NRA North West Region

THE DISINFECTION OF THE MANCHESTER SQUARE OUTFALL, BLACKPOOL, 1993

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CONTENTS

1 INTRODUCTION

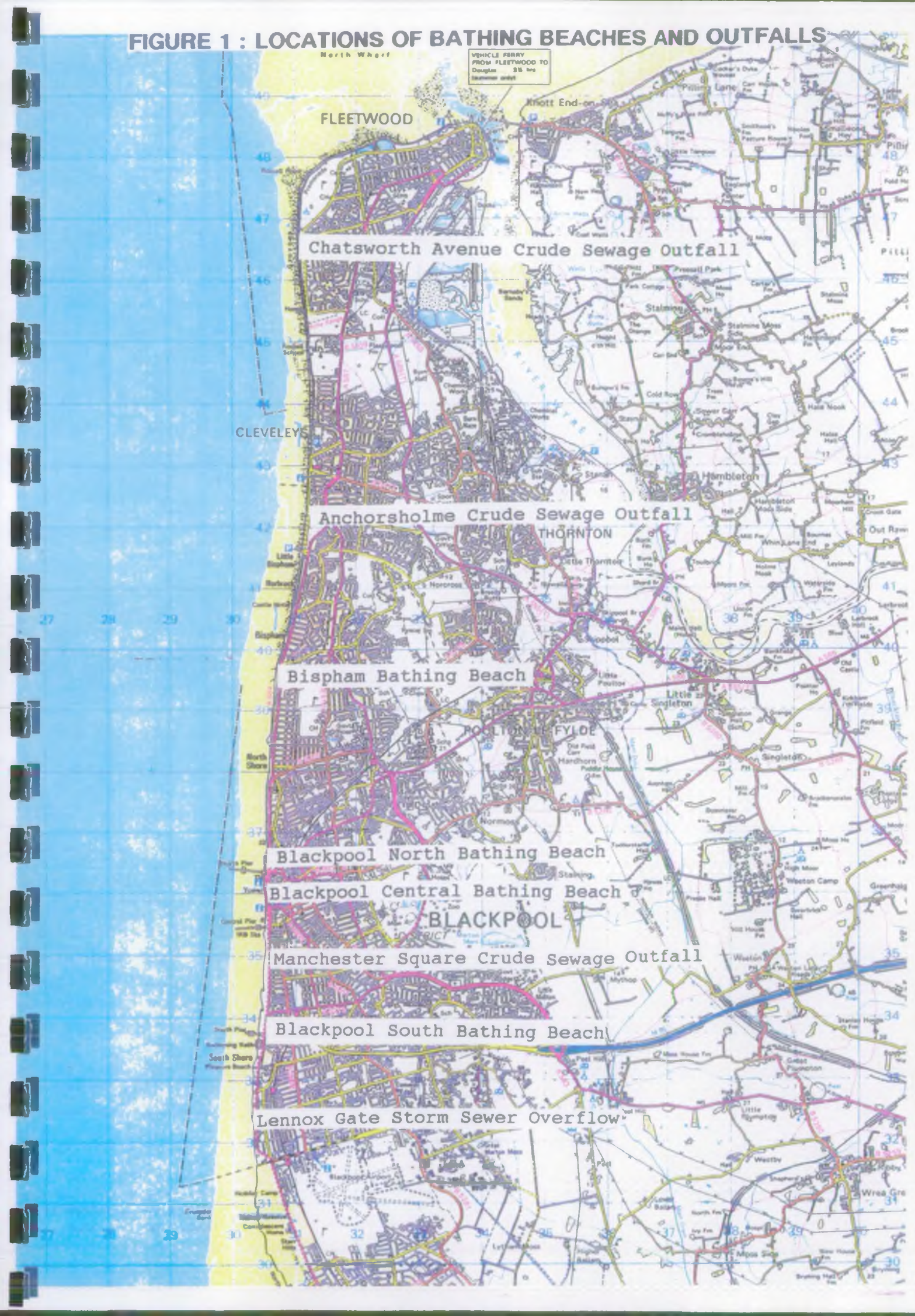
The population of Blackpool, a major tourist resort, can triple during the summer months. Among the prime attractions of the area are the four EC designated bathing beaches, the locations of which are shown in figure 1. At present, Blackpool is served by two crude sewage outfalls, Manchester Square and Anchorsholme. These, together with Chatsworth Avenue at Fleetwood and the Lennox Gate storm sewer overflow contribute to the consistent failure of the bathing waters to meet the standards of the EC Bathing Water Directive (76/160/EEC).

Under the North West Water Fylde Scheme, the sewage wastewater from Blackpool, together with that from Fleetwood, will be transferred Northward to a new secondary treatment plant near Fleetwood. The wastewater will then be discharged through a long outfall to the Lune Deep. The tunnel constructed to transfer the wastewater will also serve the purpose of a holding tank under times of high flow. The present storage tanks at Manchester and Anchorsholme will be utilized as a further store for storm water. By this stage, discharges along the Fylde coast will only occur under extreme weather conditions. The scheme is due for completion in 1995.

As an interim measure until the completion of the Fylde scheme, North West Water applied to the NRA for a consent to disinfect the flow from the two crude sewage outfalls at Blackpool and the discharges from Chatsworth Avenue and Lennox Gate during the bathing season. A consent to carry this out at Manchester Square only, was granted in September, 1992, on an interim basis, and subject to monitoring of the environmental impact.

ICI Watercare were commissioned by North West Water to install their 'CoastGuard' system (which utilizes Sodium Hypochlorite) at Manchester Square at the end of April, 1993. The method by which the disinfectant was to be

FIGURE 1 : LOCATIONS OF BATHING BEACHES AND OUTFALLS



added to the wastewater was governed by the layout of the works. At Manchester Square, two wastewater influents flow into a central holding tank located underneath the promenade, until the tidal state appropriate for discharge is reached. For safety reasons, the disinfectant could not be added to the sewage in this tank. The sodium hypochlorite was pumped into the wastewater at a controlled concentration as it flowed to sea via the outfall pipe. The pipe could therefore be thought of as the 'mixing chamber' for the chlorine to react with the wastewater before entering the marine environment. The time of travel from the holding tank to the end of the outfall was approximately 10 to 15 minutes.

1.1 Conditions Of Consent

The main conditions governing the consent to discharge at Manchester Square are outlined below. The full details are listed in appendix A.

i) In dry weather conditions, the discharge would commence no more than 30 minutes before high water and cease no more than 2 hours after high water.

ii) Under wet weather conditions, the discharge could be made outside this 'window', once the storage facilities had been fully utilized.

iii) The disinfecting agent could only be used during the bathing season, and on an interim basis until October 1995.

iv) At or beyond a mixing zone of 100 metres radius from the outfall, the Total Residual Oxidant should not exceed 0.01mg/l and chloroform should not exceed 0.012μg/l.

v) The dosing rate of the disinfectant was set on a concentration basis, which varied if discharge was made outside the 'tidal window'. This rate was reduced on two occasions over the course of the 1993 bathing season as detailed in table 1.

Table 1 : Dosing Regime Over the 1993 Bathing Season

	Initial Rate	Dates Of Change 30/6/93	9/8/93
dry weather	17.50	10.50	8.75
storm ebb	8.75	8.75	8.75
storm flood	35.00	14.00	8.75

All values are mg/l

The reason for the reductions was that levels of Total Residual Oxidant were exceeding the consent conditions. The concentration rate of 8.75mg/l represents the lowest concentration possible with the installed pumps.

1.2 Chemical Reactions Induced by Chlorination

Adding a powerful oxidant to wastewater results in a series of reactions with any available substrate.

The addition of chlorine to freshwater results in both free and combined forms of chlorine predominating. Hence, the proposed freshwater standard is based on Total Available Chlorine.

However, different chemical species will result from the addition of chlorine to marine waters. The prescence of bromide in marine water (at 68ppm) will result in the rapid displacement of chlorine by bromine, thus forming hypobromous acid.

$$HOCl + Br^- \longrightarrow HOBr + Cl^-$$

This will further react with ammonia in sewage to form bromamines.

$$HOBr + NH_3 \longrightarrow H_2O + NH_2Br$$

However, at the initial stage ammonia will also compete with bromide for the chlorine. Therefore, some monochloramine will form before the chlorine is reduced by the bromide.

$$HOCl + NH_3 \longrightarrow H_2O + NH_2Cl$$

This will then react with hypobromous acid, at a fairly slow rate, to form various Bromamines. With the presence of sewage, di-chloramine ($NHCl_2$) and organochloramines may also be formed by analogous reactions.

Bromine oxidants are less stable than the corresponding chlorine species and will therefore be more toxic, but less persistent.

A standard expressed as Total Residual Oxidants (TRO) covers the various chlorine and bromine species, and the proposed EQS based upon available toxicity data is 10μg/l. (NRA R&D Note 53, Final Draft).

2 SAMPLING REGIME

To investigate the environmental impact of disinfection at Manchester Square, extensive survey work was carried out over the 1993 bathing season.

The NRA undertook boat surveys on eight occasions, utilizing either the NRA Survey vessel 'Coastal Guardian', or a semi-rigid inflatable.

As the 'competent authority' in England and Wales to implement the EC Bathing Water Directive, the NRA sampled regularly at the four designated bathing beaches.

An intensive one day beach survey over a full tide was also carried out. This involved the use of All Terrain Motorbikes to take near synoptic bacterial sample runs at up to 31 sites along the Blackpool coast.

As a condition of the consent, North West Water obtained samples on a weekly interval for the determinands outlined in schedule 1 (see Appendix A). Acer Environmental were contracted to carry out this work on behalf of North West Water, having already carried out similar work in 1992 so that comparisons before and after chlorination could be made.

3 METHODOLOGY

3.1 NRA BOAT SURVEYS

The details of the eight boat surveys are listed in Appendix B. The plume was clearly visible and could be tracked well away from the outfall. As the primary role of the NRA surveys was to ascertain whether the conditions of the consent were being met, the number and location of samples varied considerably depending upon the conditions present on the day.

Although TRO measurements can be made by amperometric and potentiometric titration under laboratory conditions, the only available method for field analysis involves colorimetric titration utilizing DPD (N,Ndiethyl-p-phenylenediamine).

In freshwater this method allows both free chlorine and TRO to be measured. The DPD reacts with the free chlorine to give a measurable colour. After the further addition of iodide, the weaker oxidants react to form iodine which then reacts with the DPD.

In the case of seawater, other reactions occur in the presence of bromine, as noted earlier, and free chlorine will instantaneously be consumed. The addition of DPD will react with any strong oxidative species, such as monochloramine, to give a value that is termed in this report Free Oxidant. Even though iodide already exists in seawater and may, in time, react with the weaker oxidants to give a value for TRO, additional iodide is added to quickly complete this reaction.

Given the crucial importance of decay reactions, TRO was determined in the field using a Lovibond Chlorine Nessler test kit. The detection limit was 0.02mg/l, improving to 0.01mg/l towards the end of the bathing season when a

new filter was acquired. The upper limit of detection was 0.5mg/l.

Samples were taken for bacterial analysis of total coliforms, E.coli and faecal streptococci. A crystal of Sodium Thiosulphate was added to each sample to neutralize any further oxidative effect during transport and analysis.

Samples were also taken to be analysed for bromoform, chloroform, and various other associated compounds.

3.2 ACER ENVIRONMENTAL SURVEYS

Acer Environmental carried out twenty two surveys at approximately weekly intervals over the course of the bathing season. Samples were taken at each influent, at the outfall and 105 metres downstream of the outfall.

Analysis of seawater samples for residual oxidants was carried out on site using DPD colorimetric titration method to a lower detection limit of 0.02mg/l, and an upper limit of 0.5mg/l. Samples were also taken from the Manchester Square wastewater influents for microbiological analysis at approximately the same time.

The full set of parameters that were analysed are outlined in appendix E.

The 1992 Baseline survey was carried out similarly, but samples were taken at mid-ebb as opposed to high tide.

Full details can be found in their final report to North West Water (Acer Environmental, 1993).

3.3 EC BATHING WATERS

Under the terms of the European Community Directive

76/160/EEC, the four beaches at Blackpool, are classified as 'bathing waters'. Twenty samples were taken for microbiological analysis at each beach over the course of the bathing season at Blackpool. The primary parameters, by which a beach passes or fails the directive, are total coliforms and E.coli.

3.4 TIDAL BEACH SURVEY

On the 9/8/93 an intensive sampling program was carried out along the whole of the Blackpool foreshore. All Terrain Motorbikes were used to take six sets of bathing water samples, each set as near synoptical as possible, at up to 31 sample locations over a full tide. Each run took approximately one hour to complete. The exact locations of the sampling points are shown in appendix C.

Each sample was analysed for total coliforms and E.coli.

4 RESULTS

4.1 NRA BOAT SURVEYS

Four surveys were carried out under the first dosing regime, two surveys under the second and two surveys under the third. The full set of results for all the surveys are listed in Appendix D. Chloroform and bromoform were the only organic parameters tested for until the survey on the 8/6/93. Subsequent samples were tested for a range chloroform compounds as well.

In figures 2 to 8, values reported as exceeding a figure are plotted at that value with a '>' sign marked at the point. Oxidant values <0.02mg/l are plotted as zero.

4.1.1 Survey 1 4/5/93 Dose Rate : 17.5mg/l

During the first survey a fault in the dosing system meant that no disinfectant was added to the wastewater. However, as all oxidant tests proved negative, the survey did serve to confirm that the background oxidative capacity was below the detection limit. Bromoform and Chloroform samples were also found to be below the limit of detection.

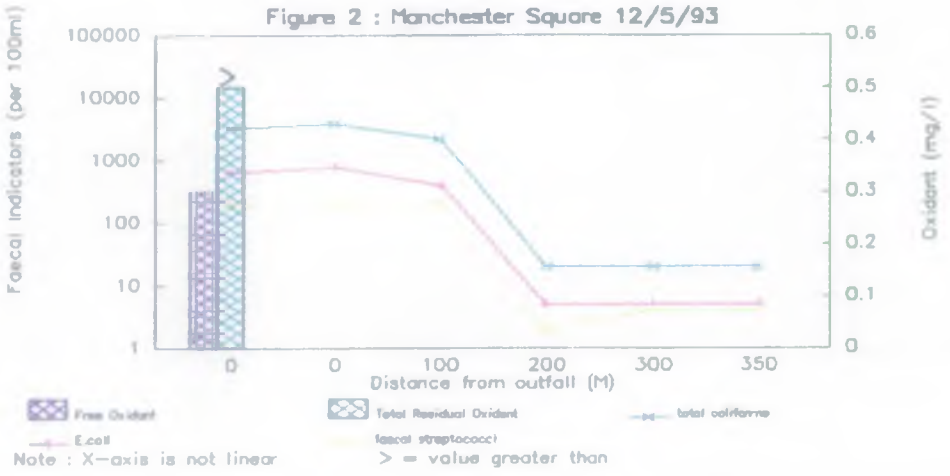
Total coliform and E.coli values were generally reported as greater than 10,000 counts per 100mls total coliforms, and greater than 2,000 counts per 100mls E.coli.

4.1.2 Survey 2 12/5/93 Dose Rate : 17.5mg/l

On this survey, some samples were taken close to high water in conjunction with Acer Environmental. Two oxidant tests were performed, on the boil and at 350 metres. On the boil 3800 total coliforms per 100mls and 780 E.coli per 100mls were found. Faecal streptococci were reported as exceeding 200 counts per 100mls.

The free oxidant was 0.3mg/l and the TRO was > 0.5mg/l on the boil. The results at 350 metres were below the limit of detection of 0.02mg/l (see figure 2). A chloroform value of 2µg/l was found on the boil.

Figure 2 : Manchester Square 12/5/93

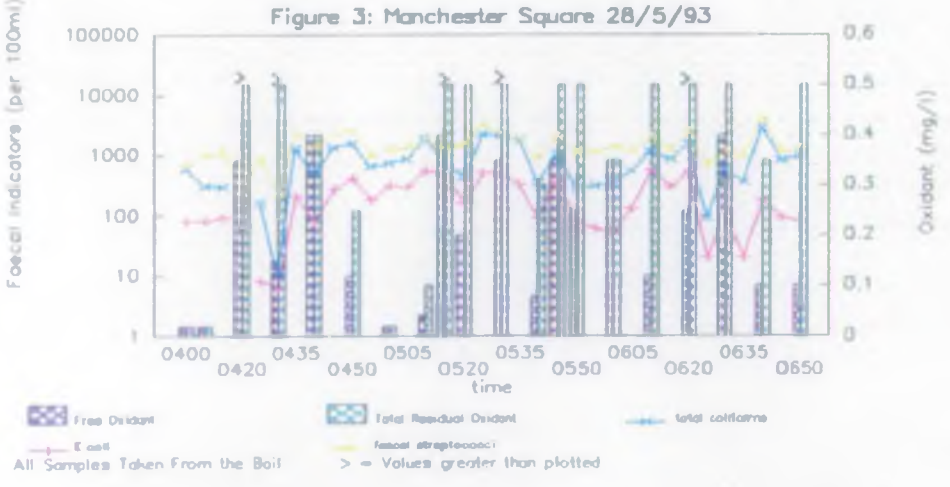


4.1.3 Survey 3 28/5/93 Dose Rate : 17.5mg/l

On the 28/5/93, samples were taken soley from the boil over a period of nearly 3 hours. The results in figure 3 indicate that total coliforms and E.coli are of the same magnitude as found on the previous survey, and that feacal streptococci peak at over 4,000 counts per 100mls.

Free Oxidant was found up to a level of 0.35mg/l and TRO was found above 0.5mg/L. A chloroform value of 4.9µg/l was found.

Figure 3: Manchester Square 28/5/93

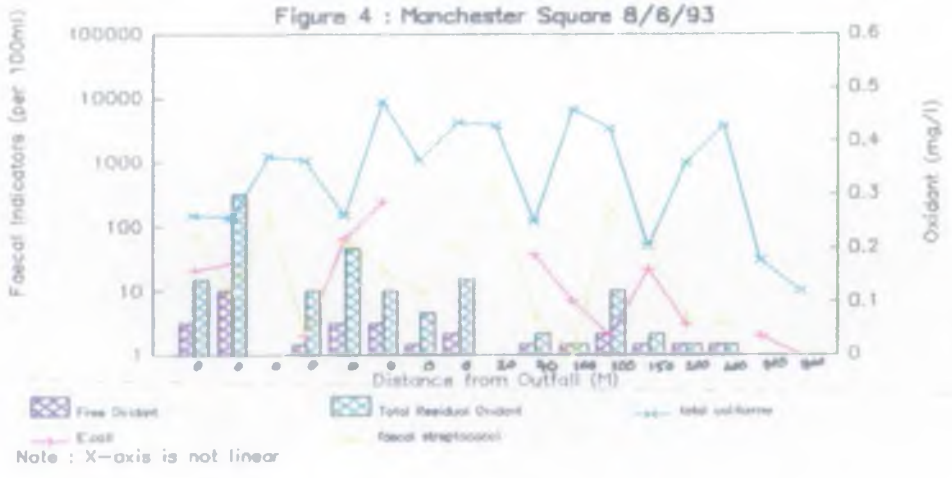


4.1.4 Survey 4 8/6/93 Dose Rate : 17.5mg/l

On the 8/6/93, samples were taken both in and away from the boil. Total coliform values were slightly higher in the boil, up to 8680 counts per 100mls, but E.coli and faecal steptococci were greatly lower than found previously (see figure 4).

Peak Free oxidant of 0.12mg/l and a TRO of 0.14mg/l were found in the boil. The highest values at 100 metres were 0.04 and 0.12 mg/l respectively. Levels of 0.02mg/l were found for both Free and TRO at a distance of 400 metres.

Figure 4 : Manchester Square 8/6/93



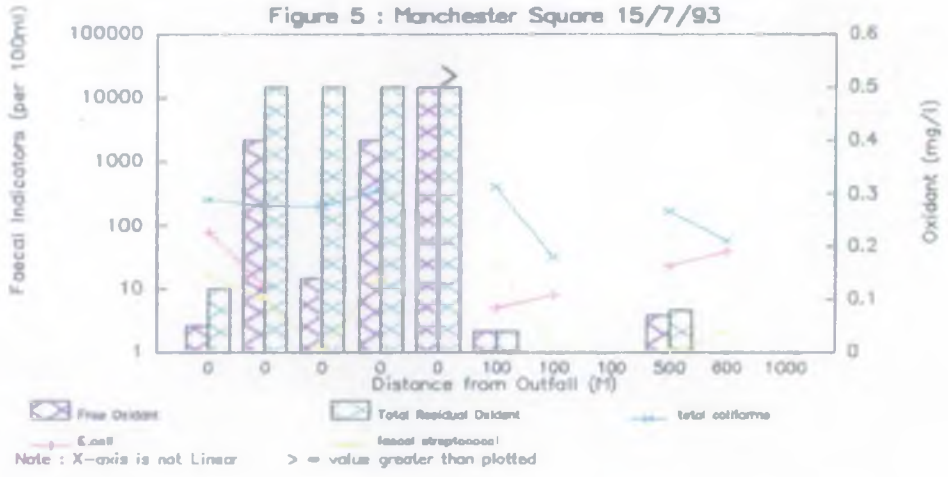
Note : X-axis is not linear

4.1.5 Survey 5 15/7/93 Dose Rate : 10.5mg/l

The first survey under the second dosing regime was carried out on the 15/7/93. The bacterial levels found were low, as shown in figure 5. The highest total coliform result was 400 counts per 100mls, actually found 100 metres away from the boil.

Free and Total Residual Oxidant values of 0.5 and >0.5mg/l were found in the boil. Away from the outfall, the highest values were found at 500 metres, being 0.07mg/l Free Oxidant and 0.08 mg/l TRO.

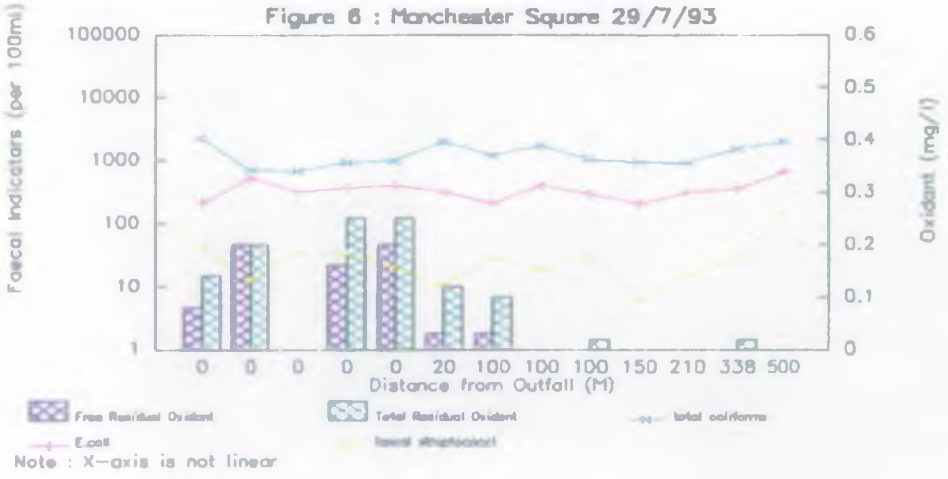
Chloroform was found up to 1.8μg/l. Three samples proved positive for tetrachloroethylene, the maximum value found being 6.5μg/l.



4.1.6 Survey 6 29/7/93 Dose Rate : 10.5mg/l

A survey on the 29/7/93 found a maximum total coliform value of 2160 counts per 100mls. The maximum values of E.coli and Faecal streptococci were found at a distance of 500 metres from the boil.

The maximum Free and TRO were 0.2mg/l and 0.25mg/l respectively on the boil, and 0.03mg/l and 0.1mg/l at a distance of 100 metres. Chloroform was found up to 1.9μg/l.

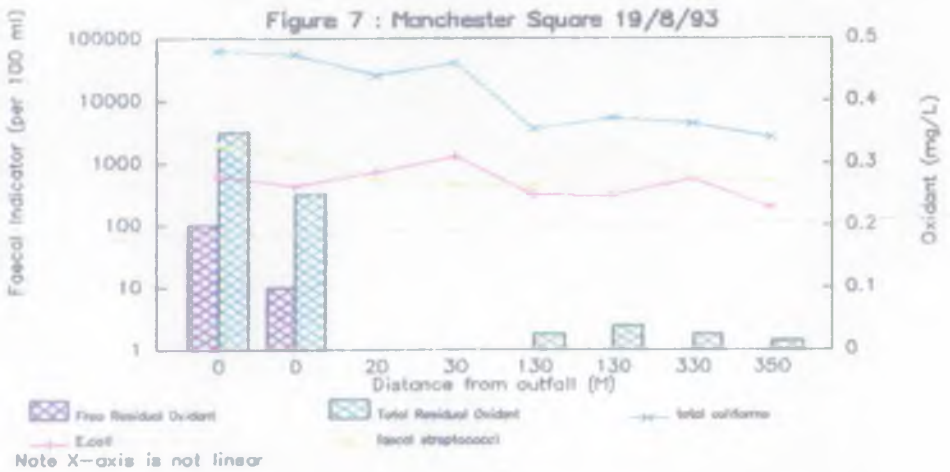


4.1.7 Survey 7 19/8/93 Dose Rate : 8.75mg/l

A survey carried out on the 19/8/93 under the third dosing regime found significantly higher total coliform values, having a maximum of 62,000 per 100mls in the boil. The maximum count for E.coli was 1270 per 100mls, and for faecal streptococci the maximum was 1820 per 100mls.

Free oxidant was only found on the boil, with a maximum of 0.2mg/l. Total Residual Oxidant was found on the boil up to 0.35mg/l and at a distance of 330 metres 0.025mg/l was found.

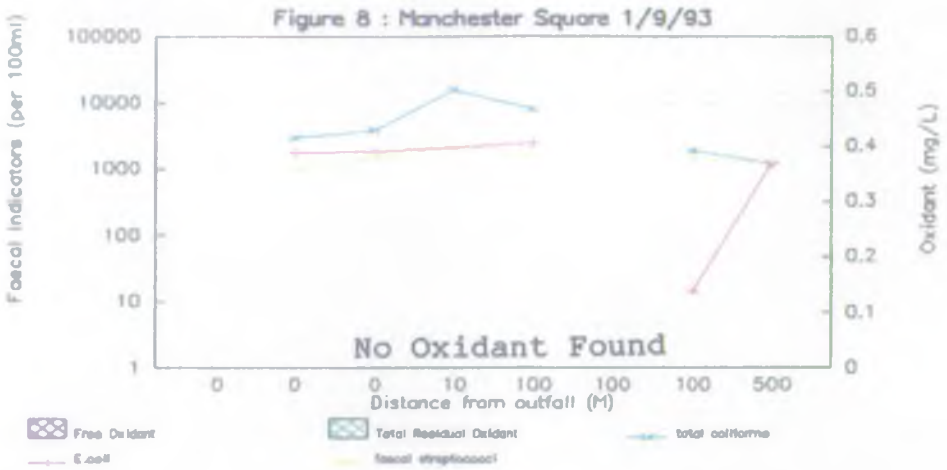
Chloroform was found up to 2.2µg/l. Two samples proved positive for Trichloroethane, being 1.2 and 1.5µg/l.



4.1.8 Survey 8 1/9/93 Dose Rate : 8.75mg/l

On the 1/9/93 a survey was carried out with the assistance of Acer Environmental. The maximum total coliform value was found to be 15,600 counts per 100mls close to the boil. The peak values for E.coli and faecal streps were 2400 and 2010 counts per 100 mls.

On this occasion no trace of Free or Total Residual Oxidant was found either on or away from the boil (see figure 8).



4.2 ACER ENVIRONMENTAL SURVEYS

The full set of results are detailed in Appendix E.

Eight surveys were carried out under the first dosing regime, five under the second, and nine under the third regime.

Figures 9 and 10 show the bacterial and oxidant levels found on the boil and at a distance of approximately 100 metres, over the course of the bathing season. Figures 11 and 12 show the bacterial levels found in the low and high level influents at Manchester Square.

Figure 9 : The Boil

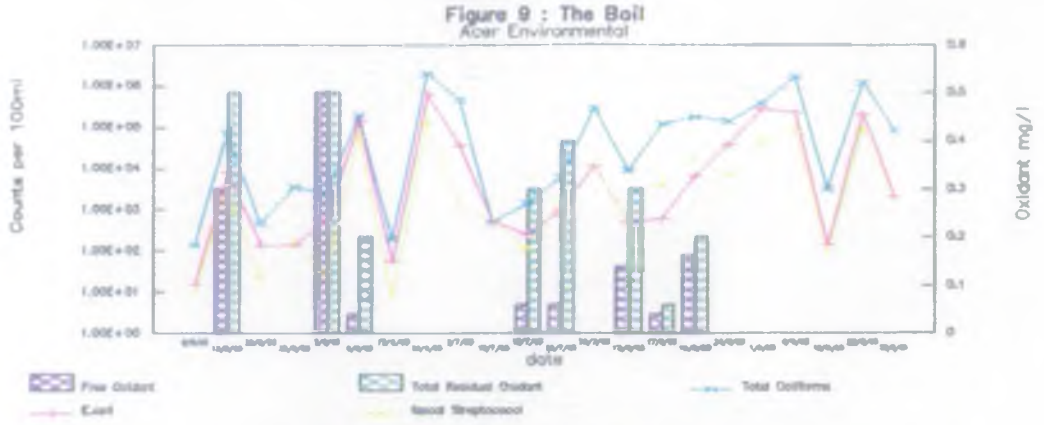


Figure 10 : 105 Metres Downstream 1993

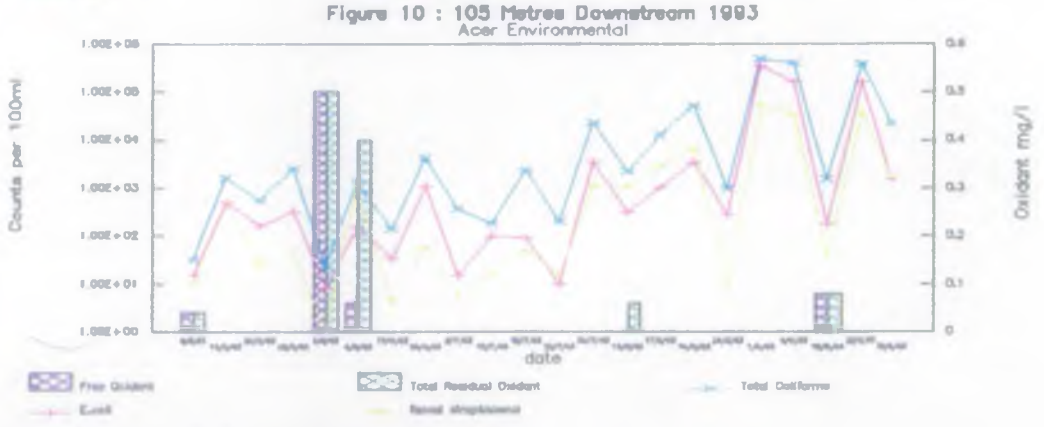


Figure 11 : Manchester Square Influent (high level)

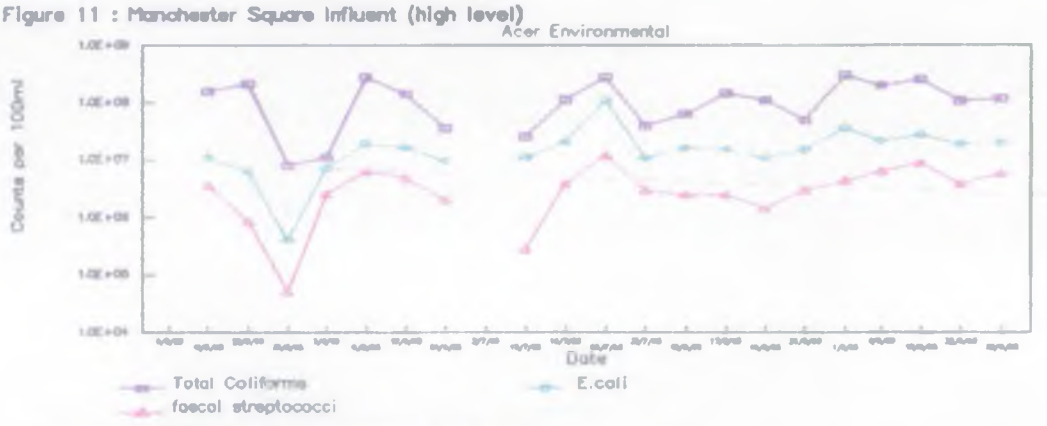
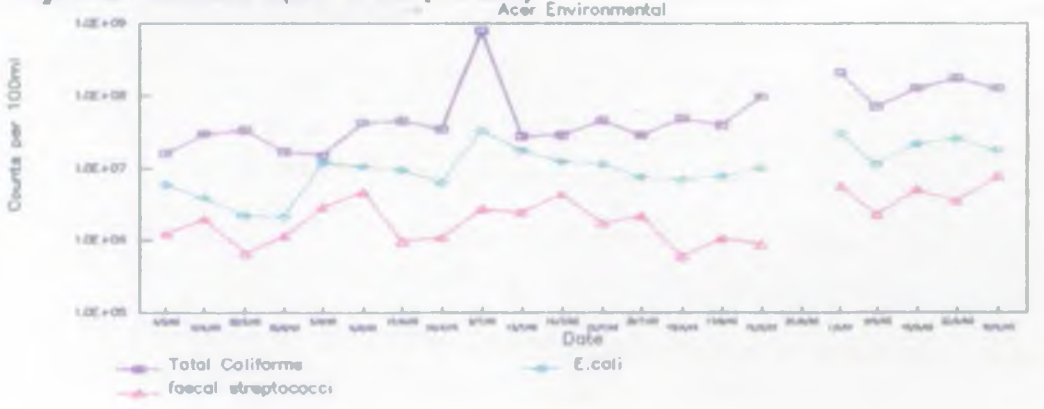


Figure 12 : Manchester Square Influent (low level)



4.3 EC BATHING BEACH PROGRAM

The primary parameters under the EC bathing water directive are total and faecal coliforms. To 'pass' the directive, 95% of samples must meet the imperative values of less than 10,000 total coliforms and less than 2,000 faecal coliforms per 100mls. In effect, at least 20 samples are taken over the course of a bathing season, of which no more than one value of total and/or one value of faecal coliforms can exceed this imperative value.

All four bathing beaches failed the mandatory EC standards. The number of failures in the bathing seasons 1990 to 1993 are listed in table 2.

TABLE 2 : BATHING BEACH FAILURES

SITE	1990		1991		1992		1993	
	TC	EC	TC	EC	TC	EC	TC	EC
Bispham	5	6	2	2	4	7	0	2
BP North	6	4	6	8	5	8	2	4
BP Central	5	4	3	6	5	10	1	3
BP South	6	5	4	6	7	10	1	5

4.4 TIDAL BEACH SURVEY

The sampling took place after a period of unusually high rainfall which caused the high level emergency overflow system to operate. This meant that unchlorinated crude sewage ran across the beach from Manchester Square at approximately 08.00 on the morning of the 9/8/93.

The results of each run are displayed in figure 13, with the timing of each sample run listed in Table 3. Each run took approximately one hour. High water was at 03.43 BST and 15.48 BST. Low water was at 10.18 BST.

TABLE 3 : BEACH SAMPLE RUNS

RUN	START TIME	END TIME	MID TIME	TIME RELATIVE TO HIGH WATER
1	08.24	09.28	08.56	-7.32
2	10.05	10.58	10.32	-5.16
3	12.28	13.20	12.54	-2.54
4	14.13	15.24	14.38	-1.10
5	16.06	16.47	16.27	+0.39
6	18.32	19.27	19.00	+3.12

The first run took place around one and a half hours before low water. The faecal indicators, total coliforms and E.coli, were at their highest just to the North of M (Manchester Square), with 13 sites failing the mandatory EC standard.

On the second run, taken around low water, the peak faecal indicators were lower and located further North. Seven sites fail the mandatory standard.

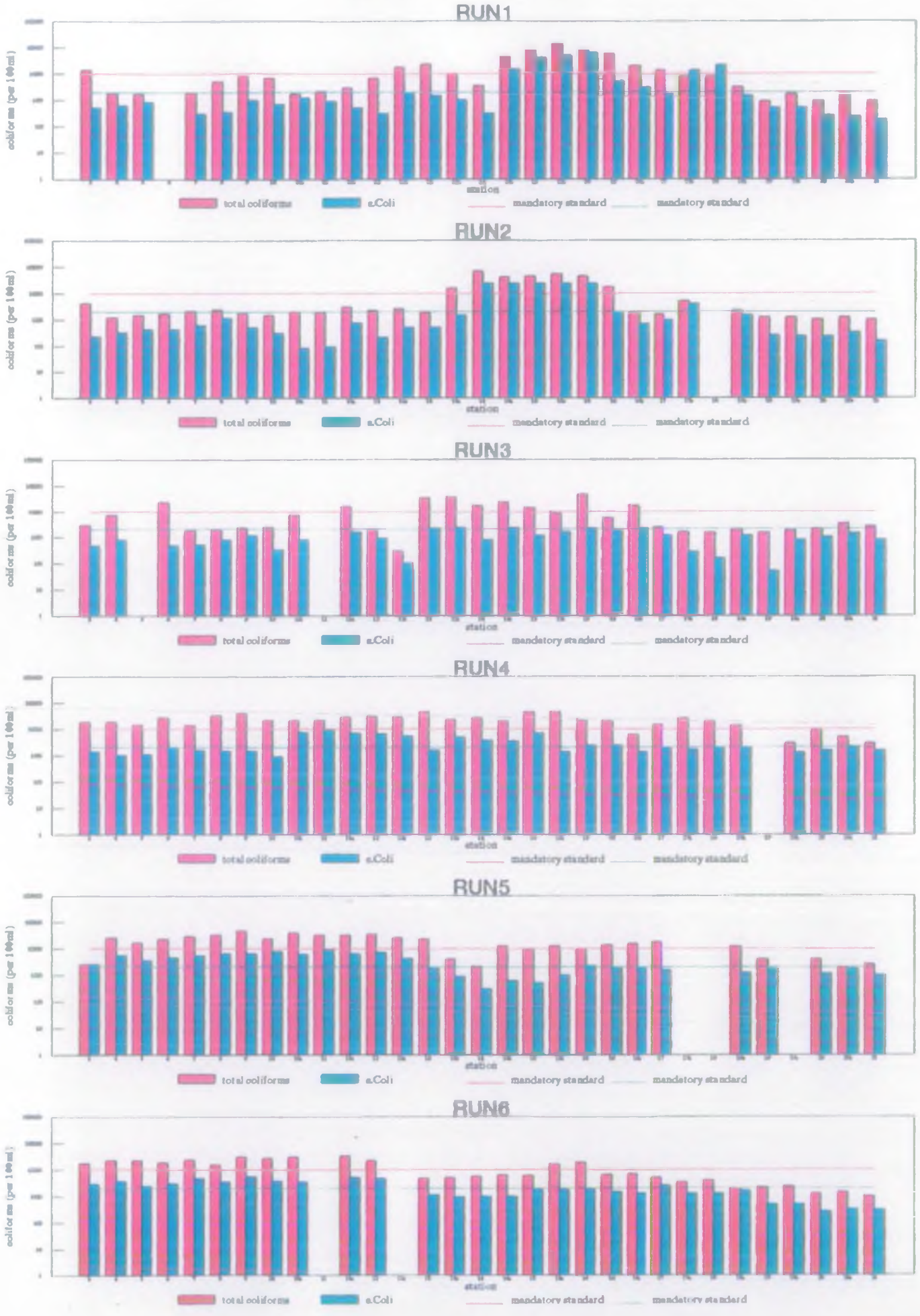
During the third run, about 3 hours before high water, the peak values were lower, but 9 samples failed the mandatory EC standards.

On run 4, about an hour before high water, all but one sample to the north of site 18A failed the mandatory standard.

On run 5, about 30 minutes after high water, much the same situation exists, but with markedly lower values around site 14. Twenty sites failed the mandatory standards.

The last run took place 3 hours after high water. Every sample to the North of site 12 failed the mandatory EC standard.

Figure 13 : Tidal Beach Survey



5 DISCUSSION

5.1 COMPARISON OF DATA

It is commonly accepted that values of faecal indicators vary widely with relatively small temporal and spatial changes. This will have contributed to the somewhat unclear picture of the situation at Blackpool over the summer.

Data comparisons were made between the data gathered by Acer Environmental in 1993 and their baseline survey in 1992, and between the 1993 NRA data and the 1993 Acer data.

Coliform data in natural waters tend to follow a log normal distribution. Therefore the geometric mean was used as the most appropriate average of the data sets.

5.1.1 Comparison of 1992 and 1993 Acer Environmental Data

Direct comparison of the 1992 and 1993 seawater samples is invalid as in 1992 the samples were taken on the mid ebb tide, whilst in 1993 they were taken at high tide. However, the results obtained from the influents can be compared directly. The geometric means of samples obtained from the influents are listed in table 4. The value for the combined influents is a weighted mean of the high and low levels, taking into account the fact that the flow from the high level influent is approximately twice that of the low level influent.

TABLE 4 : COMPARISON OF 1992 AND 1993 COMBINED INFLUENTS

	total coliforms	E.coli	faecal streptococci
	all values are counts per 100ml		
1992	$7.48*10^6$	$1.97*10^6$	$3.63*10^5$
1993	$7.61*10^7$	$1.22*10^7$	$2.28*10^6$

It can be seen that the reported concentrations in 1993 are approximately an order of magnitude higher than those found in 1992.

5.1.2 Comparison of Acer Data with NRA Data

5.1.2.1 Microbiology

The NRA results do not tie in closely to that of Acer Environmental as the comparison of geometric means of data from the boil in table 5 indicates.

TABLE 5 : GEOMETRIC MEANS OF DATA FROM THE BOIL

	total coliforms		E.coli		faecal streptococci	
	NRA	Acer	NRA	Acer	NRA	Acer
DOSE 1	1,118	11,168	86	2,354	175	569
DOSE 2	490	5,304	62	960	12	896
DOSE 3	13,884	117,085	946	6,715	1,349	5,736

Values are geometric means for the Acer Environmental data and geometric means of a geometric mean of each survey for the NRA data.

On two occasions samples were taken in conjunction with Acer Environmental, on the 12/5/93 and the 1/9/93. The results from those two days on the boil are shown in table 6.

TABLE 6 : COMPARISON OF DATA FROM THE BOIL ON TWO INDIVIDUAL DAYS

	total coliforms		E.coli		faecal streptococci	
	NRA	Acer	NRA	Acer	NRA	Acer
12/5/93	3487	72,000	706	7950	>200	3200
1/9/93	3301	382,000	1770	272000	1188	43364

This indicates inadequacies in the data sets, possibly due to an inadequate number of samples for the high spatial and temporal variability of the faecal indicators and the differences in the number and timing of samples.

5.1.2.2 Free and Total Residual Oxidant

The NRA surveys found significantly higher levels of both Free and Total Residual Oxidant than Acer Environmental, both in the boil and outside the mixing zone. The NRA surveys were generally of longer duration and may have been more successful in finding the peak concentrations. It is possible that by taking one sample from the boil and then moving to the edge of the mixing zone to take another (as instructed by North West Water), Acer Environmental may have been missing these peaks.

5.2 ENVIRONMENTAL IMPACT

The consent as regards TRO was breached on several occasions. Of the 22 surveys carried out by Acer Environmental, results exceeding the consent were found on five occasions. Of the six relevant NRA surveys (i.e. where measurements were made outside the mixing zone) TRO was found to exceed the consent on four occasions.

There was no simple correlation between the reduction of the dosing rate of sodium hypochlorite added to the wastewater and reduction of TRO in the boil. One possible explanation for this is that the method of colorimetric determination with the use of DPD may have been giving slightly misleading results. Among the species expected to be formed by chlorination are organo-chloramines and monochloramine. Although the rate of formation of organo-chloramines is much faster than that of monochloramine, the high level of ammoniacal N compared with organic N in sewage results in the actual amounts of each species formed being similar (Jolley, R.L. & Carpenter, J., 1981).

Monochloramine is more acutely toxic and therefore less persistent than organo-chloramines. Therefore, with time the relative amount of organo-chloramine will increase and it may be this species of relatively low toxicity

that is causing the consent to be breached in terms of TRO. It may be thought that as this species is of low toxicity it should not be included under the terms of the consent.

However, there are two points of concern following on from this. Firstly, there is no currently available field method of determining between the two species and samples brought back to the laboratory are of no use because further reactions during transit and analysis. Secondly, although organo-chloramine is of low acute toxicity compared to monochloramine, its reaction with DPD obviously shows an oxidative capacity. Little is known about any chronic toxicity affects.

Another possible contributing factor to the TRO found may be due to the method by which chlorination was achieved. The outfall pipe, which effectively served as the mixing chamber, may not have been always enabling the completion of the chemical reactions before the wastewater reached the marine environment.

Chloroform values found were below the proposed EQS of 12μg/l. Tetrachloroethylene and Trichloroethane were found once, on separate occasions. Both of these are declared as priority hazardous substances under the Hague Convention.

Positive microtox results were found by Acer Environmental on several occasions. This test determines the toxicity of aquatic contaminants to the marine bacterium Photobacterium phosphoreum. Toxicity occurred most frequently during the period of lowest chlorine dose. No evidence of toxicity was found during the 1992 baseline survey.

5.3 THE EFFECTIVENESS OF CHLORINATION

The Acer Environmental data does have the advantage of regular data at consistent points and, with data from the influents, a 'before and after' insight can also be gained. It can be seen in figures 9 and 10 that the faecal indicator counts increase over the course of the bathing season both at the boil and, more obviously, at the edge of the mixing zone, and that this coincides with reductions in the dosage rate of chlorine.

If you consider the geometric means found by Acer Environmental under each dosing regime (table 7), at the boil and at the edge of the mixing zone, it seems that decreasing the dose rate to 10.5mg/l has led to no readily apparent rise in the faecal indicator levels, but that they have risen significantly with the further reduction to 8.75mg/l.

TABLE 7 : GEOMETRIC MEANS OF ACER DATA UNDER DIFFERENT DOSAGE RATES

Total Coliforms

Dose	Combined Influents	Boil	Edge of Mixing Zone
1	55,329,557	11,168	623
2	61,380,916	5,304	1,157
3	129,785,511	117,085	36,899

E.coli

1	6,765,868	2,354	140
2	20,124,980	960	131
3	17,665,878	6,715	6,225

Faecal Streptococci

1	1,877,783	569	35
2	3,017,041	896	59
3	4,038,188	5,736	4,048

However, the data also indicate that the faecal indicator counts in the low level and high level influents also

increase, as shown in figures 11 and 12. This would account for some of the increase in the seawater. If you consider the geometrical means of total coliforms under dose rate 1 and dose rate 3 as shown in table 7, then the concentrations in the influents approximately doubles, but the level at the edge of the mixing zone increases by approximately a factor of 60.

However, by looking at individual data points on an un-averaged basis, a different view can be seen. Figures 14 and 15 show % reductions in faecal indicators from the influents to the boil, and from the influents to the edge of the mixing zone respectively. The % reduction value is derived by dividing the appropriate seawater value by the corresponding combined influent value.

Figure 11 : % Reduction in Faecal Indicators at the Boil

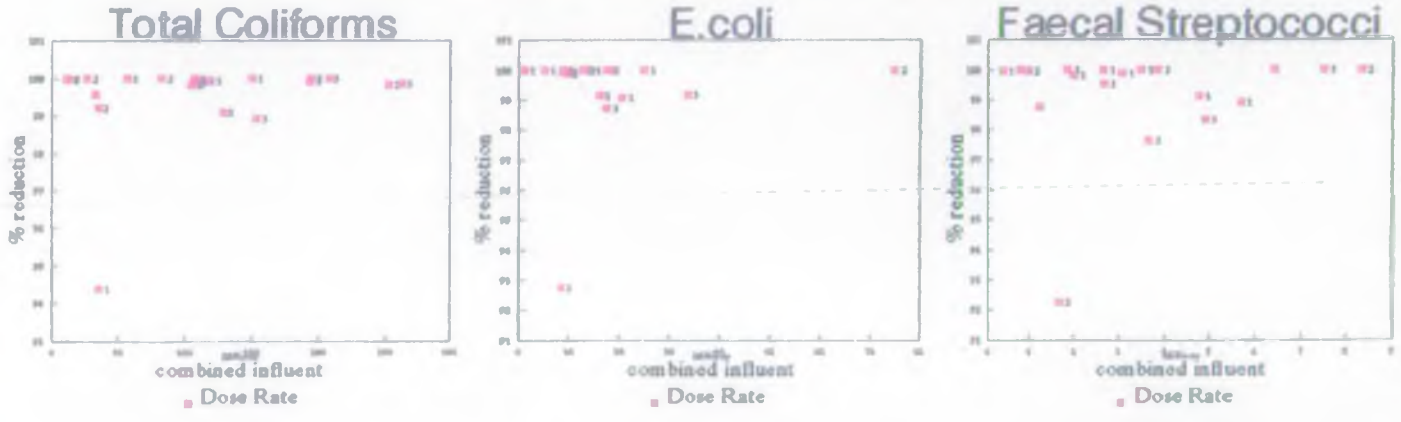
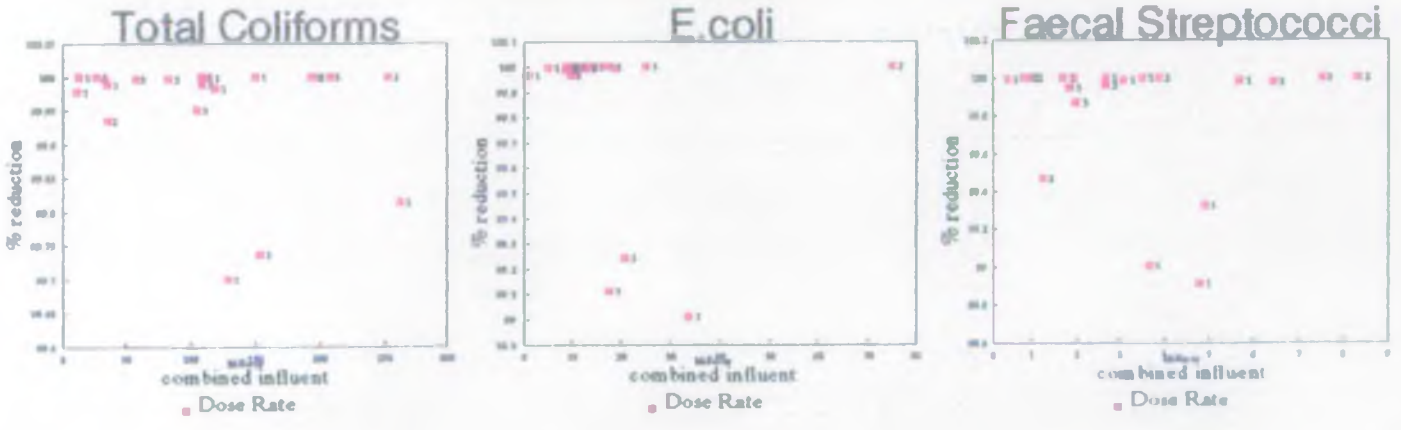


Figure 12 : % Reductions in Faecal Indicators at the Edge of the Mixing Zone



If a reduction in the chlorine dose rate was having a consistent effect on the level of faecal indicators, then it would be expected that the % reduction in faecal indicators would be consistently reduced for the lower dose rate.

It can be seen in figures 14 and 15 that on approximately five out of the eight occasions that Acer Environmental sampled under the third dosing regime (depending on which faecal indicator and on whether the boil or the mixing zone is considered), there was no readily apparent difference in % reduction of faecal indicators as compared to dose rate 1.

5.4 TIDAL BEACH SURVEY

The tidal beach survey showed the catastrophic effect on water quality of the storm sewage overflow operating. On the day of the survey gross sewage solids were clearly and readily visible. Prompt public warning if the beach has, or is expected to become, grossly polluted would not necessarily have a damaging effect on the public view of the water quality at Blackpool. Indeed, if it was known that severe weather conditions had caused the type of situation apparent on the day of the survey, and that this was not representative of the normal situation, the view of the water quality may be improved. At present, records are not kept of when the sewer overflows.

5.5 FUTURE SURVEY WORK

It is felt that if chlorination does proceed at Blackpool then the role of the NRA should be extended from solely verifying that the conditions of the consent are met to include an investigation of the whole process. This would

involve sampling before the sewage is chlorinated as well as after the chlorinated sewage has reached the sea.

Replicate samples, with a more systematic spatial sampling pattern may well reduce the apparent 'randomness' of some of the data.

Given that Acer Environmental found positive microtox results, it is proposed that these tests will also be carried out by the NRA.

6 CONCLUSIONS

The outfall failed the consent in terms of the Total Residual Oxidant on many occasions over the course of the bathing season.

All four designated bathing beaches failed to meet the mandatory standards of the EC Bathing Water Directive (76/160/EEC).

Chlorination did reduce the level of faecal indicators, but the exact details of the effect are unclear.

There was an environmental impact outside the mixing zone of the outfall, but again the exact details are unclear.

The operation of the storm sewage overflow had a catastrophic effect on water quality.

If chlorination proceeds at Blackpool, more rigourous survey work will be needed.

REFERENCES

NRA, 'Proposed Provisional Environmental Quality Standards for Chlorine in Fresh and Marine Waters' Draft Report, R&D Project 53, Final Draft

Acer Environmental, 'Fylde Coast Monitoring Study', Final Report, November, 1993.

Jolley R.L. & Carpenter, J., 'A review of the Chemistry and Environmental Fate of Reactive Oxidant Species in Chlorinated Water', in 'Water Chlorination: Environmental Impact & Health Effects', Vol. 4 Book 1, Chemistry and Water Treatment, 1981.

APPENDIX A : CONSENT TO DISCHARGE AT MANCHESTER SQUARE

NATIONAL RIVERS AUTHORITY - NORTH WEST REGION

NRA
National Rivers Authority
North West Region

WATER RESOURCES ACT 1991
CONSENT TO DISCHARGE

CONSENT NO. 017160287

Consent of the National Rivers Authority (hereinafter called "the Authority") is hereby granted to

North West Water Limited
Dav[illegible] House
Liverpool Road
Great Sankey
Warrington
WA5 3LW

to discharge screened sewage effluent (including storm water) from Manchester Square Sewage Pumping Station to the Irish Sea (being "controlled waters" within the area of the Authority), subject to the following conditions:

1. Nature and Composition

The effluent discharged to 'controlled waters' shall consist solely of screened sewage effluent, including storm water, to which, for the periods and conditions specified below may be added a disinfecting agent.

2. Conditions applicable throughout the year:

(a) Flows discharged up to a rate of 15,000 litres per second shall pass through a 6 mm mesh drum screen.

(b) Flows in excess of 15,000 litres per second shall pass through bar screens of 12.5 mm apertures.

(c) All screenings shall be collected and removed from the site.

(d) The discharge shall be made through an outfall extending 375 metres beyond Mean Low Water Springs to SD 2957 3507, terminating in a single riser with 8 discharge ports.

3. Conditions applicable during the period 10th April to 30th September (inclusive) in any year

(a) In dry weather conditions, the discharge of effluent shall only take place for a period of 2 hours 30 minutes commencing 30 minutes before local high water on each tide. Under wet weather conditions, when the storage facilities have been fully utilised, a discharge may be made outside this "tidal window" as necessary.

(b) In the years 1993, 1994 and 1995 only, a disinfecting agent may be added to the sewage discharge.

(c) The disinfecting agent shall be sodium hypochlorite and this consent does not grant or imply approval for any other disinfection process.

(d) Disinfectant shall only be added to the discharges from:

1. The high level pump rated at 15,200 cubic metres per hour.

2. The low level pump rated at 7,700 cubic metres per hour.

(e) The discharges from the additional storm pumps shall not be disinfected.

(f) When the discharges are within the "tidal window" the application of disinfectant shall be controlled so that the concentration of available chlorine in the pumped flow at the above rates does not exceed 17.5 milligrams per litre.

(g) If, as a result of wet weather, the storage capacity is exceeded and the pumps activate outside the "tidal window" the application of disinfectant shall be controlled so that the concentration of available chlorine in the pumped flow at the above rates does not exceed:-

For the flood tide period - 35 mg/l
For the ebb tide period - 9 mg/l

4. Environmental Quality Standards applicable during disinfection periods

At or beyond the mixing zone defined as 100 metre radius of the outfall the following standards apply:

Total Residual Oxidant shall not exceed 10 micrograms per litre.
Chloroform shall not exceed 12 micrograms per litre.

5. Cessation of Disinfection:

If, as a result of analytical or survey work undertaken by either the Company or the Authority, there is evidence of environmental damage caused by the disinfection process, the use of disinfectant shall cease immediately upon receipt of written notification from the Authority to the Quality Director of North West Water Ltd.

6. Outlet

(a) The outlet shall be located at National Grid Reference SD 2957 3507 at the position indicated on the plan submitted with the application.

(b) The outlet shall only be used for the discharge of screened sewage effluent (including storm water) from Manchester Square Sewage Pumping Station, Blackpool.

7. Samples of the receiving water

Samples of the receiving water will be obtained by the Authority's officers from time to time at or beyond the mixing zone defined above and by the Consent Holder as per the attached Schedule 1.

The Conditions attached to the Consent hereby given will be subject to review from time to time but will not without the Consent in writing of the person to whom this Consent is given (or his successor) be altered before the expiration of the period ending with 30 September 1994.

Your attention is drawn to the statutory right of appeal to the Secretary of State for the Environment should it be considered that the conditions attached to the consent are unreasonable.

This Consent is granted solely under and for the purpose of the Water Resources Act, 1991 and is without prejudice to the operation of any other legal provisions now or at any other time hereinafter applicable to the aforesaid matter.

This Consent supersedes Deemed Consent No DA96 and shall remain in force until the commissioning of the works connected with the Fylde Coast Improvement Scheme, when the conditions contained in the Consent of the same number issued on 17 July 1992 shall come into force.

Dated this 10th day of September 1992

Signed C. Harpley

DR. C. HARPLEY
Regional General Manager

CONSENT NO 0171160287

SCHEDULE 1

Monitoring Requirements to be undertaken by the Company:

Sampling frequency:	Weekly
Sampling Points:	1. At the surface at the point of discharge.
Analysis	Total residual oxidant Monochloramine Dichloramine - Chloroform Bromoform - 3-chloro-4-(dichloromethyl)-5- hydroxy-2 (5H) - furanone 'MX' "Microtox" toxicity faecal coliforms - salmonellae - faecal streptococci F+ phage assay Absorbable organic Halogen (AOX)
	2. At 100 metre radius of the discharge.
Analysis:	Total residual oxidant Monochloramine Dichloramine - Chloroform Bromoform - 3-chloro-4-(dichloromethyl)-5- hydroxy-2 (5H) - furanone 'MX' "Microtox" toxicity faecal coliforms salmonellae faecal streptococci F+ phage assay
	3. High level influent to the plant.
	4. Low Level influent to the plant.
Analysis:	faecal coliforms salmonellae faecal streptococci
REPORTING:	The Company shall supply the results of all analyses carried out to the Authority within ten working days of the completion of the analysis.

APPENDIX B : SUMMARY OF NRA BOAT SURVEYS

Survey	Date	Vessel	Comments
1	4/5/93	Coastal Guardian	Before chlorination had commenced.
2	12/5/93	(Acer Env'tal)	Only 2 TRO measurements. Met Consent.
3	28/5/93	Coastal Guardian	Survey overnight. Samples taken only from boil
4	8/6/93	Coastal Guardian	Sampled in and away from boil. Failed Consent..
5	15/7/93	Sea Mew	Sampled in and away from boil. Failed Consent.
6	29/7/93	Coastal Guardian	Sampled in and away from boil. Failed Consent.
7	19/8/93	Coastal Guardian	Sampled in and away from boil. Failed Consent.
8	1/9/93	(Acer Env'tal)	Sampled in and away from boil. Met Consent.

APPENDIX C : TIDAL BEACH SURVEY SAMPLING POINTS

SITE 3 - 10 KM — C2 marked on seaward side of sea-wall. Opposite gates from Rossall School. Steps down onto shore at short breakwater.

SITE 4 - 9.5 KM — E5 on wall. At gates leading off main promenade. Last of houses before Rossall School.

SITE 5 - 9 KM — Opposite Durban hotel. Small type slipway (no access). Last lamp post on seaward side of promenade.

SITE 6 - 8.5 KM — Large obelisk, Jubilee gardens, Royal hotel. Access to beach via slip near Royal.

SITE 7 - 8 KM — First house hotel (Morvern). Just south of two obelisks.

SITE 8 - 7.5 KM — Two red lights on beach.

SITE 9 - 7 KM — Second shelter on promenade, south of outfall.

SITE 10 - 6.5 KM — South of little Bispham slip. 1560 m marked on wall. Gap in wall to shore.

SITE 10a - 6 KM — 1170 m marked on wall next to steps. North of Norbreck Castles. Just south of small red roofed shelter on prom.

SITE 11 - 5.5 KM — 510 m marked on the wall. Four detached houses between red brick conglomeration to North and yellow block to South. First slip to South of Norbreck Castle.

SITE 11a - 5 KM — Two southerly recurved breakwateras at HWM. 0 m on sea wall.

SITE 12 - 4.5 KM — Opposite southerly recurved groyne. Gravel patch on beach, pool area closer inshore. North of Miners hostel (red brick with cupola).

SITE 12a - 4 KM — Large slipway with gates, north of boating pool. Series of descending footpaths from promenade.

SITE 13 - 3.5 KM — Boating pool. Doric Hotel.

SITE 13a - 3 KM — Gynn Square outfall onto beach at HWM. Two pillars each with a stone urn.

SITE 14 - 2.5 KM — Imperial hotel. Large red brick building with weathervane and flagpole.

SITE 14a - 1.5 KM — Metropole hotel (Butlins), large red brick building north of obelisk. Beach patrol Hut on lower Prom. Just north of north pier (can gain entry to lower Prom). Beach access.

SITE 15 - 1.25 KM — Lewis's large square building, honeycombe pattern. North of tower.

SITE 15a - 0.9 KM — Coral island passenger gantry on Prom.

SITE 16 - 0.2 KM — Foxhall hotel, black and white Tudor style.

M - 0 K — Ladies and Gents on Prom. Outfall, black and white tower.

M - 0 K — Ladies and Gents on Prom. Outfall, black and white tower.

SITE 16a - 0.5 KS — Flagstaff.

SITE 17 - 0.9 KS — Windmill.

SITE 17a - 1.5 KS — Sandcastle, massive building on Prom., south of South Pier.

SITE 18 - 2 KS — Big dipper. Tall white tower with yellow top, red and white cage goes up and down it. Slipway.

SITE 18a - 2.5 KS — Model boat pool with 4 towers. Lennox gate SWO. Slipway.

SITE 19 - 3 KS — New Mayfair, blue sign on small hotel.

SITE 19a - 3.4 KS — Squires gate slip. End of Prom. Boating pool.

SITE 20 - 3.7KS — Middle Pontins, yellow building red roof. Two posts HWM. Gap in dunes.

SITE 20a - 4.5 KS — Two convalescent homes, 1 white Tudor looking, other red. Gap on shoreline where vehicles gain access to beach.

SITE 21 - 5 KS — Fylde International Sand Yacht Club, white building. Coastguard building, red brick.

APPENDIX D : DETAILS OF NRA BOAT SURVEYS

Survey 1 : 4 May 1993

Time	TRO mg/l	Free Oxidant mg/l	Total Coliforms /100mls	e.coli /100mls	Chloro-form µg/l	Bromo-form µg/l
09.49	< 0.02	< 0.02	520	200	<1	<1
09.51	< 0.02	< 0.02	500	180		
10.00	< 0.02	< 0.02	300	250	<1	<1
10.05	< 0.02	< 0.02	1100	280		
10.05	< 0.02	< 0.02	> 10000	> 2000		
10.10	< 0.02	< 0.02	> 10000	> 2000		
10.15	< 0.02	< 0.02	> 10000	> 2000		
10.20	< 0.02	< 0.02	> 10000	> 2000	<1	<1
10.25	< 0.02	< 0.02	> 10000	> 2000		
10.30	< 0.02	< 0.02	> 10000	> 2000		
10.35	< 0.02	< 0.02	> 10000	> 2000		
10.40	< 0.02	< 0.02	> 10000	> 2000	<1	<1
10.45	< 0.02	< 0.02	> 10000	> 2000		
10.50	< 0.02	< 0.02	> 10000	> 2000		
10.55	< 0.02	< 0.02	> 10000	> 2000		
11.00	< 0.02	< 0.02	> 10000	> 2000	<1	<1
11.10	< 0.02	< 0.02	> 10000	> 2000		
11.15	< 0.02	< 0.02	9400	> 2000		
11.20	< 0.02	< 0.02	7600	> 2000	<1	<1
11.25	< 0.02	< 0.02	> 10000	> 2000		
11.30	< 0.02	< 0.02	8200	> 2000		
11.35	< 0.02	< 0.02	> 10000	> 2000		
11.40	< 0.02	< 0.02	4800	> 2000	<1	<1
11.45	< 0.02	< 0.02	5800	> 2000		
11.50	< 0.02	< 0.02	4500	> 2000		
11.55	< 0.02	< 0.02	3700	> 2000		
12.00	< 0.02	< 0.02	6000	> 2000	<1	<1
12.05	< 0.02	< 0.02	2800	> 2000		
12.10	< 0.02	< 0.02	1200	1120		
12.15	< 0.02	< 0.02	2000	1280		
12.20	< 0.02	< 0.02	4700	1320	<1	<1
12.25	< 0.02	< 0.02	2100	1040		
12.30	< 0.02	< 0.02	2200	600		

Survey 2 : 12 May 1993

Time	Outfall Distance (metres)	TRO mg/l	Free mg/l	Total Coliforms /100mls	E.coli /100mls	faecal streps. /100mls	Chloro-form µg/l	Bromo form µg/l
16.20	0	> 0.5	0.3	3200	640 >	200	2	<1
16.25	0			3800	780 >	200	<1	<1
16.30	100			2200	400 >	200	1	<1
16.35	200			< 20	< 5	2		
16.40	300			< 20	< 5	4	<1	<1
16.45	350	<0.02	<0.02	< 20	< 5	4		

Survey 3 : 28 May 1993

time	TRO	Free Oxidant	Total Coliforms	E.coli	faecal streps.	Chloro-form	Carbon tetra chloride
	mg/l	mg/l	/100mls	/100mls	/100mls	µg/l	µg/l
0400	0.02	0.02	580	80	680	<1	<1
0410	0.02	0.02	310	80	1020		
0415			290	90	1100		
0420	> 0.5	0.35	0	0	310	4.9	<1
0425			160	8	850		
0430	> 0.5	0.15	10	6	220		
0435			1290	210	2320		
0440	0.4	0.4	480	80	1400	1.8	<1
0445			1350	270	2140		
0450	0.25	0.12	1540	410	2480		
0455			640	180	970		
0500	0.02	0.02	720	310	1230	<1	<1
0505			850	290	1310		
0510	0.1	0.04	1880	540	1880		
0515	> 0.5	0.4	830	480	1270		
0520	0.5	0.2	420	160	1480	<1	<1
0525			2150	490	3170		
0530	> 0.5	0.35	2080	510	2140		
0535			1760	320	1790		
0540	0.3	0.08	350	90	880	1.2	<1
0545	> 0.5	0.35	1020	360	2010		
0550	0.5	0.25	270	80	1060		
0555			310	60	1090		
0600	0.35	0.35	330	50	1320	<1	<1
0605			540	130	1160		
0610	0.5	0.12	1120	560	2040		
0615			850	300	1190		
0620	0.5	0.25	1490	510	2310		
0625			90	20	680		
0630	> 0.5	0.4	570	100	1080		
0635			360	20	940		
0640	0.35	0.1	2850	180	4120	1.7	<1

Survey 4 : 8 June 1993

time	Outfall Distance (Metres)	TRO	Free Oxidant	Total Coliforms	E.coli	faecal streps.
		mg/l	mg/l	/100mls	/100mls	/100mls
1425	0	0.14	0.06	150	21	74
1438	0	0.3	0.12	140	27	9
1550	0	< 0.02	< 0.02	1250	0	139
1432	0	0.12	0.02	1060	2	2
1503	0	0.2	0.06	150	65	58
1435	0	0.12	0.06	8680	245	21
1530	0	0.08	0.02	1090	0	9
1535	0	0.14	0.04	4160	0	48
1600	20			3730	0	422
1452	70	0.04	0.02	120	38	4
1543	100	0.02	0.02	6680	7	1
1508	100	0.12	0.04	3280	2	176
1456	150	0.04	0.02	50	22	46
1514	200	0.02	0.02	970	3	4
1522	400	0.02	0.02	3720	0	3
1418	800	< 0.02	< 0.02	30	2	0
1415	1600	< 0.02	< 0.02	10	1	1

Survey 5 : 15 July 1993

time	Distance Outfall (Metres)	TRO /100mls	Free Oxidant /100mls	Total Coliforms /100ml	E.coli /100ml	faecal streps. /100ml	Chloro -form µg/l	Bromo -form µg/l	Carbon tet rachloride µg/l	Tetrachlo roethylene µg/l	Trichloro ethylene µg/l	Dichloro ethane1,2 µg/l	Trichloro benzene µg/l
0944	0	0.12	0.05	256	78	16							
0901	0	0.5	0.4	204	11	7							
0804	0	0.5	0.14	204	0	1							
0825	0	0.5	0.4	360	17	15	1.3	<1	<1	6.5	<1	<1	<1
1017	0	> 0.5	0.5				1.8	<1	<1	2.7	<1	<1	<1
0835	100	0.04	0.04	400	5	26	<1	<1	<1	1.5	<1	<1	<1
0815	100	< 0.02	< 0.02	32	8	1	<1	<1	<1	<1	<1	<1	<1
0951	100	< 0.02	< 0.02				<1	<1	<1	<1	<1	<1	<1
0915	500	< 0.08	0.07	164	23	1	<1	<1	<1	1	<1	<1	<1
0848	600	< 0.02	< 0.02	56	39	2	<1	<1	<1	<1	<1	<1	<1
0959	1000	< 0.02	< 0.02				<1	<1	<1	<1	<1	<1	<1

Survey 6 : 29 July 1993

Time	Distance Outfall (Metres)	TRO (mg/l)	Free Oxidant (mg/l)	Total Coliforms /100ml	e.coli /100ml	faecal streps /100ml	Chloro -form µg/l	Bromo -form µg/l	Carbon tet rachloride µg/l	Tetrachlo roethylene µg/l	Trichloro ethylene µg/l	Dichloro ethane1,2 µg/l	Trichloro benzene µg/l
10.33		0.04	< 0.02	990	392	27							
10.26				830	253	18	<1	<1	<1	<1	<1	<1	<1
10.00	0	0.14	0.08	2160	212	41							
08.40	0	0.2	0.2	688	512	12	1	<1	<1	<1	<1	<1	<1
08.54	0			664	318	34							
10.10	0	0.25	0.16	900	365	31							
08.47	0	0.25	0.2	970	392	20							
09.46	20	0.12	0.03	1920	308	10	1.9	<1	<1	<1	<1	<1	<1
10.20	100	0.1	0.03	1170	205	28							
09.40	100			1650	388	18							
08.59	100	0.02	< 0.02	1020	288	30							
09.20	150			910	204	6							
09.05	210			900	296	15	<1	<1	<1	<1	<1	<1	<1

Survey 7 : 19 august 1993

Time	Distance Outfall (Metres)	TRO (mg/L)	Free Oxidant (mg/L)	Total Coliforms /100ml	E.coli /100ml	faecal streps. /100ml	Chloro -form µg/l	Bromo -form µg/l	Carbon tet rachloride µg/l	Tetrachlo roethylene µg/l	Trichloro ethylene µg/l	Dichloro ethane1,2 µg/l	Trichloro benzene µg/l	Trichloro ethane1,1,1 µg/l	Trichloro ethane1,1,2 µg/l
12.50	0	0.35	0.2	62000	610	1820	2.1	<1	<1	<1	<1	<1	<1	1.5	<1
12.59	0	0.25	0.1	55000	420	1290	2.2	<1	<1	<1	<1	<1	<1	1.2	<1
12.29	20	< 0.01	< 0.01	25200	720	510	<1	<1	<1	<1	<1	<1	<1	<1	<1
12.38	30	< 0.01	< 0.01	39000	1270	450	<1	<1	<1	<1	<1	<1	<1	<1	<1
13.08	130	0.03	< 0.01	3500	312	430	<1	<1	<1	<1	<1	<1	<1	<1	<1
13.19	130	0.04	< 0.01	5200	306	1760	<1	<1	<1	<1	<1	<1	<1	<1	<1
13.38	330	0.03	< 0.01	4200	560	560	<1	<1	<1	<1	<1	<1	<1	<1	<1
13.51	350	0.02	< 0.01	2580	194	520	<1	<1	<1	<1	<1	<1	<1	<1	<1

Survey 8 : 1 september 1993

time	Distance Outfall (Metres)	TRO (mg/L)	Free Oxidant (mg/L)	Total Coliforms /100ml	E.coli /100ml	faecal streps. /100ml	Chloro -form µg/l	Bromo -form µg/l	Carbon tet rachloride µg/l	Tetrachlo roethylene µg/l	Trichloro ethylene µg/l	Dichloro ethane1,2 µg/l	Trichloro benzene µg/l
12:58	0	<0.01	<0.01										
13:50	0	<0.01	<0.01	2930	1740	960							
14:05	0	<0.01	<0.01	3720	1800	1470							
12:50	10	<0.01	<0.01	15600	2110	2010	<1	<1	<1	<1	<1	<1	<1
13:05	100	<0.01	<0.01	8000	2400	1620	<1	<1	<1	<1	<1	<1	<1
13:35	100	<0.01	<0.01										
14:30	100	<0.01	<0.01	1840	14	1400							
13:20	500	<0.01	<0.01	1210	1160	1200	<1	<1	<1	<1	<1	<1	<1

APPENDIX E : ACER ENVIRONMENTAL SURVEY RESULTS

Above Outfall (WQ1)

Date	Free Chlorine mg/l	Free Chlorine/ Monochloramine mg/l	Total Residual Oxidants mg/l	Trichloromethane µg/l	Tribromomethane µg/l	MX µg/l	AOX mg/l
06/05/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.03
12/05/93	0.3	>0.5	>0.5	<3.0	<2.80	<0.01	0.06
20/05/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	3.22
25/05/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	
03/06/93	0.5	>0.5	>0.5	<3.0	<2.80	<0.01	<0.01
09/06/93	0.04	0.2	0.2	<3.0	<2.80	<0.01	0.04
17/06/93	<0.02	0.04	0.04	<3.0	<2.80	<0.01	<0.10
24/06/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	
02/07/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	<0.01
13/07/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.32
16/07/93	0.06	0.3	0.3	<3.0	<2.80	<0.01	1.21
22/07/93	0.06	0.4	0.4	<3.0	<2.80	<0.01	0.40
30/07/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.50
13/08/93	0.14	0.25	0.3	<3.0	<2.80	<0.01	1.79
17/08/93	0.04	0.04	0.06	3.3	<2.80	<0.01	0.76
19/08/93	0.16	0.2	0.2	<3.0	<2.80	<0.01	0.23
24/08/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.75
01/09/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.58
06/09/93	<0.02	<0.02	<0.02	3.7	<2.80	<0.01	0.61
16/09/93	<0.02	0.1	0.12	<3.0	<2.80	<0.01	0.56
22/09/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.58
30/09/93	<0.02	<0.02	<0.02	4.9	<2.80	<0.01	

Above Outfall (WQ1)

Date	Total coliforms per 100 ml	Faecal coliforms per 100 ml	Faecal streptococci per 100 ml	Salmonellae MPN per litre	F+ phage per ml	Microtox 5-min EC50 (% vol/vol)	Microtox 15-min EC50 (% vol/vol)	Enteroviruses pfu per 10 litres
06/05/93	141	15	10	<1	3	NT	NT	
12/05/93	72 000	7 950	3 200	<1	113	NT	NT	228
20/05/93	467	140	21	<1	429	NT	NT	
25/05/93	3 582	136	163	<1	9	NT	NT	105
03/06/93	2 472	557	27	<1	<1	NT	NT	
09/06/93	191 150	137 400	63 000	2	64	NT	20.2	
17/06/93	194	57	8	<1	5	NT	NT	
24/06/93	1 963 500	606 000	130 000	17	76	NT	NT	
02/07/93	450 500	35 630	1 136	8	6	NT	NT	
13/07/93	<500	<500	<500	<1	2	NT	NT	
16/07/93	1 409	243	100	<1	87	NT	NT	ND
22/07/93	6 036	914	1 557	<1	159	NT	NT	
30/07/93	279 500	11 486	12 477	<1	516	26.9	41.9	
13/08/93	9 000	<500	<500	161	187	NT	NT	6
17/08/93	119 400	591	3 909	<1	241	20.3	20.7	
19/08/93	172 000	6 364	15 450	5	95	2.6	1.3	
24/08/93	138 700	38 200	6 909	5	48	NT	NT	5
01/09/93	382 000	272 000	43 364	11	77	32.7	43.8	
06/09/93	1 632 000	225 000	82 700	7	468	23.2	26.9	2
16/09/93	3 182	136	100	<1	269	NT	NT	
22/09/93	1 182 000	194 000	85 900	22	139	NT	NT	
30/09/93	81 500	2 045	1 892	<2	36	NT	NT	

105 M Downstream of Outfall (WQ2)

Date	Free Chlorine mg/l	Free Chlorine/ Monochloramine mg/l	Total Residual Oxidants mg/l	Trichloromethane µg/l	Tribromomethane µg/l	MX µg/l	AOX mg/l
06/05/93	0.04	0.04	0.04	<3.0	<2.80	<0.01	0.20
12/05/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.12
20/05/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.17
25/05/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	
03/06/93	0.5	>0.5	>0.5	<3.0	<2.80	<0.01	<0.01
09/06/93	0.06	0.4	0.4	<3.0	<2.80	<0.01	0.06
17/06/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.06
24/06/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	
02/07/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.02
13/07/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.23
16/07/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.76
22/07/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.50
30/07/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	1.10
13/08/93	<0.02	0.06	0.08	<3.0	<2.80	<0.01	0.43
17/08/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.25
19/08/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.30
24/08/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.03
01/09/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.18
06/09/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.60
16/09/93	0.08	0.08	0.08	<3.0	<2.80	<0.01	0.35
22/09/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	0.74
30/09/93	<0.02	<0.02	<0.02	<3.0	<2.80	<0.01	

105 M Downstream of Outfall (WQ2)

Date	Total coliforms per 100 ml	Faecal coliforms per 100 ml	Faecal streptococci per 100 ml	Salmonellae MPN per litre	F+ phage per ml	Microtox 5-min EC50 (% vol/vol)	Microtox 15-min EC50 (% vol/vol)	Enteroviruses pfu per 10 litres
06/05/93	32	15	<10	<1	7	NT	NT	
12/05/93	1 582	486	436	<1	40	NT	NT	ND
20/05/93	552	161	24	1	<1	NT	NT	
25/05/93	2 482	318	39	<1	<1	NT	NT	ND
03/06/93	23	8	<1	<1	3	NT	NT	
09/06/93	1 287	150	1 132	<1	36	54.2	34.2	
17/06/93	138	33	4	<1	4	NT	NT	
24/06/93	4 095	1 059	55	1	<1	NT	NT	
02/07/93	359	15	<5	1	<1	NT	NT	
13/07/93	176	99	15	<1	<1	NT	NT	
16/07/93	2 318	90	50	<1	19	NT	NT	5
22/07/93	194	10	15	1	10	NT	NT	
30/07/93	22 636	3 347	1 081	<1	4	NT	NT	
13/08/93	2 189	305	995	18	28	NT	NT	ND
17/08/93	12 455	1 000	2 604	1	95	NT	NT	
19/08/93	51 182	3 374	6 545	5	36	51.6	25.2	
24/08/93	950	277	10	1	<1	NT	NT	ND
01/09/93	486 000	334 000	52 091	28	75	NT	NT	
06/09/93	404 000	155 000	33 273	13	154	NT	NT	15
16/09/93	1 477	182	41	<1	137	NT	NT	
22/09/93	386 000	156 000	36 318	35	42	NT	NT	
30/09/93	22 000	1 491	1 649	2	12	NT	NT	

Influent (Low Level)

Date	Total coliforms per 100 ml	Faecal coliforms per 100 ml	Faecal streptococci per 100 ml	Salmonellae MPN per litre	F+ phage per ml	Enteroviruses pfu per litre
06/05/93	15 364 000	5 773 000	1 176 000	21	7 040	
12/05/93	28 919 000	3 682 000	1 909 000	11	1 389	259
20/05/93	32 568 000	2 091 000	636 000	1	429	
25/05/93	16 532 000	2 000 000	1 100 000	54	920	1 461
03/06/93	14 775 000	11 802 000	2 773 000	9	3 920	
09/06/93	41 982 000	10 360 000	4 505 000	22	795	
17/06/93	44 550 000	9 318 000	954 500	>180	676	
24/06/93	33 514 000	6 136 000	1 081 000	11	1 165	
02/07/93	756 667 000	31 982 000	2 613 000	430	575	
13/07/93	26 802 000	17 072 000	2 364 000	540	4 320	
16/07/93	27 727 000	11 818 000	4 144 000	350	604	388
22/07/93	44 009 000	11 216 000	1 667 000	56	716	
30/07/93	27 973 000	7 387 000	2 091 000	540	2 391	
13/08/93	47 727 000	6 847 000	590 900	1 600	451	50
17/08/93	39 009 000	7 591 000	1 036 000	920	4 960	
19/08/93	95 000 000	9 775 000	863 600	350	1 080	
24/08/93	NS	NS	NS	NS	NS	
01/09/93	205 455 000	29 279 000	5 676 000	540	6 091	
06/09/93	69 090 000	10 991 000	2 182 000	8	2 518	620
16/09/93	123 636 000	21 126 000	5 000 000	32	7 300	
22/09/93	170 909 000	24 775 000	3 378 000	38	2 782	
30/09/93	123 636 000	17 477 000	7 748 000	39	60	

Influent (High Level)

Date	Total coliforms per 100 ml	Faecal coliforms per 100 ml	Faecal streptococci per 100 ml	Salmonellae MPN per litre	F+ phage per ml	Enteroviruses pfu per litre
06/05/93	NS	NS	NS	NS	NS	
12/05/93	155 000 000	11 036 000	3 636 000	54	12 800	40
20/05/93	207 727 000	6 261 000	863 600	18	1 142	
25/05/93	7 838 000	400 000	<50 000	7	394	140
03/06/93	10 946 000	7 162 000	2 591 000	21	3 600	
09/06/93	267 727 000	19 009 000	6 261 000	35	1 542	
17/06/93	138 000 000	16 532 000	4 730 000	161	3 680	
24/06/93	35 541 000	9 505 000	1 982 000	>180	1 629	
02/07/93	NS	NS	NS	NS	NS	
13/07/93	25 360 000	10 901 000	272 700	81	7 040	
16/07/93	109 545 000	20 455 000	3 694 000	69	1 880	875
22/07/93	268 636 000	106 818 000	11 667 000	280	971	
30/07/93	37 703 000	10 721 000	2 955 000	41	2 345	
13/08/93	61 863 000	15 541 000	2 455 000	430	1 465	ND
17/08/93	142 273 000	15 135 000	2 455 000	150	11 300	
19/08/93	108 182 000	10 856 000	1 409 000	1 600	2 400	
24/08/93	48 514 000	14 279 000	2 909 000	>1 800	8 800	775
01/09/93	290 455 000	35 856 000	4 318 000	47	8 836	
06/09/93	194 545 000	20 676 000	6 261 000	47	10 691	210
16/09/93	248 636 000	26 667 000	8 784 000	39	11 400	
22/09/93	106 818 000	18 468 000	3 773 000	19	9 200	
30/09/93	115 909 000	19 595 000	5 766 000	81	96	

Legend

MPN	Most probable number
ND	None detected
PFU	Plaque forming units
EC50	The concentration of test sample that inhibited light output by 50%
NT	No evidence of toxicity at the highest dose tested (50% volume/volume)
NS	Not sampled