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MEMORANDUM
November 6, 1985

To: Tom Eaton

From: Will Kendra and Tim Determan

Subject: Effects of Three Small Sewage Treatment Plants on Budd Inlet Receiving Waters

ABSTRACT

In June and July of 1985, the Water Quality Investigations Section (WQIS) of the Washington State Department of Ecology (WDOE) conducted receiving water studies in Budd Inlet in conjunction with Class II inspections at the Beverly Beach, Tamoshan, and Seashore Villa sewage treatment plants (STPs). Outfalls were located with fluorescent dye. Initial dilution of Beverly Beach STP wastewaters was minimal due to shallow discharge depth. STP chlorination efficiency was inadequate during flow surges. Fecal coliform levels in the Beverly Beach mixing zone and at Tamoshan nearshore sites exceeded the water quality standard for Class A marine waters. Fecal contamination of Tamoshan nearshore waters is a historic and recurrent problem which does not appear to be related to discharges from Tamoshan STP. Sampling in the offshore mixing zone at Tamoshan was complicated by intermittent STP discharge, but effluent seemed to have little impact on receiving water quality. Wastewaters from Seashore Villa STP apparently had little or no effect in the discharge zone, but presence of an algal bloom during the survey may have masked effluent impacts.

INTRODUCTION

The Southwest Regional Office of WDOE requested Class II inspections at three STPs which serve residential developments on Budd Inlet. The Class II inspections were performed by Dale Clark of WQIS. Receiving water studies were conducted in conjunction with the STP inspections. The basis for these studies was to provide supplementary data to the URS Company for use in a water quality assessment of southern Puget Sound.

The Tamoshan and Beverly Beach developments are located on the west side of Budd Inlet nearly six miles north of Olympia (Figure 1). Tamoshan lies on a ridge that is bisected by a short ravine. An intermittent stream flows through the ravine and enters Budd Inlet on the northern flank of Silver Spit. Tamoshan STP was constructed on the north side of the stream about 200 meters upstream of the mouth. Silver Spit has been stabilized by riprap and bulkheads, and is presently the site of a small recreational park. Beverly Beach, 0.4 mile south of Tamoshan, consists of a number of ridgetop, sidehill, and waterfront homes. A floating dock which fronts the shoreline of Beverly Beach extends the length of the intertidal zone (40 meters). The STP which serves this community is situated adjacent to the beach, just north of the dock.

Seashore Villa Mobile Home Park is located on the east side of Budd Inlet, four miles north of Olympia between Priest Point and Gull Harbor (Figure 1). The park lies atop a ridge and consists of more than 50 mobile homes. A road winds 100 meters downhill to a beach southwest of the park. The beach borders a Washington State Department of Natural Resources (DNR) laboratory and pier. Another road leads away from the beach, traveling a short distance (50 meters) through wooded terrain to the site of the Seashore Villa STP.

The three STPs serving the residential developments are small aeration systems which discharge to Class A receiving waters. During the investigation, flows at Tamoshan, Beverly Beach, and Seashore Villa were 14,000, 5,000, and 11,500 gallons per day, respectively (Clark, 1985). At Tamoshan STP, chlorinated effluent collects in a wet well. When the well becomes full, effluent is pumped into the outfall line. As a result, discharges from Tamoshan STP into Budd Inlet are intermittent (about 10 minutes every hour during the late morning). Effluent is continually discharged from the Beverly Beach and Seashore Villa STPs into Budd Inlet. However, discharge from the Beverly Beach facility is characterized by periodic flow surges which are coincident with plant aeration cycles. During late morning hours, aeration cycles occur every half hour and persist for about 10 minutes.

The receiving water studies in Budd Inlet were designed to address two objectives. The first was to precisely locate the discharge point of each STP. The second objective was to measure the effects of each outfall on surrounding marine waters.

METHODS

Intensive receiving water studies were conducted on June 17 and 18 (Beverly Beach and Tamoshan, respectively) and July 2 (Seashore Villa), 1985. Survey days were warm and sunny, with minimal wind. Sampling was scheduled to coincide with lower low tides in order to measure discharge effects when initial dilution and dispersion would be minimal (Figure 2).

STP outfalls were located through use of Rhodamine B and WT fluorescent dyes. Bearings were shot at each discharge point with a hand-bearing compass and/or sextant (Appendix A). Outfall locations were later plotted using a parallel rule, three-armed protractor, and aerial photographs.

The mixing zones of all three discharges were sampled, as were a number of nearshore stations at Tamoshan and Seashore Villa (Table 1). Temperature, salinity, dissolved oxygen, and pH were measured in the field with a Hydrolab Surveyor II. Some oxygen readings were thought to be abnormally high because Winter, et al. (1975) reported that oxygen saturation levels exceeding 150 percent are unusual for marine systems. Hence, performance of the Hydrolab's oxygen probe was periodically field-tested by collecting water samples for chemical analysis (Winkler azide modification, APHA 1980). Results compared closely with Hydrolab readings. Post-calibration of the Hydrolab showed instrument drift to be low (Table 2). As a result, correction of data was not required.

Sampling and analytical methodology conformed to EPA (1979) and APHA (1980). Subsurface water samples were collected with a Kemmerer bottle. Fecal coliform samples from mixing zone waters were dechlorinated with sodium thiosulfate. Seawater density was determined using the method of Bailek (1966). Density, a function of salinity (s) and temperature (t), is reported as sigma-t:

$$\text{sigma-t} = (\text{density}_{s,t} - 1.000) \times 10^3$$

A drift drogue was repeatedly deployed over the Tamoshan and Seashore Villa outfalls during intensive sampling. Drogue depth was 1m. Bearings were shot with compass and/or sextant at drogue recovery sites to estimate current direction and velocity.

Mixing zone sampling at Beverly Beach was accomplished by stretching a marked 30m line along the water's edge parallel to the shoreline and to the direction of current movement. Samples were collected at distances of 5, 10, and 15m both upcurrent and downcurrent of the discharge which was 2m offshore at the time of sampling. The discharge point was identified as sampling site 2. Sites 3 to 5 were 5, 10, and 15m downcurrent of site 2, respectively. Sites 1A to 1C were control stations located 15, 10, and 5m upcurrent of site 2, in that order. Due to shallow depth of discharge, sampling at all stations was restricted to surface waters only.

Mixing zone sampling at Tamoshan and Seashore Villa was also accomplished using a marked 30m line. However, unlike Beverly Beach, the line was tied to a buoy anchored directly over the outfall. A small drogue and float were attached to the other end of the line. The line stretched out parallel to the prevailing current, allowing precise sampling of a two-dimensional grid within the mixing zone (Figure 3). Again, site 2 corresponded to the STP discharge point at both Tamoshan and Seashore Villa. Sites 3 to 5 were located at the 10m, 20m, and 30m marks of the line. Station 1, the control, was situated about 30m upcurrent of the discharge point, 60m away from site 5. Water samples were collected at surface, mid-depth, and bottom at all stations.

RESULTS AND DISCUSSION

Beverly Beach

The Beverly Beach STP discharge was located 10 to 15 minutes after addition of 5 mL of dye to plant effluent. Wastewaters were discharged at a single point downslope from the STP, just north of the dock (Figure 4). Because effluent percolated upward through sediment, it was unknown if the source of discharge was the actual outfall or a break in the outfall line. Elevation of the discharge point was approximately 2 feet above mean lower low water. As a result, effluent was discharged onto an exposed beach during low tide.

At the time of the intensive survey, the effluent plume was visible as a surface boil about 2m offshore. Depth of discharge was 0.25m. Movement of dye clouds indicated that current direction was southerly and parallel to the shoreline. Results of water quality sampling at Beverly Beach are presented in Appendix B and summarized in Table 3.

Fecal coliform bacteria were abundant in the mixing zone of the STP discharge. Fecal coliform levels at the control site were less than 10 organisms per 100 mL, but densities in the discharge plume reached 50,000. Levels in STP effluent averaged 35 organisms per 100 mL, indicating sporadic disinfectant efficiency. Specifically, the plant's chlorinator was not flow-paced and thus inadequately disinfected effluent during flow surges. Dispersion of STP wastewaters was evidenced by the persistent decrease in bacterial numbers with increasing distance downcurrent from the point of discharge. Residual chlorine levels in plant effluent measured 0.3 mg/L, but only trace amounts (<0.1 mg/L) were present in the discharge plume.

The water quality standard for fecal coliform bacteria in Class A marine waters is as follows (WDOE, 1982): "Fecal coliform organisms shall not exceed a geometric mean value of 14 organisms/100 mL, with not more than 10 percent of samples exceeding 43 organisms/100mL." Levels of fecal coliforms at Beverly Beach clearly exceeded the standard. Sanitary problems at this site stem from sporadic chlorination efficiency and shallow depth of discharge. Repair of the outfall line or extension to deeper waters would permit greater initial diultion of STP effluent. WDOE design requirements specify that dilution zone boundaries shall be at least 100 feet from the shoreline at mean lower low water (WDOE, 1980).

Physico-chemical quality of Beverly Beach receiving water was clearly affected by effluent discharge. Salinity and density dropped sharply at the discharge site (station 2), but quickly returned to ambient levels. Total suspended solids and turbidities in the mixing zone were elevated relative to the control station. Nitrate, orthophosphate, and total phosphate levels in the receiving water reached 1.5, 2.4, and 3.6 mg/L, respectively. Using the method of Hazel, et al. (1971), an estimated 1 to 2 percent of total ammonia measured at station 2 (0.12 mg/L) was present in the toxic un-ionized form. This concentration of un-ionized ammonia (<0.003 mg/L) was likely well below the toxicity threshold for marine life (EPA, 1976; Willingham, et al., 1979).

Tamoshan

On June 17, 1985, 250 mL of dye were poured into the Tamoshan STP outfall line. Emergence of a dye cloud from a single point about 200 m offshore (Figure 4) confirmed the outfall location reported by Determan (1981).

On June 18, effluent was again marked with 250 mL of dye. Emergence of a dye cloud was to signal onset of a discharge cycle. Sampling was to commence simultaneously. However, a cloud did not appear following the addition of dye. Another 500 mL of dye were added to the STP waste stream. This time a cloud surfaced near the buoy, but it was faint and difficult to see. There was some question as to why the dye was highly visible one day and barely detectable the next day (tidal conditions were similar both days). Detection of precipitate in the dye container suggested that inadvertent combination of Rhodamine B and WT dyes had induced a chemical reaction that greatly attenuated dye visibility.

Drogue studies conducted at Tamoshan, in conjunction with field observations, indicated that currents were variable and eddy-like as slack tide approached, but clearly oriented to the south as the tide began to rise (Figure 4). The same pattern was reported by Determan (1981). Drogue release dates and times, as well as drift durations, were as follows: #1 - June 17, 1115, 79 minutes; #2 - June 18, 1020, 60 minutes; and #3 - June 18, 1150, 135 minutes. Low tide on the 17th and 18th occurred at 1156 and 1231, respectively. Mean current velocity ranged from 0.02 to 0.32 m/s.

Water quality sampling commenced upon detection of the faint dye cloud on June 18. Outfall depth at the time of the intensive survey was 12.5m. Due to the short duration of each STP discharge cycle, wastewater was not continuously discharged during the receiving water study. Results of water quality sampling at Tamoshan are presented in Appendix C and summarized in Table 3.

Fecal coliform levels in the offshore mixing zone of the STP discharge were low. In fact, levels at the upcurrent control station were slightly higher than those at downcurrent sites. Levels in STP effluent averaged nearly 1,000 organisms per 100 mL. Fecal coliform densities at nearshore stations were elevated relative to offshore sites. Densities nearshore ranged from 11 to 200 organisms/100 mL, exceeding the Class A marine water quality standard.

Fecal contamination at Tamoshan nearshore sites has been a recurrent problem which does not appear to be related to discharges from Tamoshan STP. Three previous surveys of Tamoshan nearshore waters also showed violations of the state water quality standard for fecal coliforms (Table 4). Inadequate disposal of domestic wastes by shoreside residences may account for the high bacterial levels (these homes are not connected to the Tamoshan sewer system). Other suspected sources include an exposed PVC line which drains sewage from the southeast part of the development. However, inspection of the line by both Determan (1981) and the present authors revealed no breakage. The intermittent stream described earlier was not a potential source of contamination as it was dry at the time of the survey.

Data collected in the Tamoshan mixing zone suggest that STP discharge had little impact on physical and chemical receiving water quality. Water quality standards were satisfied both inside and outside design dilution zone boundaries (WDOE, 1980). Decreased surface salinity and density at station 2, coupled with an increase in these parameters downcurrent, confirmed that sampling was conducted in the discharge plume. Effluent surfaced rapidly and initial dilution was apparently satisfactory. However, because the discharge of wastes from the STP was intermittent, an effluent plume was likely present in the mixing zone for only a portion of the survey. Hence, data collected in the Tamoshan mixing zone may not fully characterize dilution and dispersion at the site.

Nutrient levels at Tamoshan nearshore stations were relatively low given the high fecal coliform densities observed at the same sites. High ammonia and total phosphate concentrations at stations A and D were likely a result of the boat propeller churning up nearshore sediments. Elevated suspended solids and turbidities at the same stations support this explanation.

Seashore Villa

Emergence of a dye cloud at the Seashore Villa outfall occurred 20 minutes after addition of 250 mL of dye to the STP effluent. Dye rose to the surface from a single point northwest of the DNR pier (Figure 5). Depth of discharge at the time of the intensive survey was 2m (lower low water). Results of water quality sampling at Seashore Villa are presented in Appendix D and summarized in Table 3.

Drogue studies showed that currents were northerly on the ebb tide, but reversed to a southerly direction after slack low tide (Figure 5). Drogue release times and drift durations were as follows: #1 - 0920, 50 minutes; #2 - 1015, 50 minutes; #3 - 1110, 95 minutes; and #4 - 1250, 55 minutes. Low tide occurred at 1216. Mean current velocity ranged from 0.05 to 0.10 m/s.

Fecal coliform bacteria were virtually absent from surface waters in the mixing zone at Seashore Villa. Of 10 samples collected, seven had fewer than one organism per 100 mL. Fecal coliforms were more abundant at nearshore stations, but the highest density observed was only 11 per 100 mL. Levels in STP effluent averaged 89 per 100 mL.

Bacteriological surveys of shellfish-growing areas by DSHS between 1973 and 1981 showed that waters in the vicinity of Seashore Villa had high densities of fecal coliforms (Table 4). The present survey found very low levels of these organisms both nearshore and in the mixing zone. However, sampling and analytical differences may explain much of the difference. DSHS samples were collected at various times and tidal stages throughout the year. By comparison, the present work was instantaneous. In addition, DSHS estimated fecal coliform densities using the MPN technique (APHA, 1980). In 1985, membrane filter (MF) analyses were performed. Several investigators have shown that MF analyses yield consistently lower results than MPN analyses performed on split samples (Presnell, 1975; Determan, et al., in press).

Analysis of mixing zone data indicates that STP effluent had little impact on physical and chemical receiving water quality. Water quality standards were satisfied both inside and outside design dilution zone boundaries (WDOE, 1980). Initial dilution and dispersion appeared satisfactory, but presence of an algal bloom during sampling produced physical and chemical changes in water quality which may have masked effects of the effluent. For example, dissolved oxygen levels at mid-depth peaked at station 2 and dropped off at stations downcurrent of the discharge. However, the effluent plume did not play a role in this phenomenon. Mixing zone sampling began at station 1 (control). Sampling then proceeded from station 5 upcurrent to station 2. During this period subsurface waters assumed a reddish hue characteristic of certain algal blooms. Apparently, photosynthetic activity associated with the bloom was responsible for the observed upcurrent increase in oxygen levels. Microscopic analysis demonstrated that the "red tide" was predominantly a monoculture of the dinoflagellate *Ceratium fusus*.

SUMMARY AND RECOMMENDATIONS

Receiving water surveys conducted for three STPs discharging into Budd Inlet demonstrated that:

- Fecal coliform levels at Beverly Beach exceeded the water quality standard for Class A marine waters. Initial dilution of STP wastewater was minimal due to shallow depth of discharge. Extension or repair of the STP outfall line would encourage rapid and complete mixing of plant effluent with receiving waters. STP chlorination efficiency was inadequate during plant flow surges. The operator should consider using flow-paced chlorination.

- Discharge of sewage effluent from Tamoshan STP had little impact on quality of offshore receiving waters. However, because discharge was intermittent, dilution and dispersion of the effluent plume may not have been fully characterized.

- Fecal coliform pollution is a historic and recurrent problem in Tamoshan nearshore waters. Bacterial numbers exceeded the Class A receiving water standard. High fecal coliform levels appear to be unrelated to discharges from Tamoshan STP. Causes of contamination may include inadequate disposal of domestic wastes by shoreside residences that are not connected to the Tamoshan sewer system.

- Discharge from Seashore Villa STP had little or no effect on receiving water quality. Initial dilution and dispersion appeared to be satisfactory. However, presence of an algal bloom during sampling may have masked effluent impacts.

WK:TAD:cp

Attachments

cc: Charlie Tang, URS Co.
Darrel Anderson, WDOE

REFERENCES

APHA (American Public Health Association), 1980. Standard Methods for the Examination of Water and Wastewater. 15th Ed., Washington, DC. 1134 pp.

Bailek, E.L., 1966. Handbook of Oceanographic Tables. U.S. Naval Oceanographic Office, H.O. Publ. No. 9. Washington, DC. 1524 pp.

Clark, D., 1985. Preliminary report of flow and laboratory analysis for three (3) package plant WTPs in Thurston County. WDOE memorandum of September 13, 1985, to Lynn Singleton. Olympia, WA. 1 pp.

Determan, T.A., 1981. Effects of Tamoshan STP outfall on water quality at Silver Spit, Budd Inlet. WDOE memorandum of February 19, 1981, to John Bernhardt. Olympia, WA. 6 pp.

Determan, T.A., B.M. Carey, W.H. Chamberlain, and D.E. Norton, in press. Sources Affecting the Sanitary Conditions of Water and Shellfish from Minter Bay and Burley Lagoon. WDOE Report No. 84-10.

EPA (Environmental Protection Agency), 1976. Quality Criteria for Water. U.S. Gov't. Printing Office, Washington DC. 256 pp.

EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. Cincinnati, OH. 460 pp.

Hazel, C.R., W. Thomsen, and S.J. Meith, 1971. Sensitivity of striped bass and stickleback to ammonia in relation to temperature and salinity. In: CA Fish and Game 57:138 - 153.

Hydrolab, 1984. Operation and Maintenance Manual for Hydrolab Surveyor II. Hydrolab Corporation, Austin, TX. 59 pp.

Presnell, M.W., 1975. Evaluation of membrane filter methods for enumerating coliforms and fecal coliforms in estuarine waters. In: D.S. Wilt (ed.). Proceedings of the Eighth National Shellfish Sanitation Workshop. Dept. Health, Educ. and Welfare Publ. No. (FDA) 75-2025. 127-131 pp.

WDOE, 1980. Criteria for Sewage Works Design. WDOE Report 78-5, Olympia, WA. 357+ pp.

WDOE, 1982. Water Quality Standards for Waters of the State of Washington. Chapter 173-201 WAC.

Willingham, W.T., J.E. Colt, J.A. Fava, B.A. Hillaby, C.L. Ho, M. Katz, R.C. Russo, D.L. Swanson, and R.V. Thurston, 1979. Ammonia. In: A Review of the EPA Red Book: Quality Criteria for Water. Water Quality Section, American Fisheries Society, Bethesda, MD. 6-18 pp.

Winter, D.F., K. Banse, and G.C. Anderson, 1975. The dynamics of phytoplankton blooms in Puget Sound, a fjord in the northwestern United States. In: Marine Biology 29:139 - 176.

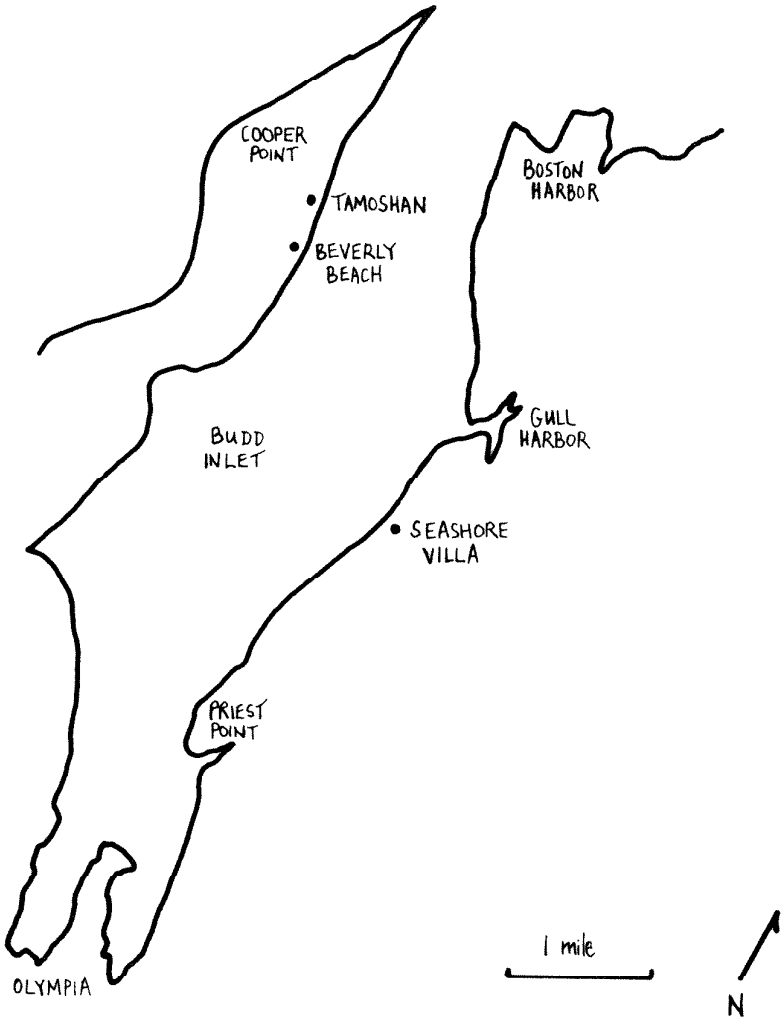

Figure 1. Map of Budd Inlet showing location of Tamoshan, Beverly Beach, and Seashore Villa developments.

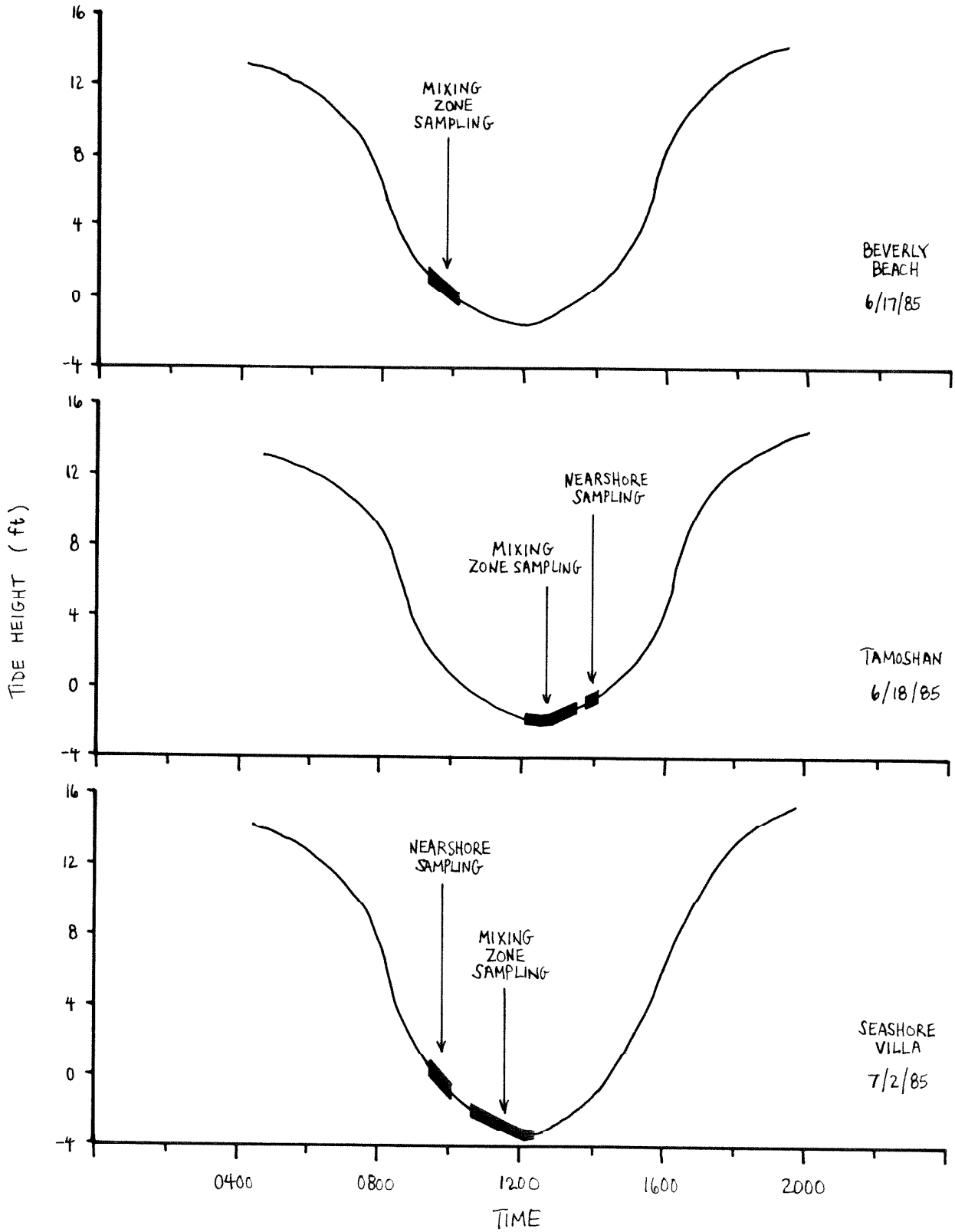

Figure 2. Tide heights during STP receiving water surveys conducted in Budd Inlet, 1985 (tide datum is mean lower low water).

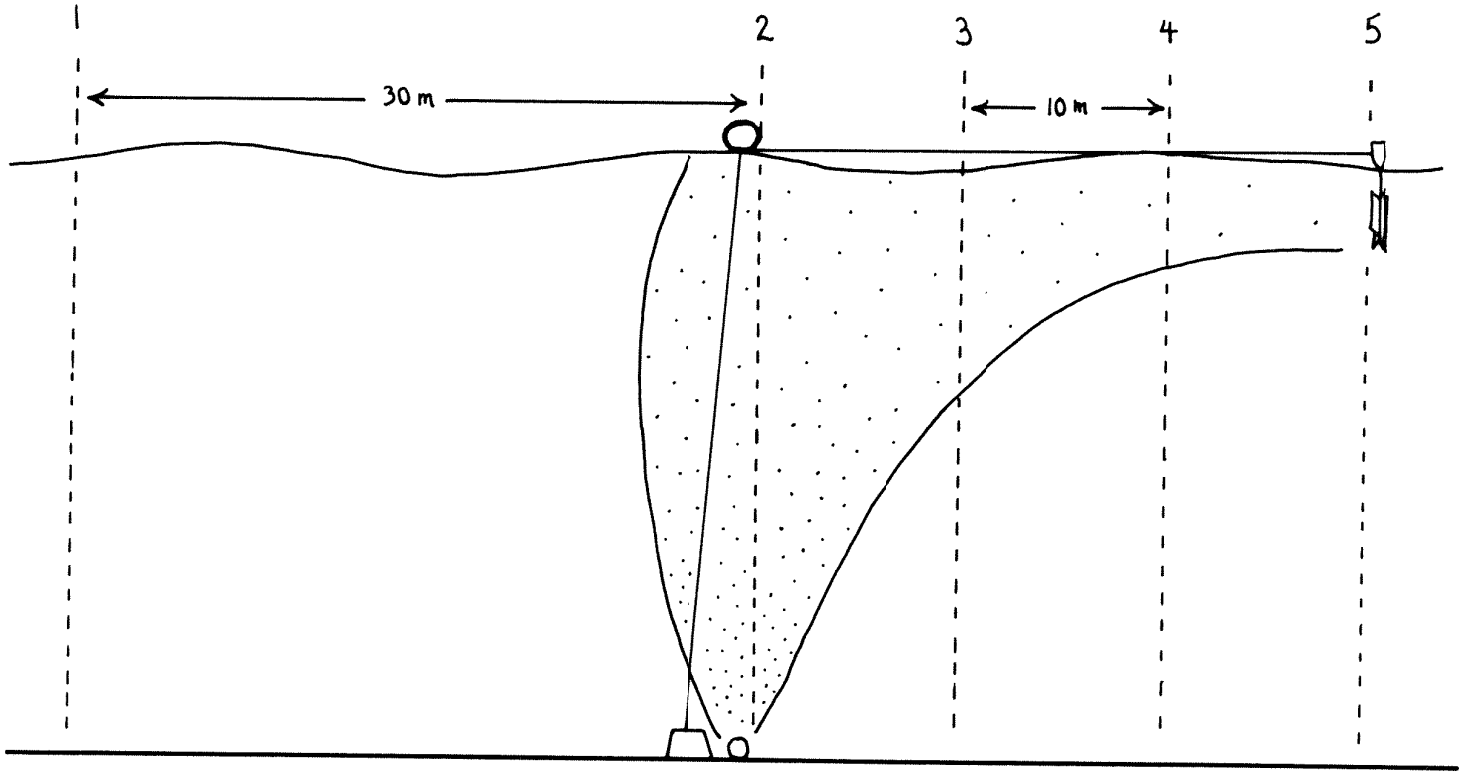

Figure 3. Generalized view of a two-dimensional sampling grid designed to provide position control within the mixing zone of an STP discharge.

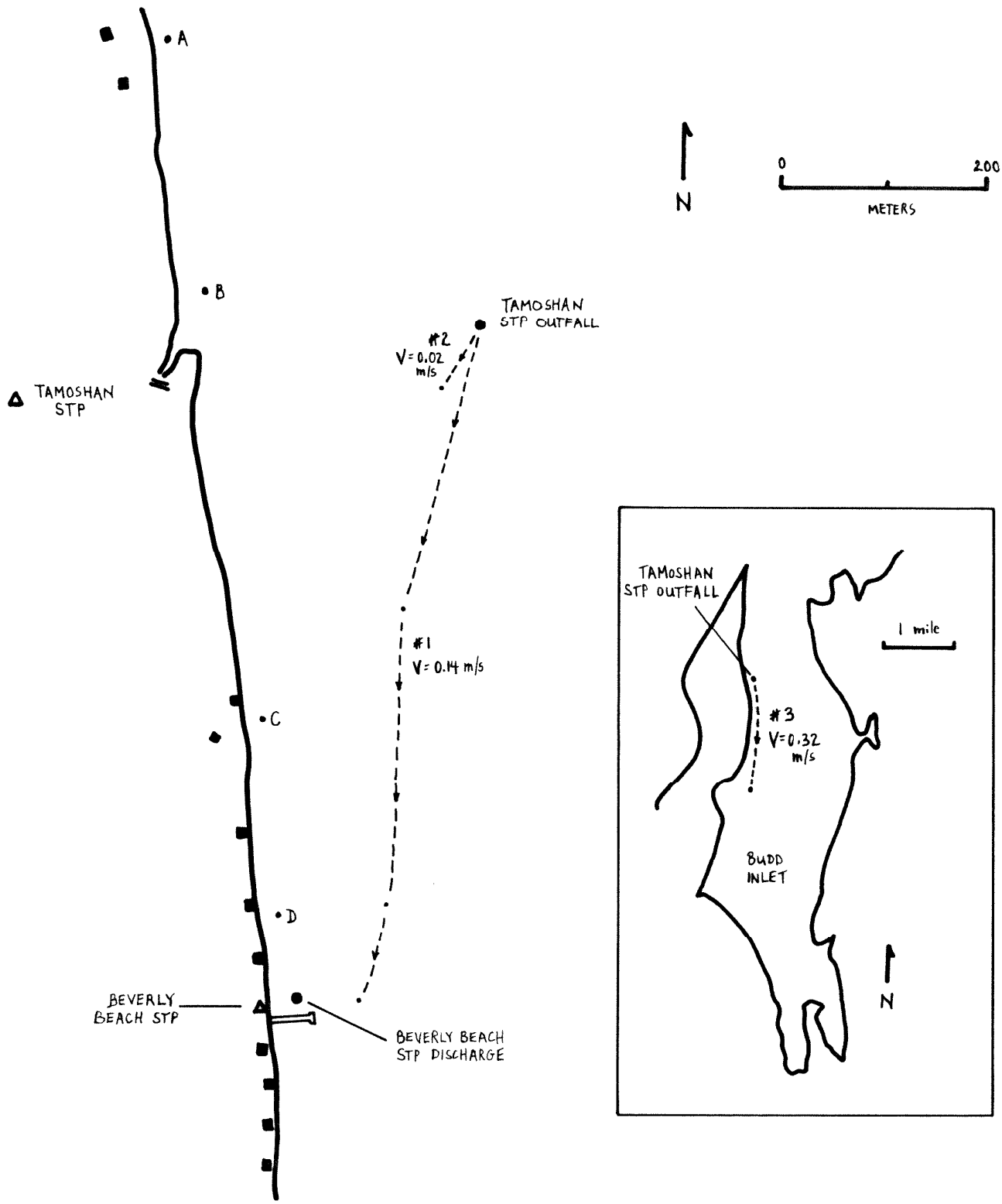

Figure 4. Map of Tamoshan and Beverly Beach STPs showing location of discharges and nearshore sampling sites (A - D) as well as drift paths of a drogue released at the Tamoshan STP outfall on three separate occasions (V = drogue velocity). Shaded rectangles denote shoreside residences.

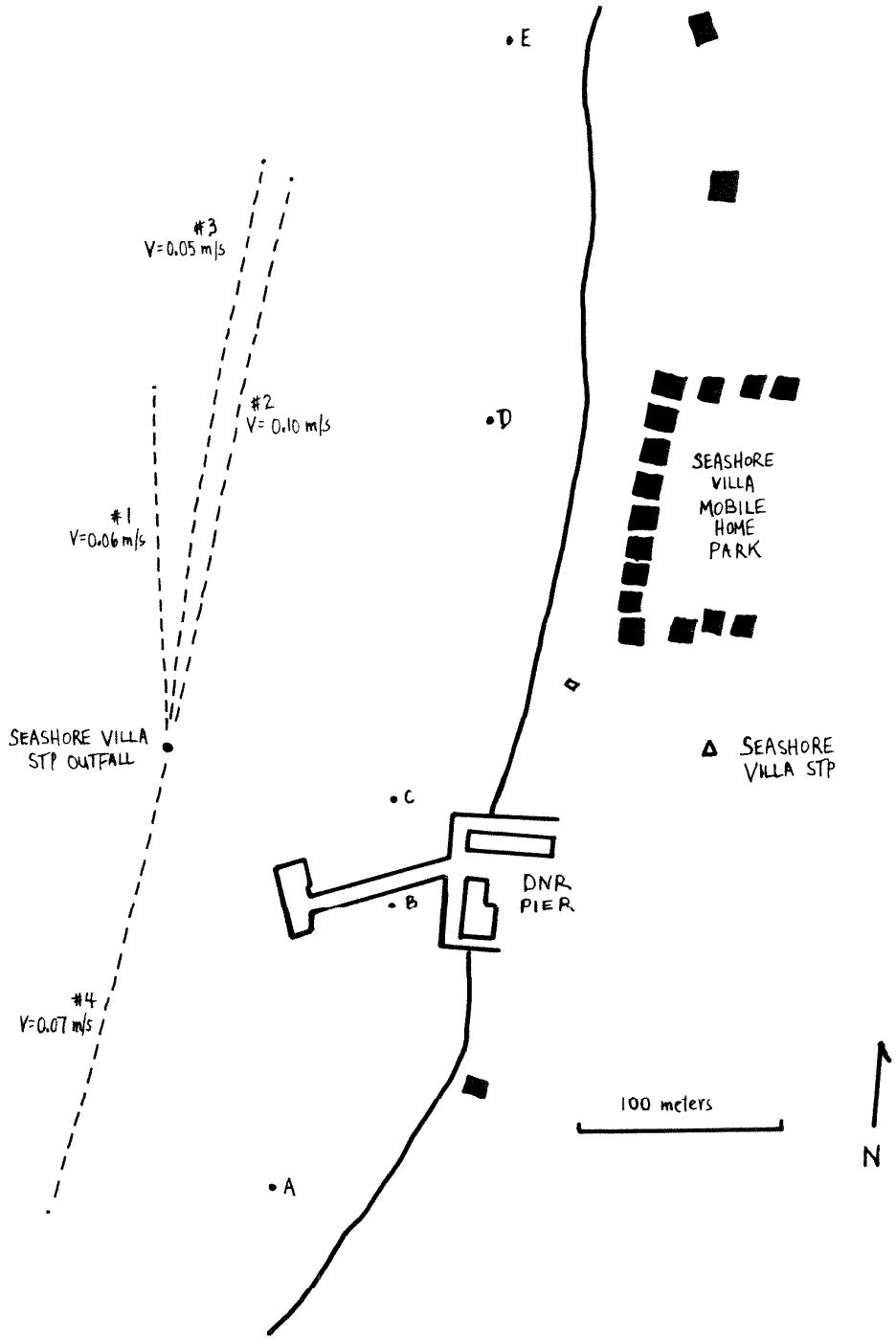

Figure 5. Location of Seashore Villa STP and outfall as well as nearshore sampling sites (A - E). Drift paths of a drogue released at the STP outfall on four different occasions are traced (V = drogue velocity). Shaded rectangles denote shoreside residences.

Table 1. Water quality parameters measured during the Beverly Beach, Tamoshan, and Seashore Villa STP receiving water surveys conducted in Budd Inlet, 1985.

	Beverly Beach	Tamoshan		Seashore Villa	
Parameter	Mixing Zone Stations 1-5	Mixing Zone Stations 1-5	Near-shore Stations A-D	Mixing Zone Stations 1-5	Near-shore Stations A-E
Field Analyses					
pH	X	X	X[1]	X	X
Temperature	X	X	--	X	X
Salinity	X	X	X[1]	X	X
Dissolved Oxygen	X	X	--	X	X
Chlorine Residual	X[2]	--	--	--	--
Secchi Depth	--	--	--	X	--
Laboratory Analyses					
Nutrients	X	X	X	X	X
Total Suspended Solids	X	X	X	X	X
Turbidity	X	X	X	X	X
Fecal Coliforms	X	X	X	X	X

[1]Laboratory analyses.

[2]Station 2 only.

Table 2. Performance of Hydrolab Surveyor II during receiving water surveys in Budd Inlet, 1985.

Survey	Date	Parameter	Value of Standard	Post-Survey Hydrolab Reading	Instrument Drift
Tamoshan/ Beverly Beach	June 17-18	Dissolved Oxygen (mg/L)	7.65	7.83	+0.18
		pH (S.U.)	7.00 10.00	7.01 9.90	+0.01 -0.10
		Conductivity (mmhos/cm)	58.64	58.38	-0.26
		Salinity[1] (o/oo)	39.15	38.96	-0.19
Seashore Villa	July 2	Dissolved Oxygen (mg/L)	7.85	7.83	-0.02
		pH (S.U.)	7.00 10.00	6.95 9.97	-0.05 -0.03
		Conductivity (mmhos/cm)	58.64	58.46	-0.18
		Salinity[1] (o/oo)	39.15	39.02	-0.13

[1]Salinity values were computed from conductivity values using the conversion formula in Hydrolab (1984).

Table 3. Summary of data collected during intensive receiving water surveys on Budd Inlet, 1985 ($\bar{X}$ = mean; s.d. = standard deviation; n = sample size).

Location	Station	pH (S.U.)			Temperature (°C)			Salinity (o/oo)			Sigma-t			D.O. (mg/L)			D.O. (% Saturation)		
		$\bar{X}$	s.d.	n	$\bar{X}$	s.d.	n	$\bar{X}$	s.d.	n	$\bar{X}$	s.d.	n	$\bar{X}$	s.d.	n	$\bar{X}$	s.d.	n
SURFACE																			
Beverly Beach	Control	7.7	0.1	3	14.4	0.2	3	28.7	0.3	3	21.3	0.2	3	9.7	0.2	3	112	3	3
	Mixing Zone	7.8	0.1	4	14.5	0.3	4	27.4	1.5	4	20.3	1.1	4	10.0	0.1	4	116	3	4
Tamoshan	Control	7.9	--	1	19.2	--	1	24.3	--	1	16.9	--	1	10.5	--	1	129	--	1
	Mixing Zone	7.8	0.1	4	20.1	0.9	4	23.8	1.0	4	16.2	1.0	4	10.1	0.5	4	126	4	4
	Nearshore[1]	8.0	0.2	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Seashore Villa	Control	7.7	--	1	18.9	--	1	24.9	--	1	17.4	--	1	9.6	--	1	118	--	1
	Mixing Zone	7.8	0.0	4	18.7	0.7	4	26.2	0.3	4	18.4	0.4	4	9.8	0.1	4	120	1	4
	Nearshore	7.7	0.0	5	17.1	0.1	5	25.7	0.1	5	18.5	0.1	5	9.6	0.4	5	114	5	5
ALL DEPTHS																			
Tamoshan	Control	7.9	0.1	5	15.3	2.9	5	27.7	2.4	5	20.3	2.4	5	10.7	0.8	5	126	12	5
	Mixing Zone	7.9	0.1	20	15.5	3.0	20	27.5	2.3	20	20.1	2.4	20	10.6	0.7	20	124	10	20
Seashore Villa	Control	7.8	0.1	6	17.0	1.5	6	27.8	1.8	6	20.0	1.6	6	10.4	0.9	6	125	10	6
	Mixing Zone	7.9	0.1	23	17.0	1.1	23	28.4	1.2	23	20.5	1.1	23	12.2	1.7	23	148	20	23

[1]Results may show effects of propeller disturbance.

Table 3. (continued)

Location	Station	NO_3-N (mg/L)			NH_3-N (mg/L)			O-PO_4-P (mg/L)			T-PO_4-P (mg/L)			TSS (mg/L)			Fecal Coliforms (org/100 mL)		
		$\overline{X}$	s.d.	n	$\overline{X}$	s.d.	n	$\overline{X}$	s.d.	n	$\overline{X}$	s.d.	n	$\overline{X}$	s.d.	n	$\overline{X}$	s.d.	n
SURFACE																			
Beverly Beach	Control	0.17	--	1	0.05	--	1	0.10	--	1	0.13	--	1	48	--	1	6	--	2
	Mixing Zone	0.59	0.61	4	0.07	0.04	4	0.90	1.01	4	1.26	1.56	4	80	10	4	1141	--	8
Tamoshan	Control	0.04	--	1	0.10	--	1	0.07	--	1	0.09	--	1	36	--	1	8	--	2
	Mixing Zone	0.03	0.01	4	0.06	0.03	4	0.06	0.01	4	0.07	0.00	4	40	4	4	2	--	8
	Nearshore[1]	0.04	0.01	4	0.38	0.37	4	0.12	0.06	3	0.18	0.05	4	168	235	4	42	--	8
Seashore Villa	Control	0.02	--	1	0.06	--	1	0.07	--	1	0.09	--	1	51	--	1	<1	--	2
	Mixing Zone	0.02	0.01	4	0.08	0.01	4	0.08	0.00	4	0.10	0.01	4	38	8	4	<1	--	8
	Nearshore	0.03	0.01	5	0.09	0.01	5	0.09	0.01	5	0.10	0.01	5	36	17	5	3	--	10
ALL DEPTHS																			
Tamoshan	Control	0.06	0.03	3	0.06	0.04	3	0.06	0.01	3	0.08	0.01	3	46	10	3	--	--	--
	Mixing Zone	0.06	0.03	12	0.05	0.03	12	0.05	0.01	12	0.07	0.01	12	48	8	12	--	--	--
Seashore Villa	Control	0.01	0.01	3	0.04	0.02	3	0.07	0.01	3	0.09	0.01	3	45	11	3	--	--	--
	Mixing Zone	0.02	0.01	12	0.04	0.03	12	0.07	0.01	12	0.10	0.02	12	41	7	12	--	--	--

[1]Results may show effects of propeller disturbance.

Table 4. Summary of historical fecal coliform studies conducted in the vicinity of the Tamoshan, Beverly Beach, and Seashore Villa developments, 1973 - 1981.

			Fecal Coliform Levels		
Location	Date	Investigator	Sample Size	Geometric Mean (org/ 100 mL)	Percent of Samples over 43 org/ 100 mL
Tamoshan Nearshore	3/07/79	D. Cunningham, WDOE (WQIS)	6	24	33
	10/28/80	Determan (1981)	8	23	38
	11/05/80	Determan (1981)	7	17	29
Tamoshan Offshore (near STP outfall)	3/07/79	D. Cunningham, WDOE (WQIS)	3	4	0
	11/05/80	Determan (1981)	5	1	0
Tamoshan/ Beverly Beach Vicinity	8/14/73 to 3/15/79	J. Lilja, DSHS[1]	27	10	19
Seashore Villa Vicinity	8/14/73 to 1/22/81	J. Lilja, DSHS	25	65	60

[1]Washington State Department of Social and Health Services

Appendix A. Compass bearings (variation from true north) and sextant angles measured in Budd Inlet to precisely locate STP discharge points, 1985.

Discharge Point or Sampling Site	Landmarks "Shot" with Compass or Sextant	Compass Bearing (CB) or Sextant Angle (SA)	
Beverly Beach STP Discharge	Northeast corner of STP	290°30'	(CB)
	Northwest corner of house located immediately south of dock	248°30'	(CB)
	South extension of bulkhead located north of 2nd house south of dock	221°30'	(CB)
Tamoshan STP Discharge	Vertical post north of stream to northwest corner of white house located on beach mid-way between Tamoshan and Beverly Beach	62°49'	(SA)
	Vertical post north of stream to second stairway north of stream leading uphill to ridgetop house	32°58'	(SA)
Seashore Villa STP Discharge	Northwest corner of beach shack located north of DNR facilities	65°30'	(CB)
	Northwest corner of DNR pier	130°00'	(CB)
	Southwest corner of DNR pier	139°30'	(CB)

Appendix B. Results of an intensive water quality survey conducted on Budd Inlet in the vicinity of the Beverly Beach development, June 17, 1985 (STP data from D. Clark, WDOE, personal communication).

			Field Analyses						Laboratory Analyses							
Site	Depth (m)	Time	pH (S.U.)	Temp (°C)	Sal. (o/oo)	Sigma -t	D.O. mg/L (% Sat.)	Secchi Depth (m)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	O-PO_4-P (mg/L)	T-PO_4-P (mg/L)	TSS (mg/L)	Turb (NTU)	Fecal Coliforms (org/100 mL)
STP Effluent		--	7.3[1]	19.6[1]	--	--	1.2[1](13)	--	3.40	<0.01	0.20	7.1	9.0	24	11	3[2]; 420
MIXING ZONE																
1A	0	0938	7.7	14.5	29.0	21.5	9.8(114)	--	--	--	--	--	--	--	--	--
		0955	--	--	--	--	--(--)	--	0.17	<0.01	0.05	0.10	0.13	48	9	7[2]; 6[2]
1B	0	0936	7.6	14.4	28.5	21.1	9.8(113)	--	--	--	--	--	--	--	--	--
1C	0	0934	7.7	14.2	28.5	21.2	9.5(109)	--	--	--	--	--	--	--	--	--
2	0	0925	7.7	14.3	25.2	18.6	9.9(112)	--	--	--	--	--	--	--	--	--
		1000	--	--	--	--	--(--)	--	1.5	0.01	0.12	2.4	3.6	87	18	22,800[2]; 50,000
3	0	0928	7.7	14.2	28.3	21.0	10.0(115)	--	--	--	--	--	--	--	--	--
		1003	--	--	--	--	--(--)	--	0.32	<0.01	0.05	0.52	0.63	66	10	600; 1,200
4	0	0930	7.8	14.9	28.0	20.6	10.2(118)	--	--	--	--	--	--	--	--	--
		1006	--	--	--	--	--(--)	--	0.33	<0.01	0.06	0.44	0.51	81	22	320; 480
5	0	0932	7.8	14.7	28.3	20.9	10.1(117)	--	--	--	--	--	--	--	--	--
		1008	--	--	--	--	--(--)	--	0.22	<0.01	0.04	0.23	0.32	86	18	184; 124

[1]Mean of 5-6 effluent grab samples collected over a 31-hour period (remaining STP parameters, except FC, were estimated from a 24-hour composite effluent sample).

[2]Estimated (FC count was less than the required minimum of 20 colonies per plate).

Appendix C. Results of an intensive water quality survey conducted on Budd Inlet in the vicinity of the Tamoshan development, June 18, 1985 (STP data from D. Clark, WDOE, personal communication).

			Field Analyses						Laboratory Analyses							
Site	Depth (m)	Time	pH (S.U.)	Temp (°C)	Sal. (o/oo)	Sigma -t	D.O. mg/L (% Sat.)	Secchi Depth (m)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	O-PO_4-P (mg/L)	T-PO_4-P (mg/L)	TSS (mg/L)	Turb (NTU)	Fecal Coliforms (org/100 mL)
STP Effluent		--	7.4[1]	18.2[1]	--	--	5.3[1](56)	--	8.6	0.3	4.7	9.7	11.5	9	7	660; 1,500
MIXING ZONE																
1	0	1238	7.9	19.2	24.3	16.9	10.5(129)	--	0.04	<0.01	0.10	0.07	0.09	36	2	10[2]; 7[2]
	1	--	8.0	17.5	26.2	18.7	11.1(134)	--	--	--	--	--	--	--	-	--
	2	--	7.9	14.5	28.7	21.3	11.5(133)	--	--	--	--	--	--	--	-	--
	5	--	7.9	13.1	29.4	22.1	11.2(127)	--	0.05	<0.01	0.02	0.05	0.07	47	3	--
	11.5	--	7.7	12.3	29.8	22.5	9.4(105)	--	0.09	<0.01	0.05	0.06	0.08	56	2	--
2	0	1210	7.8	21.0	22.7	15.2	9.6(121)	--	0.02	<0.01	0.04	0.05	0.07	34	2	<1; <1
	1	--	8.0	17.6	26.4	18.8	11.3(137)	--	--	--	--	--	--	--	-	--
	2	--	7.9	14.5	28.6	21.2	11.4(132)	--	--	--	--	--	--	--	-	--
	5	--	7.8	13.0	29.2	21.9	10.7(121)	--	0.04	<0.01	0.02	0.05	0.06	44	1	--
	9.5	--	7.7	12.6	29.4	22.2	9.8(110)	--	0.10	<0.01	0.06	0.06	0.08	60	3	--
3	0	--	7.9	19.9	23.8	16.3	10.1(126)	--	0.04	<0.01	0.10	0.07	0.08	40	1	<1; 1[2]
	1	--	8.0	17.4	26.6	19.0	11.2(135)	--	--	--	--	--	--	--	-	--
	2	--	7.9	14.2	28.7	21.3	11.4(131)	--	--	--	--	--	--	--	-	--
	5	--	7.8	12.7	29.3	22.1	10.1(113)	--	0.04	<0.01	0.02	0.04	0.05	54	1	--
	9	--	7.8	12.6	29.5	22.2	9.8(110)	--	0.09	<0.01	0.06	0.06	0.08	54	3	--
4	0	--	7.8	20.6	23.5	15.9	10.0(126)	--	0.03	<0.01	0.05	0.05	0.07	42	1	3[2]; 2[2]
	1	--	8.0	17.5	26.3	18.8	11.2(135)	--	--	--	--	--	--	--	-	--
	2	--	7.9	14.4	28.7	21.3	11.3(130)	--	--	--	--	--	--	--	-	--
	5	--	7.8	12.8	29.3	22.1	10.4(117)	--	0.04	<0.01	0.02	0.04	0.05	54	1	--
	9.5	--	7.8	12.5	29.5	22.3	9.7(108)	--	0.09	<0.01	0.09	0.06	0.09	52	3	--
5	0	1232	7.9	18.9	25.0	17.5	10.7(132)	--	0.03	<0.01	0.05	0.06	0.07	43	1	3[2]; 2[2]
	1	--	8.0	17.4	26.5	19.0	11.2(135)	--	--	--	--	--	--	--	-	--
	2	--	7.9	15.2	28.2	20.7	11.2(131)	--	--	--	--	--	--	--	-	--
	5	--	7.8	12.8	29.3	22.0	10.7(120)	--	0.05	<0.01	0.02	0.04	0.06	52	2	--
	10	--	7.8	12.4	29.6	22.4	9.6(107)	--	0.10	<0.01	0.06	0.06	0.07	49	3	--
NEARSHORE STATIONS[3]																
A[4]	0	1345	8.0	--	25	--	--	--	0.04	<0.01	0.55	--	0.19	66	8	53; 37
B	0	1350	8.1	--	25	--	--	--	0.03	<0.01	0.08	0.09	0.15	42	4	84; 200
C	0	1355	8.2	--	26	--	--	--	0.04	<0.01	0.05	0.08	0.13	46	1	32; 24
D[4]	0	1400	7.8	--	25	--	--	--	0.03	<0.01	0.82	0.18	0.24	520	8	11[2]; 35

[1]Mean of 6-8 effluent grab samples collected over a 30-hour period (remaining STP parameters, except FC, were estimated from a 24-hour composite effluent sample).

[2]Estimated (fecal coliform count was less than the required minimum of 20 colonies per plate).

[3]Salinity and pH measured in laboratory.

[4]Results may show effects of propeller disturbance.

Appendix D. Results of an intensive water quality survey conducted on Budd Inlet in the vicinity of the Seashore Villa development, July 2, 1985 (STP data from D. Clark, WDOE, personal communication).

			Field Analyses						Laboratory Analyses							
Site	Depth (m)	Time	pH (S.U.)	Temp (°C)	Sal. (o/oo)	Sigma -t	D.O. mg/L (% Sat.)	Secchi Depth (m)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	O-PO_4-P (mg/L)	T-PO_4-P (mg/L)	TSS (mg/L)	Turb (NTU)	Fecal Coliforms (org/100 mL)
STP Effluent		--	6.7[1]	18.2[1]	--	--	0.9[1](10)	--	8.2	<0.1	4.0	10.1	14.2	200	120	80; 100
MIXING ZONE																
1	0	1040	7.7	18.9	24.9	17.4	9.6(118)	3.3[3]	0.02	<0.01	0.06	0.07	0.09	51	1	<1; 1[2]
	0.5	--	7.8	17.8	26.7	19.0	10.3(125)	--	--	--	--	--	--	--	-	--
	1.0	--	7.8	17.7	27.7	19.8	9.6(117)	--	--	--	--	--	--	--	-	--
	1.5	--	7.9	16.6	29.1	21.1	10.3(124)	--	<0.01	<0.01	0.03	0.06	0.08	33	1	--
	2.0	--	8.0	15.9	29.2	21.3	12.1(144)	--	--	--	--	--	--	--	-	--
	3.0	--	7.8	14.9	29.4	21.7	10.3(121)	--	<0.01	<0.01	0.02	0.07	0.10	52	1	--
2	0	1207	7.8	19.0	25.8	18.0	9.7(120)	2.1[3]	0.03	<0.01	0.08	0.08	0.11	41	2	<1; 1[2]
	0.5	--	8.0	17.8	28.5	20.4	14.8(182)	--	--	--	--	--	--	--	-	--
	1.0	--	8.2	16.8	28.9	20.9	15.7(190)	--	0.02	<0.01	0.01	0.06	0.08	51	1	--
	1.5	--	8.1	16.2	29.2	21.3	13.8(166)	--	--	--	--	--	--	--	-	--
	2.0	--	8.0	16.0	29.2	21.3	12.9(154)	--	<0.01	<0.01	0.02	0.06	0.15	37	3	--
3	0	1155	7.8	19.5	26.0	18.1	9.7(122)	2.4[3]	0.03	<0.01	0.09	0.08	0.10	44	1	<1; <1
	0.5	--	7.9	17.9	28.3	20.2	12.3(152)	--	--	--	--	--	--	--	-	--
	1.0	--	8.0	17.1	28.9	20.8	14.8(180)	--	--	--	--	--	--	--	-	--
	1.5	--	8.0	16.0	29.3	21.4	13.3(159)	--	<0.01	<0.01	0.02	0.06	0.08	42	1	--
	2.0	--	8.0	15.8	29.3	21.4	12.5(149)	--	--	--	--	--	--	--	-	--
	2.4	--	8.0	15.7	29.4	21.5	12.4(148)	--	<0.01	<0.01	0.02	0.07	0.10	52	2	--
4	0	1115	7.8	17.9	26.6	18.9	9.9(121)	2.8[3]	0.02	<0.01	0.06	0.08	0.09	26	1	<1; 1[2]
	0.5	--	7.9	17.8	28.0	20.0	10.3(126)	--	--	--	--	--	--	--	-	--
	1.0	--	7.9	17.6	28.5	20.4	12.3(151)	--	--	--	--	--	--	--	-	--
	1.5	--	8.0	16.3	29.0	21.1	13.7(164)	--	<0.01	<0.01	0.02	0.06	0.10	40	1	--
	2.0	--	8.0	15.9	29.1	21.3	12.6(150)	--	--	--	--	--	--	--	-	--
	2.6	--	8.0	15.8	29.1	21.3	12.3(146)	--	<0.01	<0.01	0.02	0.06	0.09	43	2	--
5	0	--	7.8	18.4	26.2	18.5	9.7(119)	2.6[3]	0.02	<0.01	0.08	0.08	0.10	42	1	<1; <1
	0.5	--	7.8	17.7	27.3	19.5	10.0(122)	--	--	--	--	--	--	--	-	--
	1.0	--	7.9	17.5	28.6	20.5	11.5(141)	--	--	--	--	--	--	--	-	--
	1.5	--	8.0	16.3	29.3	21.3	12.5(150)	--	<0.01	<0.01	0.02	0.06	0.08	42	1	--
	2.0	--	7.9	15.8	29.4	21.5	11.9(142)	--	--	--	--	--	--	--	-	--
	2.6	--	7.9	15.8	29.3	21.4	11.9(142)	--	<0.01	<0.01	0.02	0.06	0.07	35	1	--
NEARSHORE STATIONS																
A	0	0930	7.6	17.2	25.8	18.5	9.5(114)	--	0.04	<0.01	0.08	0.10	0.12	25	1	11[2]; 9[2]
B	0	0936	7.7	17.2	25.8	18.5	9.6(115)	--	0.02	<0.01	0.08	0.08	0.10	15	1	<1; <1
C	0	0945	7.7	17.1	25.8	18.5	9.1(109)	--	0.04	<0.01	0.10	0.09	0.10	38	1	10[2]; 3[2]
D	0	0955	7.7	17.2	25.7	18.4	10.2(122)	--	0.03	<0.01	0.10	0.09	0.10	45	2	4[2]; 2[2]
E	0	1000	7.7	17.0	25.6	18.4	9.4(112)	--	<0.01	<0.01	0.08	0.08	0.10	59	3	3[2]; 3[2]

[1]Mean of 6 effluent grab samples collected over a 25-hour period (remaining STP parameters, except FC, estimated from a 24-hour composite effluent sample).

[2]Estimated (fecal coliform count was less than the required minimum of 20 colonies per plate).

[3]On bottom.