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South West Water Services Ltd
and
National Rivers Authority
South West Region

ROADFORD OPERATIONAL AND ENVIRONMENTAL STUDY

Draft Final Report

Volume 2 - Annex A Hydrology
Annex B Water Quality
Annex C Consultation

November 1991

HALCROW

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November 1991

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Annex A

HYDROLOGY

HALCROW

ROADFORD OPERATIONAL AND ENVIRONMENTAL STUDY

FINAL REPORT

ANNEX A - HYDROLOGY

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ANNEX A - HYDROLOGY

A1 INTRODUCTION

In order to assess the yield of the Roadford Reservoir System, the environmental impact and the impact on the operating costs, the system was simulated using a series of computer models which have been mainly written 'in-house' by SWWSL staff. This appendix briefly describes those programs and the assumptions that have been made when carrying out the simulations.

A2 SIMULATION PROGRAMS

A2.1 Description

The Roadford System was simulated using a suite of computer programs (FORTRAN 77) written 'in-house' by SWWSL staff. A list of the programs is given in Table A.1.

PG98D is a simulation program of the Dart System. It calculates the daily amount of water needed to be taken from each source in the Dart System and the amount of water needed to be transferred via the South Devon Trunk Main.

Computer programs PG266, PG314 and PG411 derive control curves for Burrator, Meldon and Roadford reservoirs respectively. The calculation of the curves is based on P.Walsh's (1971) method (2), although historical rather than theoretical data is used.

PG400 is the main simulation program of the Roadford Reservoir System. It calculates the daily amount of water needed from each source and uses the outputs from all the above programs.

PG413 is an economic analysis program, written for the Company by outside contractors but based on a program written 'in-house' by SWWSL staff. It calculates the operating costs and revenue implications of each simulation and includes pumping costs, HEP and treatment costs.

Simulations have been carried out using historic river flows from 1957-1989 with given demand horizons for the different 'cases' described in the Main Report.

A2.2 Inputs and Assumptions

<u>River Flows</u>

The simulations used the recorded daily mean flows (DMF's), naturalised where necessary, from the gauging stations given in Table A.2.

When gauging station records were too short or there was no suitable record, theoretical data was used which had been derived by SWWSL staff. Further details of the calculation of the theoretical flow data is given in N.Whiter's paper to the 1987 BHS National Symposium (1).

Table A.3 gives a list of the gauging station data which was naturalised and the factors which were taken into account.

Reservoir Inflows

With the exception of Roadford, reservoir inflows were calculated by multiplying the daily mean flows (DMF's) from the nearest suitable gauging station by the ratio of average daily flows (ADF's) to the dam site. However for Roadford, inflows before 1978 were estimated from either Gunnislake or Tinhay Gauging Station. After 1978, and before impoundment in October 1989, data was available from gauging stations at the dam site. After impoundment, inflows were calculated by multiplying the daily mean flows at the nearest suitable gauging station by the ratio of ADF's.

Compensation Releases

With the exception of Meldon Reservoir, all compensation flows were assumed to be the current licensed values. However, Meldon compensation release was modelled at 7.7 Ml/d, as the compensation flow will revert to this value in 1993. Roadford compensation flow was modelled as either the 9 Ml/d or as the proposal put forward in the Halcrow Operating Case.

Demand Data

Annual average demands for the different demand zones were supplied by SWWSL's Planning Department. Weekly demand pattern factors were derived from historical demand patterns and applied to the annual average demands so that seasonal variation in demands were modelled. The assumed annual average demands for the areas within the Roadford Scheme are given in Table A.4 and the weekly demand factors in Table A.5.

In the simulations, it was assumed there was a 10% reduction in demand between week 26 and week 38 inclusive in the 1976 drought, because of restrictions such as hosepipe bans.

Licence Details

Current licences were assumed to continue for all local intakes in the Roadford Reservoir System with the exception of Taw Marsh and Leehamford Bridge. At these intakes it was assumed no water would be abstracted at times of low flow.

Pipeline. Pumping and Water Treatment Works Constraints

Although all the computer models are able to take into account pipeline, pumping and water treatment works constraints, for these simulations the licences were considered to be the major constraints.

Operational Practicalities

Certain operational practicalities were modelled into the simulation in order to prevent "over-optimisation" of the system. These included:

- minimum pumping constraints (generally about 2 Ml/d)
- 'delay factors' in order to prevent daily switching between sources. The factors ranged from a couple of days to a week.

Regulation Release Losses

Regulation losses from Roadford to Gunnislake and Meldon to Torrington were taken as 10%.

Devonport Leat Details

Both the Dart program and the Roadford program model the water leaving the Dart catchment and entering the Meavy catchment via the Devonport Leat. The values of the prescribed flows on the Devonport Leat intakes were as agreed at the Public Inquiry ie 9.5 Ml/d, 8.0 Ml/d,and 7.6 Ml/d on the West Dart, Cowsic and Blackbrook tributaries respectively.

Morwellham Canal Details

The Roadford program models the water leaving the Tavy via the Morwellham Canal. The prescribed flow at the intake was as agreed at the Public Inquiry.

A3 WATER RESOURCE PRIORITIES

A3.1 Dart District (SW Devon)

Dart District Resources includes four reservoirs (Avon, Venford, Fernworthy and the group Kennick, Trenchford and Tottiford) and one river (Dart) and a few other local sources. The first priority for water was from these local sources, the reservoirs or the rivers. Any deficits were met by transferring water via the South Devon Trunk Main from the new High Level WTW near Plymouth to Dart District. The new High Level WTW was fed from either Burrator, River Tamar or Roadford (via the River Tamar). The source of raw water was determined from the position of Burrator storage in relation to the control curves.

A3.2 Plymouth

Water was supplied to Plymouth from Burrator Reservoir, the River Tavy, River Tamar or Roadford (via the River Tamar). The first priority of water was from Burrator Reservoir as this is a relatively inexpensive, good quality source. Second priority was from the River Tavy, the third was from the River Tamar and finally water was taken from Roadford (via the River Tamar).

Dousland WTW was supplied by the Devonport Leat as a first priority and then Burrator Reservoir. Dousland WTW was always used as much as possible.

Releases from Burrator to Crownhill and the new High Level WTW's was controlled by a series of control curves in Burrator Reservoir. These existed because of constraints in the system and are further defined in Section 4 of this appendix.

A3.3 North Devon

North Devon Resources include Wistlandpound Reservoir, Upper Tamar Lake and a variety of small local sources; the assumed reliable yields for these sources are given in Table A.6. Water is also available from Vellake Intake on the West Okement, Meldon Reservoir, the River Torridge and River Taw.

The first priority for water was from the small local sources and Vellake/Meldon, then from the River Taw and/or River Torridge and finally water was transferred from Roadford Reservoir.

The use of Meldon water is controlled by control curves in Meldon Reservoir which existed because of constraints in the system and are further defined in Section 4 of this appendix.

Water was released from Meldon for abstraction at Torrington as often as possible, thus minimising the quantity of water that was transferred from Roadford.

It was assumed that the Exe-Taw transfer was not be available after 1995.

A4 RESERVOIR CONTROL CURVES

It should be noted that the positioning of all control curves given in this report are only approximate.

A4.1 Burrator

There were two control curves in Burrator reservoir giving three zones. These existed in order to take as much Burrator water as possible but still conserve the necessary reservoir storage. Some storage was needed to support Dousland WTW and some was needed to support the Plymouth WTW's when demand at Crownhill and the High Level WTW exceeded the maximum licensed take at Gunnislake of 148 Ml/d.

The control curves represented the following operating rules:

Zone 1: - Take as much Burrator water as possible before taking any river water

Zone 2: - Take as much natural river water (R.Tavy and R.Tamar) as possible

- Then take Burrator water

- Then take Roadford water

Zone 3: - Take as much natural river water as possible

- Then take Roadford water

- Then take Burrator water (this was necessary if demand was greater than the Gunnislake licence of 148 Ml/d)

The top control curve influenced the timing of Autumn spill by maximising the pumping from the Rivers Tavy and Tamar and affected the volume of spill in the early part of the year. The control curves could have been used to control the minimum acceptable drawdown of the reservoir but this would have been at the expense of yield.

A typical set of control curves are shown in Fig A.1.

A4.2 Meldon

There were two control curves in Meldon reservoir giving three zones. These existed in order to make as much use of Meldon water as possible but conserve enough reservoir storage to supply the area which was not able to be supplied by Northcombe WTW.

The control curves represented the following operating rules:

Zone 1: - Meldon can supply as much water as is needed, including releases for Torrington WTW if necessary.

Zone 2: - Meldon supplies only the area which cannot be supplied by Northcombe WTW and still makes releases for Torrington WTW if necessary.

Zone 3: - Meldon supplies only the area which cannot be supplied by Northcombe WTW.

A typical set of control curves are given in Fig A.2.

A4.3 Roadford

Under the currently proposed 'Halcrow Operating Case', there was one control curve giving two zones of Roadford storage. The positioning of the curve was critical and affected the yield of the scheme.

Under the proposal to re-introduce Zone C, there were two control curves giving three zones of Roadford storage and the positioning of the bottom curve was critical in terms of the yield of the scheme.

A5 CHOICE OF DEMAND YEAR

A definition of the 'Drought Reliable Yield' of the scheme for the purposes of this report is given in the main report in section xxx.

A6 MODEL OUTPUT

Outputs from the Roadford Hydrological and Operational Model included daily reservoir storages, daily mean flows upstream and downstream of abstraction points and treatment works outputs. Some of these outputs have been plotted and are given in the Main Report.

The program also gave summaries of average monthly and weekly values for various abstractions/outputs/releases of the system. Sample weekly print-outs are given in Tables A.7 to A.10. The tables show the following values under the 'Halcrow Operating Case' set of operating rules for a drought year (1976), a wet year (1986), an unremarkable year (1987) and a dry year (1989):

Dousland WTW output
Burrator releases to Crownhill, High Level WTW and Dousland
Raw water to Crownhill WTW from Lopwell and Gunnislake
Raw water to the High Level WTW from Gunnislake
Volume of water abstracted from the natural River Tamar
Releases from Roadford (excluding compensation releases)
Releases from Roadford for water supply
Specific releases for HEP
Roadford compensation releases
Abstractions from the River Torridge and River Taw
Abstraction from Roadford for North Devon
Transfer from High Level WTW to SW Devon
Roadford inflow and spill
Burrator inflow and spill

A7 OPERATING COSTS

A7.1 Inputs

The outputs from computer program PG400 were inputs to the operating cost program PG413. This calculated the annual operating costs of pumping raw water to the water treatment works, pumping treated water to SW Devon, the treatment costs at Crownhill and Roborough WTW's, and the benefit of HEP generation from Burrator and Roadford. The benefit of HEP generation at Meldon was not included because different amounts generated under the different operating scenarios is not thought to be significant.

The program included the different costs of pumping depending on the time of year, fixed monthly charges, and financial benefits of HEP generation.

Treatment costs for the Plymouth High Level WTW and Crownhill WTW were included as this was where there was the greatest difference in treating the different sources of water. For the purpose of this study, the cost of treating water from the River Taw, River Torridge and Roadford was assumed to be about equal.

A8 QUALITY ASSURANCE

Computer program PG98D, written by SWWSL staff, was also used extensively by Halcrows for the 1988 River Dart Study and was rigourosly checked at this time.

Computer programs PG266, PG314 and PG400 were written and checked by SWWSL staff.

Computer program PG413 was written by outside contractors only after extensive consultations and detailed discussions with SWWSL Energy Staff concerning the interpretation of the different tariff structures.

The output from every 'run' was examined critically by several members of the Halcrow Study Team as a routine part of their specialist studies. Critical examination of model output, particularly hydrographs, invariably show any deficiencies or errors in the model. On all occasions no fault has been found with the computer program which has led the team to having great confidence in the computer model.

REFERENCES

(1) Whiter, N: "A Hydrological and Operational Model of the Roadford Reservoir System" BHS National Hydrology Symposium, University of Hull 14-16 September 1987.

(2) Walsh, P D: "Designing Control Rules for the Conjunctive Use of Impounding Reservoirs." J.Inst. Water Eng. V 25(7) p47-61.

TABLE A.1 Description of Computer Models

PROGRAM	DESCRIPTION
PG98D	Dart District Model
PG266	Burrator Control Curves
PG314	Meldon Control Curves
PG400	Roadford Hydrological and Operational Model (HOMER)
PG411	Roadford Control Curves
PG413	Roadford Revenue Costs Program

TABLE A.2 Historical Daily Mean Flow Data

LOCATION	RIVER	DATA AVAILABLE
Combe Park/Roadford Dam Site	Wolf	1978-1989
Tinhay	Thrushel	1970-1989
Lifton	Lyd	1975-1989 (intermittent)
Gunnislake	Tamar	1957-1989
Lopwell	Tavy	1957-1976
Denham	Tavy	1976-1989
Austins Bridge	Dart	1958-1989
Bellever	E. Dart	1965-1989
Torrington	Torridge	1963-1989
Umberleigh	Taw	1959-1989
Preston	Teign	1957-1989

TABLE A.3 Naturalised Data

Gauging Station	River	Factor Naturalised
Torrington	Torridge	Post impoundment of Meldon
Austins Bridge	Dart	Devonport Leat
Newbridge	Taw	Exe-Taw abstractions
Gunnislake	Tamar	Post impoundment of Roadford
Tinhay	Thrushel	" " " "
Roadford	Wolf	" " " "

TABLE A.4 Annual Average Demands

Area	Annual Average Demand (Ml/d) in 2010
Dart District	101.9
Plymouth	115.5
North Devon	91.4

TABLE A.5 Weekly Demand Factors

NORTH DEVON WEEKLY DEMAND PATTERN

0.996	0.959	0.975	0.949	0.949	0.964	0.954
0.960	0.968	0.963	0.956	0.915	0.943	0.969
1.142	1.131	1.091	1.124	1.119	1.139	1.102
0.981	0.966	0.968	0.951	0.950	0.955	0.973

PLYMOUTH WEEKLY DEMAND PATTERN

0.986	0.989	0.990	1.017	1.010	0.984	0.989
0.979	0.981	0.981	0.991	0.972	0.979	0.998
1.070	1.035	1.043	1.067	1.035	1.013	1.040
0.978	0.985	0.989	0.989	0.984	0.995	1.010

YENNADON ETC WEEKLY DEMAND PATTERN

0.986	0.939	0.990	1.017	1.010	0.984	0.989
0.979	0.931	0.981	0.991	0.972	0.979	0.998
1.070	1.035	1.043	1.067	1.035	1.013	1.040
0.978	0.935	0.989	0.989	0.984	0.995	1.010

PLYMOUTH HIGH WEEKLY DEMAND PATTERN

0.986	0.989	0.990	1.017	1.010	0.984	0.989
0.979	0.981	0.931	0.991	0.972	0.979	0.998
1.070	1.035	1.043	1.067	1.035	1.013	1.040
0.978	0.935	0.989	0.989	0.984	0.995	1.010

HOUNDALL WEEKLY DEMAND PATTERN

0.986	0.989	0.990	1.017	1.010	0.984	0.989
0.979	0.931	0.981	0.991	0.972	0.979	0.998
1.070	1.035	1.043	1.067	1.035	1.013	1.040
0.973	0.935	0.989	0.989	0.984	0.995	1.010

PREWLY WEEKLY DEMAND PATTERN

0.996	0.959	0.975	0.949	0.949	0.964	0.954
0.960	0.963	0.963	0.956	0.915	0.943	0.969
1.142	1.131	1.091	1.124	1.119	1.139	1.102
0.931	0.966	0.968	0.951	0.950	0.955	0.973

0.968	0.949	0.954	0.927	0.944	0.923
1.004	1.013	0.953	1.005	1.069	1.049
1.134	1.117	1.073	1.080	1.026	1.011
0.988	0.964	0.941	0.922	0.996	0.976

0.979	0.958	0.968	0.966	0.969	0.969
0.974	0.961	1.010	1.002	1.022	1.039
1.008	0.999	1.002	1.008	0.980	1.000
1.015	1.022	1.016	1.001	1.027	0.976

0.979	0.958	0.968	0.966	0.969	0.969
0.974	0.961	1.010	1.002	1.022	1.039
1.008	0.999	1.002	1.008	0.980	1.000
1.015	1.022	1.016	1.001	1.027	0.976

0.979	0.958	0.968	0.966	0.969	0.969
0.974	0.961	1.010	1.002	1.022	1.039
1.008	0.999	1.002	1.008	0.980	1.000
1.015	1.022	1.016	1.001	1.027	0.976

0.979	0.958	0.968	0.966	0.969	0.969
0.974	0.961	1.010	1.002	1.022	1.039
1.008	0.999	1.002	1.008	0.980	1.000
1.015	1.022	1.016	1.001	1.027	0.976

0.968	0.949	0.954	0.927	0.944	0.923
1.004	1.013	0.953	1.005	1.069	1.049
1.134	1.117	1.073	1.080	1.026	1.011
0.988	0.964	0.941	0.922	0.996	0.976

TABLE A.6 Reliable Yields of North Devon Sources

Source		Ml/d
Wistlandpound	)	
Challacombe	)	
Leehamford Bridge	)	13.7
Melbury		1.36
Loxhore		5.46
Slade		1.59
Parracombe		0.03
West Lyn		1.36
Upper Tamar		8.18
Total		31.68

TABLE A.7 1976 Weekly Output for Halcrow Operating Case

1976 - WEEKLY AVERAGE VALUES IN ML/D

	DOUTW	BUCRO	BUROB	BTDOU	LOPCR	GUNCR	GUNRO	GUNAT	ROADREL EX.COMP	RSUP	RHEP	COMP	TORAB	TAW	ROADAB	SWDSUP	RIN	RSPILL	BIN	BSPILL
1	21.69	0.00	0.00	0.68	81.52	0.29	0.00	0.05	0.00	0.00	0.00	9.00	16.18	16.18	0.00	0.00	37.74	0.00	59.53	0.00
2	21.76	0.00	0.00	2.43	81.76	2.66	0.00	2.55	0.00	0.00	0.00	9.00	14.49	14.49	0.00	0.00	26.42	0.00	35.33	0.00
3	21.78	0.00	0.00	3.11	77.29	6.20	0.00	6.20	0.00	0.00	0.00	9.00	15.22	15.22	0.00	0.00	19.46	0.00	42.63	0.00
4	22.37	0.00	0.00	2.79	80.59	7.80	0.00	7.80	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	33.24	0.00	53.73	0.00
5	22.22	11.37	0.00	1.49	81.47	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	50.19	0.00	53.89	0.00
6	21.65	79.56	0.00	0.60	5.55	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.72	14.72	0.00	0.00	49.59	0.00	98.15	0.00
7	21.76	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.26	14.26	0.00	0.00	157.53	0.00	167.92	88.70
8	21.54	22.73	0.00	0.00	62.17	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.00	42.45	0.00	72.05	36.94
9	21.08	56.83	0.00	0.37	25.83	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	31.12	0.00	44.33	12.30
10	21.30	22.73	0.00	5.01	60.79	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.26	14.26	0.00	0.00	18.97	0.00	23.57	0.00
11	21.25	56.83	0.00	0.00	26.52	0.00	0.00	0.00	0.00	0.00	0.00	9.00	13.03	13.03	0.00	0.00	65.32	0.00	105.13	23.56
12	21.32	22.73	0.00	0.00	60.87	0.00	0.00	0.00	0.00	0.00	0.00	9.00	13.81	13.81	0.00	0.00	95.40	0.00	76.92	39.09
13	21.32	56.83	0.00	0.81	26.78	0.00	0.00	0.00	0.00	0.00	0.00	9.00	12.85	12.85	0.00	0.00	47.03	0.00	49.47	25.07
14	21.54	22.73	0.00	1.84	61.74	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.54	14.54	0.00	0.00	25.52	0.00	33.43	0.00
15	21.58	0.00	0.00	5.58	83.20	1.78	0.00	1.39	0.00	0.00	0.00	9.00	17.18	17.18	0.00	0.00	15.58	0.00	23.11	0.00
16	21.58	79.56	0.00	8.30	5.08	0.00	0.00	0.00	0.00	0.00	0.00	9.00	17.91	17.91	0.00	0.00	10.64	0.00	18.78	0.00
17	21.80	0.00	0.00	10.44	38.08	47.42	0.00	47.42	0.00	0.00	0.00	9.00	17.67	17.67	0.00	0.00	7.08	0.00	15.71	0.00
18	21.38	0.00	0.00	10.41	49.72	34.15	0.00	34.15	0.00	0.00	0.00	9.00	16.23	16.23	0.00	0.00	6.55	0.00	15.10	0.00
19	21.54	0.00	0.00	11.66	29.53	54.94	4.75	59.69	0.00	0.00	0.00	9.00	14.80	10.24	9.39	4.75	5.30	0.00	13.35	0.00
20	21.96	9.15	0.00	9.63	36.42	40.54	11.13	51.66	0.00	0.00	0.00	9.00	15.95	2.59	17.71	11.13	5.80	0.00	31.58	0.00
21	21.43	13.95	0.00	7.84	39.58	30.51	6.91	37.41	0.00	0.00	0.00	9.00	15.92	8.29	14.49	6.91	6.53	0.00	27.80	0.00
22	21.14	62.76	1.83	12.11	18.05	2.10	28.66	30.76	0.00	0.00	0.00	9.00	8.18	0.00	31.15	30.49	3.36	0.00	12.00	0.00
23	22.22	75.61	14.89	13.79	11.53	0.00	23.09	12.00	12.24	12.24	0.00	4.44	8.18	0.00	26.95	37.98	2.34	0.00	11.04	0.00
24	22.12	11.03	1.95	14.11	9.69	65.73	39.23	0.33	115.08	115.08	0.00	3.00	5.84	0.00	32.93	41.18	1.85	0.00	10.38	0.00
25	22.52	0.00	0.00	11.40	12.19	75.98	33.28	25.04	92.64	92.64	0.00	4.71	9.10	9.44	24.72	33.26	2.84	0.00	21.30	0.00
26	21.81	0.00	0.00	14.47	1.45	79.24	47.03	0.00	138.89	138.89	0.00	3.00	0.00	0.00	34.50	46.98	0.83	0.00	8.98	0.00
27	22.73	0.00	0.00	15.72	0.00	83.09	61.27	0.00	158.79	158.79	0.00	3.00	0.00	0.00	40.37	60.32	0.16	0.00	8.22	0.00
28	22.73	0.00	0.00	15.68	0.44	83.81	61.85	0.00	160.22	160.22	0.00	3.00	0.00	0.00	39.68	60.62	0.11	0.00	8.30	0.00
29	21.29	33.67	5.29	13.69	2.25	45.07	54.17	0.00	194.87	109.16	0.00	3.00	0.00	0.00	37.15	59.46	0.26	0.00	9.56	0.00
30	22.73	46.30	6.49	15.93	0.00	36.56	60.19	0.00	106.43	106.43	0.00	3.00	0.00	0.00	39.24	65.19	0.00	0.00	7.74	0.00
31	22.73	0.00	0.00	16.05	0.00	80.37	66.34	0.00	161.38	161.38	0.00	3.00	0.00	0.00	38.92	65.33	0.00	0.00	7.48	0.00
32	22.73	0.00	0.00	16.34	0.00	78.66	64.30	0.00	157.26	157.26	0.00	3.00	0.00	0.00	40.18	62.99	0.00	0.00	6.81	0.00
33	22.73	0.00	0.00	16.37	0.00	80.76	64.44	0.00	159.71	159.71	0.00	3.00	0.00	0.00	37.85	62.33	0.00	0.00	6.74	0.00
34	22.73	0.00	0.00	16.37	0.00	78.27	64.70	0.00	242.98	157.27	0.00	3.00	0.00	0.00	39.87	63.44	0.00	0.00	6.74	0.00
35	22.15	0.00	0.00	15.40	0.00	77.57	60.64	0.00	152.04	152.04	0.00	3.00	0.00	0.00	38.79	60.10	0.60	0.00	7.62	0.00
36	22.73	3.13	0.00	16.36	0.00	74.67	68.51	0.00	157.50	157.50	0.00	3.00	0.00	0.00	36.02	67.44	0.02	0.00	6.77	0.00
37	20.54	0.69	0.00	11.83	4.59	73.00	67.74	1.79	152.85	152.85	0.00	3.00	0.00	0.00	36.46	67.54	4.63	0.00	11.29	0.00
38	19.45	0.80	0.00	8.19	17.84	57.47	57.06	0.00	125.98	125.98	0.00	3.86	2.36	2.36	28.33	57.06	2.43	0.00	18.61	0.00
39	22.00	0.00	0.00	1.33	46.02	40.26	43.42	60.35	25.66	25.66	0.00	7.29	19.21	19.98	0.00	43.42	9.26	0.00	52.04	0.00
40	21.52	0.00	0.00	0.00	77.56	6.82	0.00	6.82	0.00	0.00	0.00	9.00	17.24	17.24	0.00	0.00	87.22	0.00	246.31	0.00
41	21.67	0.00	0.00	0.00	84.38	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.81	14.81	0.00	0.00	85.25	0.00	136.42	0.00
42	21.76	68.19	0.00	0.00	17.74	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.00	284.32	0.00	264.41	166.90
43	21.76	79.56	0.00	0.00	5.77	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.13	14.13	0.00	0.00	142.06	0.00	164.15	81.96
44	21.65	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.08	14.08	0.00	0.00	76.53	0.00	127.57	45.38
45	21.89	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.31	14.31	0.00	0.00	125.61	0.00	118.06	35.87
46	22.22	56.83	0.00	0.00	29.53	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.13	15.13	0.00	0.00	45.82	0.00	78.32	0.77
47	22.33	11.37	0.00	0.00	77.94	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.82	15.82	0.00	0.00	45.07	0.00	47.52	20.87
48	22.48	79.56	0.00	0.00	8.01	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.72	14.72	0.00	0.00	233.86	0.00	186.21	54.18
49	22.35	79.56	0.00	0.00	8.01	0.00	0.00	0.00	0.00	0.00	0.00	9.00	13.67	13.67	0.00	0.00	253.75	0.00	182.74	100.55
50	22.02	79.56	0.00	0.00	7.50	0.00	0.00	0.00	0.00	0.00	0.00	9.00	12.80	12.80	0.00	0.00	80.78	0.00	102.72	20.84
51	22.59	56.83	0.00	0.00	30.58	0.00	0.00	0.00	0.00	0.00	0.00	9.00	16.18	16.18	0.00	0.00	107.96	0.00	111.86	30.93
52	21.47	22.73	0.00	0.00	62.68	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.27	15.27	0.00	0.00	71.14	0.00	66.52	51.38

ANNUAL AVERAGE VALUES IN ML/D

	DOUTW	BUCRO	BUROB	BTDOU	LOPCR	GUNCR	GUNRO	GUNAT	ROADREL EX.COMP	RSUP	RHEP	COMP	TORAB	TAW	ROADAB	SWDSUP	RIN	RSPILL	BIN	BSPILL
	21.86	23.39	0.56	6.28	29.94	25.74	18.91	7.37	44.27	40.99	0.00	7.21	[illegible]	9.94	12.33	19.28	47.02	0.00	60.44	16.18

TABLE A.8 1986 Weekly Output for Halcrow Operating Case

1986 - WEEKLY AVERAGE VALUES IN ML/D

	DOUTW	BUCRO	BUROB	BTDOU	LOPCR	GUNCR	GUNRO	GUNAT	ROADREL EX.COMP	RSUP	RHEP	COMP	TORAB	TAW	ROADAB	SWDSUP	RIN	RSPILL	BIN	BSPILL
1	21.69	79.56	0.00	0.00	5.25	0.00	0.00	0.00	0.00	0.00	0.00	9.00	16.18	16.18	0.00	0.00	119.15	110.15	203.23	121.05
2	21.76	79.56	0.00	0.00	5.25	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.49	14.49	0.00	0.00	138.93	129.92	173.25	91.07
3	21.78	79.56	0.00	0.00	5.25	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.22	15.22	0.00	0.00	112.05	103.04	161.70	79.51
4	22.37	79.56	0.00	0.00	5.25	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	168.35	159.35	200.38	118.20
5	22.22	79.56	0.00	0.00	5.25	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	60.23	51.23	89.63	9.52
6	21.65	45.46	0.00	0.00	34.57	4.82	0.00	4.82	0.00	0.00	0.00	9.00	14.72	14.72	0.00	0.00	28.12	19.11	48.52	0.00
7	21.76	34.10	0.00	2.05	44.75	13.18	0.00	13.18	0.00	0.00	0.00	9.00	14.26	14.26	0.00	0.00	18.09	9.09	29.26	14.50
8	21.54	45.46	0.00	5.30	18.52	20.49	0.46	20.95	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.46	11.75	2.75	23.49	0.00
9	21.08	1.44	0.00	5.49	31.92	49.30	8.18	57.48	0.00	0.00	0.00	9.00	14.03	14.03	0.00	8.18	11.75	2.75	57.61	0.00
10	21.30	79.56	0.00	0.59	3.96	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.26	14.26	0.00	0.00	20.92	11.92	59.68	5.80
11	21.25	0.00	0.00	1.14	46.40	36.95	0.00	36.95	0.00	0.00	0.00	9.00	13.03	13.03	0.00	0.00	13.86	4.85	34.97	0.00
12	21.32	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	13.81	13.81	0.00	0.00	47.11	38.11	111.97	24.73
13	21.32	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	12.85	12.85	0.00	0.00	100.87	91.87	135.14	52.82
14	21.54	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.54	14.54	0.00	0.00	53.79	44.78	79.40	0.07
15	21.58	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.00	64.41	55.41	115.54	30.49
16	21.58	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.67	14.67	0.00	0.00	112.43	103.42	126.60	44.41
17	21.80	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.35	14.35	0.00	0.00	81.74	72.74	85.01	7.29
18	21.38	34.10	0.00	0.00	52.45	0.00	0.00	0.00	0.00	0.00	0.00	9.00	12.48	12.48	0.00	0.00	33.44	24.43	66.73	25.54
19	21.54	45.46	0.00	0.00	40.64	0.51	0.00	0.51	0.00	0.00	0.00	9.00	13.76	13.76	0.00	0.00	39.28	30.28	108.15	60.50
20	21.96	79.56	0.00	0.00	4.91	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.95	14.95	0.00	0.00	176.02	167.02	160.59	77.97
21	21.43	79.56	0.00	0.00	4.91	0.00	0.00	0.00	0.00	0.00	0.00	9.00	16.55	16.55	0.00	0.00	35.65	26.65	90.19	34.12
22	21.14	34.10	0.00	0.00	44.47	5.56	0.00	5.56	0.00	0.00	0.00	9.00	16.96	16.96	0.00	0.00	20.51	11.51	55.44	12.60
23	22.22	45.46	0.00	1.00	29.04	12.64	0.00	12.64	0.00	0.00	0.00	9.00	14.22	14.22	0.00	0.00	32.47	23.47	96.53	47.44
24	22.04	45.46	0.00	0.57	34.68	6.31	0.00	6.31	0.00	0.00	0.00	9.00	16.59	16.59	0.00	0.00	31.15	22.15	47.86	5.06
25	22.48	34.10	0.00	0.93	40.42	13.66	0.00	13.66	0.00	0.00	0.00	9.00	19.52	19.52	0.00	0.00	29.35	20.35	53.74	15.78
26	22.73	45.46	0.07	2.47	33.82	9.53	0.05	9.58	0.00	0.00	0.00	9.00	18.60	18.60	0.00	0.00	19.52	10.52	35.35	0.00
27	22.73	35.42	0.00	2.42	40.54	16.53	26.08	29.77	13.94	13.94	0.00	7.29	21.37	16.33	8.01	25.27	30.26	16.98	45.61	5.78
28	22.73	48.23	6.81	6.50	28.64	17.41	13.29	30.70	0.00	0.00	0.00	9.00	19.00	15.27	10.44	18.96	16.38	0.00	23.47	0.00
29	22.73	55.97	18.31	9.25	32.54	1.48	33.45	33.70	87.07	1.36	0.00	8.14	16.44	0.00	24.60	51.54	10.24	0.00	19.09	0.00
30	22.73	54.43	13.86	5.76	29.14	8.66	37.06	29.64	17.57	17.57	0.00	6.14	14.83	3.26	25.98	50.18	9.95	0.00	46.16	0.00
31	22.73	19.21	1.47	0.66	66.86	3.51	6.85	9.45	0.70	0.70	0.00	6.30	18.20	6.80	18.62	8.28	16.28	0.00	66.37	0.00
32	22.29	0.00	0.00	1.01	76.35	11.06	1.42	12.48	0.00	0.00	0.00	9.00	22.72	22.72	0.00	1.42	20.56	0.00	59.66	0.00
33	22.73	0.00	0.00	2.32	67.86	22.14	3.21	25.08	42.86	0.00	0.00	9.00	21.03	21.03	0.00	3.06	23.76	0.00	47.14	0.00
34	22.18	56.83	0.00	0.50	23.44	6.70	0.05	6.76	42.86	0.00	0.00	9.00	19.95	19.28	5.76	0.05	208.98	0.00	194.19	115.17
35	21.98	79.56	0.00	0.00	6.63	0.00	0.00	0.00	0.00	0.00	0.00	9.00	21.71	21.71	0.00	0.00	116.31	62.45	85.13	9.19
36	22.04	34.10	0.00	0.25	47.45	4.91	0.00	4.91	0.00	0.00	0.00	9.00	19.70	19.70	0.00	0.00	27.09	18.09	44.38	1.17
37	22.18	45.46	0.00	1.57	31.77	9.74	0.00	9.74	0.00	0.00	0.00	9.00	20.02	20.02	0.00	0.00	25.36	16.35	64.65	19.33
38	21.56	34.10	0.00	3.57	25.76	24.70	1.19	25.89	0.00	0.00	0.00	9.00	17.55	17.55	0.00	1.19	15.20	6.20	26.06	0.00
39	22.00	39.69	12.27	6.66	22.85	23.74	9.36	33.10	0.00	0.00	0.00	9.00	16.87	16.87	0.00	21.63	11.64	2.64	22.06	0.00
40	21.52	61.55	8.45	7.59	11.21	11.90	21.40	33.02	0.00	0.00	0.00	9.00	15.71	11.07	4.21	29.85	8.40	0.22	19.80	0.00
41	21.67	69.50	1.08	8.52	6.63	8.86	33.14	41.35	0.72	0.72	0.00	8.28	18.39	2.58	8.65	34.23	7.92	0.00	18.57	0.00
42	21.76	50.86	6.18	5.20	27.53	6.94	15.57	16.62	6.48	6.48	0.00	5.58	13.13	6.39	10.29	21.76	39.10	1.98	116.97	0.00
43	21.76	22.73	0.00	0.00	62.60	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.13	14.13	0.00	0.00	139.51	130.51	205.06	50.51
44	21.65	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.08	14.08	0.00	0.00	101.59	92.59	152.57	70.39
45	21.89	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.31	14.31	0.00	0.00	110.48	101.48	215.99	133.80
46	22.22	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.13	15.13	0.00	0.00	255.08	246.08	371.85	289.66
47	22.33	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.82	15.82	0.00	0.00	259.34	250.34	338.55	256.36
48	22.48	79.56	0.00	0.00	14.49	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.72	14.72	0.00	0.00	91.52	82.52	136.41	54.22
49	22.35	79.56	0.00	0.00	8.10	0.00	0.00	0.00	0.00	0.00	0.00	9.00	13.67	13.67	0.00	0.00	127.65	118.65	176.58	94.39
50	22.02	79.56	0.00	0.00	6.81	0.00	0.00	0.00	0.00	0.00	0.00	9.00	12.80	12.80	0.00	0.00	300.44	291.44	311.82	229.63
51	22.59	79.56	0.00	0.00	6.81	0.00	0.00	0.00	0.00	0.00	0.00	9.00	16.18	16.18	0.00	0.00	152.98	143.98	173.91	91.73
52	21.47	79.56	0.00	0.00	6.81	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.27	15.27	0.00	0.00	151.66	142.65	192.96	110.78

ANNUAL AVERAGE VALUES IN ML/D

DOUTW	BUCRO	BUROB	BTDOU	LOPCR	GUNCR	GUNRO	GUNAT	ROADREL EX.COMP	RSUP	RHEP	COMP	TORAB	TAW	ROADAB	SWDSUP	RIN	RSPILL	BIN	BSPILL
21.94	55.76	1.31	1.56	22.80	6.74	4.04	10.05	4.07	0.78	0.00	8.80	15.97	14.51	2.24	5.29	74.85	59.74	108.51	46.26

TABLE A.9 1987 Weekly Output for Halcrow Operating Case

1987 - WEEKLY AVERAGE VALUES IN ML/D

	DOUTW	BUCRO	BUROB	BTDOU	LOPCR	GUNCR	GUNRO	GUNAT	ROADREL EX.COMP	RSUP	RHEP	COMP	TORAB	TAW	ROADAB	SWDSUP	RIN	RSPILL	BIN	BSPILL
1	21.69	79.56	0.00	0.00	5.25	0.00	0.00	0.00	0.00	0.00	0.00	9.00	16.18	16.18	0.00	0.00	125.20	116.20	154.86	72.68
2	21.76	56.33	0.00	0.00	26.98	1.15	0.00	1.15	0.00	0.00	0.00	9.00	14.49	14.49	0.00	0.00	57.25	48.24	87.40	7.52
3	21.79	22.73	0.00	0.00	52.53	10.78	0.00	10.78	0.00	0.00	0.00	9.00	15.22	15.22	0.00	0.00	30.94	21.94	53.72	26.72
4	22.37	56.33	0.00	0.34	18.21	11.04	0.00	11.04	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	26.02	17.02	49.72	0.00
5	22.22	22.73	0.00	1.74	46.51	19.56	0.00	19.56	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	25.17	16.17	75.05	27.37
6	21.65	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.72	14.72	0.00	0.00	69.05	60.05	121.80	33.28
7	21.76	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.26	14.26	0.00	0.00	53.76	44.76	78.20	7.33
8	21.54	11.37	0.00	0.01	55.82	17.35	0.00	17.35	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.00	27.74	18.73	33.43	8.11
9	21.08	68.19	0.00	0.00	14.83	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	99.34	90.34	176.16	105.34
10	21.30	79.56	0.00	0.00	3.10	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.26	14.26	0.00	0.00	50.19	41.19	77.84	1.63
11	21.25	22.73	0.00	0.00	45.21	15.20	0.00	15.20	0.00	0.00	0.00	9.00	13.03	13.03	0.00	0.00	29.64	20.64	52.47	21.13
12	21.32	56.83	0.00	0.00	21.85	5.99	0.00	5.99	0.00	0.00	0.00	9.00	13.81	13.81	0.00	0.00	206.03	197.03	178.33	118.88
13	21.32	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	12.85	12.85	0.00	0.00	176.76	167.76	216.49	134.31
14	21.54	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.54	14.54	0.00	0.00	68.51	59.51	289.72	207.54
15	21.58	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.00	48.78	39.78	111.92	29.73
16	21.58	79.56	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.67	14.67	0.00	0.00	26.81	17.80	71.62	0.00
17	21.80	11.37	0.00	2.50	53.91	19.96	0.00	19.96	0.00	0.00	0.00	9.00	14.35	14.35	0.00	0.00	18.49	9.49	28.51	1.44
18	21.38	68.19	0.76	2.41	15.37	3.50	0.00	3.50	0.00	0.00	0.00	9.00	12.48	12.48	0.00	0.76	15.38	7.30	27.65	3.73
19	21.54	11.31	1.68	4.50	29.49	43.52	14.07	57.59	0.00	0.00	0.00	9.00	15.73	15.73	0.00	15.75	5.98	0.00	26.31	0.00
20	21.96	33.59	1.21	5.33	27.47	25.05	24.24	49.29	0.00	0.00	0.00	9.00	13.19	11.61	6.91	25.44	8.61	0.00	28.35	0.00
21	21.43	72.01	7.58	7.02	10.17	1.85	31.48	32.22	1.21	1.21	0.00	7.79	12.37	13.25	13.08	39.06	6.98	0.00	20.58	0.00
22	21.14	46.54	10.24	3.67	30.71	5.81	22.90	21.56	7.87	7.87	0.00	7.29	14.08	8.43	16.82	33.14	10.10	0.00	55.74	0.00
23	22.22	45.46	0.00	0.00	41.68	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.22	14.22	0.00	0.00	25.67	0.00	163.38	0.00
24	22.04	34.97	0.00	1.05	36.30	15.18	0.98	16.16	0.00	0.00	0.00	9.00	16.59	16.59	0.00	0.98	9.10	0.00	31.26	0.00
25	22.48	45.46	0.74	1.19	36.60	6.11	0.00	6.11	0.00	0.00	0.00	9.00	18.63	20.41	0.00	0.74	11.79	0.00	60.74	0.00
26	22.73	34.10	0.05	0.42	44.82	10.41	7.19	17.33	0.00	0.00	0.00	9.00	18.60	18.60	0.00	7.12	22.22	0.00	59.54	6.74
27	22.73	39.72	28.75	7.00	49.12	3.48	23.94	25.37	2.26	2.26	0.00	8.14	14.92	19.38	11.41	51.88	9.32	0.00	22.68	0.71
28	22.73	55.49	26.06	6.45	38.12	0.00	29.39	6.68	24.97	24.97	0.00	3.86	10.21	3.19	31.31	54.31	7.12	0.00	27.89	0.00
29	22.73	28.80	18.97	0.78	43.82	17.26	15.92	23.36	96.23	10.51	0.00	7.29	13.25	5.36	22.44	34.67	20.86	0.00	60.75	0.00
30	22.73	43.21	12.68	4.82	43.54	5.30	46.93	52.24	0.00	0.00	0.00	9.00	14.25	7.14	22.67	58.86	9.33	0.00	26.45	0.00
31	22.73	46.90	25.33	5.05	42.50	0.00	29.15	18.00	12.26	12.26	0.00	5.57	14.48	3.11	26.01	54.45	8.38	0.00	36.64	0.00
32	22.29	77.18	13.74	9.10	9.93	0.29	41.78	0.00	46.28	46.28	0.00	3.00	8.72	0.00	36.72	55.52	4.66	0.00	18.63	0.00
33	22.73	45.46	6.49	10.80	1.94	42.33	48.37	0.00	142.63	99.77	0.00	3.00	8.18	0.00	33.87	54.71	3.79	0.00	16.62	0.00
34	22.18	0.00	0.00	11.82	0.00	86.97	55.93	0.00	200.05	157.19	0.00	3.00	8.18	0.00	36.80	55.93	3.13	0.00	14.12	0.00
35	21.98	68.19	9.74	11.67	0.00	18.00	43.35	0.00	67.48	67.48	0.00	3.00	8.18	0.00	35.24	53.08	2.79	0.00	14.04	0.00
36	22.04	11.37	1.62	4.85	0.67	74.42	45.50	0.00	131.91	131.91	0.00	3.00	8.18	0.00	31.22	47.12	4.27	0.00	40.58	0.00
37	22.18	0.00	0.00	4.48	20.19	66.78	31.99	0.00	108.66	108.66	0.00	3.00	8.53	0.00	31.51	31.99	3.42	0.00	43.08	0.00
38	21.56	75.96	12.77	6.78	4.32	4.28	24.58	0.00	31.75	31.75	0.00	3.86	8.18	0.00	26.92	37.34	3.47	0.00	24.62	0.00
39	22.00	0.00	0.00	7.50	3.78	82.50	42.94	0.90	137.00	137.00	0.00	3.00	8.25	2.41	23.07	42.94	3.33	0.00	22.29	0.00
40	21.52	3.23	0.00	1.37	64.13	15.11	6.37	3.06	20.27	20.27	0.00	8.14	8.73	11.32	10.95	6.37	84.18	0.00	184.91	0.00
41	21.67	0.00	0.00	0.00	83.92	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.81	14.81	0.00	0.00	225.34	0.00	173.38	0.00
42	21.76	56.83	0.00	0.00	31.81	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.00	433.70	0.00	241.18	124.24
43	21.76	79.56	0.00	0.00	5.77	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.13	14.13	0.00	0.00	88.43	0.00	116.21	32.02
44	21.65	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.08	14.08	0.00	0.00	47.54	0.00	69.15	0.00
45	21.89	11.37	0.00	0.00	68.13	1.51	0.00	1.31	0.00	0.00	0.00	9.00	14.31	14.31	0.00	0.00	196.33	0.00	144.19	117.17
46	22.22	68.19	0.00	0.00	23.86	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.13	15.13	0.00	0.00	274.89	0.00	165.66	94.84
47	22.33	79.56	0.00	0.00	7.58	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.82	15.82	0.00	0.00	78.00	0.00	102.69	19.61
48	22.48	11.37	0.00	0.00	77.24	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.72	14.72	0.00	0.00	56.40	12.42	74.93	36.57
49	22.35	68.19	0.00	0.00	19.47	0.00	0.00	0.00	0.00	0.00	0.00	9.00	13.67	13.67	0.00	0.00	59.15	50.15	46.96	6.86
50	22.02	11.37	0.00	1.14	64.65	10.35	0.00	10.35	0.00	0.00	0.00	9.00	12.80	12.80	0.00	0.00	40.15	31.15	87.29	0.00
51	22.59	68.19	0.00	0.00	20.42	0.00	0.00	0.00	0.00	0.00	0.00	9.00	16.18	16.18	0.00	0.00	61.93	52.93	119.51	24.23
52	21.47	79.56	0.00	0.00	4.65	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.27	15.27	0.00	0.00	99.90	90.90	249.79	150.93

ANNUAL AVERAGE VALUES IN ML/D

	DOUTW	BUCRO	BUROB	BTDOU	LOPCR	GUNCR	GUNRO	GUNAT	ROADREL EX.COMP	RSUP	RHEP	COMP	TORAB	TAW	ROADAB	SWDSUP	RIN	RSPILL	BIN	BSPILL
	21.94	47.53	3.42	2.37	26.43	12.29	11.26	8.36	19.77	16.43	0.00	7.81	13.43	11.61	8.03	14.62	59.52	23.94	86.23	27.47

TABLE A.10 1989 Weekly Output for Halcrow Operating Case

1989 - WEEKLY AVERAGE VALUES IN ML/D

	DOUTW	BUCRO	BURDB	BTDOU	LOPCR	GUNCR	GUNRO	GUNAT	ROADREL EX.COMP	RSUP	RHEP	COMP	TORAB	TAW	ROADAB	SWDSUP	RIN	RSPILL	BIN	BSPILL
1	21.69	0.00	0.00	1.61	61.52	23.55	0.00	23.55	0.00	0.00	0.00	9.00	16.18	16.18	0.00	0.00	40.12	31.12	73.69	0.00
2	21.76	0.00	0.00	0.00	75.25	7.27	0.00	7.27	0.00	0.00	0.00	9.00	14.49	14.49	0.00	0.00	60.76	51.75	99.44	0.00
3	21.78	79.56	0.00	0.00	8.67	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.22	15.22	0.00	0.00	57.18	48.18	64.07	0.00
4	22.37	0.00	0.00	0.00	70.69	17.06	0.00	17.06	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	42.09	33.09	45.85	0.00
5	22.22	53.19	0.00	1.66	15.81	3.14	0.00	3.14	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	24.32	15.32	31.03	0.00
6	21.65	11.37	0.00	1.18	53.97	19.56	0.00	19.56	0.00	0.00	0.00	9.00	14.72	14.72	0.00	0.00	32.76	23.76	47.42	0.00
7	21.76	56.83	0.00	0.00	25.30	3.20	0.00	3.20	0.00	0.00	0.00	9.00	14.26	14.26	0.00	0.00	69.02	60.02	181.98	95.15
8	21.54	79.56	0.00	0.00	4.91	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.00	151.01	142.01	182.40	100.21
9	21.08	79.56	0.00	0.00	3.13	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.03	14.03	0.00	0.00	165.23	156.23	204.96	122.77
10	21.30	79.56	0.00	0.00	3.10	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.26	14.26	0.00	0.00	87.65	78.65	162.74	80.55
11	21.25	79.56	0.00	0.00	3.13	0.00	0.00	0.00	0.00	0.00	0.00	9.00	13.03	13.03	0.00	0.00	185.39	176.38	231.27	149.09
12	21.32	79.56	0.00	0.00	3.10	0.00	0.00	0.00	0.00	0.00	0.00	9.00	13.81	13.81	0.00	0.00	161.40	152.40	149.50	67.32
13	21.32	79.56	0.00	0.00	3.10	0.00	0.00	0.00	0.00	0.00	0.00	9.00	12.85	12.85	0.00	0.00	60.49	51.48	76.25	1.74
14	21.54	34.10	0.00	0.00	43.90	5.70	0.00	5.70	0.00	0.00	0.00	9.00	14.54	14.54	0.00	0.00	43.81	34.80	62.12	17.72
15	21.58	45.46	0.00	0.00	38.27	5.13	0.00	5.13	0.00	0.00	0.00	9.00	14.90	14.90	0.00	0.00	64.42	55.42	123.82	75.74
16	21.53	79.56	0.00	0.00	5.08	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.67	14.67	0.00	0.00	35.82	26.82	108.79	36.86
17	21.80	22.73	0.00	0.00	54.12	8.65	0.00	8.65	0.00	0.00	0.00	9.00	14.35	14.35	0.00	0.00	32.64	23.64	72.44	36.83
18	21.38	56.83	0.00	0.71	22.55	4.49	0.00	4.49	0.00	0.00	0.00	9.00	12.48	12.48	0.00	0.00	24.86	15.86	37.21	13.71
19	21.54	22.73	0.00	4.36	32.26	29.30	1.05	30.36	0.00	0.00	0.00	9.00	14.25	14.25	0.00	1.05	16.29	7.29	24.99	0.00
20	21.96	11.11	0.00	7.32	29.96	45.34	25.91	70.95	0.00	0.00	0.00	9.00	17.93	18.32	0.00	25.91	11.23	2.23	20.94	0.00
21	21.43	57.25	5.00	8.85	10.67	16.12	35.94	48.16	4.29	4.29	0.00	7.29	17.47	11.20	10.03	40.95	7.69	0.00	17.66	0.00
22	21.14	56.83	8.11	9.60	9.28	16.81	29.79	18.55	30.85	30.85	0.00	4.71	11.79	5.62	21.93	37.90	5.52	0.00	16.01	0.00
23	22.22	24.76	3.25	10.91	22.47	39.92	18.42	46.71	12.80	12.80	0.00	7.29	13.59	12.67	8.87	21.67	5.14	0.00	15.63	0.00
24	22.04	56.83	8.11	11.76	4.65	24.97	29.97	9.20	50.31	50.31	0.00	3.00	8.18	0.00	30.59	38.08	3.42	0.00	14.01	0.00
25	22.48	0.00	0.00	13.65	10.59	77.58	37.91	13.04	112.70	112.70	0.00	3.00	8.18	0.00	35.08	37.91	1.03	0.00	11.69	0.00
26	22.73	0.00	0.00	13.29	11.45	78.19	37.20	21.77	102.99	102.99	0.00	3.00	11.11	0.00	30.75	37.07	1.97	0.00	12.65	0.00
27	22.73	2.32	0.00	14.04	5.32	84.68	48.13	8.24	137.02	137.02	0.00	3.00	8.18	0.00	40.19	47.26	4.40	0.00	11.47	0.00
28	22.73	6.57	0.00	14.97	3.05	83.99	59.05	0.00	157.35	157.35	0.00	3.00	4.68	0.00	42.93	56.64	2.67	0.00	9.84	0.00
29	22.73	5.72	0.00	15.65	0.33	83.94	63.59	0.00	247.99	162.28	0.00	3.00	0.00	0.00	44.80	60.53	0.49	0.00	8.59	0.00
30	22.73	13.89	0.00	15.76	0.00	78.17	69.83	0.00	162.80	162.80	0.00	3.00	0.00	0.00	47.11	65.72	0.76	0.00	8.12	0.00
31	22.73	11.62	0.00	15.78	1.04	76.65	70.71	0.00	162.10	162.10	0.00	3.00	0.00	0.00	46.76	67.50	0.95	0.00	8.10	0.00
32	22.48	4.37	0.00	14.03	0.00	83.03	63.11	0.00	160.76	160.76	0.00	3.00	0.00	0.00	48.17	61.75	10.21	0.00	10.75	0.00
33	22.73	0.00	0.00	8.80	18.92	70.82	54.86	6.43	174.03	131.17	0.00	3.00	0.00	0.00	45.57	54.71	6.31	0.00	19.43	0.00
34	22.32	2.06	0.00	14.20	1.29	83.52	64.04	0.00	205.29	162.43	0.00	3.00	0.00	0.00	47.82	64.02	1.97	0.00	10.54	0.00
35	22.69	0.72	0.00	15.25	2.31	83.17	63.19	0.00	160.99	160.99	0.00	3.00	0.00	0.00	46.62	62.45	1.26	0.00	9.21	0.00
36	22.73	1.50	0.00	15.63	0.42	84.53	61.24	0.00	160.35	160.35	0.00	3.00	0.00	0.00	43.54	59.43	1.22	0.00	8.43	0.00
37	22.26	11.48	1.62	2.15	38.01	37.65	22.30	0.00	65.95	65.95	0.00	5.57	11.72	6.01	25.74	23.89	35.95	0.00	185.42	0.00
38	21.56	0.00	0.00	0.00	68.74	15.82	0.00	15.82	0.00	0.00	0.00	9.00	17.55	17.55	0.00	0.00	52.75	0.00	88.13	0.00
39	22.00	0.87	0.00	3.33	36.80	48.61	0.24	48.85	0.00	0.00	0.00	9.00	16.87	16.87	0.00	0.24	11.72	0.00	27.29	0.00
40	21.52	22.62	0.00	5.19	24.35	37.42	7.13	44.54	0.00	0.00	0.00	9.00	15.06	8.86	7.08	7.13	7.42	0.00	23.62	0.00
41	21.67	33.35	0.00	5.63	27.97	23.66	17.25	40.91	0.00	0.00	0.00	9.00	13.74	7.80	8.08	17.25	7.75	0.00	23.18	0.00
42	21.76	35.65	5.61	4.21	48.41	1.28	15.05	16.15	0.29	0.29	0.00	8.71	12.75	6.39	10.65	20.65	87.20	0.00	150.66	0.00
43	21.76	68.19	0.00	0.00	17.14	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.13	14.13	0.00	0.00	79.33	0.00	131.80	39.26
44	21.65	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.08	14.08	0.00	0.00	137.09	0.00	214.02	131.84
45	21.89	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.31	14.31	0.00	0.00	135.44	0.00	211.45	129.26
46	22.22	79.56	0.00	0.00	5.34	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.13	15.13	0.00	0.00	58.20	0.00	101.38	19.20
47	22.33	22.73	0.00	0.00	65.81	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.82	15.82	0.00	0.00	36.42	0.00	64.00	6.91
48	22.48	34.10	0.00	1.53	56.30	0.00	0.00	0.00	0.00	0.00	0.00	9.00	14.72	14.72	0.00	0.00	23.20	0.00	31.25	9.57
49	22.35	45.46	0.00	5.42	36.03	6.17	0.00	6.17	0.00	0.00	0.00	9.00	13.67	13.67	0.00	0.00	18.67	0.00	24.59	0.00
50	22.02	0.00	0.00	0.92	80.23	4.82	0.00	4.82	0.00	0.00	0.00	9.00	12.80	12.80	0.00	0.00	116.62	0.00	178.64	25.99
51	22.59	79.56	0.00	0.00	10.40	0.00	0.00	0.00	0.00	0.00	0.00	9.00	16.18	16.18	0.00	0.00	162.54	0.00	248.74	166.56
52	21.47	79.56	0.00	0.00	4.65	0.00	0.00	0.00	0.00	0.00	0.00	9.00	15.27	15.27	0.00	0.00	135.14	0.00	211.45	129.26

ANNUAL AVERAGE VALUES IN ML/D

	DOUTW	BUCRO	BURDB	BTDOU	LOPCR	GUNCR	GUNRO	GUNAT	ROADREL EX.COMP	RSUP	RHEP	COMP	TORAB	TAW	ROADAB	SWDSUP	RIN	RSPILL	BIN	BSPILL
	21.97	36.32	0.51	4.94	22.84	27.11	17.13	10.52	40.44	37.16	0.00	7.28	11.65	10.18	12.32	17.45	48.61	22.75	79.06	27.96

FIG A.1 An Example of Burrator Control Curves

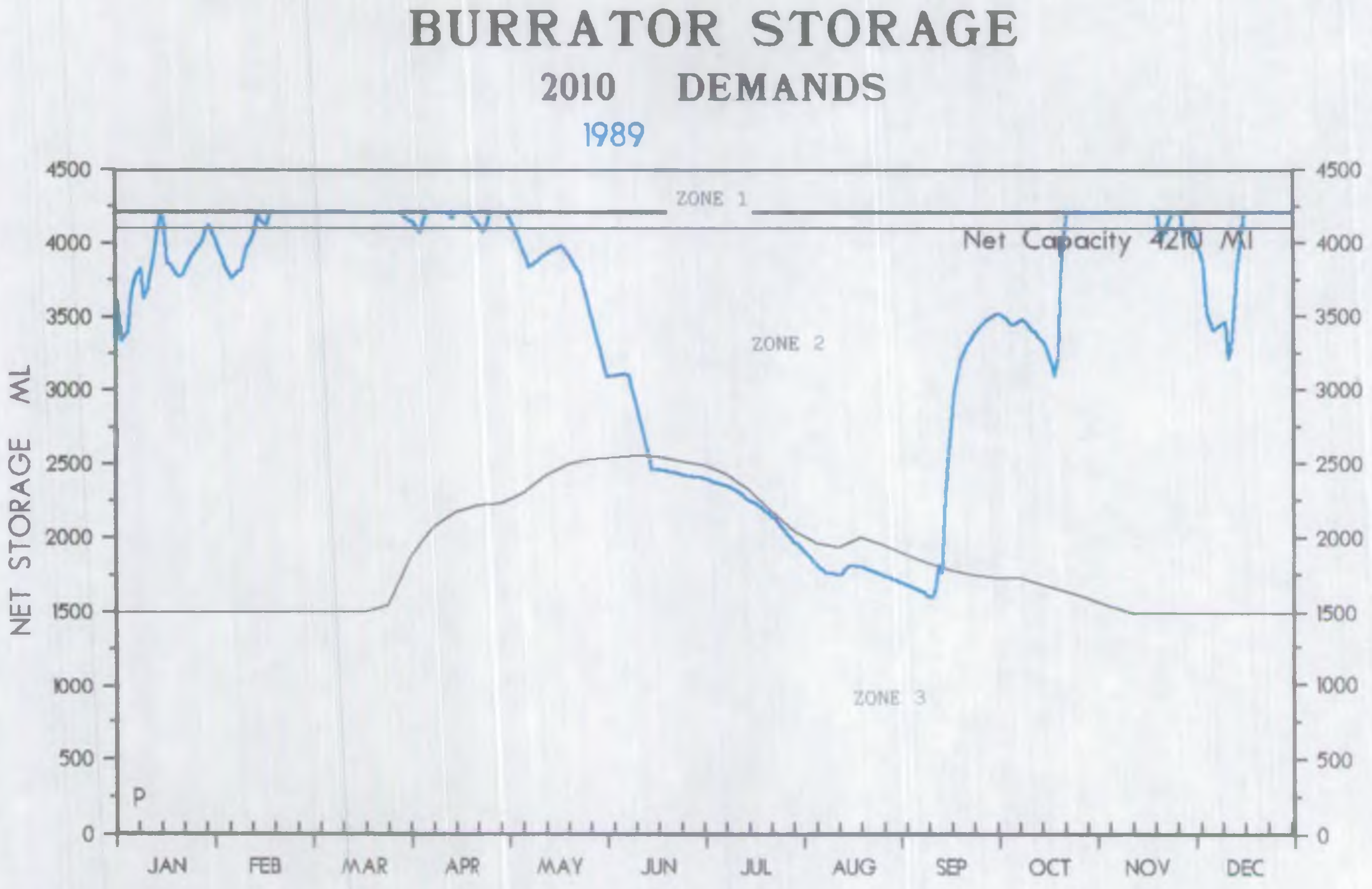
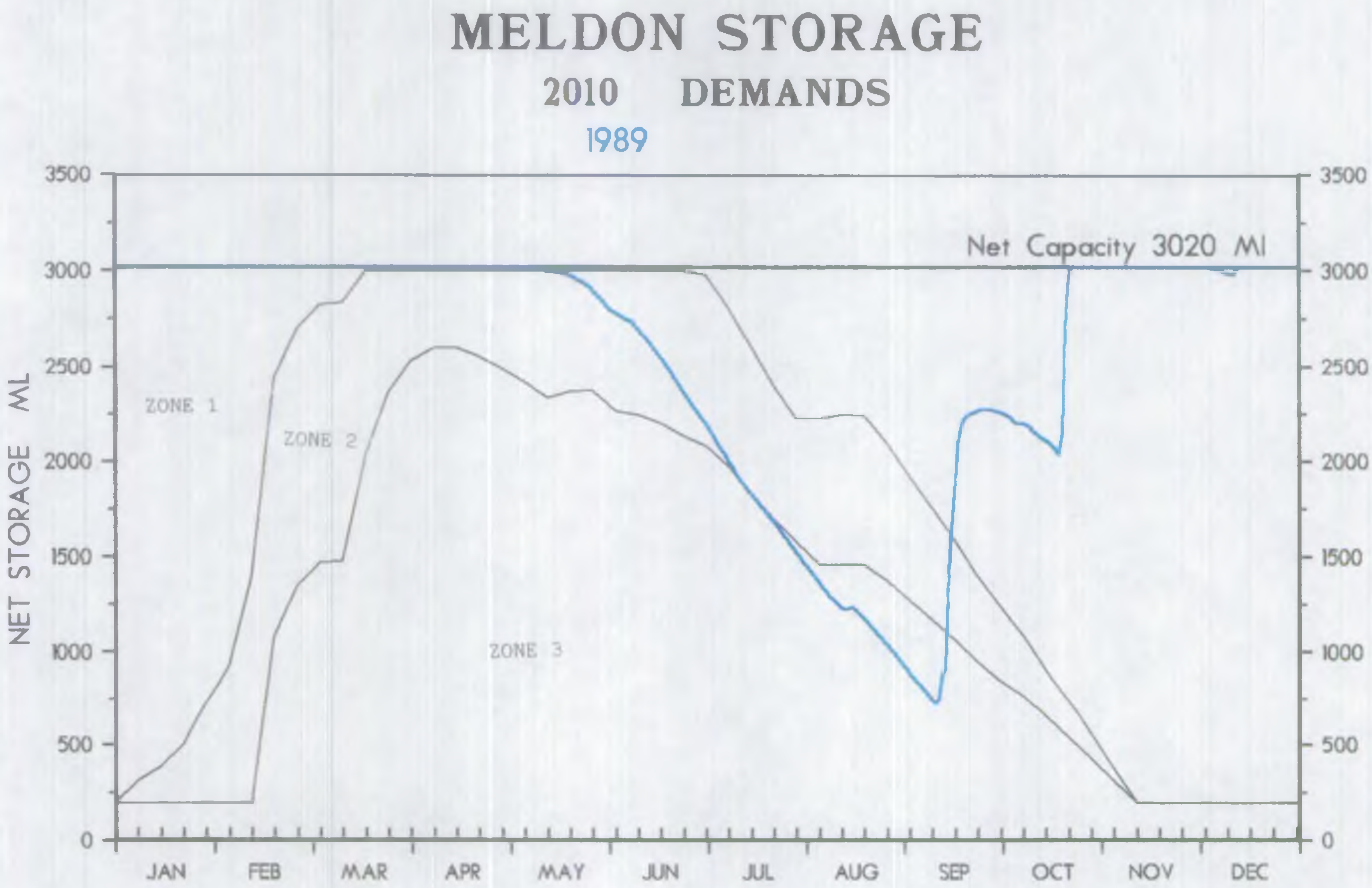


FIG A.2 An Example of Meldon Control Curves



Annex B

WATER QUALITY

HALCROW

ANNEX B - WATER QUALITY

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ANNEX B - WATER QUALITY

B1 INTRODUCTION

Water quality, both in its own right and as regards its relevance to other areas of study, is an important consideration in the development of complex water resource schemes such as Roadford. Such other areas of study include fisheries, ecology and recreation. Scheme operating rules must be developed so as to cause no deterioration in, or to minimize any adverse impacts upon, water quality. Indeed, rules should be adopted which are of demonstrable benefit to water quality wherever this is possible without prejudice to the overall objective of the scheme. This overall objective is to provide the optimum balance between yield, environmental protection and operating costs.

These considerations should be viewed, for the reaches of river where water quality will be influenced by the scheme, in the context both of the existing water quality and of the environmental quality objectives (EQO's) which apply to those reaches. The following EQO's are of particular relevance:

(a) river and estuary quality classifications as defined by the former National Water Council,

(b) the European Community Directive (78/659/EEC) on the Quality of Fresh Waters needing Protection or Improvement in order to support Fish Life.

Section B2 summarises the manner in which these EQO's apply to the reaches of river potentially affected by the Roadford scheme, and the actual water quality relative to these objectives.

There are two primary areas for consideration in relation to the potential impacts of the Roadford scheme upon water quality:

(a) impacts which accrue from changes in the pattern of dilution available for effluent discharges,

(b) impacts upon estuarine quality brought about by changes in the flow (and possibly in consequence upon the quality) of fresh water inputs to the estuaries.

The National Rivers Authority (NRA) have established guidelines for assessing the acceptability (or otherwise), in water quality terms, of proposed licensable water abstractions. These guidelines have been adopted as a basis for assessing the water quality impacts of the Roadford scheme. The methodology and results of this assessment are presented in Section B3 of this Annex. The discussion of existing water quality, contained in Section B2, concentrates on those criteria which are of relevance when applying the NRA's guidelines.

Section B4 of this Annex addresses the issues relating to estuarine water quality.

The water quality annex to the Interim Report for this study (April 1990) included a report relating to modelling studies of the River Tamar, undertaken and reported by Dr Neil Murdoch and Mr Brian Mann of the NRA. That modelling report contained the results of simulations of two hypothetical scenarios for the operation of Roadford. These results are unaffected by the development of the Halcrow Operating Case (HOC). Accordingly it is considered appropriate that the modelling report should remain a stand-alone document and consequently is not reproduced in this Final Report.

B2 EXISTING WATER QUALITY

B2.1 Introduction

Table B1 summarises the recent history of water quality in the reaches which are under consideration. The quality classifications shown are compiled by the NRA from an assessment of water quality data on a rolling three year basis, using their standard river quality classification system.

B2.2 The Tamar Catchment

B2.2.1 The River Tamar and its Tributaries

The Tamar catchment is illustrated in Figure B1. Its waters are of fair quality, typically bordering between classes 1B and 2A. The fresh water river supports a salmonid fishery, and is designated as such under EC Directive 78/659/EEC. It receives a number of small and relatively insignificant effluent discharges, of which the three most significant entering the reaches affected by Roadford are:

(a) Ambrosia Creamery, which discharges an average of 0.7 Ml/day into the River Lyd at Lifton.

(b) A trout farm at Hartwell, which discharges an average of 0.8 ml/day via a small tributary in the vicinity of Latchley.

(c) Launceston sewage treatment works (STW), which discharges an average of 1.7 Ml/day into the Tamar itself, 3 km upstream of the confluence of the Rivers Lyd and Tamar.

The upper reaches of the Tamar estuary suffer from occasional sharp sags in dissolved oxygen which, at the very least, cause distress to fish, and, in extreme cases, lead to fish mortalities on a large scale. It has been noted that the severity of such sags is most pronounced at a location which is just seaward of the zone of maximum turbidity, in the vicinity of Cotehele Quay. This phenomenon is greatly exacerbated by high temperatures, sustained low fresh water flows over Gunnislake Weir, and a high spring tide. This is evidenced by the particularly severe and very localised depletion of oxygen (falling to only 3% of saturation) which was observed on a spring tide during the 1984 drought.

Volumes of sewage and other point source effluents entering the fresh water Tamar catchment are totally insufficient to contribute significantly to this problem. Its cause is thought to lie in the enrichment of the upper estuary by the naturally occurring nutrients in the Tamar; this gives rise to algal growth, and subsequently to an accumulation of organic detritus at the tidal limit. H T Sambrook and K Broad have given a quantitative assessment of water quality data obtained from the continuous monitoring stations at St Leonards and Gunnislake (see Appendix B1).

B2.2.2 Roadford Reservoir

Roadford reservoir was formed by impounding the headwaters of the River Wolf, a third order tributary of the River Tamar. The quality of water entering the reservoir will therefore be that of the Wolf itself, which borders between classes 1A and 1B.

De-stratification equipment which is installed in the reservoir will serve to ensure that the impounded water is reasonably homogeneous in quality, and naturally occurring organic contaminants and nutrients can be expected to stabilise at levels which are characteristic of mesotrophic waters. Consequently algal blooms are unlikely to present a problem in the reservoir, although they can be expected to occur from time to time in hoot weather, particularly during extreme draw down. The water is expected to be of class 1A quality for at least 95% of the time. Dissolved oxygen levels may at times fall slightly below the 80% of saturation which is the limiting criterion for class 1A, due to the relative immobility of the water body as a whole.

The water temperature will be less variable than that in the Wolf immediately upstream of the reservoir. Consultations with Dr Bruce Webb of Exeter University have concluded that:

(a) The annual mean temperature of reservoir water will be the same as the typical annual mean temperature which obtained previously in the River Wolf at the same location.

(b) Seasonal variations in the temperature of reservoir water will lag approximately one month behind similar variations which obtained previously in the River Wolf at the same location.

(c) The range of temperature variation in the reservoir will be approximately 20% less than the range which obtained previously in the River Wolf at the same location. Accordingly, the maximum temperature in the reservoir will be reduced by about 1.6°C, while the minimum temperature will be elevated by the same amount, relative to the River Wolf upstream of the reservoir.

Thus, although Roadford reservoir as such has been filled only comparatively recently, it is nevertheless possible to deduce what will be the quality of its waters, and consequently how releases from the reservoir are likely to affect the reaches downstream.

B2.3 The Tavy Catchment

The Tavy catchment is illustrated in Figure B2. Table B2 provides a summary of relevant water quality statistics derived from routine samples collected over the five year period 1984 to 1988. Both the Tavy itself and its tributary the River Lumburn are designated as salmonid fisheries, being typically of class 1A/1B quality. The Tavy carries a relatively high load of nutrients, of which Crowndale STW (Tavistock) is a significant source. The Tavy is impounded at its tidal limit by Lopwell Dam.

B2.4 The Plym Catchment

The Plym catchment is illustrated in Figure B3. The source of the River Plym itself lies approximately 1 km south of Crame Hill on Dartmoor. The upper Plym flows over moorland, through an area of china clay extraction. The waste water from the open cast hydraulic mining process is allowed to stand in lagoons, where a large proportion of the micaceous residues settles out. The resulting treated waste water is neither toxic nor deoxygenating, although inevitably it retains significant traces of the micaceous residues.

The River Plym is joined near the village of Shaugh Prior by its tributary, the River Meavy. Tables B5 and B4 provide a summary of relevant water quality statistics for the Rivers Plym and Meavy respectively, derived from routine samples collected over the five year period 1984 to 1988. The upper reaches of the Plym are generally of class 1A quality, although an excursion into class 3A was reported in 1986, as a result of pH values which fell below the required minimum. (Minimum recorded pH over the period studied is 4.2 below the Blackabrook confluence, as compared with the required minimum of 5.0 for classes 1A, 1B, 2A and 2B). It should be noted also that almost all of the Plym upstream of the Meavy confluence fails to comply with the pH criteria for salmonid fisheries, contained in EC Directive 78/659/EEc (the so-called Fish Directive, requiring that 95% of samples should have pH values in the range 6 to 9).

The River Meavy has been of consistently high quality, typically in class 1A. The apparent deterioration to class 1B in the lowest reach of the Meavy does not represent a significant change in the nature of the river from the fisheries viewpoint.

The effluent from Marsh Mills STW enters the Plym at the tidal limit of the estuary.

B2.5 The Dart Catchment

The Dart Catchment is illustrated in Figure B4. Table B5 contains a summary of relevant water quality statistics, derived from routine samples collected over the five year period 1984 to 1988.

The Dart is typically of class 1A/1B quality. It receives an average of 3.9 Ml/day of treated effluent from Ashburton and Buckfastleigh STW. This has only a minimal impact upon water quality, causing a small increase in concentrations of phosphate and ammonia.

The Dart estuary is likewise of high quality. Totnes STW discharges an average of 5 Ml/day of treated sewage effluent into the head of the estuary.

B2.6 The Torridge Catchment

The Torridge catchment is illustrated in Figure B5. Table B6 contains a summary of relevant water quality statistics, derived from routine samples collected over the five year period 1984 to 1988.

Water is abstracted from the River Torridge at Great Torrington. The river receives two significant effluent discharges immediately downstream of this abstraction:

(a) Great Torrington STW discharges an average of 2.8 ml/day of treated domestic and trade effluent.

(b) The Torridge Vale Creamery, owned by Dairy Crest Limited, has consent to discharge cooling water with traces of solids settled from river water, boiler blow-down and condensate. The maximum discharge permitted under the terms of this consent is 4.5 Ml/day in the period May to October inclusive, and 3.2 Ml/day in the period November to April inclusive. It is understood that this consent is presently under review.

The Torridge is typically of class 1B quality upstream of the effluents described above, and at the point of abstraction at Great Torrington. The quality objective for this reach (1B) reflects the use of the river as a potable water supply source. The combined impact of the two effluent discharges serves to reduce the river quality from class 1B to class 2.

Treated sewage effluent from Weare Giffard STW enters the Torridge estuary near its head. The main body of the estuary receives a large number of effluents from the Bideford region. The primary objective for the Torridge estuary relates to the requirement to comply with the European Community Directive on the quality of Bathing Waters. Restoration of the estuary to compliance with its objectives has been the subject of intensive study in recent years (South West Water Services Limited (SWWS), Taw-Torridge Tidal Waters Management Plan), and SWWS are already taking major steps to improve both its chemical and bacteriological quality.

There is no straightforward or obvious explanation for the occasional unsuitability of the upper Torridge estuary for fish migration. Transient elevation in water temperature have been implicated, but the evidence is far from conclusive.

Accordingly the primary issues in the Torridge catchment regarding the impact of the Roadford Scheme relate to:

- The dilution of the effluents at Great Torrington.
- Changes in freshwater inputs to the Torridge estuary.

B2.7 The Taw Catchment

The Taw catchment is illustrated in Figure B6. The river is generally of fair quality, and abstraction takes place at Newbridge, just upstream of the tidal limit. The Taw estuary receives major sewage effluent inputs from the Barnstaple area, with the most significant continuous inputs being provided by Ashford STW and, in the lower Taw estuary, Velator STW. The proposed improvements to sewage treatment in the catchment of the Torridge estuary include, in addition, similar improvements for the Taw estuary, thereby forming a single regional scheme.

B3 DILUTION FOR EFFLUENT DISCHARGES

B3.1 Methodology

Dilution for effluent discharges is of particular interest in relation to the Rivers Torridge and Dart because there are major sewage treatment works discharging to these rivers immediately downstream of the public water supply abstraction points.

The likely impact of the HOC on the dilution available for these effluents has been examined in accordance with NRA guidelines for assessing water quality criteria in relation to proposed licensable water abstractions.

Essentially, these guidelines state that the Warn-Brew system or similar water quality models should be used to identify the impact of a proposed abstraction on downstream water quality. Assessments must be made on the assumption that the relevant discharge consent conditions will be met. In order for a licence to be granted the abstraction should, where possible, meet the following criteria.

It should not:

(a) cause more than a 10% deterioration in the concentration of key determinands in the receiving waters,

(b) cause or add demonstrably to non-compliance with water quality objectives and standards,

(c) cause or add to any demonstrable detrimental effects on any identified use,

(d) cause or add demonstrably to non-compliance in respect of any EC Directive.

Calculations of whether river quality standards (RQS) can be met downstream of effluent discharges were originally based on the mass-balance equation:

$$T = \frac{FC + fc}{F + f}$$

Where: F is the river flow upstream of the discharge;

C is the concentration of pollutant in the river upstream of the discharge;

f is the flow of the discharge;

c is the concentration of pollutant in the discharge; and

T is the concentration of pollutant downstream of the discharge.

It is now known that these equations fail to define the true relation between river and discharge statistics; no matter what statistics are used for T, f, C and F, the value calculated for c is an unknown statistic. Conversely if c is presumed to be 95-percentile, the proportion of time which the RQS concentration will be met is unknown. This means that the calculation does not provide consent conditions which are matched correctly to river quality standards (Warn, 1982).

There are two methods which allow the correct calculation of mean and percentile values of T and the consent needed to achieve RQS's. These methods are called methods of Combining Distributions (CD-Methods) because they produce the distribution of T by combining the distributions of potential values of F, C, f and c.

The first method is called an analytical method because the problem is set out algebraically and solved by a series of specially derived equations which define the relation between the statistics of F, C, f and c and T. The other method uses the technique of Monte-Carlo Simulation. For routine calculations the Analytical Method is recommended because it is computationally efficient and has certain mathematical advantages over Monte-Carlo Simulation (Warn, 1982).

These methods are now commonly known as the Warn-Brew system and the Analytical Method was used to assess the impacts of the HOC on water quality downstream of Torrington and Totnes sewage treatment works.

Data which characterize the statistical distributions of the variables are required for the Warn-Brew calculations.

It has been found that the data can be presumed to be log-normally distributed which means that two statistics are required to characterize the distributions (Warn, 1982). Any two statistics may be used, so it is best to use those readily available.

These are:

- River flow - mean and 95-percent exceedence;
- Upstream river quality - mean and standard deviation;
- Discharge quality - mean and standard deviation or mean and 95-percentile.

River flow statistics for the period 1984-1989 inclusive were calculated for the historic flow regime and the modelled HOC flow regime in the Rivers Torridge and Dart, downstream of the public water supply abstraction points. These are shown in Table B7. As can be seen, the Q95 under the HOC is higher for both rivers than with the historic flow regime. On the Torridge the mean flow is virtually unchanged although on the Dart the HOC mean flow is less than historic.

These flow statistics were then used in a series of Warn-Brew calculations to compare the dilution available under the HOC flow regime with what occurred historically. Two determinands BOD and ammonia, were examined. Upstream river quality data for the period 1988-1990 inclusive was obtained from NRA Southwest. Effluent quality was assumed to comply with the relevant consent standards. The consent for Totnes STW will be significantly tighter from 1 April 1992. This higher quality has been assumed for these investigations. The results of the calculations are summarised in Figures B7 and B8. The detailed results are given in Appendix B2. As can be seen, the HOC leads to an improvement in the dilution available over the historic situation since low flows are enhanced. As a result, the concentration of pollutants downstream of Torrington and Totnes STW's should be less under the HOC than under the historic flow regime.

More generally, the dilution available for diffuse sources of effluent inputs agricultural run-off etc is also likely to be improved at times for several of the rivers. Flows in the River Tavy would be improved due to the stepped increase in pf on the Morwellham hydro-electric abstraction (agreed at Public Inquiry and incorporated into the HOC). This would also improve the dilution available for the Crownshill STW discharge. The introduction of a prescribed flow on the abstractions from the headwaters of the Dart into the Devonport Leat will lead to improved flows in the Dart at times as will the regulation releases from Roadford to the River Tamar.

Dilution for the effluent discharge from Marsh Mills STW at the top of the Plym estuary should also be improved through the HOC because spillage from Burrator Reservoir is generally greater with the HOC operating rules than occurred historically (see Hydrograph 8).

In addition to the impacts of the Roadford scheme, general water quality improvements should also result from capital works being undertaken by SWWS and farm pollution control campaigns etc being undertaken by the NRA.

B4 ESTUARINE WATER QUALITY

Each of the river abstraction which are involved in the Roadford scheme are effectively head of tide abstractions. Changes in the associated abstraction regimes is therefore of direct relevance to the quality of water in the upper estuaries, insofar as this is determined by the volume of fresh water entering the estuaries.

All of the rivers on which such abstractions are situated will, as a result of of the HOC, suffer no reductions in residual flow during low flow periods. Indeed, the converse will be true. In many cases the present residual flow will be increased. The magnitude of this increase is proportionately greatest in the Rivers Dart and Tavy. The proportionately smaller increase which will take place in the River Torridge is nevertheless of significance.

Consequently there will be no detrimental impacts upon estuarine water quality under such conditions. The dilution afforded to such effluents as Totnes STW will be increased, and very substantially so at low tide. The Rivers Dart, Tavy and Torridge each discharge into energetic, well mixed estuaries, whose tidal flushing volumes are large in comparison to the predicted changes in fresh water flows which they receive. Consequently reductions in estuarine salinity will be insignificant.

The primary factors which determine the quality of the Taw estuary are:

- The polluting loads imposed by the continuous sewage effluent discharges to the estuary.

- The way in which the tidal amplitude varies throughout the spring-neap cycle. Tidal amplitudes in both the Taw and the Torridge estuaries vary over a much wider range than those observed in the estuaries on the south coast (Tamar, Tavy, Plym and Dart). Spring tidal amplitudes are typically 40% greater in the Taw estuary than in the Dart estuary.

The Taw estuary is relatively insensitive to variations in fresh water flow, and so the predicted changes (which are very minor) in residual flow will have no significant impact upon the quality of the Taw estuary.

Quality in the upper Plym estuary is determined primarily by the polluting load from Marsh Mills STW, and by the fact that the upper estuary is comparatively broad and well flushed so close to its tidal limit. Small variations in fresh water flow will have no significant impact.

Accordingly it is concluded that the adoption of the Halcrow Operating Case could lead to an improvement in the quality of the Dart and Torridge estuaries, and to a lesser extent (since it receives no significant sewage effluents) the Tavy estuary. There will be no adverse impacts upon other estuaries.

REFERENCES

Murdoch N and Mann B (1989). Roadford Environmental Impact Assessment - Tamar Water Qaulity Modelling Study. NRA South West

Warn A E (1982). The Calculation of Consent Conditions for Discharges using Methods of Combining Distributions. Users Handbook - Anglian Water Authority

TABLE B1
SUMMARY OF EXISTING WATER QUALITY

River	Reach	EC Fishery Status	River Quality Objective	River Quality Classification					
				84	85	86	87	88	89
Tamar	Gunnislake	salmonid	1B	2	2	2	2	2	1B
Tavy	Lopwell Dam	salmonid	1B	1B	1B	1B	1A	1B	1A
Dart	Totnes Weir	salmonid	1A	1A	1A	2	1B	1B	1B
Meavy	Shaugh	salmonid	1A	1A	1A	1A	1A	1A	1B
Torridge	Torrington	salmonid	1B	1B	2	2	1B	1B	1B
Taw	New Bridge	salmonid	1B	1B	1B	1B	2	2	2

TABLE B2

WATER QUALITY IN THE TAVY CATCHMENT

*************** RIVER TAVY Existing Water Quality ***************	dissolved oxygen (mg/l) 5th percentile / median	BOD(ATU) (mg/l) median / 95th percentile	total ammonia (mg/l N) median / 95th percentile	pH 5th percentile / 95th percentile	suspended solids (mg/l) median / 95th percentile	phosphate (mg/l P) median / 95th percentile
Lopwell Dam	8.6	1.8	0.050	6.45	2.6	0.102
	10.4	3.2	0.190	7.75	26.0	0.286
Denham Bridge	9.3	1.7	0.041	6.63	3.4	0.100
	11.1	3.6	0.150	7.84	25.0	0.317
Wash Ford	9.0	1.8	0.100	6.64	3.2	0.170
	10.9	5.0	0.370	7.92	34.0	0.547
Shillamill (above Lumburn)	9.1	2.1	0.210	6.57	6.7	0.243
	11.0	5.5	0.750	7.57	67.0	0.947
West Bridge	9.3	1.6	0.023	6.47	4.2	0.023
	11.4	4.3	0.089	7.74	44.0	0.072
Harford Bridge	9.1	1.3	0.004	5.92	4.1	0.002
	11.2	4.5	0.099	7.38	49.0	0.081

TABLE B3

EXISTING WATER QUALITY IN THE PLYM

*************** RIVER PLYM Existing Water Quality ***************	dissolved oxygen (mg/l) 5th percentile / median	BOD(ATU) (mg/l) median / 95th percentile	total ammonia (mg/l N) median / 95th percentile	pH 5th percentile / 95th percentile	suspended solids (mg/l) median / 95th percentile	phosphate (mg/l P) median / 95th percentile
Plym Bridge	9.1 / 10.8	1.5 / 3.0	0.023 / 0.092	6.26 / 7.59	2.3 / 20.0	0.021 / 0.127
Shaugh Bridge	9.2 / 11.0	1.4 / 2.8	0.015 / 0.051	5.31 / 6.91	3.2 / 12.0	0.015 / 0.074
Cadover Bridge	9.1 / 10.9	1.4 / 2.6	0.017 / 0.055	4.77 / 6.49	6.7 / 29.0	0.011 / 0.026
Below Blackabrook	9.0 / 10.8	1.5 / 2.4	0.015 / 0.057	5.05 / 6.45	0.9 / 3.7	0.011 / 0.017

TABLE B4

EXISTING WATER QUALITY IN THE MEAVY

*************** RIVER MEAVY Existing Water Quality ***************	dissolved oxygen (mg/l) 5th percentile ----------- median	BOD(ATU) (mg/l) median ----------- 95th percentile	total ammonia (mg/l N) median ----------- 95th percentile	pH 5th percentile ----------- 95th percentile	suspended solids (mg/l) median ----------- 95th percentile	phosphate (mg/l P) median ----------- 95th percentile
Shaugh	9.4	1.4	0.020	6.31	1.5	0.039
	10.7	2.6	0.059	7.41	8.9	0.120
Gratton	9.5	1.4	0.017	6.03	1.7	0.011
	10.9	2.5	0.054	7.02	11.5	0.028
Below Burrator	8.7	1.4	0.022	5.81	1.6	0.008
	10.5	2.8	0.064	6.87	4.0	0.045
Above Burrator	9.7	1.3	0.012	5.56	1.0	0.011
	10.8	2.3	0.046	6.78	3.7	0.017

TABLE B5

EXISTING WATER QUALITY IN THE DART

*************** RIVER DART Existing Water Quality ***************	dissolved oxygen (mg/l) 5th percentile / median	BOD(ATU) (mg/l) median / 95th percentile	total ammonia (mg/l N) median / 95th percentile	pH 5th percentile / 95th percentile	suspended solids (mg/l) median / 95th percentile	phosphate (mg/l P) median / 95th percentile
Totnes Weir	8.6	1.1	0.050	6.95	2.0	0.032
	10.6	2.8	0.140	7.74	11.0	0.074
Riverford Bridge	8.6	1.1	0.045	7.08	1.8	0.023
	11.2	2.0	0.089	7.68	6.3	0.160
Austins Bridge	9.1	0.9	0.018	6.75	2.1	0.012
	11.2	1.9	0.041	7.77	9.3	0.029
Buckfast Abbey	9.5	0.9	0.012	6.58	1.4	0.011
	11.3	1.9	0.047	7.20	4.4	0.015

TABLE B6

EXISTING WATER QUALITY IN THE TORRIDGE

*************** RIVER TORRIDGE Existing Water Quality ***************	dissolved oxygen (mg/l)	BOD(ATU) (mg/l)	total ammonia (mg/l N)	pH	suspended solids (mg/l)	phosphate (mg/l P)
	5th percentile	median	median	5th percentile	median	median
	median	95th percentile	95th percentile	95th percentile	95th percentile	95th percentile
Beam Footbridge	8.7	1.6	0.057	7.03	8.7	0.099
	11.1	4.5	0.250	7.93	67.0	0.370
Rothern Bridge	8.5	1.6	0.050	6.83	9.9	0.092
	10.9	4.7	0.200	8.25	74.0	0.250
Town Mills, Torrington	8.3	1.5	0.031	6.48	12.4	0.088
	10.2	3.4	0.190	7.94	106.0	0.200
Newbridge	9.0	1.6	0.057	6.89	7.9	0.069
	11.1	3.7	0.200	7.89	47.0	0.250

TABLE B7

RIVER TORRIDGE AND DART FLOW STATISTICS 1984-1989
(downstream of PWS abstraction point)

RIVER	Torridge		Dart	
'CASE'	Historic	HOC	Historic	HOC
Q95 (Ml/d)	57.8	63.3	77.1	119.2
MEAN (Ml/d)	1334	1333.2	928	913.5

FIGURE B1

RIVER TAMAR CATCHMENT

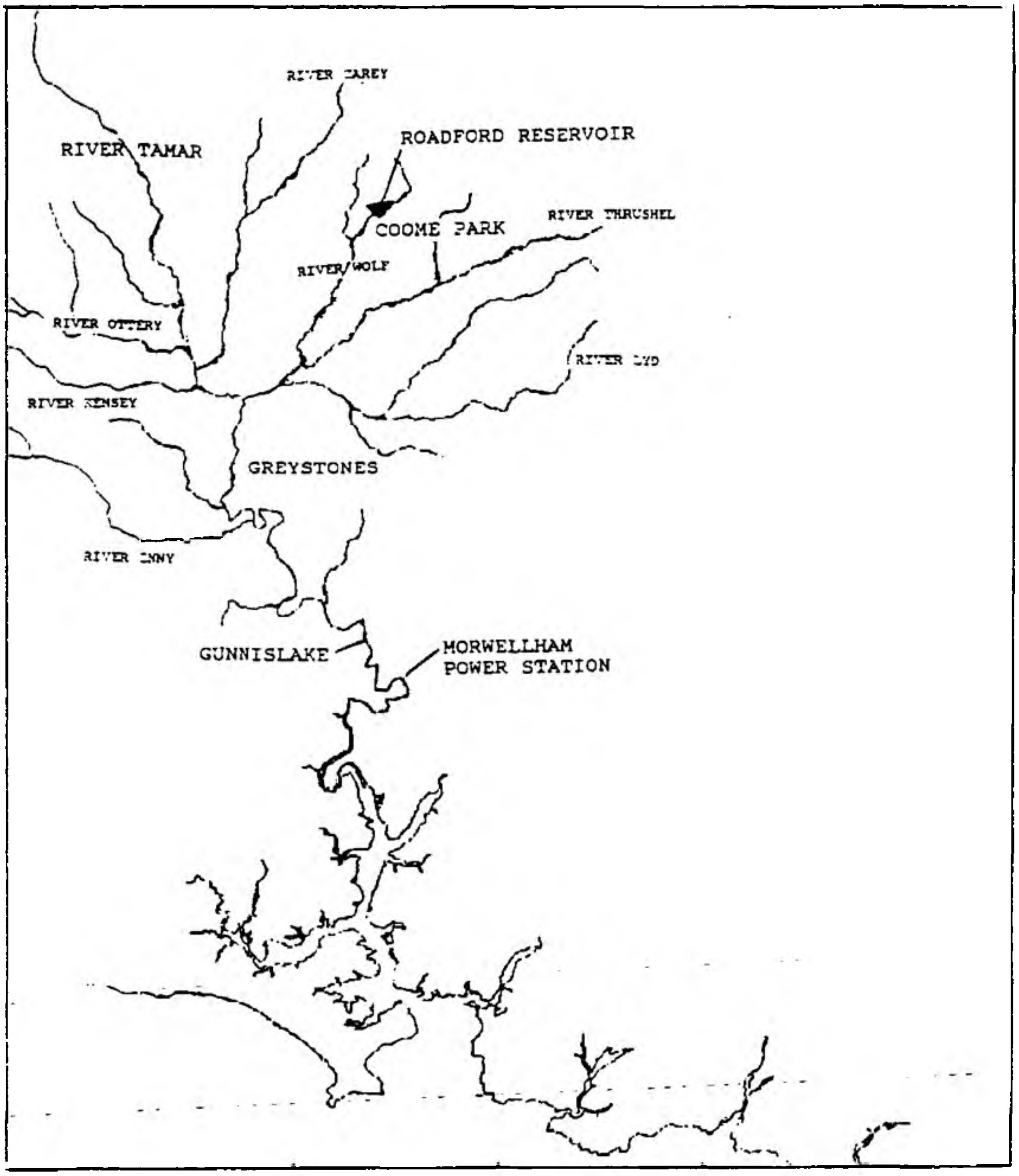
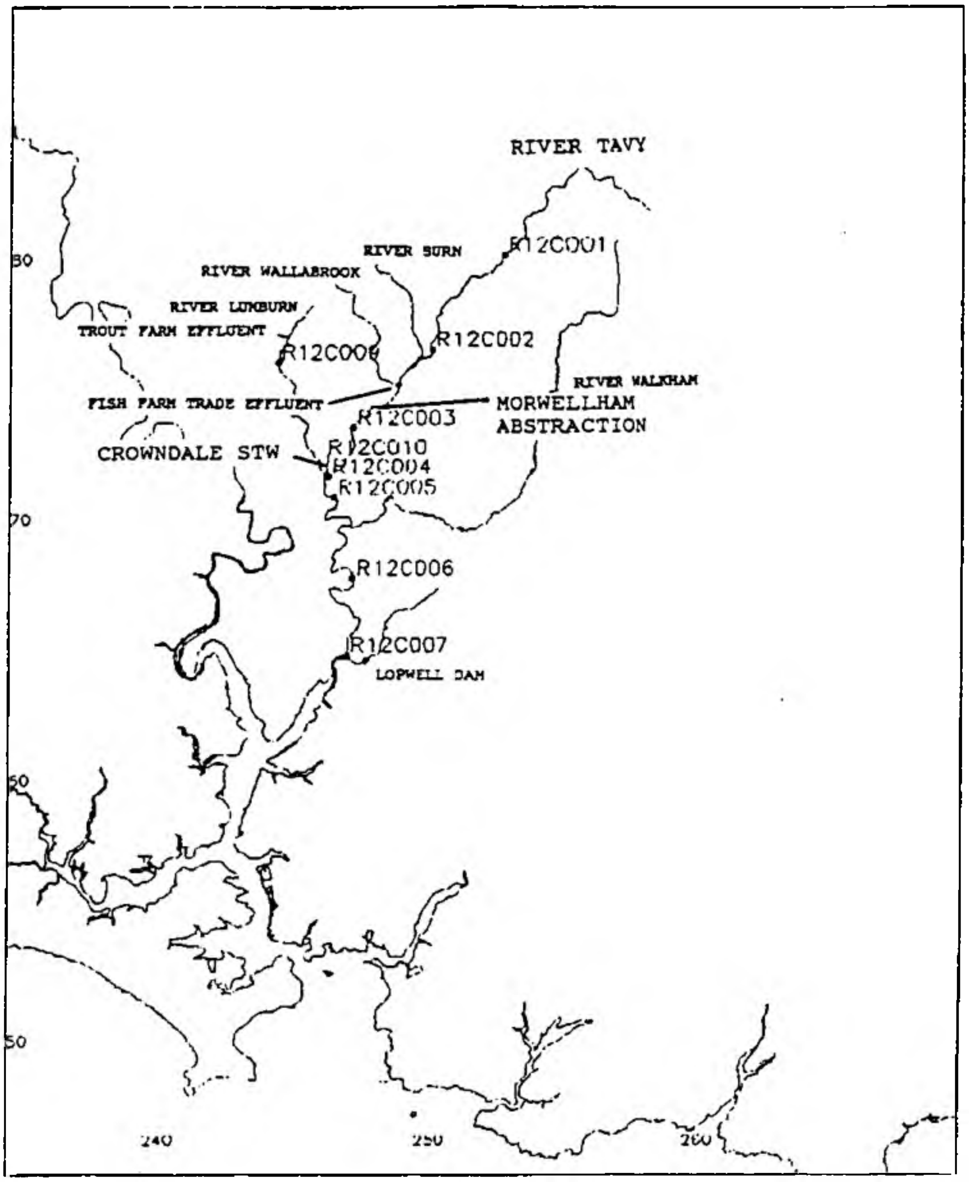


FIGURE B2

RIVER TAVY CATCHMENT



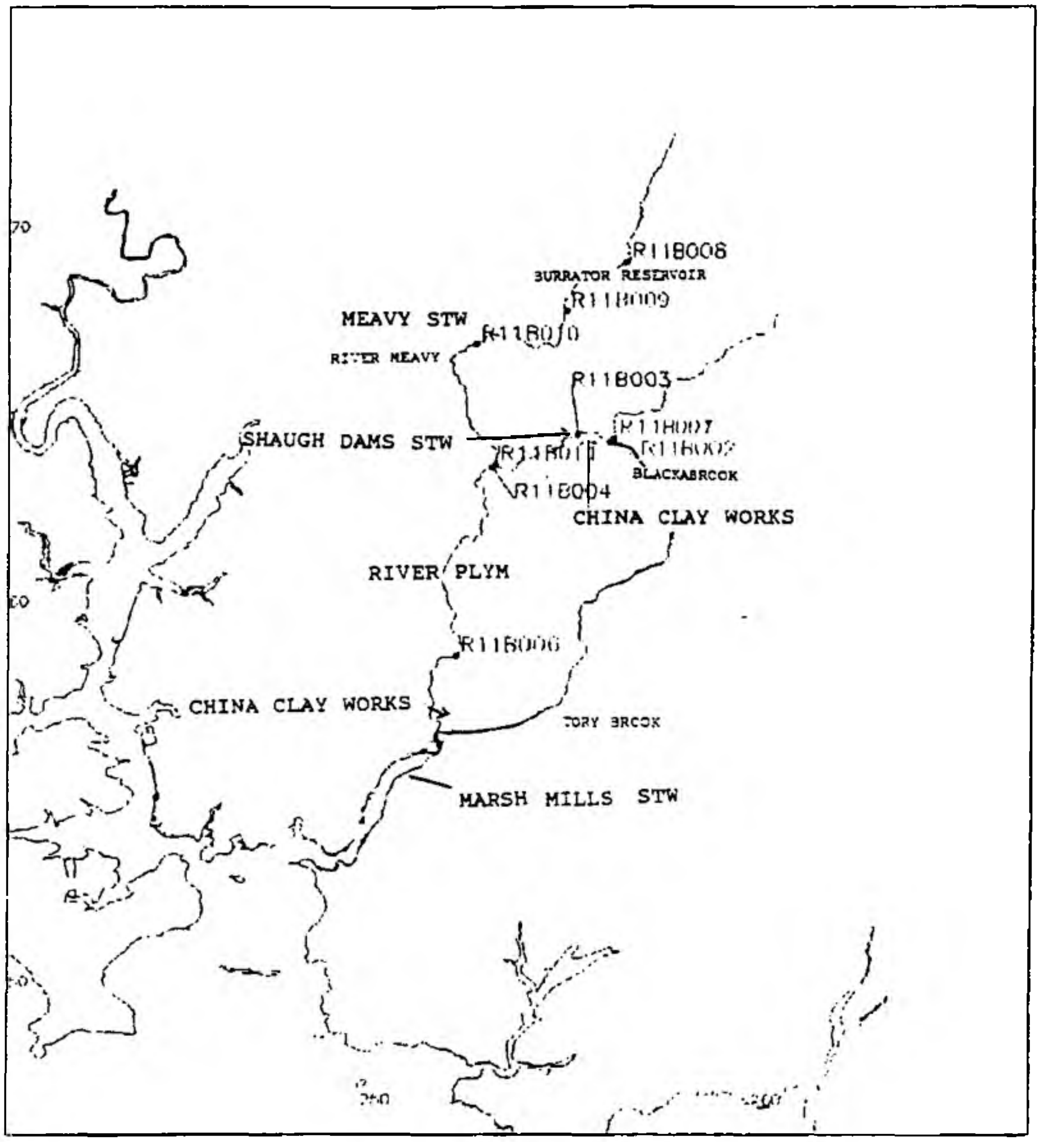
WATER QUALITY STATIONS

RIVER TAVY

R12C007	LOPWELL DAM
R12C006	DENHAM BRIDGE
R12C005	WASH FORD
R12C004	SHILLAMILL (ABOVE RIVER LUMBURN)
R12C003	WEST BRIDGE
R12C002	HARFORD BRIDGE
R12C001	HILL BRIDGE

FIGURE B3

RIVER PLYM CATCHMENT



WATER QUALITY STATIONS

RIVER PLYM

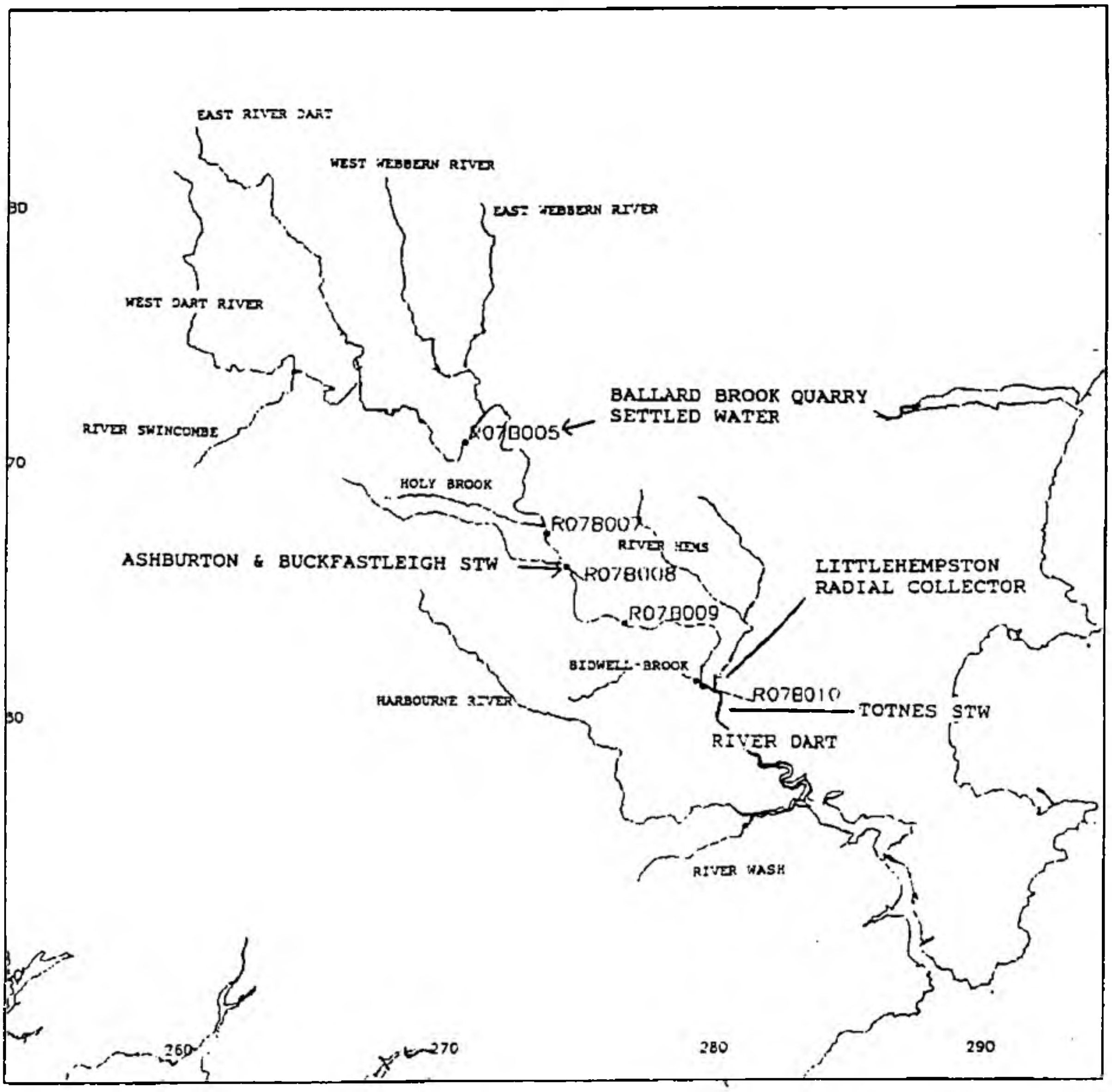
R11B006	PLYM BRIDGE
R11B004	SHAUGH BRIDGE (WOODEN)
R11B003	CADOVER BRIDGE
R11B002	BELOW BLACKABROOK
R11B001	ABOVE BLACKABROOK

RIVER MEAVY

R11B011	SHAUGH (AT CONFLUENCE)
R11B010	GRATTON FORD BRIDGE
R11B009	BELOW BURRATOR RESERVOIR (DAM)
R11B008	WEIR ABOVE BURRATOR RESERVOIR

FIGURE B4

RIVER DART CATCHMENT



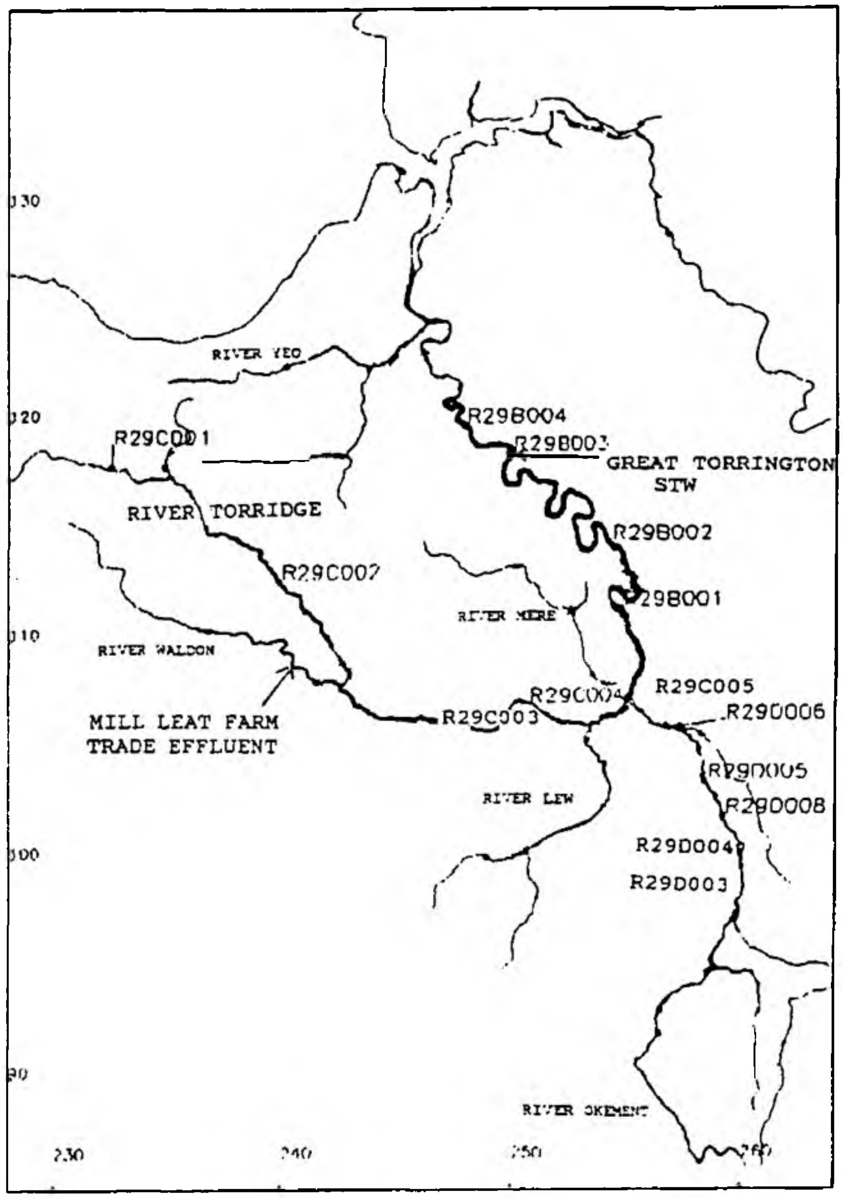
WATER QUALITY STATIONS

RIVER DART

R07B010	TOTNES WEIR
R07B009	RIVERFORD BRIDGE
R07B008	AUSTINS BRIDGE
R07B007	BUCKFAST ABBEY
R07B005	NEW BRIDGE

FIGURE B5

RIVER TORRIDGE CATCHMENT



WATER QUALITY STATIONS

RIVER TORRIDGE

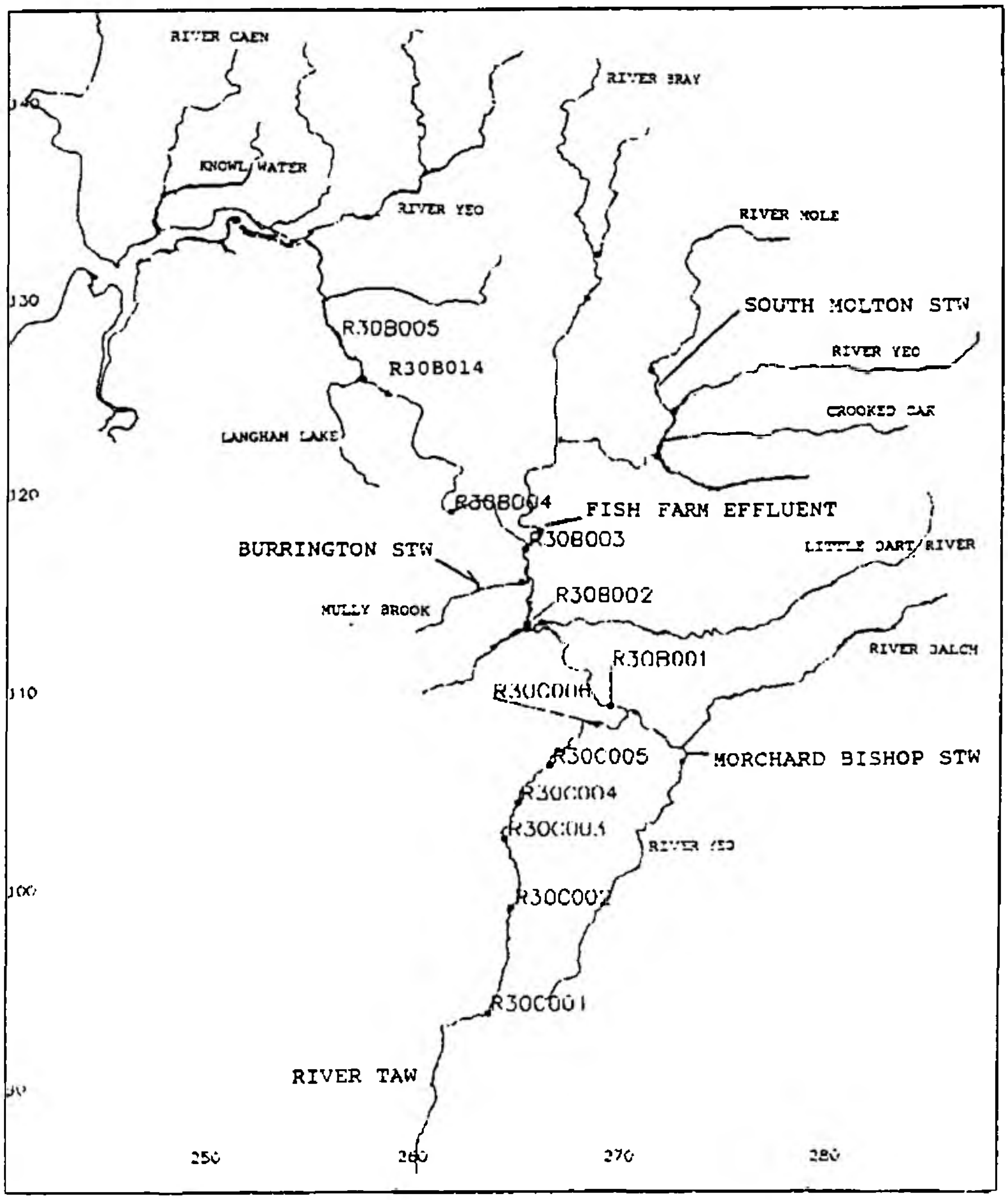
R29B034	BEAM FOOTBRIDGE
R29B004	ROTHERN BRIDGE
R29B003	TOWN MILLS TORRINGTON
R29B002	BEAFORD BRIDGE
R29B001	NEWBRIDGE
R29C005	HELE BRIDGE
R29C004	ROCKHAY BRIDGE
R29C003	KINGSLEY MILL
R29C002	WOODFORD BRIDGE
R29C001	FORDMILL FARM

RIVER OKEMENT

R29D006	IDDESLEIGH BRIDGE
R29D005	WOODHALL BRIDGE
R29D008	JACOBSTOWE
R29D004	SOUTH DORNAFORD
R29D003	BRIGHTLY BRIDGE

FIGURE B6

RIVER TAW CATCHMENT

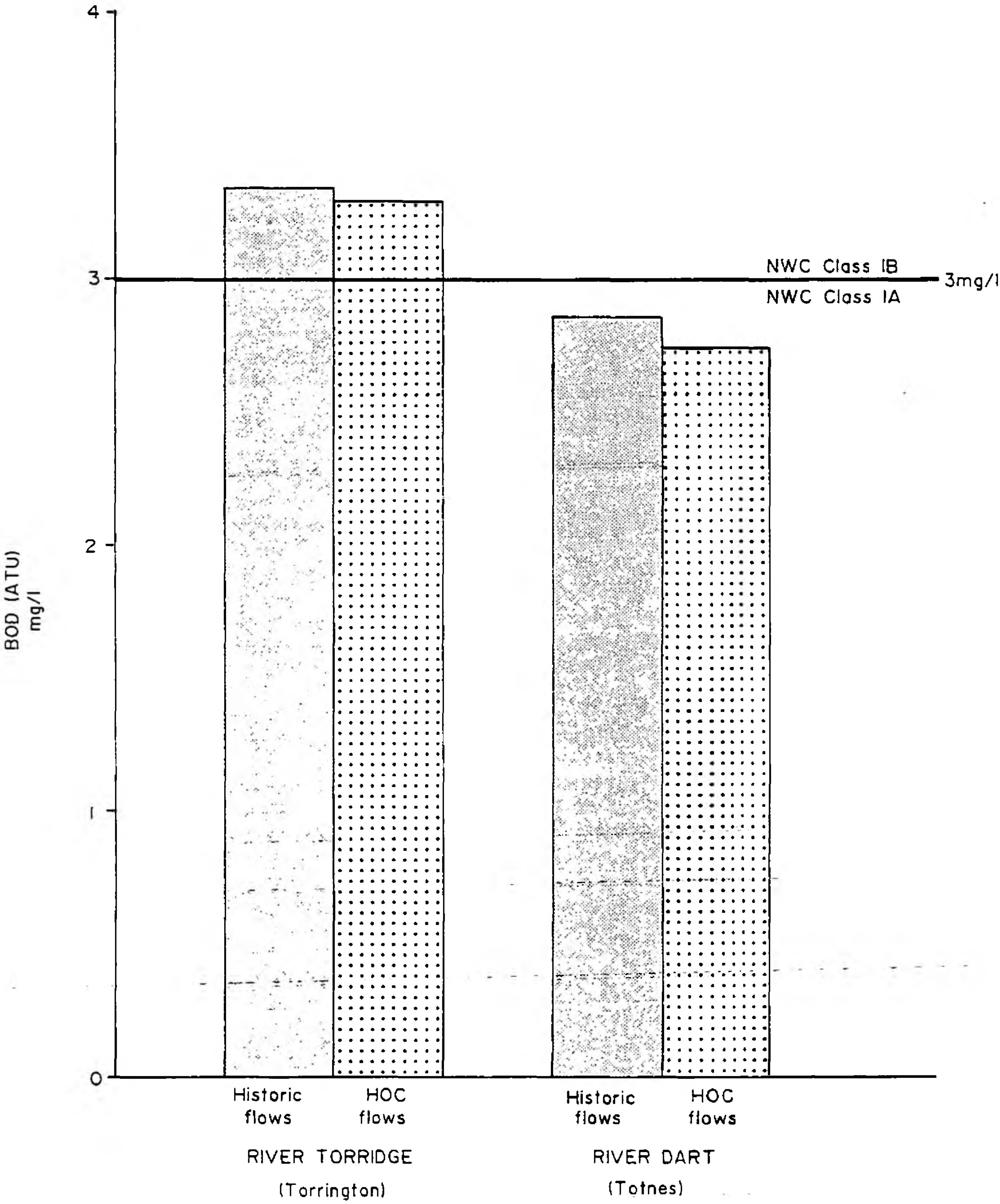


WATER QUALITY STATIONS

RIVER TAW

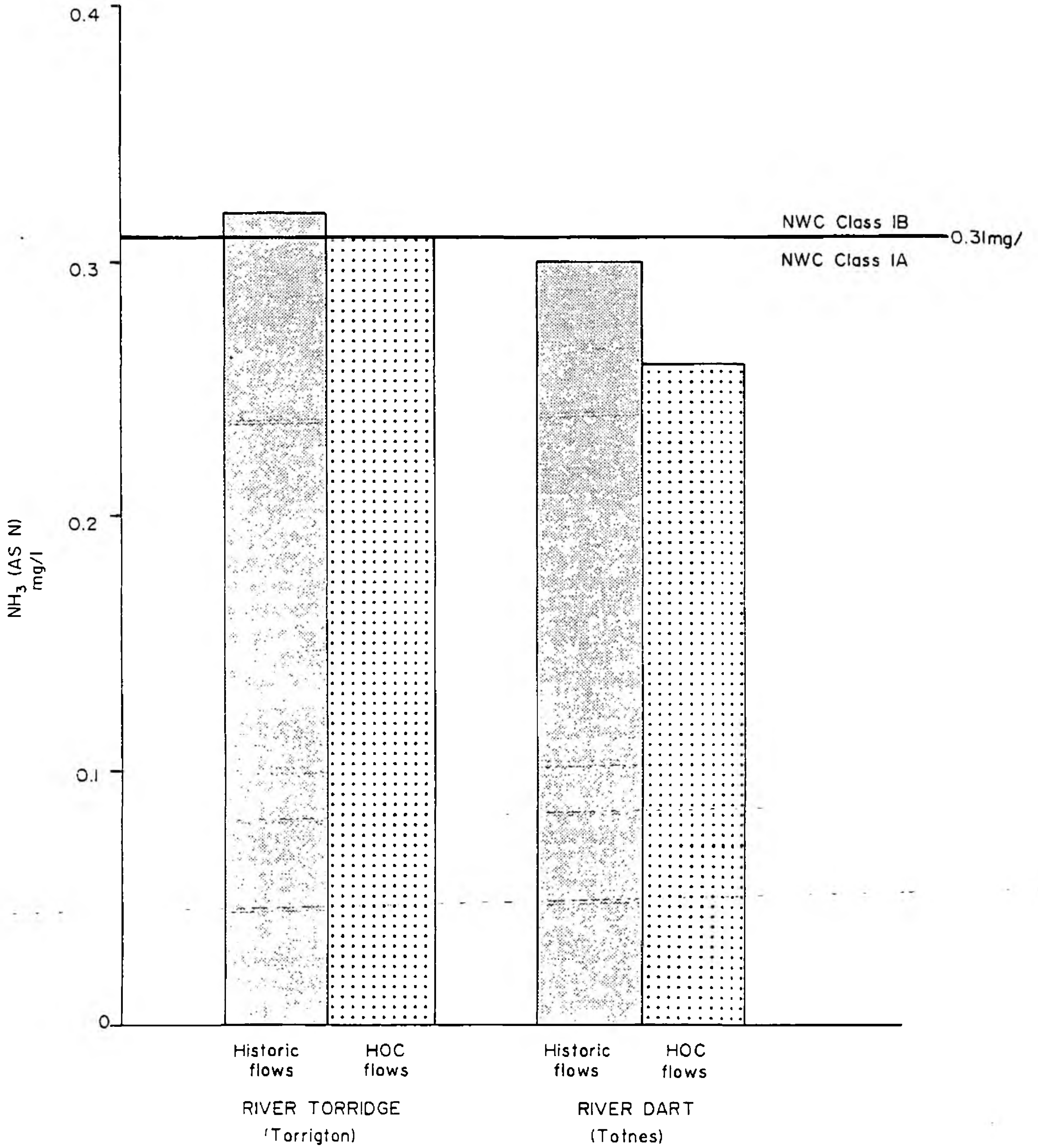
R30B005	NEW BRIDGE
R30B014	CHAPLETON
R30B004	KINGFORD
R30B003	NEWNHAM BRIDGE
R30B002	KERSHAM BRIDGE
R30B001	CHENSON
R30C006	HIGHER PARK
R30C005	TAW BRIDGE
R30C004	BONDLEIGH
R30C003	YEO FARM
R30C002	ROWDEN MOOR
R30C001	A.30 BRIDGE AT STICKLEPATH

Figure B7



BIOCHEMICAL OXYGEN DEMAND (ATU)

95 percentile river quality downstream of Torrington and Totnes STW'S



AMMONIACAL NITROGEN (AS N)
95 percentile river quality downstream of Torrington and Totnes STW'S

APPENDIX B1

HALCROW

ANNEX B1 - RIVER TAMAR

EXISITNG WATER QUALITY

B1.1 INTRODUCTION

In addition to water quality problems experienced in the estuary, concern has also been stated regarding the possible adverse effects of abstraction on the water quality in the freshwater reach downstream of Newbridge. Data derived from the continuous water quality stations at St Leonards and Gunnislake, together with the spot sample records allow an investigation of the water quality in the main stem Tamar upstream of the abstraction point. Spot samples taken at Gunnislake Weir in 1989 have been used to detect any significant deterioration downstream of the abstraction point. Water quality data derived in the drought conditions of 1989 will be similar, and possibly worse than those expected in the river when the abstraction point is operating to maximum capacity.

The main three determinands which have been investigated are dissolved oxygen (% saturation), water temperature (°C) and pH. Adverse levels of any of these determinands can inhibit fish migration and threaten both fish and the aquatic life.

Tables B1.1 and B1.2 show the mean values and range for each of these determinands recorded at St Leonards and Gunnislake, years 1987 - 89 and 1987 - 1988 respectively. The Tables present monthly summaries of approximately 2200 individual 20 - minute readings (Maximum number of individual readings per year of 26,784 for each determinand). Continuous records for the three determinands were not possible at Gunnislake during 1989. This was due to numerous and varied site problems associated with the construction works on the new abstraction point at Newbridge. Omission of the limited and unedited data is supplemented by the records for St Leonards and the spot samples in 1989. Table B1.3 shows all spot sample records for Gunnislake presented as monthly mean values for the months May to September and for each year 1987 - 1989. Table B1.4 shows the mean values for the three determinands recorded at Gunnislake Bridge and Gunnislake Weir (May - September 1989). The majority of spot samples were taken at these two sites on the same day within 15 - 30 minutes of each other.

B1.2 PHOTOSYNTHETIC ACTIVITY

Rivers receive oxygen either via atmospheric exchange or via aquatic plants and photosynthesis. Photosynthetic activity is enhanced by temperature and can result in daily and seasonal variations in dissolved oxygen and pH levels. Algae are the main primary producers in the Tamar which in the process of photosynthesis use solar energy to convert carbon dioxide and water to sugar.

The amount of oxygen produced depends on several factors, but the main factor is light intensity. As expected photosynthetic activity ceases at night.

A cyclical oscillation is recorded in dissolved oxygen concentration in each 24-hour period (eg. Figure B1.1). Photosynthetic activity results in the lowest dissolved oxygen levels around dawn, but peaks mid-afternoon as light intensity increases and temperature rises. The peak in dissolved oxygen will exceed 100% saturation, with levels up to 200% being possible. At night the saturation level falls as the demand on oxygen increases caused by the respiration of plants, animals and micro organisms. The cyclical oscilation is exaggered in slow flowing and pooled sections of river, whereas in turbulent waters little diel change is observed.

In conjunction with oscillations in dissolved oxygen, photosynthtic activity affects pH levels in the river. During daylight, when plants are excreting oxygen and consuming carbon dioxide the pH can exceed 9. Conversely at night, the plants respiration consumes oxygen and excretes carbon dioxide. Carbon dioxide reacts with water to form carbonic acid which reduces pH to less than pH7. (See Figure B1.1)

B1.3 DISCUSSION

Monthly mean dissolved oxygen concentration recorded at the continuous water quality stations rarely fell below 90% saturation. The lowest monthly mean value of 76.7% was recorded in January 1987. Under the right conditions a large daily variation in dissolved oxygen due to photosynthetic activity was recorded. The minimum and maximum individual dissolved oxygen concentrations recorded at St Leonards and Gunnislake over each period of record were 72.5 - 124% and 57.5 - 164% respectively.

The continuous records for Gunnislake are supported by the spot sample results for the same period. Mean monthly records did not drop below 90% saturation. The minimum and maximum of all spot samples were 76% and 138% respectively. The spot sample results represent samples taken in a selected time period of 10.00 hours to 15.00 hours. Hence these values are predictably higher as oxygen production due to photosynthesis is increasing to its mid-afternoon peak. The range in dissolved oxygen recorded at the water quality station represents the actual range of oxygen variation experienced by the fish and other biota in any 24 hour period. While Gunnislake was not fully operational in 1989 it can be inferred from the St Leonards data than the mean monthly values were not significantly different from those readings in previous years and as such those expected at Gunnislake in 1989. The spot samples give support to this factor, although the precise extremities of diel changes experienced in the lower Tamar are unknown. However the range of dissolved oxygen recorded at St Leonards in June 1989 was 72.5 - 164% saturation (See Figure B1.1).

The dissolved oxygen levels recorded at Gunnislake Bridge and Gunnislake Weir show mean monthly values greater than 90% saturation. The largest variation in concentrations was experienced at the weir, range 56% to 155%. Figures B1.2 and B1.3. show plots of the spot sample results for pH, dissolved oxygen and temperature levels recorded at Gunnislake Bridge and Gunnislake Weir in the period May - September 1989. Photosynthetic activity is high in the lower reaches of the Tamar, which results in a major input of oxygen into the river. The area downstream of the abstraction point is a relatively slow flowing reach retained by the weir. Blooms of algae occur on an annual basis, irrespective of dry or wet years. The magnitude, duration and frequency of occurrence of these blooms is enhanced when the most favourable conditions prevail, ie, low flows, elevated temperatures and increased solar input.

Dissolved oxygen is essential, and in some cases even the limiting factor for maintaining aquatic life. Sensitivity to low dissolved oxygen concentrations differs between species, between the various life stages (eggs - adults) and between the different life processes (feeding, reproduction, migration behaviour). Providing that other environmental factors are favourable, a minimum constant value of 5 mg/l would be satisfactory for most stages and activities in the life cycle of salmonids. However as seen earlier, dissolved oxygen levels in a river fluctuate and this resulted in criteria expressed as minimum percentage distribution over a year. An overall figure of dissolved oxygen for waters supporting salmonid fish was suggested by EIFAC, the annual 50-percentile concentration should be at least 9 mg/l, but the annual 5-percentile could be as low as 5 mg/l. The Freshwater Fish Directive (78/659/EEC) sets guide values for salmonid waters of 50-percentile concentrations of at least 9 mg/l and 100-percentile of at least 7 mg/l. The corresponding mandatory value is 50-percentile concentrations of 8 mg/l. The Directive specifies dissolved oxygen concentrations as mg/l, whereas the data presented are recorded as %age saturation. Figure B1.4 shows a nomogram for inter converting mg/l to % saturation . Table B1.5 has been compiled so that % saturation levels are placed in context of mg/l concentrations for a selected range of temperatures.

The minimum levels of dissolved oxygen recorded in the main stem Tamar between 1987 - 1989 are unlikely to have a detrimental effect on the salmonid stocks of the river. Even the extreme diel variations in dissolved oxygen concentrations alone are unlikely to inhibit the migration of salmonids in freshwater.

No single water quality criteria can be given for a specific pollutant irrespective of other environmental variables or factors. Differences in the chemical constituents of the water, and in the sensitivity of various species of fish, may all modify the potential hazard of any given concentration of pollutant. There is no definite pH range within which a fishery is unharmed and outside which it is damaged, but rather there is a gradual deterioration as the pH values are further removed from the normal range. The pH range which is not directly lethal to fish is pH 5 - 9. The toxicity of several common pollutants is markedly affected by pH changes within this range, and increasing acidity or alkalinity may make these pollutants more toxic. The productivity of the aquatic ecosystem is considerably reduced below a pH value of 5.0, so that the yield from a fishery would become less. pH values above 10 are lethal to fish life. The Freshwater Fish Directive sets mandatory values of pH 6 - 9 in order to protect both salmonid and cyprinid waters.

Overall, the pH levels in the Tamar are slightly alkaline and as such are not likely to have a direct impact on the biota. Under extreme conditions high pH values, greater than pH9, can be achieved for a short time due to the vigorous photosynthetic activity of aquatic plants. These pH levels alone are unlikely to result in fish kills. Fish behaviour may be altered due to other contributary factors such as high temperatures and supersaturation of dissolved oxygen gases.

There is a normal range of temperatures in the temperate region of 0 - 30 C to which fish are adapted. Fish differ in their tolerance to high temperature depending on species, stage of development, acclimation temperature, dissolved oxygen, pollution and season. Freshwater fish indigenous to the temperate regions are adapted to seasonal changes in temperature and they are also capable of withstanding changes outside this range for a short duration. Members of the genus Salmo can survive in natural water temperatures of 23 - 24 C. These temperatures only occur in the Tamar for relatively short periods during extreme drought conditions. These peak daily temperatures can under certain circumstances cause deaths but are more likely to place the fish under stress and cause changes in fish behaviour.

Various observers reported that throughout the harshest period of the 1989 drought, many hundreds if not thousands of adult salmon and sea trout accumulated in the freshwater reach between Newbridge and Gunnislake Weir. Fish continued to migrate into the pool retained by the weir throughout the summer. Water quality was sufficiently good to support adult salmonids for several weeks and/or months, under the extreme conditions of low flows, borderline critical water temperatures and with diel fluctuations in dissolved oxygen levels. Fish remained in the 'sanctuary' of the pool until conditions improved. The occasional summer spates were sufficient to stimulate a fresh influx of salmonids from the estuary. The salmonids 'resident' in the pool for a relatively short period of 1 - 3 weeks were available to migrate upstream. Longer term residents were unlikely to migrate out of the pool until later in the year.

Conditions encountered in the pool during 1989 would be considered stressful to salmonid life. Even so, the dissolved oxygen and temperature levels never became critical and no fish died. If water quality conditions had deteriorated significantly there would have resulted a major fish kill in this freshwater reach. This would have been in addition to other mortalities in the estuary. Historically, no major fish kills have ever been recorded in this specific freshwater reach due to deterioration in 'natural' river water quality. Freshwater quality conditions prevailing in the Gunnislake area in 1989 should be considered similar to, if not worse than those expected when the abstraction point at Newbridge is operational. As a result it is considered unlikely that the operation of the intake will have a detrimental impact on the water quality of the River Tamar.

B1.4 CONCLUSIONS

1. In the hot dry summer of 1989, the reduced flows and increased retention times in the freshwater reach between Newbridge and Gunnislake Weir were beneficial to phytoplankton growth and the enhancement of primary production. Daytime concentrations of dissolved oxygen increased to supersaturation levels due to photosynthetic activity. As a result, dissolved oxygen levels never became critical, due to increased oxygen demands and consequently salmonid life was never placed at risk. Salmonid life was sustained with extreme oxygen variations of 56 - 155% and pH 6.4 - 9.5, with maximum daily temperature of 23.7°C.

2. The presence of an algal bloom in the freshwater reach downstream of the abstraction point in any year will ameliorate for any oxygen deficiency in the river upstream of Gunnislake. Photosynthetic activity results in an increase in dissolved oxygen levels of the residual flows to the estuary. This benefits those fish entering the river from the harsh estuarine environment.

If at any time photosynthetic activity should be reduced in the freshwater reach downstream of the abstraction point then the oxygen demand would dominate. This may result in an oxygen sag in the pool relative to the background concentration of the inflow waters. Fortunately no extreme case of this scenario has occurred as historically no major fish kill has ever been recorded in this reach.

3. Any long term improvement in the water quality of the River Tamar, in particular a reduction in the BOD concentration would enable the river to comply with its RQO of 1B. This would benefit the whole river, but specifically the freshwater zone by reducing the oxygen demand at times when photosynthetic activity would be minimal.

4. The water quality conditions prevailing in the freshwater reach between Newbridge and Gunnislake Weir in 1989 are considered similar to or worse than those expected when the abstraction point is operational. Salmonid life was sustained in the pool throughout 1989. As a result it is considered unlikely that the operation of the abstraction point will have a significant effect on the water quality downstream and subsequently on the salmonid stocks resident in the freshwater reach.

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Project Manager (Roadford F & E)

K Broad
Roadford Fisheries Biologist

TABLE B1.1

Monthly Mean Values for Dissolved Oxygen, pH and Temperature.
(including minimum and maximum individual values in each month).

Water Quality Station : St. Leonards

Year	Month	D.O. - % Sat.		pH		Temperature - °C	
		Mean	Range	Mean	Range	Mean	Range
1987	Jan.	-	-	7.4	7.3 - 7.5	3.3	0.6 - 5.0
	Feb.	-	-	7.3	6.8 - 7.5	6.4	0.6 - 10.6
	Mar.	95.4	78.7 - 104.0	7.2	7.0 - 7.5	5.1	1.9 - 10.6
	Apr.	96.4	82.5 - 125.0	7.3	6.8 - 9.0	9.3	5.0 - 15.0
	May.	97.6	76.3 - 125.0	8.0	6.7 - 9.5	10.8	7.5 - 15.6
	June	79.2	66.2 - 87.5	6.9	6.7 - 7.2	11.8	6.9 - 18.7
	July	93.9	72.5 - 121.0	7.2	6.4 - 8.4	16.3	14.4 - 20.6
	Aug.	94.4	78.7 - 111.0	7.8	7.3 - 8.7	15.9	11.9 - 20.0
	Sept.	90.7	77.5 - 112.0	7.5	7.2 - 8.2	13.2	6.9 - 16.9
	Oct.	96.2	85.0 - 111.0	7.0	6.3 - 8.1	8.8	5.0 - 11.9
	Nov.	-	-	7.0	6.2 - 7.3	6.4	1.3 - 11.2
	Dec.	86.6	81.2 - 93.7	7.1	7.0 - 7.3	6.5	1.3 - 11.9
1988	Jan.	-	-	6.9	6.7 - 7.1	7.7	5.6 - 10.0
	Feb.	99.8	90.0 - 110.0	6.9	6.6 - 7.1	6.9	4.4 - 11.9
	Mar.	99.2	78.7 - 149.0	7.1	6.8 - 8.5	8.1	3.8 - 10.6
	Apr.	104.3	81.2 - 153.0	7.3	6.8 - 7.8	11.4	7.5 - 16.9
	May	94.6	68.7 - 136.0	-	-	14.1	11.2 - 20.0
	June	106.3	71.2 - 144.0	7.8	7.0 - 9.1	15.9	11.2 - 21.2
	July	89.9	77.5 - 127.0	7.0	6.4 - 8.3	15.2	11.9 - 18.7
	Aug.	93.6	78.7 - 120.0	7.2	6.4 - 8.1	15.3	11.9 - 19.4
	Sept.	97.8	78.7 - 127.0	7.2	6.7 - 8.1	13.6	10.0 - 18.1
	Oct.	98.6	91.2 - 109.0	7.1	6.8 - 7.3	10.8	5.6 - 13.8
	Nov.	96.9	78.7 - 120.0	7.3	6.8 - 7.9	5.7	0.6 - 10.6
	Dec.	92.1	78.7 102.0	7.2	6.8 - 7.3	7.9	4.4 - 11.2
1989	Jan.	90.7	82.5 - 104.0	7.2	6.8 - 7.4	6.1	2.5 - 8.8
	Feb.	88.0	78.7 - 101.0	7.1	6.6 - 7.5	5.8	1.9 - 8.8
	Mar.	91.8	75.0 - 102.0	6.9	6.4 - 7.1	7.4	3.8 - 11.9
	Apr.	-	-	7.4	6.8 - 9.0	7.6	5.0 - 10.6
	May	-	-	7.5	6.8 - 9.2	15.0	8.8 - 22.0
	June	97.5	72.5 - 164.0	7.6	7.0 - 9.0	16.0	10.6 - 23.1
	July	93.7	57.5 - 134.0	7.5	7.0 - 8.3	19.4	13.8 - 23.7

TABLE B1.2

Monthly Mean Values for Dissolved Oxygen, pH and Temperature.
(including minimum and maximum individual values in each month)

Water Quality Station : Gunnislake

Year	Month	DO - % Sat		pH		Temperature °c	
		Mean	Range	Mean	Range	Mean	Range
1987	January	76.7	72.5 - 78.7	-	-	3.6	0.6 - 7.2
	February	93.1	85.0 - 97.5	-	-	4.4	0.9 - 8.1
	March	86.1	78.7 - 96.2	-	-	4.8	1.6 - 7.8
	April	100.2	93.7 - 114.0	7.5	7.3 - 8.2	9.7	5.6 - 14.4
	May	99.2	76.3 - 124.0	7.9	7.3 - 9.1	11.0	7.8 - 14.4
	June	82.4	72.5 - 95.0	7.3	7.1 - 7.7	13.1	9.7 - 17.8
	July	-	-	7.4	7.0 - 8.1	15.9	13.1 - 20.0
	August	-	-	7.6	7.2 - 8.7	15.3	12.2 - 18.8
	September	-	-	7.5	7.3 - 8.1	13.4	7.5 - 16.9
	October	-	-	7.1	6.8 - 7.8	9.0	6.6 - 12.5
	November	91.2	77.5 - 97.5	7.2	7.0 - 7.5	6.9	2.8 - 10.0
	December	89.4	82.5 - 95.0	7.5	7.2 - 7.7	5.4	1.3 - 10.0
1988	January	98.8	91.2 - 102.0	7.6	7.3 - 7.7	6.1	4.7 - 7.2
	February	95.8	85.0 - 109.0	7.6	7.3 - 7.9	5.7	3.4 - 8.1
	March	98.7	83.7 - 111.0	7.8	7.2 - 8.2	6.7	2.8 - 8.4
	April	97.1	87.5 - 109.0	7.9	7.4 - 8.6	8.9	6.3 - 13.1
	May	93.8	85.0 - 108.0	7.8	7.5 - 8.5	11.8	9.4 - 16.9
	June	-	-	8.2	7.5 - 9.7	16.3	12.8 - 19.4
	July	99.2	93.7 - 115.0	7.4	7.1 - 9.1	15.6	13.7 - 18.8
	August	98.9	87.5 - 114.0	7.5	7.2 - 8.1	15.8	13.7 - 18.4
	September	91.2	76.3 - 104.0	7.7	7.3 - 8.1	14.6	11.6 - 17.5
	October	97.4	83.7 - 108.0	7.5	7.3 - 7.7	12.5	7.8 - 14.7
	November	93.3	77.5 - 109.0	7.6	7.2 - 7.8	7.6	3.8 - 12.2
	December	94.3	76.3 - 101.0	7.5	7.1 - 7.7	9.3	6.3 - 11.2

TABLE B1.3 Monthly Mean Values for Dissolved Oxygen, pH and Temperature for all Spot Samples Taken at Gunnislake Bridge, period 1987 - 1989

1987

a. pH

	Mean	Min - Max.
May	7.7	7.3 - 8.1
June	7.4	7.2 - 7.6
July	7.8	6.9 - 8.5
August	7.8	7.5 - 9.0
September	7.6	7.4 - 7.8

b. DO.

	Mean	Min - Max.
May	96.1	86 - 108
June	95.0	82 - 103
July	95.6	86 - 108
August	94.9	87 - 104
September	92.6	86 - 104

c. Temp.

	Mean	Min - Max.
May	11.8	10.5 - 14.0
June	14.2	12.0 - 18.0
July	17.6	15.5 - 20.0
August	16.5	14.5 - 19.0
September	14.3	8.5 - 17.0

1988

a. pH

	Mean	Min - Max.
May	7.5	6.9 - 7.8
June	8.1	7.6 - 9.2
July	7.5	6.9 - 7.8
August	7.6	7.4 - 7.7
September	7.5	6.9 - 7.8

b. DO.

	Mean	Min - Max.
May	91.2	78 - 101
June	98.6	80 - 129
July	90.8	82 - 107
August	96.4	89 - 108
September	96.5	90 - 105

c. Temp.

	Mean	Min - Max.
May	12.6	10.5 - 15.0
June	15.2	11.5 - 18.0
July	14.4	13.0 - 16.0
August	14.7	18.0 - 16.0
September	12.8	12.0 - 14.0

1989

a. pH

	Mean	Min - Max.
May	7.4	6.8 - 7.9
June	7.9	6.7 - 9.3
July	7.8	7.2 - 8.7
August	7.9	7.2 - 8.5
September	7.6	6.5 - 8.6

b. DO.

	Mean	Min - Max.
May	104.8	93 - 130
June	111.0	84 - 138
July	104.7	85 - 126
August	97.4	76 - 113
September	91.3	76 - 104

c. Temp.

	Mean	Min - Max.
May	14.9	11.0 - 20.0
June	17.8	12.0 - 20.5
July	20.4	19.0 - 22.0
August	19.5	17.5 - 27.2
September	14.7	13.5 - 16.5

TABLE B1.4 Monthly Mean Values for Dissolved Oxygen, pH and Temperature Recorded for Comparable Spot Samples Taken at Gunnislake Bridge and Gunnislake Weir in 1989

Gunnislake Bridge 1989

a. pH

	Mean	Min - Max.
May	7.4	6.8 - 7.9
June	7.8	6.7 - 9.3
July	8.0	7.3 - 8.7
August	7.9	8.2 - 8.5
September	7.4	6.5 - 8.4

b. DO.

	Mean	Min - Max.
May	108	97 - 103
June	108	84 - 138
July	110	87 - 126
August	95	76 - 113
September	92	81 - 104

c. Temp.

	Mean	Min - Max.
May	15.7	11.0 - 20.0
June	17.4	12.0 - 20.0
July	20.5	19.0 - 22.0
August	19.0	17.5 - 23.0
September	15.1	13.5 - 16.5

Gunnislake Weir 1989

a. pH

	Mean	Min - Max.
May	7.4	7.0 - 7.6
June	8.0	6.9 - 9.4
July	7.9	7.1 - 8.4
August	7.9	7.2 - 8.6
September	8.0	6.9 - 9.0

b. DO.

	Mean	Min - Max.
May	99	86 - 104
June	109	56 - 155
July	104	100 - 107
August	108	98 - 122
September	103	86 - 131

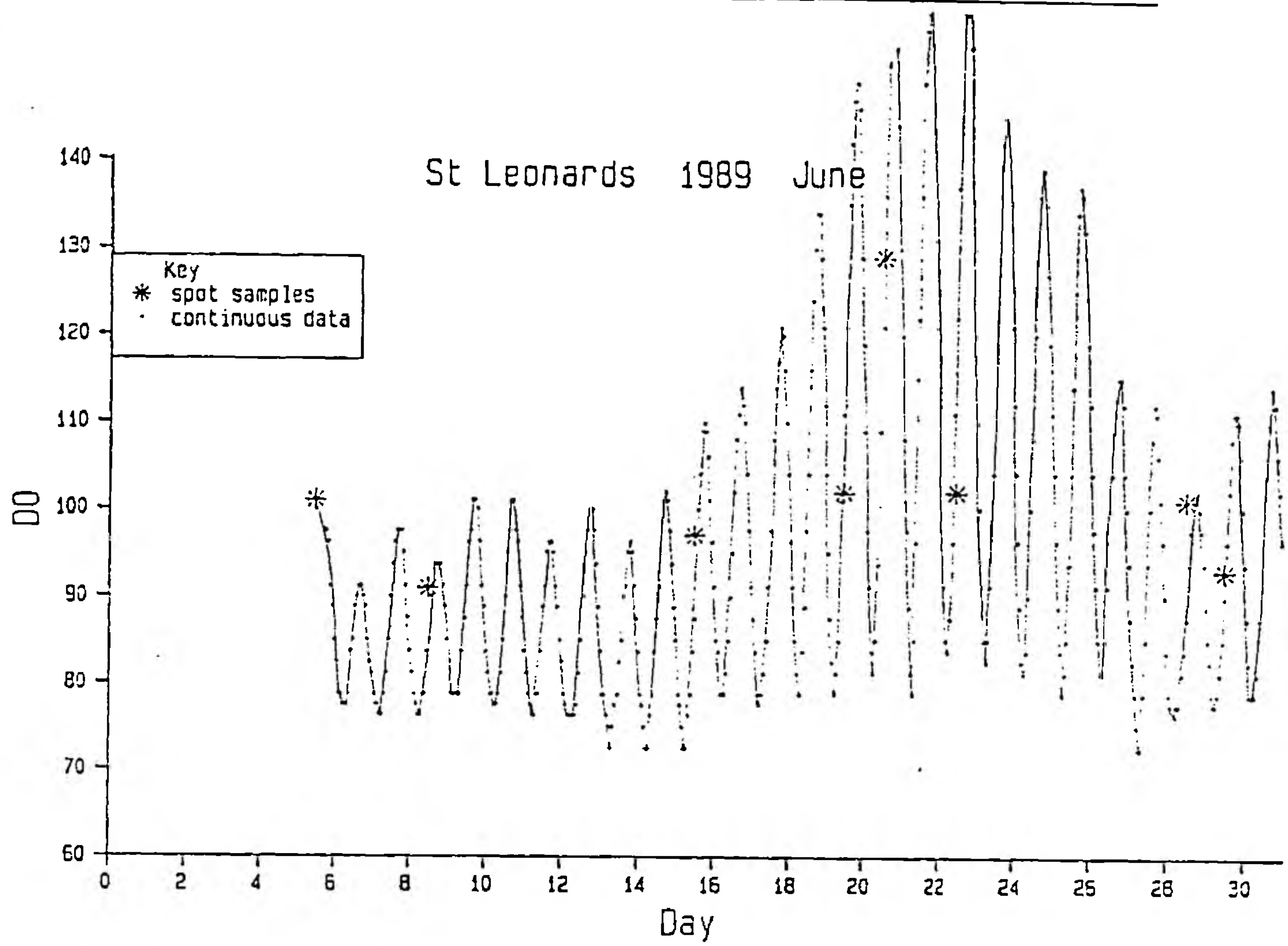
c. Temp.

	Mean	Min - Max.
May	15.5	11.0 - 20.0
June	17.9	12.0 - 22.0
July	21.7	21.0 - 22.0
August	18.9	18.0 - 20.0
September	16.4	15.0 - 17.0

TABLE B1.5 Dissolved Oxygen as % Saturation Levels for Equivalent Concentration Values (mg/l) and Selected Temperatures. [Concentration Values mg/l are those Detailed in the Freshwater Fish Directive].

Concentration mg/l	Water Temperature °C			
	5	10	15	20
5	39	45	50	56
7	55	63	70	78
8	62	72	80	89
9	70	80	90	100

FIGURE B1.1 **Daily Fluctuations in Dissolved Oxygen and pH Levels Recorded at St Leonards Water Quality Station : Period June 1989**



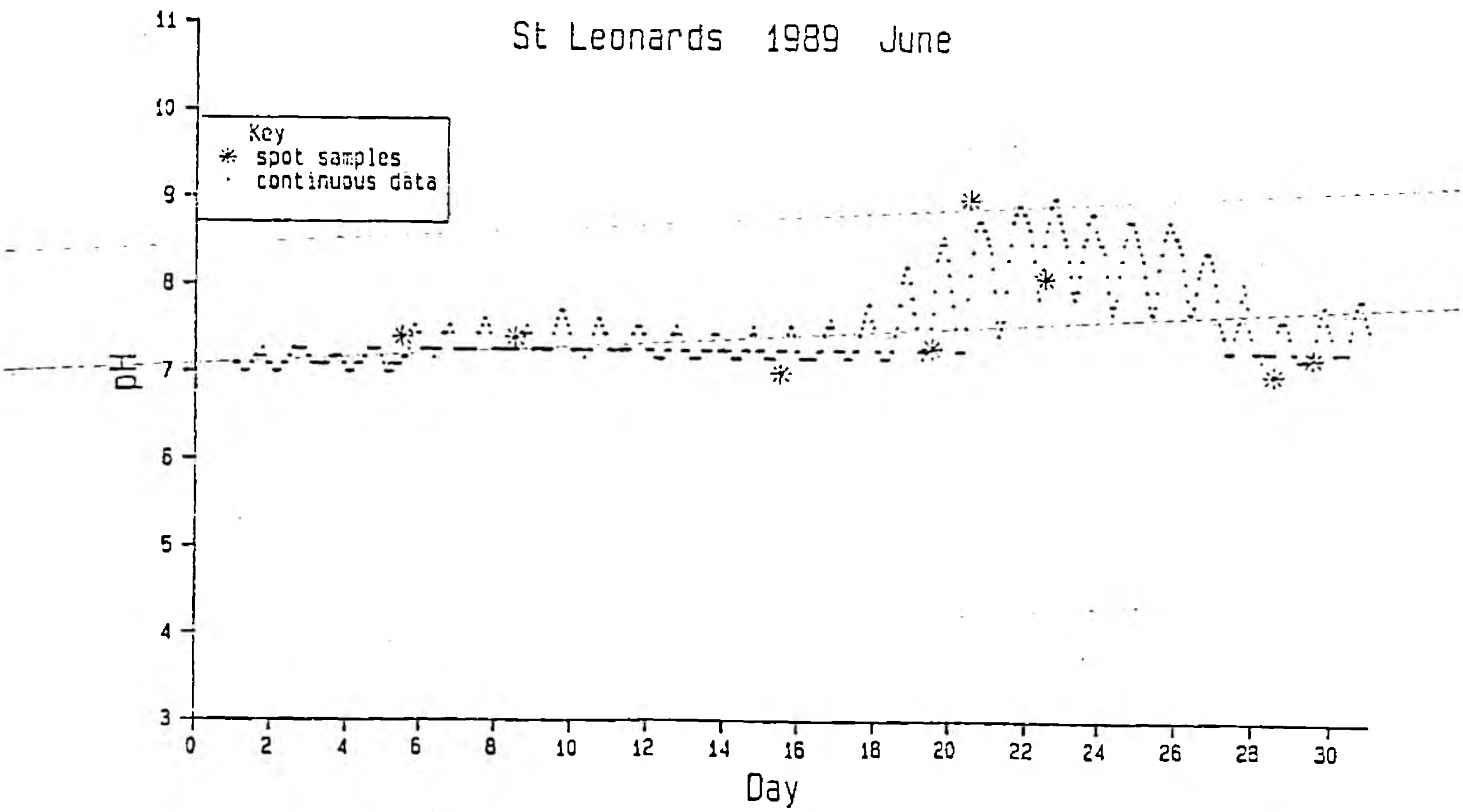
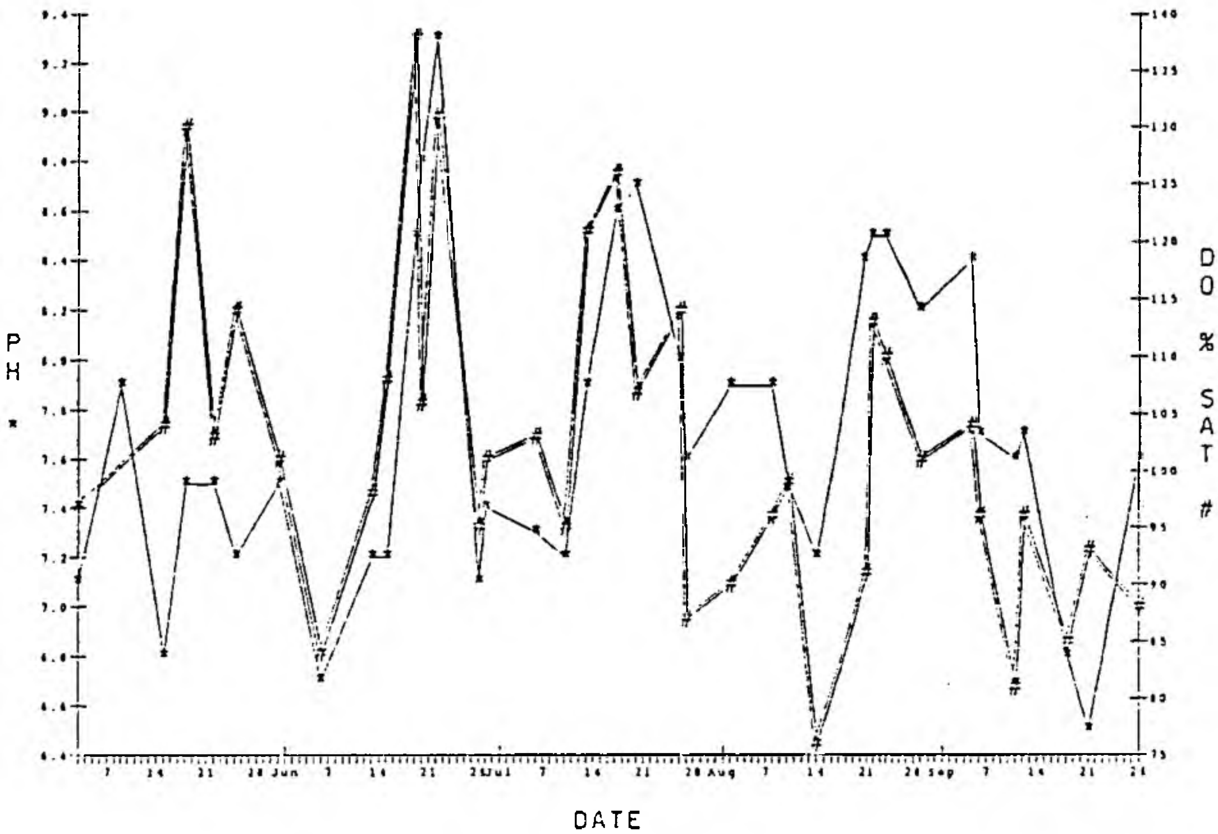


FIGURE B1.2 Spot Sample Results for pH and Dissolved Oxygen Levels at Gunnislake Bridge and Gunnislake Weir

PH & DO LEVELS AT GUNNISLAKE BRIDGE SUMMER 1989



PH & DO LEVELS AT GUNNISLAKE WEIR SUMMER 1989

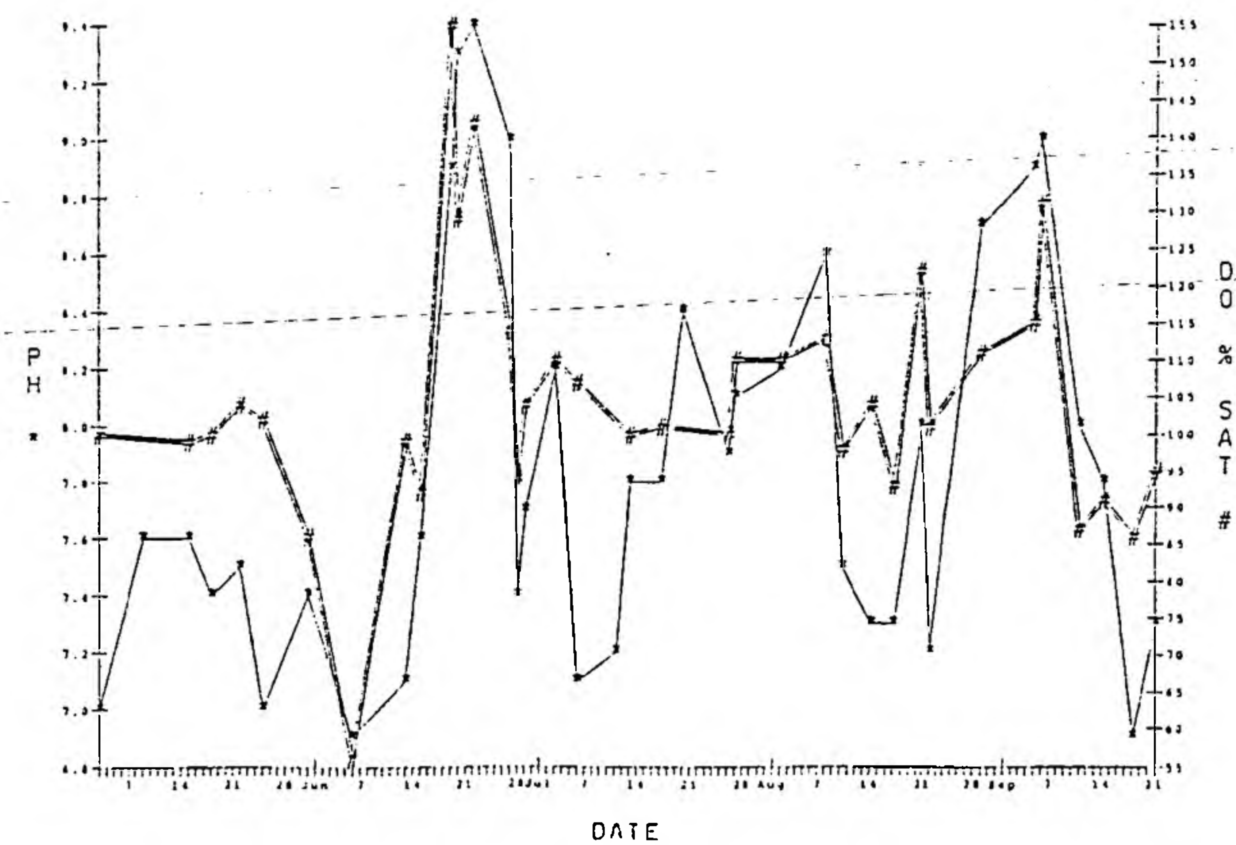
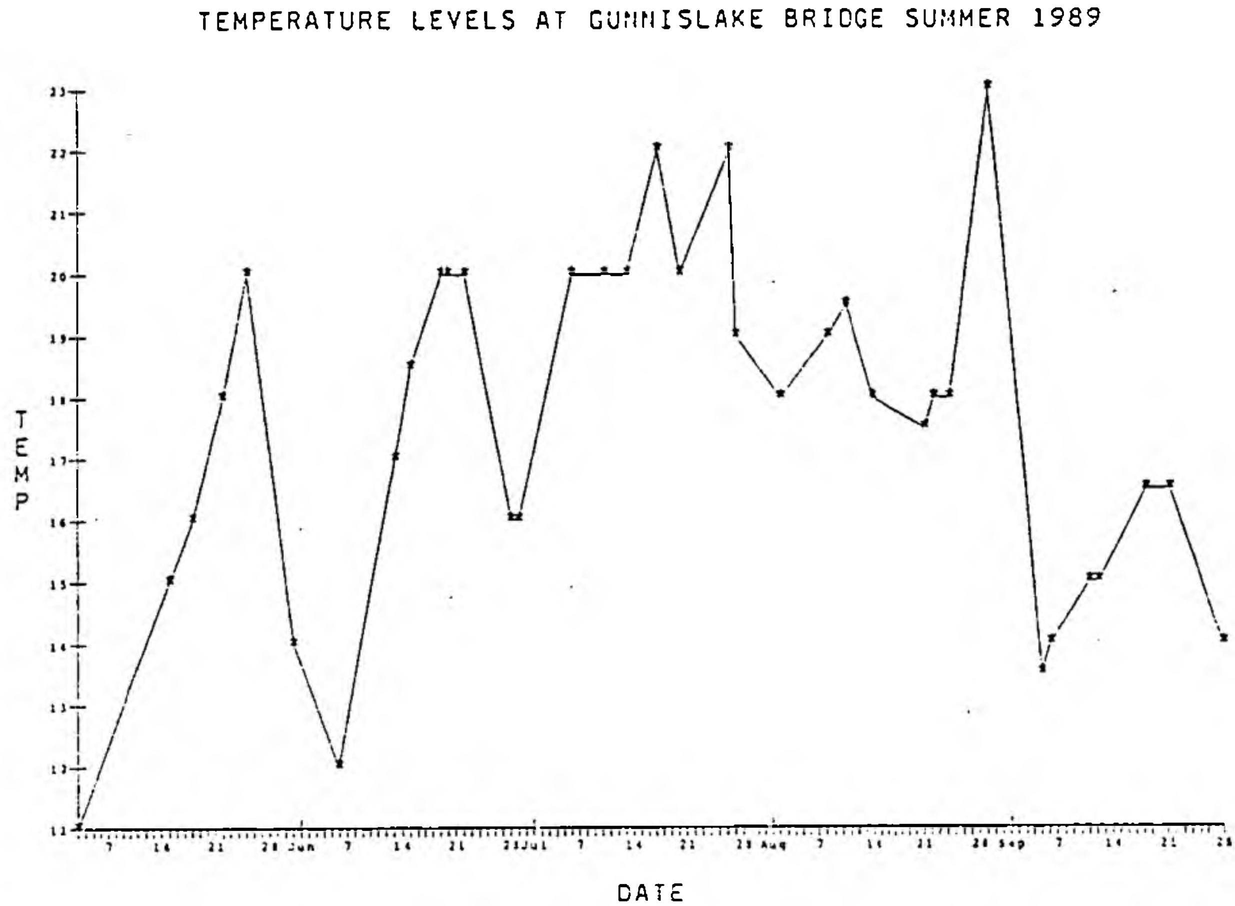


FIGURE B1.3 Spot Sample Results for Water Temperature at Gunnislake Bridge and Gunnislake Weir



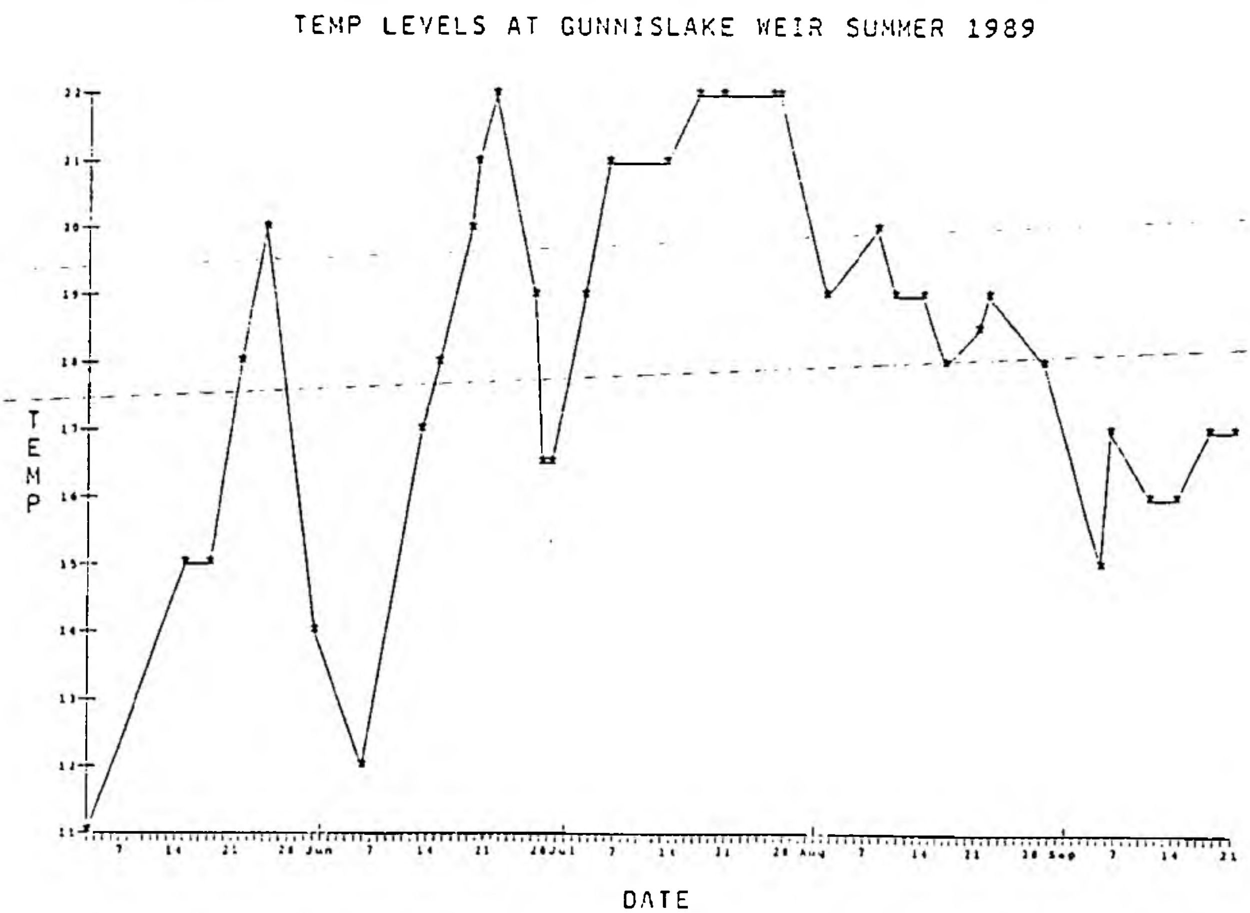
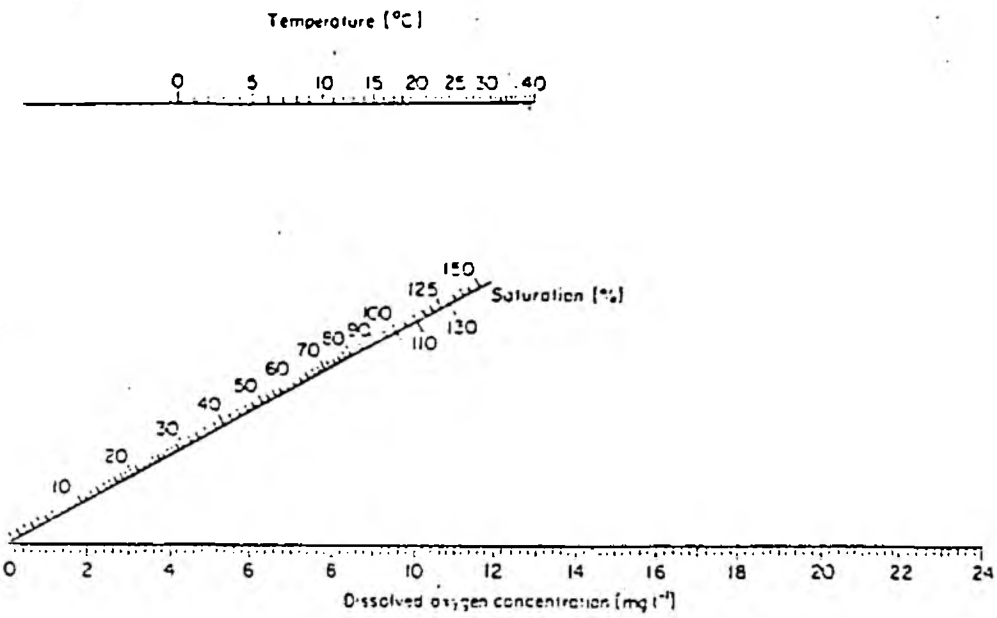


FIGURE B1.4 Nomogram for Inter Converting Oxygen Concentration (mg/l) and % Saturation in Freshwater



Draw a line connecting the temperature with the oxygen concentration. The percentage saturation is then read from the point at which the line crosses the central scale.

APPENDIX B2

HALCROW

Mass Balance Calculation	Warn-Brew Method
	Calculations done at 14.51 on 14/11/1991

Discharge: Torrington STW
River : River Torridge, Historic flows.
Pollutant: B.O.D. (atu)

Calculation of the river quality downstream of effluent discharge....

Input data ...

Mean river flow upstream of discharge	1334.00 Ml/d
95-percent exceedence river flow	57.80 Ml/d
Mean upstream river quality	1.68 mg/l
Standard deviation	.85 mg/l
Mean flow of discharge	5.00 Ml/d
Standard deviation	1.67 Ml/d
Mean quality of discharge	10.70 mg/l
Standard deviation	5.00 mg/l

Results ...

Mean river quality downstream of discharge	1.84 mg/l
Standard deviation	.88 mg/l
95-percentile river quality	3.32 mg/l
80-percentile quality of discharge	14.09 mg/l
95-percentile quality of discharge	20.14 mg/l

Mass Balance Calculation	Warn-Brew Method
	Calculations done at 14.15 on 14/11/1991

Discharge: Torrington STW
River : River Torridge, Halcrow Operating Case flows.
Pollutant: B.O.D. (atu)

Calculation of the river quality downstream of effluent discharge....

Input data ...

Mean river flow upstream of discharge	1333.20 Ml/d
95-percent exceedence river flow	63.30 Ml/d
Mean upstream river quality	1.68 mg/l
Standard deviation	.85 mg/l
Mean flow of discharge	5.00 Ml/d
Standard deviation	1.67 Ml/d
Mean quality of discharge	10.70 mg/l
Standard deviation	5.00 mg/l

Results ...

Mean river quality downstream of discharge	1.83 mg/l
Standard deviation	.87 mg/l
95-percentile river quality	3.29 mg/l
80-percentile quality of discharge	14.09 mg/l
95-percentile quality of discharge	20.14 mg/l

Mass Balance Calculation	Warn-Brew Method
	Calculations done at 12.11 on 14/11/1991

Discharge:	Torrington STW
River :	River Torridge, Historic flows.
Pollutant:	Ammoniacal Nitrogren

Calculation of the river quality downstream of effluent discharge ....

Input data ...

Mean river flow upstream of discharge	1334.00 Ml/d
95-percent exceedence river flow	57.80 Ml/d
Mean upstream river quality	.05 mg/l
Standard deviation	.06 mg/l
Mean flow of discharge	5.00 Ml/d
Standard deviation	1.67 Ml/d
Mean quality of discharge	4.50 mg/l
Standard deviation	2.90 mg/l

Results ...

Mean river quality downstream of discharge	.12 mg/l
Standard deviation	.16 mg/l
95-percentile river quality	.32 mg/l
80-percentile quality of discharge	6.21 mg/l
95-percentile quality of discharge	9.97 mg/l

Mass Balance Calculation	Warn-Brew Method
	Calculations done at 14.23 on 14/11/1991

Discharge: Torrington STW
River : River Torridge, Halcrow Operating Case flows.
Pollutant: Ammoniacal Nitrogen

Calculation of the river quality downstream of effluent discharge....

Input data ...

Mean river flow upstream of discharge	1333.20 Ml/d
95-percent exceedence river flow	63.30 Ml/d
Mean upstream river quality	.05 mg/l
Standard deviation	.06 mg/l
Mean flow of discharge	5.00 Ml/d
Standard deviation	1.67 Ml/d
Mean quality of discharge	4.50 mg/l
Standard deviation	2.90 mg/l

Results ...

Mean river quality downstream of discharge	.12 mg/l
Standard deviation	.14 mg/l
95-percentile river quality	.31 mg/l
80-percentile quality of discharge	6.21 mg/l
95-percentile quality of discharge	9.97 mg/l

Mass Balance Calculation	Warn-Brew Method
	Calculations done at 12.20 on 14/11/1991

Discharge: Totnes STW
River : River Dart, Historic flows.
Pollutant: B.O.D. (atu)

Calculation of the river quality downstream of effluent discharge....

Input data ...

Mean river flow upstream of discharge	928.00 Ml/d
95-percent exceedence river flow	77.10 Ml/d
Mean upstream river quality	1.43 mg/l
Standard deviation	.72 mg/l
Mean flow of discharge	6.38 Ml/d
Standard deviation	2.13 Ml/d
Mean quality of discharge	10.70 mg/l
Standard deviation	5.00 mg/l

Results ...

Mean river quality downstream of discharge	1.60 mg/l
Standard deviation	.74 mg/l
95-percentile river quality	2.86 mg/l
80-percentile quality of discharge	14.09 mg/l
95-percentile quality of discharge	20.14 mg/l

Mass Balance Calculation	Warn-Brew Method
	Calculations done at 14.30 on 14/11/1991

Discharge: Totnes STW
River : River Dart, Halcrow Operating Case flows.
Pollutant: B.O.D. (atu)

Calculation of the river quality downstream of effluent discharge....

Input data ...

Mean river flow upstream of discharge	913.50 Ml/d
95-percent exceedence river flow	119.20 Ml/d
Mean upstream river quality	1.43 mg/l
Standard deviation	.72 mg/l
Mean flow of discharge	6.38 Ml/d
Standard deviation	2.13 Ml/d
Mean quality of discharge	10.70 mg/l
Standard deviation	5.00 mg/l

Results ...

Mean river quality downstream of discharge	1.56 mg/l
Standard deviation	.72 mg/l
95-percentile river quality	2.75 mg/l
80-percentile quality of discharge	14.09 mg/l
95-percentile quality of discharge	20.14 mg/l

Mass Balance Calculation	Warn-Brew Method
	Calculations done at 12.31 on 14/11/1991

Discharge:	Totnes STW
River :	River Dart, Historic flows.
Pollutant:	Ammoniacal Nitrogen

Calculation of the river quality downstream of effluent discharge....

Input data ...

Mean river flow upstream of discharge	928.00 Ml/d
95-percent exceedence river flow	77.10 Ml/d
Mean upstream river quality	.09 mg/l
Standard deviation	.07 mg/l
Mean flow of discharge	6.38 Ml/d
Standard deviation	2.13 Ml/d
Mean quality of discharge	2.00 mg/l
Standard deviation	1.60 mg/l

Results ...

Mean river quality downstream of discharge	.13 mg/l
Standard deviation	.09 mg/l
95-percentile river quality	.30 mg/l
80-percentile quality of discharge	2.82 mg/l
95-percentile quality of discharge	4.97 mg/l

Mass Balance Calculation	Warn-Brew Method
	Calculations done at 14.33 on 14/11/1991

Discharge:	Totnes STW
River :	River Dart, Halcrow Operating Case flows.
Pollutant:	Ammoniacal Nitrogen

Calculation of the river quality downstream of effluent discharge....

Input data ...

Mean river flow upstream of discharge	913.50 Ml/d
95-percent exceedence river flow	119.20 Ml/d
Mean upstream river quality	.09 mg/l
Standard deviation	.07 mg/l
Mean flow of discharge	6.38 Ml/d
Standard deviation	2.13 Ml/d
Mean quality of discharge	2.00 mg/l
Standard deviation	1.60 mg/l

Results ...

Mean river quality downstream of discharge	.12 mg/l
Standard deviation	.08 mg/l
95-percentile river quality	.26 mg/l
80-percentile quality of discharge	2.82 mg/l
95-percentile quality of discharge	4.97 mg/l

Annex C

CONSULTATION

HALCROW

ANNEX C - CONSULTATION

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C3	FISHERIES	C2
C4	RECREATION	C3

APPENDIX C1
List of bodies invited to attend ecology/conservation consultation meetings

Notes from ecology/conservation meeting held on 15 October 1991

APPENDIX C2

Notes from riparian meetings held on 11 October and 6 November 1991. Responses received from riparian owners to the HOC.

C1 INTRODUCTION

As part of the investigation, and assessment of impacts, discussions have been held with interested statutory and non-statutory bodies. This process aimed to ensure that such bodies had opportunities to highlight any concerns and draw to our attention any features of particular interest within their discipline. Through this dialogue it has been possible for their aspirations to be considered when drawing up operating rules. The consultation process also had to take into account the fact that what is regarded as beneficial for one interest may be detrimental to another.

Detailed consultation has been undertaken in three main areas. These are Ecology, Fisheries and Recreation. The type and extent of consultation is outlined in the three following separate sections. It is also noteworthy that this investigation began before the formal/legal separation of the National Rivers Authority (NRA) and South West Water Services Ltd (SWWS). All the consultations with external bodies have been conducted with a joint and open participation of both the NRA and SWWS.

Submission of this Final Report brings to an end this phase of 'informal' consultation. However, this report is principally a series of draft proposals for the operation of the Roadford Scheme and associated monitoring in order to provie a more definitive basis for detailed consideration by all parties of how to progress the scheme. Statutory consultation as part of the normal abstraction licence application procedures will take place in due course.

C2 ECOLOGY

At the start of the study phone conversations were held with the bodies which have provided most ecological inputs to similar studies in the past. During these conversations the aims of the study were described and requests for information made. A meeting with them at an early stage was not deemed efficient use of available time because likely operating scenarios had not been considered to sufficient detail. Once other elements of the study were beginning to provide data which could be easily interpreted, it was deemed desirable to hold a consultation meeting.

On 2 November 1989 ten interested parties were formally invited to a meeting on the 27 November 1989 at SWWSL offices in Exeter. A copy of Halcrow's Roadford review was sent to bodies which had previously provided considerable data to similar studies.

A list of the bodies invited to attend the ecological/conservation consultation meetings is given in Appendix C1.

At the meeting of the 27 November the aims and time-table of the study were discussed in detail. All those represented were invited to comment on anything they had concerns about. A short presentation of the Devon Wildlife Trust's river corridor surveys of the Lyd sub-catchment was given by Jason Heath. In particular all were asked to suggest any other individuals or organisations which might have information that would wish us to take account of. Previous requests to make available to the study any information of relevance, or concern, were reiterated.

In the production of the Halcrow Interim Report discussions were held with all those bodies and individuals suggested at the first consultation meeting. For example, discussions were held with the Marine Biological Association in Plymouth and Peter Reay, organiser of the Birds of Estuaries Enquiry for the Tamar. Valuable discussions have been had with, and data collected from, the RSPB, NCC (now EN), DWT, CTNC, ORP and DBWPS.

Following the production of the Interim Report copies were circulated to members of the consultative group. On 3 May 1990 a meeting was held to discuss the various scenarios being considered, the adequacy and completeness of the ecological database being used, and the assessment of potential impacts on flora, fauna and habitats. Members were requested to comment on the report and submit responses in writing if they felt it necessary.

A final consultation meeting was held on 15 October 1991 to consider a Discussion Paper which described the Halcrow Operating Case (HOC). This meeting confirmed that there are few concerns remaining regarding the operation of Roadford as recommended in the HOC and that the majority of concerns and aspirations had been addressed. Outstanding concerns relate primarily to increased drawdown at Burrator and the unknown impacts of the high augmentation releases down the River Wolf. Notes from this meeting are given in Appendix C1.

C3 FISHERIES

From the start, consultation with riparian interests has been considered an essential part of the study. This is seen as a two-way process, both to access the considerable volume of knowledge and experience represented by local fishery interests, and to keep those who might be affected by the scheme informed of progress. In addition, there is the formal commitment to consultation on many aspects of the scheme in the setting-up of the Roadford Fisheries Liaison Committee.

Close contact has been maintained with the NRA throughout. Mr Sambrook, project manager of the Roadford Fisheries and Environmental programme, is a member of the study team. The whole study is jointly managed by the NRA along with the plc. In considering the impact of the scheme on the rivers other than the Tamar, the team has drawn heavily upon the data held by the Fisheries Department of SW Region NRA in the form of juvenile survey results, redd counts, catch statistics etc. Finally, consultation has taken place to ensure that the operating rules for the various options being considered are broadly consistent with NRA policy.

Liaison with riparian interests has so far taken place in three ways:

- the Roadford Fisheries Liaison Committee (RFLC)

- riparian owners meetings
- direct contact with riparian owners associations and individuals.

Although the Halcrow team has not attended any RFLC meetings, this forum does perform a most important consultation role. Mr Sambrook attends each meeting, as do several other NRA and SWWS personnel associated with the study. The resolutions and concerns of this group have, therefore, been taken into account.

Two formal meetings with riparian owner representatives from the six rivers potentially imported by the scheme took place in September and December 1989, and were of critical importance as they are the only forum where all the rivers are represented together. In each case presentations of the current state of the study were made, and useful discussions took place. A third meeting at which the Halcrow Interim Report was presented, took place on 26 April 1990.

In addition a series of visits was made by Mr Lawson and Dr Solomon to each river in September 1989. These took the form of site visits with representatives of therelevant Riparian Owners Associations. Extensive discussions took place against a backdrop of the sites of concern, and a considerable insight into each river fishery was gained. Follow-up correspondence of each case enhanced the process of information exchange.

The riparian owners were also involved in discussions regarding the Riparian Case which was one of the operating cases modelled during the evolution of the HOC rules.

Two final group meetings attended by representatives of the 'six rivers' were held on 11 October and 6 November 1991. At the October meeting a presentation was made outlining the HOC proposals. The follow-up meeting on 6 November provided the riparian owners with an opportunity to comment on the HOC and to seek clarification on any points they did not fully understand. Notes from these two meetings and copies of the responses received from the riparian owners to the HOC are given in Appendix C2.

C4 RECREATION

Roadford and Burrator are similar in that few formal recreation facilities are available at present.

The likely effects of drawdown have then been assessed drawing on the experience and knowledge of SWWS recreation management and field staff, and with reference to previous Halcrow studies and to South West Water records.

The PIEDA consultancy (currently drawing up a recreation strategy for Roadford) have been consulted and the Roadford Water and Land Use Group's views on the effects of the proposed operating regimes will be sought when PIEDA's strategy report is available.

The likely impact on Burrator has been discussed with the Dartmoor National Park Authority's Chief Planner.

APPENDIX C1

HALCROW

LIST OF BODIES INVITED TO ATTEND ECOLOGY/CONSERVATION CONSULTATION MEETINGS

Nature Conservancy Council (NCC) - now English Nature (EN)
Royal Society for the Protection of Birds (RSPB)
Dartmoor National Park Authority (DNPA)
Devon Wildlife Trust (DWT)
Cornwall Trust for Nature Conservation (CTNC)
Otters and Rivers Project (ORP) - later through Otter Conservancy and Tarka Project.
Botanical Society of the British Isles - two Devon recorders (BSBI)
Countryside Commission (CC)
Devon Association (DA)
Devon Bird Watching and Preservation Society (DBWPS)

APPENDIX C2

HALCROW

Appendix C2 contents to be discussed and once agreed, included in final report.