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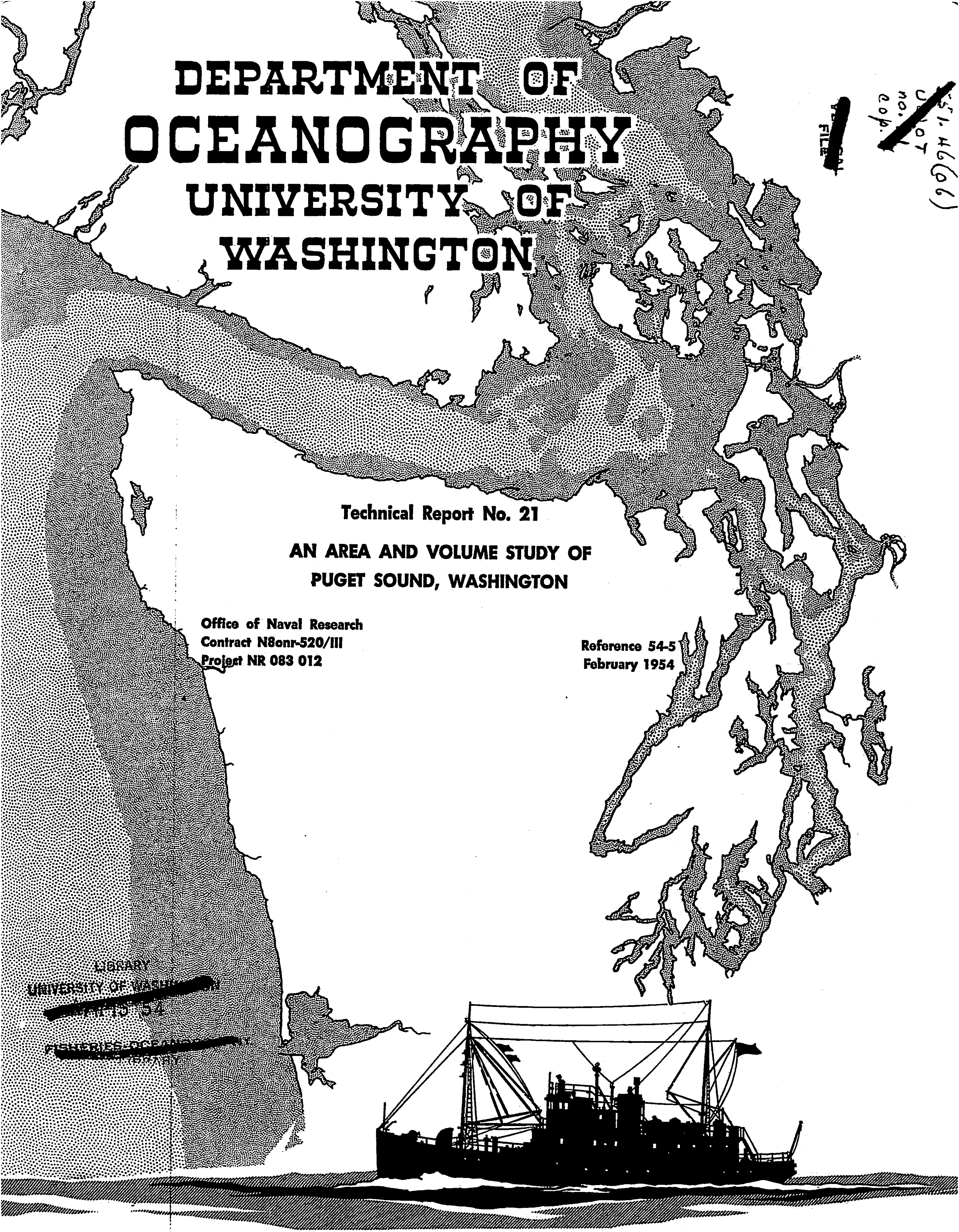

Technical Report No. 21

AN AREA AND VOLUME STUDY OF PUGET SOUND, WASHINGTON

Office of Naval Research
Contract N8onr-520/III
Project NR 083 012

Reference 54-5
February 1954

SEATTLE 5, WASHINGTON

UNIVERSITY OF WASHINGTON DEPARTMENT OF OCEANOGRAPHY
(Formerly Oceanographic Laboratories)
Seattle, Washington

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by

Peter M. McLellan

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Richard H. Fleming
Executive Officer

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INTRODUCTION

Puget Sound is one of the deepest salt-water basins in the United States. Depths of 600 to 800 feet prevail in the northern portion, while south of the Tacoma Narrows, near the headwaters, 300 feet is more typical. Deep holes occur in either area which may be illustrated by the depth of 930 feet off Point Jefferson in the northern portion and the 546 foot hole near McNeil Island in the southern portion. The underwater topography is much like that of the adjacent land areas.

The volume of water within 10-fathom increments of depth and the area within small arbitrarily set boundaries of Puget Sound have been determined. Presented here in concise tables are numerical data which may be of use to research workers in the fields of marine engineering, marine biology, and the physical and chemical fields of oceanography. Some of the more significant final values of Puget Sound measurement are as follows:

Total length of shore line . .	1,157	nautical miles
Area at mean high water. . . .	767.6	square nautical miles
Volume at mean high water. . .	26.5	cubic nautical miles
Mean tidal volume.	1.27	cubic nautical miles

BOUNDARIES

For the purpose of this report Puget Sound is here defined as that body of water extending south from:

(1) Middle Point, on the west, and Point Partridge, on the east

(2) Deception Pass

(3) Swinomish Slough

The three entrances named above constitute the water boundaries of Puget Sound. All numerical data pertaining to area, volume, and perimeter lie within these limits.

GEOGRAPHIC DIVISIONS

To facilitate analyzing and studying the relationships of area and volume in Puget Sound the over-all area has been divided into five geographic divisions. These divisions are delimited by natural physical boundaries in Puget Sound with the exception that the main basin has been divided into halves for convenience in handling the numerical data. Figure 1 outlines the location of these geographic divisions in Puget Sound.

The main basin, divisions A and B, extends south from a 240-foot sill at the intersection of Admiralty Inlet with the Strait of Juan de Fuca to a 180-foot sill at the Tacoma Narrows. Division C, south of the Tacoma Narrows, consists of a primary basin with many branching channels and inlets. Hood Canal, D, separated from Admiralty Inlet by a 180-foot sill, extends to the southwest for about 50 miles. The fifth division, E, extends north from the intersection of Possession Sound with the main body of Puget Sound to Deception Pass and the Swinomish Slough.

Subdivisions

Within the five main geographic divisions of Puget Sound, 18 subdivisions have been made. It is believed that combinations of the various subdivisions will constitute practical boundaries for most investigators who may wish to make use of these data. Individual summations have been made for the area and volume data for each subdivision. The subdivisions are shown in Figure 1 and defined in Table 1.

Unit-Areas

The 18 subdivisions were further divided into 57 smaller divisions, or unit-areas. These were selected as a basis for determining the area and volume. Their selection was governed principally by the limitations of the planimeter and the scale of charts used for determinations. However, whenever possible, consideration was given to obtaining a shape useful for geographic interpretation rather than maintaining an ideal shape for measuring. The basic unit-area boundaries from which all measurements and calculations have been made are shown in Figure 2 and their boundaries enumerated in Table 3. The complete data are given in Tables 5 and 6 for all unit-area determinations. Partial summations have been made for each subdivision and division. A cumulative total is presented at the end of the area and volume tables.

PROCEDURE

The area and volume of Puget Sound was determined using U. S. Coast and Geodetic Survey charts as enumerated in Table 2. The mean high water, mean lower low water, and 3-fathom lines on the charts were utilized. Additional contour lines were drawn at 10-fathom intervals to the bottom.

AREA DETERMINATION

The area of Puget Sound was determined by planimetering each of the 57 unit-areas as outlined in Figure 2 with a compensating polar planimeter (Keuffel and Esser No. 4236). The areas covered by mean high water (MHW), mean lower low water (MLLW), 3-fathom, 10-fathom, and thereafter every 10-fathom contour interval to the bottom were planimetered. The areas have been expressed in square nautical miles. Complete area data are given in Table 5.

VOLUME DETERMINATION

The total volume and volume between given levels were determined for the 57 unit-areas by plotting graphs with square nautical miles versus depth of water as coordinates for each unit-area. The MHW-MLLW vertical distance for each unit-area was determined from the tide table. The area within the curve of the graph was then determined by use of the planimeter for every 10-fathom increment, as well as between MHW and MLLW. With this procedure it was then possible to draw graphs showing accumulated volume versus depth for any unit-area or for any larger geographic area desired. Complete volume data are given in Table 6.

PERIMETER DETERMINATION

An analysis was made of the length of the shore line of Puget Sound to accompany the area and volume data. A map measurer (Swiss-made Minerva) was run along the entire MHW line of the contoured charts (Table 2). Perimeter values are given in Table 4 for each of the five geographic divisions. Island perimeters are included as shown.

EVALUATION AND USE OF THE DATA

Tables 5 and 6 show area and volume in square and cubic nautical miles, respectively. Graphs may be drawn from the area analysis tables for each unit-area or any given combination of areas to show depth-profile, as shown in Figures 3 and 4. Figure 4, upon integration, will yield the volume of water involved in the change of a tide of any given range for the area south of the Tacoma Narrows. The scale of exaggeration may be selected for graphical convenience as the problem requires. From these graphs other volume relationships may be suggested. Integration may be performed by any graphical method desired. From these tables one also may draw cumulative volume graphs for any given unit-area or combination of unit-areas.

An accumulative volume graph for the entire Sound is shown in Figure 5.

ACCURACY AND SIGNIFICANT FIGURES

Among the factors which limit the accuracy of area measurements are the scale of the charts used, the contouring of the depth

configuration, the human element in using the planimeter (both on the chart contours and on the graphs drawn for each unit determination of volume), and the actual handling of the final data in various stages of completion to the final printed table.

Evaluation of Errors

There are two principal types of errors present when using a planimeter, the personal errors of the operator and the instrumental limitations of the instrument. Practice will enable an operator to reduce errors in using the planimeter below that introduced by the scale of the charts and contouring. Planimeter measurements were found to be reproducible to 1 part in 1,000. For this reason no more than four significant figures have been considered reliable for area determinations and no more than three significant figures for volume determinations. Volume was determined as a function of area.

A significant error in charts is their tendency to shrink and stretch, depending upon humidity and the amount of use the charts have had. However, the limits of accuracy of the U. S. Coast and Geodetic Survey charts are considered to be standard. The mean high water line is delineated by a topographer during his traverse along the shore line. Since this is a tidal plane, the topographer must estimate this position--not difficult on abrupt shores but requiring knowledge of stage of tide on low gradient beaches and tide flats. Topographic requirements on shoreline traverse call for closures not to exceed 4 meters in a mile between control stations for sheet scales 1/20,000 or larger and 8 meters

to a mile for sheet scales smaller than 1/20,000. The accuracy of any point on the mean high water line (charted shore line) depends upon spacing of control in the area, shoreline topography, the residual evidence on the shore of this line, and the skill of the topographer. Five meters may be an average for the error from the true position on Puget Sound. Locally, minor errors may arise from changes in shore line since last surveyed, such as from slumping.

Instructions on basic hydrographic surveys call for the hydrographer, where possible, to delineate the zero depth curve (mean lower low water). This requires sounding at high water with a tide sufficient to provide for water under the keel of the sounding boat, and sea conditions suitable for sounding in shoal depths. This has not been practicable in all areas of Puget Sound because of rocks and reefs, or other navigational hazards.

The limiting scale of charts used in this study was 1:80,000. Regardless of chart scale, the mean high water area will be the most accurate figure obtainable. The accuracy of contours at depth will vary considerably due to the variation in detail in the bathymetric surveys. However, depth contouring in Puget Sound should be reasonably accurate because of the continuous steep slopes of the basin.

TABLE 1

NOMENCLATURE FOR THE DIVISIONS AND SUBDIVISIONS OF PUGET SOUND

A. Admiralty Inlet

1. Port Townsend
2. Kilisut Harbor
3. Admiralty Inlet (main body)

B. Puget Sound (central part)

1. Port Orchard area
2. Elliott Bay
3. Colvos Passage
4. Quartermaster Harbor
5. Commencement Bay
6. Puget Sound (main body)

C. The Narrows and south

1. The Narrows and Nisqually Reach
2. Carr Inlet
3. Case Inlet
4. Various small inlets

D. Hood Canal

1. Entrance
2. Hood Canal (main body)

E. Possession Sound and north

1. Possession Sound and Saratoga Passage
2. Port Susan
3. Skagit Bay

See Figure 1 for boundaries.

TABLE 2

UNIT GEOGRAPHIC AREAS AND CHARTS

UNIT-AREA	CHART NUMBER	CHART DATE
1-18, 54-57	6460	7/26/37
3	6462	6/9/46
19-24, 28	6446	7/26/48
25-27	6445	5/31/48
29-30	6449	6/21/48
31-42, 44-53	6450	Unknown--but same period as 6460
43	6380	7/26/48

See Figure 2 for boundaries.

TABLE 3

UNIT GEOGRAPHIC AREA DESIGNATIONS

NUMBER	NAME	BOUNDARY
1	Eld Inlet	Tang. Cooper Pt. 301.5° True
2	Totten and Skookum Inlets	Bisect Arcadia Inlet 176.5° T
3	Olympia Harbor and Budd Inlet	Tang. Cooper Pt. 20.5° T
4	Hammersley Inlet and Oakland Bay	Tang. Arcadia Pt. 12.5° T
5	Henderson Inlet	Tang. Johnson Pt. 235.0° T
6	Squaxon, Peale, and Pickering Passages	Tang. Dougall Pt. 312.5° T Tang. Arcadia Pt. 12.5° T Bisect Arcadia Inlet 176.5° T Tang. Cooper Pt. 301.5° T Tang. Cooper Pt. 20.5° T Tang. Brisco Pt. 116.5° T
7	Dana Passage and Case Inlet	Tang. Brisco Pt. 116.5° T Tang. Johnson Pt. 72.5° T Tang. Johnson Pt. 235.0° T Tang. Dougall Pt. 312.5° T
8	Drayton, Pitt, Balch, Cormorant, Hale Passages and Nisqually Reach	Tang. Johnson Pt. 72.5° T Pitt Passage, Pt. in center on west side from overhead cable 100.0° T Tang. Hyde Pt. 56.0° T Green Pt. Spit 108.5° T Tang. Fosdick Pt. 102.5° T
9	Carr Inlet	Tang. Hyde Pt. 56.0° T Pitt Passage, Pt. in center on west side from overhead cable 100.0° T Green Pt. Spit 108.5° T

TABLE 3 (continued)

NUMBER	NAME	BOUNDARY
10	Tacoma Narrows south of cross-section A	Tang. Fosdick Pt. 102.5° T 304° T from lat. 47°16.1', long. 122°32.5'
11	Tacoma Narrows north of cross-section A and Gig Harbor	304° T from lat. 47°16.1', long. 122°32.5' Tang. Pt. Defiance 290.0° T
12	Dalco Passage	Tang. Pt. Defiance 290.0° T Dalco Pt. 259.0° T Tang. Neill Pt. 64.5° T Dash Pt. 144.0° T lat. 47°19.0'
13	Commencement Bay	lat. 47°19.0'
14	Quartermaster Harbor	Tang. Neill Pt. 64.5° T
15	Colvos Passage	Dalco Pt. 259.0° T Tang. Vashon Pt. 264.5° T
16	East Passage (south half)	Dash Pt. 144.0° T Pully Pt. 27.5° T
17	East Passage (north half)	Pully Pt. 227.5° T Brace Pt. 246.5° T
18	Blake Island and vicinity	Brace Pt. 246.5° T Tang. Vashon Pt. 264.5° T Tang. Orchard Pt. 34.0° T Alki Pt. 281.0° T
19	Rich Passage	Tang. Orchard Pt. 34.0° T Tang. Waterman Pt. 14.5° T
20	Sinclair Inlet	Retsil Pt. 345.0° T
21	Dyes Inlet	Tang. Rocky Pt. 89.0° T
22	Port Washington Narrows	Tang. Rocky Pt. 89.0° T Tang. Pt. Herron 235.5° T

TABLE 3 (continued)

NUMBER	NAME	BOUNDARY
23	Port Orchard (south third)	Retsil Pt. 345.0° T Tang. Waterman Pt. 14.0° T Pt. Herron 236.0° T lat. 47°36.0'
24	Port Orchard (center third)	lat. 47°36.0' Battle Pt. 270.0° T
25	Port Orchard (north third)	lat. 47°42.0' lat. 47°31'48" (Battle Pt. 270.0° T)
26	Liberty Bay	lat. 47°42.0'
27	Agate Passage	lat. 47°42.0' Agate Pt. 320.5° T
28	Puget Sound (connection between charts 6460 - 6450)	Tang. Duwamish Head 271.5° T Alki Pt. 281.0° T
29	Elliott Bay	Duwamish Head 3.5° T Duwamish River, 96.0° T from lat. 47°33'47", long. 122°20'49"
30	Duwamish River	Duwamish River, 96.0° T from lat. 47°33'47", long. 122°20'49" Duwamish River, long. 122°18.0'
31	Winslow-Magnolia Bluff area	Duwamish Head 271.5° T Duwamish Head 3.5° T West Pt. 269.5° T
32	Port Madison-Meadow Point area	West Pt. 269.5° T Agate Pt. 321.5° T Pt. Jefferson 91.0° T Government Locks (seaward side)
33	Kingston-Point Wells area	Pt. Jefferson 91.0° T lat. 47°50.0'

TABLE 3 (continued)

NUMBER	NAME	BOUNDARY
34	Polot Point-Meadowdale area	lat. 47°50.0' Tang. Possession Pt. 124.0° T Tang. Point No Pt. 88.0° T
35	Possession Sound (south half)	Tang. Possession Pt. 124.0° T lat. 48°00.0'
36	Possession Sound (north half)	lat. 48°00.0' Snohomish River, lat. 47°56.9' Camano Head 43.5° T Camano Head 210.5° T
37	Port Susan	Camano Head 43.5° T West Pass, lat. 48°14.3' Stillaguamish River, long. 122°20.7'
38	Saratoga Passage (south half)	Camano Head 210.5° T Tang. Rocky Pt. 13.5° T
39	Holmes Harbor	Rocky Pt. 309.0° T
40	Saratoga Passage (north half)	Tang. Rocky Pt. 13.5° T Rocky Pt. 309.0° T Tang. Watsak Pt. (Snatelum Pt.) 44.0° T
41	Penn Cove and Crescent Harbor	Tang. Watsak Pt. (Snatelum Pt.) 44.0° T
42	Skagit Bay (south half)	Demock Pt. 319.0° T lat. 48°20.0' West Passage, lat. 48°14.3'
43	Skagit Bay (north half)	lat. 48°20.0' Swinomish Slough, lat. 48°26.3' Deception Pass Bridge
44	Point No Point-Double Bluff area	Tang. Point No Pt. 88.0° T Tang. Foulweather Bluff 59.0° T

TABLE 3 (continued)

NUMBER	NAME	BOUNDARY
45	Austin-Olele Point area	Tang. Foulweather Bluff 59.0° T Tang. Foulweather Bluff 253.0°T Bush Pt. 251.5° T Pass to Kilisut Harbor, lat. 48°01.2' North end of passage to Port Townsend, from west side 57.0° T
46	Admiralty Head-Bush Point area	Bush Pt. 251.5° T Tang. Admiralty Head 259.0° T Hudson Pt. 110.0° T
47	Kilisut Harbor	Pass to Kilisut Harbor, lat. 48°01.2' North-west spit 77.0° T
48	Port Townsend	Hudson Pt. 110.0° T North-west spit 77.0° T North end of pass to Oak Bay 237.5° T
49	Partridge Point-Point Wilson area	Tang. Partridge Pt. 206.5° T Tang. Admiralty Head 259.0° T
50	Hood Canal-Hood Head area	Foulweather Bluff 253.0° T lat. 47°50.0'
51	Hood Canal-Hazel Pt.-South Pt. area	lat. 47°50.0' lat. 47°41.6' (Hazel Pt. 90.0° T)
52	Hood Canal-Dabob Bay	Tskutsko Pt. 267.0° T
53	Hood Canal-Tekiu Pt.-Oak Head area	Tskutsko Pt. 267.0° T Tekiu Pt. 304.0° T
54	Hood Canal-Tekiu Pt.-Capstan Rock area	Tekiu Pt. 304.0° T lat. 47°30.0'
55	Hood Canal-Capstan Rock-Ayres Pt. area	lat. 47°30.0' lat. 47°22.6' (or Ayres Pt. 270.0° T

TABLE 3 (continued)

NUMBER	NAME	BOUNDARY
56	Hood Canal-The Great Bend	Ayres Pt. 270.0° T long. 123°00.0'
57	Hood Canal-Lynch Cove	long. 123°00.0'

See Figure 2 for boundaries.

TABLE 4

PERIMETER OF PUGET SOUND
(In Nautical Miles)

GEOGRAPHIC AREA DESIGNATION	SHORE PERIMETER		TOTAL
	Mainland	Island	
A	96	0	96
B	243	45	288
C	253	82	335
D	185	0	185
E	242	11	253
Totals	1,019	138	1,157

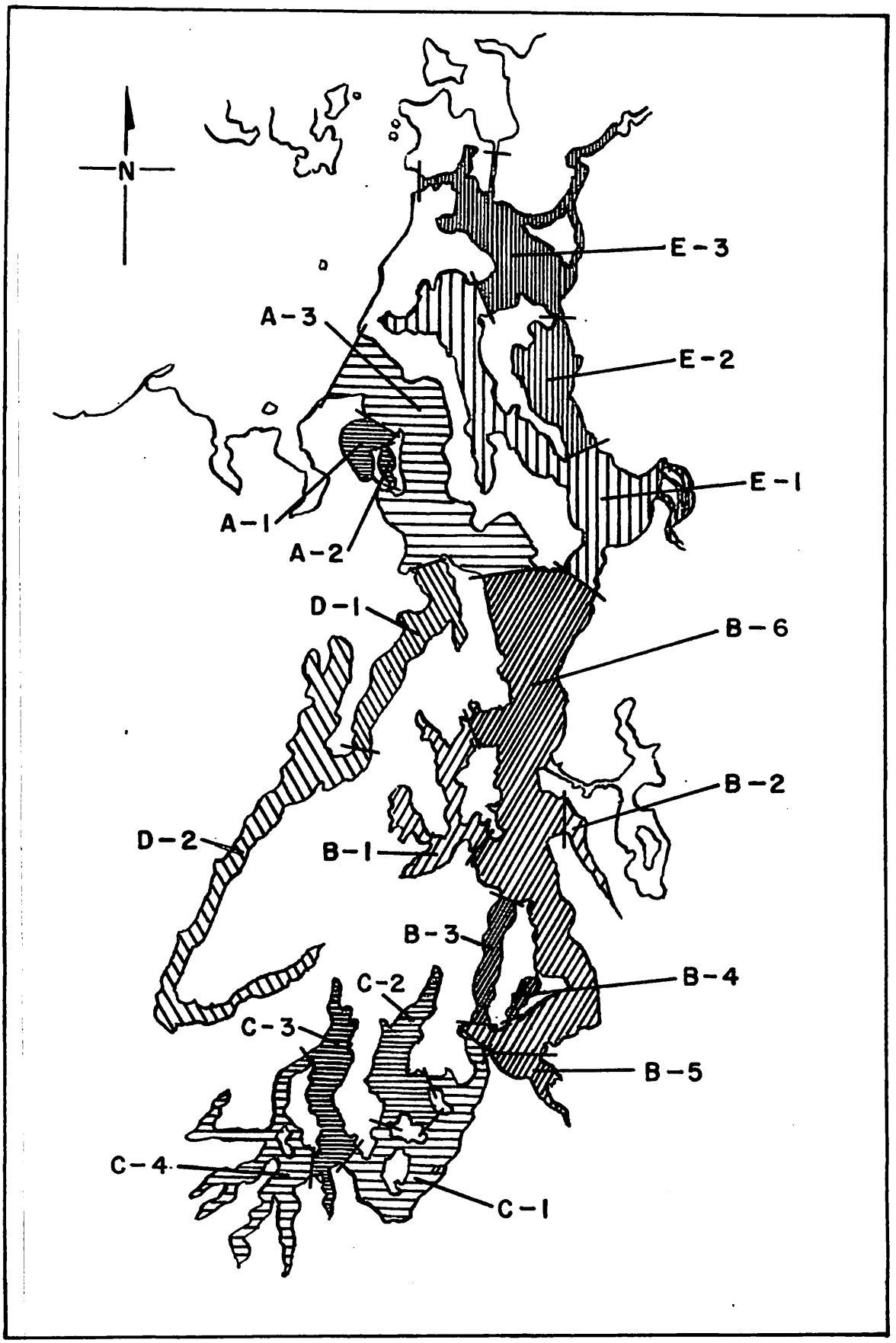

FIGURE 1. Puget Sound, divisions and subdivisions. See Table 1 for nomenclature.

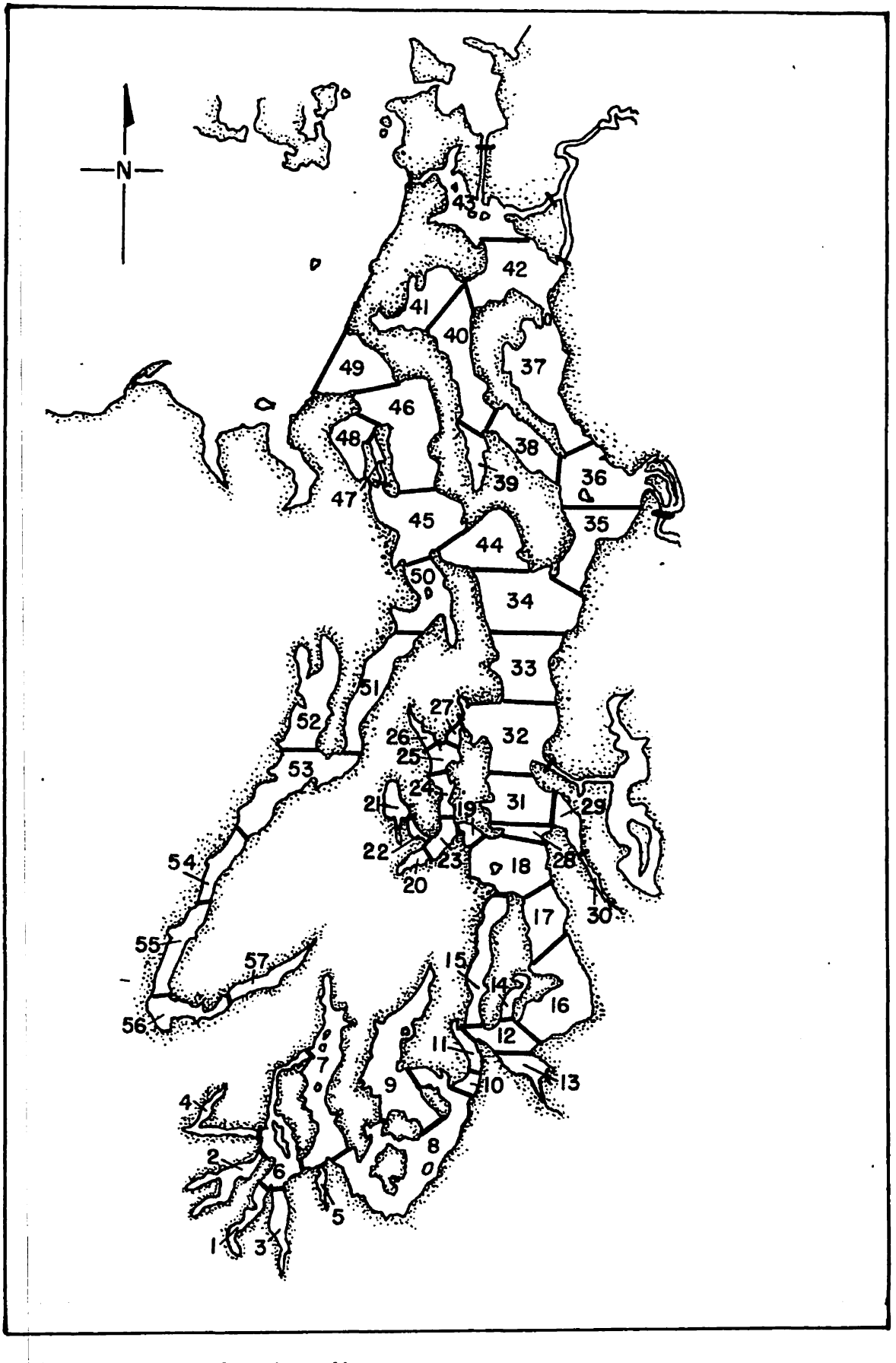

FIGURE 2. Puget Sound, unit-areas.
See Table 3 for nomenclature.

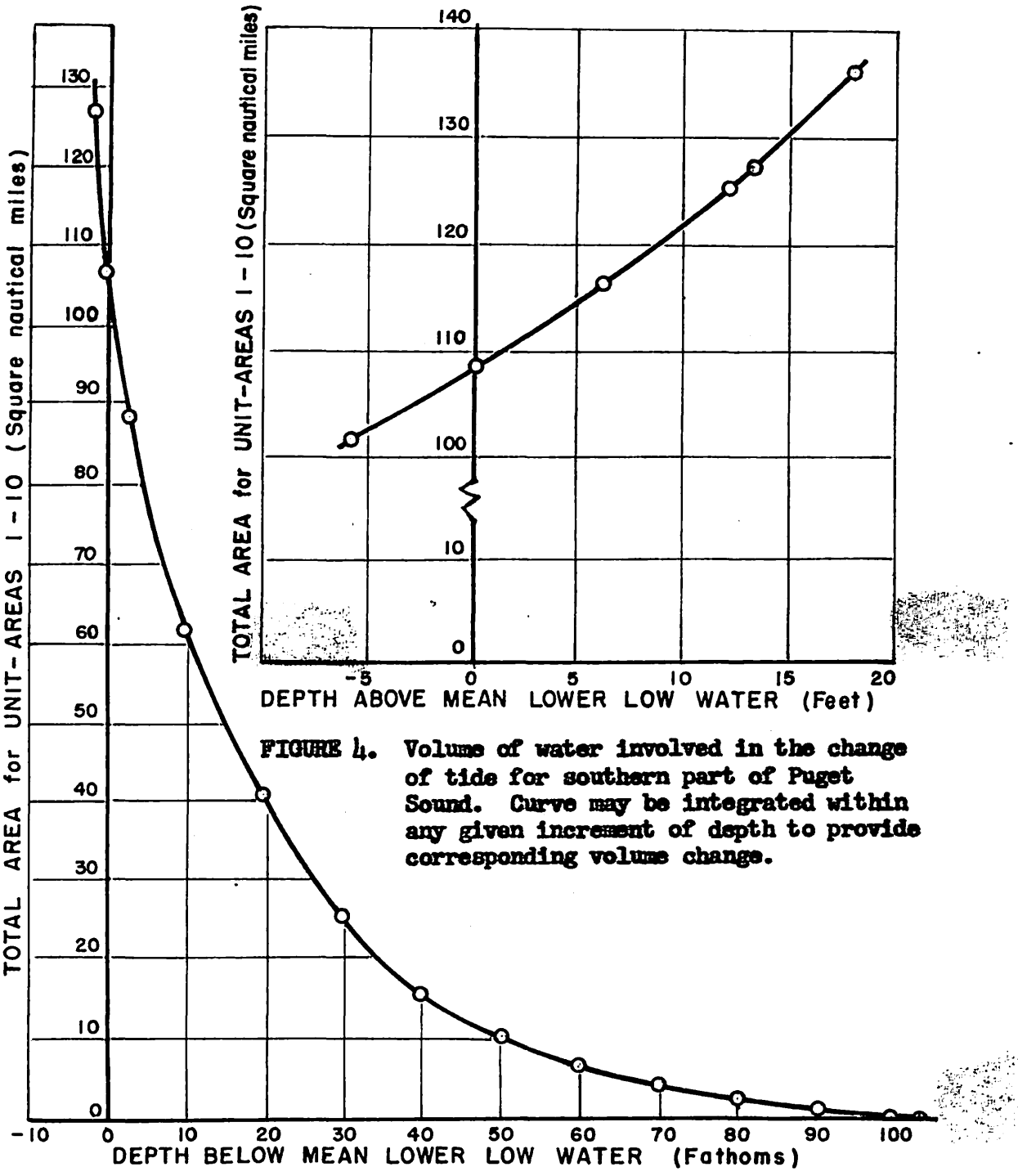

FIGURE 4. Volume of water involved in the change of tide for southern part of Puget Sound. Curve may be integrated within any given increment of depth to provide corresponding volume change.

FIGURE 3. Representation of accumulative area by depth for a portion of Puget Sound. This curve must be integrated within given increments of depth to obtain volume by increments of depth.

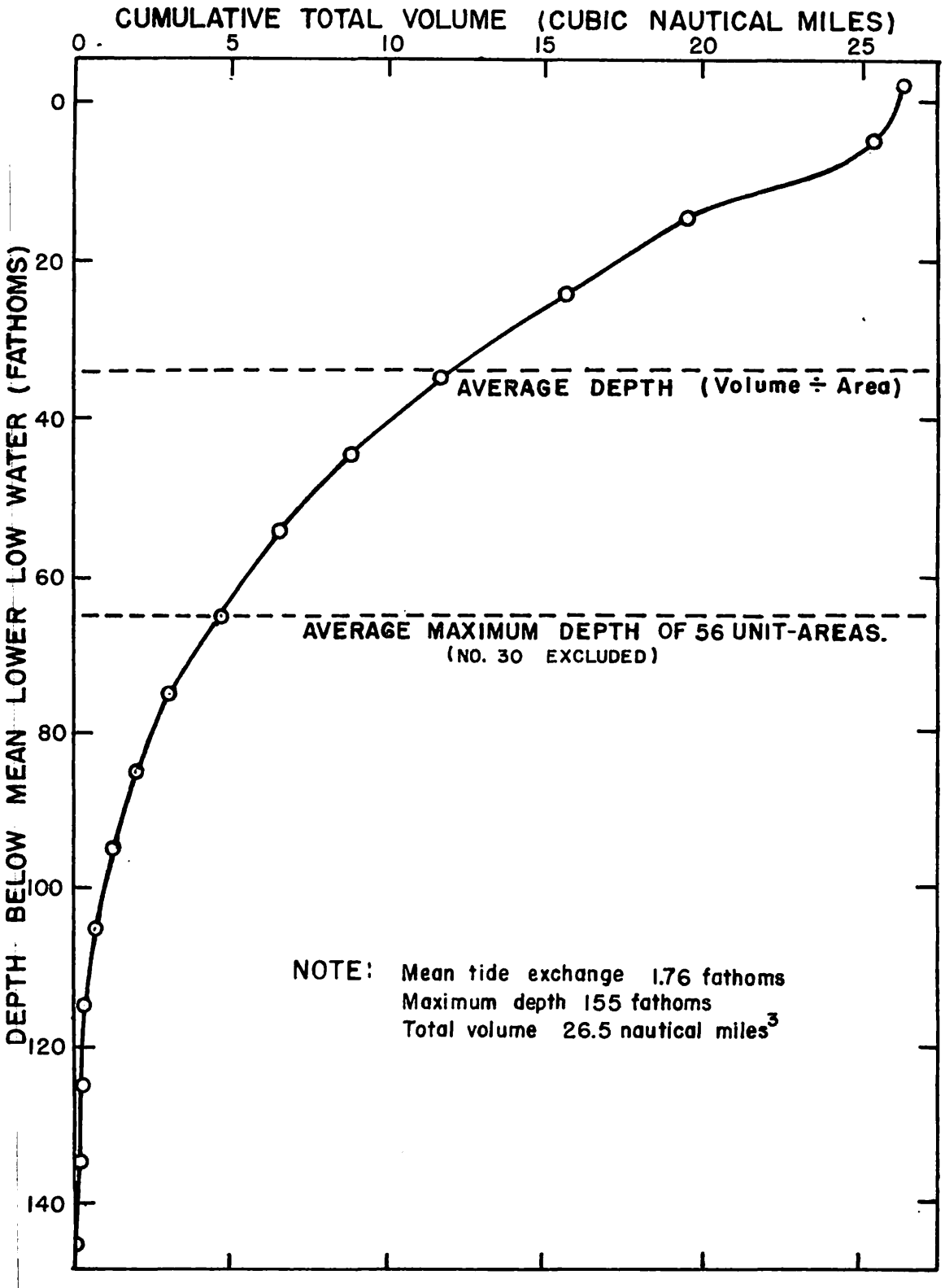

FIGURE 5. Accumulative volume by depth for all 57 unit-areas in Puget Sound. The curve was drawn from values obtained by constructing a curve similar to Fig. 3 and integrating within 10-fathom increments of level.

TABLE 5-A

AREA ANALYSIS OF ADMIRALTY INLET

Area given in square nautical miles

See Figure 2 for location map

Subdivision*		A-1					A-2	A-3	
	Unit-Area	44	45	46	49	Sub-Total	48	47	Total Div. A
DEPTH in fathoms below MLLW	MHW	22.24	29.60	33.68	17.62	103.1	9.49	2.72	115.3
	MLLW	19.77	28.59	32.87	17.25	98.48	8.85	2.26	109.6
	3	18.56	27.06	31.59	16.37	93.58	7.87	1.18	102.6
	10	16.79	23.27	27.98	13.75	81.79	4.01		85.80
	20	14.86	17.55	21.64	10.98	65.03	0.00		65.03
	30	12.65	14.86	16.02	7.32	50.85			50.85
	40	9.93	8.79	11.67	2.16	32.55			32.55
	50	7.02	5.45	8.70	0.19	21.36			21.36
	60	4.22	1.37	5.43		11.02			11.02
	70	1.73	0.09	2.49		4.31			4.31
	80	0.73		1.09		1.82			1.82
	90	0.42		0.51		0.93			0.93
	100	0.18		0.04		0.22			0.22
	110	0.01				0.01			0.01
	Max. Depth	112	75	104	58	112	18	7.5	112
	Mean Tide	1.52	1.52	1.35	1.27	1.44	1.27	1.35	1.44

*Subdivision A-1: Admiralty Inlet (main body)
A-2: Port Townsend
A-3: Kilisut Harbor

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 5-B
AREA ANALYSIS OF PUGET SOUND (CENTRAL PART)
(Part 1 of 3)

Area given in square nautical miles

See Figure 2 for location map

Subdivision*		B-1									
Unit-Area		12	16	17	18	28	31	32	33	34	Sub-Total
DEPTH in fathoms below MLLW	MHW	5.30	25.42	13.19	21.60	3.96	16.73	28.87	20.75	32.59	168.5
	MLLW	5.21	24.42	12.64	20.61	3.79	15.88	27.40	19.82	31.09	160.9
	3	5.17	23.34	12.10	19.69	3.64	14.79	25.81	18.95	29.99	153.5
	10	4.82	22.06	11.63	17.81	3.42	13.27	23.68	17.83	27.61	142.1
	20	4.61	20.51	11.02	15.06	3.10	12.06	20.76	16.46	24.44	128.0
	30	3.75	19.13	10.41	12.77	2.81	11.39	18.56	15.43	22.69	116.9
	40	3.10	17.75	9.86	10.78	2.59	10.87	16.94	14.50	21.46	107.8
	50	2.53	16.65	9.31	9.49	2.48	10.39	15.65	13.49	20.25	100.2
	60	2.02	15.31	8.73	8.40	2.31	9.88	14.34	12.44	18.82	92.25
	70	1.71	13.92	8.01	7.54	2.16	9.32	13.24	11.54	17.32	84.76
	80	1.37	12.34	7.19	6.71	2.01	8.64	12.00	10.62	15.59	76.47
	90	1.14	10.07	6.40	5.94	1.80	7.74	10.31	9.57	12.33	65.30
	100		5.20	4.29	4.66	1.64	6.13	7.82	5.10	7.17	42.01
	110		2.46	1.39	2.90	1.15	3.36	3.95	1.55	3.30	20.06
	120		0.34	0.42	1.45	0.57	1.58	1.46	0.71	1.53	8.06
	130				0.52	0.03	0.31	0.99	0.27	0.68	2.80
	140				0.02		0.02	0.09	0.09	0.07	0.29
	150							0.02	0.00		0.02
	Max. Depth	99	127	126	142	135	142	155	150	148	155
	Mean Tide	1.98	1.80	1.80	1.93	1.76	1.75	1.75	1.72	1.70	1.78

*Subdivision B-1: Puget Sound (main body)

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 5-B
AREA ANALYSIS OF PUGET SOUND (CENTRAL PART)
(Part 2 of 3)

Area given in square nautical miles

See Figure 2 for location map

Subdivision*		B-2									
Unit-Area		19	20	21	22	23	24	25	26	27	Sub-Total
DEPTH in fathoms below MLLW	MHW	2.00	2.39	4.76	1.08	3.16	3.41	4.80	2.11	0.62	24.33
	MLLW	1.75	2.10	3.91	0.90	2.95	3.10	3.70	1.60	0.51	20.52
	3	1.46	1.73	2.84	0.52	2.68	2.79	3.08	0.52	0.31	15.93
	10	0.77		0.76	0.00	1.99	2.05	0.27	0.00	0.01	5.85
	20	0.00		0.02		0.91	0.15				1.08
	30					0.11					0.11
	Max. Depth	21	9	22	13	35	27	14	11	11	35
	Mean Tide	1.76	1.80	1.90	1.85	1.80	1.80	1.80	1.83	1.75	1.82

*Subdivision B-2: Port Orchard area

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 5-B
AREA ANALYSIS OF PUGET SOUND (CENTRAL PART)
(Part 3 of 3)

Area given in square nautical miles

See Figure 2 for location map

Subdivision*		B-3			B-4	B-5	B-6	
Unit-Area		29	30	Sub-Total	15	13	14	Total Div. B
DEPTH in fathoms below MLLW	MHW	4.26	0.51	4.77	12.54	9.43	4.04	223.5
	MLLW	4.09	0.38	4.47	11.80	8.59	3.39	209.6
	3	3.85	0.16	4.01	11.05	8.12	2.40	195.0
	10	3.01		3.01	9.80	7.20	0.51	168.5
	20	2.59		2.59	8.42	6.54	0.28	146.9
	30	2.23		2.23	6.00	5.95		131.2
	40	1.45		1.45	4.19	5.35		118.8
	50	0.84		0.84	2.73	4.70		108.5
	60	0.48		0.48	0.82	4.11		97.66
	70	0.23		0.23		3.43		88.42
	80	0.08		0.08		2.63		79.18
	90					1.14		66.44
	100							42.01
	110							20.06
	120							8.06
	130							2.80
	140							0.29
	150							0.02
	Max. Depth	88	6	88	67	99	26	155
	Mean Tide	1.74	1.71	1.74	1.80	1.82	1.83	1.78

*Subdivision B-3: Elliott Bay
B-4: Colvos Passage
B-5: Commencement Bay
B-6: Quartermaster Harbor

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 5-C
AREA ANALYSIS OF THE NARROWS AND SOUTH
(Part 1 of 2)

Area given in square nautical miles

See Figure 2 for location map

Subdivision*		C-1				C-2	C-3		
	Unit-Area	8	10	11	Sub-Total	9	5	7	Sub-Total
DEPTH in fathoms below MLLW	MHW	39.35	1.12	3.39	43.86	28.00	2.10	23.76	25.86
	MLLW	34.45	1.08	3.27	38.80	25.11	1.41	21.07	22.48
	3	30.94	0.98	3.05	34.97	22.10	0.72	18.55	19.27
	10	26.12	0.81	2.35	29.28	17.87	0.01	14.02	14.03
	20	19.94	0.46	1.61	22.01	13.84		6.60	6.60
	30	13.67	0.02	0.57	14.26	10.30		1.80	1.80
	40	8.81		0.01	8.82	6.51		0.52	0.52
	50	6.35			6.35	4.01		0.19	0.19
	60	5.00			5.00	1.96			
	70	3.61			3.61	0.84			
	80	2.19			2.19	0.29			
	90	0.88			0.88				
	100	0.11			0.11				
	Max. Depth	103	32	41	103	89	12	59	59
	Mean Tide	2.08	2.00	1.83	2.08	2.12	2.17	2.20	2.02

*Subdivision C-1: The Narrows and Misqually Reach
C-2: Carr Inlet
C-3: Case Inlet

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 5-C

AREA ANALYSIS OF THE NARROWS AND SOUTH

(Part 2 of 2)

Area given in square nautical miles

See Figure 2 for location map

	Subdivision*	C-4						
	Unit-Area	1	2	3	4	6	Sub-Total	Total Div. C
DEPTH in fathoms below MLLW	MHW	4.71	7.20	6.59	3.70	10.76	32.96	130.7
	MLLW	3.55	4.89	5.41	2.30	9.18	25.33	111.7
	3	2.18	2.58	3.86	0.55	6.81	15.98	92.32
	10	0.19	0.41	0.25		2.24	3.09	64.27
	20					0.42	0.42	42.87
	30							26.36
	40							15.85
	50							10.55
	60							6.96
	70							4.45
	80							2.48
	90							0.88
	100							0.11
	Max. Depth	17	19	18.5	9	28	28	103
	Mean Tide	2.28	2.33	2.25	2.27	2.27	2.28	2.11

*Subdivision C-4: Various small inlets

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 5-D

AREA ANALYSIS OF HOOD CANAL

Area given in square nautical miles

See Figure 2 for location map

Subdivision*		D-1			D-2							
Unit-Area		50	51	Sub-Total	52	53	54	55	56	57	Sub-Total	Total Div. D
DEPTH in fathoms below MLLW	MHW	17.59	15.95	33.54	20.70	23.95	8.32	10.64	8.63	7.43	79.67	113.2
	MLLW	15.95	14.92	30.87	17.98	22.26	7.67	10.04	6.51	5.83	70.29	101.2
	3	14.07	13.90	27.97	16.26	20.75	7.06	9.38	5.69	4.76	63.90	91.87
	10	10.68	12.31	22.99	14.48	19.22	6.56	8.82	4.57	1.66	55.31	78.30
	20	8.23	9.75	17.98	12.76	17.58	5.94	8.00	2.65	0.06	46.99	64.97
	30	6.10	5.52	11.62	11.40	15.84	5.26	7.22	1.08		40.80	52.42
	40	3.87	2.80	6.67	10.18	14.10	4.76	6.28	0.47		35.79	42.46
	50	1.76	1.17	2.93	8.87	11.95	4.16	5.22	0.00		30.20	33.13
	60	0.28	0.21	0.49	7.49	9.00	3.54	3.75			23.78	24.27
	70	0.01		0.01	6.07	5.92	2.85	1.77			16.61	16.62
	80				4.13	3.14	2.07	0.88			10.22	10.22
	90				2.80	1.37	0.34				4.51	4.51
	100				0.39						0.39	0.39
	Max. Depth	73	69	73	102	99	93	87	50	22	102	102
	Mean Tide	1.59	1.65	1.62	1.78	1.78	1.78	1.81	1.81	1.81	1.79	1.75

*Subdivision D-1: Entrance
D-2: Hood Canal (main body)

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 5-E

AREA ANALYSIS OF POSSESSION SOUND AND NORTH

(Part 1 of 2)

Area given in square nautical miles

See Figure 2 for location map

Subdivision*		E-1						
	Unit-Area	35	36	38	39	40	41	Sub-Total
DEPTH in fathoms below MLLW	MHW	22.44	23.06	16.19	7.18	22.84	15.20	106.9
	MLLW	21.50	19.63	14.89	6.54	22.19	13.80	98.55
	3	19.66	13.74	13.72	5.90	21.17	11.15	85.34
	10	18.30	12.51	12.75	4.92	20.04	5.57	74.09
	20	17.31	11.49	11.54	3.09	16.51	0.02	59.96
	30	16.39	10.43	10.43	0.59	11.43		49.27
	40	15.30	9.05	9.27		6.79		40.41
	50	13.97	7.24	7.99		1.69		30.89
	60	12.30	4.25	4.79		0.11		21.45
	70	10.68	1.95	1.55				14.18
	80	8.13	1.26	0.64				10.03
	90	5.15	0.07	0.12				5.34
	100	1.28						1.28
	110	0.48						0.48
	120	0.08						0.08
	Max. Depth	123	99	97	38	68	21	123
	Mean Tide	1.68	1.73	1.72	1.72	1.77	1.77	1.72

*Subdivision E-1: Possession Sound and Saratoga Passage

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 5-E

AREA ANALYSIS OF POSSESSION SOUND AND NORTH

(Part 2 of 2)

Area given in square nautical miles

See Figure 2 for location map

	Subdivision*	E-2	E-3				
	Unit-Area	37	42	43	Sub-Total	Total Div. E	Total
DEPTH in fathoms below MLLW	MHW	32.33	26.69	18.94	45.63	184.9	767.6
	MLLW	23.06	14.73	10.63	25.36	147.0	679.1
	3	15.94	5.53	4.68	10.21	111.5	593.3
	10	13.69	2.62	1.62	4.24	92.02	489.1
	20	12.15	0.38	0.07	0.45	72.56	392.3
	30	10.79	0.13	0.00	0.13	60.19	321.0
	40	9.35	0.06		0.06	49.82	259.5
	50	7.64				38.53	212.1
	60	4.41				25.86	165.8
	70					14.18	128.0
	80					10.03	103.7
	90					5.34	78.10
	100					1.28	44.01
	110					0.48	20.55
	120					0.08	8.14
	130						2.80
	140						0.29
	150						0.02
	Max. Depth	67	46	30	46	123	155
	Mean Tide	1.73	1.75	1.60	1.68	1.72	1.76

*Subdivision E-2: Port Susan
E-3: Skagit Bay

Note: MHW - Mean high water
MLLW - Mean lower low water
Mean Tide - Difference between MHW and MLLW

TABLE 6-A
VOLUME ANALYSIS OF ADMIRALTY INLET

Volume given in cubic nautical miles

See Figure 2 for location map

	Subdivision*	A-1					A-2	A-3		
	Unit-Area	44	45	46	49	Sub-Total	48	47	Total Div. A	Cumulative Total Div. A
DEPTH in fathoms below MLLW	MHW-MLLW	0.0306	0.0456	0.0456	0.0203	0.142	0.0115	0.00335	0.157	3.41
	MLLW-10	0.179	0.259	0.304	0.155	0.897	0.0675	0.00675	0.971	3.25
	10-20	0.158	0.201	0.246	0.123	0.727	0.0160		0.743	2.28
	20-30	0.137	0.164	0.188	0.0901	0.579			0.597	1.54
	30-40	0.115	0.120	0.135	0.0488	0.419			0.419	0.959
	40-50	0.0845	0.0714	0.0968	0.00752	0.260			0.260	0.540
	50-60	0.0549	0.0331	0.0706	0.00080	0.159			0.159	0.280
	60-70	0.0294	0.00528	0.0394		0.0741			0.0741	0.120
	70-80	0.0104		0.0170		0.0274			0.0274	0.0462
	80-90	0.00528		0.00736		0.0126			0.0126	0.0189
	90-100	0.00288		0.00224		0.00512			0.00512	0.00624
	100-110	0.00112				0.00112			0.00112	0.00112
	Total to MHW	0.807	0.899	1.15	0.446	3.30	0.0950	0.0101	3.41	
	Total to MLLW	0.777	0.853	1.11	0.425	3.16	0.0835	0.00675	3.25	

*Subdivision A-1: Admiralty Inlet (main body)
A-2: Port Townsend
A-3: Kilisut Harbor

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-A.

TABLE 6-B
VOLUME ANALYSIS OF PUGET SOUND (CENTRAL PART)
(Part 1 of 3)

Volume given in cubic nautical miles

See Figure 2 for location map

Subdivision*		B-1									
Unit-Area		12	16	17	18	28	31	32	33	34	Sub-Total
DEPTH in fathoms below MLLW	MHW-MLLW	0.0105	0.0448	0.0228	0.0408	0.00672	0.0288	0.0491	0.0360	0.0541	0.294
	MLLW-10	0.0500	0.230	0.119	0.192	0.0350	0.143	0.251	0.186	0.291	1.50
	10-20	0.0477	0.212	0.112	0.165	0.0317	0.126	0.221	0.172	0.255	1.34
	20-30	0.0414	0.198	0.107	0.138	0.0294	0.115	0.194	0.158	0.232	1.21
	30-40	0.0344	0.184	0.102	0.116	0.0264	0.110	0.178	0.149	0.221	1.12
	40-50	0.0278	0.172	0.0960	0.100	0.0252	0.106	0.162	0.140	0.208	1.04
	50-60	0.0226	0.161	0.0904	0.0885	0.0239	0.101	0.151	0.130	0.196	0.965
	60-70	0.0182	0.146	0.0834	0.0790	0.0224	0.0954	0.138	0.119	0.180	0.881
	70-80	0.0155	0.131	0.0758	0.0702	0.0210	0.0886	0.126	0.110	0.162	0.800
	80-90	0.0127	0.115	0.0678	0.0638	0.0193	0.0829	0.111	0.101	0.141	0.715
	90-100	0.00660	0.0814	0.0564	0.0525	0.0174	0.0690	0.0898	0.0773	0.0963	0.547
	100-110		0.0371	0.0270	0.0373	0.0140	0.0470	0.0584	0.0301	0.0510	0.302
	110-120		0.0109	0.00760	0.0216	0.00852	0.0230	0.0237	0.0104	0.0227	0.128
	120-130		0.00112	0.00144	0.00864	0.00276	0.00768	0.0112	0.00384	0.0106	0.0472
	130-140				0.00240	0.00016	0.00128	0.00448	0.00160	0.00336	0.0133
	140-150				0.00016			0.00144	0.00048	0.00032	0.00240
	Total to MHW	0.287	1.72	0.969	1.18	0.284	1.15	1.77	1.43	2.12	10.9
	Total to MLLW	0.277	1.68	0.946	1.14	0.277	1.12	1.72	1.39	2.07	10.6

*Subdivision B-1: Puget Sound (main body)

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-B.

TABLE 6-B
VOLUME ANALYSIS OF PUGET SOUND (CENTRAL PART)
(Part 2 of 3)

Volume given in cubic nautical miles

See Figure 2 for location map

Subdivision*		B-2									
Unit-Area		19	20	21	22	23	24	25	26	27	Sub-Total
DEPTH in fathoms below MLLW	MHW-MLLW	0.00326	0.00178	0.00820	0.00187	0.00548	0.00596	0.00616	0.00351	0.00098	0.0372
	MLLW-10	0.0126	0.0114	0.0219	0.00273	0.0248	0.0258	0.0227	0.00431	0.00194	0.128
	10-20	0.00290		0.00244		0.0145	0.0102	0.00026		0.00001	0.0304
	20-30					0.00452	0.00032				0.00484
	30-40					0.00024					0.00024
	Total to MHW	0.0187	0.0132	0.0326	0.00460	0.0495	0.0424	0.0291	0.00784	0.00293	0.201
	Total to MLLW	0.0155	0.0114	0.0244	0.00273	0.0440	0.0364	0.0229	0.00433	0.00195	0.164

*Subdivision B-2: Port Orchard area

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-B.

TABLE 6-B
VOLUME ANALYSIS OF PUGET SOUND (CENTRAL PART)
(Part 3 of 3)

Volume given in cubic nautical miles

See Figure 2 for location map

Subdivision*		B-3			B-4	B-5	B-6		
Unit-Area		29	30	Sub-Total	15	13	14	Total Div. B	Cumulative Total Div. B
DEPTH in fathoms below MLLW	MHW-MLLW	0.00748	0.00076	0.00824	0.0216	0.0160	0.00652	0.383	12.1
	MLLW-10	0.0355	0.00101	0.0365	0.107	0.0785	0.0177	1.87	11.8
	10-20	0.0279		0.0279	0.0918	0.0683	0.00376	1.57	9.89
	20-30	0.0238		0.0238	0.0728	0.0623	0.00100	1.38	8.33
	30-40	0.0190		0.0190	0.0515	0.0564		1.25	6.95
	40-50	0.0110		0.0110	0.0341	0.0500		1.13	5.70
	50-60	0.00656		0.00656	0.0173	0.0441		1.03	4.57
	60-70	0.00344		0.00344	0.00208	0.0378		0.925	3.54
	70-80	0.00160		0.00160		0.0304		0.832	2.61
	80-90	0.00032		0.00032		0.0198		0.735	1.78
	90-100					0.00360		0.550	1.04
	100-110							0.302	0.493
	110-120							0.128	0.191
	120-130							0.0472	0.0629
	130-140							0.0133	0.0157
	140-150							0.00240	0.00240
	Total to MHW	0.136	0.00177	0.138	0.398	0.467	0.0290	12.1	
	Total to MLLW	0.129	0.00101	0.130	0.376	0.451	0.0225	11.8	

*Subdivision B-3: Elliott Bay
B-4: Colvos Passage
B-5: Commencement Bay
B-6: Quartermaster Harbor

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-B.

TABLE 6-C
VOLUME ANALYSIS OF THE NARROWS AND SOUTH
(Part 1 of 2)

Volume given in cubic nautical miles

See Figure 2 for location map

	Subdivision*	C-1				C-2	C-3		
	Unit-Area	8	10	11	Sub-Total	9	5	7	Sub-Total
DEPTH in fathoms below MLLW	MHW-MLLW	0.0770	0.00220	0.00624	0.0854	0.0584	0.00374	0.0498	0.0535
	MLLW-10	0.293	0.00930	0.0283	0.331	0.208	0.00483	0.172	0.177
	10-20	0.229	0.00644	0.0196	0.255	0.156		0.104	0.104
	20-30	0.168	0.00194	0.0107	0.181	0.121		0.0362	0.0362
	30-40	0.111		0.00204	0.113	0.0832		0.00976	0.00976
	40-50	0.0736			0.0736	0.0518		0.00320	0.00320
	50-60	0.0560			0.0560	0.0285			
	60-70	0.0409			0.0409	0.0133			
	70-80	0.0266			0.0266	0.00576			
	80-90	0.0155			0.0155	0.00160			
	90-100	0.00416			0.00416				
	Total to MHW	1.09	0.0199	0.0670	1.18	0.728	0.00857	0.375	0.384
	Total to MLLW	1.02	0.0177	0.0607	1.10	0.669	0.00483	0.325	0.330

*Subdivision C-1: The Narrows and Nisqually Reach
C-2: Carr Inlet
C-3: Case Inlet

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-C.

TABLE 6-C
VOLUME ANALYSIS OF THE NARROWS AND SOUTH
(Part 2 of 2)

Volume given in cubic nautical miles

See Figure 2 for location map

Subdivision*		C-4							
Unit-Area		1	2	3	4	6	Sub-Total	Total Div. C	Cumulative Total Div. C
DEPTH in fathoms below MLLW	MHW-MLLW	0.00934	0.0142	0.0139	0.00686	0.0234	0.0678	0.265	2.49
	MLLW-10	0.0154	0.0182	0.0251	0.00474	0.0534	0.117	0.833	2.23
	10-20	0.00032	0.00112	0.00064		0.0101	0.0122	0.527	1.39
	20-30					0.00048	0.00048	0.338	0.865
	30-40							0.206	0.527
	40-50							0.129	0.321
	50-60							0.0845	0.192
	60-70							0.0542	0.108
	70-80							0.0323	0.0536
	80-90							0.0171	0.0213
	90-100							0.00416	0.00416
	Total to MHW	0.0251	0.0336	0.0396	0.0116	0.0874	0.196	2.49	
	Total to MLLW	0.0158	0.0194	0.0257	0.00474	0.0640	0.129	2.23	

*Subdivision C-4: Various small inlets

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-C.

TABLE 6-D
VOLUME ANALYSIS OF HOOD CANAL
(Part 1 of 2)

Volume given in cubic nautical miles

See Figure 2 for location map

Subdivision*		D-1		
Unit-Area		50	51	Sub-Total
DEPTH in fathoms below MLLW	MHW-MLLW	0.0261	0.0245	0.0506
	MLLW-10	0.130	0.134	0.264
	10-20	0.0936	0.112	0.206
	20-30	0.0712	0.0754	0.147
	30-40	0.0491	0.0392	0.0083
	40-50	0.0267	0.0194	0.0461
	50-60	0.00896	0.00592	0.0149
	60-70	0.00160	0.00112	0.00272
	70-80	0.00016		0.00016
	Total to MHW	0.407	0.412	0.819
	Total to MLLW	0.381	0.387	0.769

*Subdivision D-1: Entrance

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-D.

TABLE 6-D
VOLUME ANALYSIS OF HOOD CANAL
(Part 2 of 2)

Volume given in cubic nautical miles

See Figure 2 for location map

Subdivision*		D-2								
Unit-Area		52	53	54	55	56	57	Sub-Total	Total Div. D	Cumulative Total Div. D
DEPTH in fathoms below MLLW	MHW-MLLW	0.0304	0.0406	0.0142	0.0185	0.0130	0.0118	0.128	0.179	3.92
	MLLW-10	0.157	0.203	0.0698	0.0923	0.0534	0.0379	0.613	0.877	3.75
	10-20	0.137	0.184	0.0628	0.0843	0.0368	0.00616	0.511	0.717	2.87
	20-30	0.123	0.165	0.0556	0.0758	0.0175	0.00064	0.438	0.584	2.15
	30-40	0.109	0.151	0.0506	0.0681	0.00704		0.386	0.474	1.57
	40-50	0.0946	0.131	0.0443	0.0571	0.00232		0.329	0.376	1.09
	50-60	0.0816	0.105	0.0388	0.0450			0.270	0.285	0.717
	60-70	0.0674	0.0744	0.0320	0.0273			0.201	0.204	0.432
	70-80	0.0504	0.0440	0.0246	0.0130			0.132	0.132	0.228
	80-90	0.0339	0.0232	0.0134	0.00392			0.0744	0.0744	0.0962
	90-100	0.0162	0.00480	0.00040				0.0214	0.0214	0.0218
	100-102	0.00048						0.00048	0.00048	0.00048
	Total to MHW	0.900	1.13	0.406	0.485	0.130	0.0565	3.10	3.92	
	Total to MLLW	0.870	1.09	0.392	0.467	0.117	0.0447	2.98	3.75	

*Subdivision D-2: Hood Canal (main body)

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-D.

TABLE 6-E
VOLUME ANALYSIS OF POSSESSION SOUND AND NORTH
(Part 1 of 2)

Volume given in cubic nautical miles

See Figure 2 for location map

Subdivision*		E-1						
Unit-Area		35	36	38	39	40	41	Sub-Total
DEPTH in fathoms below MLLW	MHW-MLLW	0.0384	0.0373	0.0272	0.0122	0.0414	0.0266	0.183
	MLLW-10	0.193	0.139	0.135	0.0556	0.209	0.0966	0.828
	10-20	0.178	0.120	0.121	0.0402	0.185	0.0203	0.665
	20-30	0.166	0.110	0.109	0.0178	0.140		0.543
	30-40	0.157	0.0982	0.0986	0.00144	0.0918		0.447
	40-50	0.145	0.0826	0.0869		0.0502		0.365
	50-60	0.131	0.0584	0.0643		0.00720		0.261
	60-70	0.114	0.0288	0.0301		0.00032		0.173
	70-80	0.0941	0.0147	0.0106				0.119
	80-90	0.0667	0.00560	0.00368				0.0760
	90-100	0.0280		0.00032				0.0283
	100-110	0.00800						0.00800
	110-120	0.00272						0.00272
	Total to MHW	1.32	0.694	0.686	0.127	0.725	0.144	3.70
	Total to MLLW	1.28	0.657	0.659	0.115	0.684	0.117	3.51

*Subdivision E-1: Possession Sound and Saratoga Passage

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-E.

TABLE 6-E
VOLUME ANALYSIS OF POSSESSION SOUND AND NORTH
(Part 2 of 2)

Volume given in cubic nautical miles

See Figure 2 for location map

Subdivision*		E-2	E-3						
Unit-Area		37	42	43	Sub-Total	Total Div. E	Cumulative Total Div.E	Total	Cumulative Total
DEPTH in fathoms below MLLW	MHW-MLLW	0.0475	0.0344	0.0221	0.0565	0.287	4.58	1.27	26.5
	MLLW-10	0.159	0.0474	0.0401	0.0880	1.07	4.29	5.62	25.3
	10-20	0.127	0.0117	0.00704	0.0187	0.811	3.21	4.36	19.6
	20-30	0.113	0.00176	0.00064	0.00240	0.659	2.40	3.54	15.3
	30-40	0.0998	0.00128		0.00128	0.548	1.75	2.89	11.7
	40-50	0.0843				0.449	1.20	2.35	8.85
	50-60	0.0619				0.323	0.747	1.88	6.50
	60-70	0.0173				0.190	0.425	1.45	4.62
	70-80					0.119	0.234	1.14	3.17
	80-90					0.0760	0.115	0.915	2.03
	90-100					0.0283	0.0390	0.609	1.11
	100-110					0.00800	0.0107	0.312	0.506
	110-120					0.00272	0.00272	0.131	0.194
	120-130							0.0472	0.0629
	130-140							0.0133	0.0157
	140-150							0.00240	0.00240
	Total to MHW	0.710	0.0965	0.0704	0.167	4.58		26.5	
	Total to MLLW	0.663	0.0621	0.0483	0.110	4.29		25.3	

*Subdivision E-2: Port Susan
E-3: Skagit Bay

Note: MHW - Mean high water
MLLW - Mean lower low water
For numerical value of MHW-MLLW see Table 5-E.

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