United States
Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101

Total Maximum Daily Load (TMDL) for Biochemical Oxygen Demand (BOD5) in the Waters of South Unalaska Bay, Alaska

In compliance with the provisions of the Clean Water Act, 33 U.S.C. § 1251 et seq., as amended by the Water Quality Act of 1987, P.L. 100-4, the Environmental Protection Agency is hereby establishing a TMDL to limit discharges of biochemical oxygen demand to the waters of south Unalaska Bay, Alaska.

This TMDL shall become effective immediately, and is incorporated into the water quality management plans for the state of Alaska under Clean Water Act § 303(e). Subsequent actions must be consistent with this TMDL.

Signed this 12th day of Feb, 1995.

Charles E. Findley, Director
Water Division

Total Maximum Daily Load for

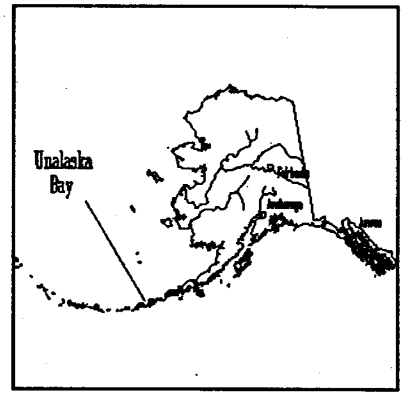
Biochemical Oxygen Demand

in the Waters of

South Unalaska Bay, Alaska

TMDL AT A GLANCE:

Water Quality-Limited?	*Yes*
Segment Identifier:	*30102-603*
Standard of Concern:	*Dissolved oxygen*
Pollutant of Concern:	*Biochemical oxygen demand*
Primary Use Affected:	*Aquatic life*
Sources:	*UniSea/Dutch Harbor Seafoods, Alyeska Seafoods, Royal Aleutian Seafoods, Queen Fisheries and Unalaska WWTP*
Loading Capacity:	*350,951 lbs BOD5/day*
Total Wasteload Allocation:	*280,761 lbs BOD5/day (80%)*
Margin of Safety:	*70,190 lbs BOD5/day (20%)*



Background

Section 303(d)(1)(C) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 CFR Part 130) require the establishment of Total Maximum Daily Loads (TMDL) for waters for which the technology-based controls required by Section 301 of the CWA or other legally required pollution control mechanisms are inadequate to ensure the achievement of state water quality standards. A TMDL is an implementation plan which identifies the degree of pollution control needed to attain and maintain compliance with state water quality standards using an appropriate margin of safety (EPA 1991). The focus of the implementation plan is the reduction of pollutant inputs to a level (or "daily load") that will meet the water quality standard and thus fully support the beneficial uses of a given waterbody. The mechanisms used to address water quality problems through the TMDL process can include effluent limits, best management practices and monitoring requirements in National Pollutant Discharge Elimination (NPDES) permits.

The state of Alaska has identified south Unalaska Bay as being water quality-limited for seafood waste (ADEC 1992). EPA Region 10 completed a TMDL Water Quality Assessment ("TMDLProblem Assessment;" EPA 1995) of the pollutants discharged to greater Unalaska Bay and concluded that seafood processing wastes from five facilities and sewage from the municipal wastewater treatment plant (WWTP) contribute significantly to the reduction of concentrations of dissolved oxygen (DO) in south Unalaska Bay below the State water quality standard of 6 mg DO/L. Two of these facilities, UniSea and Dutch Harbor Seafoods, jointly discharge a commingled effluent through a common treatment and outfall system and therefore their discharges of pollution will be discussed, analyzed and regulated as a single source herein and hereafter referred to as UniSea/Dutch Harbor Seafoods. Recent studies of ambient concentrations of DO in south Unalaska Bay indicate that water quality violations occurred during roughly half of the days monitored during a two week period in September 1992-94 (Table 1). Based on the measurements and evaluation of low concentrations of DO, a seasonal TMDL is proposed for five-day biochemical oxygen demand (BOD5) in south Unalaska Bay during the period May 1 through October 31. BOD5, the sum total of biological and chemical demand for dissolved oxygen during a five-day period, is a parameter directly related to the impact of effluent discharges on DO levels in a receiving water and measured by the seafood industry's effluent monitoring programs.

In the following discussion it will be convenient to use acronyms for the names of departments, statutes and parameters which are referred to frequently. These are presented here for referral:

AAC - Alaska Administrative Code,
ADEC - Alaska Department of Environmental Conservation,
BOD - biochemical oxygen demand,
CFR - Code of Federal Regulations,
CWA - the Clean Water Act, or Federal Water Pollution Control Act,
EPA - U.S. Environmental Protection Agency,
TMDL - total maximum daily load,
WASP - Water Quality Analysis Simulation Program,
WLA - wasteload allocation, and
ZOD - zone of deposit.

Loading Capacity

The two largest seafood processors in south Unalaska Bay may discharge as much 500,000 lbs BOD5 per day during the B-season pollock fishery in August, September and October (Table 2). This is more than ten times the permissible monthly average discharge of all of the the municipal wastewater treatment plants for the cities of Anchorage, Fairbanks and Juneau (cumulative total of 47,905 lbs BOD5 per day). UniSea/Dutch Harbor Seafoods (monthly average discharge of 303,153 lbs BOD5 per day, 9/94) and Alyeska Seafoods (monthly average discharge of 147,290 lbs BOD5 per day, 9/94) discharge almost all of this.

The results of the circulation and monitoring studies of Unalaska Bay indicate that the maximum depression in DO occurs along the shore near the discharge locations (Alyeska Seafoods 1992-95, UniSea 1992-95, CH2M-Hill1994). The average biochemical oxygen demand of the cumulative effluents on large areas of water in south Unalaska Bay is as much as 1.6 mg DO/L (saturation concentration ~9.6 mg DO/L; average ambient concentration ~ 8.0 mg DO/L). The maximum biochemical oxygen demand of the cumulative effluents on specific volumes of water in south Unalaska Bay can be as much as 8.1 mg DO/L (specific ambient concentration = 1.4 mg DO/L). In general, large depressions of dissolved oxygen at individual sites within south Unalaska Bay are associated with and indicative of significant general depressions of dissolved oxygen throughout south Unalaska Bay. Discharges of seafood effluents along western Amaknak Island produce measurable depressions in DO beyond Hog Island and Devilfish Point. The impact decreases gradually to 0.1 mg DO/l farther away from the outfalls out to the outer bay.

EPA, ADEC, the City of Unalaska, Westward Seafoods, UniSea/Dutch Harbor Seafoods, Alyeska Seafoods, Queen Fisheries and Royal Aleutian Seafoods contracted with CH2M-Hill for the development of a circulation and water quality model of greater Unalaska Bay (CH2M-Hill 1994; Appendix A). This model simulated circulation and discharges in a computer model of greater Unalaska Bay under several sets of environmental (wind and tide) and discharge conditions (Figure 1). Water quality parameters used within the computer model were based upon field studies of Unalaska Bay and the published literature (Table 3). The Water Quality Analysis Simulation Program (WASP, Ambrose et al. 1988, 1993) model of south Unalaska Bay which was developed as the result of this contract provided the starting point for the following analyses.

The water quality model is developed for realistic "worst-case" conditions during the summer months which have been characterized by violations of the water quality standard for DO. The loading capacity was assessed for a modeling scenario which incorporated the following two environmental conditions:

- Minimal 60-hr average wind conditions (worst-case wind condition) and

- Stratification of the water column under summer conditions (worst-case seasonal condition), with 100% of the BOD5 load distributed into the upper 50% of the water column (i.e., the upper layer of cells in the WASP computer model).

EPA modified the WASP model of south Unalaska Bay based upon environmental conditions appropriate during early September of 1994 (Table 4). In order to estimate these parameters EPA utilized a September 1994 study of ambient concentrations of DO and other physicochemical parameters at fourteen stations throughout south Unalaska Bay (Figure 2; Table 5). EPA selected the measurements of ambient DO for the period September 3-10, 1994 as the "calibration period" characterizing a reasonable set of "worst case" conditions (Table 6). The ebb and slack tides and low to moderate winds produce a cumulative BOD load in the portion of south Unalaska Bay south of the airport runway and adjacent to the discharges of Alyeska Seafoods, Royal Aleutian Seafoods and Queen Fisheries. The composite result of these different conditions led the scientists conducting the field study of ambient DO to determine that the net flow was to the north and west for this 8-day period. Down current stations #9 and #10, located northwest of the seafood processing discharges, were selected for monitoring. Under these conditions the combined UniSea/Dutch Harbor Seafood discharge (a joint, commingled discharge) would drift northwest and combine with the discharges of Alyeska Seafoods, Royal Aleutian Seafoods and Queen Fisheries in the portion of Unalaska Bay adjacent to and just south of the airport.

The WASP cell (#61) in this area serves as the "calibration cell" for estimating the parameters of the water quality model of south Unalaska Bay. Cell #61 represents a volume of water which is most affected by the effluents of the five facilities discharging to south Unalaska Bay under the selected set of "worst case" conditions. Alyeska Seafoods discharges into cell #61, Royal Aleutian Seafoods and Queen Fisheries discharge into a neighboring cell (#62), UniSea/Dutch Harbor Seafoods discharges into cell #58 approximately 0.5 miles upcurrent and the City of Unalaska's wastewater treatment plant (Unalaska WWTP) discharges into cell #59 approximately 0.4 miles upcurrent.

The measurements of ambient DO collected during this period were distributed bimodally, reflecting the variation in concentrations of DO within the selected calibration time period and cell across the days and depths sampled (Figure 3). These measurements were converted to differences from the saturation level of DO (DO_{sat} = 9.59 mg DO/L according to the equation of Green and Carritt 1967; Figure 4).

Various combinations of model parameters and monthly average discharges of BOD5 were utilized in simulating the effects of effluents on ambient concentrations of DO (Table 7). Several alternate sets of values for reaeration rate, horizontal dispersion and vertical dispersion provided satisfactory estimators of measured levels of DO in the area. The linear relationship of BOD and DO is apparent (Figure 5). The close agreement of these three sets of predictors indicates the robustness of the WASP computer model for water quality assessment of BOD and DO. The set of parameters consisting of a reaeration rate 0.30, horizontal dispersion of 30 m^2/sec and vertical dispersion of 0.00015 m^2/sec was selected for further analysis of water quality.

Since the most significant violations of the water quality standard under the accepted worst case conditions occur at the surface of the receiving water, the water quality analysis focused upon ambient concentrations of DO in the surface one meter of the water column. The distribution of these measurements was similar to those of the water column in general (Figures 6 and 7). In the data used for model calibration, the average DO concentration in the top one meter of the water column in WASP cell #61 was 8.70 mg/L and the 95% confidence interval was 4.93 mg/L (Table 8). In the same data, the average DO concentration in the area corresponding to WASP cell #61 (the upper fifty percent of the water column) was 7.96 mg/L.

Since the DO deficit (i.e., the difference between the saturation concentration of DO and an ambient DO concentration, $\Delta DO_{ambient} = DO_{ambient} - DO_{sat}$) approaches zero in a linear fashion as the concentration of BOD approaches zero, it is possible to calculate the algebraic relationship between the average concentration of DO in the top one meter of the water column in a cell and the average concentration of DO throughout that cell. The two values are proportional to one another. In the ambient DO data used for calibration, the average DO deficit in all of WASP cell #61 is 183% of that the average DO deficit in the top one meter of the water column of WASP cell #61:

$$\Delta DO_{\text{cell \#61}} = 1.8315 * \Delta DO_{\text{top one meter of water column in cell \#61}} .$$

Using this algebraic relationship, the average DO concentration for cell #61 can be estimated for a given average DO concentration in the top one meter of the water column of cell #61 for a uniform parameter set in the WASP computer model.

EPA analyzed the distribution of DO concentrations around the average as a distribution whose shape remained proportionally constant and whose scale approaches zero as the DO deficit approaches zero. Thus, as the DO deficit approaches zero, the range and standard deviation of DO concentrations steadily decreases and likewise approaches zero. EPA has assumed that the coefficient of variation for this distribution remains constant (C.V. = standard deviation/average = a constant for a given distribution of concentrations). The coefficient of variation for the entire volume of the calibration cell #61 is equal to 1.4781 (n = 568 DO concentrations); C.V. for the top one meter volume of cell #61 is equal to 2.5922 (n = 128 DO concentrations).

In order to protect the water quality standard of 6 mg/L with a 95% confidence interval, EPA determined that the corresponding average surface concentration of DO must be 8.84 mg/L and the corresponding average concentration in WASP cell #61 must be 8.22 mg DO/L (Table 8).

Water quality conditions were simulated for a range of discharge levels in south Unalaska Bay (Table 9). These scenarios held the relatively small discharges of BOD5 by Queen Fisheries, Royal Aleutian Seafoods and the Unalaska WWTP constant at levels exceeding their present discharges, and varied the discharges of UniSea/Dutch Harbor Seafoods and Alyeska Seafoods in equal proportion to their discharges of September 1994. It was determined that the loading capacity of south Unalaska Bay is 350,951 lbs BOD5/day.

The modeling analysis further indicated that the effect of the proposed BOD5 wasteload allocations would not violate Alaska water quality standards for DO under average summer wind conditions and the greater mixing and dispersion associated with such average conditions.

Load and Wasteload Allocations

The BOD5 loading capacity of the receiving water of south Unalaska Bay must be allocated to (1) the point sources identified as contributing pollutant loads to the waterbody (2) nonpoint sources of pollution and natural background, and, if appropriate, (3) a margin of safety. The two largest sources of BOD5 discharges to south Unalaska Bay have been identified: UniSea/Dutch Harbor Seafoods (9/94 monthly average BOD5 wasteload of 303,153 lbs/day) and Alyeska Seafoods (9/94 monthly average BOD5 wasteload of 147,290 lbs/day). Three other sources of BOD5 discharges to south Unalaska Bay have been identified: Royal Aleutian Seafoods, Queen Fisheries (a.k.a. East Point Seafoods) and the City of Unalaska WWTP.

In accordance with CWA § 303(d)(1)(C) and federal regulations (40 CFR § 130.7), a margin of safety (MOS) was established to account for uncertainty in the relationship between effluent limitations and water quality. A margin of safety may be provided (1) by using conservative assumptions in the calculation of the loading capacity of the waterbody or (2) by establishing allocations that in total are lower than the defined loading capacity (so that the unallocated portion represents the margin of safety). In the case of the south Unalaska Bay analysis for biochemical oxygen demand, both approaches were relied upon to establish a safety margin. In the first instance, EPA has selected a set of conservative modeling parameters for the discharge into the upper water column and for the circulation of south Unalaska Bay. In addition to the conservative assumptions used within the interpretation of the WASP model, EPA has proposed a numerical margin of safety of 20% of the loading capacity of BOD5 to allow for uncertainty in the modeling analysis and diurnal variation in planktonic photosynthesis and respiration.

As described above, the simulations of BOD5 discharges in Unalaska Bay included the conservative assumptions of a worst-case scenario of sustained low-wind conditions during the highly stratified water column of the Aleutian summer. In addition, the simulation included the highest monthly average discharge of BOD5 reported by Westward Seafoods during the B-season pollock fishery of 1994 as a portion of the background loading of BOD (70,194 lbs BOD5/day). The simulation also provided for relatively high levels of natural BOD5 (0.75 mg/L) and sediment oxygen demand from decaying residues across much of south Unalaska Bay (1.5-3.0 g DO/m^2-day). The assessment of the loading capacity for BOD5 in south Unalaska Bay is based upon these worst-case assumptions.

In establishing BOD5 allocations, the load allocation for the margin of safety explicitly provide for two uncertainties.

- First, uncertainty about the assumptions used in modeling the DO budget is the basis for reserving 10% of the loading capacity of south Unalaska Bay (35,095 lbs BOD5/day). This constitutes an allocation for model uncertainty as an element of the margin of safety.

- Second, uncertainty about the amount of natural oxygen demand during the night as contrasted with the assessments taken during the day is the basis for reserving 10% of the loading capacity of south Unalaska Bay (35,095 lbs BOD5/day). During periods of light the phytoplankton community is photosynthesizing and making a net contribution to dissolved oxygen in the water column. During periods of darkness this same phytoplankton community continues respiration without photosynthesis and makes a net demand on dissolved oxygen in the water column. This constitutes an allocation for natural sources of BOD5 as an element of the margin of safety.

After providing for natural sources and an appropriate margin of safety, the allocation of the allowable wasteload to sources of pollution can follow one of three basic approaches: (1) equal allocations, (2) allocations proportional to present or historical production, or (3) allocations proportional to present or historical discharges of pollutants. The allocation method for seafood processors in south Unalaska Bay uses equal allocations as a base loading for crab processing (1,000 lbs BOD5/day per facility) and adds proportional allocations on top of this foundation based upon reported BOD5 discharges of the processors which discharge directly to south Unalaska Bay. The municipal sewage treatment plant is allocated a BOD wasteload of 2,343 lbs/day (which is three times its estimated average discharge of 781 lbs BOD5/day) in deference to the relatively small size of its contribution and the considerable importance of this discharge to the City of Unalaska and the public it services.

Based on the information available at this time, EPA establishes the following allocations among these sources:

Source	BOD5 Allocation	Percent of Total Loading
UniSea/Dutch Harbor Seafoods	185,390 lbs/day	(52.8%)
Alyeska Seafoods	90,074 lbs/day	(25.7%)
Royal Aleutian Seafoods	1,477 lbs/day	(0.4%)
East Point Seafoods	1,477 lbs/day	(0.4%)
Unalaska WWTP	2,343 lbs/day	(0.7%)
Margin of Safety: Model uncertainty	35,095 lbs/day	(10.0%)
Margin of Safety: Planktonic respiration	35,095 lbs/day	(10.0%)
Total Loading Capacity	350,951 lbs/day	

The allocations for the seafood processors will constitute the basis of the BOD5 limitations in the modification or reissuance of any NPDES permits for these facilities. The allocation and limitations are established for the months of May through October.

Monitoring Requirements

It is assumed that the ambient DO monitoring program conducted by the seafood processors under their NPDES permits will continue under the modified or reissued permits, as will monitoring of process wastewater discharges for BOD5. Any monitoring required will be designed and conducted to meet the requirements of a comprehensive and efficient program of assessment (e.g., NRC 1990). The data generated from monitoring can be used to refine and calibrate the water quality model of greater Unalaska Bay and to adjust the wasteload allocation and NPDES permit limitations as appropriate.

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Table 1. Ambient concentrations of dissolved oxygen (DO) and numbers of data points below the Alaska Water Quality Standard of 6 mg DO/L for coastal water to one meter depth in the Alyeska Seafoods monitoring of the summers of 1992, 1993 and 1994[1,2,3].

Monitoring Year and Station	Number of Monitoring Days	Number of DO Samples	DO Concentrations (mg DO/l)		Days of DO < 6 mg/l		Samples of DO < 6 mg/l	
			Minimum	Maximum	Number	Percent	Number	Percent
1992: Ref.[4]	**14**	**15**	**6.0**	**10.1**	**0**	**0%**	**0**	**0%**
# 1	14	15	2.6	8.1	6	43%	7	47%
# 2	14	15	3.0	10.2	6	43%	6	40%
# 3	12	15	2.9	10.6	5	42%	7	47%
# 4	13	14	1.4	8.3	6	46%	6	43%
# 5	14	16	1.5	9.9	5	36%	6	38%
# 6	14	16	1.7	10.5	7	50%	9	64%
# 7	14	16	2.4	10.1	7	50%	8	57%
# 8	14	16	3.3	10.2	7	50%	8	57%
# 9	8	10	5.2	7.3	3	38%	4	40%
#10	8	9	4.9	9.4	3	38%	4	44%
#11	6	6	1.8	7.8	2	33%	2	33%
#12	6	6	1.6	9.1	2	33%	2	33%
1993: Ref.	**14**	**28**	**5.5**	**8.8**	**4**	**29%**	**4**	**14%**
# 1	14	28	4.0	8.2	10	71%	16	57%
# 2	14	27	4.0	7.9	11	79%	17	63%
# 3	14	28	4.1	8.8	9	64%	18	64%
# 4	14	28	4.1	8.5	9	64%	14	50%
# 5	14	28	4.5	8.7	7	50%	13	46%
# 6	14	28	4.1	8.6	8	57%	14	50%
# 7	14	28	3.8	9.2	10	71%	17	61%
# 8	14	28	3.9	8.3	10	71%	17	61%
# 9	4	8	5.2	8.4	1	25%	1	13%
#10	4	8	5.4	7.9	1	25%	2	25%
#11	10	20	4.0	7.4	8	80%	13	65%
#12	10	20	3.5	7.8	8	80%	12	60%
1994: Ref.	**14**	**28**	**7.8**	**10.7**	**0**	**0%**	**0**	**0%**
# 1	14	28	3.4	11.6	2	14%	4	14%
# 2	14	28	5.5	11.8	1	7%	2	7%
# 3	14	28	5.0	11.6	2	14%	4	14%
# 4	14	28	6.0	11.9	0	0%	0	0%
# 5	14	28	5.6	11.9	1	7%	1	4%
# 6	14	28	3.8	11.7	1	7%	2	7%
# 7	14	28	5.0	11.6	2	14%	4	14%
# 8	14	28	3.2	11.1	2	14%	4	14%
# 9	8	16	6.7	11.9	0	0%	0	0%
#10	8	16	6.4	11.6	0	0%	0	0%
#11	6	12	6.0	10.2	0	0%	0	0%
#12	6	12	5.7	10.5	1	17%	2	17%

Note: 1/ Alyeska Seafoods. 1992. Dissolved oxygen monitoring in Unalaska Bay, Sept. 1-14, 1992.
2/ Alyeska Seafoods. 1993. Dissolved oxygen monitoring in Unalaska Bay, Sept. 1-14, 1993.
3/ Alyeska Seafoods. 1994. Dissolved oxygen monitoring in Unalaska Bay, Aug. 31- Sept. 13, 1994.
4/ Reference station #13 located off of Devilfish Point, Unalaska Bay.

Table 2. Amounts of seafood processed and biochemical oxygen demand (BOD5) and total suspended solids (TSS) discharged to Greater Unalaska Bay in the months July through October of 1993 and 1994[1,2,3].

Facility, NPDES permit, and Processing Capacity[4]	Time Period	Seafood Processed (lbs/day)		BOD5 Discharge (lbs/day)		TSS Discharge (lbs/day)	
		Average	Maximum	Average	Maximum	Average	Maximum
ALYESKA SEAFOODS,	7/93	103,876	301,640	n.a.	n.a.	n.a.	n.a.
	8/93	926,877	1,376,620	n.a.	n.a.	n.a.	n.a.
permit no. AK-000027-2;	9/93	1,249,719	1,515,807	n.a.	n.a.	n.a.	n.a.
	10/93	830,114	1,385,510	n.a.	n.a.	n.a.	n.a.
fish: 2,000,000 lbs/day							
crab: 500,000 lbs/day	7/94	70,797	226,280	e. 4,697	e. 14,686	n.a.	n.a.
meal: 1,400,000 lbs/day	8/94	1,227,036	1,696,956	e. 148,202	e. 232,350	76,660	132,176
	9/94	1,346,138	1,541,910	147,290	192,289	71,352	138,874
	10/94	434,507	1,755,902	82,007	95,454	45,088	61,795
UNISEA,	7/93	4,400	456,457	n.a.	n.a.	n.a.	n.a.
	8/93	1,284,567	3,025,742	258,116	429,893	155,365	334,257
permit no. AK-002865-7;	9/93	2,847,371	3,192,283	282,609	569,376	124,881	151,603
	10/93	610,946	3,266,562	221,415	221,415	137,186	137,186
fish: 3,500,000 lbs/day							
crab: 300,000 lbs/day	7/94	190,021	2,023,044	27,122	35,752	16,865	22,314
meal: 1,600,000 lbs/day	8/94	1,370,857	3,173,745	261,282	388,853	113,150	140,846
	9/94	2,865,665	3,320,315	303,153	304,870	122,405	153,278
	10/94	703,908	3,341,534	98,940	246,243	41,013	109,857
DUTCH HARBOR	7/93	0	0	0	0	0	0
SEAFOODS,	8/93	0	0	0	0	0	0
	9/93	0	0	0	0	0	0
permit no. AK-002842-8;	10/93	0	0	0	0	0	0
fish: 80,000 lbs/day	7/94	e. 0	0	0	0	0	0
crab: 100,000 lbs/day	8/94	0	0	0	0	0	0
meal: 0 lbs/day	9/94	0	0	0	0	0	0
	10/94	e. 0	0	0	0	0	0
ROYAL ALEUTIAN	7/93	m. 202,619	n.a.	n.a.	n.a.	n.a.	n.a.
SEAFOODS,	8/93	m. 740,108	n.a.	n.a.	n.a.	n.a.	n.a.
	9/93	m. 349,286	n.a.	n.a.	n.a.	n.a.	n.a.
permit no. AK-002618-2;	10/93	m. 200,797	n.a.	n.a.	n.a.	n.a.	n.a.
fish: 150,000 lbs/day	7/94	m. 499,281	n.a.	n.a.	n.a.	n.a.	n.a.
crab: 160,000 lbs/day	8/94	m. 476,385	n.a.	n.a.	n.a.	n.a.	n.a.
meal: 0 lbs/day	9/94	m. 547,447	n.a.	n.a.	n.a.	n.a.	n.a.
	10/94	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
QUEEN FISHERIES,	7/93	0	n.a.	n.a.	n.a.	0	0
	8/93	m. 143,343	n.a.	n.a.	n.a.	n.a.	n.a.
permit no. AK-002025-7;	9/93	m. 116,845	n.a.	n.a.	n.a.	m. 43,232	n.a.
	10/93	n.a.	n.a.	n.a.	n.a.	0	0
fish: 74,000 lbs/day							
crab: 180,000 lbs/day	7/94	m. 23,000	n.a.	n.a.	n.a.	n.a.	n.a.
meal: 0 lbs/day	8/94	18,802	75,752	n.a.	n.a.	1,689	1,770
	9/94	m. 619,500	n.a.	n.a.	n.a.	1,870	2,426
	10/94	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WESTWARD SEAFOODS,	7/93	70,000	195,000	343	788	514	2,598
	8/93	1,644,000	1,826,000	84,495	148,462	27,419	60,849
permit no. AK-004978-6;	9/93	1,761,000	2,293,000	87,146	230,710	55,334	107,273
	10/93	1,810,000	2,206,000	60,700	101,563	36,102	83,184
fish: 2,156,000 lbs/day							
crab: 176,000 lbs/day	7/94	82,000	107,000	1,539	3,509	189	364
meal: 880,000 lbs/day	8/94	1,389,000	2,058,000	70,194	155,637	28,227	53,878
	9/94	1,960,000	n.a.	57,149	116,193	27,350	35,357
	10/94	1,373,000	n.a.	48,738	81,650	25,165	39,529

Note: 1/ Values are based upon data submitted to EPA by seafood processing facilities permitted under NPDES in Discharge Monitoring Reports.
2/ Data for 1993 and 1994 were utilized to reflect the current management regime of fishing seasons for pollock and other target species.
3/ "n.a." indicates that data was "not available" in the Discharge Monitoring Report (DMR).
4/ Processing capacity is based upon data in the NPDES applications submitted by the permittees.
"e" Designates estimates based on best available information within the record of DMRs for a facility.
"m" Designates monthly level of production which, lacking information on the number of processing days, could not be converted to daily values.

Table 3
Published Values for Selected Water Quality Model Parameters and Constants

Parameter	Published Range	Units	Source
Deoxygenation Rate at 20°C, k_D	0.16 - 0.21	day^{-1}	(Ref: EPA, 1993, Part A) Based on values used in Potomac Estuary Model.
Reaeration Rate at 20°C, k_2	0.23-0.35	day^{-1}	(Ref: Tchobanoglous and Schroeder, 1985) Value for sluggish streams and large lakes.
Sediment Oxygen Demand, SOD	0.07 - 1.5 0.2 - 4.0	gm/m^2-day	(Ref: Tchobanoglous and Schroeder, 1985) Oxygen demand for sediments ranging from mineral soils to estuarine mud. (Ref: EPA, 1993 Part A) Based on values used in Potomac Estuary Model.
Horizontal Dispersion Coefficient, E_H	6 - 720 10 - 1500	m^2/s	(Ref: Tchobanoglous and Schroeder, 1985) Tidal dispersion coefficients for selected estuaries. (Ref: Fischer, et al. 1979) Observed longitudinal dispersion coefficients in estuaries.

Table 4.
Unalaska Bay Water Quality Model Parameters and Constants

Parameter	Value Used	Units
Water Temperature, T	8.2 - 9.0 (top) 5.0 - 6.5 (bottom)	°C
Water Salinity, S	26 - 32 (top) 32 (bottom)	g/L
Reaeration Rate at 20°C, k_2	0.30	day^{-1}
Deoxygenation Rate at 20°C, k_D	0.21	day^{-1}
Sediment Oxygen Demand, SOD	0.0 (top layer) 0.5 - 3.0 (bottom)	gm/m^2-day
Horizontal Dispersion Coefficient, E_H	30	m^2/s
Vertical Dispersion Coefficient, E_V	0.00015	m^2/s
Boundary Condition for BOD-ultimate (cells 1-4 and 100-103)	1.2	mg/L
Boundary Condition for DO (cells 1-4 and 100-103)	12 (top) 10 (bottom)	mg/L

Table 5. Statistical Information on Ambient Levels of Dissolved Oxygen in the Upper 50% of the Water Column in the Alyeska Seafoods Study of Sept. 1994.

Station	Parameter	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 6	Visit 7	Visit 8	Visit 9	Visit 10	Visit 11	Visit 12	Visit 13	Visit 14
Stations #1-8, WASP cell #61	MIN	8.30	6.58	5.45	3.10	6.26	2.97	1.47	2.77	3.21	5.02	2.22	4.24	7.42	5.88
	MAX	10.16	10.00	9.25	10.53	11.20	11.14	13.19	10.64	7.84	7.26	7.27	8.02	10.27	7.56
	MEDIAN	9.32	7.97	8.00	9.65	9.39	10.58	11.26	10.09	5.57	6.43	6.34	6.33	9.38	7.22
	AVG	9.28	8.11	7.75	9.14	9.17	9.58	9.32	8.68	5.75	6.33	5.70	6.26	9.22	7.17
	AVEDEV	0.35	0.70	0.83	0.97	0.70	1.61	2.89	1.93	0.99	0.27	1.00	0.49	0.31	0.12
	STDS	0.45	0.86	1.01	1.38	1.00	2.08	3.32	2.24	1.21	0.38	1.17	0.67	0.46	0.21
	VARS	0.20	0.74	1.03	1.91	1.00	4.35	11.01	5.00	1.47	0.14	1.38	0.46	0.21	0.04
	KURTOSIS	-0.38	-0.59	-0.52	5.15	1.94	1.75	-0.62	-0.32	-0.79	2.01	-0.15	1.60	4.42	20.03
	SKEWNESS	-0.17	0.37	-0.44	-2.22	-1.46	-1.73	-0.95	-1.01	0.26	-1.17	-0.94	-0.29	-1.91	-3.74
Station #9 WASP cell #41	MIN				8.43	5.99	5.90	6.71	7.24	6.95	5.85	6.80			
	MAX				10.22	9.99	11.19	12.14	11.49	7.93	7.73	7.57			
	MEDIAN				9.77	9.27	7.92	7.86	8.39	7.44	6.72	6.95			
	AVG				9.45	8.85	8.72	9.21	9.16	7.40	6.87	7.04			
	AVEDEV				0.63	1.06	1.56	1.83	1.29	0.25	0.46	0.18			
	STDS				0.71	1.23	1.73	1.99	1.48	0.30	0.56	0.22			
Station #10 WASP cell #43	MIN				9.95	9.72	10.39	11.67	11.42	7.08	6.45	6.78			
	MAX				10.20	9.83	10.61	12.02	11.59	7.14	6.52	6.85			
	MEDIAN				10.06	9.79	10.46	11.67	11.51	7.11	6.48	6.80			
	AVG				10.06	9.78	10.48	11.76	11.51	7.11	6.48	6.81			
	AVEDEV				0.08	0.03	0.07	0.13	0.07	0.02	0.03	0.02			
	STDS				0.11	0.05	0.10	0.17	0.08	0.03	0.04	0.03			
Station #11 WASP cell #59	MIN	4.28	6.40	5.19									5.70	8.14	8.19
	MAX	9.81	9.78	10.22									8.15	9.63	8.52
	MEDIAN	9.66	9.18	8.92									6.31	9.44	8.35
	AVG	8.54	8.92	8.37									6.65	9.11	8.34
	AVEDEV	1.59	0.73	1.51									0.74	0.45	0.11
	STDS	2.07	1.04	1.75									0.88	0.52	0.12
Station #12 WASP cell #58	MIN	8.17	6.83	5.05									5.67	6.63	7.32
	MAX	9.62	11.00	10.50									8.95	9.38	8.48
	MEDIAN	9.03	9.52	9.21									8.49	7.19	8.08
	AVG	9.05	9.60	8.89									7.92	7.66	8.05
	AVEDEV	0.42	0.85	1.02									1.01	0.88	0.22
	STDS	0.47	1.09	1.48									1.24	1.03	0.30
Reference Station, #13 WASP cell #22	MIN	9.21	9.27	9.82	9.31	7.68	10.06	8.17	6.60	8.49	8.24	7.52	8.11	8.71	8.51
	MAX	11.29	10.46	10.31	10.61	9.20	10.47	9.80	8.26	9.95	9.93	8.25	8.68	9.54	8.86
	MEDIAN	9.03	8.11	8.00	9.31	7.79	9.58	8.47	7.24	7.08	6.45	6.80	6.31	8.14	8.05
	AVG	6.34	6.17	6.02	6.49	5.95	6.65	6.93	6.15	5.07	4.96	4.66	5.11	6.03	5.91
	AVEDEV	4.14	3.83	3.72	4.07	3.69	4.08	4.08	3.71	3.30	3.15	3.16	3.07	3.70	3.84
	STDS	4.42	4.21	4.01	4.39	4.10	4.40	4.64	4.26	3.53	3.43	3.34	3.36	4.09	4.82
All Alyeska Stations of 9/94	MIN	4.277	6.399	5.052	3.102	5.988	2.975	1.467	2.773	3.209	5.023	2.216	4.241	6.628	5.879
	MAX	11.290	11.004	10.498	10.624	11.198	11.191	13.190	11.587	9.953	9.932	8.245	8.948	10.268	8.859
	MEDIAN	9.262	8.270	8.094	9.632	9.180	10.389	9.350	8.676	6.072	6.451	6.535	6.350	9.256	7.275
	AVG	9.224	8.613	8.199	9.307	9.092	9.521	9.350	8.808	6.372	6.656	6.153	6.781	8.889	7.566
	AVEDEV	0.508	0.967	1.108	0.832	0.784	1.553	2.516	1.737	1.272	0.538	0.973	0.934	0.684	0.506
	STDS	0.840	1.137	1.345	1.239	1.026	1.939	2.945	2.075	1.489	0.872	1.227	1.125	0.873	0.578
	VARS	0.706	1.292	1.809	1.535	1.053	3.761	8.672	4.306	2.218	0.760	1.505	1.265	0.762	0.334
	KURTOSIS	15.576	-0.860	-0.653	7.105	1.058	1.528	-0.224	0.002	-0.506	4.671	0.432	-0.682	0.725	-0.536
	SKEWNESS	-2.887	0.136	-0.304	-2.439	-1.227	-1.587	-0.946	-0.903	0.185	1.996	-1.014	0.436	-1.412	0.470

Table 6.

Dissolved Oxygen Monitoring Program
Station Locations of Sampling Sites
Alyeska Seafoods
8/31/94-9/13/94

Station Number	Station Description	Target LORAN-C Readings[1]		Target Station Depth (ft)
		Latitude (north)	Longitude (west)	
DH01	Located directly over outfall, about 450 feet from shore.	53° 53.69'	166° 33.91'	55
DH02	Located 50 m offshore of outfall, west, bearing 270° magnetic.	53° 53.72'	166° 33.92'	82
DH03	Located 100 m south from outfall, south bearing 195° magnetic.	53° 53.63'	166° 33.98'	75
DH04	Located 100 m southwest from outfall, south bearing 235° magnetic.	53° 53.68'	166° 33.99'	88
DH05	Located 100 m west from outfall, south bearing 280° magnetic.	53° 53.74'	166° 33.98'	88
DH06	Located 100 m northwest from outfall, south bearing 340° magnetic.	53° 53.76'	166° 33.89'	59
DH07	Located 100 m north from outfall, south bearing 020° magnetic.	53° 53.73'	166° 33.81'	46
DH08	Located 50 m inshore of outfall, east, bearing 110° magnetic.	53° 53.67'	166° 33.88'	36
DH09	Located 500 m northwest of outfall.	53° 54.07'	166° 33.86'	122
DH10	Located 1000 m northwest of outfall.	53° 54.35'	166° 34.04'	39
DH11	Located 500 m southwest of outfall, .25 miles northwest of Cave Rock.	53° 53.56'	166° 34.49'	83
DH12	Located 1000 m soutwest of outfall, located 500 m west of Dutch Harbor sewage outf	53° 53.40'	166° 34.49'	170
DH13	Reference station selected by ADEC located 150 m off Devilfish Point.	53° 53.47'	166° 36.61'	65

[1] - LORAN-C readings are recorded in degrees, minutes and 1/100's of minutes.

Table 7. Estimations of Average Concentrations of Ambient Dissolved Oxygen within Cells of Receiving Water in South Unalaska Bay Using a WASP Computer Model of Circulation and Water Quality.

Input Filename (*.inp)	Reaeration Rate (per day)	Horizontal Dispersion Coefficient (m2/sec)	Vertical Dispersion Coefficient (m2/sec)	D.O., Cell # 8 (mg/L)	D.O., Cell # 22 (mg/L)	**D.O., Cell # 61 (mg/L)**	D.O., Cell # 42 (mg/L)	D.O., Cell # 141 (mg/L)	D.O., Cell # 43 (mg/L)
B_25AVE1	0.25	25	0.00010	9.73	8.09	7.51	7.53	8.19	7.69
B_25AVE3	0.25	25	0.00030	9.73	8.19	7.65			7.81
B_25AVE5	0.25	25	0.00050	9.71	8.22	7.69	7.71	7.78	7.84
B_25AV10	0.25	25	0.00100	9.69	8.24	7.73	7.75	7.72	7.87
B_30AVE1	0.25	30	0.00010	9.79	8.24	7.77	7.80	8.31	7.92
B_30AVE3	0.25	30	0.00030	9.78	8.33	7.89	7.91	8.05	8.03
B_30AVE5	**0.25**	**30**	**0.00050**	9.77	8.36	**7.95**	7.92	8.05	8.03
B_30AV10	0.25	30	0.00100	9.74	8.37	7.98	7.95	8.07	8.01
C_25AVE1	0.30	25	0.00010	9.71	8.25	7.68	7.70	8.23	7.84
C_25AVE3	0.30	25	0.00030	9.70	8.33	7.79	7.82	7.94	7.94
C_25AVE5	0.30	25	0.00050	9.69	8.35	7.83			7.97
C_25AV10	0.30	25	0.00100	9.67	8.36	7.86	7.88	7.82	7.98
C_30AVE1	0.30	30	0.00010	9.76	8.38	7.92	7.94	8.33	8.85
C_30AV1H	**0.30**	**30**	**0.00015**	9.76	8.40	**7.96**	7.98	8.24	8.09
C_30AVE3	0.30	30	0.00030	9.75	8.45	8.01	8.03	8.10	8.14
C_30AVE5	0.30	30	0.00050	9.74	8.46	8.04	8.06	8.03	8.16
C_30AV10	0.30	30	0.00100	9.72	8.48	8.07			8.17
D_25AVE1	0.35	25	0.00010	9.69	8.37	7.82	7.84	8.25	7.96
D_25AVE3	0.35	25	0.00030	9.68	8.44	7.92	7.94	7.99	8.05
D_25AVE5	0.35	25	0.00050	9.67	8.46	7.95	7.96	7.92	8.07
D_25AV7H	**0.35**	**25**	**0.00075**	9.66	8.46	**7.96**	7.98	7.90	8.08
D_25AV10	0.35	25	0.00100	9.66	8.47	7.97	7.99	7.90	8.08
D_30AVE1	0.35	30	0.00010	9.73	8.48	8.04	8.06	8.35	8.16
D_30AV1H	0.35	30	0.00015	9.73	8.51	8.07	8.09	8.27	8.19
D_30AVE3	0.35	30	0.00030	9.73	8.54	8.12	8.14	8.14	8.23
D_30AVE5	0.35	30	0.00050	9.72	8.56	8.56	8.56	8.56	8.56
D_30AV10	0.35	30	0.00100	9.70	8.56	8.16	8.18	8.08	8.25

Table 8. Estimation of Average and Minimum Concentrations of Ambient Dissolved Oxygen for the Upper One Meter and for Cell #61 of South Unalaska Bay Based upon a WASP Computer Model of Circulation and Water Quality.

Notes:

1.64 = Z(normal curve, one-tailed), 95% confidence interval (CI)
2.33 = Z(normal curve, one-tailed), 99% confidence interval (CI)
9.59 = DO saturation concentration at 8.7 degrees centigrade and 31 ppt (mg/L)
-0.89 = DO average deficit in upper one meter of the water column of Cell #61 for calibration conditions (mg/L)
8.70 = DO average concentration in upper one meter of the water column of Cell #61 for calibration conditions (mg/L)
2.30 = standard deviation (SD) for the DO average concentration in upper one meter of the water column of Cell #61 for calibration conditions (mg/L)
0.32 = coefficient of variation (CV) for the DO average deficit in upper one meter of the water column of Cell #61 for calibration conditions (mg/L)
-1.63 = DO average deficit in Cell #61 for calibration conditions (mg/L)
7.96 = DO average concentration in Cell #61 for calibration conditions (mg/L)
1.83 = ratio of DO average concentration in Cell #61 to DO average concentration in upper one meter of Cell #61

SD	DO, average deficit to 1 m (mg/L)	**DO, average concentration to 1 m (mg/L)**	DO, minimum deficit @ 95% CI to 1 m (mg/L)	DO, minimum concentration @ 95% CI to 1 m (mg/L)	DO, minimum deficit @ 99% CI to 1 m (mg/L)	DO, minimum concentration @ 99% CI to 1 m (mg/L)	**DO, average concentration in cell #61 (mg/L)**
2.30	-0.89	**8.70**	-4.66	4.93	-6.25	3.34	**7.96**
1.93	-0.84	8.75	-4.01	5.58	-5.34	4.25	8.05
1.82	-0.79	8.80	-3.77	5.82	-5.03	4.56	8.14
1.70	-0.74	8.85	-3.53	6.06	-4.70	4.89	8.24
1.59	-0.69	8.90	-3.30	6.29	-4.39	5.20	8.33
1.47	-0.64	8.95	-3.05	6.54	-4.07	5.52	8.42
1.36	-0.59	9.00	-2.82	6.77	-3.76	5.83	8.51
1.24	-0.54	9.05	-2.57	7.02	-3.43	6.16	8.60
1.13	-0.49	9.10	-2.34	7.25	-3.12	6.47	8.69
1.01	-0.44	9.15	-2.10	7.49	-2.79	6.80	8.78
0.90	-0.39	9.20	-1.87	7.72	-2.49	7.10	8.88
0.78	-0.34	9.25	-1.62	7.97	-2.16	7.43	8.97
0.67	-0.29	9.30	-1.39	8.20	-1.85	7.74	9.06
0.55	-0.24	9.35	-1.14	8.45	-1.52	8.07	9.15
0.44	-0.19	9.40	-0.91	8.68	-1.22	8.37	9.24
0.32	-0.14	9.45	-0.66	8.93	-0.89	8.70	9.33
0.21	-0.09	9.50	-0.43	9.16	-0.58	9.01	9.43
0.09	-0.04	9.55	-0.19	9.40	-0.25	9.34	9.52
0.00	0.00	9.59	0.00	9.59	0.00	9.59	9.59
1.73	-0.75	**8.84**	-3.59	**6.00**			**8.22**
1.29	-0.56	9.03			-3.59	6.00	8.57

Table 9. Estimation of Average Concentrations of Ambient Dissolved Oxygen within Cells in South Unalaska Bay for Different Discharge Levels of Biochemical Oxygen Demand (BOD-5 day and BOD-ultimate) Using a WASP Computer Model of Circulation and Water Quality.

BOD5 Wasteload (lbs/day)	BOD-ult Wasteload (lbs/day)	DO Level in Cell #22 (mg/L)	DO Level in Cell #58 (mg/L)	DO Level in Cell #61 (mg/L)	DO Level in Cell #62 (mg/L)	DO Level in Cell #42 (mg/L)	DO Level in Cell #43 (mg/L)	UniSea's BOD5 Wasteload in Cell # 58 (lbs/day)	Alyeska Seafood's BOD5 Wasteload in Cell # 61 (lbs/day)	Royal Aleutian Seafood's BOD5 Wasteload in Cell # 62 (lbs/day)	Queen Fisheries' BOD5 Wasteload in Cell # 62 (lbs/day)	Unalaska WWTP BOD5 Wasteload in Cell # 59 (lbs/day)
502,135	772,397	8.26	7.80	7.76	7.77	7.78	7.91	333,485	162,029	1,846	1,846	2,929
457,087	703,103	8.36	7.93	7.89	7.91	7.92	8.03	303,168	147,298	1,846	1,846	2,929
412,042	633,813	8.46	8.06	8.03	8.04	8.05	8.16	272,852	132,569	1,846	1,846	2,929
366,994	564,519	8.56	8.19	8.17	8.18	8.19	8.29	242,534	117,839	1,846	1,846	2,929
350,951	539,842	8.60	8.24	**8.22**	8.23	8.24	8.33	**231,737**	**112,593**	**1,846**	**1,846**	**2,929**
321,948	495,228	8.66	8.33	8.31	8.32	8.33	8.42	212,218	103,109	1,846	1,846	2,929
276,902	425,938	8.77	8.46	8.45	8.46	8.46	8.54	181,902	88,379	1,846	1,846	2,929
231,854	356,644	8.87	8.59	8.59	8.59	8.60	8.67	151,585	73,648	1,846	1,846	2,929
186,807	287,351	8.97	8.72	8.73	8.73	8.74	8.84	121,267	58,919	1,846	1,846	2,929
150,414	231,371	9.05	8.82	8.84	8.84	8.85	8.90	96,772	47,021	1,846	1,846	2,929
141,761	218,060	9.07	8.85	8.86	8.87	8.87	8.93	90,950	44,190	1,846	1,846	2,929
96,714	148,768	9.17	8.98	9.00	9.01	9.01	9.05	60,633	29,460	1,846	1,846	2,929

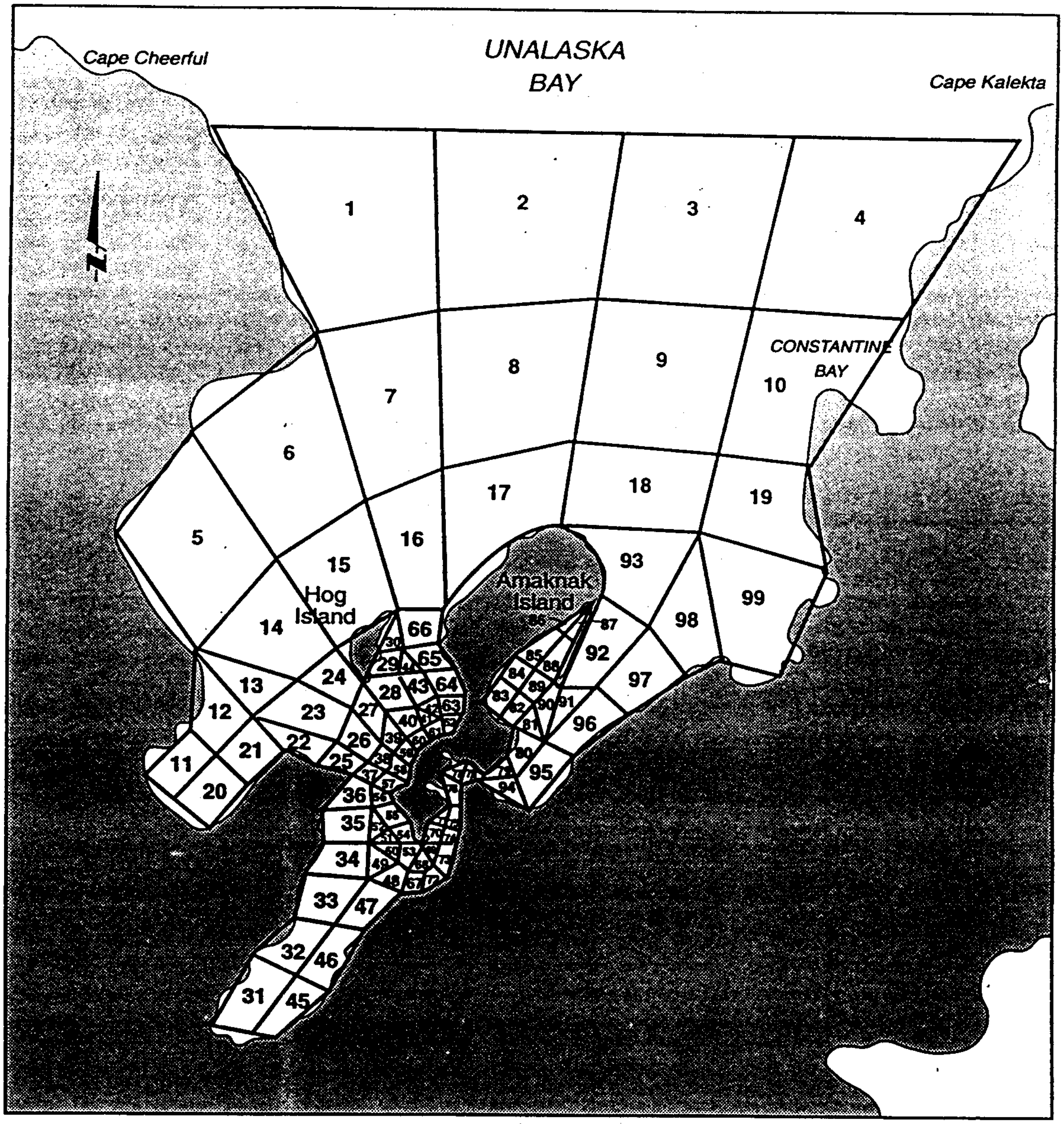


Figure 1

Model Grid For the Unalaska Bay Hydrodynamic and Water Quality Models

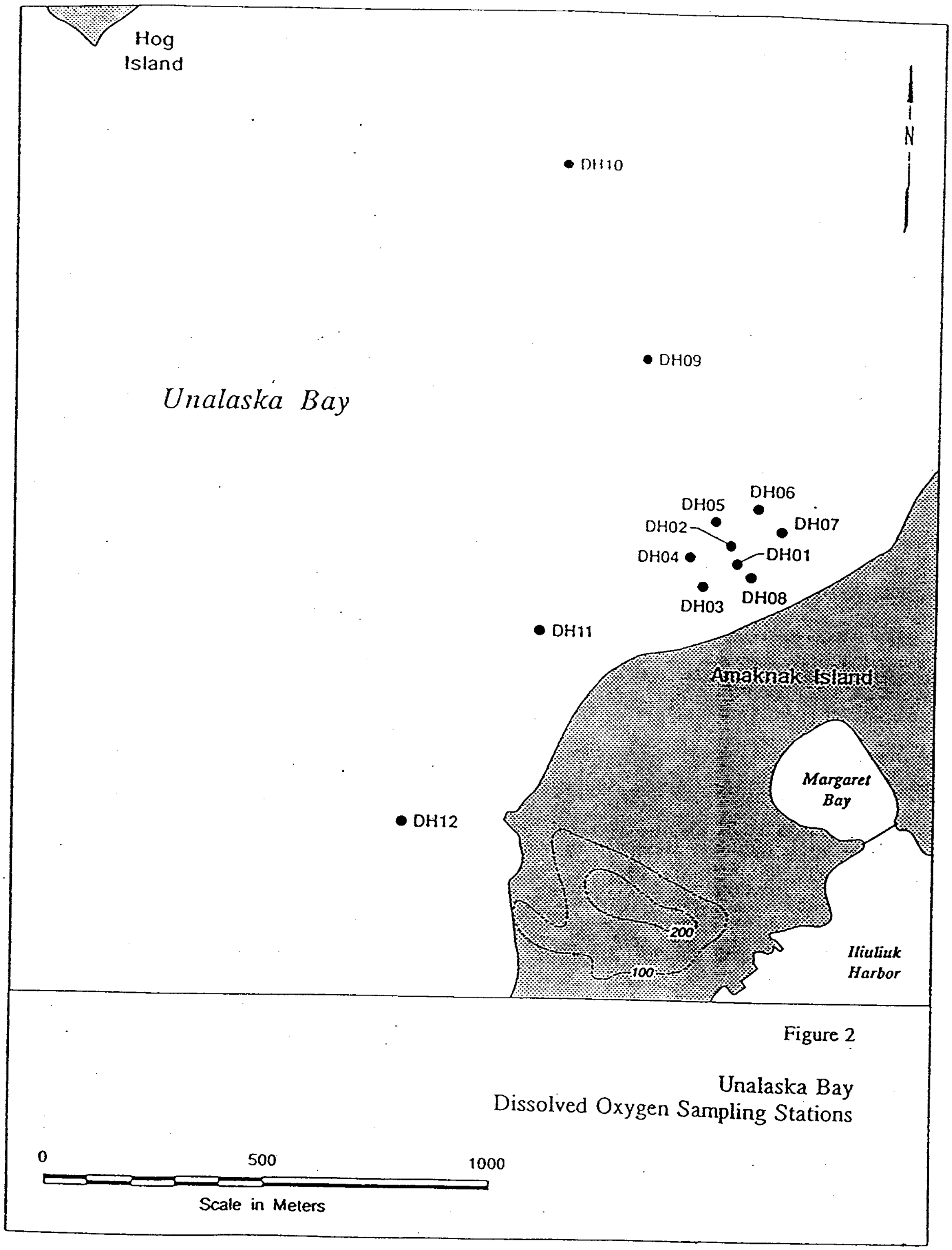


Figure 2

Unalaska Bay
Dissolved Oxygen Sampling Stations

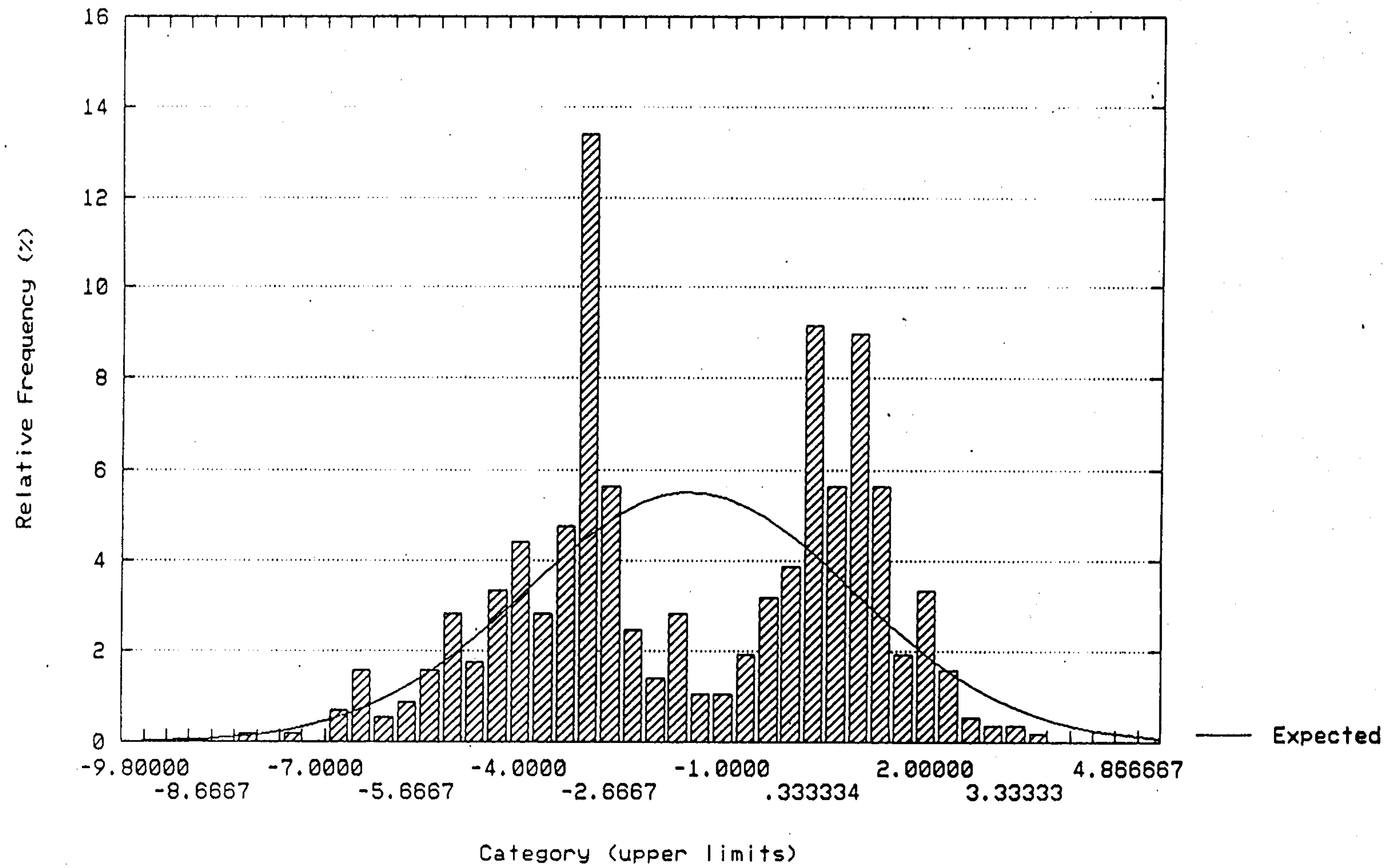


Figure 3. The relative frequency distribution of the difference between ambient concentrations of dissolved oxygen and the saturation concentration of dissolved oxygen for measurements taken in the WASP "calibration cell" #61 during the "calibration period" of August 31 through September 13, 1994 ($n = 568$; $\Delta DO_{ambient} = DO_{ambient} - DO_{saturation}$).

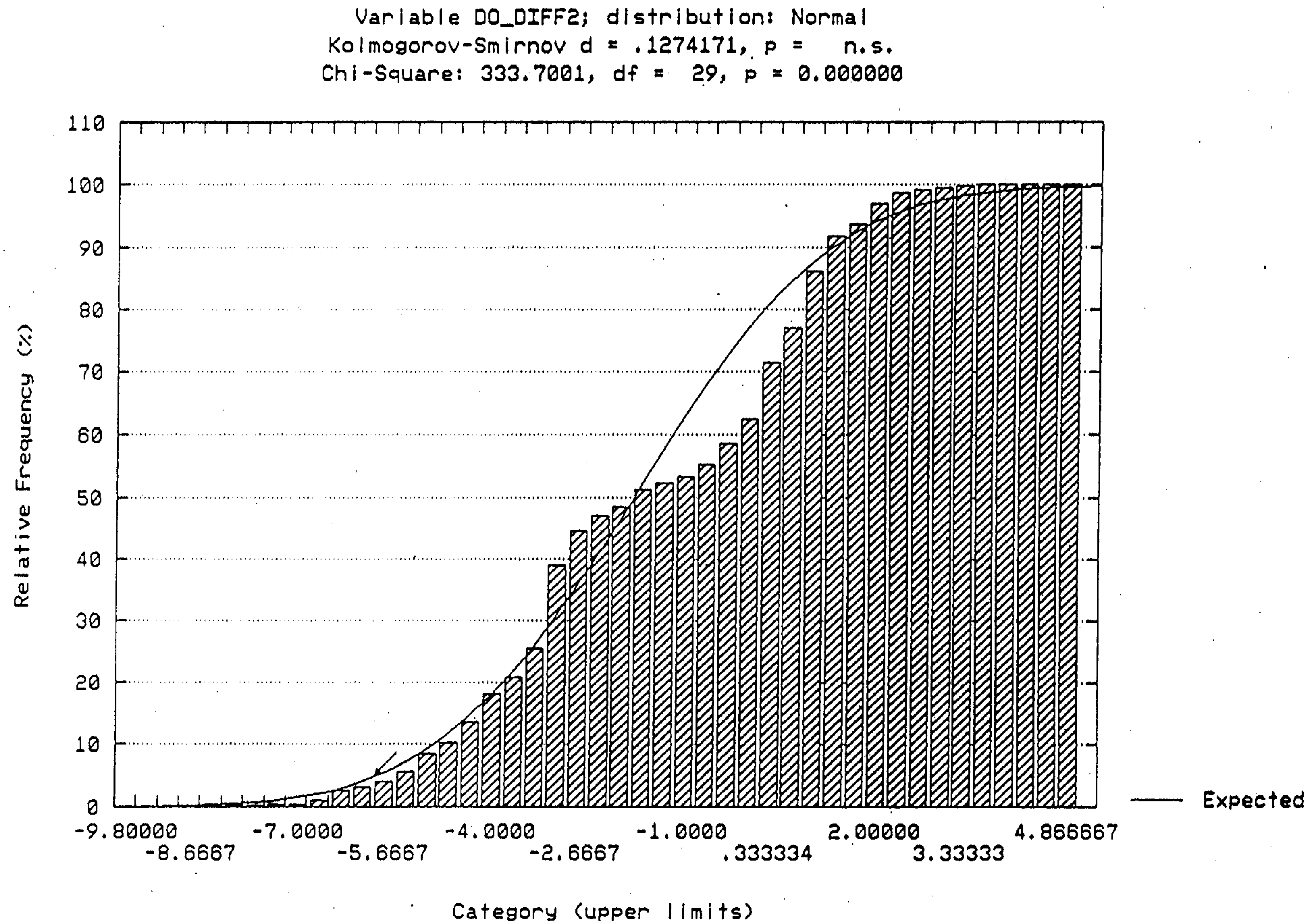
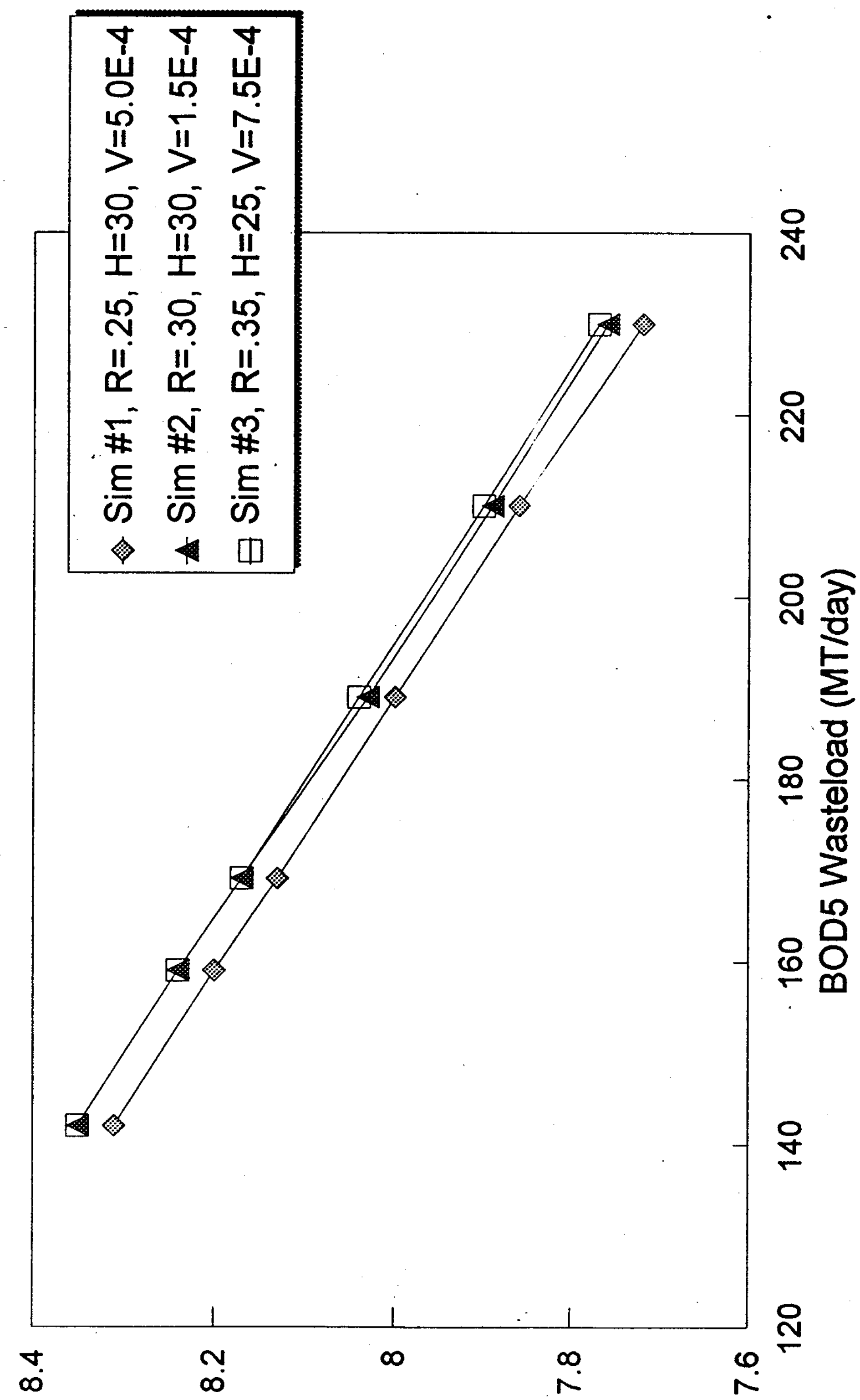


Figure 4. The cumulative relative frequency distribution of the difference between ambient concentrations of dissolved oxygen and the saturation concentration of dissolved oxygen for measurements taken in the one meter surface layer of WASP "calibration cell" #61 during the "calibration period" of August 31 through September 13, 1994 (n = 568; $\Delta DO_{ambient} = DO_{ambient} - DO_{saturation}$).

Figure 5. Effect of Varying BOD Wasteloads on DO
in Three WASP Simulations of Cell #61 in South Unalaska Bay



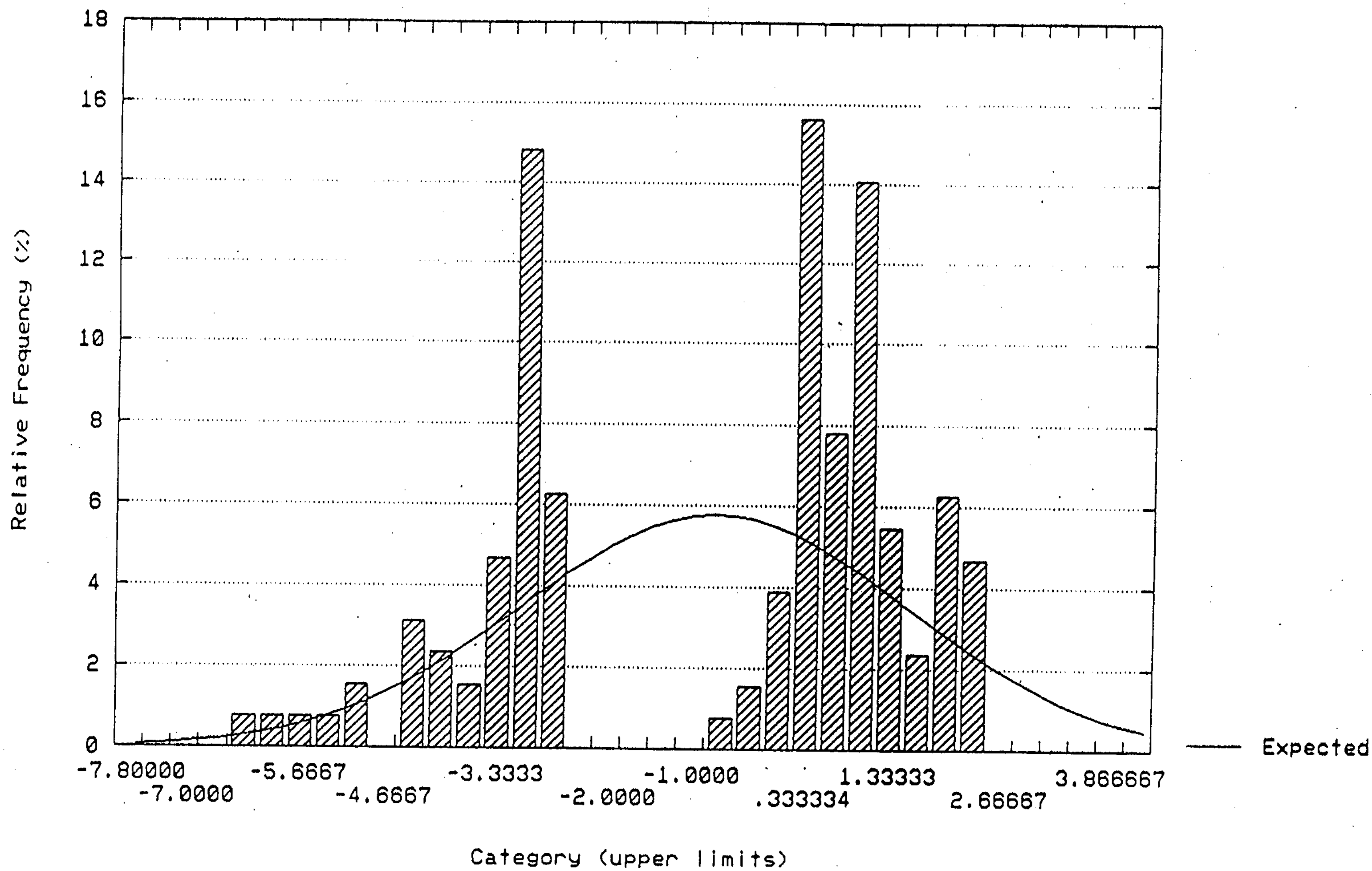


Figure 6. The relative frequency distribution of the difference between ambient concentrations of dissolved oxygen and the saturation concentration of dissolved oxygen for measurements taken in the one meter surface layer of WASP "calibration cell" #61 during the "calibration period" of August 31 through September 13, 1994 (n = 128; $\Delta DO_{ambient} = DO_{ambient} - DO_{saturation}$).

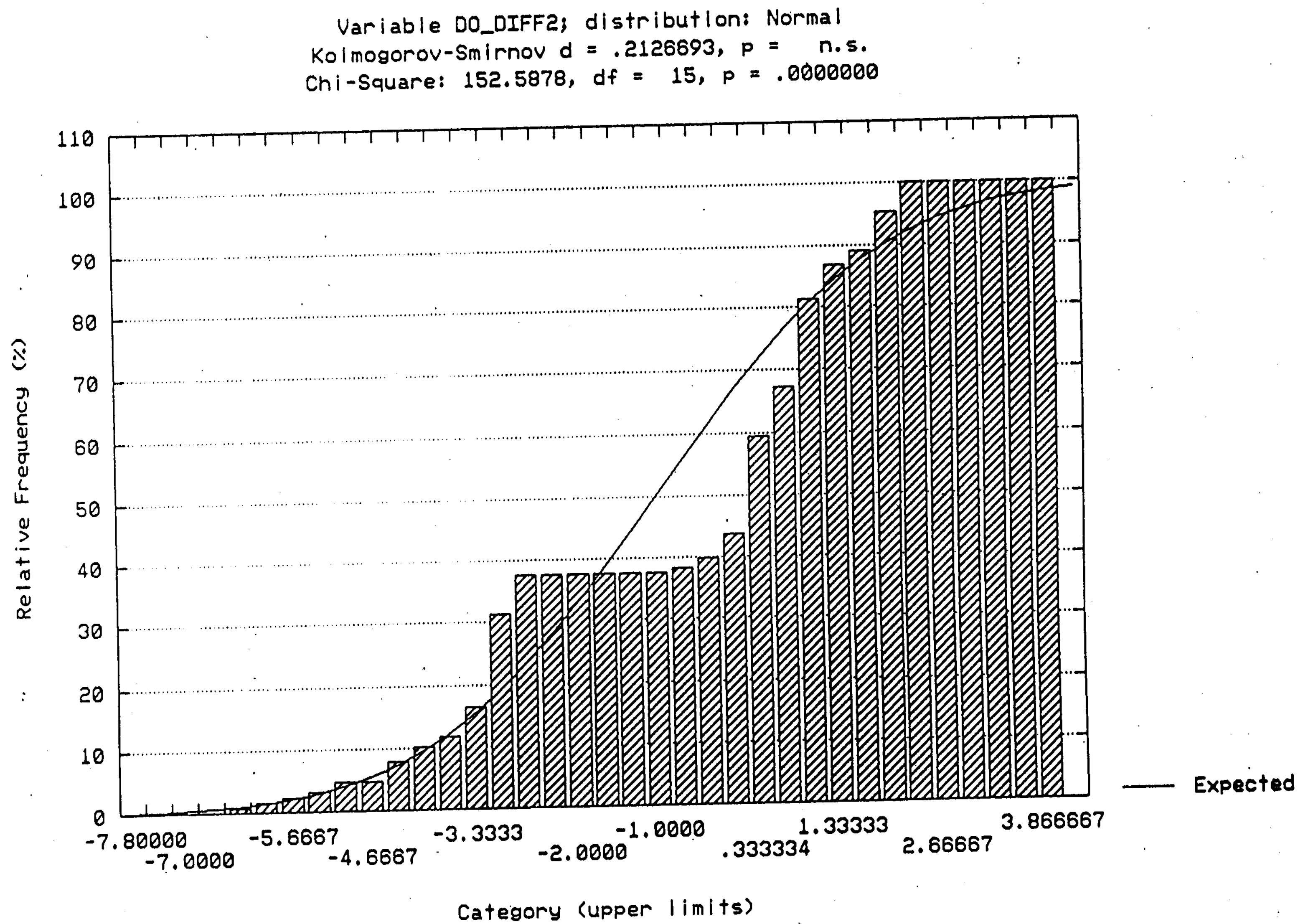


Figure 7. The cumulative relative frequency distribution of the difference between ambient concentrations of dissolved oxygen and the saturation concentration of dissolved oxygen for measurements taken in the WASP "calibration cell" #61 during the "calibration period" of August 31 through September 13, 1994 (n = 128; $\Delta DO_{ambient} = DO_{ambient} - DO_{saturation}$).

Circulation Study of Unalaska Bay and Contiguous Inshore Marine Waters

Submitted to

Harbor Circulation Study
Working Committee

Final Report

CH2M HILL
August 1994

Section 1
Introduction

1.1 Project Background

During the last decade, the Aleutian region has experienced unprecedented growth from the Americanization of the groundfish industry. In 1992, Unalaska was the top fishing port in the United States, with approximately 590,000 tons of groundfish and crab processed.

The increasing quantities of seafood processed and potential impacts of the waste discharged into Unalaska Bay have prompted the regulatory agencies to re-evaluate the cumulative and long-term impacts on water quality in the bay. However, before the impact on water quality could be assessed, it was essential to have an understanding of the hydrodynamic processes in the bay. Such an understanding is the first step in evaluating the capacity of the system to assimilate seafood processing waste.

This circulation study of Unalaska Bay and Contiguous Inshore Marine Waters (circulation study) was conducted to determine the hydrodynamic process in the bay. The study was performed in compliance with the National Pollutant Discharge Elimination System (NPDES) permits for the six main seafood processing companies in Unalaska: Queen Fisheries, Royal Aleutian, Dutch Harbor Seafoods, Westward Seafoods, Alyeska Seafoods, and UniSea. Each NPDES permit, under the section Effluent Limitation and Monitoring Requirements, specified that "The permittee shall conduct a study of the transport and fate of pollutants discharged into Unalaska Bay and Iliuliuk Harbor. The study shall include the field work necessary to adequately quantify the fate/transport mechanisms in these waters.... This requirement can be satisfied through participation in the local harbor management study."

Each of the six seafood processors chose to participate in this joint study to fulfill the requirements of the NPDES permits. In addition, the City of Unalaska and Environmental Protection Agency (EPA) contributed to the total pool of funds for the study. The location and waste discharge points of the six major shore based seafood processors and the City of Unalaska outfall are shown in Figure 1-1.

1.2 Project Organization and Participants

Under a memorandum of agreement, representatives from each of the six seafood processors and the City of Unalaska formed a working committee to oversee the circulation study. Joe Frazier of UniSea was the chairman of the committee, and the other members were Chuck Jensen of Queen Fisheries, Will Blades of Royal Aleutians, Winn Brindle of Alyeska, Dave Boisseau of Westward Seafoods, and John Bishop of the City of Unalaska, who also served as the client-designated representative. Burney Hill of EPA Region X and Robert Dolan of Alaska Department of Environmental Conservation (ADEC) were technical advisors to this working committee. CH2M HILL, an environmental consulting firm, was retained to perform the study.

The study plan approved by the working committee and EPA provided for periodic review of the field data collection plan and the modelling study plan. The EPA's participation and oversight in evaluation of various alternatives for the circulation and water quality modelling has been significant. Burney Hill of EPA Region X assisted in project planning and provided technical guidance.

1.3 Project Setting

Location

Unalaska Island is located west of Akutan Pass in the Aleutian Island chain approximately 850 miles southwest of Anchorage. Unalaska Bay and the contiguous marine waters are located at latitude 54.0°N, and longitude 166.5°W. The bay opens to the Bering Sea towards the north. Amaknak and Hog Islands are two significant land features in the bay. The City of Unalaska occupies the eastern shores of Iliuliuk Harbor and Captains Bay and extends across to the western shores of central Amaknak Island.

The project study area in Unalaska Bay is bounded by the bay's eastern, southern, and western shorelines and a line joining Capes Cheerful and Kalekta towards the north (Figure 1-2). The contiguous marine waters where field data collection was emphasized during the study include the inner Unalaska Bay, Captains Bay, Iliuliuk Bay, Iliuliuk Harbor, and Dutch Harbor. Other marine waters include Nateekan Bay, Broad Bay, Constantine Bay, and Summer Bay.

Oceanographic Conditions

Shoreline

The shoreline along the bay is formed mainly of steep cliffs, with a few narrow beaches. Several small and large semi-enclosed bays are found along edges that have traditionally provided a safe haven for ships during heavy and stormy seas. The shoreline facade is broken at several locations by seasonal streams and runoffs.

Bathymetry

The bathymetry of the region is dominated by several sills, which affect the exchange of water between smaller water bodies within Unalaska Bay. The largest sill is located at the mouth of the bay on Chelan Bank. A sill connects Eider Point with Amaknak Island, passing along the northern tip of Hog Island. This, together with the sill north of Illiuliuk Bay, forms a natural boundary between the outer and the inner bays. The other sills are along the two approaches to Captains Bay. These sills hinder free exchange of water between the respective water bodies.

The deepest waters are found in the area west of Hog Island, with an average depth of approximately 400 feet. The area east of Amaknak Island is shallower, with an average depth of approximately 90 feet. Captains Bay forms the southern portion of Unalaska bay and has an average depth of approximately 200 feet. Other contiguous water bodies—Broad Bay, Wide Bay, and Summer Bay—have wide openings towards Unalaska Bay and are relatively shallower, with average depths of approximately 60, 120, and 30 feet, respectively; Nateekin Bay and Constantine Bay have relatively narrower openings with average depths of 200 and 30 feet, respectively.

Wind

The Unalaska region experiences strong winds throughout the year. However, the wind patterns in the area have a strong seasonal component. The summer winds are generally from the south and are lighter than winter winds, which are predominantly from the north. The bay's northern opening and the long fetch over the Bering Sea allow the northerly winds to create higher swells and waves in the bay.

Tides

Historically the tidal data in the region have been obtained from Dutch Harbor, which is representative of the tides in Unalaska Bay. The tides in the bay are semi-diurnal, with a mean range of 2.2 feet and a diurnal range of 3.7 feet. Tidal elevations as high as 6.6 feet and as low as -2.7 feet have been recorded in Dutch Harbor (Harris, 1981).

1.4 Study Objectives and Scope

The overall goals of this study were to: (1) identify and explain the circulation patterns in Unalaska Bay and its contiguous nearshore waters as a basis for determining their capacity to disperse the wasteload from various wastewater discharges; and (2) provide a flexible modeling tool to be used to assess impacts of existing and future discharges to Unalaska Bay. This modeling tool had two parts:

- Circulation model to describe and predict the transport and fate of water and discharges within the bay
- Water quality model to describe and predict the fate and effects of wasteloads on the receiving waters.

The overall study goals were achieved by performing the following activities:

- Compile, verify, and analyze available current and wind data for Unalaska Bay

- Conduct season-specific simultaneous field data collection of currents, density conditions, and winds
- Develop a model grid consistent with study objectives
- Develop a model grid that would allow interfacing between hydrodynamic and water quality models
- Set up, calibrate, verify, and execute hydrodynamic models for selected tidal and wind conditions
- Set up and execute WASP5 models for selected tidal and wind conditions
- Provide tidal and wind-driven flow fields for a range of conditions for input to WASP5
- Provide the capability to generate flow field input for other conditions that might be identified in the future
- Provide a WASP5 model configuration set up for the entire Unalaska Bay system as defined by the study boundaries
- Provide capability within each of the model configuration to specify desired point-loading locations and values

The model simulations for characterization of existing impacts involved:

- Characterization of individual point source impacts from appropriate sources, which included seafood processors and municipal discharges
- Characterization of cumulative impacts from appropriate sources
- Description of the relationships between individual and cumulative impacts

1.5 Approach

The study methods used by CH2M HILL were based on our understanding of the needs of all involved groups. In developing the study methods, we recognized the need for consensus on both the approach and the acceptability of the final product. Therefore, the initial study plan provided opportunity for review and comment on the study at critical points in its development and implementation.

Field Studies

The field studies were intended to provide simultaneous and season-specific measurements of current speed and direction, density stratification conditions, tidal elevations, and winds at key locations within Unalaska and Captains Bays. These studies were designed to supplement existing hydrodynamic data and provide simultaneous data records for the selected locations. To determine seasonal variations in physical environmental conditions, field studies were conducted during the summer (July - August 1993), a long-term deployment spanning the period between summer and winter (August - December 1993), and the winter (January - February 1994).

Model Grid

A model grid was developed to meet the objectives of the study and satisfy the requirements of the numerical models. The study area was divided into a grid of 99 elements for circulation and water quality modeling. The number of elements in the model grid was restricted to allow the computations to be performed on a personal computer. The cell configuration was designed to provide for smaller cells and greater detail in the inner bay around outfalls and in constricted areas.

Hydrodynamic Modeling

Hydrodynamic modeling for this study was performed with RMA2, a finite element model developed by Resource Management Associates, Lafayette, California. The hydrodynamic model output was post-processed for input to WASP5 by using CH2M HILL-developed programs. The wind-driven current velocity profile predicted by RMA2 was adjusted during post-processing of the model output by using a functional form of the velocity profile.

Water Quality Modeling

EPA's WASP5 was used to simulate the water quality in the bay. This model was used to provide the following advantages:

- Available support within EPA and general acceptance and use by the regulatory community
- Existing linkage to kinetic submodels EUTRO5 and TOXI5 to address eutrophication/dissolved oxygen problems and toxic pollution problems
- The use of an existing platform on which other submodels and subroutines can be linked
- The ability to use output from a variety of hydrodynamic models depending on specific applications and physical situations

1.6 Model Limitations

Assumptions and limitations of the numerical models are discussed in the appropriate sections of this report. In general, the hydrodynamic model simulations were performed for representative tidal and wind conditions, and velocity profiles were generated at nearly 360 points distributed around the bay. The model was calibrated by using field data collected at 12 different locations in the bay, and the degree of confidence in model predictions for these location is high. The degree of confidence in velocity profiles predicted for other areas varies, particularly in areas where small-scale local effects are pronounced. The friction coefficients used to calibrate the model were held constant. Published values were used to determine water quality model parameters and constants.

The hydrodynamic model grid was designed to provide a description of the overall circulation patterns of Unalaska Bay. Smaller scale details of circulation were accounted for only in areas near waste discharges. The model grid was not designed to provide details of circulation on a small scale throughout the study area, although the grid may be modified for this purpose if desired in the future.

The scope of work for this study did not include formal calibration of the water quality model. Thus the results of the water quality simulation should be used only to assess relative, and not absolute, impacts on water quality. The modeling results are indicative of average water quality parameters found under average climatic and tidal conditions prevalent in Unalaska Bay. Extreme tidal or wind conditions were not simulated. However, to simulate conservative conditions, current profiles were computed for the average lowest winds recorded in a 60-hour period during the entire 7-month record. Computer simulations were performed to estimate impacts on water quality and flushing times under these conservative conditions.

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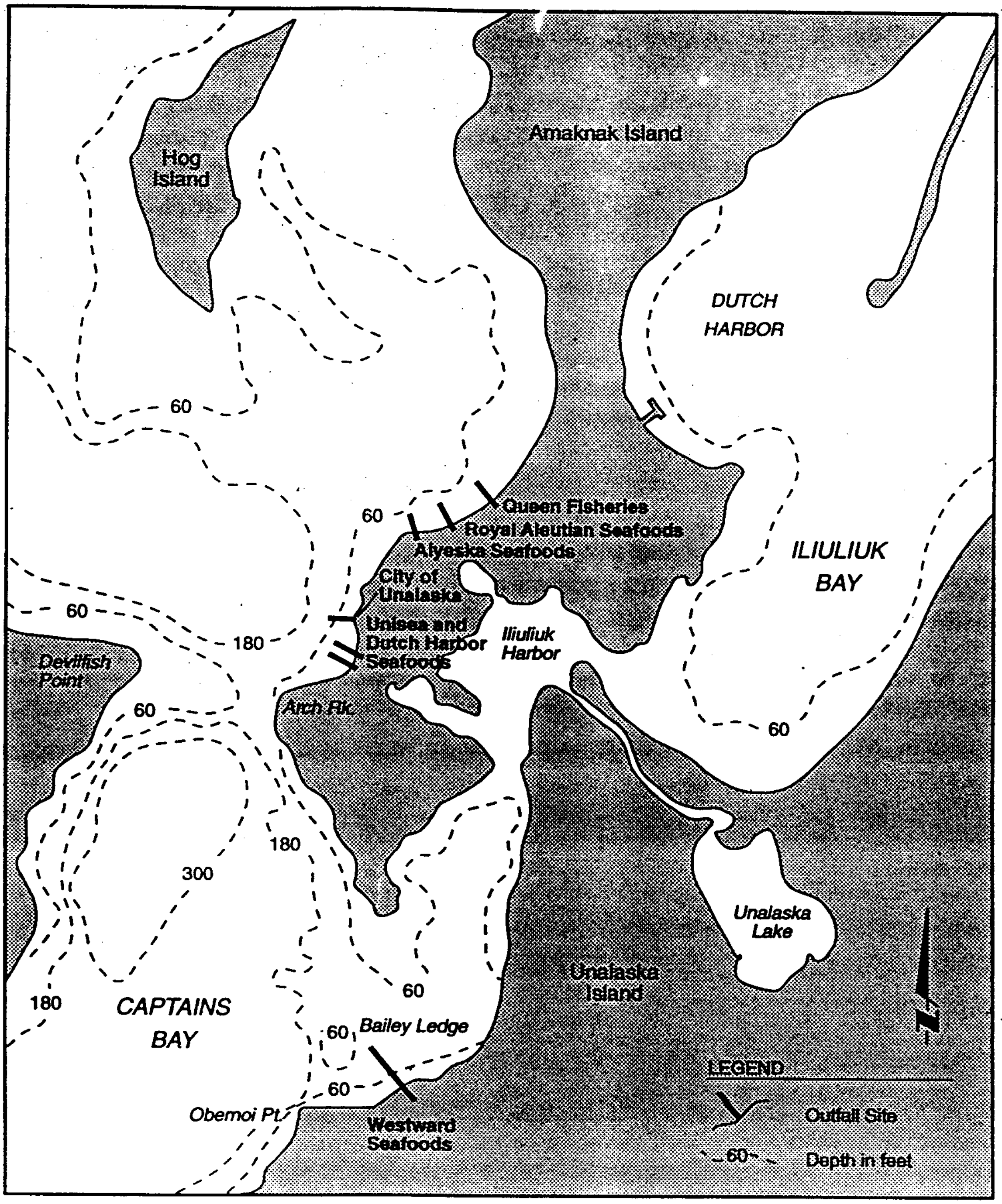

Note: Not to scale.

Figure 1-1

Seafood Processors and Outfall Locations in Unalaska Bay

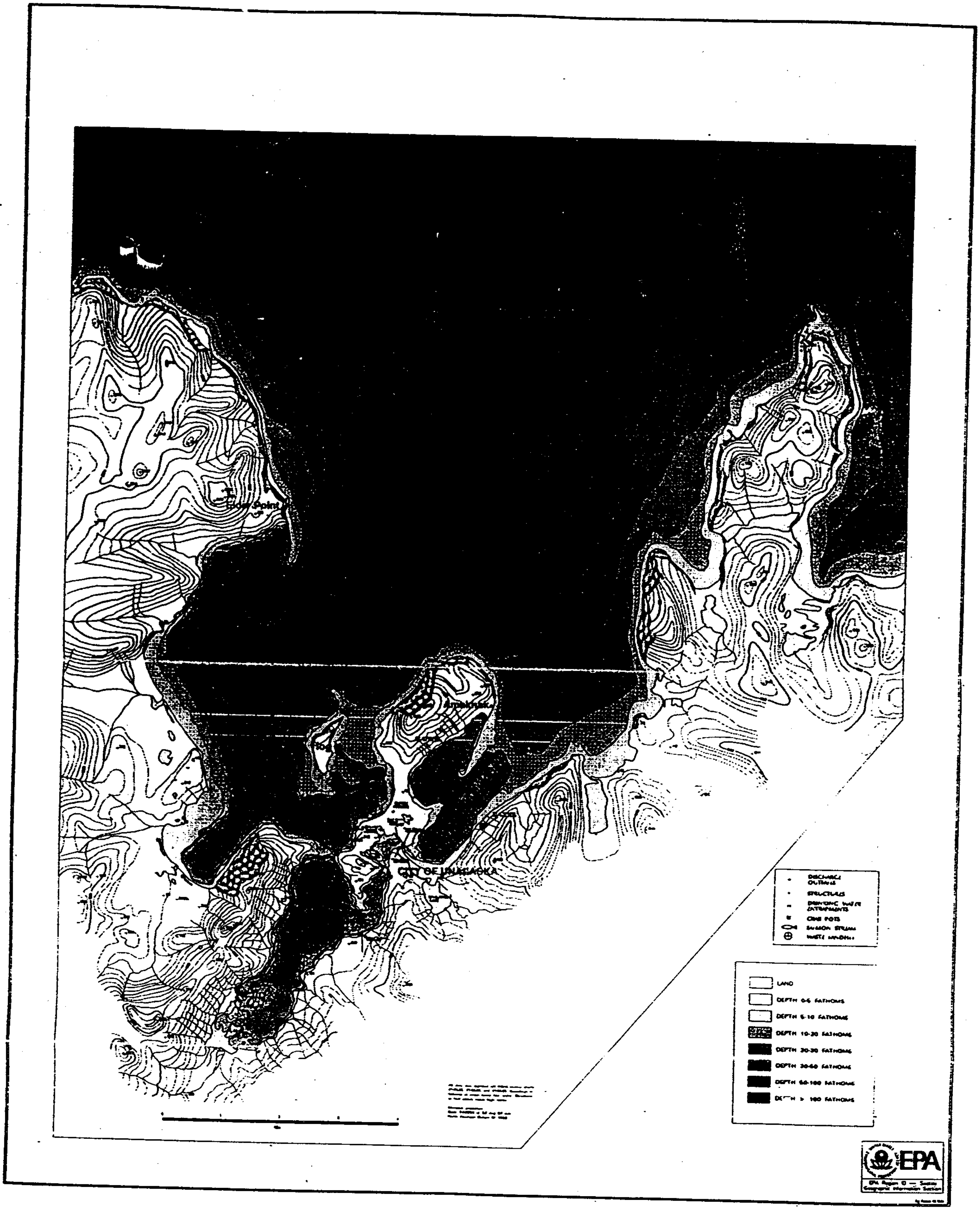

Figure 1-2
STUDY AREA