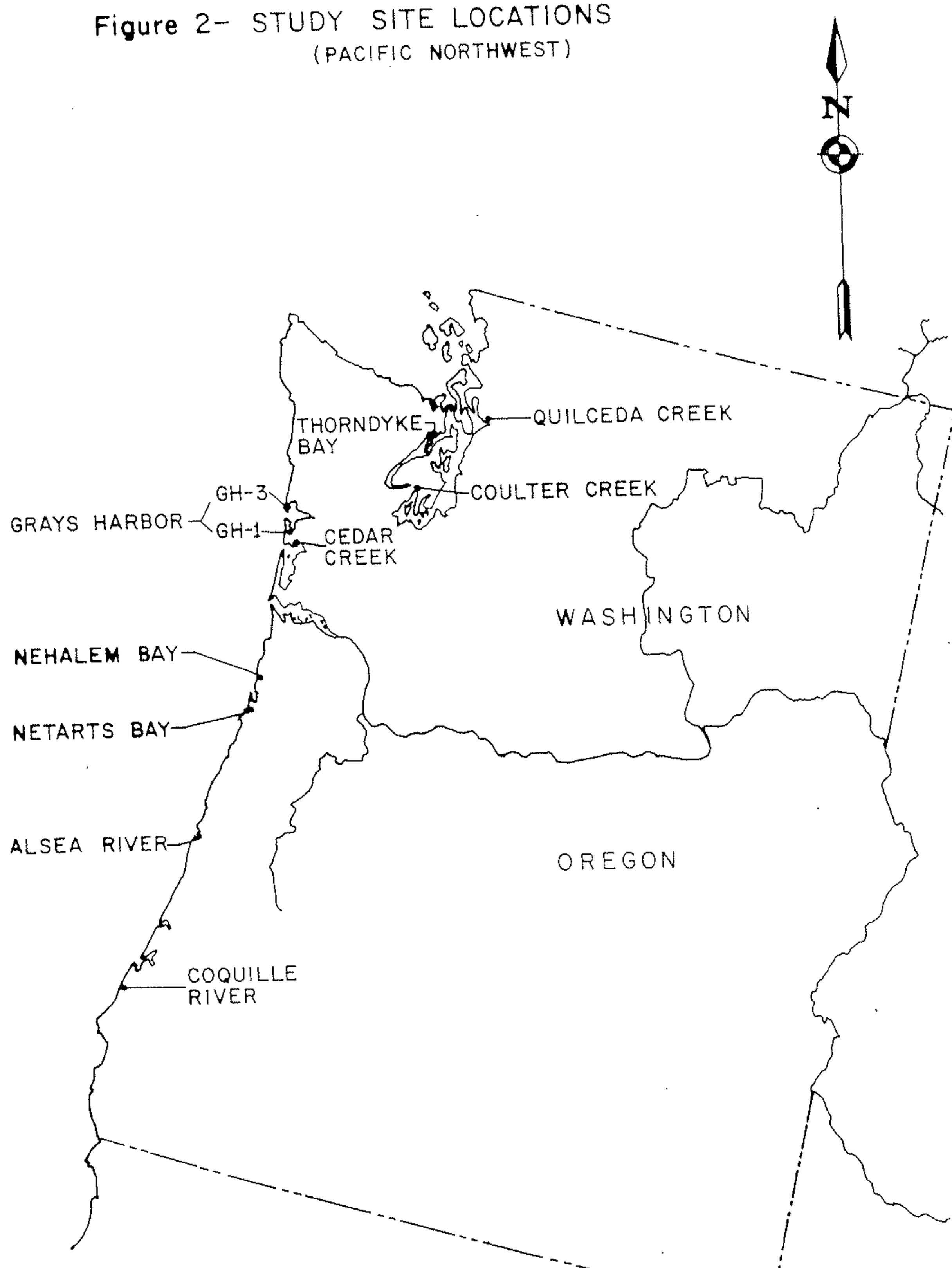


Figure 3- STUDY SITE LOCATIONS
(ALASKA)

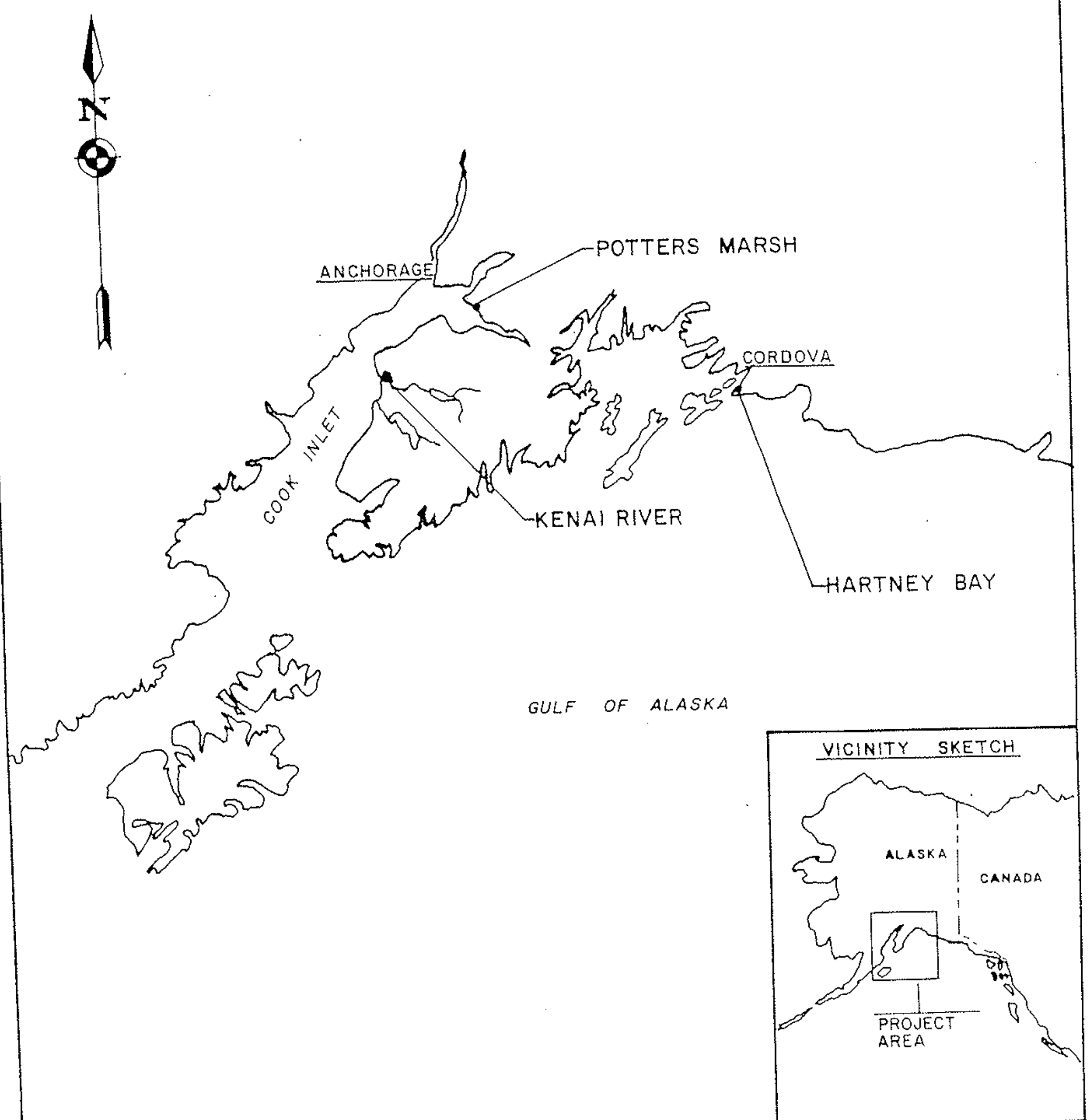
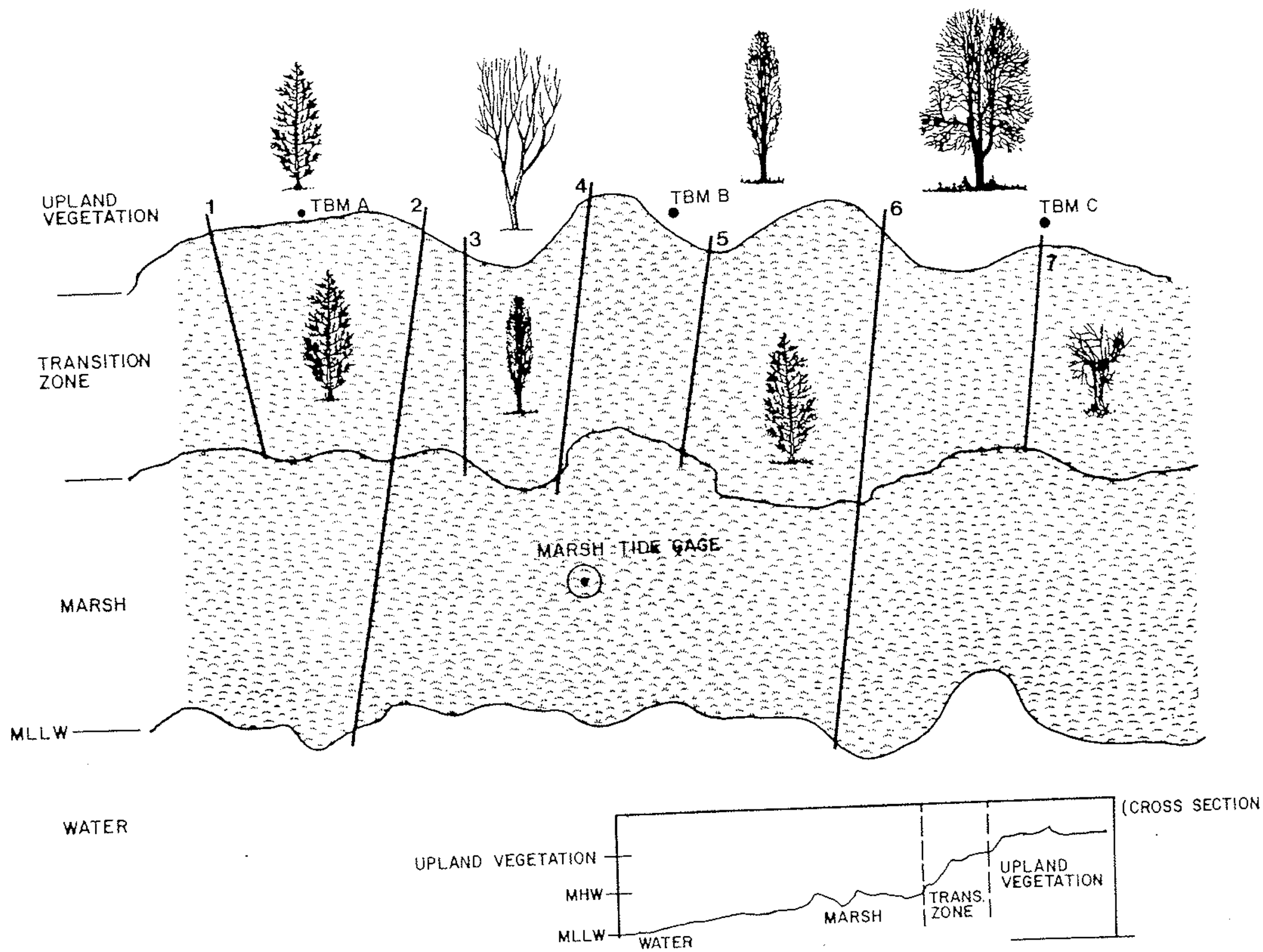


Figure 4: GENERALIZED MARSH STUDY SITE



III. GENERAL ACCURACY STATEMENT

A. Leveling

1. Third-Order Levels

The third-order levels were double run in accordance with specifications set by the Federal Geodetic Control Committee (1974). They are accurate to 2 mm $\sqrt{K}$, where K is the distance leveled in kilometers. The largest computed standard error (from the equation above), due to leveling, is 7 mm (0.02 ft) between the controlling tide station at McHugh Creek, and the study site gage in Potters Marsh, Alaska. Between the study site gage and a transect the largest standard error for control leveling is 4 mm (0.01 ft), also at Potters Marsh.

2. Engineers Levels

The transects were one or two instrument setups from a temporary bench mark. The accuracy of these levels is limited by the nature of measuring natural grades; it is estimated to be accurate within ± 15 mm (0.05 ft). The distances along each transect were measured to within ± 5 cm (0.16 ft).

B. Tidal Datums

The largest variance involved in computing tidal datums is associated with the computation of the mean values (19-year equivalent) for tidal datums at the study sites. This variance is dependent upon the accuracy of the datum at the controlling subordinate tide station and the variance involved in transferring that datum to the study site gage by the method of simultaneous comparisons. In general, the controlling subordinate tide station had a standard error of ± 2 cm (0.066 ft) (Swanson, 1974). The average standard error in transferring this datum to the study site is estimated to be 1 cm (0.033 ft). Therefore, in general, the total standard error is $\sqrt{2^2 + 1^2} = 2.2$ cm (0.072 ft). However, as mentioned earlier, desired accuracies were not attained at some sites. The actual total standard errors varied from 1 cm (0.03 ft) at the Upper Newport Bay, California, site, to 5 cm (0.16 ft) at the Kenai, Alaska site. A discussion of the individual problems and an estimate of the tidal datum accuracy for each site are found in a separate appendix of this report.

C. Tidal Epochs

In computing an accepted datum at a primary tide station, a 19-year mean is used. The 19-year mean corresponds to a "metonic cycle," a period in which 235 lunations occur almost exactly in 19 mean solar years with the same phase of the moon beginning and ending on the same day of the year. This cycle includes all periodic motions through the 18.6 year cycle for the regression of the moon's nodes and all seasonal variations in each of the 19 years (Schureman, 1975). As there are apparent secular trends in sea level, a specific 19-year cycle (The National Tidal Datum Epoch) is selected so that all tidal datum determinations will have a common reference. The epoch now in use is 1941 through 1959. It is reviewed annually but a decision on whether a revision is necessary must be made at 25-year intervals.

The equivalent of 19-year means computed for the study sites is based on the 1941-1959 epoch. Table 1 lists the apparent relative change in mean sea level (MSL) between the 1941-1959 epoch (used in this report) and the 1957-1975 epoch (a recent epoch) for the principal primary tide stations used in this study.

Table 1. Change in Mean Sea Level Elevation from the 1941-1959 Epoch to the 1957-1975 Epoch.

Primary Tide Station	Change (Meters)	Change (Feet)
Newport, CA	0.00	0.00
Los Angeles, CA	0.00	0.00
Alameda, CA	+0.01	+0.03
San Francisco, CA	+0.03	+0.10
Crescent City, CA	-0.02	-0.07
Astoria, OR	-0.02	-0.06
Neah Bay, WA	-0.03	-0.10
Seattle, WA	+0.04	+0.13

The changes shown in Table 1 are small in comparison to the sample standard deviations for the transition zone elevations (above MHW) for each marsh as shown in Table 2. Estimates of the relative apparent change in MSL for each study site are given in the separate appendix to this report.

D. Biological Data

Biological determination of the center of the transition zone (CTZ) between upland and wetland along each transect for each marsh was reported in Frenkel et al. (1978) and Frenkel (1978a) for the Pacific northwest marshes, and Harvey et al. (1978) and Harvey (1978) for the California marshes. No biological determination of the transition zone for any marsh in Alaska has been supplied to NOS.

For a complete description of the biological methods and criteria used to determine the transition zone for each marsh studied, refer to Harvey et al. (1978) and Frenkel et al. (1978).

A measure of the experimental error associated with computing a mean CTZ-MHW value for a given marsh is the sample standard deviation. These are listed in Table 2. This measure will include variability due to the biological determination of the CTZ, thought to be the largest contributor; any leveling errors; and any variation due to real differences in the vegetation within a marsh.

E. Frequency and Duration of Inundation

Frequency of inundation represents the percentage of the number of tides whose height reaches or exceeds a given elevation, duration represents the percentage of time the tide height remains at or exceeds a given elevation. For instance, at 0.43 m (1.41 ft) above MHW, a frequency of inundation of 10 percent for 19-years of data denotes that 1,339 of the 13,395 high tides either reached or exceeded that elevation. A duration of inundation of 1 percent at 0.37 m (1.21 ft) above MHW denotes that the water level either remained at or exceeded that elevation for 1,663 hours during the 19-year period (166,320 hours). These values were calculated by computer using hourly heights.

A method for transferring frequency and duration of inundation mean values from a control station to a subordinate station was developed for this report. This transfer of inundation values from a long-term to a short-term station is necessary to increase the repeatability and accuracy of the data at the subordinate station.

If a short series of data is used without reducing it to a 19-year mean, the results obtained can be very erratic. Figure 5a plots the frequency of inundation versus elevation above MHW at Crescent City, California for (1) 19 years, (2) two of the more erratic years 1941 and 1956, and (3) one of the least erratic years--1951. At 1-percent (0.7 ft) inundation, the elevation varies by 0.2 m (0.7 ft) in this sample, Figure 5b compares monthly values instead of yearly values. In this example of monthly means, the elevation varies by 0.8 (2.6 ft) at 1-percent inundation.

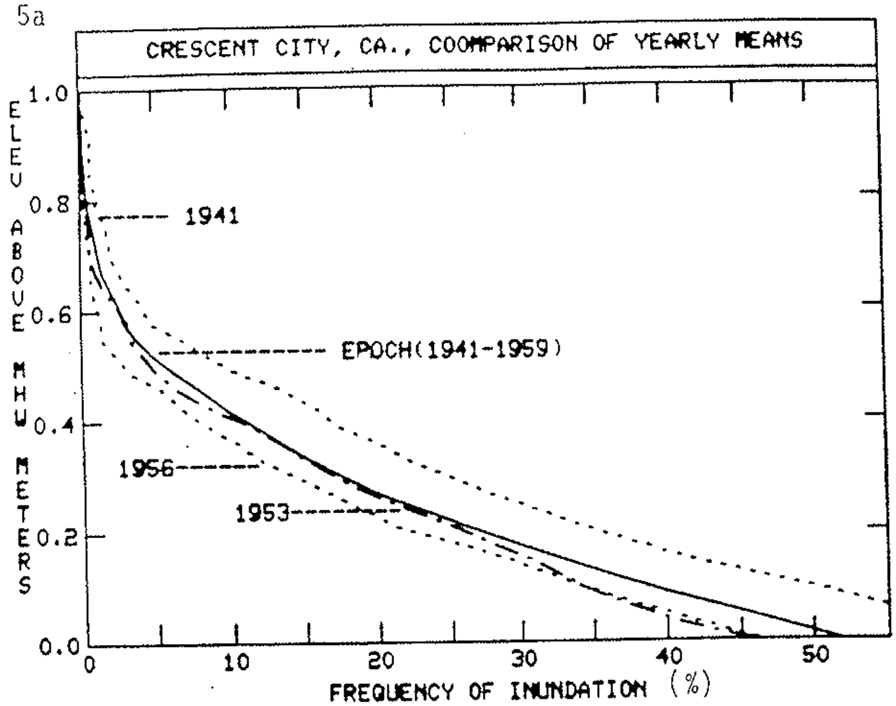
Short-term meteorological effects, seasonal, and annual variations all must be taken into account to accurately compute a tidal datum. These influences must also be taken into account to accurately determine a frequency or duration of inundation. In computing an accurate frequency or duration of inundation at a primary tide station, a 19-year mean is used. The 19-year mean includes seasonal effects, all periodic changes in sea level (due to the 18.6-year cycle for the regression of the moon's nodes), and minimizes any short-term nonperiodic meteorological effects. The 1941-1959 epoch is used to allow comparability with tidal datums (see Section C, Tidal Epochs).

Table 2. Mean Elevation of the Transition Zone (CTZ) above MHW for 17 West Coast Marshes

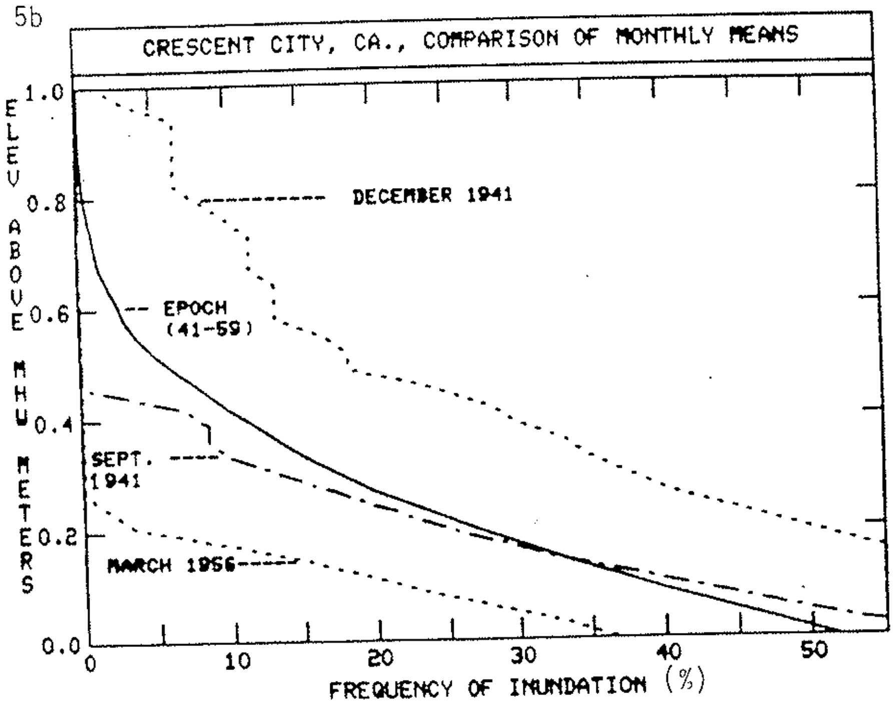
Marsh Number	Marsh Name	Sample Size (N)	Sample Variance ($Meter^2$)	Sample Standard Deviation (Meter)	Sample Standard Deviation (Foot)	Sample Mean (Meter)	Sample Mean (Feet)
1	Newport Bay, CA (NB1)	10	0.005	0.074	(0.24)	0.90	(2.95)
2	Mugu Lagoon, CA (ML1)	9	0.064	0.253	(0.83)	0.98	(3.22)
3	Elkhorn Slough, CA (ES1)	10	0.011	0.105	(0.34)	0.80	(2.62)
4	Palo Alto, CA (SF1)	10	0.012	0.110	(0.36)	0.97	(3.18)
5	Southampton Bay, CA (SF2)	9	0.034	0.184	(0.60)	0.86	(2.82)
6	Elk River, Humboldt B., CA (HB1)	10	0.003	0.056	(0.18)	0.63	(2.07)
7	South Spit, Humboldt Bay, CA (HB2)	8	0.005	0.068	(0.22)	0.61	(2.00)
8	Bandon, Oregon (CQ1)	12	0.016	0.125	(0.41)	0.48	(1.57)
9	Alsea River, Oregon (AB1)	10	0.010	0.100	(0.33)	0.44	(1.44)
10	Netarts Bay, Oregon (NT1)	10	0.004	0.066	(0.22)	0.79	(2.59)
11	Nehalem Bay, Oregon (NB2)	7	0.012	0.111	(0.36)	0.49	(1.61)
12	Nehalem Bay, Oregon (NB3)	13	0.024	0.156	(0.51)	0.40	(1.31)
13	Cedar Creek, Willapa Bay, WA (WB1)	10	0.037	0.192	(0.63)	0.43	(1.41)
14	South Bay Grays Hbr., WA (GH3)	10	0.038	0.196	(0.64)	0.57	(1.87)
15	Ocean Shores Grays Hbr., WA (GH1)	11	0.004	0.060	(0.20)	0.68	(2.23)
16	Thorndyke Bay, Hood Canal, WA (HC1)	12	0.033	0.183	(0.60)	0.39	(1.28)
17	Coulter Creek, Allyn, WA (KS2)	10	0.015	0.124	(0.41)	0.55	(1.80)
18	Pooled Transect, South & Central California (1,2,3,4,5)	48	0.027	0.164	(0.54)	0.90	(2.95)
19	Pooled Transects, Pacific Northwest (8,9,11,12,13,14,16,17)	84	0.026	0.160	(0.52)	0.46	(1.51)

FIGURE 5 COMPARISON OF INUNDATION VALUES BASED ON SHORT TERM OBSERVATIONS

5a



5b



By comparing a frequency (%F) or duration (%D) of inundation computed at a subordinate tide station to a control tide station, then reducing the data to the 19-year mean, it is possible to transfer 19-year inundation values from a control station to a subordinate station. The accuracy of this transfer is dependent upon the length of time for the comparison and the suitability of the control station.

Six control stations were compared in turn with each other, one serving as a control while the other five were used as subordinates. Accuracies were determined for this transfer of values, based on 1, 3, 6, and 12 months of data. As can be seen in Tables 3, 4, 5, and 6, the Standard Deviation (σ) decreases as the distance between station pairs decreases and the time period for comparison increases. As the elevation above MHW increases the σ decreases. This does not imply that the accuracy increases. The ratio of σ to inundation value (%F) also increases with increased heights above MHW. The statistical tolerance limits (STL) are a good measure of the accuracy of a comparison. (The smaller the STL the more accurate will be the comparison.) The STL's are set at 2σ (95.4 percent of the population will be contined within these limits). The STL's are computed and translated into elevational brackets. For example, based on 12 months of data at MHW, the σ is 3.18 percent between Alameda (control) and San Francisco (subordinate). The known percent frequency (%F) at San Francisco at MHW is 46.6 percent. Therefore, 2σ (6.36 percent) is equivalent to a range of 53.0 percent to 40.2 percent. These percent frequencies, compared to known frequencies at San Francisco and translated to elevations, are 0.05 m (0.16 ft) below MHW (53.0%) to 0.05 m (0.16 ft) above MHW (40.2%) (Table 6).

IV. DISCUSSION

A. Frequency and Duration of Inundation

The percent frequency and duration of inundation for 18 subordinate stations are listed in Table 7. These percentages are listed for forty elevations above and below MHW. The control station used to transfer the 19-year inundation values to the subordinate station is listed below each subordinate station. The time period for each comparison is listed at the bottom of each column. To obtain an estimate of the accuracy of these inundation values, refer to the appropriate table (3, 4, 5, or 6), then determine the distance between control and subordinate and select the appropriate control-subordinate pair. In general, the closest pair (San Francisco-Alameda) will be the appropriate one.

Table 8 lists the elevation above MHW for 10, 1, 0.5, 0.25 and 0.0 percent frequency of inundation values at seven primary tide stations, using 19 years of observed data. Note that at 10 percent the elevations above MHW vary from the mean by a standard deviation of 0.05 m (0.16 ft) compared to 0.11 m (0.36 ft) at 0.25 percent. Although the range of tide

TABLE 3 MEASURED VARIABILITY BETWEEN COMPUTED AND ACCEPTED VALUES OF FREQUENCY OF INUNDATION FOR SELECTED STATION PAIRINGS USING 1 MO. RUNNING MEAN VALUES

ELEVATION ABOVE MHW

CONTROL STATION	SUBORDINATE STATION	SAMPLE SIZE	0.00 m (0.0 ft.) σ/%	%F	σ/%F	STL METER	(FOOT)	0.25 m (0.8 ft.) σ/%	%F	σ/%F	STL METER	(FOOT)	0.49 m (1.6 ft.) σ/%	%F	σ/%F	STL METER	(FOOT)
LOS ANGELES	ALAMEDA	209	9.99	49.7	0.20	0.15	0.49	8.24	19.5	0.42	0.20	0.66	4.32	3.3	1.31	0.23	0.75
	SAN FRANCISCO	223	9.18	46.6	0.20	0.14	0.46	7.32	17.0	0.43	0.18	0.59	3.66	2.2	1.66	0.22	0.72
	CRESCENT CITY	163	13.26	47.2	0.35	0.24	0.79	11.36	19.4	0.59	0.21	0.69	5.34	4.7	1.14	0.32	1.05
	ASTORIA	212	19.05	47.6	0.40	0.45	1.48	13.88	22.4	0.62	0.28	0.92	8.33	7.8	1.07	0.40	1.31
	SEATTLE	225	15.29	56.6	0.27	0.29	0.95	13.56	30.3	0.45	0.32	1.05	9.65	8.9	1.08	0.36	1.18
ALAMEDA	SAN FRANCISCO	209	6.38	46.6	0.14	0.10	0.33	4.65	17.0	0.27	0.10	0.33	2.92	2.2	1.33	0.20	0.66
	CRESCENT CITY	164	10.55	47.2	0.22	0.18	0.59	8.71	19.4	0.45	0.26	0.85	3.96	4.7	0.84	0.30	0.98
	ASTORIA	197	16.67	47.6	0.35	0.36	1.18	12.21	22.4	0.54	0.51	1.67	7.65	7.8	0.98	0.40	1.31
	SEATTLE	210	13.60	56.6	0.24	0.26	0.85	11.78	30.3	0.39	0.25	0.82	9.11	8.9	1.02	0.36	1.18
SAN FRANCISCO	CRESCENT CITY	162	10.25	47.2	0.22	0.18	0.59	8.61	19.4	0.44	0.26	0.85	4.24	4.7	0.90	0.30	0.98
	ASTORIA	212	15.46	47.6	0.32	0.32	1.05	11.50	22.4	0.51	0.51	1.67	7.02	7.8	0.90	0.38	1.25
	SEATTLE	224	12.82	56.6	0.23	0.24	0.79	11.45	30.3	0.38	0.24	0.79	8.66	8.9	0.97	0.37	1.21
CRESCENT CITY	ASTORIA	150	12.32	47.6	0.26	0.24	0.79	8.95	22.4	0.40	0.26	0.85	5.58	7.8	0.72	0.37	1.21
	SEATTLE	163	12.31	56.6	0.22	0.24	0.79	9.98	30.3	0.33	0.20	0.66	7.77	8.9	0.87	0.35	1.15
ASTORIA	SEATTLE	213	10.58	56.6	0.19	0.21	0.69	9.55	30.3	0.32	0.19	0.62	7.54	8.9	0.85	0.35	1.15

TABLE 3 (CONTINUED)

ELEVATION ABOVE MHW

CONTROL STATION	SUBORDINATE STATION	SAMPLE SIZE	0.76 m (2.5 ft.) σ/%	%F	σ/%F	STL METER	(FOOT)	1.00 m (3.3 ft.) σ/%	%F	σ/%F	STL METER	(FOOT)
LOS ANGELES	ALAMEDA	209	0.83	0.1	8.30	0.16	0.52	0.11	0.0	-	-	-
	SAN FRANCISCO	223	0.78	0.0	-	0.25	0.82	0.00	0.0	-	-	-
	CRESCENT CITY	163	1.81	0.5	3.60	0.25	0.82	0.39	0.0	-	-	-
	ASTORIA	212	2.68	1.3	2.06	0.25	0.82	0.69	0.1	6.9	0.27	0.89
	SEATTLE	225	2.82	1.1	2.56	0.24	0.79	0.45	0.0	-	0.22	0.72
ALAMEDA	SAN FRANCISCO	209	0.29	0.0	-	0.16	0.52	0.11	0.0	-	-	-
	CRESCENT CITY	164	1.64	0.5	3.28	0.16	0.52	0.39	0.0	-	-	-
	ASTORIA	197	2.65	1.3	2.04	0.26	0.85	0.72	0.1	7.2	0.26	0.85
	SEATTLE	210	2.75	1.1	2.50	0.24	0.79	0.48	0.0	-	0.23	0.75
SAN FRANCISCO	CRESCENT CITY	162	1.71	0.5	3.42	0.16	0.52	0.39	0.0	-	-	-
	ASTORIA	212	2.60	1.3	2.00	0.24	0.79	0.69	0.1	6.9	0.26	0.85
	SEATTLE	224	2.71	1.1	2.46	0.23	0.75	0.45	0.0	-	0.22	0.72
CRESCENT CITY	ASTORIA	150	2.14	1.3	1.65	0.24	0.79	0.60	0.1	6.0	0.24	0.79
	SEATTLE	163	2.44	1.1	2.22	0.23	0.75	0.45	0.0	-	0.22	0.72
ASTORIA	SEATTLE	213	2.29	1.1	2.08	0.22	0.72	0.69	0.00	-	0.27	0.89

σ = Standard Deviation

σ/%F = Standard Deviation/Percent Frequency

%F = % Frequency

STL = Statistical Tolerance Limits (2σ)

TABLE 4 MEASURED VARIABILITY BETWEEN COMPUTED AND ACCEPTED VALUES OF FREQUENCY OF INUNDATION FOR SELECTED STATION PAIRINGS USING 3 MO. RUNNING MEAN VALUES

ELEVATION ABOVE MHW

CONTROL STATION	SUBORDINATE STATION	SAMPLE SIZE	0.00 m (0.0 ft.)					0.25 m (0.8 ft.)					0.49 m (1.6 ft.)				
			σ %	%F	σ/%F	STL METER	STL (FOOT)	σ %	%F	σ/%F	STL METER	STL (FOOT)	σ %	%F	σ/%F	STL METER	STL (FOOT)
LOS ANGELES	ALAMEDA	207	6.79	49.7	0.14	0.10	0.33	6.02	19.5	0.31	0.13	0.43	2.94	3.3	0.89	0.21	0.69
	SAN FRANCISCO	221	6.10	46.6	0.13	0.10	0.33	5.39	17.0	0.32	0.12	0.39	2.36	2.2	1.07	0.18	0.59
	CRESCENT CITY	161	9.56	47.2	0.20	0.16	0.52	9.00	19.4	0.46	0.28	0.92	3.64	4.7	0.77	0.29	0.95
	ASTORIA	210	14.44	47.6	0.30	0.30	0.98	11.52	22.4	0.51	0.23	0.75	6.23	7.8	0.80	0.22	0.72
	SEATTLE	223	10.98	56.6	0.19	0.21	0.69	10.43	30.3	0.34	0.21	0.69	7.47	8.9	0.84	0.35	1.15
ALAMEDA	SAN FRANCISCO	207	4.51	46.6	0.10	0.07	0.23	3.63	17.0	0.21	0.08	0.26	2.18	2.2	0.99	0.19	0.62
	CRESCENT CITY	162	7.56	47.2	0.16	0.12	0.39	6.97	19.4	0.36	0.18	0.59	2.86	4.7	0.61	0.28	0.92
	ASTORIA	195	12.74	47.6	0.27	0.25	0.82	9.37	22.4	0.42	0.28	0.92	5.56	7.8	0.71	0.37	1.21
	SEATTLE	208	9.77	56.6	0.17	0.19	0.62	8.94	30.3	0.30	0.20	0.66	7.07	8.9	0.79	0.34	1.12
SAN FRANCISCO	CRESCENT CITY	160	8.04	47.2	0.17	0.13	0.43	7.17	19.4	0.37	0.18	0.59	2.95	4.7	0.63	0.28	0.92
	ASTORIA	210	11.87	47.6	0.25	0.24	0.79	9.08	22.4	0.41	0.27	0.89	5.12	7.8	0.66	0.36	1.18
	SEATTLE	222	9.28	56.6	0.16	0.18	0.59	8.64	30.3	0.29	0.17	0.56	6.73	8.9	0.76	0.35	1.15
CRESCENT CITY	ASTORIA	148	8.94	47.6	0.19	0.16	0.52	6.01	22.4	0.27	0.16	0.52	3.58	7.8	0.46	0.25	0.82
	SEATTLE	161	8.75	56.6	0.15	0.20	0.66	6.70	30.3	0.22	0.13	0.43	5.59	8.9	0.63	0.33	1.08
ASTORIA	SEATTLE	211	7.75	56.6	0.14	0.14	0.46	7.10	30.3	0.23	0.14	0.46	5.80	8.9	0.65	0.33	1.08

TABLE 4 (CONTINUED)

ELEVATION ABOVE MHW

CONTROL STATION	SUBORDINATE STATION	SAMPLE SIZE	0.76 m (2.5 ft.)					1.00 m (3.3 ft.)				
			σ %	%F	σ/%F	STL METER	STL (FOOT)	σ %	%F	σ/%F	STL METER	STL (FOOT)
LOS ANGELES	ALAMEDA	207	0.49	0.1	4.90	0.18	0.59	0.06	0.0	-	-	-
	SAN FRANCISCO	221	0.44	0.0	-	0.19	0.62	0.00	0.0	-	-	-
	CRESCENT CITY	161	1.09	0.5	2.18	0.19	0.62	0.23	0.0	-	-	-
	ASTORIA	210	1.72	1.3	1.32	0.18	0.59	0.40	0.1	4.0	0.19	0.62
	SEATTLE	223	1.92	1.1	1.75	0.22	0.72	0.28	0.0	-	0.18	0.59
ALAMEDA	SAN FRANCISCO	207	0.18	0.0	-	0.14	0.46	0.06	0.0	-	-	-
	CRESCENT CITY	162	0.95	0.5	1.90	0.18	0.59	0.22	0.0	-	-	-
	ASTORIA	194	1.68	1.3	1.29	0.22	0.72	0.42	0.1	4.2	0.19	0.62
	SEATTLE	208	1.89	1.1	1.72	0.22	0.72	0.30	0.0	-	0.18	0.59
SAN FRANCISCO	CRESCENT CITY	160	1.03	0.5	2.06	0.18	0.59	0.23	0.0	-	-	-
	ASTORIA	210	1.66	1.3	1.28	0.22	0.72	0.40	0.1	4.0	0.19	0.62
	SEATTLE	222	1.89	1.1	1.72	0.22	0.72	0.28	0.0	-	0.16	0.52
CRESCENT CITY	ASTORIA	138	1.22	1.3	0.94	0.20	0.66	0.33	0.1	3.3	0.17	0.56
	SEATTLE	161	1.82	1.1	1.38	0.20	0.66	0.28	0.0	-	0.17	0.56
ASTORIA	SEATTLE	211	1.46	1.1	1.33	0.20	0.66	0.39	0.0	-	0.21	0.69

σ = Standard Deviation

σ/%F = Standard Deviation/Percent Frequency

%F = % Frequency

STL = Statistical Tolerance Limits (2σ)

Table 5 MEASURED VARIABILITY BETWEEN COMPUTED AND ACCEPTED VALUES OF FREQUENCY OF INUNDATION FOR SELECTED STATION PAIRINGS USING 6 MO. RUNNING MEAN VALUES

ELEVATION ABOVE MHW

CONTROL STATION	SUBORDINATE STATION	SAMPLE SIZE	0.00 m (0.0 ft.) σ %	%F	σ/%F	STL METER	(FOOT)	0.25 m (0.8 ft.) σ %	%F	σ/%F	STL METER	(FOOT)	0.49 m (1.6 ft.) σ %	%F	σ/%F	STL METER	(FOOT)
LOS ANGELES	ALAMEDA	204	4.58	49.7	0.09	0.08	0.26	4.39	19.5	0.23	0.12	0.39	1.86	3.3	0.56	0.09	0.30
	SAN FRANCISCO	218	4.06	46.6	0.09	0.07	0.23	4.22	17.0	0.25	0.09	0.30	1.55	2.2	0.70	0.18	0.59
	CRESCENT CITY	158	6.13	47.2	0.13	0.10	0.33	6.38	19.4	0.33	0.16	0.52	2.49	4.7	0.53	0.28	0.92
	ASTORIA	207	10.18	47.6	0.21	0.20	0.66	8.74	22.4	0.39	0.22	0.72	4.80	7.8	0.62	0.36	1.18
	SEATTLE	220	6.51	56.6	0.12	0.13	0.43	6.95	30.3	0.23	0.14	0.46	5.31	8.9	0.60	0.32	1.05
ALAMEDA	SAN FRANCISCO	204	3.81	46.6	0.08	0.06	0.20	3.13	17.0	0.18	0.06	0.20	1.54	2.2	0.70	0.18	0.59
	CRESCENT CITY	159	5.42	47.2	0.11	0.09	0.30	5.23	19.4	0.27	0.14	0.46	1.97	4.7	0.42	0.16	0.52
	ASTORIA	192	9.77	47.6	0.21	0.19	0.62	7.26	22.4	0.32	0.20	0.66	4.28	7.8	0.55	0.35	1.15
	SEATTLE	205	6.60	56.6	0.14	0.13	0.43	6.29	30.3	0.21	0.12	0.39	4.98	8.9	0.56	0.32	1.05
SAN FRANCISCO	CRESCENT CITY	157	6.32	47.2	0.13	0.10	0.33	5.58	19.4	0.29	0.10	0.33	2.10	4.7	0.45	0.18	0.59
	ASTORIA	207	8.77	47.6	0.18	0.16	0.52	7.05	22.4	0.31	0.18	0.59	4.02	7.8	0.52	0.34	1.12
	SEATTLE	219	6.03	56.6	0.11	0.12	0.39	5.95	30.3	0.20	0.11	0.36	4.68	8.9	0.53	0.32	1.05
CRESCENT CITY	ASTORIA	145	5.69	47.6	0.12	0.10	0.33	4.25	22.4	0.19	0.12	0.39	2.37	7.8	0.30	0.13	0.43
	SEATTLE	158	5.17	56.6	0.09	0.11	0.36	4.29	30.3	0.14	0.09	0.30	3.92	8.9	0.44	0.19	0.52
ASTORIA	SEATTLE	208	6.01	56.6	0.11	0.12	0.39	5.49	30.3	0.18	0.10	0.33	4.56	8.9	0.51	0.32	1.05

TABLE 5 (CONTINUED)

ELEVATION ABOVE MHW

CONTROL STATION	SUBORDINATE STATION	SAMPLE SIZE	0.76 m (2.5 ft.) σ %	%F	σ/%F	STL METER	(FOOT)	1.00 m (3.3 ft.) σ %	%F	σ/%F	STL METER	(FOOT)
LOS ANGELES	ALAMEDA	204	0.36	0.1	3.60	0.17	0.56	0.05	0.0	-	-	-
	SAN FRANCISCO	218	0.32	0.0	-	0.16	0.52	0.00	0.0	-	-	-
	CRESCENT CITY	158	0.77	0.5	1.54	0.18	0.59	0.00	0.0	-	-	-
	ASTORIA	207	1.28	1.3	0.98	0.21	0.69	0.28	0.1	2.8	0.17	0.56
	SEATTLE	220	1.40	1.1	1.27	0.20	0.66	0.21	0.0	-	0.14	0.46
ALAMEDA	SAN FRANCISCO	204	0.14	0.0	-	0.12	0.39	0.05	0.0	-	-	-
	CRESCENT CITY	159	0.65	0.5	1.30	0.18	0.59	0.16	0.0	-	-	-
	ASTORIA	192	1.20	1.3	0.92	0.20	0.66	0.29	0.1	2.9	0.16	0.52
	SEATTLE	205	1.34	1.1	1.22	0.20	0.66	0.22	0.0	-	0.14	0.46
SAN FRANCISCO	CRESCENT CITY	157	0.71	0.5	1.42	0.16	0.52	0.16	0.0	-	-	-
	ASTORIA	207	1.20	1.3	0.92	0.20	0.66	0.28	0.1	2.8	0.16	0.52
	SEATTLE	219	1.36	1.1	1.24	0.20	0.66	0.21	0.0	-	0.14	0.46
CRESCENT CITY	ASTORIA	145	0.82	1.3	0.63	0.18	0.59	0.22	0.1	2.2	0.14	0.46
	SEATTLE	158	1.08	1.1	0.98	0.19	0.62	0.20	0.0	-	0.14	0.46
ASTORIA	SEATTLE	208	1.17	1.1	1.06	0.20	0.66	0.28	0.0	-	0.17	0.56

σ = Standard Deviation

σ/%F = Standard Deviation/Percent Frequency

%F = % Frequency

STL = Statistical Tolerance Limits (2σ)

TABLE 6 MEASURED VARIABILITY BETWEEN COMPUTED AND ACCEPTED VALUES OF FREQUENCY OF INUNDATION FOR SELECTED STATION PAIRINGS USING 12 MO. RUNNING MEAN VALUES

ELEVATION ABOVE MHW

			0.00 m (0.0 ft.)					0.25 m (0.8 ft.)					0.49 m (1.6 ft.)				
CONTROL STATION	SUBORDINATE STATION	SAMPLE SIZE	σ/%	%F	σ/%F	STL METER	STL (FOOT)	σ/%	%F	σ/%F	STL METER	STL (FOOT)	σ/%	%F	σ/%F	STL METER	STL (FOOT)
LOS ANGELES	ALAMEDA	198	3.45	49.7	0.07	0.05	0.16	3.01	19.5	0.15	0.06	0.20	1.09	3.3	0.33	0.07	0.23
	SAN FRANCISCO	212	3.39	46.6	0.07	0.05	0.16	3.45	17.0	0.20	0.07	0.23	0.94	2.2	0.43	0.09	0.30
	CRESCENT CITY	152	3.19	47.2	0.07	0.05	0.16	2.91	19.4	0.15	0.06	0.20	1.17	4.7	0.25	0.08	0.26
	ASTORIA	201	6.46	47.6	0.14	0.11	0.36	5.16	22.4	0.23	0.13	0.43	3.17	7.8	0.41	0.19	0.62
	SEATTLE	214	3.30	56.6	0.06	0.07	0.23	3.13	30.3	0.10	0.05	0.16	2.39	8.9	0.27	0.08	0.26
ALAMEDA	SAN FRANCISCO	198	3.18	46.6	0.07	0.05	0.16	2.56	17.0	0.15	0.05	0.16	1.08	2.2	0.49	0.17	0.56
	CRESCENT CITY	153	3.38	4.72	0.07	0.06	0.20	3.07	19.4	0.06	0.08	0.26	1.14	4.7	0.24	0.08	0.26
	ASTORIA	186	7.64	47.6	0.16	0.14	0.46	5.04	22.4	0.22	0.12	0.39	3.13	7.8	0.40	0.18	0.59
	SEATTLE	199	4.90	56.6	0.09	0.10	0.33	3.90	30.3	0.13	0.06	0.20	2.43	8.9	0.27	0.09	0.30
SAN FRANCISCO	CRESCENT CITY	151	4.60	47.2	0.10	0.08	0.26	3.83	19.4	0.20	0.10	0.33	1.24	4.7	0.26	0.08	0.26
	ASTORIA	201	5.72	47.6	0.12	0.10	0.33	4.53	22.4	0.20	0.11	0.36	2.83	7.8	0.36	0.16	0.52
	SEATTLE	213	3.68	56.6	0.07	0.08	0.26	3.42	30.3	0.11	0.06	0.20	2.07	8.9	0.23	0.08	0.26
CRESCENT CITY	ASTORIA	139	3.49	47.6	0.07	0.06	0.20	2.88	22.4	0.13	0.06	0.20	1.55	7.8	0.20	0.08	0.26
	SEATTLE	152	3.84	56.6	0.07	0.08	0.26	3.12	30.3	0.10	0.05	0.16	2.19	8.9	0.25	0.08	0.26
ASTORIA	SEATTLE	202	4.65	56.6	0.08	0.10	0.33	4.28	30.3	0.14	0.08	0.26	3.18	8.9	0.36	0.12	0.39

Table 6 (CONTINUED)

ELEVATION ABOVE MHW

			0.76 m (2.5 ft.)					1.00 m (3.3 ft.)				
CONTROL STATION	SUBORDINATE STATION	SAMPLE SIZE	σ/%	%F	σ/%F	STL METER	STL (FOOT)	σ/%	%F	σ/%F	STL METER	STL (FOOT)
LOS ANGELES	ALAMEDA	198	0.27	0.1	2.70	0.14	0.46	0.03	0.0	-	-	-
	SAN FRANCISCO	212	0.24	0.0	-	0.15	0.49	0.00	0.0	-	-	-
	CRESCENT CITY	152	0.47	0.5	0.94	0.16	0.52	0.12	0.0	-	-	-
	ASTORIA	201	0.91	1.3	0.70	0.19	0.62	0.18	0.1	1.8	0.14	0.46
	SEATTLE	214	0.86	1.1	0.78	0.18	0.59	0.15	0.0	-	0.12	0.39
ALAMEDA	SAN FRANCISCO	198	0.11	0.0	-	0.10	0.33	0.03	0.0	-	-	-
	CRESCENT CITY	153	0.40	0.5	0.80	0.14	0.46	0.12	0.0	-	-	-
	ASTORIA	186	0.79	1.3	0.61	0.18	0.59	0.20	0.1	2.0	0.14	0.46
	SEATTLE	199	0.79	1.1	0.72	0.18	0.59	0.16	0.0	-	0.13	0.43
SAN FRANCISCO	CRESCENT CITY	151	0.44	0.5	0.88	0.13	0.43	0.12	0.0	-	-	-
	ASTORIA	201	0.82	1.3	0.63	0.18	0.59	0.18	0.1	1.8	0.13	0.43
	SEATTLE	213	0.82	1.1	0.75	0.15	0.49	0.15	0.0	-	0.12	0.39
CRESCENT CITY	ASTORIA	139	0.54	1.3	0.42	0.12	0.39	0.15	0.1	1.5	0.12	0.39
	SEATTLE	152	0.69	1.1	0.63	0.17	0.56	0.14	0.0	-	0.12	0.39
ASTORIA	SEATTLE	202	0.94	1.1	0.85	0.18	0.59	0.20	0.0	-	0.14	0.46

σ = Standard Deviation

σ/%F = Standard Deviation/Percent Frequency

%F = % Frequency

STL = Statistical Tolerance Limits (2σ)

Table 7-1

FREQUENCY AND DURATION OF INUNDATION
ACCEPTED VALUES FOR SUBORDINATE STATIONS

(S) = SUBORDINATE
(C) = CONTROL

		(S) 9411013 MUGU LAGOON CA. (C) 9410660 LOS ANGELES CA.		9414525 PALO ALTO CA. 9414750 ALAMEDA CA.		9414537 MARKER#8, CA. 9414750 ALAMEDA, CA.		9415143 CROCKETT, CA. 9414290 SAN FRAN. CA.	
ELEVATION ABOVE MHW METERS	(FEET)	PERCENT DURATION	PERCENT FREQUENCY	PERCENT DURATION	PERCENT FREQUENCY	PERCENT DURATION	PERCENT FREQUENCY	PERCENT DURATION	PERCENT FREQUENCY
-0.12	(-0.4)	33.0	68.9	15.9	66.8	15.3	65.9	18.4	66.2
-0.09	(-0.3)	29.0	66.8	14.5	65.1	13.9	62.4	16.7	62.4
-0.06	(-0.2)	24.4	62.1	12.8	59.0	12.6	57.6	15.1	58.2
-0.03	(-0.1)	20.1	55.3	11.7	57.7	11.6	55.3	13.4	52.7
0.0	(0.0)	16.6	47.9	10.9	54.8	10.4	52.2	11.9	48.2
0.03	(0.1)	13.1	40.0	9.3	47.3	9.2	45.5	10.4	43.3
0.06	(0.2)	11.0	37.7	8.2	40.7	8.3	42.3	8.9	40.7
0.09	(0.3)	9.2	32.4	7.0	36.5	7.2	37.7	7.4	35.3
0.12	(0.4)	8.2	29.1	6.4	34.1	6.4	34.1	5.9	30.1
0.15	(0.5)	7.9	28.5	5.4	30.5	5.5	31.5	4.6	26.1
0.19	(0.6)	6.5	25.5	4.6	26.5	4.6	26.2	3.6	22.8
0.22	(0.7)	5.7	23.9	3.7	21.6	3.8	22.0	2.8	16.4
0.25	(0.8)	5.2	21.4	2.7	18.5	3.0	18.9	2.5	16.1
0.28	(0.9)	4.4	18.6	2.3	14.7	2.5	16.5	1.8	11.7
0.31	(1.0)	3.6	16.6	1.8	11.9	2.1	13.9	1.3	8.9
0.34	(1.1)	3.2	14.7	1.6	9.4	1.7	10.4	0.8	5.8
0.37	(1.2)	2.7	12.2	1.2	8.1	1.2	8.2	0.5	4.3
0.40	(1.3)	2.2	12.4	0.9	5.9	1.0	6.8	0.3	3.3
0.43	(1.4)	1.9	10.2	0.7	5.7	0.8	6.4	0.1	2.6
0.46	(1.5)	1.4	8.0	0.5	4.9	0.6	5.0	0.0	0.0
0.49	(1.6)	1.2	7.5	0.4	3.7	0.4	3.9	0.0	0.0
0.52	(1.7)	0.8	4.5	0.4	2.7	0.3	3.0	0.0	0.0
0.55	(1.8)	0.6	2.8	0.2	2.0	0.3	2.0	0.0	0.0
0.58	(1.9)	0.6	4.0	0.2	1.9	0.2	1.5	0.0	0.0
0.61	(2.0)	0.5	2.1	0.1	1.6	0.1	1.1	0.0	0.0
0.64	(2.1)	0.4	2.0	0.1	1.3	0.0	0.4	0.0	0.0
0.67	(2.3)	0.3	1.4	0.0	0.3	0.0	0.3	0.0	0.0
0.70	(2.4)	0.1	1.5	0.0	0.2	0.0	0.2	0.0	0.0
0.73	(2.5)	0.2	1.0	0.0	0.1	0.0	0.1	0.0	0.0
0.76	(2.6)	0.2	0.8	0.0	0.1	0.0	0.1	0.0	0.0
0.79	(2.7)	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0
0.82	(2.8)	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
0.85	(2.9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.88	(3.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.91	(3.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.94	(3.2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.97	(3.3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	(3.4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.03	(3.5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.06	(3.6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		3 MONTHS		4 MONTHS		12 MONTHS		7 MONTHS	

Table 7-2

FREQUENCY AND DURATION OF INUNDATION
ACCEPTED VALUES FOR SUBORDINATE STATIONS

(S) = SUBORDINATE
(C) = CONTROL

ELEVATION ABOVE MHW METERS	(FEET)	(S) 9415143 CROCKETT, CA. (C) 9414290 SAN FRAN, CA. PERCENT DURATION	PERCENT FREQUENCY	(S) 9418686 HOOKTON SL. CA. (C) 9419750 CRES. CITY, CA. PERCENT DURATION	PERCENT FREQUENCY	(S) 9418757 ELK RIVER, CA. (C) 9419750 CRES. CITY, CA. PERCENT DURATION	PERCENT FREQUENCY	(S) 9418757 ELK RIVER, CA. (C) 9419750 CRES. CITY, CA. PERCENT DURATION	PERCENT FREQUENCY
-0.12	(-0.4)	26.0	79.1	16.9	62.7	15.0	62.0	17.3	65.1
-0.09	(-0.3)	23.5	76.9	15.5	60.4	13.8	59.9	15.9	61.1
-0.06	(-0.2)	21.1	75.8	14.3	55.9	12.7	57.2	15.2	60.3
-0.03	(-0.1)	19.2	71.5	12.8	53.6	11.1	54.0	13.4	56.4
0.0	(0.0)	17.5	67.6	11.6	49.4	10.0	48.3	11.9	51.5
0.03	(0.1)	15.8	60.1	10.4	45.1	9.1	45.0	11.0	47.0
0.06	(0.2)	13.6	52.1	9.3	39.5	7.5	38.4	10.1	44.3
0.09	(0.3)	12.1	47.9	8.3	37.5	6.8	37.0	8.7	39.1
0.12	(0.4)	10.6	42.3	7.1	33.9	6.0	34.5	7.7	37.2
0.15	(0.5)	9.5	37.5	6.3	31.3	5.3	30.5	6.6	32.6
0.19	(0.6)	8.6	34.7	5.4	28.3	4.2	26.7	6.0	32.4
0.22	(0.7)	7.7	33.8	4.7	25.7	3.4	24.7	5.2	28.6
0.25	(0.8)	6.8	34.5	4.2	22.7	3.0	22.1	4.4	24.7
0.28	(0.9)	5.5	29.7	3.5	20.0	2.3	18.4	3.7	22.5
0.31	(1.0)	4.8	26.5	2.8	17.3	1.9	16.7	3.1	18.7
0.34	(1.1)	3.7	19.9	2.1	13.7	1.4	12.9	2.9	16.9
0.37	(1.2)	2.7	15.0	2.0	12.8	1.1	12.0	2.4	14.0
0.40	(1.3)	2.4	13.1	1.6	11.3	0.7	9.0	1.8	11.6
0.43	(1.4)	2.0	10.8	1.2	8.7	0.3	5.2	1.5	9.1
0.46	(1.5)	1.4	8.0	0.8	6.6	0.3	4.6	1.1	7.0
0.49	(1.6)	0.9	6.7	0.7	6.1	0.3	5.2	0.9	5.7
0.52	(1.7)	0.7	6.5	0.5	3.5	0.0	1.0	0.7	4.5
0.55	(1.8)	0.6	4.1	0.3	2.2	0.0	0.0	0.5	3.9
0.58	(1.9)	0.3	2.5	0.1	2.1	0.0	0.0	0.3	3.5
0.61	(2.0)	0.2	1.7	0.0	1.3	0.0	0.0	0.3	2.8
0.64	(2.1)	0.1	0.7	0.0	1.6	0.0	0.0	0.3	2.6
0.67	(2.3)	0.1	0.6	0.0	0.7	0.0	0.0	0.1	1.7
0.70	(2.4)	0.1	0.5	0.0	0.7	0.0	0.0	0.1	1.2
0.73	(2.5)	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.6
0.76	(2.6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
0.79	(2.7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
0.82	(2.8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
0.85	(2.9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
0.88	(3.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
0.91	(3.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
0.94	(3.2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.97	(3.3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	(3.4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.03	(3.5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.06	(3.6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		3 MONTHS		12 MONTHS		6 MONTHS		6 MONTHS	

Table 7-3

FREQUENCY AND DURATION OF INUNDATION
ACCEPTED VALUES FOR SUBORDINATE STATIONS

(S) = SUBORDINATE
(C) = CONTROL

ELEVATION ABOVE MHW METERS	(FEET)	(S) 9432373 BANDON, OR. (C) 9419750 CRES. CITY, CA. PERCENT DURATION	PERCENT FREQUENCY	(S) 9434938 DRIFT CREEK, OR. (C) 9419750 CRES. CITY, CA. PERCENT DURATION	PERCENT FREQUENCY	(S) 9437262 NETARTS BAY, OR. (C) 9419750 CRES. CITY, CA. PERCENT DURATION	PERCENT FREQUENCY	(S) 9437815 BRIGHTON, OR. (C) 9419750 CRES.CITY, CA. PERCENT DURATION	PERCENT FREQUENCY
-0.12	(-0.4)					17.4	57.8	15.8	60.6
-0.09	(-0.3)	7.8	45.4			16.0	55.5	14.4	57.1
-0.06	(-0.2)	7.2	41.6	11.5	53.8	14.9	52.4	13.2	52.1
-0.03	(-0.1)	5.8	35.0	10.6	51.5	13.3	48.2	12.0	48.6
0.0	(0.0)	4.9	29.4	9.4	46.0	12.1	43.6	10.9	45.3
0.03	(0.1)	4.0	24.7	8.4	43.9	11.1	39.6	10.2	42.4
0.06	(0.2)	3.5	23.0	7.7	39.1	10.0	35.6	9.4	39.4
0.09	(0.3)	2.6	11.7	6.8	36.5	9.4	33.4	8.2	34.8
0.12	(0.4)	2.5	12.0	6.3	34.9	8.5	31.9	7.6	32.4
0.15	(0.5)	2.3	7.7	5.8	32.6	7.3	26.0	7.0	30.8
0.19	(0.6)	1.7	6.2	5.2	28.8	6.9	25.7	6.7	29.0
0.22	(0.7)	1.4	3.6	4.7	26.6	6.4	24.6	6.1	27.1
0.25	(0.8)	1.8	2.4	4.3	24.2	6.0	23.2	5.6	26.2
0.28	(0.9)	1.9	7.7	5.7	20.2	5.3	22.1	5.1	23.2
0.31	(1.0)	1.7	8.9	3.4	19.7	4.8	20.1	4.7	23.2
0.34	(1.1)	1.2	7.2	2.9	17.8	4.3	17.3	4.1	21.2
0.37	(1.2)	1.3	7.9	2.5	14.9	4.2	15.9	3.8	19.3
0.40	(1.3)	0.8	6.0	2.1	13.0	3.8	15.0	3.2	16.9
0.43	(1.4)	0.7	4.2	1.8	11.1	3.5	13.0	2.7	14.7
0.46	(1.5)	0.6	4.3	1.5	9.0	3.1	11.4	2.3	13.0
0.49	(1.6)	0.5	3.1	1.3	7.9	2.9	10.0	2.1	11.6
0.52	(1.7)	0.4	2.8	1.0	7.4	2.6	8.3	1.7	10.2
0.55	(1.8)	0.3	2.9	0.9	6.9	2.2	6.8	1.6	8.9
0.58	(1.9)	0.2	2.5	0.8	5.8	2.1	6.7	1.3	7.2
0.61	(2.0)	0.2	1.8	0.6	4.9	1.9	5.9	1.1	5.7
0.64	(2.1)	0.1	1.4	0.6	4.1	2.1	6.3	0.9	4.6
0.67	(2.3)	0.1	1.1	0.5	3.9	1.9	5.5	0.8	4.7
0.70	(2.4)	0.0	0.9	0.5	3.5	1.6	6.0	0.8	3.9
0.73	(2.5)	0.0	0.6	0.3	2.8	1.5	6.2	0.6	3.5
0.76	(2.6)	0.0	0.5	0.2	2.4	1.5	4.9	0.5	3.2
0.79	(2.7)	0.0	0.3	0.2	1.7	1.0	4.2	0.4	2.5
0.82	(2.8)	0.0	0.3	0.1	1.2	0.9	3.6	0.4	2.4
0.85	(2.9)	0.0	0.2	0.0	0.7	0.8	3.6	0.3	2.0
0.88	(3.0)	0.0	0.1	0.0	0.5	0.9	3.5	0.3	1.3
0.91	(3.1)	0.0	0.1	0.0	0.5	0.8	3.2	0.2	1.2
0.94	(3.2)	0.0	0.0	0.0	0.4	0.8	3.1	0.1	0.6
0.97	(3.3)	0.0	0.0	0.0	0.2	0.8	3.3	0.1	0.8
1.00	(3.4)	0.0	0.0	0.0	0.2	0.8	3.4	0.1	0.7
1.03	(3.5)	0.0	0.0	0.0	0.0	0.7	2.9	0.1	0.7
1.06	(3.6)	0.[illegible]	0.0	0.0	0.0	0.6	2.6	0.1	0.7
		2 MONTHS		10 MONTHS		12 MONTHS		12 MONTHS	

Table 7-4

FREQUENCY AND DURATION OF INUNDATION
ACCEPTED VALUES FOR SUBORDINATE STATIONS

(S) = SUBORDINATE
(C) = CONTROL

ELEVATION ABOVE MHW METERS	(FEET)	(S) 9440910 TOKE POINT, WA. / (C) 9419750 CRES. CITY, CA. PERCENT DURATION	PERCENT FREQUENCY	9440910 TOKE POINT, WA. / 9439040 ASTORIA, OR. PERCENT DURATION	PERCENT FREQUENCY	9445133 BANGOR, OR. / 9447130 SEATTLE, WA. PERCENT DURATION	PERCENT FREQUENCY	9446281 ALLYN, WA. / 9447130 SEATTLE, WA. PERCENT DURATION	PERCENT FREQUENCY
-0.12	(-0.4)					18.3	66.0	14.0	64.1
-0.09	(-0.3)	11.7	51.9	13.7	56.0	17.6	63.5	13.1	62.6
-0.06	(-0.2)	10.7	48.6	12.6	52.7	16.5	62.0	12.3	60.2
-0.03	(-0.1)	10.1	47.5	11.6	52.0	15.5	60.3	11.6	58.0
0.0	(0.0)	9.2	42.3	10.7	47.8	13.9	57.3	10.6	55.4
0.03	(0.1)	8.3	39.6	9.7	43.6	12.5	50.7	9.9	53.4
0.06	(0.2)	7.6	35.9	8.9	41.3	11.3	48.4	8.9	50.1
0.09	(0.3)	7.0	35.2	8.2	39.6	10.4	46.8	8.2	46.5
0.12	(0.4)	6.2	33.2	7.2	36.8	9.5	42.2	7.8	45.9
0.15	(0.5)	5.5	30.2	6.5	32.9	8.6	38.1	7.0	42.0
0.19	(0.6)	4.6	25.8	5.7	30.6	7.8	36.1	6.2	39.7
0.22	(0.7)	4.1	21.1	5.2	27.5	7.0	32.5	5.5	36.0
0.25	(0.8)	3.7	19.0	4.5	24.9	6.2	30.9	5.0	34.2
0.28	(0.9)	3.3	17.8	3.9	22.1	5.4	28.4	4.2	31.2
0.31	(1.0)	3.0	16.4	3.5	19.6	4.9	24.8	3.5	25.5
0.34	(1.1)	2.7	14.4	3.0	15.9	4.4	23.1	3.1	22.4
0.37	(1.2)	2.4	13.2	2.5	13.9	4.2	19.8	3.0	20.7
0.40	(1.3)	2.3	13.6	2.3	12.9	3.4	16.9	2.6	19.5
0.43	(1.4)	1.9	11.5	2.0	11.7	3.1	16.7	2.6	17.9
0.46	(1.5)	1.6	9.8	1.6	9.8	2.9	16.1	2.1	16.3
0.49	(1.6)	1.3	8.8	1.5	8.7	2.4	14.1	2.0	14.7
0.52	(1.7)	1.1	8.3	1.4	8.0	2.0	12.0	1.7	12.2
0.55	(1.8)	1.0	7.4	1.2	7.1	1.7	9.7	1.4	8.0
0.58	(1.9)	0.9	6.8	1.1	7.3	1.6	10.0	0.9	7.7
0.61	(2.0)	0.6	5.6	0.9	7.1	1.2	8.2	0.8	6.6
0.64	(2.1)	0.6	4.9	0.7	5.9	1.0	5.1	0.6	5.6
0.67	(2.3)	0.4	4.0	0.6	5.4	0.8	5.1	0.5	3.8
0.70	(2.4)	0.4	3.4	0.4	4.1	0.7	5.5	0.4	4.0
0.73	(2.5)	0.3	2.6	0.4	3.3	0.7	5.3	0.3	3.4
0.76	(2.6)	0.2	2.1	0.3	2.8	0.5	3.5	0.3	2.3
0.79	(2.7)	0.2	1.7	0.3	2.3	0.3	1.9	0.3	2.1
0.82	(2.8)	0.1	1.1	0.1	1.6	0.2	1.4	0.2	2.1
0.85	(2.9)	0.0	0.8	0.0	1.2	0.4	2.2	0.1	2.2
0.88	(3.0)	0.0	0.4	0.0	0.7	0.4	2.4	0.2	2.3
0.91	(3.1)	0.0	0.4	0.0	0.6	0.3	2.1	0.3	2.9
0.94	(3.2)	0.0	0.3	0.0	0.5	0.4	2.5	0.3	2.8
0.97	(3.3)	0.0	0.3	0.0	0.4	0.3	1.9	0.3	2.6
1.00	(3.4)	0.0	0.3	0.0	0.4	0.2	1.0	0.3	1.5
1.03	(3.5)	0.0	0.3	0.0	0.3	0.2	1.1	0.2	1.7
1.06	(3.6)	0.0	0.0	0.0	0.0	0.1	0.6	0.2	1.5
		12 MONTHS		12 MONTHS		6 MONTHS		7 MONTHS	

Table 7-5

FREQUENCY AND DURATION OF INUNDATION
ACCEPTED VALUES FOR SUBORDINATE STATIONS

(S) = SUBORDINATE
(C) = CONTROL

ELEVATION ABOVE MHW METERS	(FEET)	(S) 9447659 EVERETT, WA. (C) 9447130 SEATTLE, WA. PERCENT DURATION	PERCENT FREQUENCY	(S) 9447725 EBEY SL., WA. (C) 9447130 SEATTLE, WA. PERCENT DURATION	PERCENT FREQUENCY
-0.12	(-0.4)				
-0.09	(-0.3)	17.2	65.5	16.7	64.8
-0.06	(-0.2)	16.2	63.1	15.9	64.4
-0.03	(-0.1)	15.3	60.7	14.7	60.4
0.0	(0.0)	14.0	57.6	12.2	52.2
0.03	(0.1)	12.6	55.2	12.3	54.8
0.06	(0.2)	11.6	50.8	11.2	49.8
0.09	(0.3)	10.8	49.4	10.5	47.1
0.12	(0.4)	9.6	45.4	9.1	39.2
0.15	(0.5)	8.7	44.2	8.9	44.5
0.19	(0.6)	7.7	39.3	7.5	36.3
0.22	(0.7)	6.5	34.3	6.6	36.4
0.25	(0.8)	5.7	31.0	5.0	29.4
0.28	(0.9)	5.1	29.2	4.8	29.6
0.31	(1.0)	4.4	24.5	4.5	24.3
0.34	(1.1)	3.7	21.4	4.0	25.0
0.37	(1.2)	3.2	19.1	3.6	22.5
0.40	(1.3)	2.5	15.4	2.7	16.4
0.43	(1.4)	2.1	13.8	2.2	13.9
0.46	(1.5)	1.7	11.0	1.7	12.1
0.49	(1.6)	1.4	10.2	1.6	10.3
0.52	(1.7)	1.1	7.7	1.1	8.6
0.55	(1.8)	0.8	5.6	0.5	3.7
0.58	(1.9)	0.7	4.1	0.6	4.4
0.61	(2.0)	0.5	3.5	0.5	3.4
0.64	(2.1)	0.4	3.2	0.5	4.4
0.67	(2.3)	0.4	2.5	0.4	3.8
0.70	(2.4)	0.2	1.7	0.3	3.3
0.73	(2.5)	0.1	1.4	0.1	1.4
0.76	(2.6)	0.1	1.5	0.1	1.1
0.79	(2.7)	0.1	0.8	0.1	0.8
0.82	(2.8)	0.0	0.3	0.0	0.6
0.85	(2.9)	0.0	0.5	0.0	0.5
0.88	(3.0)	0.0	0.3	0.0	0.3
0.91	(3.1)	0.0	0.2	0.0	0.2
0.94	(3.2)	0.0	0.1	0.0	0.1
0.97	(3.3)	0.0	0.1	0.0	0.1
1.00	(3.4)	0.0	0.0	0.0	0.1
1.03	(3.5)	0.0	0.0	0.0	0.0
1.06	(3.6)	0.0	0.0	0.0	0.0
		5 MONTHS		1 MONTHS	

TABLE 8. ELEVATIONS ABOVE MHW AT VARIOUS PERCENTAGES FOR FREQUENCY OF INUNDATION

PRIMARY TIDE STATION	MEAN RANGE		DHQ		10%		1%		0.5%		0.25%		0.0%	
	METER	(FEET)	METER	(FOOT)	METER	(FEET)	METER	(FEET)	METER	(FEET)	METER	(FEET)	METER	(Feet)
Newport Bay, CA	1.13	3.71	0.21	0.69	0.42	1.38	0.69	2.26	0.73	2.40	0.76	2.49	0.91	2.99
Los Angeles, CA	1.15	3.77	0.23	0.75	0.43	1.41	0.69	2.26	0.72	2.36	0.76	2.49	0.79	2.59
San Francisco, CA	1.22	4.00	0.18	0.59	0.33	1.08	0.56	1.84	0.61	2.00	0.66	2.17	0.76	2.59
Alameda, CA	1.43	4.69	0.19	0.62	0.36	1.18	0.59	1.94	0.64	2.10	0.68	2.23	0.79	2.59
Crescent City, CA	1.54	5.05	0.20	0.66	0.38	1.25	0.68	2.23	0.76	2.49	0.84	2.76	0.94	3.08
Astoria, OR	2.00	6.56	0.20	0.66	0.45	1.48	0.81	2.66	0.88	2.89	0.94	3.08	1.03	3.38
Seattle, WA	2.33	7.64	0.26	0.85	0.46	1.51	0.77	2.53	0.85	2.79	0.90	2.95	1.00	3.28
MEAN ELEVATION					0.40	1.31	0.68	2.23	0.74	2.43	0.79	2.59	0.89	2.93
STANDARD DEVIATION (σ)					0.05	0.16	0.09	0.30	0.10	0.33	0.11	0.36	0.11	0.36

seems to be a factor, it is not significant since it takes a large change in the tidal range to produce a small change in the elevation above MHW corresponding to a given percentage of inundation.

B. Elevation of the Transition Zone above MHW.

Biological consultants provided NOS with an upper and lower limit of the transition zone for each transect. In some cases, only a single transition point in the CTZ was provided. All transition zone points were referenced horizontally from a stake placed along the transect. When an upper and lower transition point was reported, a mid-point between the two was inferred. An elevation could then be interpolated from either an inferred CTZ or the reported CTZ.

The CTZ-MHW differences are tabulated for 17 sites in California, Oregon, and Washington (Table 2). In Alaska, the biological consultant did not fulfill the requirements for this survey. The profiles were inadequately defined and points were not marked along the transition zone.

Inconsistencies in the field procedures employed to obtain biological data presented problems in correlating the survey for the marsh at Ebey Slough, Washington (EP1). On the recommendations of Dr. R. E. Frenkel, the biological data were rejected (Frenkel 1978b).

The physical data for the three Alaska marshes and for Ebey Slough, Washington (EP1) are included in the separate appendix to this report.

C. Analysis of Data

Given the following hypothesis: For a given marsh community, whether that community consists of a section of a marsh, a single marsh, contiguous marshes, or marshes for an entire biogeographical region, it is hypothesized that there will be one elevation above a tidal datum that will delineate the upper limit of this marsh community.

Test of this hypothesis*

For each of (k) marshes we randomly select (n_j) transects and compute the elevation of the CTZ above MHW.

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*An "Analysis of Variance (ANOVA) procedure" is used here as outlined in Canavos (1978).

Data may be represented as follows:

Marsh

A	B	. . . .	j^{th}	k^{th}
$CTZ_{1,1}$	$CTZ_{1,2}$		$CTZ_{1,j}$	$CTZ_{1,k}$
$CTZ_{2,1}$	$CTZ_{2,2}$		$CTZ_{2,j}$	$CTZ_{2,k}$
$CTZ_{3,1}$	$CTZ_{3,2}$		$CTZ_{3,j}$	$CTZ_{3,k}$
.	.		.	.
.	.		.	.
.	.		.	.
$CTZ_{n_{1},1}$	$CTZ_{n_{2},2}$		$CTZ_{n_{j},j}$	$CTZ_{n_{k},k}$

We define the i^{th} elevation of the CTZ at the j^{th} marsh by the following model:

(1) $$CTZ_{ij} = \mu + M_j + \varepsilon_{ij}$$

$i = 2,1, \ldots n_j$

$j = 1,2, \ldots k$

where μ = overall mean elevation of the CTZ

M_j = the enhancement (+ or -) of the mean elevation, which is unique to the j^{th} marsh.

ε_{ij} = is the error associated with the measure of CTZ_{ij}

Therefore the hypothesis to be tested is:

H_0: $M_j = 0$ for all $j - 1,2\ldots k$

H_1: At least one of the M_j is not equal to zero and hence different than the rest.

If the null hypothesis, H_0: $M_j = 0$ for all j, is true, then the CTZ_{ij} is simply the elevation above MHW of the CTZ plus some random error ε_{ij}. Thus, there would be no real difference between marshes in regard to elevation above MHW of the CTZ.

The alternate hypothesis states that for at least one marsh the CTZ elevation is significantly different from the others. Equation (1) is dependent on the assumption that any variation is not due to some real difference in the elevation of the CTZ above MHW from one transect to another within one marsh.

Consider the following:

(2) $$N = \sum_{j=1}^{k} n_j = \text{total number of measurements}$$

(3) $$\overline{CTZ}_{..} = 1/N \sum_{j=1}^{k} \sum_{i=1}^{n_j} CTZ_{ij} = \text{grand mean elevation}$$

(4) $$T_{..} = \sum_{i=1}^{k} \sum_{i=1}^{n_j} CTZ_{ij} = \text{grand total}$$

(5) $$T_{.j} = \sum_{i=1}^{n_j} CTZ_{ij} = \text{total of the } j^{th} \text{ marsh}$$

(6) $$\overline{CTZ}_{.j} = 1/n_j \sum_{i=1}^{n_j} CTZ_{ij} = \text{mean for the } j^{th} \text{ marsh}$$

(7) $$\underset{(A)}{\sum_{i=1}^{n} \sum_{j=1}^{k} (CTZ_{ij} - \overline{CTZ}_{..})^2} = \underset{(B)}{\sum_{i=1}^{n} \sum_{j=1}^{k} (\overline{CTZ}_{.j} - \overline{CTZ}_{..})^2} + \underset{(C)}{\sum_{i=1}^{n} \sum_{j=1}^{k} (CTZ_{ij} - \overline{CTZ}_{.j})^2}$$

Equation (7) expresses the idea that the total sum of squares of deviations from the grand mean (A) is equal to the sum of squares of deviations between factor level means (differences between marshes) and the grand mean (B) plus the sum of squares of deviations within marshes (random error) (C).

(8) $$SS_{total} = \underset{(A)}{\sum_{i=1}^{n} \sum_{j=1}^{k} (CTZ_{ij} - \overline{CTZ}_{..})^2} = \sum_{j=1}^{k} \sum_{i=1}^{n_j} CTZ_{ij}^2 - T_{..}^2/N$$

$$(9)\quad SS_{marsh} = \sum_{i=1}^{n_j} \sum_{j=1}^{k} (\overline{CTZ}._j - \overline{CTZ}..)^2 = \sum_{j=1}^{k} T._j{}^2/n_j - T..^2/N$$

(B)

$$(10)\quad \therefore\ SS_{Total} - SS_{Marsh} = \sum_{i=1}^{n_j} \sum_{j=1}^{k} (CTZ_{ij} - \overline{CTZ}._j)^2 = SS_{Error}$$

(C)

Degrees of Freedom

For each sum of squares, the degrees of freedom are equal to the number of squares making the sum, less the number of parameters that must be estimated before the sum of squares can be computed.

The degrees of freedom for equation (7) are: Term A, $\sum_{j=1}^{k} n_j - 1$, Term B, k-1, Term C, $\sum_{j=1}^{k} n_j - k$.

The ANOVA Table follows below:

Source of Influence	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Between Marshes	k-1	SS_{marsh}	$SS_{marsh}/k-1$	$F_{cal.} = \frac{SS_{marsh/k-1}}{SS_{error/N-k}}$
Error	$\sum_{j=1}^{k} n_j - k = N - k$	SS_{error}	$SS_{error}/N-k$	
Total	$\sum_{j=1}^{k} n_j - 1$	SS_{total}		

The null hypothesis, that there is no real differences between marshes (in regard to elevation above MHW of the CTZ), is rejected whenever

$F_{cal.} > F_{(k-1)}, (N-k), (1-\sigma)$, where α = type 1 error.

V. RESULTS

The elevations of the CTZ above MHW for 17 marshes on the west coast of the United States are tabulated in Table 2. Included is the sample standard deviation of the mean elevation (CTZ-MHW) for each marsh. Using the "ANOVA" technique discussed in the analysis of data section, various groupings of marshes are examined in Table 9. The null hypothesis states that all marshes in a grouping have the same CTZ-MHW relationship and that any small differences in elevations are due to random error. For the case of all 17 marshes, the null hypothesis must be rejected with 95 percent confidence (α = 0.05). However, several large groupings of marshes among the 17 appear to be closely related.

Marshes 1 through 5 are compared, and at the 95 percent level of confidence, there is no difference in the CTZ-MHW elevation. This grouping includes all of the marshes from southern and central California.

Marshes 8 through 17, the Pacific northwest marshes, are compared and the null hypothesis is rejected. However, when marshes 10 and 15, Netarts Bay and Ocean Shores, respectively, are deleted from this group, the null hypothesis is accepted, i.e., no significant difference (α = 0.05) exists in the CTZ-MHW elevation of any marsh in this group. The null hypothesis was rejected when marshes 6, 7, 10, and 15 were compared. However, when marsh 10 (Netarts Bay, Oregon) was deleted, the null hypothesis was accepted for the other three marshes of the group.

Marshes 6, 7, 10, and 15 were examined to determine why there appeared to be significant differences between them and all other marshes studied. Frenkel et al. (1978) reports that the marshes at Ocean Shores, Washington (GH1) (15) and Netarts Bay, Oregon (NT1) (10) are low sand marshes (vegetation going directly from marsh to sand dune, as one progresses toward upland). Frenkel et al. (1978) also states that these are the only two marshes in the Pacific northwest of this type that both he and NOS obtained data for. Harvey et al. (1978) states that for both Elk River, Humboldt Bay, California, (HB1) (6) and South Spit (HB2) (7) the upland was a sand dune community.

Distribution of the pooled transect elevations for the southern and central California marshes and for the Pacific northwest marshes (less 6, 7, 10, 15) are shown in Figures 6 and 7 respectively.

Table 9. Hypothesis Tests

$\alpha = 0.05$

Marshes Compared	Degrees of Freedom	F_{Table}	$F_{Calculated}$	Hypothesis
1 thru 17	16,154	1.70	29.71	Rejected
1 thru 5	4,43	2.58	2.33	Accepted
1 thru 7	6,59	2.25	11.16	Rejected
1 thru 6	5,52	2.39	7.90	Rejected
8,9,11,12, 13,14,15,16, 17	8,86	2.04	8.11	Rejected
8,9,10,11,12, 13,14,16,17	8.85	1.99	7.41	Rejected
8,9,11,12,13, 14,16,17	7,76	2.13	2.02	Accepted
6,7,10,15	3,35	2.87	16.01	Rejected
6,7,15	2,26	3.37	3.14	Accepted

Criteria: Null Hypothesis is accepted (H_0) when $F_{calculated}$ is less than F_{Table} $(k-1)$, $(n-k)$, $(1-\alpha)$.

Null Hypothesis is rejected when $F_{calculated}$ is greater than F_{Table} $(k-1)$, $(n-k)$, $(1-\alpha)$.

NOTE: For a complete discussion of how these values were computed, consult the Analysis of Data Section.

Figure 6: DISTRIBUTION OF TRANSECTS FOR SOUTHERN+CENTRAL CALIFORNIA MARSHES- (1,2,3,4,5)

N= 48
SAMPLE MEAN ($\bar{x}$) = 0.90 METER
MEDIAN = 0.88 METER
SAMPLE VARIANCE (S^2) = 0.027 METER^2
SAMPLE STANDARD DEVIATION (S) = 0.16 METER

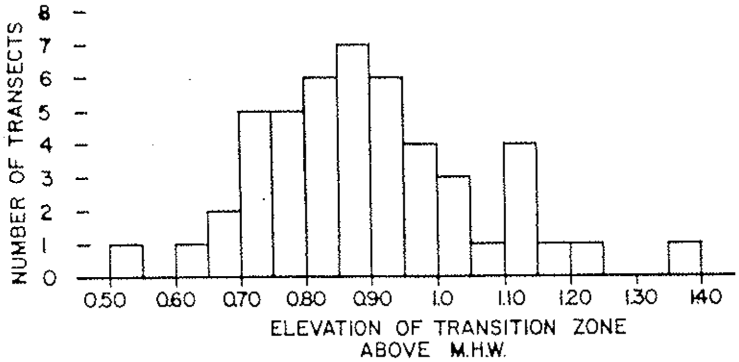
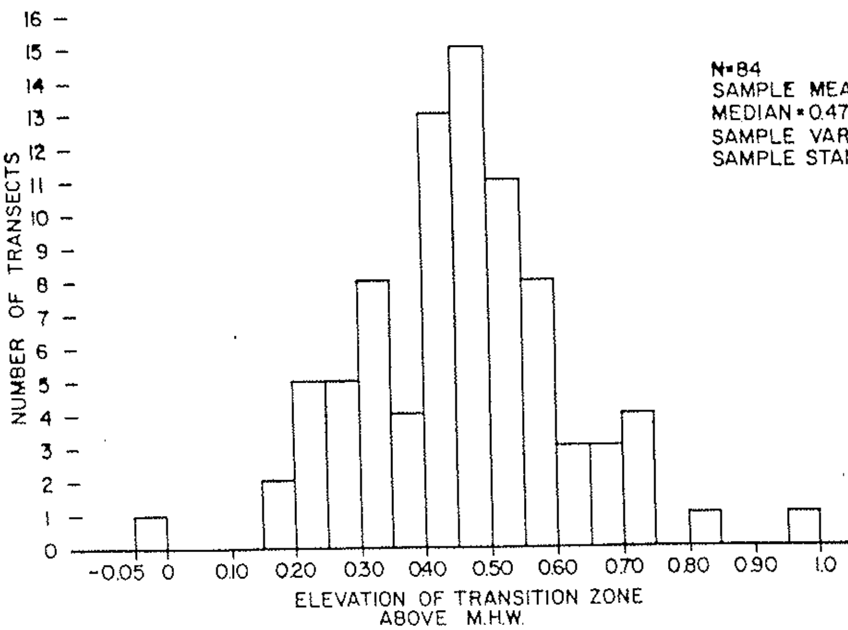


Figure 7: DISTRIBUTION OF TRANSECTS FOR PACIFIC NORTHWEST MARSHES- (8,9,11,12,13,14,16,17)

N=84
SAMPLE MEAN ($\bar{x}$) = 0.46 METER
MEDIAN = 0.47 METER
SAMPLE VARIANCE (S^2) = 0.026 METER^2
SAMPLE STANDARD DEVIATION (S) = 0.16 METER



Pooled CTZ-MHW elevations for the Pacific northwest marshes (less 6, 7, 10, 15) and for the south and central California marshes are listed in Table 2. The CTZ-MHW elevation values tabulated in Table 2, were used to compute the percent frequency and the percent duration of inundation at the upper limits of various coastal marshes, as listed in Table 10.

The CTZ of the California marshes [upper Newport Bay, California (NB1), Elkhorn Slough, California (ES1), and Palo Alto, California (SF1)] corresponds to an inundation level (duration or frequency) of 0.0 percent at either the subordinate station (Table 7) or the controlling station (see Table 10). This information is of little value in determining where the upper limit of a coastal marsh (in this region) is located. For example, the percent frequency and/or percent duration of inundation at 0.79 meter (2.59 feet) above MHW is 0.0 percent (using 19 years of observed data, 1941-1959) at the Los Angeles, California, primary control station. Any elevation greater than 0.79 meter (2.59 feet) above MHW will also have the same percent frequency and/or percent duration of inundation (i.e., 0.0 percent). Since the CTZ in this case is 0.98 m (3.2 feet), a unique CTZ-MHW elevation cannot be determined from inundation information.

The CTZ of the Humboldt Bay marshes [South Spit (HB2) and Elk River (HB1)] corresponds to a frequency of inundation of 1.4 percent and a duration of inundation of 0.1 percent (Table 7). At the primary tide station (Crescent City), the frequency of inundation is 1.8 percent and the duration of inundation is 0.2 percent (see separate appendix). These values are based on an average CTZ-MHW value for only these two marshes [0.62 m (2.03 ft.)].

The CTZ of the Pacific northwest marshes (8, 9, 11, 12, 13, 14, 16, 17) corresponds to a frequency of inundation of 11.6 percent and a duration of inundation of 2.8 percent (Table 10). At the primary tide stations (Crescent City and Seattle), the average frequency of inundation is 8.4 percent, and the duration of inundation is 1.2 percent (see separate appendix). All inundation values listed in this discussion are either based on 19 years of data (primaries) or are the equivalent of 19-year mean values (subordinate stations, Table 7).

Boon et al. (1977) determined a frequency of inundation (using a different method than NOS) for the upper limit of saline marshes in the Chesapeake Bay region of approximately 10 percent.

Table 11, Highest Water Levels for Selected West Coast Primary Tide Stations, lists the average highest water level per month over 19 years. This average extreme water level appears to be fairly constant for all west coast primary tide stations.

TABLE 10. PERCENT FREQUENCY AND DURATION OF INUNDATION AT THE UPPER LIMITS OF VARIOUS COASTAL MARSHES

CONTROL STATION	CONTROL NUMBER	SUBORDINATE	MARSH	CTZ-MHW (METER)	(FEET)	%FREQUENCY CORRECTED VALUE	%DURATION CORRECTED VALUE
Newport Beach	941-0580		Upper Newport Bay(NB1)	0.90	2.95	0.0	0.0
Los Angeles	941-0660	Mugu Lagoon (941-1013)	Mugu Lagoon(ML1)	0.98	3.22	0.0	0.0
Alameda	941-4750	Palo Alto, CA (941-4525)	Palo Alto, CA(SF1)	0.97	3.18	0.0	0.0
Alameda	941-4750	Palo Alto CM #8 (941-4525)	Palo Alto, CA(SF1)	0.97	3.18	0.0	0.0
San Francisco	941-4290	Crocket, CA (941-5143)	Southampton Bay (SF2)	0.86	2.82	0.0	0.0
Crescent City	941-9750	Hookton Slough (941-8686)	South Spit Humboldt Bay(HB2)	0.61	2.00	4.2	0.5
Crescent City	941-9750	Elk River (941-8757)	Elk River Humboldt Bay(HB1)	0.63	2.07	4.0	0.5
Crescent City	941-9750	Bandon, Oregon (943-2373)	Bandon, Oregon	0.48	1.57	7.7	1.6
Crescent City	941-9750	Drift Cr., OR (943-4938)	Alsea River(AB1)	0.44	1.44	16.8	3.1
Crescent City	941-9750	Netarts Bay, OR (943-7262)	Netarts Bay(NT1)	0.79	2.59	5.4	1.2
Crescent City	941-9750	Brighton, OR (943-7815)	Nehalem Bay(NB2)	0.49	1.61	11.2	3.1
Crescent City	941-9750	Brighton, OR (943-7815)	Nehalem Bay(NB2)	0.40	1.31	23.0	4.6
Crescent City	941-9750	Toke Point (944-0910)	Cedar Creek(WB1) Willapa Bay	0.43	1.41	17.2	3.2
Astoria	943-9040	Toke Point (944-0910)	Cedar Creek Willapa Bay	0.43	1.41	11.7	2.0
Seattle, WA	944-7130	Bangor, WA (944-5133)	Thorndyke Bay(HC1)	0.39	1.28	16.9	3.4
Seattle, WA	944-7130	Allyn, WA (944-6281)	Coulter Creek(KS2)	0.55	1.80	8.0	0.9
Pooled Value South and Central California (1,2,3,4,5)				0.90	2.95	0.0	0.0
Pooled Value Pacific Northwest (8,9,11,12,13,14,16.17)				0.46	1.51	11.6 (σ=2.7%)	2.0 (σ=0.6%)

Table 11. Highest Water Levels for Selected West Coast Primary Tide Stations

Primary Tide Station	Average Highest Water Level per month (Above MHW) Meter	(Feet)	(Time Period)		Extreme Highest Water Level Observed (Above MHW) Meter	(Feet)	(Dates)
941-0170 San Diego, CA	0.64	(2.10)	228 months (1941-59)		1.00	(3.28)	12/20/68
941-0580 Newport Bay, CA	0.61	(2.00)	224 months (1956-1974)		0.82	(2.69)	2/4/58, 12/29/59 12/30/59
941-0660 Los Angeles, CA	0.62	(2.03)	228 months (1941-59)		0.94	(3.08)	1/8/74
941-4290 San Francisco, CA	0.50	(1.64)	228 months (1941-59)		1.01	(3.31)	1/16, 18/73
941-4750 Alameda, CA	0.48	(1.57)	227 months (1941-59)		1.16	(3.81)	2/4/58
943-9040 Astoria, OR	0.66	(2.17)	204 months (1941-59)		1.37	(4.49)	12/17/33
944-3090 Neah Bay, WA	0.71	(2.33)	213 months (1941-59)		1.49	(4.89)	11/30/51
944-7130 Seattle, WA	0.61	(2.00)	228 months (1941-59)		1.34	(4.40)	12/15/77

It was hypothesized that there should be some correlation between the upper limits of coastal marshes and an average of the highest water level per month. If this hypothesis were true, as the average highest water level per month varied from area to area, so should the elevation of CTZ vary above MHW for a marsh. This does not seem to be the case, as can be seen by comparing CTZ-MHW values in Table 2 to the average highest water level per month at appropriate primary tide stations in Table 11. The extreme highest water level observed and the dates when observed for selected primary tide stations are included in Table 11. Again, there appears to be no obvious correlation between such extreme values and the CTZ-MHW elevations listed in Table 2.

VI. CONCLUSION

This project investigated and documented the elevations of tidal datums and how they relate to the transition zone between marsh and upland vegetation on the west coast of the United States. The study indicates that no one elevation above MHW may be used for the west coast of the United States. There does appear, however, to be justification for using a constant elevation above MHW to demark the CTZ between marsh and upland within a given region of the western United States, subject to the following qualification: this relationship does not apply in marshes which progress from marsh to sand dune vegetation (at least for an area somewhat south of Humboldt Bay northward to the Canadian border).

For the south and central California marshes a standard CTZ-MHW elevation can be given [0.90 m (2.95 ft) above MHW)]. For marshes in the Pacific Northwest (other than marshes which progress from marsh to sand dune) a standard CTZ-MHW elevation can also be given [(0.46 m (1.5 ft) above MHW)].

Eighteen frequency and duration of inundation tables were prepared for various subordinate stations along the west coast. Each was compared to a control station to produce the equivalent of 19-year mean values. It was not possible to determine a unique percent frequency and/or percent duration of inundation for the CTZ of the south and central California marshes. The elevation of the mean CTZ in this area was above any appreciable inundation level.

For the Pacific Northwest, average percent frequency and percent duration of inundation were calculated based on subordinate station data (11.6 percent frequency, 2.0 percent duration). These mean values (19-year equivalent) may be used with the CTZ-MHW value to select an appropriate percent frequency and/or percent duration of inundation for the upper limit of coastal marshes. (Again, this relationship does not apply in areas which progress from marsh to sand dune).

When the elevation of the CTZ above MHW for each of the 17 marshes was compared to the highest water level per month over 19 years at nearby primary tide stations, no obvious correlations were noted.

The separate appendix to this report gives inundation information for various west coast primary control stations. Information for each study site which includes transect and tide gage locations, profile elevations, description of bench mark locations and the MHW determined for each study site are all included in the separate appendix.

VII. RECOMMENDATIONS

Because of problems with the biological data for the Alaskan marshes, no CTZ-MHW or inundation values are reported here. To determine these values a resurvey of the Alaskan marshes by a biological consultant would have to be performed.

Because of statistical anomalies occurring with the data from Netarts Bay (NB1) and other marsh to sand dune areas, a resurvey of these marshes should be performed.

As was noted previously, there are significant differences between the marshes in southern and central California and the marshes in the Pacific Northwest. Different biological consultants performed the analyses in each region. To remove any possibility of statistical bias due to these differences, the following recommendation made in the NOS pilot study (National Ocean Survey, 1975, p. 83) should be followed. A marsh that is selected should be surveyed completely three times, following the field procedures outlined in this report. A different biologist should be utilized to identify the CTZ for each survey, and a minimum of ten transects should be completed for each survey.

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