Tidal Study of Three Oregon Estuaries

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TIDAL STUDY OF THREE OREGON ESTUARIES

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Introduction:

Increasing activity and development along the Oregon coast has caused concern over the utilization and management of our estuaries. Bills proposing study and conservation on these estuaries are presently before the Oregon Legislature. A major prerequisite for the efficient use and wise management of this limited resource is a good understanding of the interchange of water in each and every estuary on the coast.

During the summer of 1969 the Civil Engineering Department at Oregon State University measured tidal elevations and current velocities in the Yaquina, Alsea, and Siletz estuaries (Figure 1). Data were gathered on the physical characteristics (depths, areas, volumes, streamflow, etc.) of the estuaries, and basic water quality measurements were also made to improve our understanding of the stratification structure of the estuaries.

This report essentially presents a summary and an overview of the data collected on the tidal and physical characteristics of the estuaries. Detailed analyses of these data and comparisons with mathematical models will follow in a later report. It is hoped that the information presented herein will prove useful to those involved in planning and managing the use of our estuaries.

Data Collection Program:

To simultaneously record tidal heights and their times of occurrence, automatic Leupold-Stevens Type F strip-chart recorders were used. Four stations were established on the Yaquina (in addition to the existing station at the OSU Marine Science Center in Newport), four stations on the Siletz, and three stations on the Alsea (Table 1). On the Yaquina,

FIGURE 1

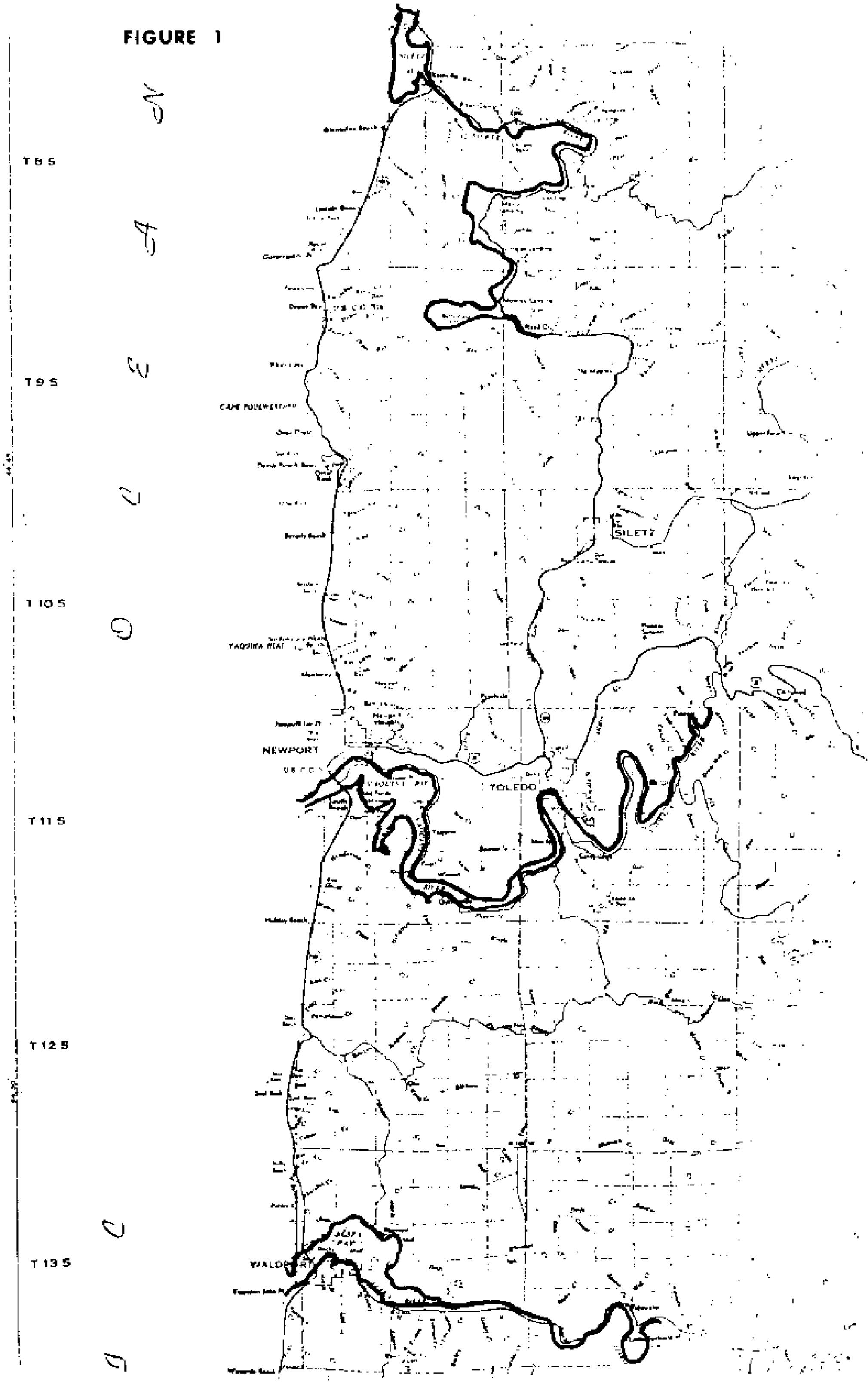
T 8 S
T 9 S
T 10 S
T 11 S
T 12 S
T 13 S
CAPE FOULWEATHER
YAQUINA HEAD
NEWPORT
TOLEDO
SILETZ

Table 1
Station Identification

	Approx. Dist. from Mouth of Estuary (ft)	Cross Sectional Area at MTL (ft^2)	Hydraulic Depth (ft)	Drainage Area (mi^2)
Yaquina				
--Newport	10,000	35,500	17.8	244
--River's Bend	29,000	20,600	12.9	---
--G.P. Dock	56,500	8,900	9.6	---
--Mill Creek	80,000	3,700	16.1	---
--Elk City	118,500	1,200	10.0	
--head of high tide	137,500	---	---	161
Alsea				
--Waldport	10,000	15,000	10.0	468
--Oakland	30,000	4,600	10.0	---
--Kozy Kove	62,000	2,100	7.5	---
--head of high tide	84,500	---	---	349
Siletz				
--Taft	1,000	3,400	6.2	364
--Kernville	13,000	5,400	12.9	---
--Howard's	57,000	2,200	11.6	---
--Strome	95,500	1,100	6.5	---
--head of high tide	128,000	---	---	268

21 days (4 July - 25 July) of data were obtained; on the Alsea, 25 days (5 August - 30 August); and on the Siletz, 13 days (3 September - 16 September). Tide charts were changed every day, and tidal elevations were read to the nearest one hundredth of a foot and tidal times to the nearest five minutes. The accuracy of the data is judged to be ± 0.05 feet for elevations and ± 2.5 minutes for times. In addition, water level measurements were conducted on suitable tides in the ocean surf outside the estuaries. To improve the data's usefulness, all tide stations and cross-sectional areas were referenced to a common datum (Mean Sea Level) by leveling to existing bench-marks in the area. A longitudinal reference system was established for each estuary, sections of which were sounded and plainmetered in order to establish cross-sectional areas and water volumes. Stream-flow data were collected and drainage areas determined in order to establish fresh water inflows.

Current measurements were conducted over one or one-half tidal cycle in each estuary at each of the tide stations. In the Yaquina these measurements were performed on 21 July (0900 - 2000 hours PDT), in the Alsea on 28 August (0800 - 2200 hours PDT), and in the Siletz on 12 September (0900 - 1630 hours PDT). The current measurements were performed from boats or suitable piers and were gathered from as many as five stations (Yaquina) simultaneously. Current velocities were measured at various depths and, when a boat was used, also at various locations along the width of the cross-section. Salinity samples and temperatures were obtained in conjunction with the current measurements. Several regular cup-type current meters (Price) and one Savonius meter were used. For the relatively high velocities observed (up to 7 feet/second) the meters performed satisfactorily. A boat especially equipped for current, depths, and water quality measurements in the estuaries was made available, courtesy United States Geological Survey. The boat and its equipment proved very useful.

Previous work:

Attempts to quantify the behavior of Oregon estuaries reveal, paradoxically, better information on the water quality than on the physical parameters or tidal conditions in the estuaries. In some estuaries not enough quantitative information exists to define cross-sectional areas or volumes let alone tidal prisms.

In its Tide Tables (References 1 and 2), the Coast and Geodetic Survey attempts to predict high and low tide levels, their times of occurrence, and times of slack current at the most pertinent locations on the Oregon coast. These predictions are based on actual measurements made in the estuaries. However, conditions probably have changed in the estuaries (erosion, sedimentation, dredging, breakwater construction, landfill, etc.) because the observed tide levels and times even near the estuary mouths often are quite different than predicted.

In 1957 W. V. Burt and L. D. Marriage published a report dealing with the possible pollution in the Yaquina estuary resulting from a pulp mill at Toledo (3). In 1959 W. V. Burt and W. B. McAlister discussed and attempted to classify the various Oregon estuaries according to their stratification structure (4). In 1966 V. T. Neal published the findings of tidal measurements he performed in the Yaquina estuary (5). Dr. Neal's data constitute most of the quantitative information available on the tidal mechanism in the Yaquina, Alsea, and Siletz estuaries.

L. D. Kulm and J. V. Byrne studied sediment transport in Yaquina Bay (6 and 7). The Fish and Wildlife Service has studied the fish and wildlife of Yaquina Bay (8). Washington State University has made a model study of the movements of pollutants in the Umpqua estuary (9). Data on streamflow in the larger creeks or rivers discharging into the Yaquina, Alsea, and Siletz have been taken from the United States Geological Survey records (10).

Other general publications relating to tidal mechanics and characteristics of estuaries are: Glenne (11, 12, and 13), Ippen (14), Dorrestein (15), Harleman (16), Dronkers (17), Keulegan (18 and 19), and Leendertse (20).

The Pacific Northwest Laboratory in Corvallis and the Civil Engineering Department at Oregon State University also have studies in progress on the water quality of the Yaquina estuary.

Physical Characteristics of Estuaries:

The location map (Figure 1) shows drainage areas and the general shapes and positions of the Yaquina, Alsea, and Siletz estuaries. The Station Identification table (Table 1) lists the approximate drainage areas, lengths, cross-sectional areas, and hydraulic depths of the estuaries. The smallest estuary is seen to have the largest drainage area and vice versa. Average July fresh water flow in Mill Creek (4.08 square mile drainage area), a tributary of the Yaquina, is given by the United States Geological Survey (10) as 2.2 cfs for 1961-1967. The average September fresh water flow in the Siletz River at Siletz (202 square miles drainage area) is given as 110 cfs for 1961-1967. On the Alsea the average August fresh water flow in the Alsea River near Tidewater (334 square miles drainage area) is given as 104 cfs for 1961-1967.

The estuaries all have sizeable bays just landward of their ocean entrances. This phenomenon can also be observed from the plots of cross-sectional areas versus distance from the estuary mouths (Figures 2, 3, and 4). Once landward of these bays the cross-sectional areas vary approximately logarithmicaly with distance from the estuary mouths.

Tidal Elevations:

Tidal elevations, as observed at the five tide gaging stations in the Yaquina, are plotted in Figure 5. Tying the levels of the stations into available benchmarks along the estuary makes it possible to superimpose

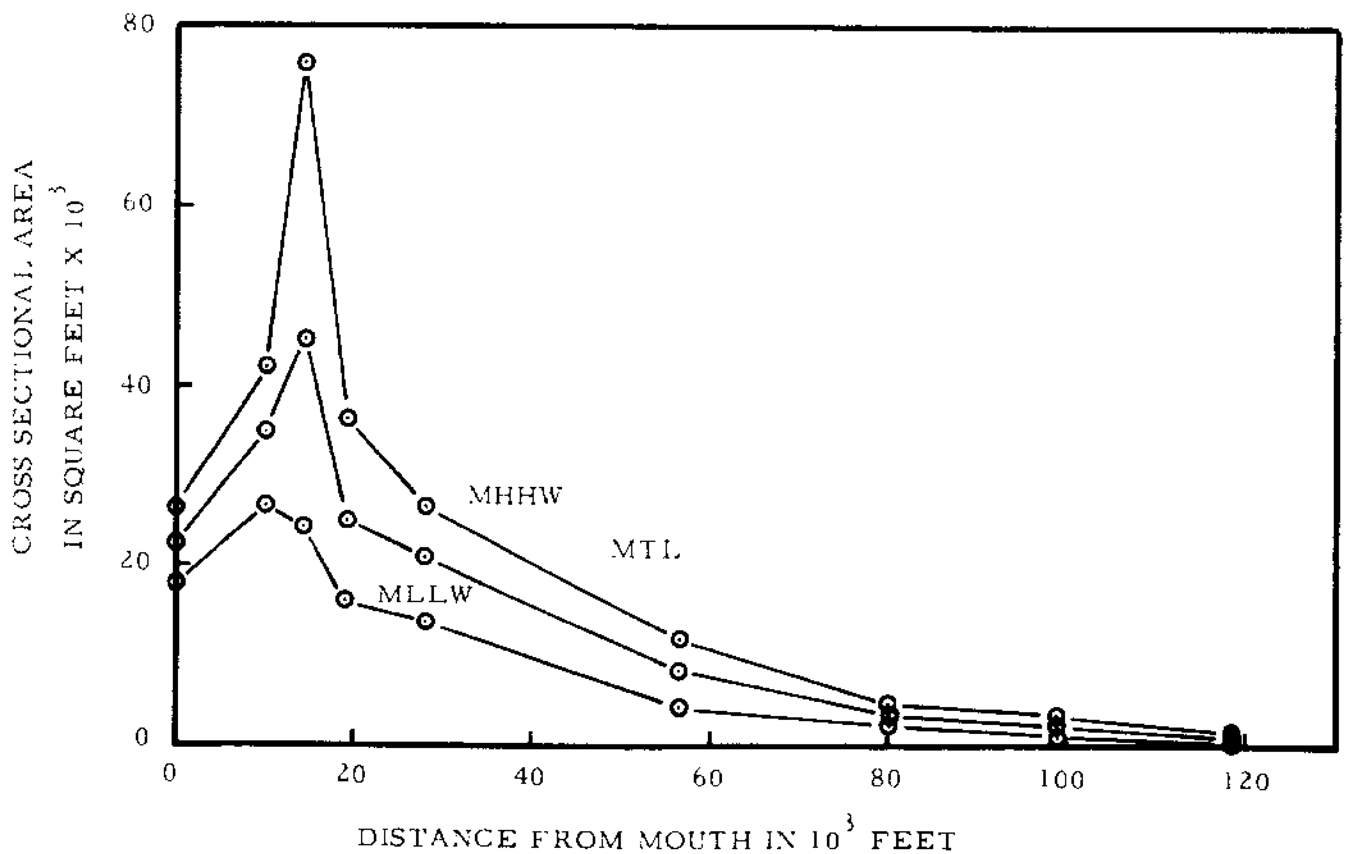

Figure 2. Cross Sectional Area - Yaquina Estuary.

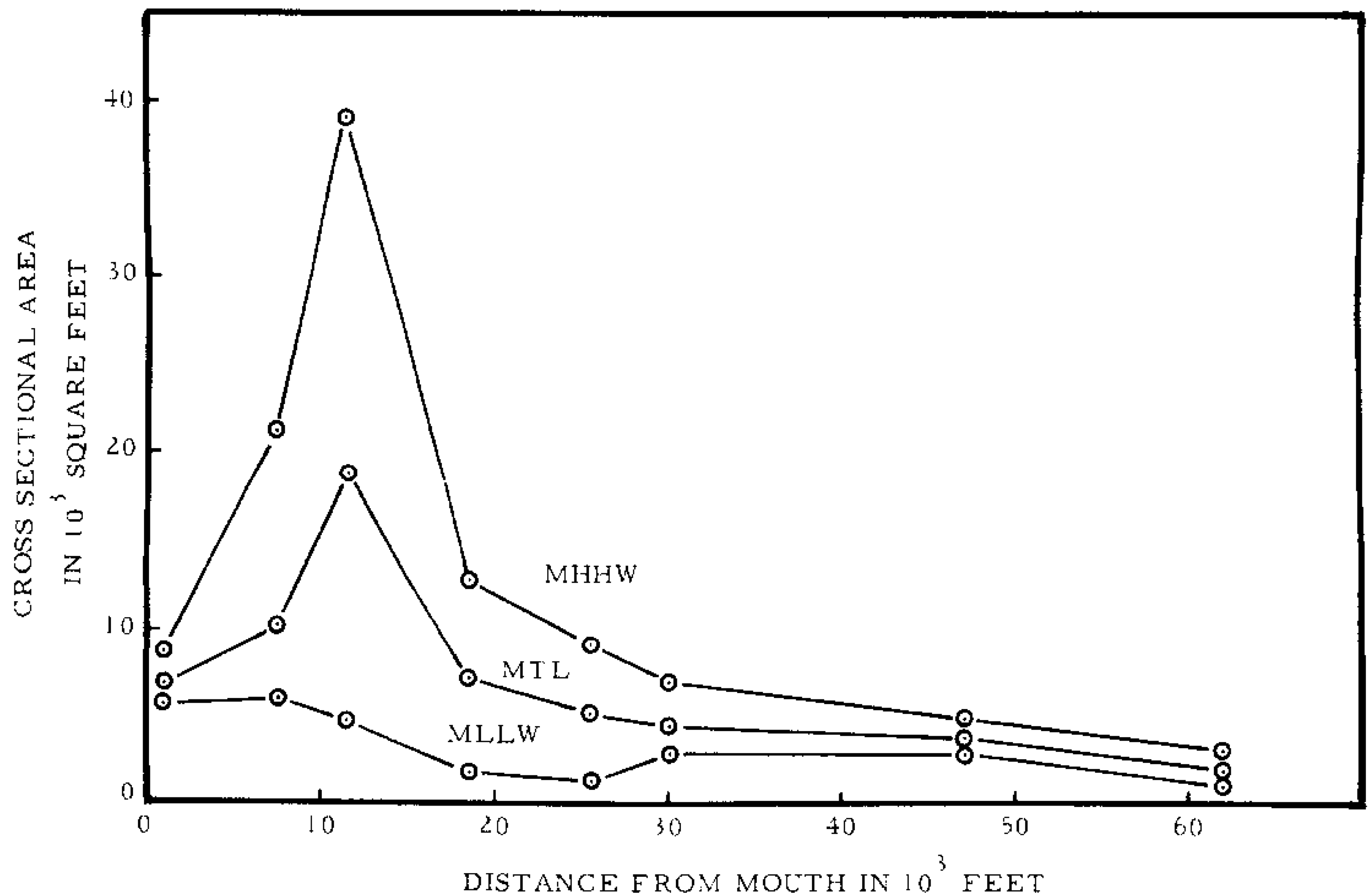

Figure 3. Cross Sectional Area - Alsea Estuary.

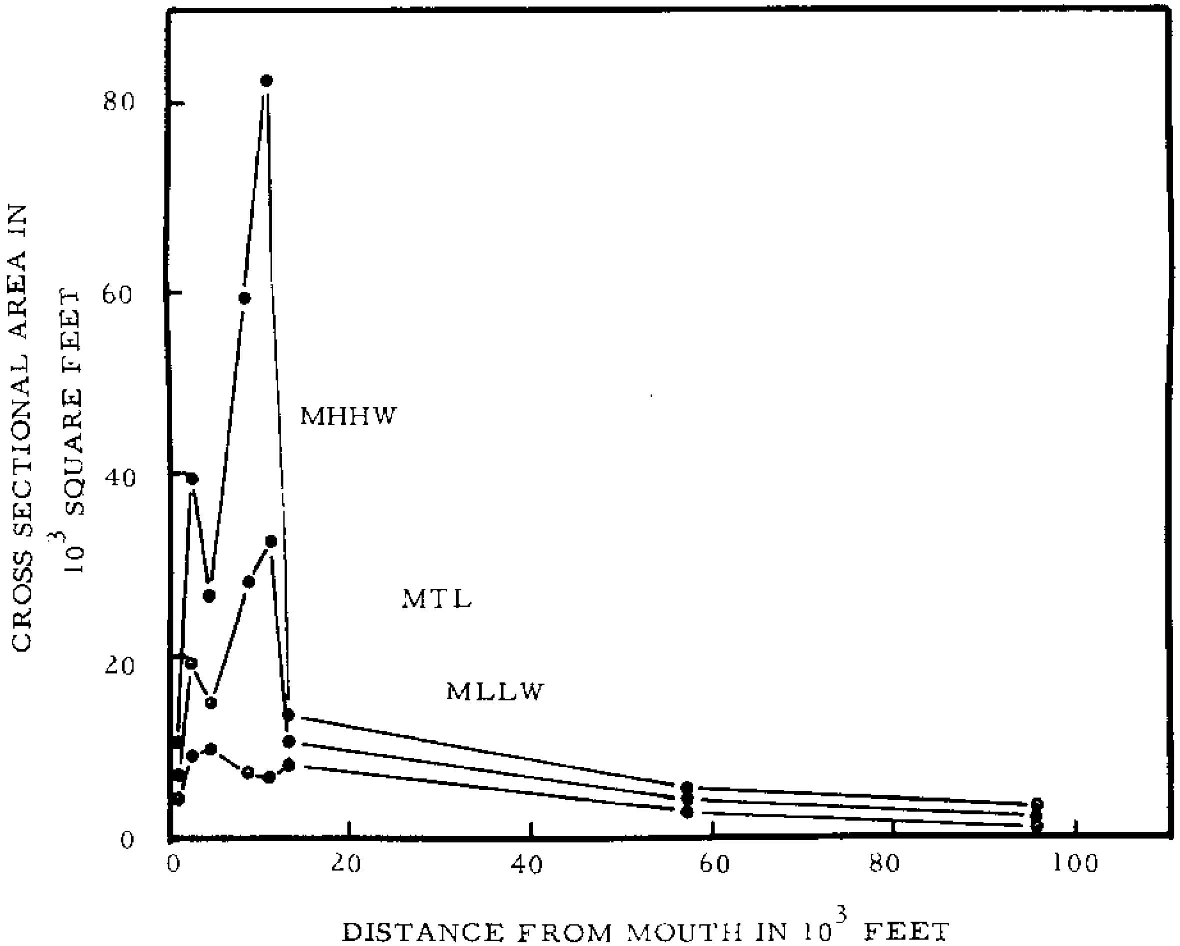

Figure 4. Cross Sectional Area - Siletz Estuary.

FIGURE 5

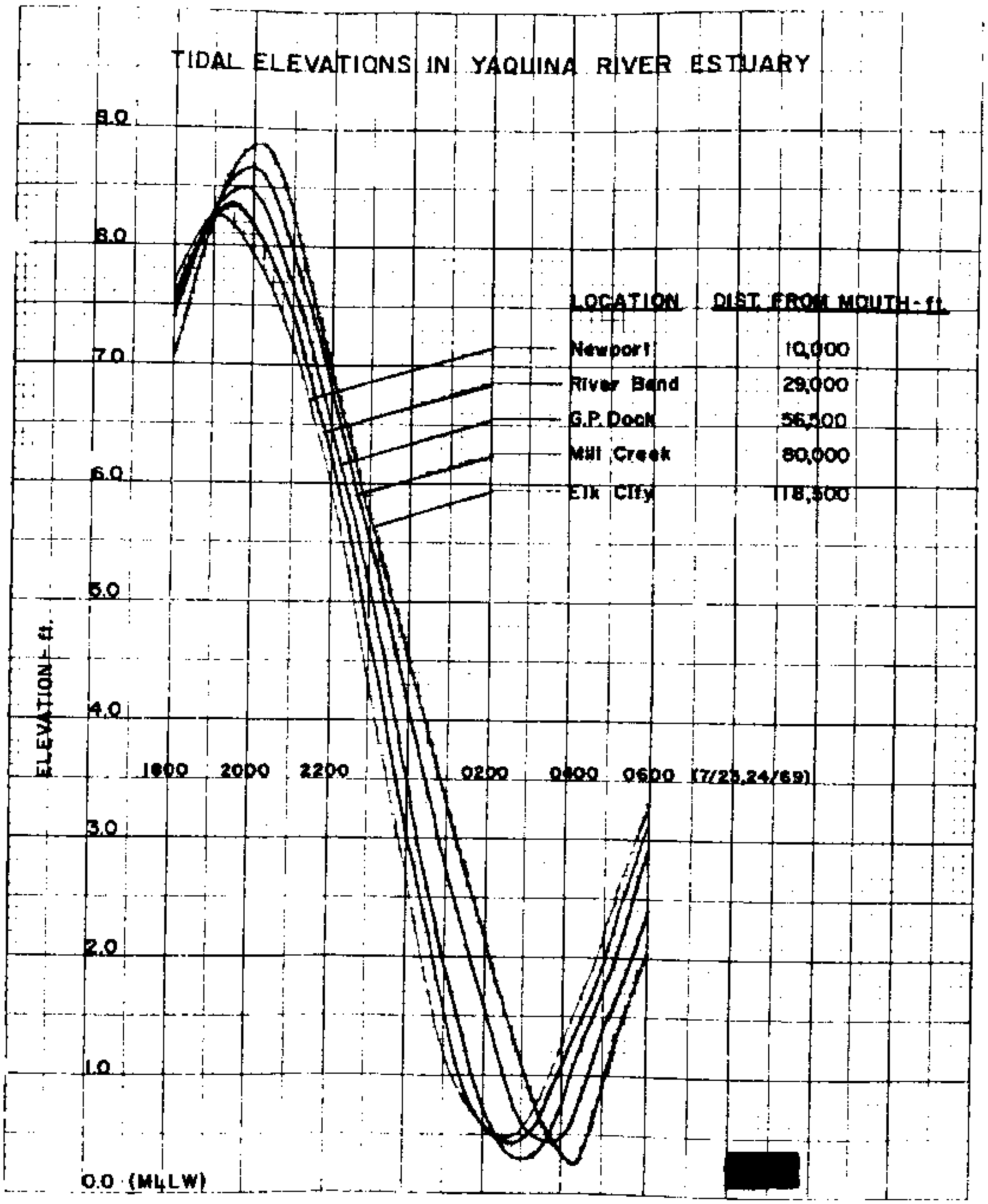

Figure 5. Tidal Elevations in Yaquina River Estuary.

the curves. From this plot time lags and instantaneous water surface profiles can readily be calculated for 23-24 July in the Yaquina.

The average tidal elevations for the appropriate observation periods in each estuary are given in Table 2 and plotted in Figures 6, 7, and 8. The amplitude characteristics of the tidal mechanisms in each estuary can be observed from these graphs of averaged tidal data versus distance from the mouth. Gently diverging mean higher high water (MHHW) and mean lower low water (MLLW) elevations are characteristic of the Yaquina with one exception in the MLLW curve between the Georgia Pacific Loading Dock and Mill Creek stations. This is apparently due to a channel constriction within the reach which becomes increasingly pronounced as the tidal elevation lowers. The mean tide level (MTL) slopes gently up from mean sea level (MSL) datum.

In the Alsea, a marked "choking" of the tidal amplitude is apparent in MLLW up to the Oaklands Marina station. This is also reflected in the rapid departure of MTL from MSL. Above Oaklands, the same gentle divergence as in the Yaquina seems to prevail.

The Siletz is characterized by rising curves of all three tidal datums (MHHW, MTL, and MLLW). The most pronounced changes occur in the MLLW curve in the lower and upper reaches of the estuary. It is probable that channel constrictions also cause these rises.

To more completely represent the variations of the tidal ranges throughout each estuary, plots have been made of tidal range amplification factor versus distance from the mouth (Figures 9, 10, and 11). The tidal amplification factor is here defined as the local tidal range divided by the tidal range at or near the mouth of the estuary. For the Yaquina this plot reveals an increasing amplification factor with increasing upstream distance. The amplification factor can also be seen to increase with decreasing tidal range at the estuary's mouth. Thus a 2 ft. tidal range at Newport gives about a 2.8 ft. tidal range at Elk City, while a 9 ft. tidal range at Newport results in approximately a 9.6 ft. tidal range at Elk City. Measurements taken in the surf outside the Yaquina breakwaters show

Table 2

Average Tidal Elevations

Yaquina Estuary: 4-25 July, 1969

Station	MSL	MTL	MLLW	MHHW
Newport	4.16	4.12	-0.12	7.78
River Bend	4.16	4.18	-0.18	7.94
G. P. Dock	4.16	4.24	-0.22	8.15
Mill Creek	4.16	4.38	-0.05	8.34
Elk City	4.16	4.42	-0.11	8.55

Alsea Estuary: 5-30 August, 1969

Station	MSL	MTL	MLLW	MHHW
*Ocean	3.47	4.08	-0.45	7.97
Waldport	3.47	4.46	0.49	7.95
Oakland	3.47	4.82	1.52	8.05
Kozy Kove	3.47	4.91	1.43	8.35

Siletz Estuary: 3-16 September, 1969

Station	MSL	MTL	MLLW	MHHW
*Ocean	2.46	2.39	-1.57	5.36
Taft	2.46	3.00	0.12	5.57
Kernville	2.46	3.10	0.42	5.61
Howard's	2.46	3.31	0.52	5.92
Strome's	2.46	3.55	1.01	6.12

* Elevations computed from data at Newport during the same period

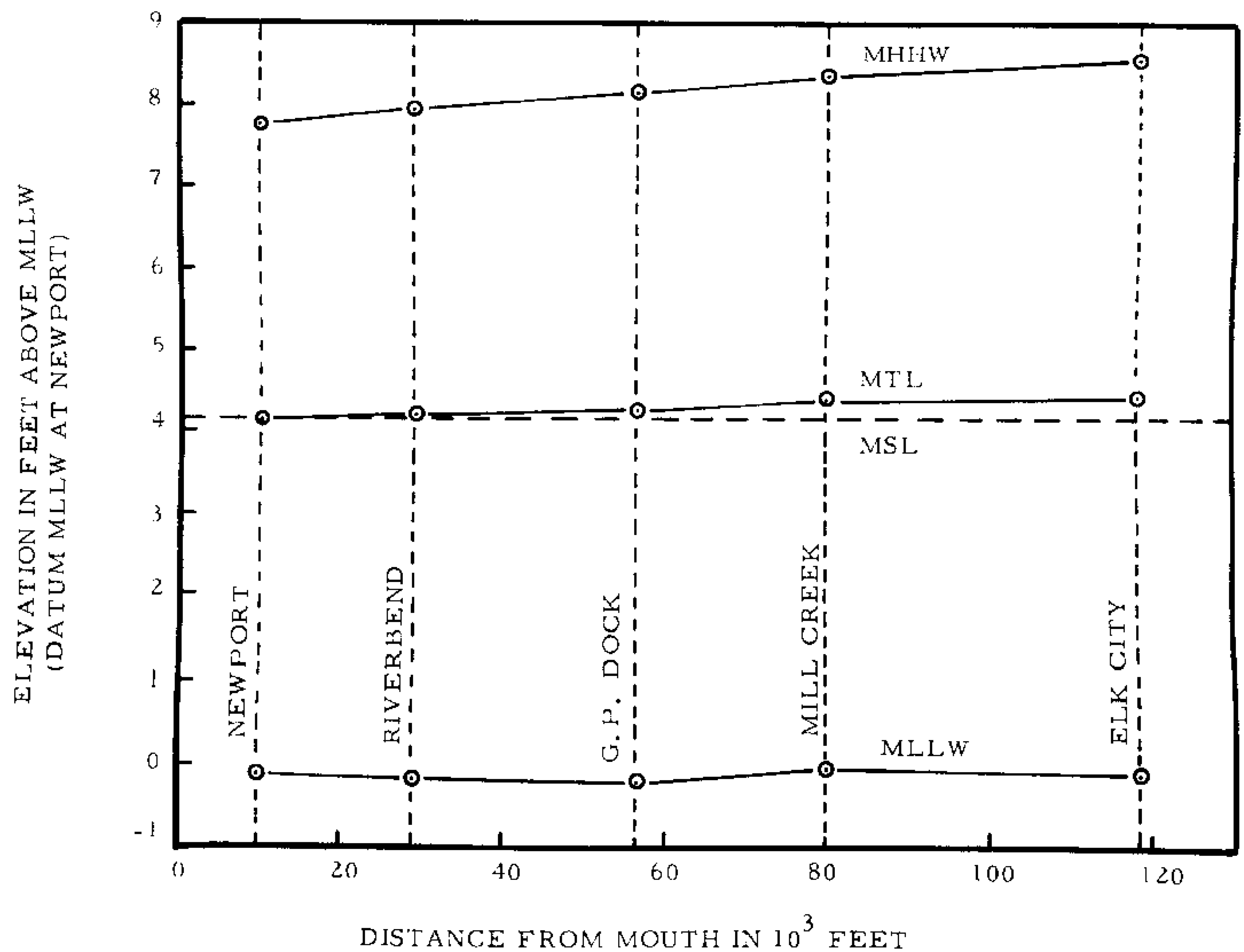

Figure 6. Tidal Observations - Yaquina Estuary - July 4 - 25, 1969.

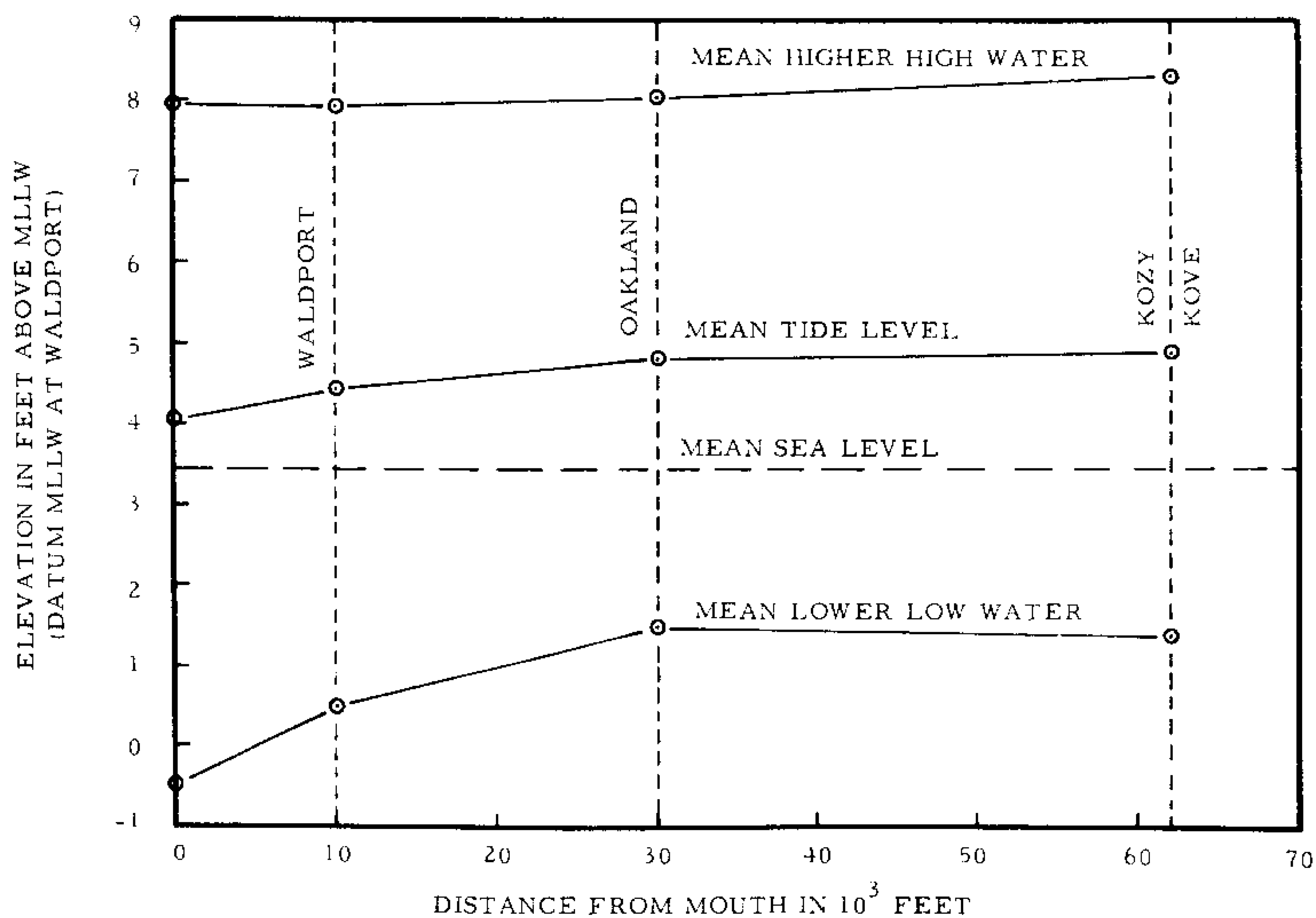

Figure 7. Tidal Observations - Alsea Estuary - August 5 - 30, 1969.

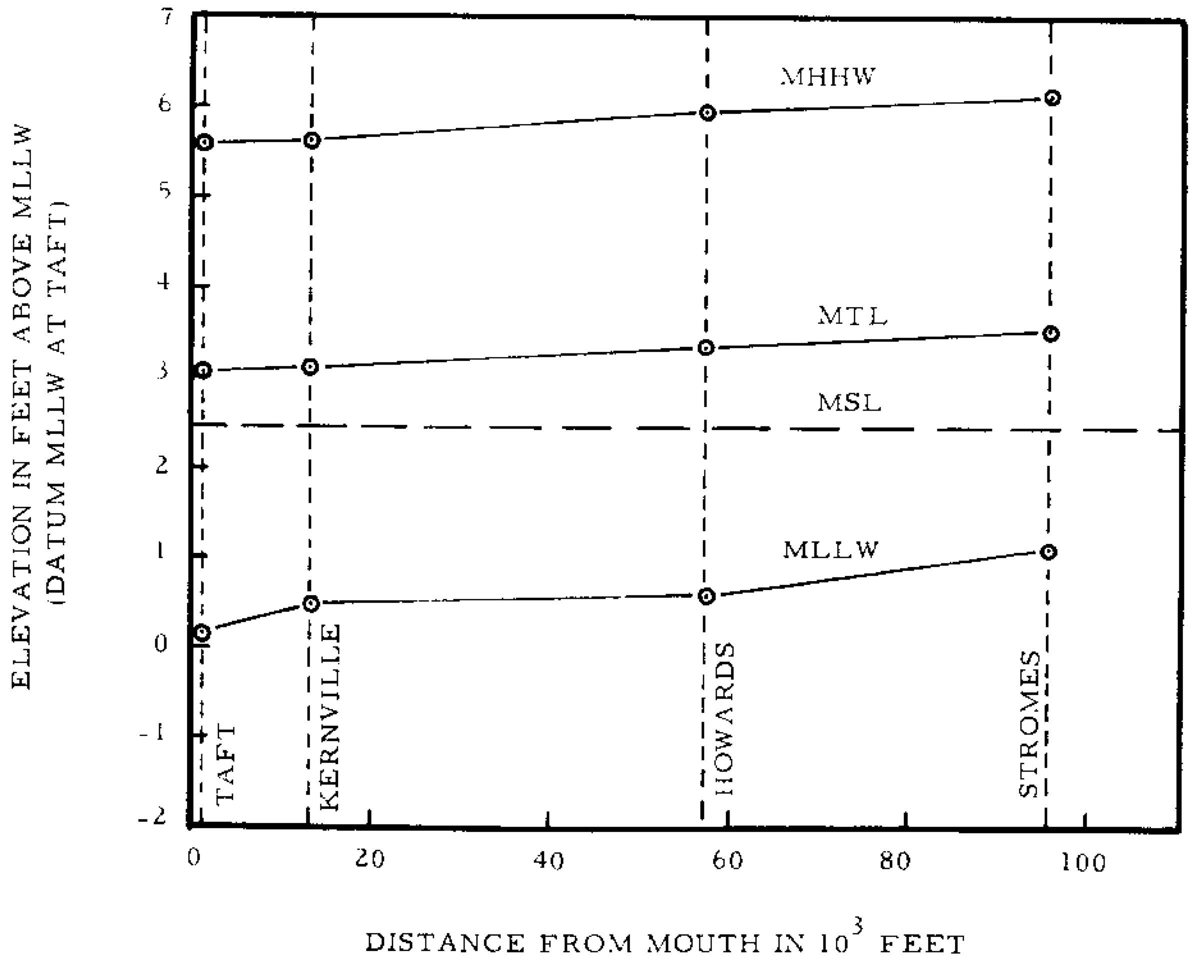

Figure 8. Tidal Observations - Siletz Estuary - September 3 - September 16, 1969.

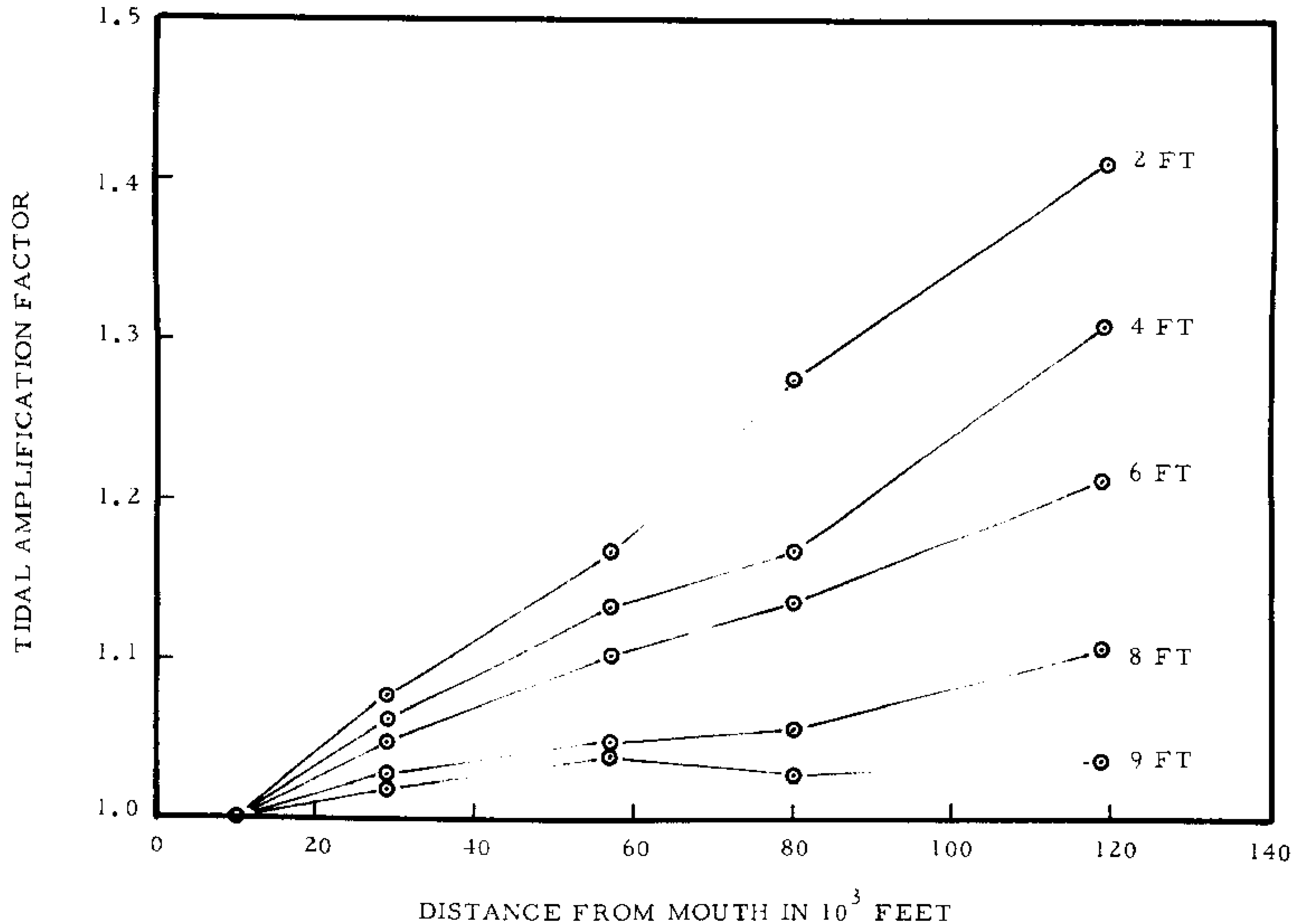

Figure 9. Tidal Amplification Factors - Yaquina Estuary.

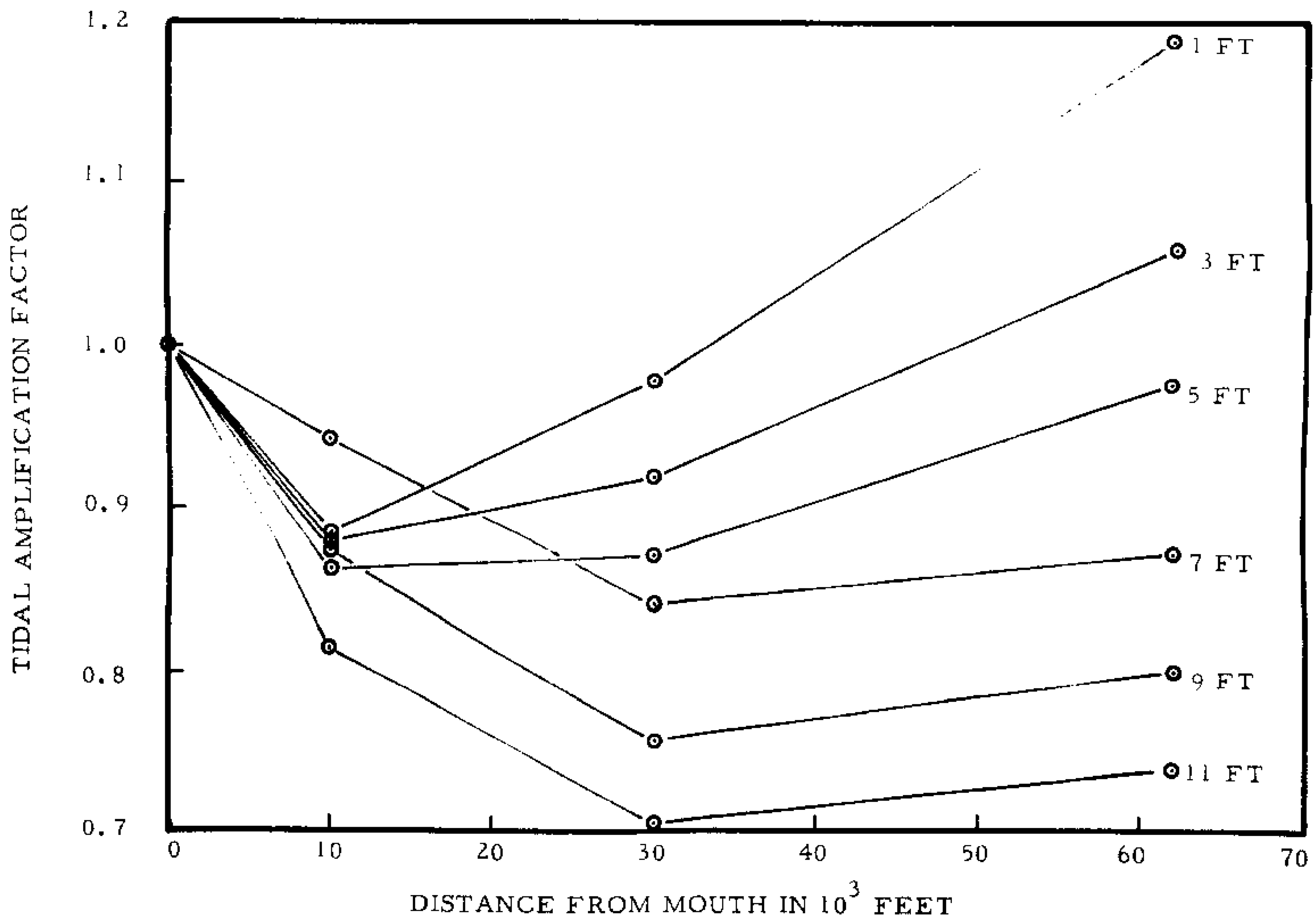

Figure 10. Tidal Amplification Factors - Alsea Estuary.

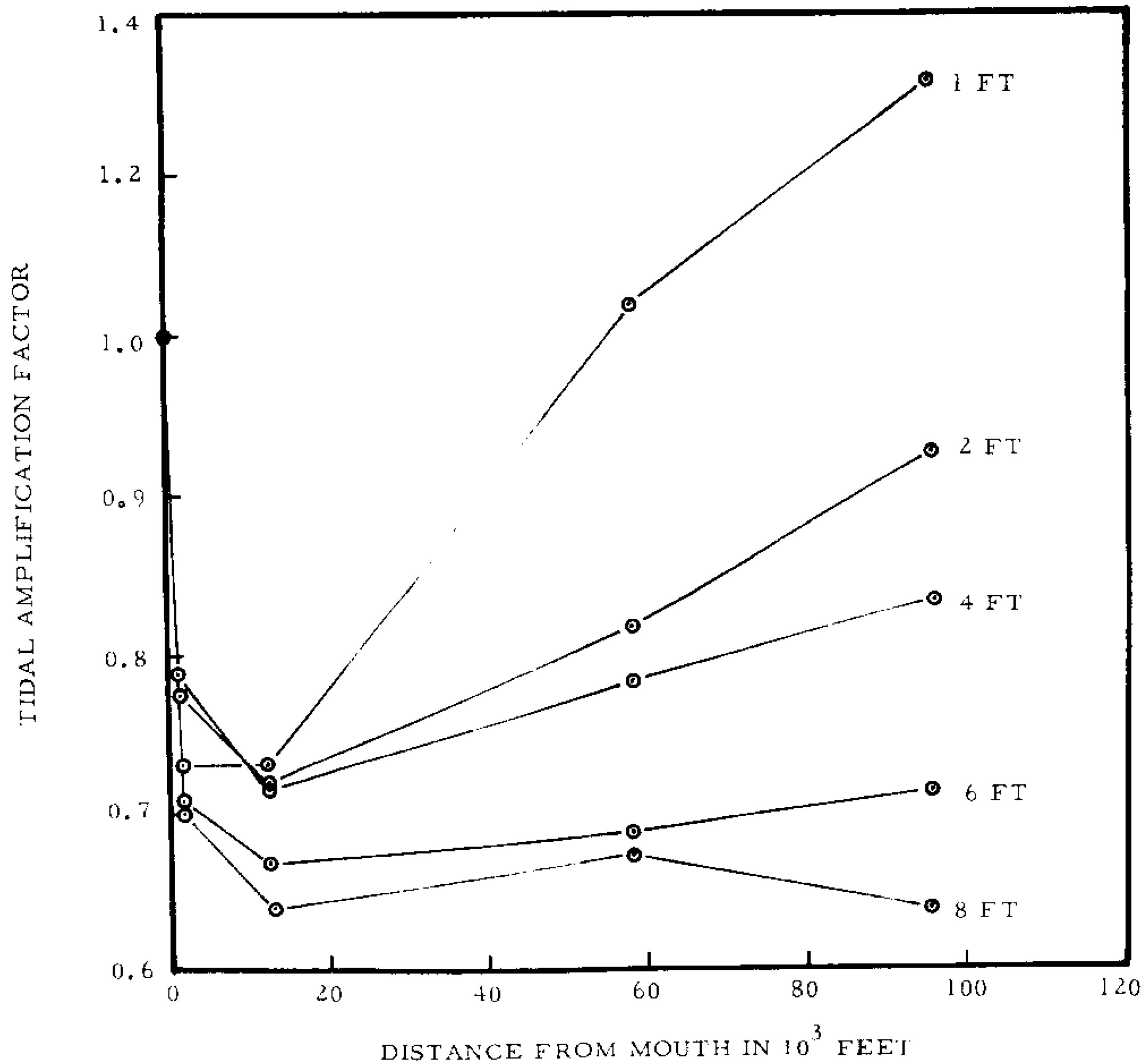

Figure 11. Tidal Amplification Factors - Siletz Estuary.

essentially no time lag of high or low tide (less than 5 minutes) and negligible tidal range reduction between the outside of the estuary and the Marine Science Center across the bay from Newport.

In the Alsea and the Siletz estuaries the tidal range variations are different than in the Yaquina. A marked choking of the tidal ranges is observed through and inside the entrance sections. Further landward, the more familiar amplifications of the tidal ranges are observed.

Tidal Currents:

The measured tidal currents have been averaged over depth and plotted versus times of observation (Figures 12, 13, and 14). Calculations of instantaneous and total discharge at each station can be made from these data. From the graphs it is relatively easy to determine times of slack water at the various stations. However, the times of maximum flood or ebb currents are more difficult to estimate due to the flat current curves. The high flood currents and comparatively low ebb currents typical of a "choked" estuary can be observed in the Alsea.

When assessing the quantitative behavior of estuaries, the phase differences between tidal elevations and tidal currents is always of interest. For the Yaquina, Alsea, and Siletz three tables have been constructed to show the times of high and low tides and slack currents for the day the current measurements were performed (Tables 3, 4, and 5). The tables also show the relative propagation time of the tidal wave towards the head of the estuaries. The time lags between times of high tide and high slack current in the Yaquina, Alsea, and Siletz estuaries have been plotted in Figure 15. It can be seen that these time lags are approximately 0-20 minutes, resulting in phase differences between tidal elevations and tidal currents of 90-100 degrees. The seaward part of the Siletz estuary appears to have a somewhat larger phase difference. A phase difference of 90 degrees between elevations and currents is usually associated with a standing wave form.

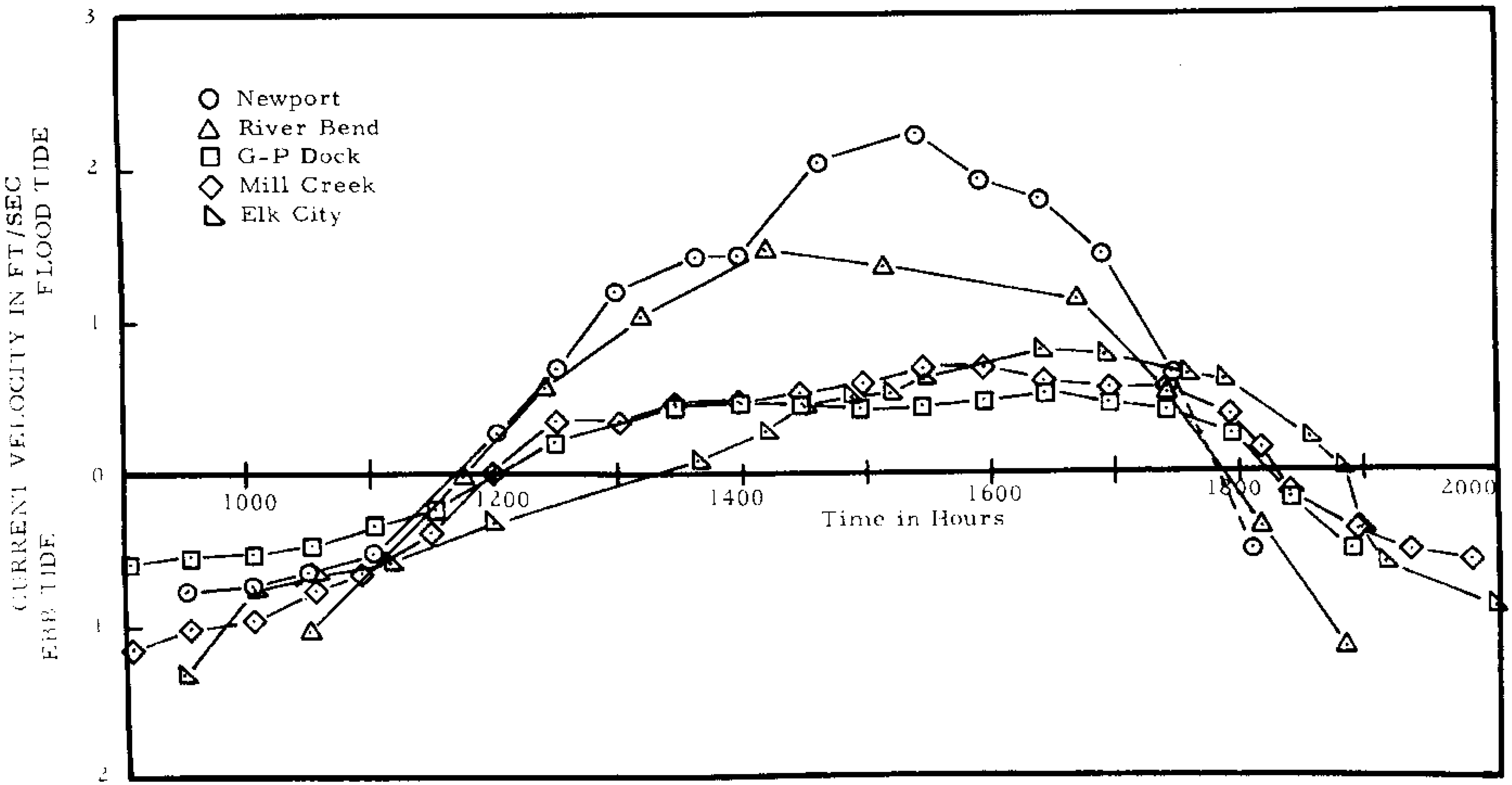

Figure 12. Tidal Currents in Yaquina Estuary July 21, 1969.

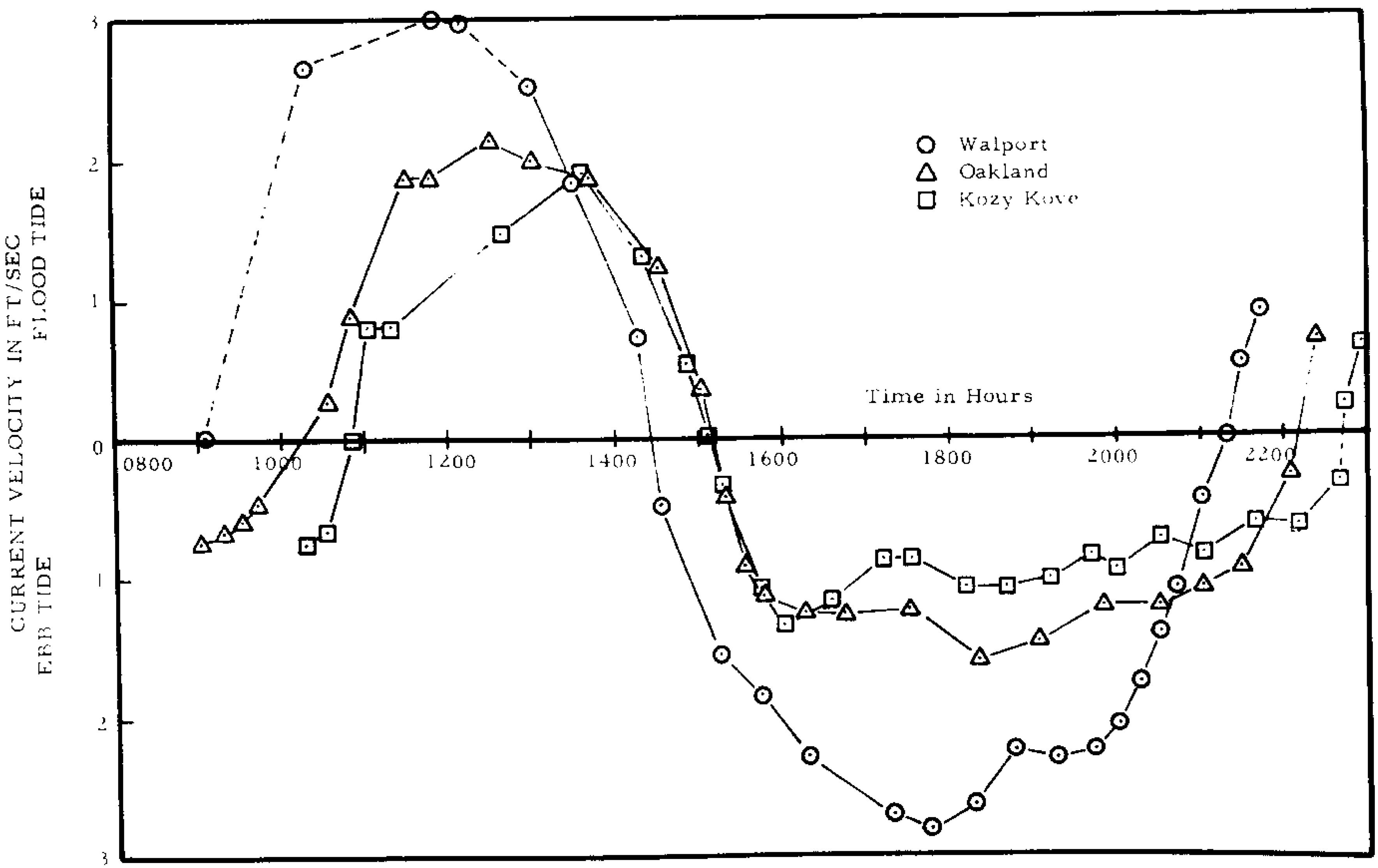

Figure 13. Tidal Currents in Alsea Estuary August 28, 1969.

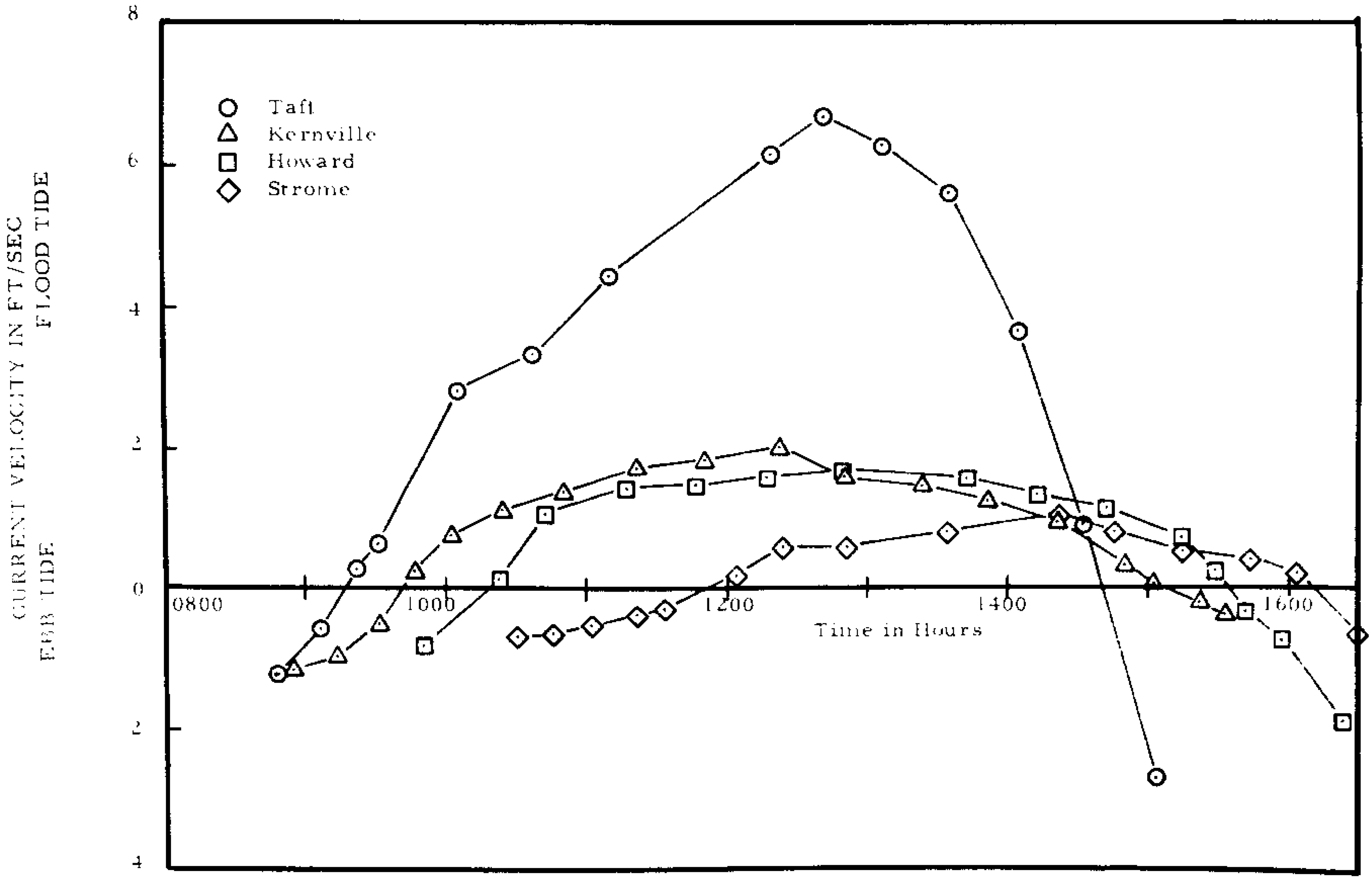

Figure 14. Tidal Currents in Siletz Estuary September 12, 1969.

Table 3

Tidal Data -- Yaquina Estuary, 21 July 1969 (OSU)

	Newport	River Bend	GP Dock	Mill Creek	Elk City
Distance from mouth in ft.	10,000	29,000	56,500	80,000	118,500
Low Tide					
--Height of	0.95	0.89	0.82	0.91	0.70
--Time of	1105	1110	1125	1150	1250
--Lag from Newport	0	+5	+20	+45	+105
High Tide					
--Height of	7.18	7.33	7.62	7.81	8.05
--Time of	1745	1755	1805	1815	1855
--Lag from Newport	0	+10	+20	+30	+70
Low Slack					
--Time of	1140	1145	1200	1205	1320
--Lag from Newport	0	+5	+20	+25	+100
Maximum flood					
--Avg. velocity in ft/sec	1.92	1.40	0.54	0.72	0.81
--Time of	1530	1505	1635	1605	1630
--Lag from Newport	0	-25	+65	+35	+60
High Slack					
--Time of	1755	1800	1820	1825	1855
--Lag from Newport	0	+5	+25	+30	+60
Phase Lags					
--Low tide to low slack	+35	+35	+35	+15	+30
--High tide to max. flood (unreliable data)	---	---	---	---	---
--High tide to high slack	+10	+5	+15	+10	0

Note: Tidal heights are expressed in feet above local mean lower low water (MLLW). Tidal times are referenced to the 24 hour clock on Pacific Daylight Time (PDT). Time lags and phase lags are given in minutes.

Table 4

Tidal Data -- Alsea Estuary, 28 August 1969 (OSU)

	Waldport	Oakland	Kozy Kove
Distance from mouth in ft.	10,000	30,000	62,000
Low Tide			
--Height of	0.16	1.67	1.54
--Time of	0835	1005	1040
--Lag from Waldport	0	+90	+125
High Tide			
--Height of	8.14	8.40	8.93
--Time of	1430	1455	1500
--Lag from Waldport	0	+25	+30
Low Tide			
--Height of	1.49	2.21	2.07
--Time of	2045	2150	2215
--Lag from Waldport	0	+65	+90
Low Slack			
--Time of	0905	1015	1050
--Lag from Waldport	0	+70	+105
Maximum Flood			
--Velocity in ft/sec	(3.1)	2.2	2.1
--Time of	1150	1235	1325
--Lag from Waldport	0	+45	+95
High Slack			
--Time of	1425	1510	1510
--Lag from Waldport	0	+45	+45
Maximum Ebb			
--Velocity in ft/sec	2.8	1.6	1.1
--Time of	1745	1820	(1840)
--Lag from Waldport	0	+35	+55
Low Slack			
--Time of	2115	2210	2245
--Lag from Waldport	0	+55	+90
Phase Lags			
--Low tide to low slack	+30	+10	+10
--High tide to max. flood	-160	-140	-95
--High tide to high slack	-5	+15	+10
--Low tide to max. ebb	-180	-210	-215
--Low tide to low slack	+30	+20	+30

Note: Tidal heights are expressed in feet above local mean lower low water (MLLW). Tidal times are referenced to the 24 hour clock on Pacific Daylight Time (PDT). Time lags and phase lags are given in minutes.

Table 5

Tidal Data -- Siletz Estuary, 12 September 1969 (OSU)

	Taft	Kernville	Howard's	Strome's
Distance from mouth in ft.	1,000	13,000	57,000	95,500
Low Tide				
--Height of	0.35	0.71	0.84	1.11
--Time of	0835	0920	1010	1110
--Lag from Taft	0	+45	+95	+155
High Tide				
--Height of	5.69	5.63	5.90	6.10
--Time of	1400	1430	1520	1605
--Lag from Taft	0	+30	+80	125
Low Slack				
--Time of	0915	0940	1020	1150
--Lag from Taft	0	+25	+65	+155
Maximum Flood				
--Avg. velocity in ft/sec	6.8	2.0	1.8	1.1
--Time of	1240	1225	1250	1420
--Lag from Taft	0	-15	+10	+40
High Slack				
--Time of	1440	1510	1535	1600
--Lag from Taft	0	+30	+55	+80
Phase Lags				
--Low tide to low slack	+40	+20	+10	+40
--High tide to max. flood	-80	-125	-150	-105
--High tide to high slack	+40	+40	+15	-5

Note: Tidal heights are expressed in feet above local mean lower low water (MLLW). Tidal times are referenced to the 24 hour clock on Pacific Daylight Time (PDT). Time lags and phase lags are given in minutes.

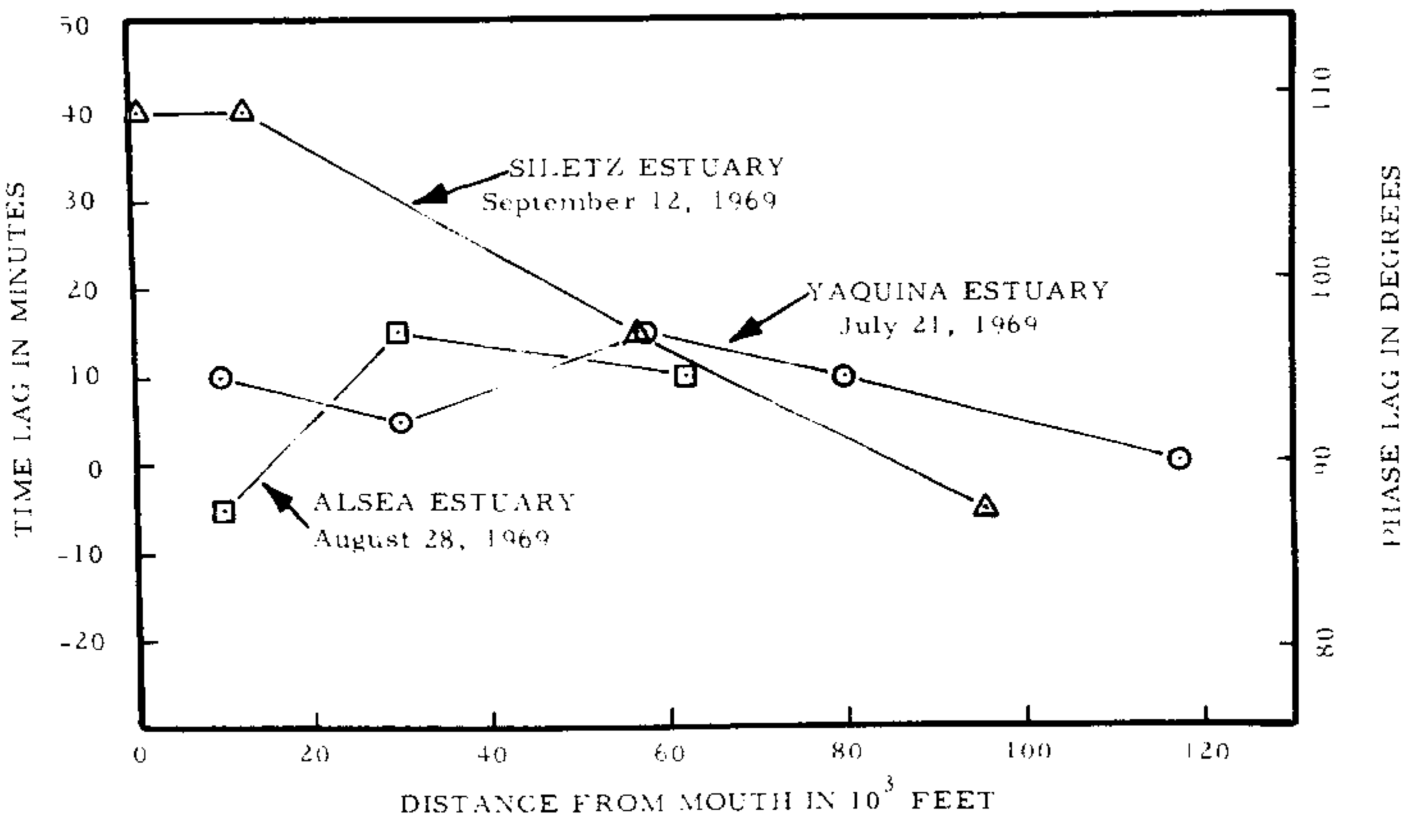

Figure 15. Time Lags From Time of High Tide Level to Time of High Slack Current.

The tidal amplification factors larger than unity also indicate the presence of resonance or standing wave conditions.

Figure 16 depicts the tidal prism of each estuary versus distance from the mouth. This is simply the volume of water which could be contained between MHHW and MLLW upstream of a particular channel cross-section. By this measure the Yaquina is clearly the largest of the three estuaries.

O'Brien's (21) relationship of total tidal prism versus entrance cross-sectional area at MTL level was extended to interior points with the result shown in Figure 17. This graph shows several interesting features. The first is that most of the interior points in all three estuaries lie to the right of and nearly parallel to O'Brien's curve. An obvious conclusion is that the wave-induced longshore currents supplies additional material, not available to the upstream sections, which reduces the entrance cross-sectional area.

Another feature of interest is the location of the entrance points of each estuary. The Yaquina point, which has no choking through the entrance (see Figure 9), is very close to O'Brien's curve. The Alsea point, with entrance choking of about 15% at an average tidal amplitude of 8 feet (see Figure 10), is displaced to the left of the curve. The Siletz point, with more entrance choking--30% for an 8-foot tide (see Figure 11), is displaced even further from O'Brien's curve. In conclusion then, O'Brien's relationship between tidal prism and cross-sectional area at MTL seems to hold for non-choked estuary entrances. Additional work should be done to determine if a similar relationship holds for interior points and what modifications could be made to account for various degrees of choking.

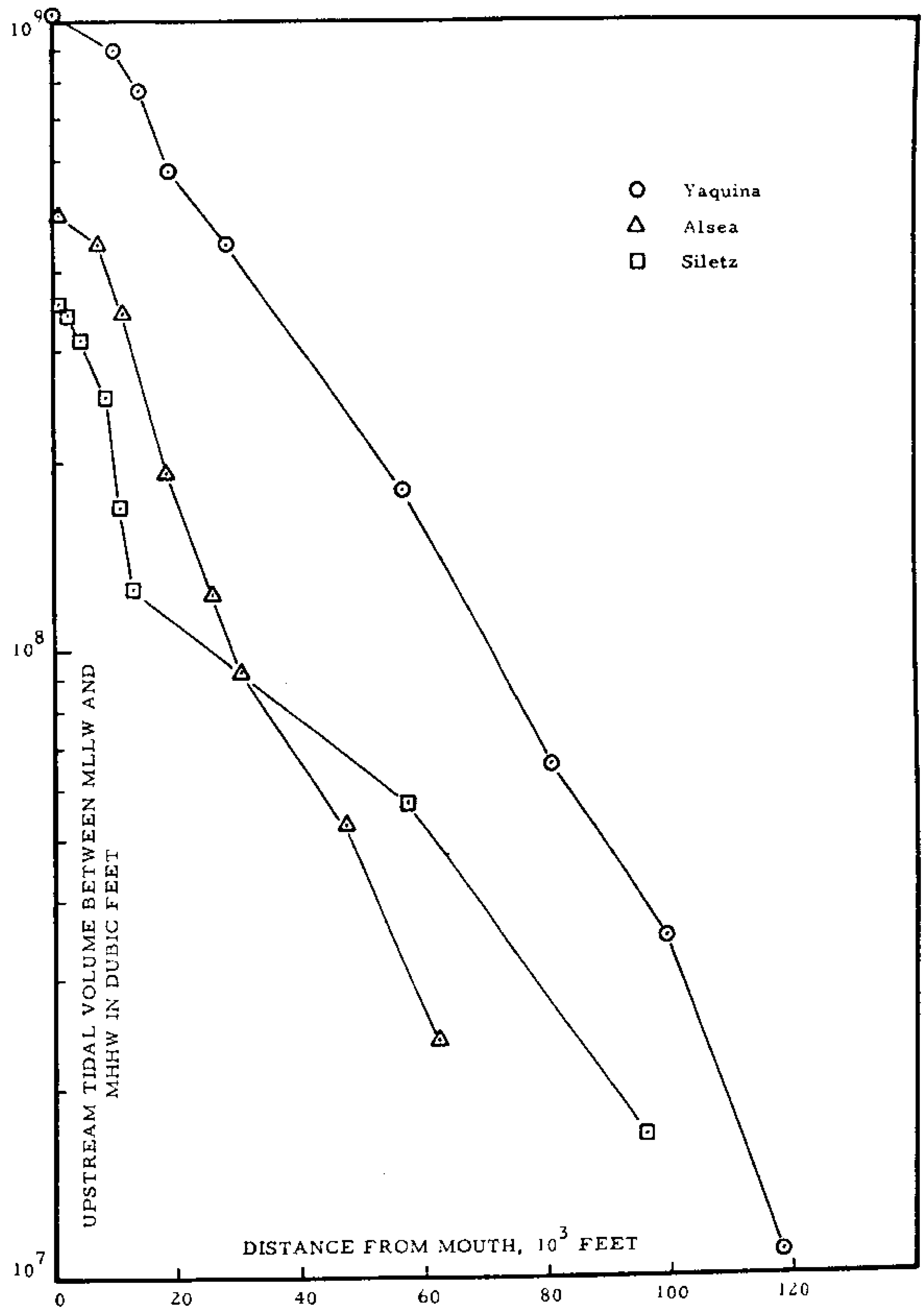

Figure 16. Tidal Volumes of Three Oregon Estuaries

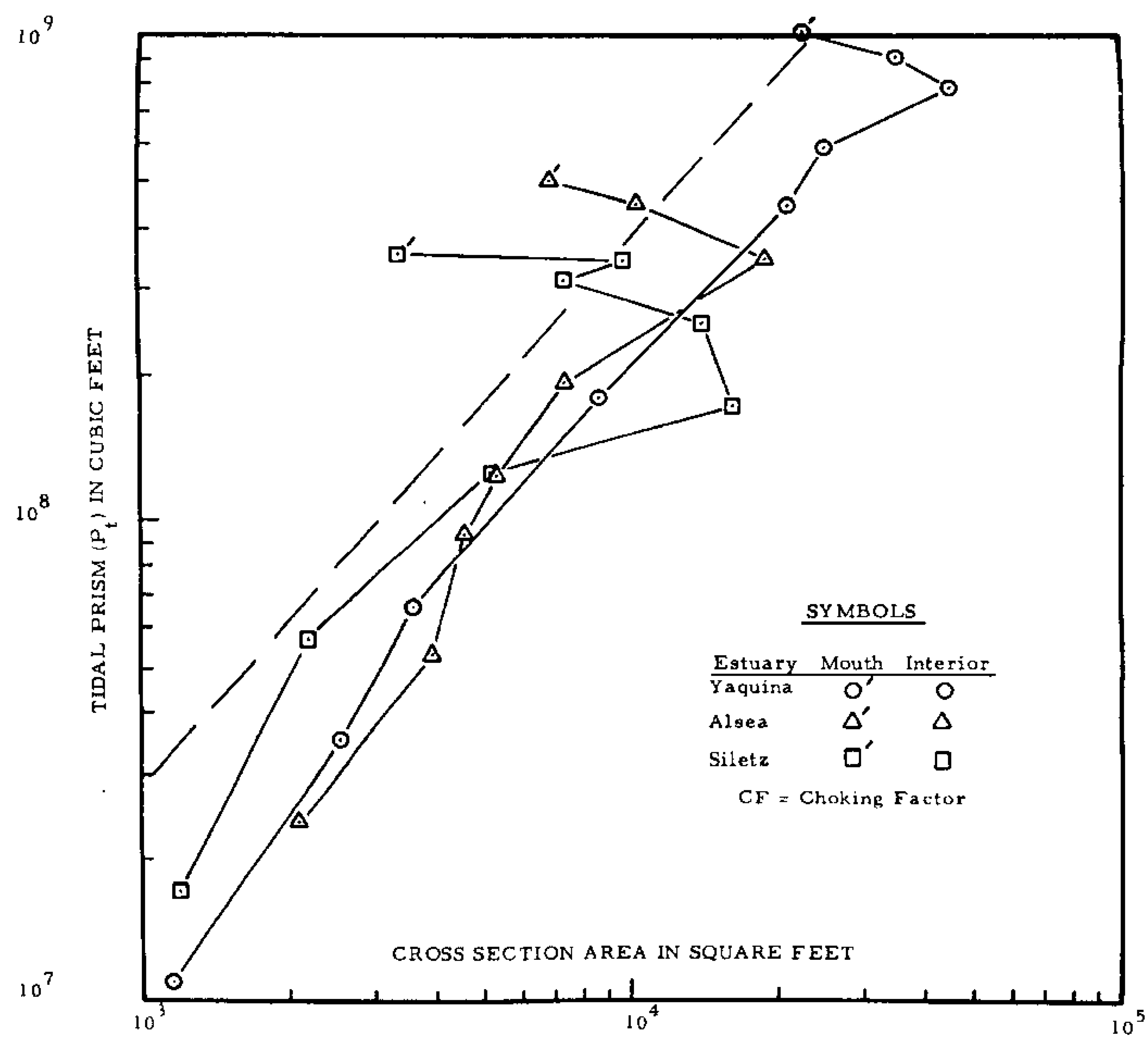

Figure 17. Tidal Prism vs. Cross Sectional Area of Three Oregon Estuaries.

Conclusions:

This report has attempted to make available the results of tidal measurements in the Yaquina, Alsea, and Siletz estuaries. Further analyses of the data will be forthcoming.

Investigations of the tidal mechanisms in these estuaries show amplifications of the entrance tidal range throughout the Yaquina estuary. In the Alsea and Siletz estuaries a marked choking of the tidal range takes place through the entrance. In the Alsea the choking continues past Waldport before amplification of the tidal range occurs.

A phase difference of 90-100 degrees is found to exist between tidal elevations and tidal currents in the three estuaries. This as well as amplification in the tidal range indicate the presence of reflected waves and/or resonance conditions.

Lack of information on hydrographic and tidal conditions in estuaries hamper efficient estuarine planning and utilization. The relatively small expense incurred by hydrographic and tidal studies make them a sound investment in our future.

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List of References

1. U. S. Coast and Geodetic Survey, Tide Tables West Coast North and South America, 1969.

2. U. S. Coast and Geodetic Survey, Tidal Current Tales Pacific Coast of North America and Asia, 1969.

3. Burt, W. V., and Marriage, L. D., "Computation of Pollution in the Yaquina River Estuary," Sewage and Industrial Wastes, Vol. 29, No. 12, December 1957.

4. Burt, W. V., and McAlister, W. B., "Recent Studies in the Hydrography of Oregon Estuaries," Research Briefs, Fish Commission of Oregon, Vol. 7, No. 1, July 1959.

5. Neal, V. T., "Tidal Currents in Yaquina Bay," Northwest Science, Vol. 40, No. 2, 1966.

6. Kulm, L. D., and Byrne, J. V., "Sediments of Yaquina Bay, Oregon," Estuaries, American Association for the Advancement of Science, 1967.

7. Kulm, L. D., and Byrne, J. V., "Sedimentary Response to Hydrography in an Oregon Estuary," Marine Geology, Vol. 4, 1966.

8. U. S. Fish and Wildlife Service, Fish and Wildlife of Yaquina Bay Oregon, November 1968.

9. Gladwell, J. S., and Tinney, E. R., Umpqua Estuary Model Study, Washington State Institute of Technology, Bull. 265, August 1962.

10. U. S. Geological Survey, Surface Water Records of Oregon, 1961-67.

11. Glenne, B. and Simensen, T., "Tidal Current Choking in the Landlocked Fjord of Nordasvatnet," Sarsia 11, March 1963.

12. Selleck, R. E., Pearson, E. A., Glenne, B., and Storrs, P. N., A Comprehensive Study of San Francisco Bay - Volume IV, University of California Berkeley, June 1966.

13. Glenne, B., "Classification System for Estuaries," Journal of the Waterways and Harbors Division, ASCE, Vol. 1, February 1967.

14. Ippen, A. T. (editor), Estuary and Coastline Hydrodynamics, McGraw Hill, New York, 1966.

15. Dorrestein, R., "Amplification of Long Waves in Bays." Engineering Progress at the University of Florida, Vol. XV, No. 12, Technical Paper No. 213, Dec. 1961.

16. Harleman, D. R. F., and Ippen, A. T., Two-Dimensional Aspects of Salinity Intrusion in Estuaries: Analysis of Salinity and Velocity Distributions, U. S. Army Corps of Engineers, Technical Bulletin No. 13, June 1967.

17. Dronkers, J. J., Tidal Computations, North-Holland Publishing Co., Amsterdam, 1964.

18. Keulegan, G. H., Tidal Flow in Entrances Water-Level Fluctuations of Basins in Communication with Seas, U. S. Army Corps of Engineers, Technical Bulletin No. 14, July 1967.

19. Keulegan, G. H., "The Mechanism of an Arrested Saline Wedge," Estuary and Coastline Hydrodynamics, (Ippen, A. T., editor), McGraw-Hill, New York, 1966, pp. 546-574.

20. Leendertse, J. J., "Two-Dimensional Tidal Computations for Pollution Studies," Paper presented at 17th Annual ASCE Hydraulics Division Specialty Conference, Logan, Utah, August 1969.

21. O'Brien, Morrough P., "Estuary Tidal Prisms Related to Entrance Areas," Civil Engineering, Vol. 1, No. 8, May 1931.

APPENDIX

Tidal Data

Tidal Data - Yaquina Estuary, July 4-25, 1969

Date	Newport		River Bend		G. P. Dock		Mill Creek		Elk City	
	Time	Elev.	Time	Elev.	Time	Elev.	Time	Elev.	Time	Elev.
7/4/69	0400	7.82	0410	8.03	0430	8.24	0435	8.52	0510	8.79
	1030	-0.98	1045	-0.98	1110	-0.99	1150	-0.55	1305	-0.52
	1730	7.85	1740	8.03	1755	8.31	1805	8.52	1835	8.79
	2315	1.90	2320	1.83	2345	1.74	*0015	1.76	*0115	1.77
7/5/69	0505	6.83	0515	6.97	0525	7.28	0535	7.56	0615	7.73
	1110	0.03	1120	-0.02	1145	-0.07	1220	0.10	1330	0.00
	1810	7.83	1820	8.04	1830	8.32	1840	8.54	1915	8.78
7/6/69	0020	1.48	0030	1.45	0045	1.31	0110	1.31	0225	1.32
	0610	5.86	0625	6.04	0635	6.34	0645	6.42	0720	6.59
	1155	1.04	1210	0.90	1225	0.85	1250	0.90	1355	0.67
	1855	7.73	1900	7.92	1910	8.08	1920	8.32	1950	8.55
7/7/69	0130	1.06	0140	0.93	0150	0.88	0220	0.97	0330	0.72
	0735	5.17	0745	5.23	0750	5.45	0755	5.67	0830	5.77
	1255	2.02	1300	2.00	1305	1.95	1325	1.84	1425	1.63
	1935	7.64	1945	7.85	1955	8.07	2000	8.22	2025	8.32
7/8/69	0235	0.55	0245	0.44	0300	0.32	0325	0.48	0435	0.25
	0900	5.00	0910	5.15	0910	5.33	0915	5.48	0940	5.63
	1350	2.74	1355	2.75	1400	2.73	1410	2.75	1505	2.52
	2030	7.61	2035	7.72	2040	7.94	2045	8.21	2110	8.30
7/9/69	0330	0.12	0345	0.05	0405	-0.03	0430	0.10	0545	-0.08
	1015	5.19	1020	5.33	1025	5.51	1030	5.78	1050	5.94
	1450	3.41	1455	3.43	1500	3.35	1505	3.36	1550	3.11
	2120	7.72	2125	7.80	2130	7.91	2135	8.19	2155	8.37
7/10/69	0430	-0.12	0440	-0.16	0505	-0.19	0535	-0.09	0650	-0.25
	1120	5.81	1130	5.92	1135	6.07	1145	6.30	1200	6.32
	1555	3.84	1605	3.79	1610	3.77	1615	3.79	1650	3.54
	2210	8.04	2215	8.13	2220	8.36	2225	8.55	2245	8.63
7/11/69	0515	-0.34	0530	-0.40	0555	-0.46	0630	-0.29	0745	-0.44
	1215	6.03	1230	6.17	1235	6.45	1245	6.63	1305	6.85
	1645	3.80	1655	3.77	1700	3.75	1710	3.68	1745	3.43
	2250	8.05	2300	8.12	2305	8.37	2315	8.54	2335	8.75
7/12/69	0600	-0.86	0610	-0.93	0640	-0.95	0715	-0.64	0835	-0.60
	1305	6.13	1315	6.31	1320	6.60	1335	6.79	1400	7.03
	1735	3.65	1740	3.62	1750	3.58	1805	3.55	1845	3.32
	2330	8.07	2345	8.19	2355	8.40	*0010	8.64	*0025	8.79
7/13/69	0640	-1.06	0650	-1.10	0715	-1.11	0805	-0.78	0920	-0.67
	1340	6.28	1350	6.44	1405	6.67	1415	6.94	1440	7.12
	1810	3.52	1820	3.46	1830	3.34	1850	3.32	1930	3.05
7/14/69	0010	8.11	0020	8.24	0035	8.44	0045	8.75	0100	8.91
	0720	-1.13	0725	-1.19	0755	-1.22	0840	-0.82	0955	-0.69
	1415	6.46	1425	6.73	1435	6.96	1455	7.14	1520	7.36
	1845	3.50	1900	3.45	1910	3.33	1930	3.26	2020	3.02
7/15/69	0050	8.04	0100	8.25	0110	8.38	0120	8.58	0140	8.73
	0750	-1.18	0800	-1.23	0825	-1.26	0915	-0.94	1020	-0.74
	1445	6.48	1450	6.75	1500	6.99	1525	7.16	1555	7.32
	1920	3.09	1935	3.08	1950	2.91	2020	2.85	2100	2.57

continued

Tidal Data - Yaquina Estuary (page 2)

Date	Newport Time	Newport Elev	River Bend Time	River Bend Elev.	G. P. Dock Time	G. P. Dock Elev.	Mill Creek Time	Mill Creek Elev.	Elk City Time	Elk City Elev.
7/16/69	0130	7.95	0135	8.15	0150	8.33	0200	8.48	0225	8.64
	0825	-1.06	0830	-1.05	0900	-1.10	0945	-0.82	1045	-0.69
	1515	6.60	1520	6.82	1530	7.07	1550	7.25	1625	7.45
	2010	2.87	2025	2.87	2035	2.76	2105	2.69	2145	2.38
7/17/69	0210	7.72	0215	7.96	0225	8.26	0240	8.42	0310	8.46
	0855	-0.93	0905	-0.95	0930	-0.45	1010	-0.73	1110	-0.64
	1545	6.69	1550	6.88	1600	7.07	1620	7.31	1655	7.53
	2055	2.62	2105	2.59	2120	2.45	2150	2.40	2225	2.19
7/18/69	0245	7.28	0255	7.46	0305	7.57	0315	7.76	0350	8.04
	0925	-0.69	0925	-0.70	0955	-0.71	1035	-0.57	1135	-0.55
	1615	6.68	1615	6.91	1630	7.16	1645	7.31	1720	7.54
	2145	2.37	2145	2.34	2205	2.24	2235	2.16	2310	1.90
7/19/69	0320	6.81	0320	6.98	0345	7.19	0355	7.37	0435	7.51
	0955	-0.16	0955	-0.20	1025	-0.24	1100	-0.10	1200	-0.18
	1640	6.88	1640	7.12	1655	7.39	1715	7.56	1750	7.86
	2230	2.03	2230	2.01	2250	1.91	2320	1.88	2355	1.69
7/20/69	0405	6.14	0405	6.34	0435	6.54	0440	6.71	0520	6.94
	1030	0.27	1030	0.12	1100	0.16	1120	0.23	1225	0.10
	1710	6.98	1710	7.22	1725	7.51	1740	7.70	1820	8.00
	2320	1.63	2320	1.61	2345	1.43	*0005	1.28	*0050	1.26
7/21/69	0500	5.48	0500	5.66	0530	5.83	0535	6.02	0615	6.21
	1105	0.95	111[illegible]	0.89	1125	0.82	1150	0.91	1250	0.70
	1745	7.18	1755	7.33	1805	7.62	1815	7.81	1855	8.05
7/22/69	0020	1.11	0020	1.05	0040	0.92	0110	0.91	0200	0.70
	0610	4.93	0610	5.06	0645	5.24	0655	5.36	0730	5.48
	1145	1.76	1145	1.75	1200	1.66	1220	1.56	1320	1.31
	1830	7.52	1830	7.66	1850	7.86	1910	8.05	1930	8.26
7/23/69	0125	0.72	0125	0.66	0145	0.54	0220	0.60	0310	0.42
	0745	4.95	0745	5.07	0810	5.23	0825	5.44	0850	5.51
	1225	2.75	1225	2.76	1240	2.72	1300	2.72	1405	2.47
	1915	8.13	1915	8.29	1940	8.42	2000	8.65	2020	8.87
7/24/69	0235	0.40	0235	0.36	0300	0.23	0340	0.38	0425	0.20
	0920	5.39	0920	5.49	0930	5.65	0950	5.84	1010	6.00
	1325	3.54	1325	3.52	1340	3.44	1410	3.41	1500	3.21
	2010	8.40	2010	8.57	2030	8.74	2055	8.87	2120	9.15
7/25/69	0340	-0.56	0340	-0.64	0410	-0.72	0500	-0.49	0555	-0.45
	1040	5.57	1040	5.71	1050	5.80	1100	6.06	1135	6.23
	1445	3.65	1445	3.62	1505	3.54	1525	3.53	1605	3.28
	2110	8.65	2110	8.77	2135	8.93	2150	9.15	2220	9.36

* These tides actually occurred early the following day.

Note: Tidal heights are expressed in feet above local mean lower low water (MLLW).
Tidal times are referenced to the 24 hour clock on Pacific Daylight Time (PDT).

Tidal Data - Alsea Estuary, August 5-30, 1969

Date	Waldport		Oakland's		Kozy Kove	
	Time	Elev.	Time	Elev.	Time	Elev.
8/5/69	1245	3.17	1305	3.28	1320	3.24
	1855	7.47	1905	7.60	1915	7.91
8/6/69	0255	0.96	0420	1.58	0445	1.49
	0915	4.78	0940	4.94	0955	5.10
	1335	3.56	1400	3.68	1405	3.68
	1950	7.18	2005	7.35	2015	7.62
8/7/69	0345	0.72	0525	1.45	0600	1.35
	1045	5.07	1055	5.23	1110	5.51
	1455	3.85	1520	3.88	1530	3.86
	2050	7.08	2110	7.22	2115	7.40
8/8/69	0445	0.39	0635	1.28	0705	1.21
	1155	5.41	1205	5.61	1220	5.84
	1605	4.00	1625	4.02	1645	4.00
	2145	7.31	2210	7.46	2215	7.68
8/9/69	0555	0.21	0740	1.29	0805	1.21
	1240	5.66	1300	5.86	1315	6.10
	1705	3.79	1720	3.80	1745	3.70
	2245	7.37	2300	7.53	2310	7.74
8/10/69	0645	0.11	0830	1.29	0850	1.17
	1320	5.90	1345	6.06	1400	6.31
	1750	3.52	1815	3.55	1840	3.42
	2335	7.59	2350	7.68	*0000	8.04
8/11/69	0720	-0.07	0910	1.32	0930	1.21
	1350	6.08	1415	6.25	1430	6.62
	1835	3.24	1905	3.29	1930	3.20
8/12/69	0020	7.78	0030	7.89	0045	8.23
	0740	-0.05	0935	1.28	1000	1.17
	1420	6.37	1440	6.56	1450	6.86
	1915	3.26	1950	3.27	2015	3.14
8/13/69	0055	8.08	0110	8.28	0130	8.52
	0810	0.24	0950	1.46	1025	1.34
	1445	6.80	1505	6.97	1515	7.34
	2000	2.94	2040	3.01	2105	2.85
8/14/69	0135	7.89	0150	8.04	0205	8.34
	0835	0.22	1010	1.44	1050	1.40
	1505	6.89	1525	7.10	1535	7.53
	2040	2.51	2125	2.70	2150	2.58
8/15/69	0215	7.62	0230	7.75	0245	8.08
	0905	0.42	1040	1.53	1110	1.47
	1525	7.23	1550	7.38	1600	7.84
	2120	2.16	2215	2.43	2240	2.33
8/16/69	0300	7.21	0315	7.33	0330	7.63
	0940	0.61	1105	1.59	1130	1.52
	1545	7.18	1610	7.40	1620	7.85
	2200	1.87	2300	2.23	2325	2.12

continued

Tidal Data - Alsea Estuary, August 5-30, 1969 (page 2)

Date	Waldport Time	Waldport Elev.	Oakland's Time	Oakland's Elev.	Kozy Kove Time	Kozy Kove Elev.
8/17/69	0350	6.86	0400	6.97	0415	7.26
	1005	1.20	1120	1.85	1145	1.80
	1610	7.68	1630	7.84	1640	8.29
	2250	1.76	2340	2.11	*0020	2.01
8/18/69	0445	6.44	0455	6.54	0510	6.82
	1030	1.96	1130	2.21	1200	2.12
	1640	7.99	1700	8.12	1705	8.55
	2340	1.95	*0035	2.20	*0120	2.10
8/19/69	1540	6.23	0550	6.33	0610	6.60
	1055	2.82	1145	2.74	1210	2.76
	1715	8.18	0725	8.29	1730	8.70
8/20/69	0035	1.42	0155	1.89	0225	1.83
	0655	5.56	0705	5.64	0715	5.90
	1135	3.31	1205	3.20	1230	3.19
	1755	8.02	1805	8.11	1810	8.45
8/21/69	0155	1.04	0310	1.62	0340	1.57
	0815	5.22	0830	5.30	0845	5.57
	1230	3.90	1245	3.82	1305	3.82
	1845	7.92	1855	8.06	1900	8.31
8/22/69	0315	0.74	0425	1.46	0455	1.36
	0945	5.55	1005	5.71	1025	5.91
	1345	4.40	1355	4.36	1425	4.34
	2000	8.25	2010	8.38	2015	8.54
8/23/69	0410	0.50	0540	1.41	0615	1.33
8/25/69	1240	6.94	1305	7.24	1320	7.59
	1800	3.20	1830	3.32	1905	3.14
	2335	9.08	2345	9.33	*0000	9.56
8/26/69	0725	-0.15	0845	1.48	0925	1.31
	1325	7.49	1345	7.79	1355	8.16
	1900	2.77	1945	2.94	2010	2.71
8/27/69	0030	9.25	0050	9.44	0100	9.67
	0805	0.19	0930	1.62	1005	1.43
	1400	8.05	1420	8.29	1425	8.75
	1955	2.13	2050	2.55	2110	2.40
8/28/69	0125	8.84	0140	9.05	0155	9.38
	0835	0.16	1005	1.67	1040	1.54
	1430	8.14	1455	8.40	1500	8.93
	2045	1.49	2150	2.21	2215	2.07
8/29/69	0220	8.21	0240	8.42	0255	8.80
	0905	0.28	1040	1.71	1110	1.56
	1510	8.32	1530	8.58	1535	9.04
	2130	1.01	2255	1.92	2320	1.80
8/30/69	0320	7.46	0340	7.64	0350	8.03
	0935	0.74	1110	1.77	1140	1.66
	1550	8.20	1605	8.50	1605	8.95

* These tides actually occurred early the following day.

Note: Tidal heights are expressed in feet above local mean lower low water (MLLW).
Tidal times are referenced to the 24 hour clock on Pacific Daylight Time (PDT).

Tidal Data - Siletz Estuary, September 3-16, 1969

Date	Taft		Kernville		Howard's		Strome's	
	Time	Elev.	Time	Elev.	Time	Elev.	Time	Elev.
9/3/69	1810	5.31	1830	5.40	1915	5.79	1935	5.94
9/4/69	0220	0.05	0305	0.25	0410	0.34	0515	0.90
	0850	3.26	0925	3.33	1005	3.64	1025	3.79
	1255	2.49	1315	2.51	1355	2.61	1430	2.57
	1910	4.96	1930	5.03	2010	5.37	2035	5.52
9/5/69	0340	-0.17	0420	0.01	0520	0.10	0630	0.87
	1030	3.36	1055	3.45	1140	3.80	1150	3.95
	1415	2.76	1435	2.83	1520	2.99	1550	2.91
	2025	4.96	2035	5.04	2115	5.40	2145	5.53
9/6/69	0445	-0.19	0530	0.04	0620	0.12	0735	0.86
	1110	3.76	1140	3.78	1230	4.11	1245	4.31
	1545	2.46	1600	2.55	1645	2.70	1705	2.61
	2140	5.06	2155	5.13	2235	5.48	2300	5.69
9/7/69	0545	-0.14	0625	0.13	0720	0.19	0830	0.88
	1145	4.21	1220	4.15	1310	4.51	1330	4.71
	1645	2.35	1700	2.42	1745	2.55	1815	2.46
	2235	5.53	2255	5.58	2345	5.91	*0005	6.10
9/8/69	0635	0.03	0715	0.32	0805	0.46	0915	0.91
	1220	4.70	1255	4.63	1340	4.92	1410	5.19
	1735	2.18	1755	2.13	1845	2.25	1925	2.21
	2320	5.86	2340	5.83	*0030	6.13	*0100	6.36
9/9/69	0720	0.03	0750	0.33	0845	0.42	0950	0.96
	1250	4.78	1325	4.71	1410	4.98	1445	5.23
	1815	1.50	1845	1.60	1945	1.69	2030	1.73
9/10/69	0000	5.70	0025	5.67	0110	5.98	0145	6.21
	0750	-0.04	0825	0.29	0920	0.39	1020	0.96
	1310	4.80	1350	4.83	1440	5.11	1515	5.29
	1905	1.00	1940	1.31	2040	1.43	2125	1.48
9/11/69	0045	5.65	0115	5.73	0200	6.00	0230	6.18
	0815	0.13	0850	0.53	0945	0.68	1045	1.08
	1335	5.20	1410	5.26	1500	5.55	1540	5.76
	1950	0.90	2030	1.24	2130	1.40	2215	1.48
9/12/69	0130	5.73	0200	5.79	0240	6.07	0315	6.27
	0835	0.35	0920	0.71	1010	0.84	1110	1.11
	1400	5.69	1430	5.63	1520	5.90	1605	6.10
	2040	0.61	2120	0.95	2220	1.09	2310	1.28
9/13/69	0205	5.55	0240	5.48	0325	5.76	0400	5.98
	0855	0.41	0940	0.76	1030	0.90	1125	1.18
	1430	5.86	1455	5.83	1545	6.09	1625	6.28
	2130	0.46	2215	0.77	2310	0.91	*0000	1.18
9/14/69	0245	5.20	0330	5.15	0410	5.42	0445	5.64
	0910	0.62	1000	0.94	1050	1.08	1145	1.28
	1500	6.07	1525	6.14	1610	6.39	1645	6.63
	2225	0.37	2310	0.72	0000	0.82	*0050	1.14

continued

Tidal Data - Siletz Estuary, September 3-16, 1969 (page 2)

	Taft		Kernville		Howard's		Strome's	
Date	Time	Elev.	Time	Elev.	Time	Elev.	Time	Elev.
9/15/69	0335	4.89	0415	4.85	0505	5.11	0535	5.33
	0935	0.87	1020	1.10	1105	1.20	1200	1.34
	1530	6.20	1600	6.20	1640	6.49	1715	6.74
	2325	0.22	*0000	0.54	*0050	0.64	*0150	1.06
9/16/69	0430	4.47	0510	4.45	0600	4.72	0635	4.94

* These tides actually occurred early the following day.

Note: Tidal heights are expressed in feet above local mean lower low water (MLLW).
Tidal times are referenced to the 24 hour clock on Pacific Daylight Time (PDT).

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ENGINEERING EXPERIMENT STATION
CORVALLIS, OREGON

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Oregon State University

CORVALLIS

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Undergraduate Liberal Arts and Sciences

- School of Humanities and Social Sciences (B.A., B.S. degrees)
- School of Science (B.A., B.S. degrees)

Undergraduate Professional Schools

- School of Agriculture (B.S., B.Agr. degrees)
- School of Business and Technology (B.A., B.S. degrees)
- School of Education (B.A., B.S. degrees)
- School of Engineering (B.A., B.S. degrees)
- School of Forestry (B.S., B.F. degrees)
- School of Home Economics (B.A., B.S. degrees)
- School of Pharmacy (B.A., B.S. degrees)

Graduate School Fields of Study

- Agriculture (M.S., M.Agr., Ph.D. degrees)
- Biological and Physical Sciences (M.A., M.S., Ph.D. degrees)
- Business and Technology (M.B.A., M.S. degrees)
- Education (M.A., M.S., Ed.M., Ed.D., Ph.D. degrees)
- Engineering (M.A., M.S., M.Bioeng., M.Eng., M.Mat.Sc., A.E., Ch.E., C.E., E.E., I.E., M.E., Met.E., Min.E., Ph.D. degrees)
- Forestry (M.S., M.F., Ph.D., degrees)
- Home Economics (M.A., M.S., M.H.Ec., Ph.D. degrees)
- Pharmacy (M.A., M.S., M.Pharm., Ph.D. degrees)

Summer Term (four, eight, and eleven week sessions)

Short Courses, Institutes, Workshops

RESEARCH AND EXPERIMENTATION

(Date indicates year established)

General Research (1932)

Agricultural Experiment Station (1888)

Branch stations at Astoria, Union, Klamath Falls, Ontario, Hood River, Aurora, Pendleton, Moro, Medford, Burns, Hermiston, and Redmond.

Engineering Experiment Station (1927)

Forest Research Laboratory (1941)

Sea-Grant Institutional Program (1968)

RESEARCH CENTERS

- Air Resources Center (1968)
- Computer Center (1965)
- Environmental Health Sciences Center (1967)
- Marine Science Center at Newport (1965)
- Radiation Center (1964)

RESEARCH INSTITUTES

- Genetics Institute (1963)
- Nuclear Science and Engineering Institute (1966)
- Nutrition Research Institute (1964)
- Science Research Institute (1952)
- Transportation Research Institute (1960)
- Water Resources Research Institute (1960)

EXTENSION

Federal Cooperative Extension (Agriculture and Home Economics)

Division of Continuing Education, State System of Higher Education