NRA 504.454

DRAFT WORKING PAPER 3

ENVIRONMENTAL ASSESSMENT OF DENVER MRF
IMPACT OF FRESHWATER FLOW ON WATER QUALITY OF THE GREAT OUSE ESTUARY

1. INTRODUCTION

1.1 The water quality data collected by NRA in the Great Ouse estuary, including its tributaries and effluent sources, have been reviewed to assess the current water quality of the estuary. The data have been used to set up boundary conditions for the Great Ouse estuary water quality model which predicts water quality conditions that are broadly in agreement with the observed conditions.

1.2 The model is used to predict water quality in the estuary as a result of changes to the Ely Ouse flow at Denver. The results demonstrate that the estuary water quality declines as total freshwater flows reduce, provided tributary and effluent quality remains constant. The results indicate that it does not make much difference whether the fresh water in the estuary comes from the Ely Ouse or the Bedford Ouse. Changing the Ely Ouse discharge from the Tail Sluice to Denver Sluice has a negligible effect on estuary water quality.

1.3 The model predictions may be used to indicate the order of deterioration in water quality associated with a reduction in freshwater flow. In autumn water quality seems more sensitive to freshwater flow than during the remainder of the year.

ENVIRONMENT AGENCY

2. SAMPLING POINTS

2.1 The waters of the Great Ouse estuary have been sampled routinely at the nine points shown on Figure 1 and listed in Table 1. Samples have not been collected at Welney Bridge since 1990. In addition, samples are routinely taken of the tributaries and effluent discharges listed in Table 1. Since 1989 the samples of the estuary have been collected on about six days each year at both high and low tide. Summaries of the data obtained from February 1989 to June 1992 are included in Tables 2, 3 and 4 for the estuary, tributaries and effluent discharges respectively. The estuary sampling points do not include Welney Bridge.

2.2 In addition to the routine sampling, continuous water quality monitors are maintained at Freebridge and Salters Lode. They are also shown on Figure 1 and listed on Table 1. These continuous monitors measure dissolved oxygen, temperature, conductivity and water level. Unfortunately only 5½ months of dissolved oxygen data have been retrieved from the Freebridge monitor and none from the Salters Lode monitor. The dissolved oxygen data obtained from the Freebridge monitor have been analysed and the processed data are presented in Appendix A.

3. ESTUARY WATER QUALITY

Chloride content

3.1 The data of Table 2 show how the average chloride content of the estuary waters reduces along the estuary. The data show that chloride concentrations in excess of 100 mg/l are rarely reported in the analyses of New Bedford River water samples taken from Mepal Bridge. Further downstream, the proportion of samples when chloride concentration is less than 100 mg/l reduces. At times of low freshwater flow chlorides are higher than at times of high freshwater flow. The frequency of occurrence of high chloride concentrations at Downham Bridge and in the New Bedford River are discussed in the Working Paper on saline intrusion.

Dissolved oxygen, BOD and ammonia

3.2 In the section of the Great Ouse estuary that passes through Kings Lynn from Wiggenhall St Germans to The Point (Figure 1), Table 2 indicates that the amount of dissolved oxygen (DO) in the water averages between 78 and 73%. The shape of the DO profile is illustrated on Figure 2. The data suggest the values measured at Freebridge are marginally higher than those measured upstream or downstream. Upstream from Wiggenhall St Germans there is a steady increase in the average amount of DO present. The highest average DO content of 87% is found at Mepal Bridge in the upper part of the New Bedford River.

3.3 Within the estuary, the concentrations of BOD follow the opposite trend with the peak average value of 3.8 mg/l occurring at Wiggenhall St Germans as shown in Figure 3 with lower values upstream and downstream. A generally similar pattern is evident for ammonia with a peak average concentration of 0.30 mg/l at Freebridge as Figure 4 shows.

3.4 If the DO measured during the routine sampling at Freebridge is compared with the data from the Freebridge continuous quality monitor, significant differences are evident. Table 5 shows that three of the four routine samples collected at times when the continuous monitor was operating contained significantly more DO than the monitor recorded.

3.5 The results over the period when data are available from the two methods cannot be directly compared. However the monitor records less DO on average and has lower maxima and minima. This tends to suggest a systematic difference between the routine samples and the automatic monitor, with the automatic monitor frequently recording less DO than the routine laboratory analyses. We have assumed the routine samples to be accurate, but that the automatic monitor can be used to indicate the variability of DO from day to day.

3.6 The analysis of the continuous monitor data in Appendix A indicates that during the 5½ month period of data analysis, the average DO content was 65.7% saturation. A DO of less than 45% saturation was recorded 1 hour in 10 during this period. DO levels below 45% saturation are particularly evident in October 1991 (3.8 hours/day on average) and July 1992 (8.2 hours/day on average), but occurred for only 7 hours during the whole of March, April and May 1992. Assuming that these monitor results are typical of the whole year would imply that the 10 percentile DO NRA propose to use to assess the river and estuary Fisheries Ecosystem (Ref 1) will be 20% saturation less than the long-term average. Applying this to the routine samples, for example at Wiggenhall St Germans which has an average of 73% saturation, the 90 percentile value will be around 53% saturation.

Nutrients

3.7 The concentration of total oxidized nitrogen and particulate orthophosphate are highest at Brownshill and reduce all the way down the estuary as Tables 2 and 3 illustrate. The concentration of both nutrients are higher in the Bedford Ouse at Brownshill than in the Ely Ouse at Denver or the other tributaries listed in Table 3. The profile of both nutrients along the estuary is plotted against the chloride content in Figure 5 showing the importance of low nutrient seawater for diluting nutrients in the fresh water entering the estuary.

Bacterial numbers

3.8 The numbers of bacteria at each sampling site in the Great Ouse estuary varies markedly between high tide and low tide as Table 6 indicates. At The Point and Cork Hole, which are seaward of Kings Lynn, the highest numbers are reported at low tide. From Wiggenhall St Germans to Downham Bridge the highest numbers are found at high tide. The distribution of bacteria in the estuary at high and low tide is shown in Figure 6.

3.9 The distribution of bacterial numbers between high tide and low tide reflects the influence of the discharge from Kings Lynn sewage works which causes high numbers of bacteria downstream at low water and high numbers upstream at high water. The influence of the Kings Lynn effluent at high tide is evident as far upstream as Downham Bridge. In the New Bedford River, at Mepal and Welney, bacterial numbers are higher at low tide, suggesting additional sources.

Seasonal water quality changes

3.10 The samples collected between 1981 and 1991 from the five main tributaries at Brownshill have been analysed seasonally. In the first stage of this analysis the average for all samples collected in each individual month was obtained. The results for individual months have then been grouped to obtain the average concentration in each month of a typical year. The results are presented in:

Table 7 for the Bedford Ouse at Brownshill
Table 8 for the Ely Ouse at Denver
Table 9 for the Flood Relief channel at Saddlebow
Table 10 for the Middle Level Drain at St Germans
Table 11 for the River Nar at the Kings Lynn bypass

3.11 The seasonal results show marked variations in the majority of parameters. Temperature and BOD are usually highest in the summer months when dissolved oxygen, ammonia and oxidized nitrogen are at their lowest concentrations. These seasonal results have been used to provide input for the Great Ouse estuary water quality model.

4. GREAT OUSE ESTUARY WATER QUALITY MODELLING

Model boundary conditions

4.1 The main boundary conditions for the Great Ouse estuary water quality model are the flow and quality of water entering the estuary from each tributary and effluent source. Tributary water quality is assumed to vary seasonally as indicated on Tables 7 to 11 for each tributary. Effluent water quality is assumed to remain constant throughout the year at the average quality given in Table 4.

4.2 Modelling was carried out for four representative months, January, April, July and October. These four months enable the effect of the seasonal changes in water quality and temperature to be taken into account as well as the presence of the British Sugar effluent which discharges from September to February. The sea water quality and water temperature assumed for each of the tests are listed in Table 12.

4.3 The flows for the Ely Ouse were calculated for three conditions, drought, dry and average for each of the four months used in the modelling. Drought conditions were defined as close to the lowest monthly average flow in the past 30 years. Dry conditions chosen to be approximately a 1 in 5 year drought were selected from around the sixth lowest monthly average flow in the past 30 years . In most cases a suitable month could be selected from the past 10 years, as these would best reflect current catchment conditions. Flows in the same months were chosen for the Bedford Ouse, Middle Level and river Nar to ensure consistent conditions. Average conditions were defined from the long-term monthly average flows for each tributary. The months selected and the tributary flows used are listed in Table 13. For effluents the consented dry weather flows listed in Table 14 have been used.

Model test conditions

4.4 The model was first used to predict estuary water quality for the chosen drought, dry and average months. Additional tests were then carried out for residual flows in the Ely Ouse of 318 tcmd in October and January only and 114, 50 and 0 tcmd in all four months. These tests used drought year flows for the other tributaries. Tests using the higher dry year flows in other tributaries were carried out to check the sensitivity of the results to these flows. Sensitivity tests were also carried out to examine whether the estuary water quality would be changed by discharging the residual flow through Denver Sluice rather than the Tail Sluice which is used at present. The final set of tests examined the sensitivity of estuary water quality to the effluent load arising from Kings Lynn sewage works.

4.5 The input data used for each of the 35 test conditions is listed in Appendix B. This appendix also gives a summary of the model output, listing the maximum BOD and ammonia concentrations and the minimum DO levels predicted by the model for the estuary. These maxima and minima occur approximately midway between Denver and Kings Lynn and represent high tide conditions.

4.6 The model predictions of DO are shown in Figure 7. This shows that there are important seasonal variations in the DO level as well as a major influence due to freshwater flow. The seasonal variations arise from three factors; effluent discharge, water temperature and tributary water quality.

4.7 The seasonal effluent from British Sugar increases the oxygen demand during the autumn and winter. High water temperatures in summer cause the oxygen demand to be exerted more rapidly causing lower DO levels in summer than in winter. In addition, the reducing solubility of oxygen in water as its temperature rises leads to lower concentrations of dissolved oxygen for a given percentage saturation. The final effect is that in autumn, the percentage saturation of oxygen in the waters of the Bedford Ouse and Ely Ouse as they enter the estuary are at their lowest as Tables 7 to 9 indicate.

4.8 These three effects all combine to give the minimum percentage saturation of DO in autumn as illustrated on Figure 7 and the maximum dissolved oxygen percentage saturation in April for the same total freshwater flow. The reduction in solubility of oxygen with rising water temperature means that the minimum concentration of dissolved oxygen will normally occur in summer.

4.9 The model results show a noticeable decrease in the minimum DO content as freshwater flows fall. This effect becomes more marked as freshwater flows decline.

Comparison of observations with model predictions.

4.10 The model predictions are based on the dry weather effluent flows permitted by their various discharge consents. In most cases, the discharge consent is a realistic assessment of the dry weather flow, but at Kings Lynn sewage works, Anglian Water Services report their current dry weather flow is 26 Mld compared with their 53.1 Mld consent. NRA have indicated that this discrepancy has arisen because of reductions in the volume of cannery effluent. Sensitivity tests using this reduced flow show an increase of ** in dissolved oxygen percent saturation.

4.11 The model predictions shown on Figure 7 are compared with the average DO reported during October 1991 and April and July 1992 by the Freebridge continuous monitor. There is good agreement with the monitor reporting an average oxygen content close to the model prediction. However, these model predictions assume the effluent flow from Kings Lynn sewage works was twice the quantity reported by Anglian Water Services. Taking this into account, the continuous monitor reports lower DO than the model predictions or the routine samples. Overall, the model predictions seem consistent with the results of the routine monitoring.

5. IMPACT OF CHANGES IN DENVER MRF ON ESTUARY WATER QUALITY

Overall impact

5.1 The impact of changes in the Denver MRF on estuary water quality, may be predicted using the estuary water quality model. The results for each of the four months tested are shown on Table 15. The changes are largest in October when reducing the MRF to zero from the 318 tcmd at present increases the ammonia concentration by 0.11 mg/l and reduces the DO by 5.2% of saturation These changes are expressed as a proportion of the existing minimum estuary water quality in Table 16.

5.2 The results in Table 16 may be used to estimate the reduction in flow that would cause a 5% or 10% deterioration in water quality during months when abstractions have already reduced the Ely Ouse flow to the current MRF. The Ely Ouse flows associated with a 5% or 10% deterioration in the quality associated with the current MRF are listed below.

	5% deterioration	10% deterioration
January	15 tcmd	0 tcmd
April	45(0) tcmd	0 tcmd
July	50(0) tcmd	0 tcmd
October	240(105) tcmd	165(0) tcmd

Note: bracketted figures are based on dissolved oxygen alone

5.3 In all months except January, the deterioration in percentage terms is more marked for ammonia than for dissolved oxygen. This is because the rate coefficient for ammonia is more sensitive to water temperature than the other rate coefficients. The importance of freshwater flow to limit deterioration in October water quality is particularly noteworthy.

5.4 The changes in water quality resulting from changes to the Denver MRF must also make allowance for the deterioration in water quality associated with reducing flows from their natural value to the proposed MRF value and the proportion of time when no abstraction of Ely Ouse water is necessary.

Choice of discharge point

5.5 Several tests were carried out to check whether releasing Ely Ouse flows at Denver Sluice instead of the Tail Sluice would have any impact on water quality. The results in Table 17 show a very minor effect with releases through Denver Sluice causing marginally lower dissolved oxygen. The differences are less than 0.5% in the dissolved oxygen percent saturation and less than 0.01 mg/l of ammonia. This indicates that water quality considerations should not normally influence the choice of sluice for residual flow releases.

Sensitivity to flows in other tributaries

5.6 From the water quality point of view, in the Great Ouse estuary with the current effluent discharges, the most important feature affecting estuary water quality is the total freshwater flow entering the estuary. This is evident from Figure 7. There are two pairs of runs which may be compared to examine the difference in water quality for similar freshwater flows arising from a different balance between Ely Ouse and Bedford Ouse flows. These runs are compared in Table 18.

5.7 The comparison for April conditions indicate that the test with a greater proportion of Ely Ouse water resulted in more DO and less ammonia. Conversely in October, the test with the higher total flow which would be expected to have had more DO and less ammonia because of the increased freshwater flow, did not. This is presumably because of the higher proportion of Ely Ouse water in the estuary which in this month depressed water quality.

5.8 These two pairs of results indicate that small variations in estuary water quality will arise if the balance between Bedford Ouse and Ely Ouse flows changes. The change can be in either direction depending on the water quality of these two tributaries at the time.

TABLE 1

LOCATIONS ON THE GREAT OUSE ESTUARY

		Position relative to Denver	
Location	Description	Site	(km)
Cork Hole	Sample point	S1	35.0
The Point	Sample point	S2	25.0
Kings Lynn stw	Effluent	E5	23.5
Porvair	Effluent	E4	23.1
Dow Chemical	Effluent	E3	22.7
River Nar	Tributary	T5	20.5
Freebridge	Sample point, WQ monitor	S3	19.6
British Sugar	Effluent	E2	18.7
Tail Sluice	Tributary	T3	18.3
Middle Level	Tributary	T4	15.0
Wiggenhall St Germans	Sample point	S4	14.2
Watlington stw	Effluent	E1	12.0
Wiggenhall St Mary	Sample point	S5	11.2
Stow Bridge	Sample point	S6	6.6
Downham Bridge	Sample point	S7	2.3
Salters Lode	WQ monitor	S8	0.6
Denver Sluice	Tributary	T2	0.0
Welney Bridge	Sample point	S9	-9.7
Mepal Bridge	Sample point	S10	-25.0
Brownshill	Tributary	T1	-36.0

Distances are measured positive downstream of Denver
Sites are shown on Figure 1

TABLE 2

WATER QUALITY OF GREAT OUSE ESTUARY
JANUARY 1989 - DECEMBER 1991

	BOD mg/l	DO % Sat	Chloride mg/l	Ammonia mg/l	Oxidized nitrogen mg/l	Ortho phosphate mg/l
Cork Hole						
No. of samples	39	39	36	38	38	36
maximum	4.25	103	19600	0.38	1.31	0.72
average	1.86	82.4	17999	0.09	0.39	0.08
minimum	<1.0	16.9	1900	<0.02	0.24	0.021
The Point						
No. of samples	37	39	36	37	37	35
maximum	8.83	96.5	19047	0.97	11.33	7.49
average	2.92	75.3	8344	0.26	2.49	0.67
minimum	<1.0	43.2	227	<0.02	0.26	0.06
Freebridge						
No. of samples	40	51	43	51	40	38
maximum	12.9	134	19000	0.76	12.07	1.51
average	2.90	78.2	8150	0.30	2.79	0.53
minimum	1.0	47.9	42.7	0.06	0.32	<0.06
Wiggenhall St Germans						
No. of samples	38	40	40	40	40	38
maximum	8.2	119	16153	0.55	11.33	1.88
average	3.78	72.9	3859	0.25	4.15	0.79
minimum	1.25	41.1	60.5	0.038	<0.5	0.15
Wiggenhall St Mary						
No. of samples	38	39	40	40	40	38
maximum	8.35	123	15304	0.64	12.45	2.06
average	3.44	76.9	3204	0.26	4.52	0.88
minimum	1.4	41.9	59.6	0.039	<0.5	0.14
Stow Bridge						
No. of samples	36	39	40	39	39	37
maximum	10.0	147	11830	0.71	14.18	2.17
average	3.31	79.3	1951	0.25	5.38	1.00
minimum	1.4	40.8	62.0	0.043	<0.5	0.34
Downham Bridge						
No. of samples	36	35	39	38	38	36
maximum	8.05	115	6200	0.59	13.97	2.28
average	3.36	82.1	937	0.24	5.94	1.17
minimum	1.3	39.8	57.5	<0.04	<0.5	0.46
Mepal Bridge						
No. of samples	49	48	64	51	51	48
maximum	10.2	145	1102	1.03	15.89	3.3
average	2.92	87.2	95.9	0.16	7.51	1.97
minimum	0.8	59.0	49.1	0.028	2.69	0.77

TABLE 3

TRIBUTARY WATER QUALITY
JANUARY 1989 - DECEMBER 1991

	BOD mg/l	DO % Sat	Chloride mg/l	Ammonia mg/l	Oxidized nitrogen mg/l	Ortho phosphate mg/l
Bedford Ouse (Brownshill)						
No. of samples	37	35	37	37	37	37
maximum	9.5	156	128	0.37	20.1	6.34
average	2.89	98.5	79.2	0.13	8.31	2.07
minimum	0.8	73.0	48.2	<0.023	3.19	0.42
Ely Ouse (Denver)						
No. of samples	169	158	203	176	174	168
maximum	8.79	222	2890	3.9	17.0	3.30
average	3.07	95.8	128	0.22	6.05	1.06
minimum	0.95	9.2	36.6	<0.023	<0.5	0.3
Middle Level Drain (St Germans ps)						
No. of samples	35	32	34	34	34	33
maximum	20.36	130.3	759	0.70	18.2	1.57
average	3.76	86.5	266	0.12	4.07	0.70
minimum	1.02	51.7	134	<0.023	<0.2	<0.06
River Nar (bypass bridge)						
No. of samples	37	37	38	38	38	37
maximum	5.76	145	54.0	0.47	8.66	0.14
average	2.50	89.6	37.8	0.10	4.89	0.05
minimum	1.45	43.0	29.5	<0.023	0.86	<0.021

TABLE 4

EFFLUENT WATER QUALITY
JANUARY 1989 - DECEMBER 1991

	BOD mg/l	Chloride mg/l	Ammonia mg/l	Oxidized nitrogen mg/l	Ortho phosphate mg/l
British Sugar					
No. of samples	51	49	50	53	19
maximum	6105	9280	83.0	4.85	3.45
average	2761	784	27.70	0.69	1.27
minimum	6.3	87.0	<0.04	0.08	0.26
Porvair					
No. of samples	31	29	31	31	12
maximum	5095	35700	10.6	11.74	1.25
average	434	5383	1.62	7.28	0.68
minimum	109	155	<0.04	1.04	0.02
Dow Chemical					
No. of samples	79	75	78	76	37
maximum	480	9172	170.2	16.15	33.4
average	161	3533	4.57	8.87	7.36
minimum	5.8	72.7	0.01	<0.5	<0.02
Watlington sewage works					
No. of samples	45	45	45	15	15*
maximum	17.38	321	4.31	33.4	7.40
average	5.86	100	1.34	28.15	6.34
minimum	<6.0	58.7	<0.2	21.9	4.91
Kings Lynn sewage works					
No. of samples	54	54	54	18	18*
maximum	>2478	1892	47.65	0.66	11.40
average	479	630	27.26	0.60	7.04
minimum	>5.8	154	0.17	<0.6	4.50

*Dissolved fraction only

TABLE 5

COMPARISON OF DISSOLVED OXYGEN MEASUREMENTS AT FREEBRIDGE

	Routine sampling	Continuous monitor
Number of samples	39*	16228
Number of days sampled	20*	169
Period of samples	6.2.89 - 3.12.91	1.10.91-31.10.91 1.3.91-9.6.92 24.6.92-31.7.92
Period average	78.2	65.7
Maximum	(109)	91.7 (116.1)**
Minimum	(51.1)	22.5 (00.0)**
Detailed comparisons		
14.5.92 0610	94.6	66.4
14.5.92 1420	98.6	74.1
3.6.92 0955	78.6	50.6
3.6.92 1815	66.0	82.7
Average	84.45	68.45

* Data in this table based on 39 individual samples analyses provided by NRA. Table 2 contains 51 samples in the period 1989-91.

** Daily average (max/min hourly value)

TABLE 6

BACTERIAL NUMBERS IN THE GREAT OUSE ESTUARY 1991

	High tide			Low tide		
	E Coli	Faecal streptococci	Total coliforms	E Coli	Faecal streptococci	Total coliforms
Cork Hole	38	25*	136	2570	864	8780
The Point	6664	1037*	29880	20140	6954	36600
Freebridge	10190	1215*	34380	10920	5492	38800
Wiggenhall St Germans	29160	3605*	48860	4404	3604	17780
Wiggenhall St Mary	31280	6533*	44660	4842	3368	16086
Stow Bridge	7544	4591*	23420	3524	2160*	12776
Downham Bridge	5770+	1850*	11592	3002	1922*	11134
Welney Bridge	1188	490*	8942	3690	2833*	11804
Mepal Bridge	454	140*	2444	348	300*	2180

Values shown are arithmetic averages of the 5 samples for each site and tide state.

* 6 samples
\+ 4 samples

Ignoring the abnormal high AMM value 1.65 gives this new column.

R02BF26M06 - R.OUSE/BROWNSHILL STAUNCH

Maximum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO	AMM
1	8.260	3.500	14.400	105.000	10.000	94.000	1257.000	1.650	16.600	1.200	1.060
2	8.200	2.600	13.400	108.000	10.500	71.000	1180.000	0.620	18.600	0.990	0.620
3	8.850	6.350	15.400	126.000	12.000	67.000	1080.000	0.420	16.800	0.940	0.420
4	8.730	9.500	13.100	119.000	14.500	93.700	980.000	0.280	17.700	0.960	0.280
5	8.900	9.600	15.400	156.000	17.000	74.550	970.000	0.270	12.800	1.370	0.270
6	8.990	9.040	14.900	155.000	22.000	79.560	878.000	0.340	10.100	1.750	0.340
7	8.600	8.500	12.800	158.000	27.000	107.000	941.000	0.180	10.800	2.590	0.180
8	8.330	3.300	9.800	100.000	21.500	87.110	999.000	0.120	7.200	2.100	0.120
9	8.280	6.000	10.400	108.000	18.500	96.470	908.000	0.580	18.500	2.290	0.580
10	8.310	4.300	11.500	114.000	18.000	96.360	1007.000	0.500	13.000	2.970	0.500
11	8.120	3.100	11.200	95.000	10.500	92.090	933.000	0.370	17.400	2.640	0.370
12	8.270	3.100	13.400	117.000	8.500	93.980	946.000	0.340	20.100	1.040	0.340

R02BF26M06 - R.OUSE/BROWNSHILL STAUNCH

Average Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO	AMM
1	8.027	2.163	12.295	96.287	4.812	66.500	976.083	0.589	12.618	0.853	0.412
2	8.040	1.533	12.033	95.200	5.714	57.867	908.250	0.290	12.273	0.613	0.290
3	8.256	3.544	11.838	101.381	7.708	55.704	934.467	0.169	11.667	0.813	0.169
4	8.284	3.972	11.869	103.400	9.571	60.678	872.429	0.143	10.974	0.793	0.143
5	8.539	5.900	13.200	129.000	13.357	59.906	853.667	0.091	9.828	1.112	0.091
6	8.346	5.543	10.717	110.900	16.475	58.166	800.188	0.087	7.081	1.201	0.087
7	8.201	3.950	8.798	98.583	19.600	67.930	854.000	0.058	6.089	1.667	0.058
8	7.928	2.400	8.300	87.900	17.167	68.852	853.600	0.051	6.016	1.538	0.051
9	8.024	2.119	8.435	88.754	16.204	71.450	834.524	0.193	7.699	1.883	0.193
10	7.919	1.717	8.879	85.756	13.361	66.151	819.214	0.133	8.043	1.844	0.133
11	7.949	1.755	10.025	85.280	8.208	70.202	847.375	0.202	9.094	1.875	0.202
12	8.006	2.124	11.224	91.986	5.958	59.726	913.400	0.219	12.785	0.855	0.219

R02BF26M06 - R.OUSE/BROWNSHILL STAUNCH

Minimum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO	AMM
1	7.800	1.400	9.700	78.000	1.000	50.000	859.000	0.129	9.090	0.460	0.129
2	7.940	0.800	10.800	85.000	0.000	46.000	650.000	0.130	9.690	0.330	0.130
3	8.060	1.700	10.400	84.000	5.500	34.000	806.000	0.025	8.500	0.300	0.025
4	7.950	1.900	9.800	91.000	5.000	42.000	805.000	0.015	8.100	0.550	0.015
5	7.990	2.300	9.300	103.000	4.000	29.000	632.000	0.005	5.937	0.900	0.005
6	7.800	2.400	7.300	77.000	13.500	36.000	726.000	0.015	4.286	0.620	0.015
7	7.770	0.500	4.900	51.000	16.500	53.000	762.000	0.005	4.440	1.190	0.005
8	7.680	1.900	7.700	78.000	14.000	57.000	756.000	0.020	3.194	0.310	0.020
9	7.670	0.900	6.500	79.000	12.000	58.000	780.000	0.015	3.877	0.870	0.015
10	7.610	1.100	7.300	65.000	10.000	41.000	670.000	0.005	3.400	0.430	0.005
11	7.800	0.500	8.700	73.000	5.000	43.000	770.000	0.115	5.800	0.490	0.115
12	7.700	1.400	9.800	80.000	4.000	46.000	816.000	0.010	7.694	0.680	0.010

Bedford Ouse
Brownshill
Table 7

R02BF51M01 - TEN MILE R./DENVER SLUICE
Maximum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	8.210	3.610	12.600	105.000	7.500	132.000	1130.000	0.870	17.600	0.600
2	8.360	3.920	12.900	102.000	9.000	93.647	1260.000	0.761	17.200	0.630
3	8.770	6.360	14.550	128.000	11.000	86.616	1074.000	0.740	13.700	0.710
4	8.820	7.330	17.400	162.000	13.000	86.000	1150.000	0.480	19.500	0.530
5	9.160	10.700	21.350	201.000	20.500	81.000	1010.000	0.460	12.300	0.770
6	9.080	9.800	19.400	222.000	24.000	99.880	890.000	0.213	9.500	1.640
7	9.120	6.200	18.700	210.000	25.000	2890.000	813.000	0.250	7.000	0.990
8	8.810	8.790	13.600	168.000	26.000	407.200	1240.000	0.309	6.400	1.430
9	8.760	8.050	18.800	189.000	22.000	754.100	8000.000	0.306	8.400	1.350
10	8.580	8.500	14.000	139.000	17.500	118.190	1420.000	0.580	13.300	1.330
11	8.270	2.800	11.600	93.000	12.000	122.000	1150.000	0.874	14.300	1.140
12	8.160	2.500	11.500	92.000	9.500	89.900	1140.000	0.950	16.400	1.140

R02BF51M01 - TEN MILE R./DENVER SLUICE
Average Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	7.924	1.957	10.836	84.275	4.658	67.357	1006.286	0.462	11.453	0.381
2	7.978	2.048	11.074	87.102	5.071	64.604	975.667	0.422	11.312	0.389
3	8.096	2.375	11.712	97.106	7.164	60.982	943.000	0.297	10.008	0.457
4	8.301	3.701	12.654	111.350	9.826	60.570	910.896	0.110	9.853	0.384
5	8.551	5.311	13.953	138.232	14.592	58.681	775.542	0.079	7.400	0.435
6	8.524	4.735	12.000	127.794	17.119	60.145	756.000	0.054	6.291	0.606
7	8.354	3.301	9.919	110.123	20.058	120.421	696.429	0.082	4.913	0.612
8	8.368	3.190	10.176	112.733	19.983	95.408	799.929	0.064	4.240	0.756
9	8.320	2.939	9.860	100.353	16.646	110.897	900.018	0.080	4.885	0.822
10	8.085	2.469	9.345	88.272	12.373	68.873	861.229	0.147	6.836	0.727
11	7.970	1.911	9.463	79.679	7.912	69.976	901.586	0.293	8.728	0.756
12	7.852	1.732	9.991	78.594	5.174	69.364	915.833	0.499	9.158	0.595

R02BF51M01 - TEN MILE R./DENVER SLUICE
Minimum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	7.740	1.300	8.800	69.000	0.000	36.600	890.000	0.230	6.410	0.160
2	7.660	1.100	8.300	72.600	0.000	49.000	834.000	0.160	7.256	0.150
3	7.860	0.700	8.500	71.900	2.600	37.000	755.000	0.012	7.660	0.230
4	7.830	1.700	9.500	82.000	7.000	47.000	749.000	0.012	6.000	0.230
5	7.820	2.400	9.200	88.000	10.000	46.000	610.000	0.012	4.444	0.260
6	7.950	1.910	7.650	72.800	13.000	49.000	670.000	0.012	3.070	0.260
7	7.530	1.600	4.000	42.000	16.000	47.000	500.000	0.015	2.055	0.250
8	8.100	1.390	6.650	73.400	16.000	50.000	662.000	0.012	0.576	0.220
9	7.620	1.250	3.700	9.200	12.000	44.000	650.000	0.012	0.250	0.310
10	7.550	0.950	5.950	64.000	5.000	39.800	710.000	0.012	3.700	0.200
11	7.630	1.000	7.300	64.000	3.000	52.000	760.000	0.120	4.740	0.210
12	7.630	0.500	7.200	57.200	1.500	52.000	760.000	0.223	6.210	0.270

Ely Ouse Denver
Table 8

R02BF56M13 - FLOOD RELIEF CHANNEL/SADDLEBOW BRIDGE

Maximum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	8.370	4.150	12.900	96.000	7.000	2055.600	1120.000	0.950	19.700	0.670
2	8.300	4.580	13.300	102.000	8.000	1411.600	1180.000	0.610	17.700	0.480
3	9.180	12.720	16.800	141.000	12.000	1462.800	931.000	0.310	12.300	0.400
4	9.080	16.060	19.400	178.000	16.000	1701.700	950.000	0.268	12.400	0.480
5	9.240	11.960	17.700	179.000	17.500	925.840	1100.000	0.250	12.300	0.470
6	9.210	8.400	20.000	203.000	26.500	1411.700	895.000	0.366	8.200	0.500
7	9.190	9.270	19.100	227.000	24.000	1402.800	845.000	0.190	6.200	0.560
8	9.010	10.900	14.100	173.000	25.500	2087.200	940.000	0.166	8.300	0.760
9	8.870	4.500	13.800	152.000	20.000	2057.000	910.000	0.160	7.500	0.880
10	8.750	6.300	12.800	127.000	16.000	2493.800	1020.000	0.230	11.900	1.220
11	8.560	4.400	12.500	111.000	11.000	2403.600	1125.000	0.390	15.400	1.480
12	8.280	4.240	11.900	103.000	10.000	2294.000	1020.000	0.490	15.200	0.710

R02BF56M13 - FLOOD RELIEF CHANNEL/SADDLEBOW BRIDGE

Average Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	7.995	2.418	10.943	85.289	4.370	320.940	1016.667	0.449	10.966	0.318
2	8.015	2.292	11.230	85.780	4.710	233.505	1035.833	0.334	11.951	0.324
3	8.201	3.557	11.936	102.561	8.528	294.463	882.800	0.174	9.362	0.278
4	8.437	5.851	13.225	120.430	11.005	256.610	846.875	0.090	8.832	0.267
5	8.547	7.451	12.745	125.245	14.318	209.185	768.000	0.054	6.915	0.234
6	8.499	4.415	11.761	130.820	18.182	226.927	723.562	0.114	5.027	0.244
7	8.417	3.759	9.581	107.556	20.719	206.256	693.562	0.087	4.212	0.365
8	8.573	4.322	10.190	111.800	19.386	443.609	759.375	0.049	3.317	0.419
9	8.380	3.052	9.844	103.925	16.333	356.917	772.722	0.079	3.960	0.550
10	8.292	2.746	9.741	93.870	12.275	600.732	783.750	0.072	4.627	0.668
11	8.165	2.408	9.771	82.503	7.735	480.386	908.071	0.141	6.908	0.800
12	7.999	2.471	10.092	81.578	6.000	327.778	931.500	0.296	9.078	0.505

R02BF56M13 - FLOOD RELIEF CHANNEL/SADDLEBOW BRIDGE

Minimum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	7.540	1.500	9.580	73.000	1.000	52.000	976.000	0.061	2.975	0.140
2	7.770	0.500	8.400	70.000	1.000	58.000	870.000	0.106	7.455	0.170
3	7.760	0.900	7.300	62.000	6.000	56.000	829.000	0.012	2.971	0.090
4	8.130	1.800	10.000	86.000	8.500	54.000	769.000	0.015	4.641	0.050
5	7.950	2.500	9.100	87.000	10.500	28.000	528.000	0.012	2.383	0.010
6	7.860	2.000	6.650	84.000	15.000	34.000	560.000	0.010	2.100	0.010
7	8.090	1.200	7.000	76.000	18.000	51.000	605.000	0.015	0.807	0.090
8	8.190	1.100	7.900	83.000	15.000	48.000	610.000	0.015	0.100	0.010
9	7.940	1.600	6.700	65.200	12.000	46.000	692.000	0.010	0.250	0.250
10	8.050	0.550	6.700	68.000	9.000	56.000	650.000	0.010	0.250	0.010
11	7.760	0.700	6.100	49.000	4.000	54.000	770.000	0.010	0.250	0.230
12	7.690	1.700	8.700	63.000	2.000	53.000	852.000	0.010	0.250	0.300

Flood Relief Channel
Saddlebow Bridge
Table 9

R02BF53M15 - MIDDLE LEVEL MD/WIGGENHALL ST GERMAN PS
Maximum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	8.300	2.100	11.500	90.000	7.000	238.500	2430.000	0.696	14.400	-999.999
2	8.170	3.850	12.300	99.100	7.000	208.000	2400.000	1.110	18.200	-999.999
3	8.510	6.900	13.350	109.000	9.500	285.000	2180.000	1.010	11.400	-999.999
4	8.740	8.180	14.400	123.000	11.500	349.000	2228.000	0.820	16.100	-999.999
5	8.700	4.020	12.200	110.000	19.000	344.040	2460.000	0.070	9.500	-999.999
6	8.720	20.360	13.700	130.300	17.500	421.000	2170.000	0.238	12.600	-999.999
7	8.980	10.300	14.400	169.000	25.500	547.000	2110.000	0.292	3.900	-999.999
8	8.690	8.150	8.100	85.000	19.000	596.690	2200.000	0.270	6.600	-999.999
9	8.310	7.160	9.300	86.400	14.000	759.000	-999.999	0.058	2.420	-999.999
10	8.450	8.000	10.200	99.000	16.000	544.500	2010.000	1.000	12.100	-999.999
11	8.160	3.920	10.850	90.000	10.000	233.200	2190.000	0.730	6.000	-999.999
12	8.280	2.350	8.700	69.200	5.500	191.000	2340.000	0.610	9.900	-999.999

R02BF53M15 - MIDDLE LEVEL MD/WIGGENHALL ST GERMAN PS
Average Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	8.200	1.450	10.080	81.160	6.100	186.980	2430.000	0.300	8.780	-999.999
2	7.987	2.262	10.675	84.550	5.383	169.378	2236.667	0.517	12.613	-999.999
3	8.226	3.168	11.470	94.280	6.800	206.719	2180.000	0.244	8.108	-999.999
4	8.420	5.220	11.308	97.333	8.667	199.227	1964.000	0.234	9.208	-999.999
5	8.453	3.117	9.967	97.600	15.283	280.573	2160.000	0.038	4.669	-999.999
6	8.370	7.788	9.850	99.000	15.700	250.332	1861.333	0.102	6.067	-999.999
7	8.323	6.419	10.507	120.371	20.214	332.234	1805.000	0.111	1.265	-999.999
8	8.243	4.293	7.217	76.900	18.300	324.130	1863.000	0.096	1.886	-999.999
9	8.100	4.505	8.600	81.600	13.000	451.500	-999.999	0.051	1.335	-999.999
10	8.102	2.637	8.648	81.095	12.345	191.115	1513.250	0.175	3.715	-999.999
11	7.954	2.422	8.210	67.000	6.900	176.710	1835.000	0.270	4.429	-999.999
12	8.015	2.075	8.250	65.100	5.250	177.800	2340.000	0.354	5.475	-999.999

R02BF53M15 - MIDDLE LEVEL MD/WIGGENHALL ST GERMAN PS
Minimum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	8.110	1.020	9.300	76.700	5.000	140.400	2430.000	0.032	2.933	-999.999
2	7.790	1.400	9.700	78.000	3.000	138.370	2140.000	0.012	4.176	-999.999
3	7.850	2.060	9.700	80.000	5.000	156.100	2180.000	0.012	5.248	-999.999
4	7.960	2.800	9.000	73.000	6.000	143.000	1700.000	0.012	4.377	-999.999
5	8.150	2.300	7.500	81.100	10.500	212.000	1930.000	0.012	2.440	-999.999
6	7.930	1.290	7.450	72.700	13.000	107.000	1674.000	0.015	2.135	-999.999
7	7.960	2.500	5.900	82.000	17.000	191.950	1490.000	0.025	0.050	-999.999
8	7.920	2.200	4.900	53.000	17.500	129.000	1520.000	0.040	0.100	-999.999
9	7.890	1.850	7.900	76.800	12.000	144.000	-999.999	0.044	0.250	-999.999
10	7.630	1.000	7.200	65.000	8.800	119.000	1180.000	0.012	0.601	-999.999
11	7.460	1.400	5.600	50.000	3.000	135.000	1480.000	0.100	2.473	-999.999
12	7.750	1.800	7.800	61.000	5.000	164.600	2340.000	0.097	1.051	-999.999

Middle Level Drain
St Germans
Table 10

R02BF58M11 - R.NAR/BY-PASS BRIDGE KINGS LYNN

Maximum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	8.230	3.150	14.500	105.000	6.000	62.687	792.000	0.486	11.800	0.105
2	8.330	2.020	15.550	121.000	9.000	44.918	755.000	0.280	10.200	0.090
3	8.450	5.760	15.100	134.000	11.000	58.000	714.000	0.162	10.000	0.070
4	8.570	6.000	18.200	173.000	14.000	49.000	730.000	0.150	9.500	0.060
5	8.560	5.140	14.000	141.000	20.000	93.000	950.000	0.690	8.200	0.060
6	8.590	4.000	23.200	258.000	27.000	40.200	614.000	0.120	6.600	0.120
7	8.370	3.700	13.400	147.700	21.000	39.000	950.000	0.400	6.100	0.060
8	8.630	4.000	13.000	145.000	25.500	94.000	606.000	0.052	5.500	0.040
9	8.520	4.400	15.200	145.000	20.000	80.000	762.000	0.190	6.200	1.050
10	8.500	5.360	12.500	120.000	16.500	49.230	697.000	0.180	8.400	0.360
11	8.190	2.250	12.100	101.000	11.000	68.000	719.000	0.250	10.500	0.130
12	8.170	3.200	12.500	97.000	11.000	55.000	810.000	0.450	9.400	0.120

R02BF58M11 - R.NAR/BY-PASS BRIDGE KINGS LYNN

Average Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	8.006	1.978	11.459	86.479	4.157	43.990	681.000	0.238	8.224	0.074
2	8.081	1.564	12.382	97.271	5.250	38.263	685.500	0.119	8.420	0.066
3	8.193	2.561	12.533	106.667	8.222	39.618	632.400	0.061	7.665	0.032
4	8.227	2.639	12.487	112.500	10.259	36.736	592.625	0.044	7.029	0.031
5	8.193	2.668	11.175	111.300	15.100	41.701	634.250	0.139	5.752	0.026
6	8.354	1.921	12.094	129.086	18.479	33.953	564.188	0.040	5.013	0.061
7	8.139	2.137	10.494	114.522	19.278	32.979	599.429	0.083	4.571	0.050
8	8.261	2.136	10.780	114.780	18.150	38.146	539.688	0.024	4.097	0.023
9	8.162	2.183	11.135	110.806	15.389	39.965	585.278	0.049	4.066	0.224
10	8.117	2.323	9.752	89.061	11.311	37.270	592.250	0.062	5.519	0.094
11	8.053	1.623	10.501	86.398	6.950	38.081	647.889	0.110	6.845	0.084
12	8.002	1.785	10.670	85.400	6.300	40.132	724.250	0.214	7.129	0.064

R02BF58M11 - R.NAR/BY-PASS BRIDGE KINGS LYNN

Minimum Value:

MO	PH	BOD	DO	DO(%SAL)	TEMP	CHLOR	CONDUCT	AMM	TON	ORTHO
1	7.820	1.450	7.500	58.800	2.000	32.000	648.000	0.060	7.167	0.050
2	7.760	0.800	10.100	84.000	3.000	34.000	625.000	0.015	6.880	0.030
3	7.910	0.800	10.000	86.000	6.000	32.000	572.000	0.012	5.305	0.010
4	7.890	1.300	9.300	75.000	6.000	29.000	535.000	0.012	4.827	0.010
5	8.080	2.200	9.250	88.000	12.000	30.000	535.000	0.012	4.065	0.010
6	7.970	0.700	4.450	43.000	13.500	28.000	515.000	0.012	0.863	0.010
7	7.390	1.100	6.700	71.000	18.000	28.000	491.000	0.012	1.346	0.020
8	7.980	1.000	7.500	75.000	14.000	28.000	492.000	0.012	1.094	0.010
9	7.790	1.000	6.000	64.000	9.000	31.000	510.000	0.010	0.874	0.010
10	7.860	1.100	7.100	67.800	7.000	29.000	520.000	0.012	3.711	0.020
11	7.840	1.000	7.150	66.000	4.800	26.000	672.000	0.025	5.400	0.040
12	7.720	1.100	6.600	51.700	0.600	31.000	614.000	0.050	4.861	0.010

River Nar
Kings Lynn Bypass
Table 11

TABLE 12

SEAWATER QUALITY AND WATER TEMPERATURE USED FOR WATER QUALITY MODELLING

	Month			
	January	April	July	October
Water temperature (°C)	4.2	9.8	19.2	11.8
Sea water quality				
BOD (mg/l)	2.2	2.2	2.2	2.2
ammonia (mg/l)	0.13	0.05	0.06	0.14
oxidized nitrogen (mg/l)	0.50	0.50	0.50	0.50
dissolved ozygen (% sat)	91	91	85	86

TABLE 13

HYDROLOGICAL CONDITIONS USED FOR WATER QUALITY MODELLING

	Month			
	January	April	July	October
Drought conditions (year)	**1991**	**1973**	**1990**	**1989**
Ely Ouse-Denver Sluice	6.33	7.50	0.6	1.43
Ely Ouse-Tail Sluice	2.00	0.0	0.7	2.25
Bedford Ouse	9.1	3.8	2.3	2.5
Middle Level	1.0	0.6	0.0	1.3
River Nar	0.6	0.8	0.3	0.4
Dry conditions (year)	**1992**	**1990**	**1989**	**1985**
Ely Ouse-Denver Sluice	13.24	10.82	2.30	0.62
Ely Ouse-Tail Sluice	0.24	0.14	1.75	4.48
Bedford Ouse	19.2	6.3	3.4	4.0
Middle Level	1.4	0.0	0.2	1.0
River Nar	0.5	0.9	0.5	0.7
Average conditions				
Ely Ouse-Denver Sluice	10.9	11.2	5.1	6.2
Ely Ouse-Tail Sluice	16.5	8.9	2.0	4.3
Bedford Ouse	25.5	17.6	4.1	7.9
Middle Level	5.9	3.3	0.9	2.0
River Nar	1.5	1.5	0.8	0.8

TABLE 14

EFFLUENT FLOWS

Source	Flow Mld
Kings Lynn STW	53.1 (26.0)+
Watlington STW	0.75
British Sugar	3.0*
Dow Chemical	2.0
Porvair	0.4

* Discharge limited to September to February
+ Sensitivity test

TABLE 15

EFFECT OF ELY OUSE FLOW ON GREAT OUSE ESTUARY WATER QUALITY

Ely Ouse flow tcmd	Month	Model test	Minimum DO % sat	Maximum ammonia mg/l
318*	January	9	70.31	0.52
112	January	10	68.05	0.53
50	January	13	67.30	0.54
0	January	17	66.65	0.54
112*	April	11	70.07	0.46
50	April	14	69.37	0.48
0	April	18	68.83	0.50
112*	July	3	52.58	0.63
50	July	15	52.02	0.66
0	July	19	51.44	0.69
318*	October	4	53.68	0.45
112	October	12	51.18	0.51
50	October	16	49.91	0.54
0	October	20	48.50	0.56

All runs assume 'drought' flows given in Table 12 and the effluent flows given in Table 13.
*Current Denver minimum residual flow

TABLE 16

EFFECT OF CHANGES IN DENVER MRF ON PREDICTED ESTUARY WATER QUALITY

	Predicted change as % of current MRF predicted water quality			
Proposed MRF at Denver	January	April	July	October
112 tcmd (constant) dissolved oxygen ammonia	 -3.21 +1.9	 0 0	 0 0	 -4.66 +13.3
50 tcmd (constant) dissolved oxygen ammonia	 -4.28 +3.8	 -1.00 +4.3	 -1.07 +4.8	 -7.02 +20.0
0 tcmd (constant) dissolved oxygen ammonia	 -5.21 +3.8	 -1.77 +8.7	 -2.17 +9.5	 -9.65 +24.4

TABLE 17

SENSITIVITY OF ESTUARY WATER QUALITY TO ELY OUSE DISCHARGE LOCATION

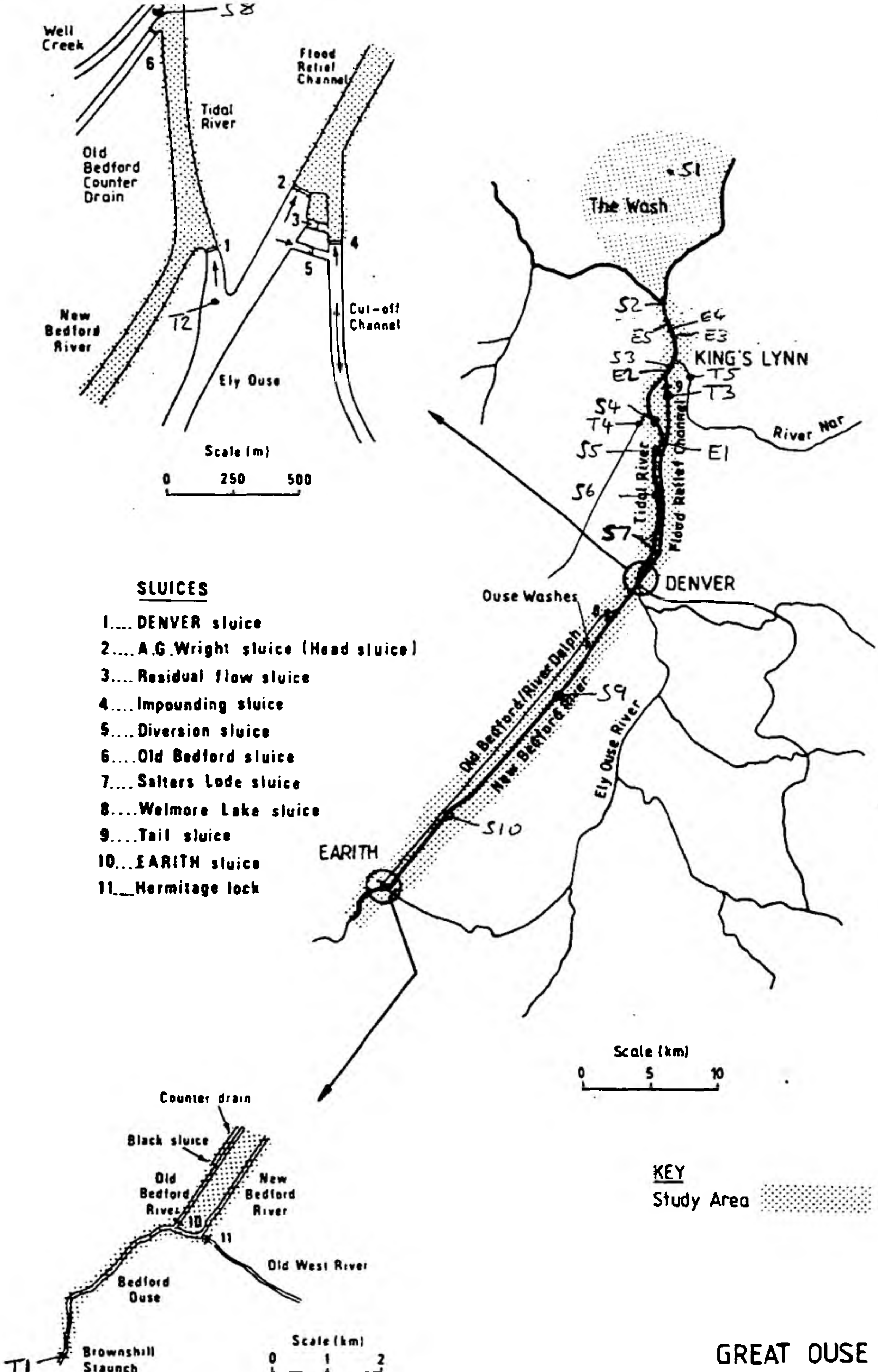
Model test	Ely Ouse discharge site	Month	Ely Ouse flow tcmd	Minimum DO % sat	Maximum ammonia mg/l
11 25	Tail Sluice Denver Sluice	April April	112 112	70.1 69.9	0.46 0.46
15 26	Tail Sluice Denver Sluice	July July	50 50	52.0 51.9	0.66 0.66
12 27	Tail Sluice Denver Sluice	October October	112 112	51.2 50.7	0.51 0.51

All tests for 'drought' flows in other tributaries

TABLE 18

EFFECT OF BALANCE BETWEEN BEDFORD OUSE AND ELY OUSE FLOWS ON ESTUARY WATER QUALITY

Run	Month	Total freshwater flow m^3/s	Ely Ouse proportion %	Minimum DO % sat	Maximum ammonia mg/l
2 6	April April	19.67 18.80	38.1 58.3	74.2 75.8	0.39 0.30
8 24	October October	11.47 10.05	44.5 36.6	53.6 54.8	0.43 0.42



GREAT OUSE ESTUARY
STUDY LIMITS
Figure 1

BINNIE & PARTNERS
CONSULTING ENGINEERS

Job number 4134	
Calc. sheet no. / /	Rev.
Job name Denver MRF	Drawings nos.
Structure Estuary Water Quality	Calculations by DCE Date 1/2/93
	Checked by Date / /
Section DO % sat	Reviewed by Date / /

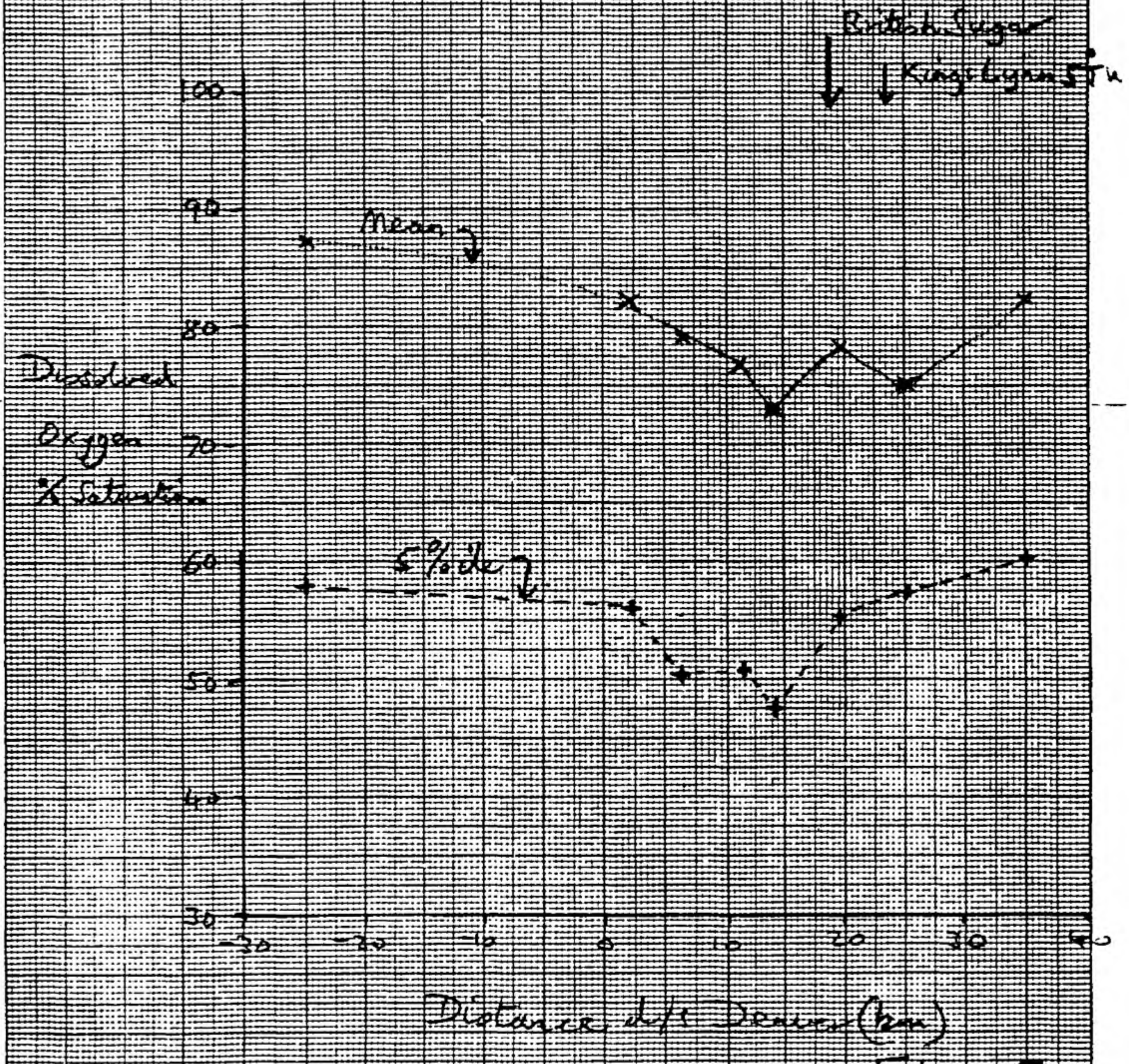


Figure 2

Form 215A

BINNIE & PARTNERS
CONSULTING ENGINEERS

Job number 4134	
Calc. sheet no. / / Rev.	
Job name Denver MRF	Drawings nos.
Structure Estuary Water Quality	Calculations by DCK Date 4 / 2 / 93
	Checked by Date / /
Section BOD	Reviewed by Date / /

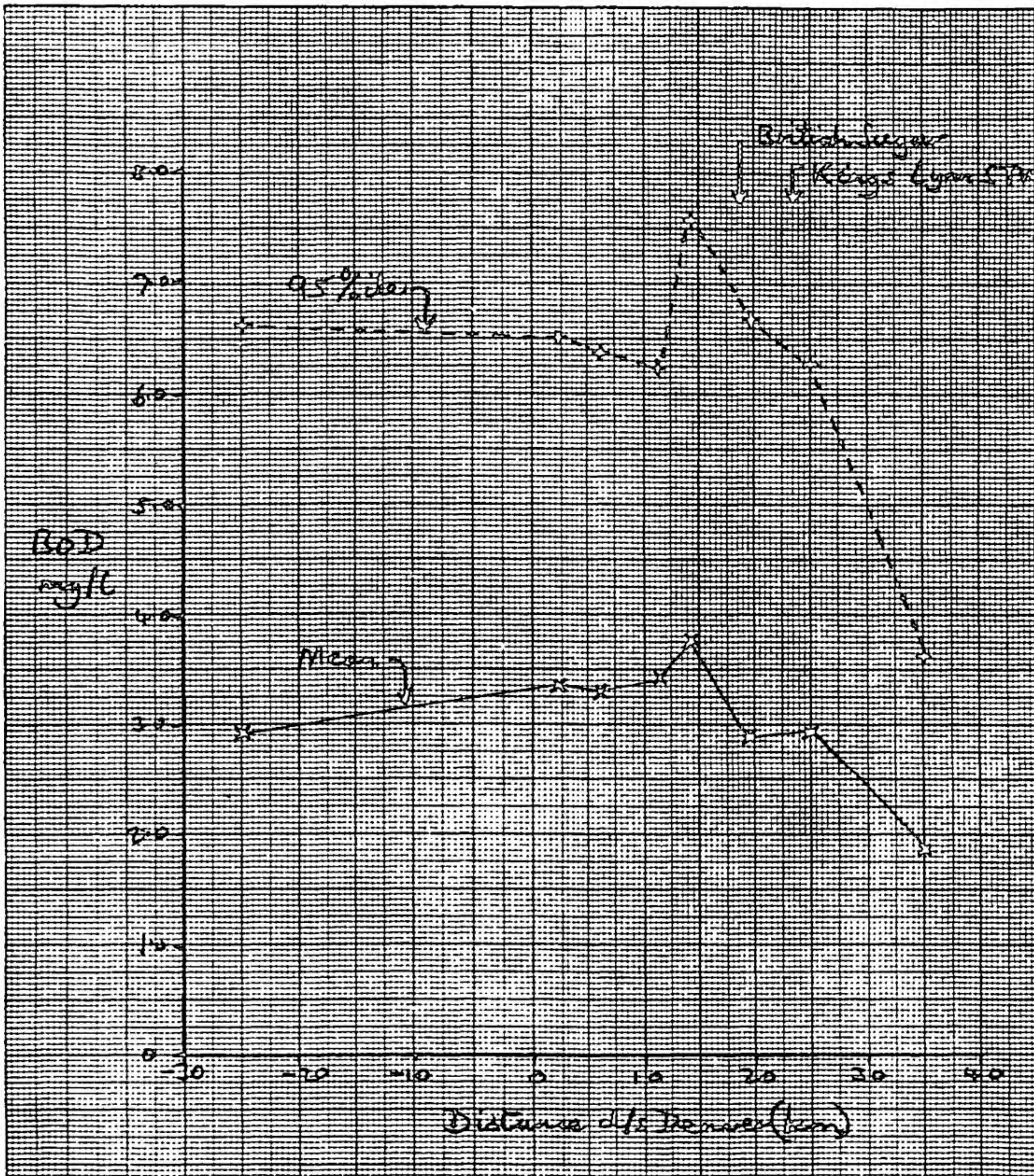


Figure 3

Form 215A

BINNIE & PARTNERS
CONSULTING ENGINEERS

	Job number 4134
	Calc. sheet no. / / Rev.
Job name Denver MRF	Drawings nos.
Structure Estuary Water Quality	Calculations by DCE Date 4/2/93
	Checked by Date / /
Section Ammonia	Reviewed by Date / /

Form 215A

Figure 4

BINNIE & PARTNERS
CONSULTING ENGINEERS

Job number	4134
Calc. sheet no. / /	Rev.
Job name: Denver MRF	Drawings nos.
Structure: Estuary Water Quality	Calculations by DCK Date 4/2/92
	Checked by Date / /
Section: Nutrient Concentrations	Reviewed by Date / /

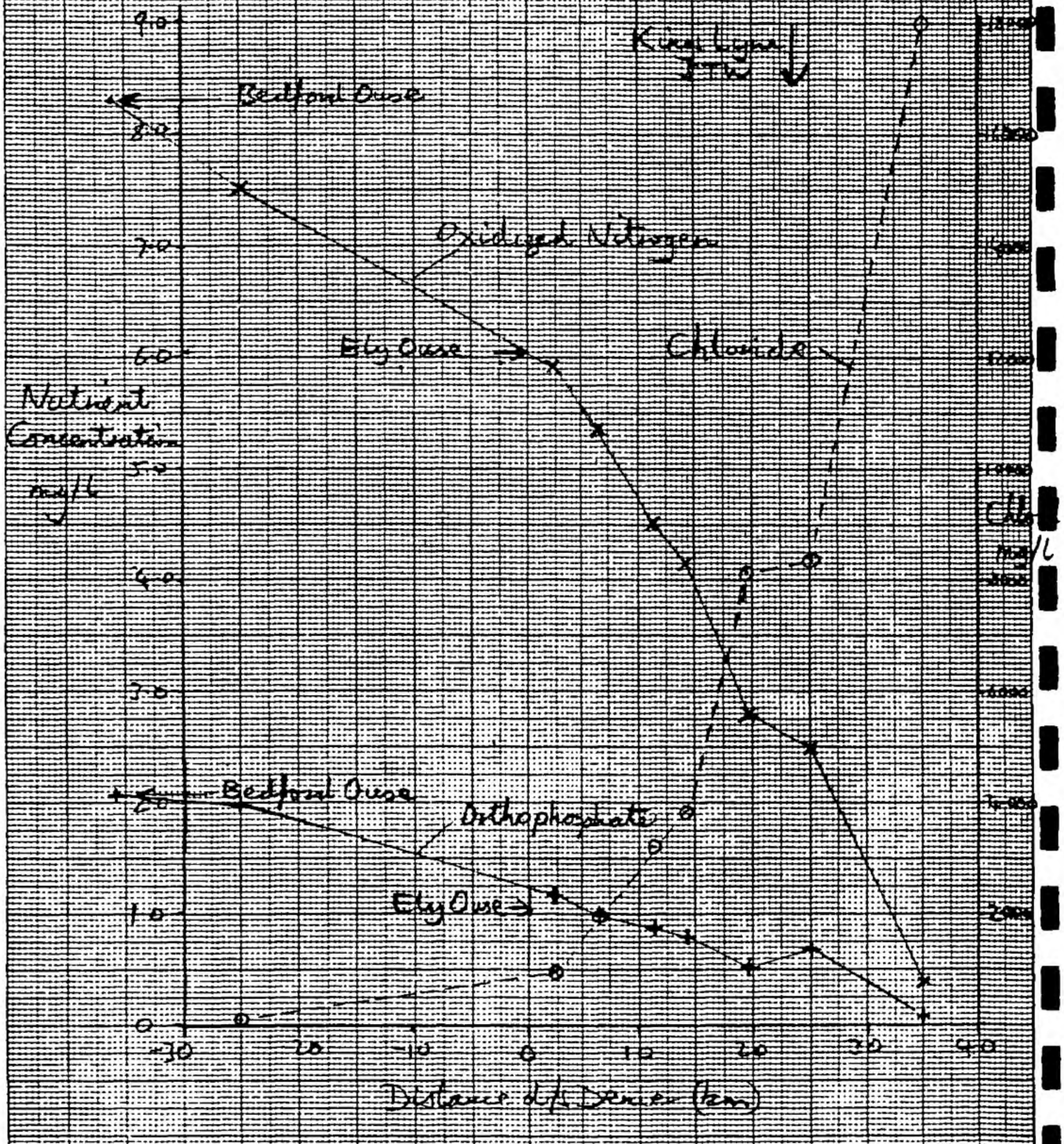


Figure 5

Form 215A

BINNIE & PARTNERS
CONSULTING ENGINEERS

Job name	Drover MRF	Job number	4136
		Calc. sheet no. / /	Rev.
		Drawings nos.	
Structure	Estuary Water Quality	Calculations by DCK	Date 5/2/93
		Checked by	Date / /
Section	E Coli Numbers	Reviewed by	Date / /

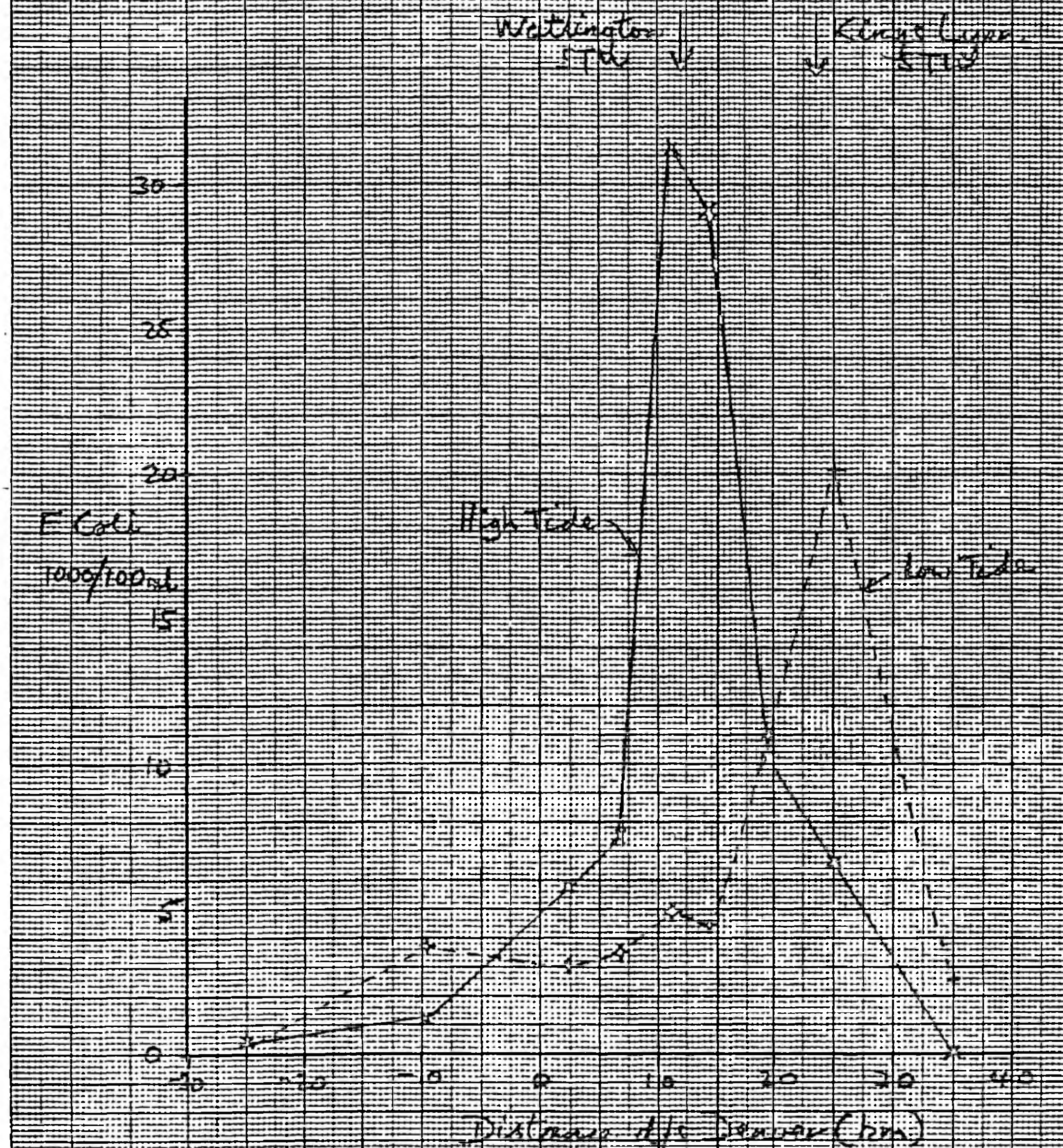
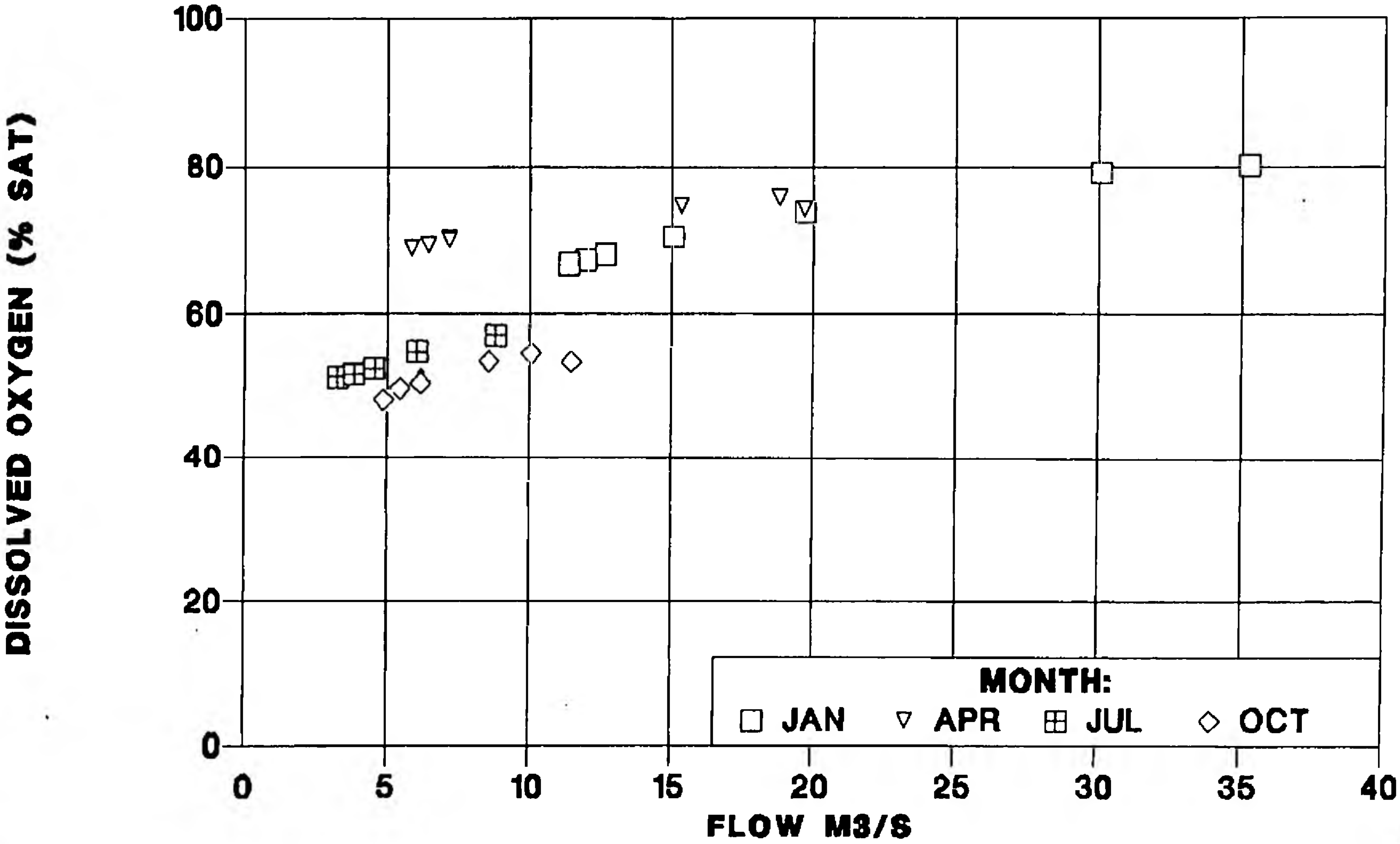


Figure 6

Form 215A

MINIMUM DISSOLVED OXYGEN (% SAT)

BASED ON NRA WATER QUALITY MODEL



LAH 27.01.93

Great Ouse Estuary
Water Quality Model
Predictions of DO
Figure 7

TABLE A1

Binnie & Partners
DHILL
urrey

AVERAGE DAILY DISSOLVED OXYGEN (%)

DOFREE
06-Jan 1992

Station no. -
River - TIDAL RIVER - OUSE
Station Name - FREEBRIDGE

Level - m
Station type -
Grid ref. -
Authority - NRA ANGLIAN

YEAR 1991 - 1992

Date	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Date
1			72.7					67.7	60.5	72.5	55.5	58.3	1
2			70.3					67.3	61.5	69.9	57.8	60.2	2
3			72.2					68.8	68.7	72.2	58.3	50.6	3
4			62.7					70.8	69.3	76.5	59.0	48.0	4
5			58.4					69.4	69.5	78.3	67.4	59.8	5
6			55.5					70.7	69.3	77.9	71.3	63.6	6
7			56.1					70.4	69.3	84.4	65.9	56.7	7
8			57.0					70.0	71.9	82.7	60.5	43.6	8
9			54.1					67.9	75.4	75.1	56.9	40.3	9
10			51.7					68.1	77.5	73.1		35.6	10
11			52.2					64.1	80.9	75.9		45.5	11
12			45.6					67.1	82.2	79.7		41.9	12
13			33.9					66.6	78.3	84.7		43.8	13
14			22.5					62.3	74.6	91.7		42.9	14
15			32.5					61.5	72.2	86.8		44.0	15
16			67.9					62.6	68.2	83.6		44.7	16
17			73.7					65.3	69.9	81.2		45.7	17
18			65.6					68.2	73.6	80.3		50.4	18
19			64.6					63.7	77.2	86.4		64.5	19
20			62.1					57.7	78.5	88.4		64.8	20
21			60.4					56.8	77.1	86.7		51.3	21
22			60.0					56.3	77.1	86.3		62.8	22
23			59.8					55.3	80.7	86.0		57.9	23
24			60.6					54.8	84.2	85.7	61.4	55.8	24
25			62.6					54.5	83.3	87.4	61.3	60.5	25
26			59.7					53.9	84.6	91.1	64.6	71.8	26
27			55.0					51.3	80.1	79.2	67.3	71.6	27
28			56.5					56.6	74.8	73.7	70.5	69.1	28
29			60.2					60.0	74.4	69.5	66.2	71.1	29
30			59.9					59.2	73.7	62.8	59.4	74.2	30
31			65.0					59.5		62.9		69.2	31

onthly values (%)

	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	
n	0	0	31	0	0	0	0	31	30	31	16	31	n
tal	0.0	0.0	1791.0	0.0	0.0	0	0.0	1948.6	2238.7	2472.6	1003.3	1720.2	Total
ean	-	-	57.77	-	-	-	-	62.86	74.62	79.76	62.71	55.49	Mean
x.	-	-	73.70	-	-	-	-	70.80	84.59	91.74	71.30	74.20	Max.
n.	-	-	22.50	-	-	-	-	51.33	60.55	62.82	55.53	35.63	Min.

nual values
n 65.7 (%) Max.- (91.7)(%) ; Min.- 22.5 (%)

TABLE A2

Binnie & Partners
DHILL
rrey

DISSOLVED OXYGEN MEASUREMENTS LESS THAN 50% (Hours)

DOFREE
06-Jan 1992

Station no. -
River - TIDAL RIVER - OUSE
Station Name - FREEBRIDGE

Level - m
Station type -
Grid ref. -
Authority - NRA ANGLIAN

YEAR 1991 - 1992

Date	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Date
1			0.0					0.00	0.00	0.00	10.25	7.50	1
2			0.0					0.00	0.00	0.00	8.00	1.75	2
3			0.0					0.00	0.00	0.00	11.00	11.00	3
4			0.0					0.00	0.00	0.00	8.00	14.00	4
5			1.3					0.00	0.00	0.00	0.25	2.00	5
6			3.3					0.00	0.00	0.00	0.50	0.50	6
7			5.0					0.00	0.00	0.00	3.25	2.75	7
8			4.3					0.00	0.00	0.00	2.75	21.50	8
9			10.5					0.00	0.00	0.00		22.50	9
10			11.8					0.00	0.00	0.00		24.00	10
11			12.0					0.00	0.00	0.00		18.75	11
12			16.0					0.00	0.00	0.00		20.50	12
13			23.3					0.00	0.00	0.00		18.75	13
14			24.0					0.25	0.00	0.00		19.75	14
15			19.5					0.00	0.00	0.00		19.50	15
16			4.5					0.00	0.00	0.00		17.50	16
17			0.0					0.00	0.00	0.00		16.75	17
18			0.0					0.00	0.00	0.00		14.25	18
19			0.0					0.00	0.00	0.00		8.00	19
20			0.0					0.00	0.00	0.00		11.50	20
21			0.0					0.00	0.00	0.00		16.75	21
22			2.8					0.00	0.00	0.00		13.00	22
23			5.0					0.00	0.00	0.00		9.50	23
24			6.3					0.00	0.00	0.00		7.75	24
25			4.5					0.00	0.00	0.00	2.50	6.00	25
26			5.5					0.00	0.00	0.00	2.25	1.25	26
27			11.3					6.75	0.00	1.50	0.50	1.00	27
28			7.5					0.00	0.00	0.00	0.75	1.00	28
29			3.3					0.00	0.00	0.50	1.75	4.25	29
30			1.3					0.75	0.00	3.50	5.50	6.00	30
31			3.0					0.00		1.25		8.25	31
Monthly values (HRS)													
n	0	0	31	0	0	0	0	31	30	31	14	31	n
otal	0.0	0.0	186.0	0.0	0.0	0	0.0	7.8	0.0	6.8	57.3	347.5	Total
Mean	-	-	6.00	-	-	-	-	0.25	0.00	0.22	4.09	11.21	Mean
Max.	-	-	24.00	-	-	-	-	6.75	0.00	3.50	11.00	24.00	Max.
in.	-	-	0.00	-	-	-	-	0.00	0.00	0.00	0.25	0.50	Min.

Annual values
ean 3.6 (HRS) Max.- (24.0)(HRS) ; Min.- 0.0 (HRS)

TABLE A3

Binnie & Partners
REDHILL
Surrey

DISSOLVED OXYGEN MEASUREMENTS LESS THAN 45% (Hours)

DOFREE
05-Feb 1992

Station no. -
River - TIDAL RIVER - OUSE
Station Name - FREEBRIDGE

Level - m
Station type -
Grid ref. -
Authority - NRA ANGLIAN

YEAR 1991 - 1992

Date	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Date
1			0.0					0.00	0.00	0.00	4.00	4.00	1
2			0.0					0.00	0.00	0.00	4.00	0.75	2
3			0.0					0.00	0.00	0.00	4.25	6.75	3
4			0.0					0.00	0.00	0.00	5.25	10.50	4
5			0.0					0.00	0.00	0.00	0.25	0.25	5
6			0.0					0.00	0.00	0.00	0.25	0.25	6
7			0.0					0.00	0.00	0.00	2.50	1.00	7
8			0.0					0.00	0.00	0.00	1.25	14.00	8
9			2.5					0.00	0.00	0.00		18.75	9
10			7.8					0.00	0.00	0.00		23.00	10
11			7.8					0.00	0.00	0.00		16.75	11
12			11.8					0.00	0.00	0.00		16.25	12
13			20.8					0.00	0.00	0.00		14.75	13
14			23.8					0.00	0.00	0.00		16.00	14
15			18.8					0.00	0.00	0.00		17.25	15
16			4.3					0.00	0.00	0.00		12.75	16
17			0.0					0.00	0.00	0.00		14.00	17
18			0.0					0.00	0.00	0.00		8.25	18
19			0.0					0.00	0.00	0.00		3.75	19
20			0.0					0.00	0.00	0.00		5.50	20
21			0.0					0.00	0.00	0.00		11.75	21
22			0.0					0.00	0.00	0.00		8.00	22
23			0.8					0.00	0.00	0.00		6.00	23
24			1.8					0.00	0.00	0.00		4.25	24
25			1.0					0.00	0.00	0.00	0.50	3.00	25
26			3.0					0.00	0.00	0.00	0.25	1.00	26
27			5.5					1.50	0.00	1.50	0.00	0.25	27
28			5.5					0.00	0.00	0.00	0.25	1.00	28
29			0.0					0.00	0.00	0.25	0.75	3.25	29
30			0.8					0.00	0.00	2.50	1.25	4.50	30
31			1.8					0.00		1.25		7.50	31

Monthly values (HRS)

	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	
n	0	0	31	0	0	0	0	31	30	31	14	31	n
Total	0.0	0.0	117.3	0.0	0.0	0	0.0	1.5	0.0	5.5	24.8	255.0	Total
Mean	-	-	3.78	-	-	-	-	0.05	0.00	0.18	1.77	8.23	Mean
Max.	-	-	23.75	-	-	-	-	1.50	0.00	2.50	5.25	23.00	Max.
Min.	-	-	0.00	-	-	-	-	0.00	0.00	0.00	0.00	0.25	Min.

Annual values
Mean 2.40 (HRS) Max.- (23.8)(HRS) ; Min.- 0.0 (HRS)

TABLE A4

Binnie & Partners
P[illegible]DHILL
S[illegible]rrey

DISSOLVED OXYGEN MEASUREMENTS LESS THAN 30% (Hours)

DOFREE
06-Jan 1992

Station no. -
River - TIDAL RIVER - OUSE
Station Name - FREEBRIDGE

Level - m
Station type -
Grid ref. -
Authority - NRA ANGLIAN

YEAR 1991 - 1992

Date	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Date
1			0.0					0.00	0.00	0.00	0.00	0.00	1
2			0.0					0.00	0.00	0.00	0.00	0.00	2
3			0.0					0.00	0.00	0.00	0.00	0.00	3
4			0.0					0.00	0.00	0.00	0.00	0.25	4
5			0.0					0.00	0.00	0.00	0.00	0.00	5
6			0.0					0.00	0.00	0.00	0.00	0.00	6
7			0.0					0.00	0.00	0.00	0.00	0.00	7
8			0.0					0.00	0.00	0.00	0.00	0.25	8
9			0.0					0.00	0.00	0.00		0.75	9
10			0.0					0.00	0.00	0.00		2.75	10
11			0.0					0.00	0.00	0.00		6.50	11
12			1.0					0.00	0.00	0.00		2.00	12
13			9.8					0.00	0.00	0.00		0.75	13
14			20.0					0.00	0.00	0.00		0.75	14
15			13.3					0.00	0.00	0.00		0.50	15
16			2.3					0.00	0.00	0.00		0.25	16
17			0.0					0.00	0.00	0.00		1.25	17
18			0.0					0.00	0.00	0.00		0.25	18
19			0.0					0.00	0.00	0.00		0.00	19
20			0.0					0.00	0.00	0.00		0.00	20
21			0.0					0.00	0.00	0.00		1.00	21
22			0.0					0.00	0.00	0.00		0.00	22
23			0.0					0.00	0.00	0.00		1.50	23
24			0.0					0.00	0.00	0.00		0.75	24
25			0.0					0.00	0.00	0.00	0.00	0.50	25
26			0.0					0.00	0.00	0.00	0.00	0.00	26
27			0.0					0.00	0.00	1.50	0.00	0.00	27
28			0.0					0.00	0.00	0.00	0.00	0.00	28
29			0.0					0.00	0.00	0.00	0.00	2.25	29
30			0.0					0.00	0.00	0.00	0.75	0.50	30
31			0.0					0.00		0.00		2.50	31
Monthly values (HRS)													
n	0	0	31	0	0	0	0	31	30	31	14	31	n
Total	0.0	0.0	46.4	0.0	0.0	0	0.0	0.0	0.0	1.5	0.8	25.3	Total
Mean	-	-	1.50	-	-	-	-	0.00	0.00	0.05	0.05	0.81	Mean
Max.	-	-	20.00	-	-	-	-	0.00	0.00	1.50	0.75	6.50	Max.
Min.	-	-	0.00	-	-	-	-	0.00	0.00	0.00	0.00	0.00	Min.

Annual values
Mean 0.4 (HRS) Max.- (20.0)(HRS) ; Min.- 0.0 (HRS)

TABLE B1

GREAT OUSE ESTUARY WATER QUALITY MODEL
TEST CONDITIONS

				Ely Ouse flow m^3/s	
Test No	Type	Month	Tributaries	Denver Sluice	Tail Sluice
1	Natural flow	January	Drought	6.33	2.00
2	"	April	Drought	7.50	00.0
3	"	July	Drought	0.60	0.70
4	"	October	Drought	1.43	2.25
5	"	January	Dry	13.24	0.24
6	"	April	Dry	10.82	0.14
7	"	July	Dry	2.30	1.75
8	"	October	Dry	0.62	4.48
9	mrf 318 tcmd	January	Drought	1.68	2.00
10	mrf 112 tcmd	January	Drought	0	1.30
11	"	April	Drought	0	1.30
12	"	October	Drought	0	1.30
13	mrf 50 tcmd	January	Drought	0	0.58
14	"	April	Drought	0	0.58
15	"	July	Drought	0	0.58
16	"	October	Drought	0	0.58
17	mrf 0 tcmd	January	Drought	0	0
18	"	April	Drought	0	0
19	"	July	Drought	0	0
20	"	October	Drought	0	0
21	Offord sensitivity	January	Dry	6.33	2.00
22	"	April	Dry	7.50	0.00
23	"	July	Dry	0.60	0.70
24	"	October	Dry	1.43	2.25
25	Discharge sensitivity	April	Drought	1.30	0
26	"	July	Drought	0.58	0
27	"	October	Drought	1.30	0
28	Natural	January	Average	10.9	16.5
29	"	April	Average	11.2	8.9
30	"	July	Average	5.1	2.0
31	"	October	Average	6.2	4.3
32	Kings Lynn stw sen.	January	Drought	0	1.30
33	"	April	Drought	0	1.30
34	"	July	Drought	0.60	0.70
35	"	October	Drought	0	1.30

Tributary flows are based on the river flows in Table 13. Ely Ouse flows use historic division between Denver Sluice and Tail Sluice. Kirtling Green flows have been added to Denver Sluice.

TABLE B2

GREAT OUSE ESTUARY WATER QUALITY MODEL
TEST RESULTS

Test No	Minimum DO (% sat)	Maximum BOD (mg/l)	Maximum Ammonia (mg/l)
1	73.87	5.54	0.51
2	74.18	4.84	0.39
3	52.58	3.40	0.63
4	53.68	5.20	0.45
5	80.20	4.73	0.48
6	75.81	4.83	0.30
7	57.20	3.67	0.48
8	53.61	5.25	0.43
9	70.31	5.84	0.52
10	68.05	6.03	0.53
11	70.07	4.65	0.46
12	51.18	5.36	0.51
13	67.30	6.09	0.54
14	69.37	4.49	0.48
15	52.02	3.31	0.66
16	49.91	5.36	0.54
17	66.65	6.13	0.54
18	68.83	4.35	0.50
19	51.44	3.15	0.69
20	48.50	5.35	0.56
21	79.16	4.96	0.47
22	74.72	4.79	0.35
23	54.87	3.51	0.55
24	54.77	5.15	0.42
25	69.94	4.44	0.46
26	51.87	3.30	0.66
27	50.72	5.34	0.51

MANAGEMENT AND CONTACTS:

The Environment Agency delivers a service to its customers, with the emphasis on authority and accountability at the most local level possible. It aims to be cost-effective and efficient and to offer the best service and value for money.

Head Office is responsible for overall policy and relationships with national bodies including government.

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The 24-hour emergency hotline number for reporting all environmental incidents relating to air, land and water

ENVIRONMENT AGENCY EMERGENCY HOTLINE

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ENVIRONMENT AGENCY

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