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REPORT FOR ANGLIAN WATER, Plc ON THE USE OF THE ORWELL ESTUARY MATHEMATICAL MODEL TO DERIVE LONG TERM CONSENT LIMITS FOR CLIFF QUAY STW.

C.J. PENNEY

APRIL 1989

National Rivers Authority
Anglian Region

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SUMMARY

Following an investigation into estuary uses it was agreed to set the long term Environmental Quality Specification to achieve CEWP class B from the freshwater limit (Horseshoe Weir) to Pin Mill and Class A from Pin Mill to the Estuary Mouth.

To achieve this the following EQS limits are proposed:-

B.O.D	6 mg/l	95 %tile	-	entire length
NH3	1.5 mg/l	"	-	entire length
D.O	40% sat.	5 %tile	-	Horseshoe Weir to Pin Mill
D.O	60% sat.	"	-	Pin Mill to Estuary Mouth

The Orwell estuary model was used to assess the resulting estuary water quality with different effluent flows and qualities and so used to propose Long Term Consent limits for Cliff Quay STW.

Proposed consent:-

DISCHARGE	FLOW	B.O.D	NH3
	tcmd	mg/l	
Cliff Quay	30 DWF	200	45

It is proposed that should the volumes discharged alter then the consent is recalculated to maintain the same load. A matrix of consents for Cliff Quay STW for different flows has been calculated.

The Ipswich B.C. sewage model was assessed and the relevent data extracted to enable the Storm Water Overflows to be added to the Orwell model. The alterations to the computer programme were undertaken by the staff at Anglian Water NRA unit Headquarters at Peterborough.
Due to the complexity of this task and the need of more detailed information on the SWO discharges, currently being produced by WRc, further work is needed to completely assess the impact of the SWO and set consent limits for them.

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MAP OF THE AREAS USED FOR WATERSPORTS IN THE ORWELL AND STOUR ESTUARIES

1. INTRODUCTION

1.1. The Water Research Centre (WRc) were contacted by Anglian Water and asked to provide mathematical models to assist them in determining consent conditions for discharges to the Orwell Estuary relavent to the appropriate quality objectives.

WRc produced a one-dimensional model as data indicated that most of the estuary was not apppreciably statified under normal low freshwatwer flow conditions. Water quality determinands are predicted as averages over the cross section of the estuary. Intensive fixed - point surveys were carried out by Anglian Water in June and December 1986 to provide data to calibrate and validate the model.

Three types of model were produced - a hydrodynamic model to calculate water levels and water movements, a water quality model to predict the distibutions of Dissolved Oxygen and associated substances and a model to predict the distibution of faecal coliforms.

After initial calibration and validation by WRc the Mathematical Model of the Orwell Estuary was transfered to Anglian Water in 1987.

1.2. In order for the model to be used to determine consent conditions for discharges Anglian Water adapted the model to include a "Monte Carlo" type proceedure to estimate consent conditions in statistical terms.

1.3. To enable the model to be used for its design purpose it was felt that further evaluation of the model would be needed and a report on the appraisal and evaluation of the model was produced in 1988. This report went some way in estabishing Environmental Quality Standards and levels of discharge qualities needed to achieve them and started to look at the posibilty of including Storm Water Overflows in the model, But it was evident that further work was still needed.

1.4. The uses of the Orwell Estuary were assesd to enable Environmental Quality Objectives to be agreed. To use the mathematical model to derive long term consent limits, for all the inputs to the Orwell estuary, to ensure compliance with EQS's set to protect the estuary uses. The inclusion of the storm sewage discharges (SWO) into the estuary model using data from the WASSP model of Ipswich sewerage system so that the model can be used to derive the consent limits to be applied to the SWO's.

2. ENVIRONMENTAL QUALITY SPECIFICATION - ORWELL ESTUARY

2.1. The Orwell estuary is currently classed from D to A in the CEWP classification as follows:-

D - Horseshoe Weir to Cliff Quay
C - Cliff Quay to Orwell Bridge
B - Orwell Bridge to Pin Mill
A - Pin Mill to Estuary Mouth

Following an investigation into the estuary uses it was decided in order to protect these uses the estuary should achieve CEWP status B from Horseshoe Weir to Pin Mill (stretch 1) and A from Pin Mill to the Estuary Mouth. (stretch 2). Fisheries and wildlife protection extend the full length of the estuary and a map of the watersports activities is appended.

To achieve this it is proposed that the following E.Q.S 's are applied :-

AMMONIA	-	1.5 mg/l 95 percentile
B.O.D.	-	6.0 mg/l 95 percentile
DISSOLVED OXYGEN	-	40% 5 percentile for stretch 1
DISSOLVED OXYGEN	-	60% 5 percentile for stretch 2

2.2. The ammonia limit was derived from consultation with Water Quality staff of Anglian Water who have experience of other estuaries which support good fisheries and taking into account the fresh water EQS for a course fishery.

A minimum of 40% dissolved oxygen will also allow the maintenance of a fishery and will prevent objectionable conditions occurring in the upper stretches. It is also sufficient to enable the top section of the estuary to achieve a class B.

The B.O.D. standard has been included for the following reasons:-

(i) Easier auditing of water quality.
(ii) Analogy with fresh water rivers.
(iii) To use with the Estuary model to give confidence to the dissolved oxygen results.

2.3. BACTERIOLOGICAL QUALITY

At present there is no agreed bacteriological standard for the Orwell estuary.
The identification of uses of the estuary showed that Water contact sports occur from the Lock Gates at Ipswich to Shotley Point, including some swimming at Nacton Amenity Beach.
Also viable stocks of shellfish occur from the Orwell Bridge to Shotley Point. These are currently harvested on a small scale by hand raking.

If a coliform standard is applied these uses should be considered.

3. DATA TO BE USED TO DERIVE LONG TERM CONSENT LIMITS FOR ALL INPUTS TO THE ORWELL ESTUARY

To use the model to determine consent limits certain parameters in the model must remain unchanged. The following sections explain the values used.

3.1. WATER QUALITY

3.1.1. BOUNDARY VALUES FOR EACH END OF THE ESTUARY

Incoming water from the river Gipping is assumed to achieve the long term objective as class 1B, with values calculated to put it in the middle of the NWC class. B.O.D. and Ammonia were calculated from the mid point of the 95 - percentile values.
For Dissolved Oxygen a 5 - percentile of 70% saturation was required, a review of 1988 annual statistics for rivers in the area was used to obtain suitable figures.

Seaward boundary quality was estimated from past annual statistics of routine sampling by Anglian Water at Felixstowe.

TABLE 1 - Lists the boundary values for each end of the estuary.

These values result in the quality of incoming water being 0.48 mg/l for NH_3 and 3.8 mg/l for B.O.D. as 95-percentiles and Dissolved Oxygen of 69.5% saturation as a 5-percentile.

3.1.2. BELSTEAD BROOK

As for the river Gipping it is assumed to achieve its RQO as a class 1B river, with values calculated to put it in the middle of the NWC class.
For the Belstead Brook the model requires the Dissolved Oxygen value in mg/l. At temperatures of 16-17 oC they are equivalent, as temperatures recorded occur in this range it was assumed that a D.O of 85% = 8.5 mg/l.

TABLE 2 - Lists the water quality concentrations for the Belstead Brook.

3.2. EFFLUENT QUALITIES

3.2.1. STORM WATER OVERFLOWS

Due to the nature of storm water overflows (SWO) there can be little control over the quality of these effluents.

In the absence of specific monitored data from SWO 's it has been necessary to estimate polluting load. Cliff Quay Sewage works data for 1986/87 has been utilised as to the strength of sewage and a correcting factor applied to take account of the differing quality of storm sewage. (From WRC report SRM-II)

TABLE 3 - Calculation of the Mean Storm Sewage Concentration.

The Mean and S.D of the SWO 's can be estimated from table 3 as :-

	X	S.D
B.O.D	163	54.30
NH3	11	3.70

3.2.2. FELIXSTOWE STW.

The effluent quality from Felixstowe STW was derived from the statistical summary of samples taken in 1987.

TABLE 4 - Lists the Effluent quality from Felixstowe STW.

3.3. RIVER FLOWS

3.3.1. TIDAL LIMIT

The flow of the river Gipping is gauged at Constantine weir. From the flow duration curve for Jan 84 - Dec 84 :-

MEAN FLOW	1.3 CUMECS
95 % LOW FLOW	0.2 CUMECS

3.3.2. BELSTEAD BROOK

The Belstead Brook is gauged near Belstead Bridge which is upstream of Chantry STW so some additional flow must be added to allow for this.

River flows were obtained from the flow duration curve for Jan 84 - Dec 84.
Chantry STW flow from 1988 monthly mean daily flows.

3.3.2. Calculation of the flow from the Belstead Brook into the Orwell Estuary :-

	BELSTEAD BROOK ESTUARY	CHANTRY STW	ESTIMATED FLOW INTO ORWELL
MEAN	0.16	0.05	0.21
95	LOW FLOW	0.056	
SD	0.082	0.02	0.07

ALL FLOWS IN CUMECS

3.4. INDUSTRIAL DISCHARGES

There are three Industrial discharges into the Orwell Estuary in the Ipswich area. The outfalls are all in a short section of the estuary downstream of Stoke Bridge.

The flows used in the model for these discharges is summarised in TABLE 5.

3.5. STORM WATER OVERFLOWS

The mean and standard deviation of the SWO 's can be calculated from the results of the WASSP model (Ipswich B.C) using the time series rainfall.

For this information WRC have been asked to run the model for the first 26 storms in the series, with the sewage system at the initial development stage.

3.6. SEWAGE TREATMENT WORKS

3.6.1. CLIFF QUAY STW

Informal discussions with Anglian Water Plc have suggested a 1992 DWF of 30 tcmd. Assuming the MEAN FLOW = 1.25 X DWF the consent for Cliff Quay has been calculated with the following values:-

MEAN = 37.5 tcmd   S.D = 12.5

3.6.2. FELIXSTOWE STW

The flow from Felixstowe is not metered but an informed guess is :-

MEAN = 10 TCMD   S.D = 3.3

4. CALCULATION OF CLIFF QUAY STW LONG TERM CONSENT

4.1.

The estuary model was run using the data in section 3 and various effluent qualities for Cliff Quay STW. This resulted in the proposed effluent qualities from Cliff Quay as 95-percentiles of:-

B.O.D.	200
AMMONIA	45
DWF	30 tcmd

4.2.

With this quality effluent from Cliff Quay the model predicts a maximum ammonia of 1.39 mg/l and maximum B.O.D of 6.3 mg/l as 95-percentiles. The minimum 5-percentile D.O calculated is 41.4% saturation.

The B.O.D marginally exceeds the recommended E.Q.S. in one segment which is considered acceptable.

FIGURE 1 is a map of the Orwell Estuary showing the position of the segments used by the model to predict water quality.

TABLE 6 - Lists the results for each segment of the estuary for Ammonia and B.O.D, Mean and 95-percentile results and Dissolved Oxygen, Mean and 5-percentile.

These results are display as graphs in FIGURE 2.

4.3.

The proposed consent from Cliff Quay STW has been assessed in relation to other discharges into the estuary in keeping with current H.M.I.P thinking that all discharges should be treated as part of one system with inter-related effects.

5. <u>CLIFF QUAY STW. CONSENT WITH VARIOUS FLOWS</u>

5.1. The consent for Cliff Quay has been calculated, with the aid of the Orwell Estuary model, using a DWF of 30 tcmd and assuming the mean = DWF X 1.25.

It is proposed that the loading of pollutants from the Cliff Quay discharge should remain constant regardless of flow. Thus if the 1992 DWF should exceed 30 tcmd then the consent must be recalculated.

5.2. MATRIX OF CONSENTS WITH DIFFERENT FLOWS

The Orwell Estuary model has been used to recalculate the consent for Cliff Quay at DWF of 32, 36 & 40 tcmd so as to maintain the similar loadings.

The values for B.O.D and Ammonia needed to achieve this are summarised in TABLE 7 - Consent Matrix for Cliff Quay Sewage Treatment Works.

The calculated water quality in the first 12 segments is shown as bar charts for the different consents required at the increasing flows, in FIGURE 3. This demonstrates that the values in the matrix maintain very similar calculated water quality in the estuary at the different flows.

5.3. If the relationship between mean flow and DWF for Cliff Quay STW is found to be significantly different to that used then the consent must be recalculated using new mean flow.

6. IPSWICH B.C HIGH AND LOW LEVEL SEWER CATCHMENT DRAINAGE AREA PLAN - RELEVANCE TO ORWELL ESTUARY MODEL

6.1. A computer model of the Ipswich high and low level sewer catchment has been produced. In January 1985 Anglian Water initiated a hydraulic Analysis of the Ipswich catchment using WASSP. (Wallingford Storm Sewage Package)

This used the Time Series Rainfall - the 99 most significant observed rainfall events which occur in a typical year, to study pollution effects. For cost effective reasons a selective "run" was done using the 5 highest ranked storms and every fifth storm thereafter.

Ipswich B.C produced a report in March 1988 with the results of this analysis.

6.2 A total of 20 storm water overflows have been built into the sewage system discharging into the the River Gipping and Orwell Estuary.

The results from the time series rainfall gives values of the frequency and quantity that each SWO discharges in a "typical" year.

This hydraulic analysis was done at four levels :-

1) The existing system.
2) A rehabilitated system - the existing system is improved to remove all flooding.
3) Initialdevelopment- includes discharges from land already set aside for housing or industrial development.
4) Final development - utilising all other areas of land where development is possible.

For options 2,3 and 4 it was agreed with A.W that the system should not worsen the situation and ideally some improvement should be achieved, regarding SWO's.

6.3. To use the results of this study in the Orwell Estuary model it was decided that the Initial Development stage should be used. As looking to the future there will be further development in the area, but it is not as speculative as the Final Development.

6.4. POLLUTION ASSESSMENT USING WASSP AT THE INITIAL DEVELOPMENT STAGE

A total of 12 SWO 's discharge into the Orwell Estuary in this scheme, some combine before discharging giving 7 outfalls. Of these number 215 at Cliff Quay is insignificant and will be ignored . FIGURE 4 is a map of the part of the sewer system which discharges to the estuary showing the outfall locations.

1 - D/S Horseshoe Weir
2 - D/S Constantine Weir
3 - D/S Constantine Weir
4 - U/S Stoke Bridge
5 - D/S Lock Gates
6 - West Bank Ferry Terminal

6.5. The Ipswich B.C report included the following results relating to SWO's which discharge into the Orwell Estuary.

1) The number of times each SWO discharged in a "typical" year.
2) The Maximum spill volume.
3) The annual spill volume.

This information was collated for the following discharge points 1 to 6 and is summarised in TABLE 8.
Using the estimated strength of the storm water as detailed in section 3 the loadings can be calculated.

6.6. More information is available in the raw data produced by the model including the length of time each SWO discharged for.

7. INCLUSION OF STORM WATER OVERFLOWS INTO THE ORWELL ESTUARY MODEL

7.1. To enable the estuary model to assess all discharges in relation to each other the information available from the Ipswich B.C. report was utilised so that the Storm Water Overflows (SWO) could be included in the Orwell Model.
Information on the SWO 's was supplied to Anglian Water, NRA Regional Headquarters to enable the SWO to be included.

The data required was:-

1) Position of the SWO, Km d/s of Horseshoe Weir.
2) Maximum Length of operation.
3) The Volume discharged.
4) The quality of the discharge.

7.2. The positions of the SWO 's was obtained from the Ipswich B.C. report.

Ipswich B.C did not run the full TSR but the first 5 then every Fifth storm. This showed that the SWO 's only discharged during the first 25/26 storms. It was assumed at this stage that the first storm in the TSR would cause the longest discharge from the SWO. So this data was extracted from the print out of the initial development stage (supplied by Ipswich B.C.) A request was also made to at this time to run the first 26 storms of the TSR at the initial development stage.

The volume discharged was initially calculated by taking the maximum volume discharged as a 95-percentile and calculating the mean and standard deviation from this. When the run of the first 26 storms of the TSR is completed more accurate figures can be used.

The quality of the discharge was calculated as described in section 3.

7.3. To make an initial assessment of the impact of the SWO 's on the water quality of the Orwell Estuary the SWO 's were added to the model so that it could be run with them all discharging or for them to be turned off independently of each other.

The model was run with the proposed consents from the main discharges and a mean flow from Cliff Quay of 37.5 tcmd.(at this stage of development of the model the quality of incoming river water was at the bottom of NWC class 1B and the ammonia limit for Cliff Quay was 40 mg/l)

The following combination of SWO 's discharging was used:-

1) All on.
2) 4 Off.
3) 4 & 5 Off.
4) 4,5 & 6 Off.
5) 1,4,5 & 6 Off.
6) 1,2,4,5, & 6 Off

This relates to the frequency with which discharges occur from the different points.

7.4. The resulting water quality in the first 9 segments of the estuary are plotted in FIGURE 5.

This shows an anomaly of worse conditions in the first 2 segments of the estuary when SWO 4 is not discharging! This may be due to the geography of the top segments of the estuary or in the programme. Apart from this as each SWO is turned off there is the expected improvement in quality.

The greatest improvement in quality occurs when SWO 1 is removed - the Ammonia level decreases by 0.81 mg/l, the B.O.D decreases by 11.3 mg/l and Dissolved Oxygen increases by 5.1 % saturation.

Apart from SWO 1 the SWO 's which discharge less frequently but greater volumes are having the greatest effect on water quality.

7.5 In this form the model is assuming the SWO 's are discharging for every shot of the Monte-Carlo calculation and these results cannot be used to show compliance with the EQS.
The model is therefore being refined further by the NRA headquarters so that the SWO 's operate for a proportion of the time according to their frequency of operation. The results tables are also being extended to include 99-percentiles as since they operate less than 5 percent of the time their effect on the estuary water quality will not be apparent in the 95 percentile table.

7.6. Current RQS 's are expressed in terms of standards for continuous pollution control. The NWC classification takes no explicit account of transient pollution caused by intermittent discharges such as SWO 's. For current rehabilitation schemes interim procedures are required. Two such procedures have been produced for river systems which use empirically derived, acceptable, transient river quality conditions based upon the NWC classification system (report ER317E)

A draft report by Welsh Water Authority (pers. comm.) also propose the use of Maximum Acceptable Concentrations (MAC values) of pollutants in the watercourse receiving a SWO discharge. These are derived by using 99 percentile relationships to 95 percentile NWC Standards.

Extending this theory to the Orwell Estuary proposed EQS would result in MAC values of:-

Ammonia	3.0 mg/l
B.O.D.	12 mg/l
D.O.	20% sat. (min) - stretch 1
D.O.	30% sat. (min) - stretch 2

7.6. This suggests that intermittent discharges such as SWO 's can cause a local deterioration in the receiving water and providing it does not exceed the MAC value then no long term damage will result and it will not negate any improvements in water quality achieved by improving other discharges into the watercourse.

7.7. Once the alterations to the estuary model have been completed and the results of the WRc WASSP run have been received the work on setting consent limits for the SWO can proceed.

TABLE 1- BOUNDARY VALUES FOR EACH END OF THE ESTUARY

Mean (X) and Standard Deviation (SD) values in mg/l

LANDWARD		SEAWARD		VARIABLE
X	SD	X	SD	
2.4	0.80	2.5	0.83	BOD
0.2	0.07	0.1E-10	0.1E-10	TOTAL ORGANIC N.
0.3	0.10	0.1	0.1	AMMONIA
7.9	2.37	0.2	0.07	OXIDISED NITROGEN
85.0	10.00	100.0	15.0	DISSOLVED OXYGEN
10.8	5.92	13.0	5.0	TEMPERATURE

TABLE 2 - WATER QUALITY CONCENTRATIONS FOR THE BELSTEAD BROOK

Mean (X) and Standard Deviation (SD) values in mg/l

X	SD	VARIABLE
2.4	0.8	BOD
0.3	0.1	AMMONIA
7.9	2.6	OXIDISED NITROGEN
0.5	0.2	TOTAL ORGANIC NITROGEN
8.5	1.0	DISSOLVED OXYGEN

TABLE 3 - CALCULATION OF MEAN STORM SEWAGE CONCENTRATION

DETERMINAND	STRENGTH mg/l	FACTOR SRM TABLE F1	STORM FLOW CONC. mg/l
BOD	327	0.5	163.5
AMMONIA	38.8	0.3	11.64

TABLE 4 - EFFLUENT QUALITY FROM FELIXSTOWE STW

Mean (X) and Standard Deviation (SD) values in mg/l

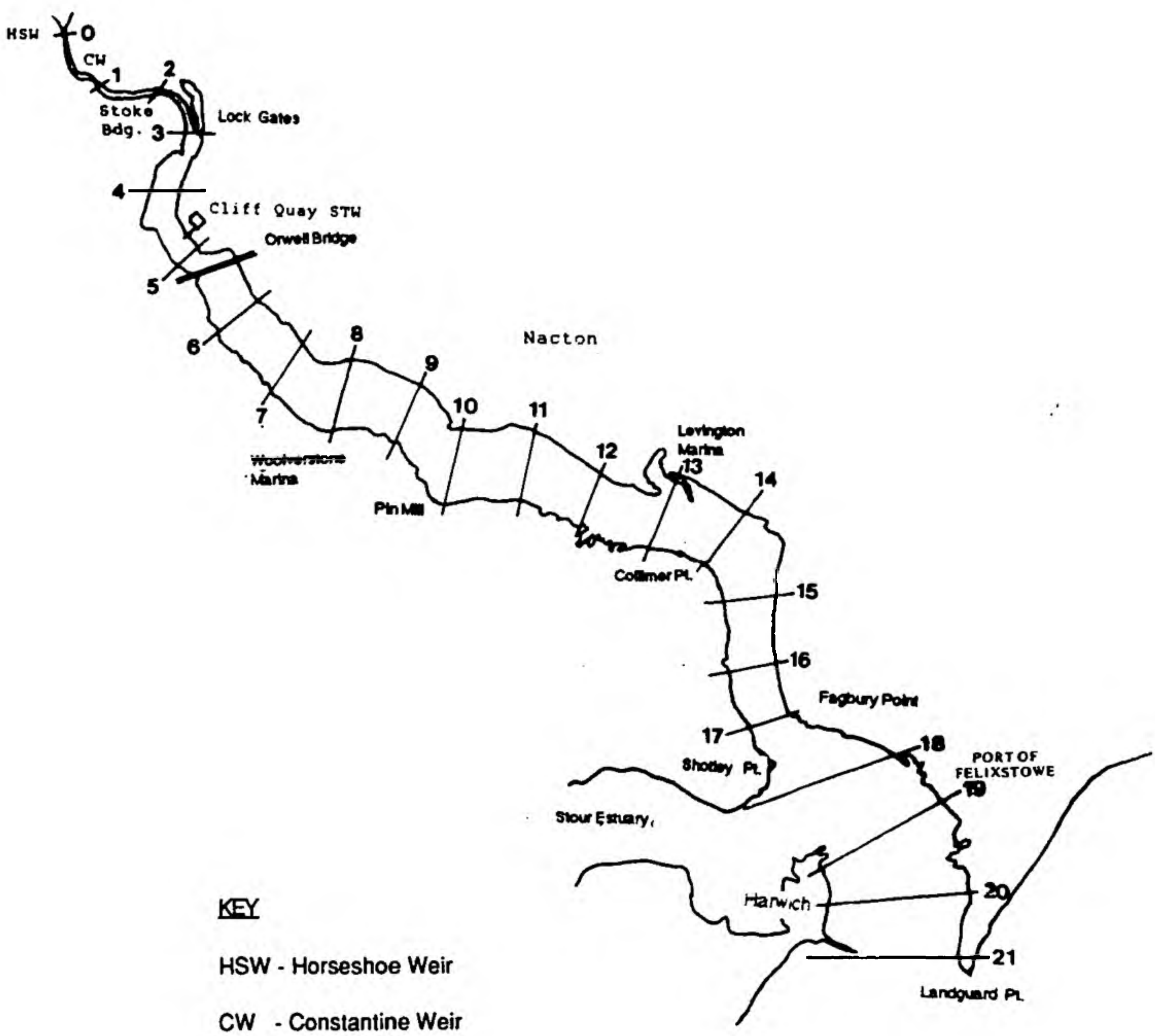
X	SD	VARIABLE
200	60	BOD
50	11	AMMONIA
0.1E-10	0.1E-10	OXIDISED NITROGEN
0.5	0.2	TOTAL ORGANIC NITROGEN
0.1E-10	0.1E-10	DISSOLVED OXYGEN

TABLE 5 - SUMMARY OF FLOWS OF INPUTS INTO THE ESTUARY

All flows in tcmd unless otherwise stated

INPUT	MEAN FLOW	STANDARD DEVIATION	LOW FLOW
Tidal Limit	1.3 CUMECS		0.2 CUMECS
Belstead Brook	0.21 CUMECS	0.07 CUMECS	
Industrial X	0.06	0.02	
Industrial Y	0.47	0.04	
Industrial Z	1.49	0.58	
Cliff Quay	37.5	12.5	
Felixstowe	10.0	3.3	

FIGURE 1 - MAP OF THE ORWELL ESTUARY SHOWING THE SEGMENTS



KEY

HSW - Horseshoe Weir

CW - Constantine Weir

Numbers are 1 Kilometre segments used by the model to predict water quality.

TABLE 6 - CALCULATED WATER QUALITY FOR EACH SEGMENT OF THE ESTUARY WITH THE PROPOSED CONSENT FROM CLIFF QUAY STW.

SEGMENT	AMMONIA		B.O.D		D.O	
	MEAN	95%tile	MEAN	95%tile	MEAN	5%tile
0	0.29	0.48	2.35	3.8	84.95	69.5
1	0.46	0.87	3.29	5.3	82.22	67.2
2	0.67	1.30	3.95	6.3	74.88	55.3
3	0.74	1.39	3.84	6.0	69.06	44.5
4	0.75	1.37	3.63	5.6	66.46	41.4
5	0.75	1.38	3.67	5.6	67.65	44.6
6	0.65	1.19	3.31	4.9	70.19	48.8
7	0.56	1.05	3.04	4.5	71.88	51.4
8	0.48	0.91	2.81	4.2	73.81	54.5
9	0.41	0.77	2.61	3.9	76.05	58.2
10	0.33	0.63	2.45	3.7	78.48	62.3
11	0.26	0.50	2.33	3.5	81.13	66.6
12	0.21	0.43	2.28	3.5	82.84	69.3
13	0.20	0.40	2.27	3.5	83.55	70.3
14	0.18	0.37	2.26	3.5	84.30	71.8
15	0.17	0.35	2.26	3.5	85.14	73.2
16	0.15	0.32	2.27	3.5	86.13	75.0
17	0.14	0.31	2.29	3.6	87.28	77.4
18	0.13	0.29	2.31	3.7	88.63	79.6
19	0.12	0.28	2.33	3.7	90.37	82.6
20	0.11	0.27	2.36	3.7	92.72	86.7
21	0.10	0.27	2.40	3.8	95.83	92.4

FIGURE 2

ORWELL ESTUARY – CALC. WATER QUALITY

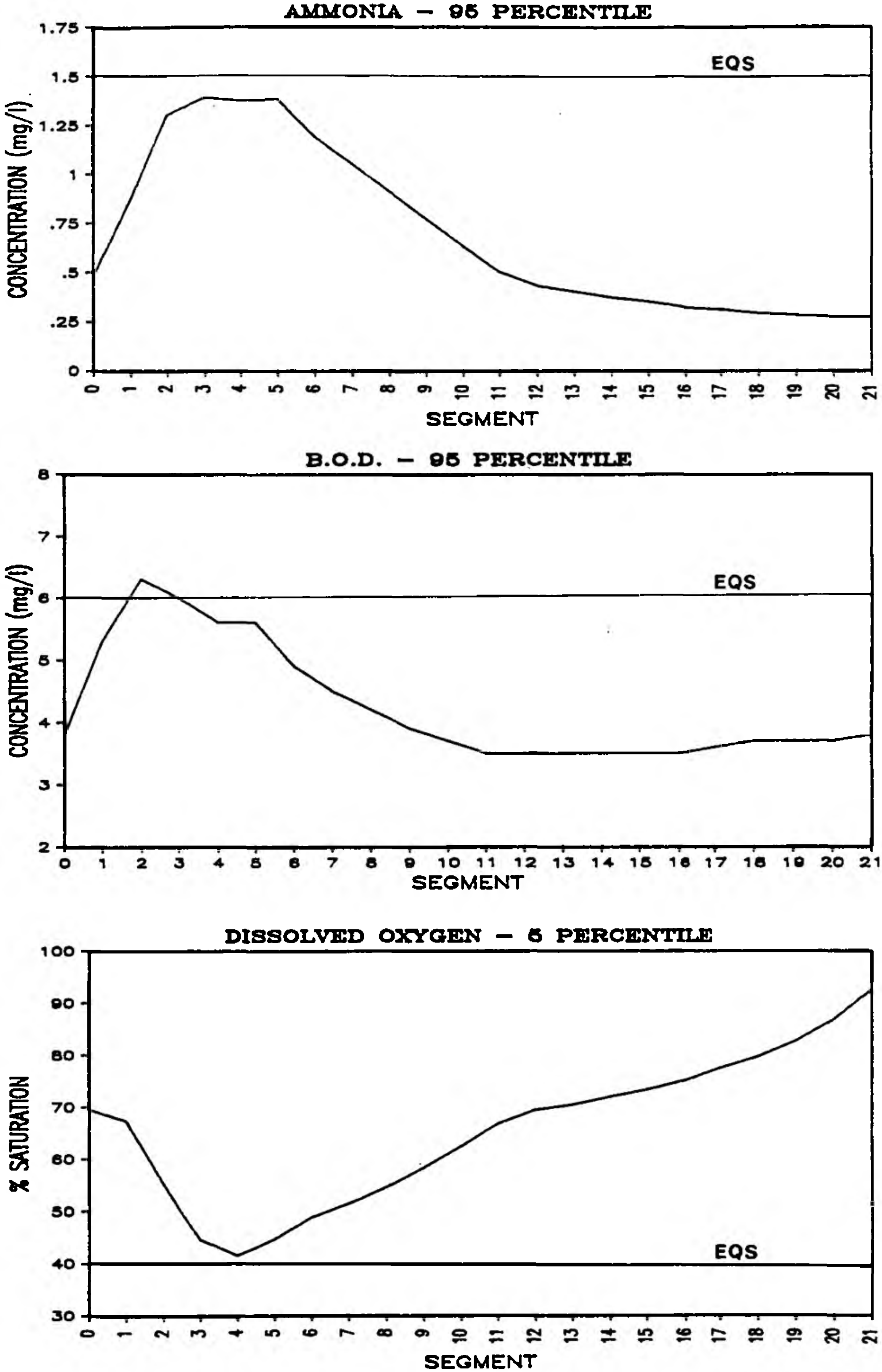


TABLE 7 - CONSENT MATRIX FOR CLIFF QUAY STW.

DWF tcmd	CONSENT B.O.D.	AMMONIA
30	200	45
32	185	42.5
36	170	37.5
40	150	34

FIGURE 3

WATER QUALITY WITH DIFF. CONSENTS & DWF.

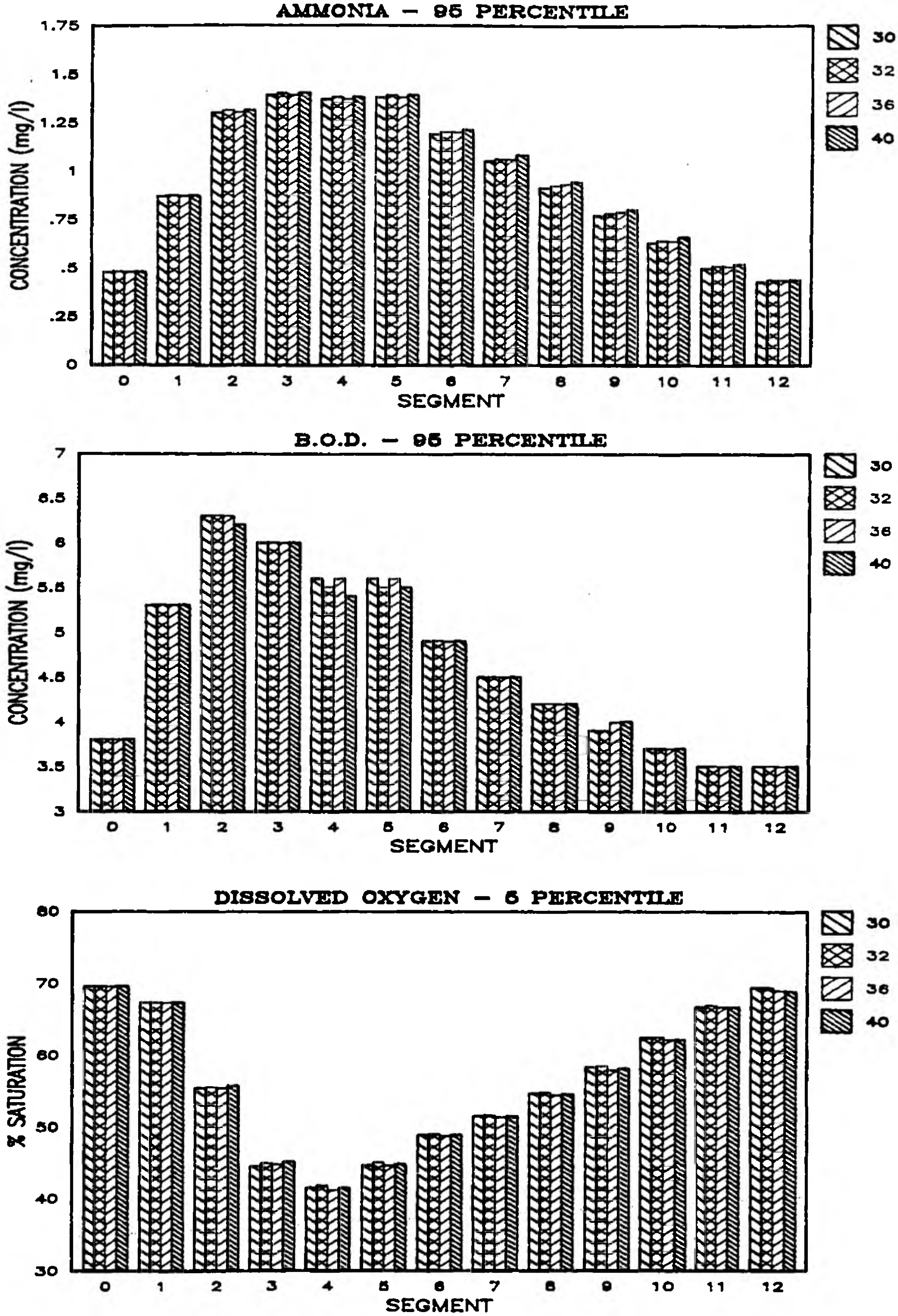


FIGURE 4 - DIAGRAM OF THE IPSWICH SEWER SYSTEM SHOWING THE POSITION OF STORM WATER OVERFLOWS INTO THE ORWELL ESTUARY

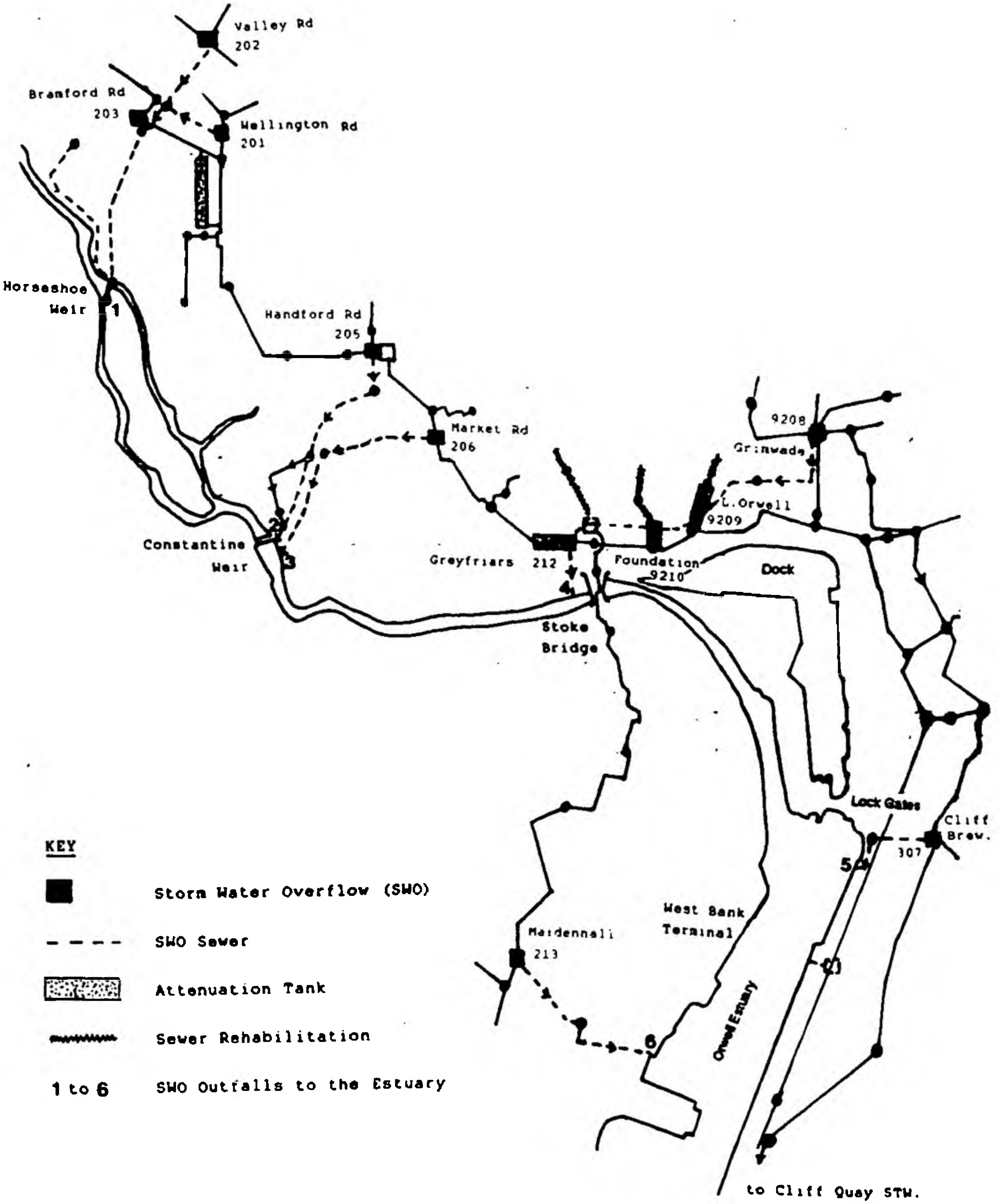


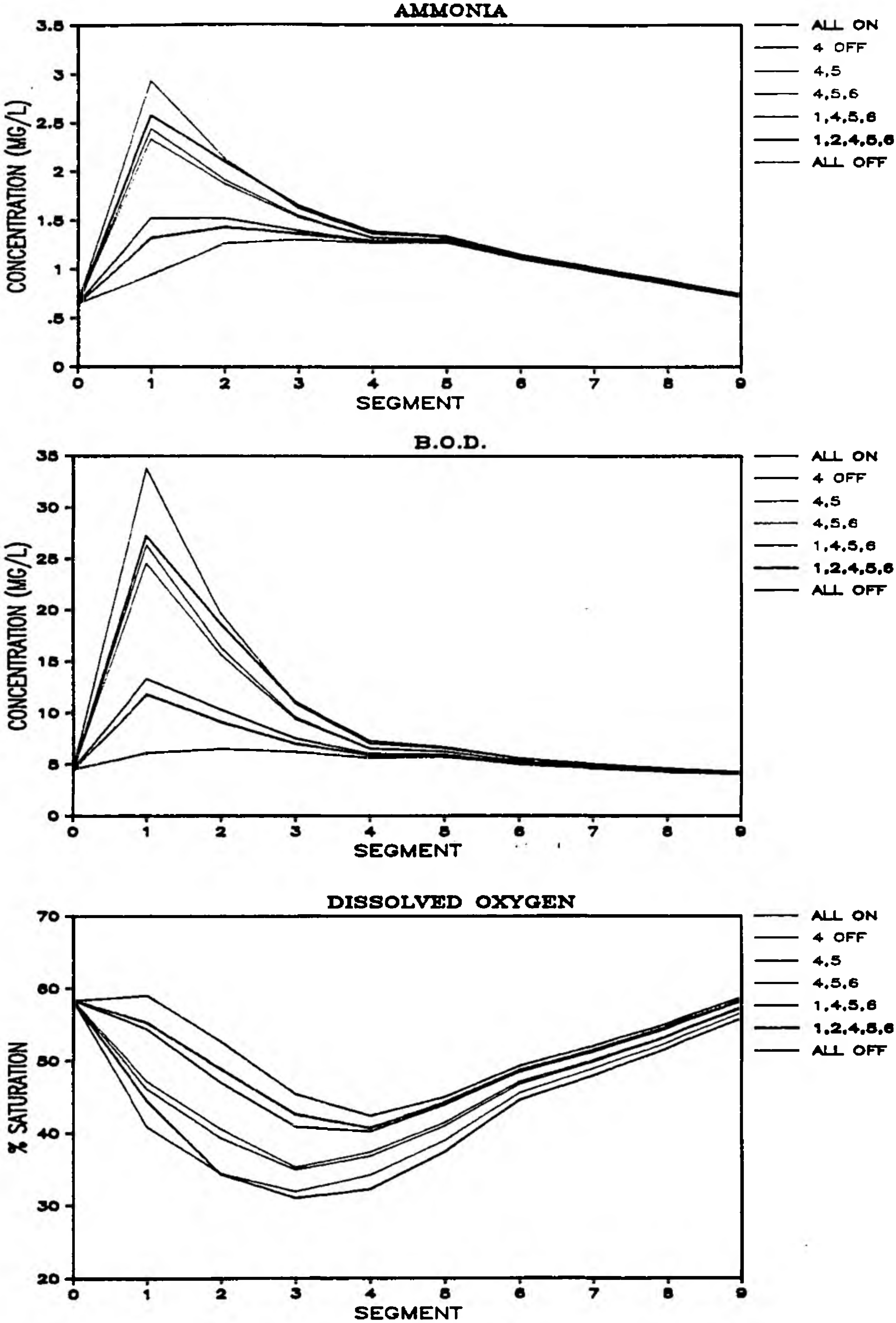
TABLE 8 - <u>STORMWATER OVERFLOWS - ESTIMATED DISCHARGE WHEN INITIAL DEVELOPMENT IS COMPLETED</u>

Discharge Point (map ref)	LOCATION SWO/TANK	Ref No	Ajust No. of events	MAX SPILL VOL. point	MAX VOL. per	ANN. SPILL VOL. event	AVE. VOL. per point	AVE. VOL. per
	Valley Rd	202	17	1291		5212	306	
1	Bramford Rd	203	17	1527	4542	5618	90	529
	Wellington	201	13	1724		5141	133	
2	Handford Rd	205	17	982	982	3507	206	206
3	Market Rd	206	22	899	899	4349	198	198
	Greyfriars	212	2	289		290	145	
	Foundation	9210	3	450		618	206	
4	L.Orwell	9209	4	1422	3010	3134	784	1512
	Grimwade	9208	4	849		1506	377	
5	Cliff Brew.	307	8	3545	3545	8734	1092	1092
6	Maidenhall	213	13	627	627	1286	99	99

ALL VOLUMES IN m3

FIGURE 5

ORWELL ESTUARY MODEL – INCLUDING SWO



8. REFERENCES

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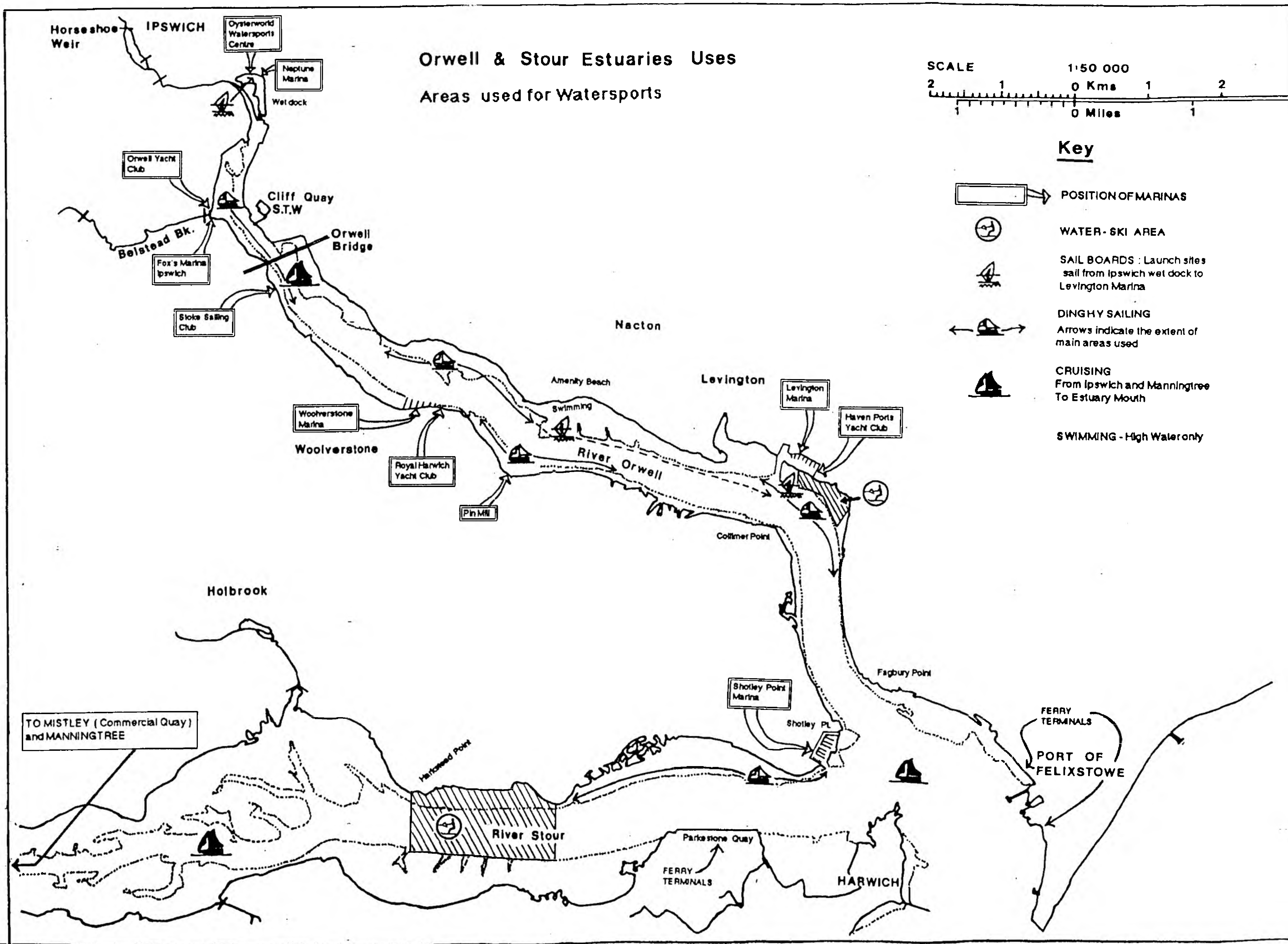

Orwell & Stour Estuaries Uses
Areas used for Watersports
SCALE 1:50 000
2 1 0 Kms 1 2
1 0 Miles 1
Key
POSITION OF MARINAS
WATER-SKI AREA
SAIL BOARDS : Launch sites sail from Ipswich wet dock to Levington Marina
DINGHY SAILING Arrows indicate the extent of main areas used
CRUISING From Ipswich and Manningtree To Estuary Mouth
SWIMMING - High Water only
Horseshoe Weir
IPSWICH
Oysterworld Watersports Centre
Neptune Marina
Wet dock
Orwell Yacht Club
Cliff Quay S.T.W
Belstead Bk.
Fox's Marina Ipswich
Orwell Bridge
Stoke Sailing Club
Nacton
Amenity Beach
Swimming
Levington
Levington Marina
Haven Ports Yacht Club
Woolverstone Marina
Woolverstone
Royal Harwich Yacht Club
Pin Mill
River Orwell
Collimer Point
Holbrook
Fagbury Point
Shotley Point Marina
Shotley Pt.
FERRY TERMINALS
PORT OF FELIXSTOWE
TO MISTLEY (Commercial Quay) and MANNINGTREE
River Stour
Parkestone Quay
FERRY TERMINALS
HARWICH