ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC AND YUKON REGION

LADYSMITH HARBOUR CONDITIONALLY APPROVED AREAS
1986 MONITORING DATA REPORT
JUNE 23-27, 1986

Regional Data Report DR 86-06

By

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1 INTRODUCTION

Bacteriological sampling of the two conditionally approved shellfish growing areas identified in the Ladysmith Harbour Management plan (EPS, 1985) was conducted from June 23 to 27, 1986. In addition, bacteriological, chemical and flow measurements were taken of chlorinated effluent at the Ladysmith sewage treatment plant at a point just before de-chlorination. A chlorine contact chamber dye study was also undertaken as suggested by the 1985 monitoring report. An assessment of the alarm procedure for the plant was performed in accordance with the conditions outlined in the management plan (EPS, 1985).

2 RESULTS

2.1 Marine Sampling

Samples were collected daily at all marine stations (tides permitting) on both flood and ebb tides (Figure 1). Depth samples were also collected at Stations 22, 38, 40 and 62. Daily bacteriological results are presented in Appendix I. Table 1 summarizes the marine fecal coliform data for the survey period. Based on this data all stations within the conditionally approved area met the approved shellfish growing water standard.

TABLE 1 SUMMARY OF BACTERIOLOGICAL RESULTS FOR MARINE SAMPLE STATIONS

SAMPLE STATION	NUMBER OF SAMPLES	FECAL COLIFORM (MPN/100 ml)		
		Range	Median	90 Percentile
LH009	10	< 2 - 5	< 2	5
LH013	10	< 2 - 2	2	2
LH019	10	< 2 - 23	2	13
LH022 S		< 2 - 11	2	8
LH022 M (2 m)		< 2 - 31	< 2	8
LH022 D (5 m)		< 2 - 5	< 2	3
LH022 C	27	< 2 - 31	2	6
LH030	10	< 2 - 5	< 2	4
LH031	10	< 2 - 11	< 2	7
LH032	10	< 2 - 5	< 2	5
LH034	10	< 2 - 2	< 2	2
LH036	10	< 2 - 8	< 2	4
LH038 S		< 2 - < 2	< 2	< 2
LH038 M (5 m)		< 2 - < 2	< 2	< 2
LH038 D (15 m)		< 2 - 7	< 2	5
LH038 C	27	< 2 - 7	< 2	< 2
LH040 S		< 2 - 2	< 2	< 2
LH040 M (5 m)		< 2 - 2	< 2	< 2
LH040 D (15 m)		< 2 - 11	< 2	8
LH040 C	26	< 2 - 11	< 2	3
LH062 S		< 2 - < 2	< 2	< 2
LH062 M (5 m)		< 2 - 2	< 2	2
LH062 D (15 m)		< 2 - 17	< 2	4
LH062 C	28	< 2 - 17	< 2	2
LH 9, 13, 19, 22	57	< 2 - 31	2	6.0
LH 30, 31, 32, 34	50	< 2 - 11	< 2	5

S = surface; M = mid-depth; D = 1 m off bottom; C = combined data, all depths

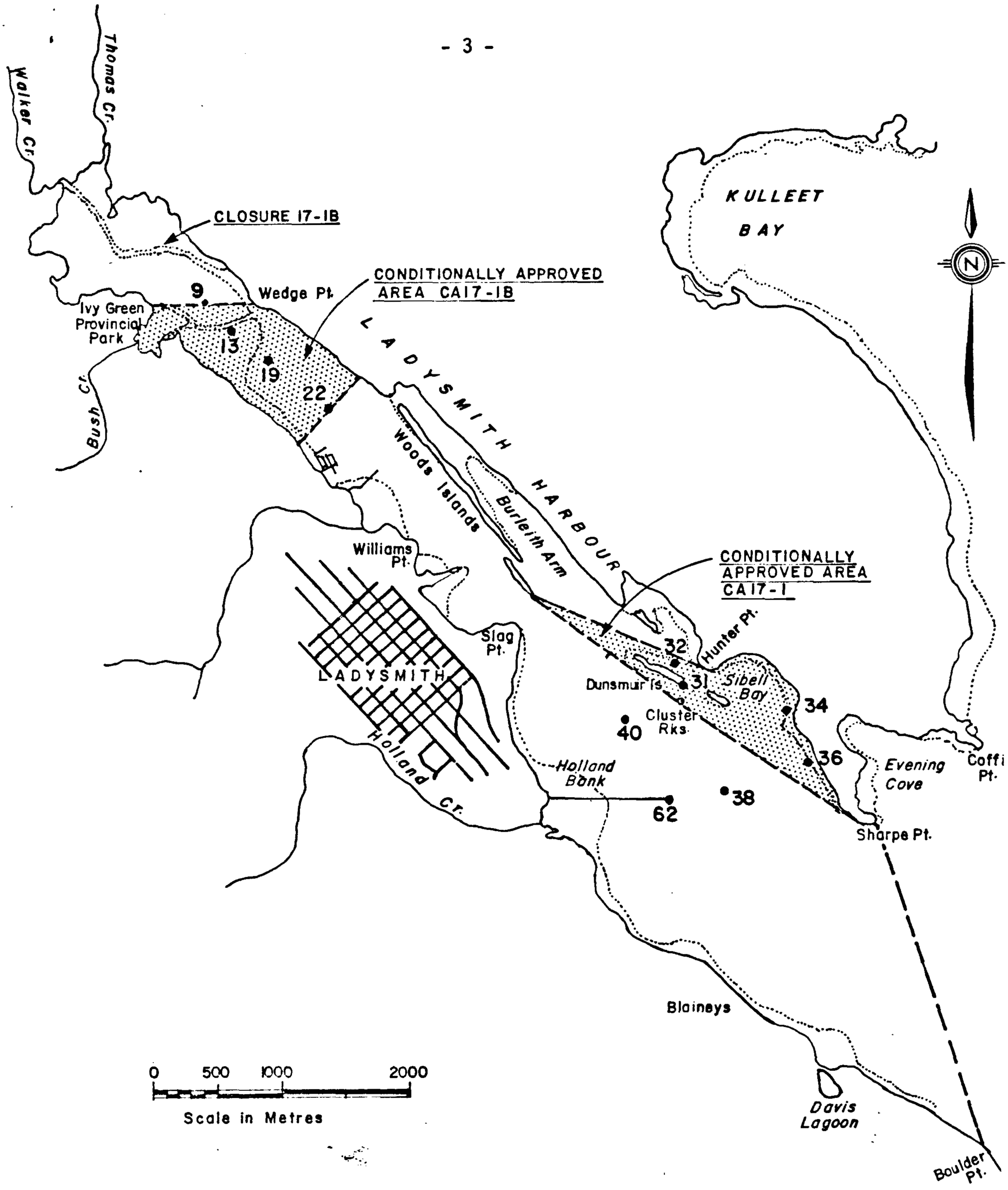


FIGURE 1 MARINE SAMPLING STATIONS - LADYSMITH HARBOUR

Combined data for stations in conditionally approved area CA17-1B had a median of < 2 FC/100 ml and a 90 percentile of 6 FC/100 ml. Combined data for conditionally approved area CA17-1 produced a median of 2 FC/100 ml and a 90 percentile of 5 FC/100 ml. For all stations and all sample days only two counts above standard were recorded. Station 19 produced a count of 23 FC/100 ml on June 27 (flood tide) and Station 22 had a count of 31 FC/100 ml on June 24 (ebb tide).

Station 62 over the outfall recorded one sample over standard, taken from a depth of 15 m (17 FC/100 ml). Combined data for 28 samples produced a median of < 2 FC/100 ml and a 90 percentile of 2 FC/100 ml.

2.2 Physical Data

Salinity, temperature and dissolved oxygen measurements were recorded at 1 m intervals at the outfall station (LH 62) on June 23, 1986. Measurements were made using a Hydrolab Surveyor II (model 9000). Salinity measurements on all bacteriological samples were done with an American Optical Refractometer.

Profiling data for Station LH62 is presented in Table 2 and indicates a stratified water column was present at the time of the survey. Using these values in the OUTPLM dilution model, the effluent from the sewage treatment plant was predicted to be trapped 4-5 meters under the surface of the water with an initial dilution of 80:1 (Appendix II).

Salinity measurements ranged from 21.0 to 26.0 ppt for the surface stations and from 22.0 to 28.0 ppt for the depth stations. Rainfall did not occur during the survey period (Table 3) hence the relatively high salinities due to the absence of freshwater input to the harbour.

2.3 Ladysmith Sewage Treatment Plant Assessment

2.3.1 Alarm Procedure.

The open period for the conditionally approved area is dependent on the operation of the Ladysmith sewage treatment plant and the volume of effluent by-passed when the treatment system is

TABLE 2 WATER COLUMN PROFILE AT STATION 62 - JUNE 23, 1986

DEPTH (m)	SALINITY (ppt)	DISSOLVED OXYGEN (mg/l)	pH	TEMPERATURE (°C)
0	21.70	8.20	7.30	16.80
1	21.70	8	7.40	16.80
2	21.90	8.10	7.40	16.10
3	22.10	7.80	7.40	14.90
4	22.50	8	7.40	13.90
5	22.70	6.80	7.30	13.10
6	22.80	6.60	7.20	12.70
7	23.20	6.30	7.20	11.50
8	23.30	6.50	7.20	11.30
9	23.40	6.50	7.20	11.20
10	23.40	6.70	7.20	11.10
11	23.50	7.30	7.30	10.90
12	23.70	7.10	7.30	10.80
13	23.80	7.10	7.30	10.70
14	23.90	6.60	7.20	10.60
15	24	6.10	7.20	10.40
16	24	6.60	7.20	10.30
17	24.10	6.10	7.10	10.20

TABLE 3 DAILY RAINFALL RECORD, NANAIMO AIRPORT (CASSIDY), JUNE 1986

JUNE, 1986	RAINFALL (mm)	JUNE, 1986	RAINFALL (mm)	JUNE, 1986	RAINFALL (mm)
1	NIL	11	NIL	21	NIL
2	NIL	12	NIL	22	.80
3	NIL	13	.60	23*	NIL
4	TRACE	14	6.30	24*	NIL
5	NIL	15	7.60	25*	NIL
6	NIL	16	4.50	26*	NIL
7	TRACE	17	1.20	27*	NIL
8	NIL	18	2.40	28	4.50
9	NIL	19	7.80	29	1.80
10	NIL	20	NIL	30	3.70

* denotes sampling day

overloaded. These conditions are monitored by three alarm systems which will engage under the following circumstances:

1) chlorine failure i) loss of chlorine gas pressure through the rotameter,
   ii) loss of water pressure;
2) bypass (overflow) of 30 IMP gal/min (1% of the flow on the overflow transmitter) for more than 2 hours;
3) power failure for more than one hour.

When one or more of these conditions are met, the controller sends a signal through the phone line to a 24 hour answering service (Sounder Alarm & Power Ltd.) in Duncan. The alarm condition is identified by the following codes.

CODE 4 - Chlorine failure
CODE 5 - Power failure
CODE 6 - Overflow failure

The answering service then contacts the following phone numbers in sequence.

Public Works Yard	245-2433 (working hours)
City Hall	245-2218 (working hours)
Brian Mattershead (STP Operator)	245-4779
Bill Bonsall	245-7691
John Vreeling	245-3364
Tommy Cloke	245-3558

2.3.2 EPS Alarm Test. On June 23, the Environmental Protection Service initiated a series of tests simulating alarm conditions. The power failure alarm system did not respond because of a malfunction in the controller. The alarm system responded satisfactorily to the chlorine failure/low water pressure and bypass situations.

On July 29, 1986 EPS personnel were informed by J. Vreeling, Works Superintendant, that the power failure alarm system had been repaired and operated satisfactorily when tested.

3 CHLORINE CONTACT CHAMBER

3.1 Results and Discussion

3.1.1 Dye Study. A primary consideration in the design of a chlorine contact chamber is that the hydraulic characteristics of the reactor incorporate a minimum of chlorine usage with a maximum of exposure to the microorganisms present in the effluent (EPA, 1979). Tracer studies, and the resulting dispersion flow curve, are the most common approach to analyzing the hydraulic efficiency of a contact chamber (Figure 2).

The ideal situation in the design of a chlorine contact chamber is to achieve plug flow. The closer hydraulic flow patterns are to achieving plug flow the more efficient will be the disinfection characteristics of the chamber. The hydraulic characteristic plug flow assures that each part of the fluid entering a chamber will pass evenly and constantly through the chamber so that actual residence time will equal theoretical residence time. Flow through the tank in this manner decreases undesirable tank conditions such as dead spaces, short circuiting, eddy currents, spiralling, and solids deposition (Kothandaraman and Evans, 1974).

Marshe and Boyle (1973) have determined that the dispersion index d and the Morril index, t_{90}/t_{10}, were the strongest statistical and conventional parameters to describe the hydraulic performance of a contact chamber in terms of plug flow performance. For good plug flow conditions (small amounts of dispersion) d approaches zero while the Morril index approaches 1.0. Conversely as flow in the chamber approaches conditions of complete mix or backmix, d increases to infinity, although values > 0.025 indicate intermediate amounts of dispersion and values > 0.2 indicate large amounts of disperions. Morril index values > 3 indicate large amounts of dispersion.

Four separate dye tracer studies were performed on the chlorine contact chamber at the Ladysmith treatment plant between June 23 and June 27. On each occasion a slug of Rhodamine WT dye was injected into the influent pipe of the chamber at a point just prior to chlorine addition. Chlorine gas is flow-proportionally fed to a water line that joins the effluent pipe just

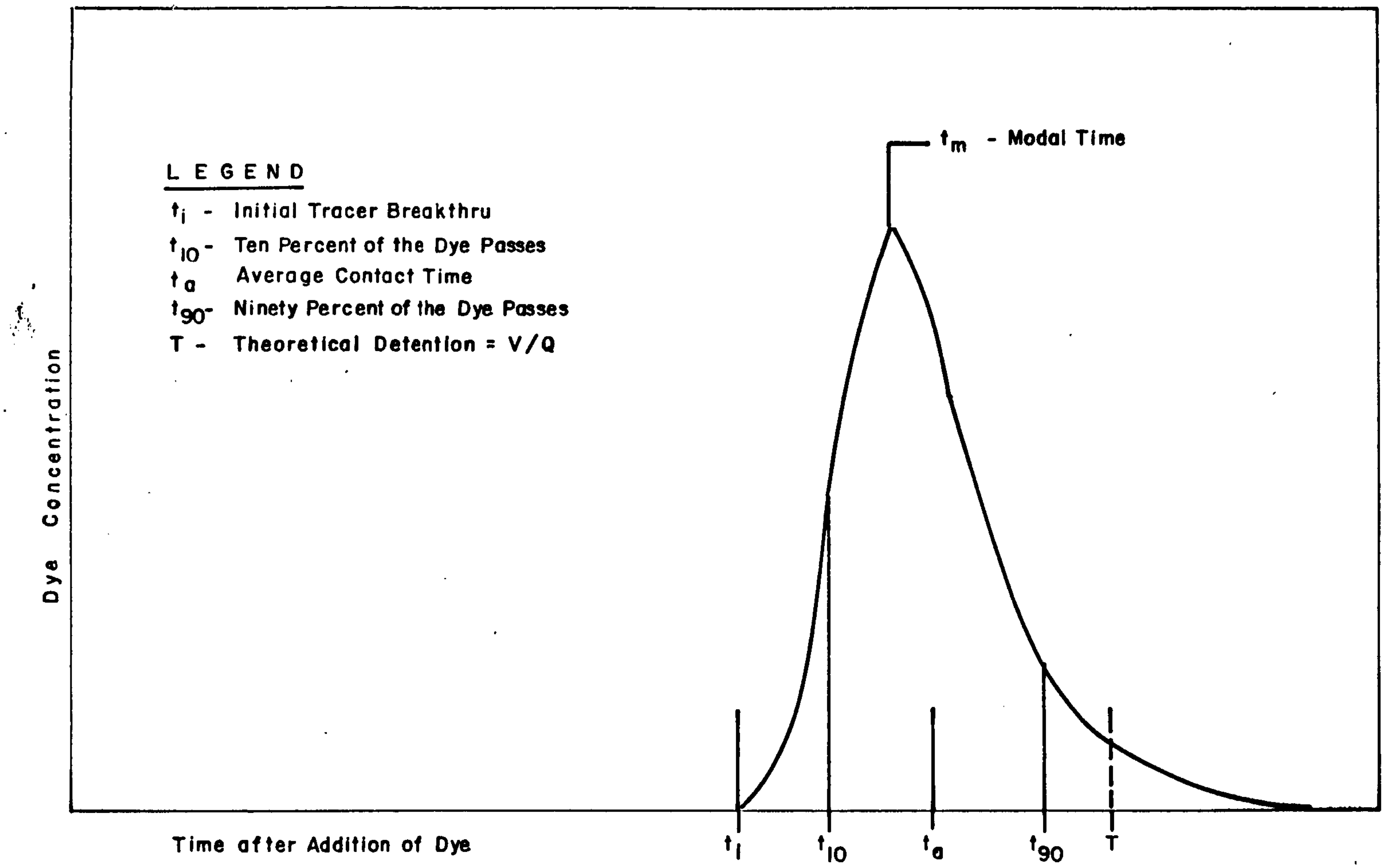


FIGURE 2 TYPICAL TRACER CURVE (Sepp 1977)

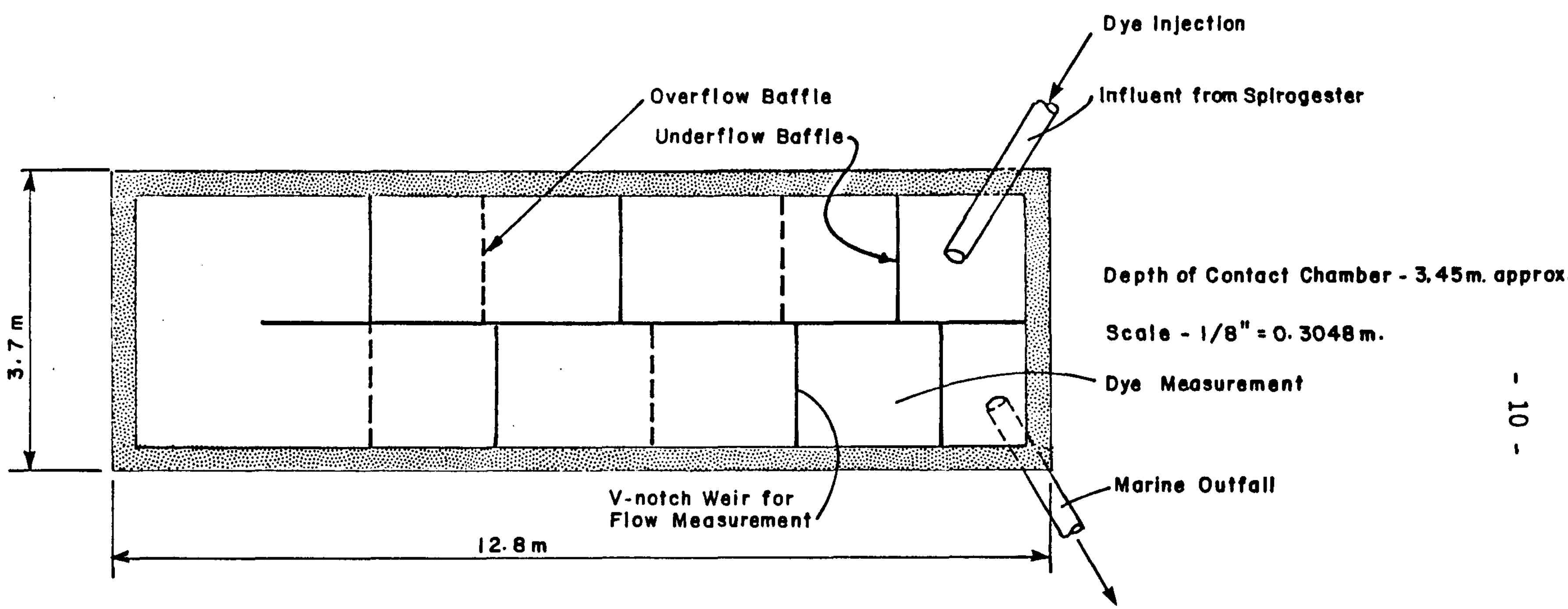


FIGURE 3 LADYSMITH STP CHLORINE CONTACT CHAMBER - PLAN VIEW

prior to the contact chamber (Figure 3). This method of chlorine addition should achieve good initial mixing, resulting in uniform contact of chlorine with the microorganisms. Dye concentrations were measured with a Turner Designs Model 10 fluorometer at the exit of the contact chamber.

Tracer curves for the four tests are presented in Figure 4 and results from these tests are presented in Table 4. The Dispersion Index for this chamber was 0.061 and the Morril Index was 2.53 (mean value in each cases). Both indices suggest that there is better than an intermediate amount of dispersion. The mean time for the initial appearance of the dye was 18.75 minutes while the average residence time was 81 minutes.

The ratio t_a/T gives an indication of dead space in the contact chamber. Dead space decreases the overall disinfection efficiency of the chamber by creating solids accumulation and resulting in an increased chlorine demand. For a chamber that has no dead spaces, the average detention time would be equal to the theoretical detention time hence $t_a/T = 1$. The mean value for t_a/T for this chamber was 0.94. This value could however, be biased high because t_a could be considerably greater if dye were caught in dead spaces then slowly released through the latter stages of the study. This is indicated by tailing out of the curve on the dispersion plot as shown to be the case in this plant (Figure 4).

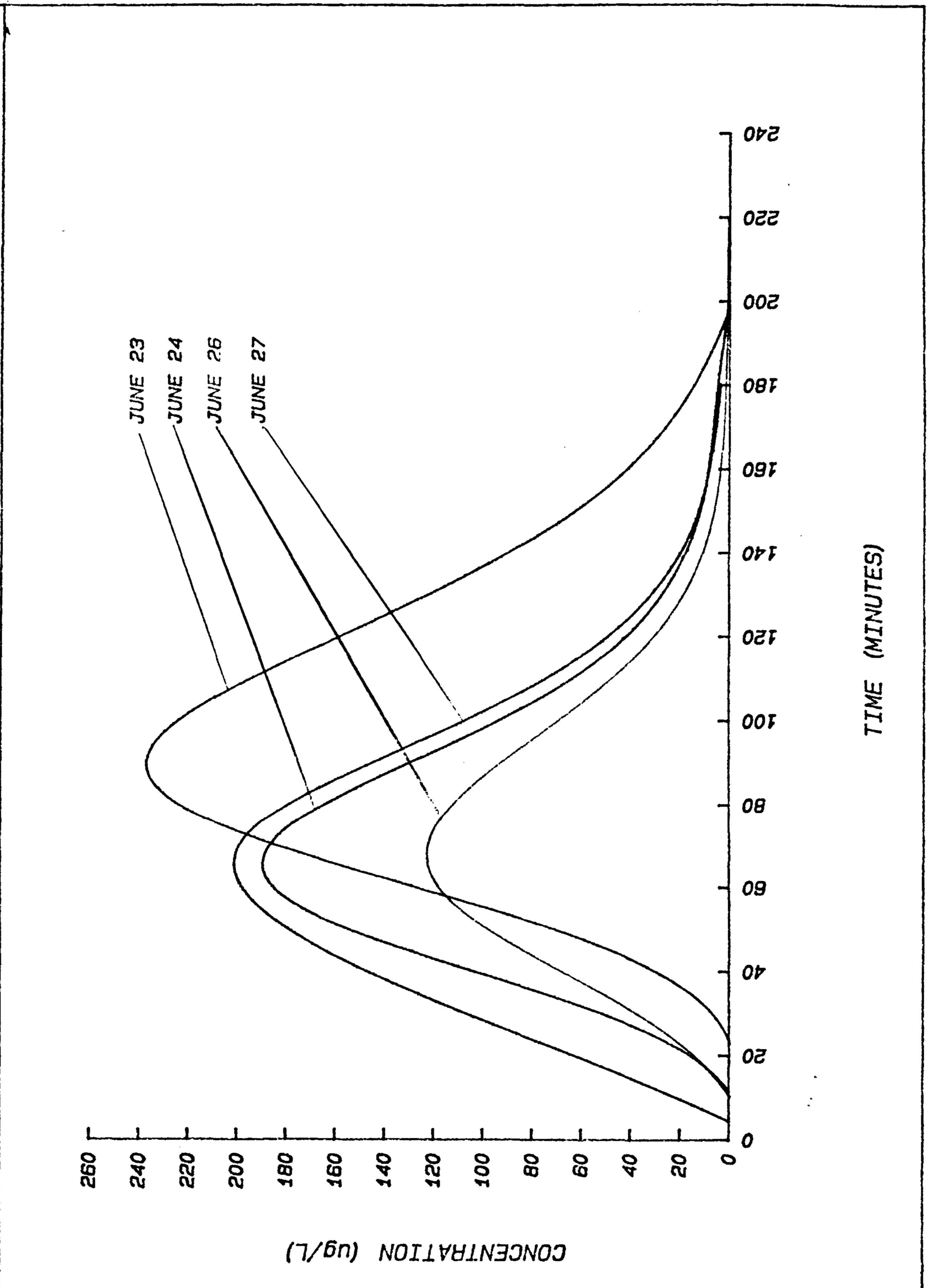
Length-to-width ratios also play an important part in the design of a contact chamber in that the greater the length-to-width ratio the closer a chamber will be to achieving plug flow. A minimum of 40:1 is required to achieve optimum plug flow performance (Marske and Boyle, 1973). The length-to-width ratio for ths contact chamber is 22:1, taking into account the underflow/overflow baffle system. A lower L/W ratio has the effect of decreasing the contact time and thereby requiring a higher dose of chlorine to accomplish the required kill of bacteria.

TABLE 4 DYE TRACER STUDY RESULTS

DATE	L/W	H/W	T	ta	ta/T	Ti	Tm	T_{10}	T_{50}	T_{90}	d	MORRIL	Q m^3/min.
June 23	22:1	1.98	97	99	1.02	20	90	68	103.5	149	0.046	2.2	1.59
June 24	22:1	1.98	83	76	0.91	15	65	48	79	128	0.0725	2.67	1.86
June 26	22:1	1.98	85	77	0.91	15	60	49	80.3	127	0.050	2.6	1.82
June 27	22:1	1.98	81.7	75	0.92	15	65	46.6	78.7	125	0.075	2.68	1.89
Mean			87	81	0.94	18.75					0.061	2.53	

L - Length
W - Width
H - Height
T - Theoretical Detention
ta - Average Contact Time
Ti - Initial Trace Breakthrough
Tm - Modal Time

T_{10} - 10 percent of the dye passes
T_{50} - 50 percent of the dye passes
T_{90} - 90 percent of the dye passes
d - Dispersion Index
Morril - Morril Index
Q - flow



LADYSMITH CHLORINE CONTACT CHAMBER DYE STUDY

4 OPERATIONAL PERFORMANCE

4.1 Effluent

Bacterial and chemical (chlorine) analyses were carried out simultaneously with the marine sampling program. In certain cases sampling was also concurrent to the dye study. Results for the five sampling days are shown in Table 5. Those samples marked with an asterisk are samples taken during a dye study.

High fecal coliform values were recorded on the first four days of the study. Coliform levels throughout the study period were not consistent, but rather tended to fluctuate. On June 26 the chlorine feed system was found to be leaking at the point of injection to the effluent pipe and was subsequently repaired that afternoon.

Sample numbers 5, 6, 9 and 11 recorded some of the highest fecal coliform levels (58,000, 320,000, 60,000, and 9200 FC/100 ml), while the lowest chlorine residuals were recorded in 6 and 9. Chlorine measurements were not done for sample number 11, however this was the last sample taken before repairs were made and subsequent data indicate that sufficient chlorine was present to effect an adequate kill of bacteria.

4.2 Sludge

During the EPS survey of Ladysmith Harbour in 1983 (Kay and Walker, 1985) an assessment of the treatment plant found that mercury levels in the sludge were high (7.14 mg/kg in the stabilized layer).

During this study replicate samples of the sludge produced Hg values of 1.82 and 1.49 mg/kg. The sludge age in this case was not old because the digester had recently been drawn down and wasted through the outfall.

TABLE 5 BACTERIOLOGICAL, FLOW AND CHLORINE RESIDUAL DATA FOR LADYSMITH STP

DATE 1986	TIME	FLOW (gpm)	SAMPLE NUMBER	MF/100 ml	CHLORINE	
					FREE	TOTAL
June 23	10:00	420	1	50	-	-
June 23	10:30	330	2*	< 10	-*	-
June 23	19:15	340	3*	4,600	-*	-
June 24	10:00	420	4*	220	1.45*	1.05
June 24	14:45	300	5	54,000	0.75	0.2
June 24	18:10	340	6	320,000	0	0.1
June 25	11:00	400	7	50	-	-
June 25	16:20	320	8	740	0.05	0.25
June 25	18:00	340	9	60,000	0.05	0.05
June 26	08:45	420	10	260	0.15	0.3
June 26	12:00	380	11	9,200	-	-
June 26	17:10	320	12	170	0.2	0.15
June 27	10:54	400	13*	470	0.45*	1.2
June 27	13:30	330	14*	120	0.3*	1.25
June 27	16:00	310	15	20	-	-

* taken during dye study

CONCLUSIONS AND OBSERVATIONS

1. The waters of conditionally approved area CA17-1B (Inner Harbour) met the approved shellfish growing water standard.

2. The waters of conditionally approved area CA17-1 (Outer Harbour) met the approved shellfish growing water standard.

3. The discharge of chlorinated sewage from the Ladysmith Treatment Plant did not result in measureable contamination in the marine waters.

4. The power failure alarm did not respond to the power failure simulation test. The alarm was subsequently repaired and reported functioning normally.

5. Adequate disinfection of the final effluent was not taking place during a portion of the survey due to a leak in the chlorine injection system. This was repaired during the survey.

6. As indicated by Shepherd (1982), and further verified by the results of this study, the design of the contact chamber at the Ladysmith treatment plant is somewhat less than optimal. This in part is due to the small length-to-width ratio and the design of the baffle system. The use of baffles can improve the efficiency of a chamber by increasing the length-to-width ratios. However, in this case, the dispersion index and the Morril index both indicate better than intermediate amounts of dispersion. This is likely due to the creation of dead space by the underflow/overflow baffles and to a lesser extent the longitudinal baffle, at the point where the liquid is required to change direction at one end of the chamber.

7. The data indicate that the present dosage of chlorine is adequate in reducing bacteria to acceptable levels provided the chlorination system

is not malfunctioning. However, if problems exist in the chlorination system such as those identified in both the 1986 and the 1985 monitoring program (and since the outfall can no longer act as a second contact chamber because of dechlorination), bacteria levels may not be sufficiently reduced in the effluent, and the potential for contamination of the surrounding shellfish growing waters exists.

8. A high concentration of solids was observed in the effluent moving over the spiragester weirs into the chlorine contact chamber. This problem reportedly worsened toward the end of the conditionally open period (J. Vreeling, pers. comm.). This is due to the lengthy amount of holding time required for the accumulation of solids during the conditionally open period. The deposition of solids in the contact chamber creates a higher demand for chlorine and results in a decrease in the reduction of bacteria in the final effluent.

RECOMMENDATIONS

1. A complete alarm test should be carried out once per week during the conditionally approved opening (area CA17-1).

2. Chlorine residuals are generally done by the plant operator at the same time each morning, usually in conjunction with the daily maintenance operations between 8 and 10 a.m. Chlorine residuals should be taken during peak flows when chlorine demand is high and contact time is at a minimum.

3. The alarm monitoring procedure should be activated 14 days prior to the opening of conditionally approved area CA17-1.

4. Copies of flow recording charts for the plant and bypass, and the totalized daily volume discharges for each month were not provided to the Environmental Protection Service during the open period as detailed in Appendix VI(3) of the Management Plan. The Town of Ladysmith should be advised of this requirement.

5. Due to the decrease in effluent quality and disinfection efficiency caused by the loss of solids towards the end of the conditionally approved opening, weekly status reports on effluent quality should be obtained by EPS and monthly operational audits should be conducted.

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APPENDIX I

APPENDIX I
TABLE : Daily Data Record for Marine Sample Stations
(Area LH)

tion	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
09	49 01.02	123 50.27	86/06/23	1030	Ebb	5	23.5	
			86/06/23	1705	Flood	<2	24.0	
			86/06/24	0825	Ebb	5	23.5	
			86/06/24	1820	Flood	<2	23.5	
			86/06/25	0845	Ebb	5	25.5	
			86/06/25	1715	Flood	<2	24.0	
			86/06/26	1005	Ebb	<2	23.5	
			86/06/26	1610	Flood	2	23.5	
			86/06/27	0725	Flood	4	22.5	
			86/06/27	1345	Ebb	<2	24.0	
13	49 00.56	123 50.10	86/06/23	1040	Ebb	2	22.0	
			86/06/23	1710	Flood	<2	24.0	
			86/06/24	0825	Ebb	<2	23.5	
			86/06/24	1825	Flood	2	24.0	
			86/06/25	0850	Ebb	2	26.0	
			86/06/25	1720	Flood	2	24.0	
			86/06/26	1010	Ebb	2	23.5	
			86/06/26	1615	Flood	<2	23.5	
			86/06/27	0730	Flood	<2	22.0	
			86/06/27	1350	Ebb	2	24.5	
19	49 00.48	123 50.00	86/06/23	1045	Ebb	2	23.0	
			86/06/23	1710	Flood	2	23.0	
			86/06/24	0830	Ebb	11	23.5	
			86/06/24	1825	Flood	2	24.0	
			86/06/25	0850	Ebb	5	24.5	
			86/06/25	1720	Flood	<2	24.0	
			86/06/26	1010	Ebb	13	23.5	
			86/06/26	1615	Flood	2	24.0	
			86/06/27	0730	Flood	23	23.0	
			86/06/27	1350	Ebb	<2	23.0	
22	49 00.38	123 49.35	86/06/23	1050	Ebb	<2	23.5	
			86/06/23	1715	Flood	<2	23.5	
			86/06/23	1715	Flood	<2	24.0	*
			86/06/23	1715	Flood	2	24.0	*
			86/06/24	0835	Ebb	11	24.0	
			86/06/24	0835	Ebb	31	24.0	*
			86/06/24	0835	Ebb	2	24.5	*
			86/06/24	1655	Flood	2	24.0	
			86/06/24	1655	Flood	<2	24.5	*
			86/06/24	1655	Flood	2	25.0	*
			86/06/25	0920	Ebb	8	24.0	
			86/06/25	0920	Ebb	4	23.5	*
			86/06/25	0920	Ebb	<2	24.5	*
			86/06/25	1530	Flood	2	25.0	
			86/06/25	1530	Flood	2	25.0	*

depth sample

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TABLE : Daily Data Record for Marine Sample Stations
(Area LH)

tion	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
22	continued...		86/06/25	1530	Flood	<2	25.0	*
			86/06/26	0845	Ebb	<2	24.0	
			86/06/26	0845	Ebb	<2	23.5	*
			86/06/26	0845	Ebb	<2	24.5	*
			86/06/26	1610	Flood	2	24.0	
			86/06/26	1610	Flood	<2	23.5	*
			86/06/26	1610	Flood	<2	23.5	*
			86/06/27	0720	Flood	2	22.5	
			86/06/27	0720	Flood	2	22.5	*
			86/06/27	0720	Flood	5	23.0	*
			86/06/27	1350	Ebb	<2	23.0	
			86/06/27	1350	Ebb	<2	23.0	*
30	48 59.33	123 47.38	86/06/23	0850	Ebb	5	24.0	
			86/06/23	1810	Flood	<2	23.5	
			86/06/24	0930	Ebb	4	25.0	
			86/06/24	1710	Flood	<2	25.0	
			86/06/25	0940	Ebb	<2	25.0	
			86/06/25	1555	Flood	<2	25.0	
			86/06/26	0905	Ebb	<2	23.0	
			86/06/26	1715	Flood	<2	22.0	
			86/06/27	0830	High Slack	<2	22.0	
			86/06/27	1450	Low Slack	<2	21.5	
31	48 59.29	123 47.19	86/06/23	0905	Ebb	2	24.5	
			86/06/23	1810	Flood	<2	23.5	
			86/06/24	0930	Ebb	11	24.5	
			86/06/24	1715	Flood	<2	25.0	
			86/06/25	0945	Ebb	<2	25.0	
			86/06/25	1555	Flood	<2	25.0	
			86/06/26	0905	Ebb	<2	23.0	
			86/06/26	1715	Flood	7	22.0	
			86/06/27	0825	High Slack	<2	21.5	
			86/06/27	1450	Low Slack	<2	21.5	
32	48 59.34	123 47.22	86/06/23	0855	Ebb	<2	24.0	
			86/06/23	1815	Flood	2	23.0	
			86/06/24	0935	Ebb	5	24.5	
			86/06/24	1755	Flood	<2	25.0	
			86/06/25	0940	Ebb	2	25.5	
			86/06/25	1630	Flood	2	25.0	
			86/06/26	0900	Ebb	<2	23.0	
			86/06/26	1720	Flood	<2	23.0	
			86/06/27	0835	High Slack	5	22.5	
			86/06/27	1455	Low Slack	<2	22.0	
34	48 59.21	123 46.36	86/06/23	0910	Ebb	<2	23.5	

lepth sample

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TABLE : Daily Data Record for Marine Sample Stations
(Area LH)

tion	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
34	continued...		86/06/23	1740	Flood	<2	23.5	
			86/06/24	0905	Ebb	2	24.5	
			86/06/24	1720	Flood	<2	24.5	
			86/06/25	0945	Ebb	2	25.5	
			86/06/25	1600	Flood	<2	25.0	
			86/06/26	0910	Ebb	<2	23.5	
			86/06/26	1645	Flood	<2	21.0	
			86/06/27	0820	High Slack	<2	22.0	
			86/06/27	1445	Low Slack	<2	22.0	
36	48 59.08	123 46.24	86/06/23	0910	Ebb	<2	23.5	
			86/06/23	1735	Flood	2	24.0	
			86/06/24	0905	Ebb	<2	25.0	
			86/06/24	1720	Flood	<2	25.0	
			86/06/25	0945	Ebb	<2	25.0	
			86/06/25	1605	Flood	4	25.0	
			86/06/26	0910	Ebb	<2	22.5	
			86/06/26	1640	Flood	<2	21.5	
			86/06/27	0815	High Slack	8	22.0	
			86/06/27	1440	Low Slack	<2	22.0	
38	48 58.59	123 46.58	86/06/23	0915	Ebb	<2	24.0	
			86/06/23	1745	Flood	<2	25.0	
			86/06/23	1745	Flood	<2	25.0	*
			86/06/23	1745	Flood	<2	26.0	*
			86/06/24	0910	Ebb	<2	24.5	
			86/06/24	0910	Ebb	<2	25.0	*
			86/06/24	0910	Ebb	<2	26.0	*
			86/06/24	1725	Flood	<2	25.0	
			86/06/24	1725	Flood	<2	25.0	*
			86/06/24	1725	Flood	<2	28.5	*
			86/06/25	0955	Ebb	<2	25.0	
			86/06/25	0955	Ebb	<2	25.0	*
			86/06/25	0955	Ebb	<2	25.5	*
			86/06/25	1605	Flood	<2	25.0	
			86/06/25	1605	Flood	<2	25.0	*
			86/06/25	1605	Flood	<2	26.0	*
			86/06/26	0915	Ebb	<2	23.0	
			86/06/26	0915	Ebb	<2	24.0	*
			86/06/26	0915	Ebb	<2	25.5	*
			86/06/26	1650	Flood	<2	22.5	
			86/06/26	1650	Flood	<2	23.0	*
			86/06/26	1650	Flood	5	25.5	*
			86/06/27	0805	High Slack	<2	22.0	
			86/06/27	0805	High Slack	<2	22.0	*
			86/06/27	0805	High Slack	<2	25.0	*
			86/06/27	1430	Low Slack	<2	22.5	

lepth sample

APPENDIX I
TABLE : Daily Data Record for Marine Sample Stations
(Area LH)

tion	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
38	continued...		86/06/27	1430	Low Slack	7	22.0	*
40	48 59.17	123 47.43	86/06/23	0920	Ebb	<2	24.0	
			86/06/23	1800	Flood	<2	23.5	
			86/06/23	1800	Flood	<2	25.0	*
			86/06/24	0920	Ebb	<2	24.5	
			86/06/24	0920	Ebb	<2	24.5	*
			86/06/24	0920	Ebb	<2	26.0	*
			86/06/24	1745	Flood	<2	24.5	
			86/06/24	1745	Flood	<2	25.5	*
			86/06/24	1745	Flood	<2	26.5	*
			86/06/25	1010	Ebb	2	25.0	
			86/06/25	1010	Ebb	<2	25.5	*
			86/06/25	1010	Ebb	5	25.0	*
			86/06/25	1620	Flood	<2	24.5	
			86/06/25	1620	Flood	<2	25.0	*
			86/06/25	1620	Flood	<2	26.5	*
			86/06/26	0930	Ebb	<2	23.0	
			86/06/26	0930	Ebb	<2	23.0	*
			86/06/26	0930	Ebb	<2	26.0	*
			86/06/26	1700	Flood	<2	22.0	
			86/06/26	1700	Flood	2	23.0	*
			86/06/26	1700	Flood	11	25.5	*
			86/06/27	0745	High Slack	<2	22.0	
			86/06/27	0745	High Slack	<2	23.0	*
			86/06/27	0745	High Slack	7	26.5	*
			86/06/27	1410	Low Slack	<2	25.5	
			86/06/27	1410	Low Slack	<2	22.5	*
62	48 59.00	123 47.25	86/06/23	0920	Ebb	<2	24.0	
			86/06/23	1800	Flood	<2	24.0	
			86/06/23	1800	Flood	<2	25.0	*
			86/06/23	1800	Flood	<2	25.5	*
			86/06/24	0915	Ebb	<2	24.5	
			86/06/24	0915	Ebb	<2	24.5	*
			86/06/24	0915	Ebb	2	25.5	*
			86/06/24	1735	Flood	<2	24.5	
			86/06/24	1735	Flood	<2	25.0	*
			86/06/24	1735	Flood	<2	27.0	*
			86/06/25	1020	Ebb	<2	23.5	
			86/06/25	1020	Ebb	<2	24.0	*
			86/06/25	1020	Ebb	2	25.0	*
			86/06/25	1610	Flood	<2	24.5	
			86/06/25	1610	Flood	<2	25.0	*
			86/06/25	1610	Flood	<2	26.0	*
			86/06/26	0925	Ebb	<2	23.0	
			86/06/26	0925	Ebb	<2	23.0	*

:pth sample

APPENDIX I
TABLE : Daily Data Record for Marine Sample Stations
(Area LH)

ıtion	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
)62	continued...		86/06/26	0925	Ebb	<2	25.0	*
			86/06/26	1655	Flood	<2	22.0	
			86/06/26	1655	Flood	2	23.0	*
			86/06/26	1655	Flood	<2	26.0	*
			86/06/27	0755	High Slack	<2	22.0	
			86/06/27	0755	High Slack	2	22.0	*
			86/06/27	0755	High Slack	17	25.0	*
			86/06/27	1420	Low Slack	<2	23.0	
			86/06/27	1420	Low Slack	<2	23.0	*
			86/06/27	1420	Low Slack	2	25.0	*

depth sample

APPENDIX II

APPENDIX II OUTFALL PLUME IN A FLOWING STRATIFIED MEDIA - Model OUTPLM

INITIAL DATA - LADYSMITH JUNE 23/86

OUTFALL DEPTH	17.00 m	MAX. HORIZONTAL DISTANCE	1000 m
DIAMETER .	.610 m	VERTICAL DISTANCE	500 m
ANGLE	0.00 deg up	MAX. No. OF CALCULATIONS	1000
		CALCULATIONS PER LINE ...	50
EFFLUENT FLOW RATE	2782.0 cu·m/d		
HOR. VEL.	.110 m/sec	IMPINGEMENT COEFFICIENT .	1.000
VER. VEL.	0.000 m/sec	ASPIRATION COEFFICIENT .	.100
PLUME RADIUS	.305 m		
THICKNESS ..	.305 m	VELOCITY FACTOR (K)	11.018
TEMPERATURE	15.00 deg.C	FROUDE NUMBER (FR)	.331
SALINITY ...	1.000 ppt	VOLUME RATE OF DISCHARGE	.032
DENSITY	1.000 gm/cu·cm		
CURRENT VELOCITY .	.010 m/sec		

AMBIENT CONDITIONS:

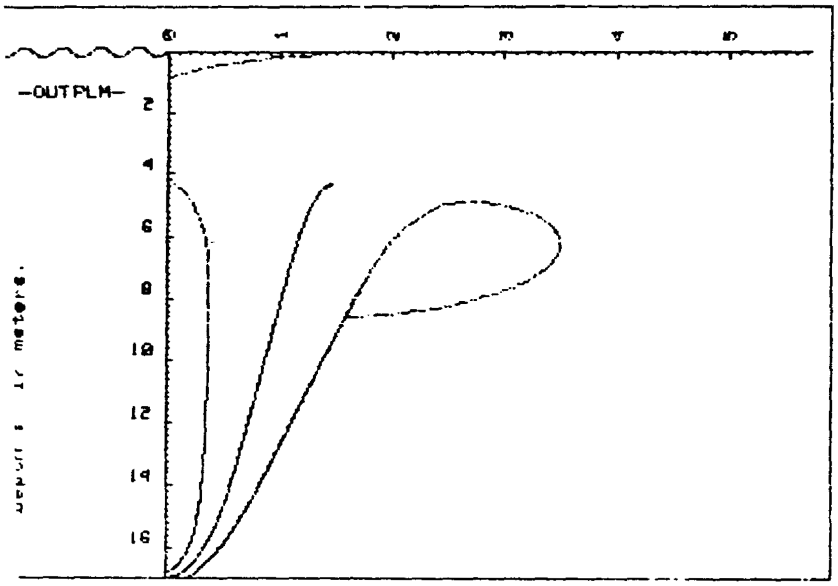
POINT	DEPTH (m)	TEMPERATURE (°C)	SALINITY (ppt)	SIGMA (T)	DENSITY (gm/cu·cm)
1	0.0	16.80	21.700	15.431	1.015
2	1.0	16.80	21.700	15.431	1.015
3	2.0	16.10	21.900	15.730	1.016
4	3.0	14.10	22.100	16.275	1.016
5	4.0	13.90	22.500	16.619	1.017
6	5.0	13.10	22.700	16.918	1.017
7	6.0	12.70	22.800	17.064	1.017
8	7.0	11.50	23.200	17.573	1.018
9	8.0	11.30	23.300	17.683	1.018
10	9.0	11.20	23.400	17.776	1.018
11	11.0	10.90	23.500	17.900	1.018
12	12.0	10.80	23.700	18.071	1.018
13	13.0	10.70	23.800	18.163	1.018
14	15.0	10.40	24.000	18.364	1.018
15	17.0	10.20	24.100	18.472	1.018

APPENDIX II (Continued)

PLUME SITUATION:

DISTANCE (m)	DEPTH (m)	RADIUS (m)	THICK (m)	MASS (gm)	EINS	ZWEI	DILUTION	DENSITY DIFFERENCE	HORIZONTAL VELOCITY (m/s)	VERTICAL VELOCITY (m/s)	TOTAL VELOCITY (m/s)	TEMPERATURE DIFFERENCE (°C)
0.00	17.00	.30	.30	89.1	.3	5.96	1.00	18.43	.1	0.0	.1	4.8000
.01	17.00	.31	.31	89.7	.3	5.96	1.01	18.41	.1	0.0	.1	4.7668
.21	16.65	.22	.79	126.0	.1	.87	1.41	13.10	.1	.3	.3	3.3646
.30	16.25	.25	.88	178.3	.1	1.23	1.98	9.25	.1	.3	.3	2.3456
.38	15.78	.30	.88	252.1	.2	1.73	2.80	6.52	0.0	.3	.3	1.6190
.45	15.21	.36	.85	356.5	.3	2.45	3.95	4.59	0.0	.3	.3	1.0970
.52	14.52	.44	.80	504.2	.4	3.46	5.57	3.20	0.0	.3	.3	.6963
.60	13.67	.55	.75	713.0	.6	4.90	7.87	2.19	0.0	.3	.3	.3645
.68	12.61	.67	.69	1008.4	.9	6.92	11.13	1.46	0.0	.2	.3	.1559
.78	11.31	.84	.63	1426.0	1.4	9.78	15.73	.88	0.0	.2	.2	0.0000
.89	9.67	1.06	.56	2016.7	2.2	13.83	22.24	.51	0.0	.2	.2	-.1950
.05	7.59	1.35	.48	2852.1	3.7	19.52	31.45	.21	0.0	.2	.2	-.3751
.33	4.70	2.45	.19	4033.4	17.8	24.71	44.48	-.53	0.0	.1	.1	-1.8956
.45	4.34	6.85	.04	5704.1	39.4	.03	62.91	-.47	0.0	0.0	0.0	-1.5960
.47	4.33	8.51	.03	7270.2	50.2	.02	79.64	-.37	0.0	-0.0	0.0	-1.2558

Number of Steps = 635


-OUTPLM-
2
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