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TERRESTRIAL & FRESHWATER SCIENCES DIRECTORATE

NATIONAL RIVERS AUTHORITY
THAMES REGION

MAIDENHEAD, WINDSOR and ETON
FLOOD ALLEVIATION SCHEME
WATER QUALITY STUDY

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FINAL REPORT

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FLOOD ALLEVIATION SCHEME

WATER QUALITY STUDY

FINAL REPORT

Institute of Hydrology, Wallingford
RPS Clouston, Clwyd

In association with
Institute of Freshwater Ecology
Institute of Terrestrial Ecology

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1. Executive Summary

1. The study was undertaken on behalf of the Thames Region of the National Rivers Authority to assess the impact of the Maidenhead, Windsor and Eton Flood Alleviation Scheme on the aquatic environment.

2. The studies have included an assessment of surface and groundwater quantity and quality, bird life and stream biology including algae, macrophytes and fisheries.

3. A modelling strategy has been used to assess groundwater and surface water quantity and quality changes. The Institute of Hydrology QUASAR (QUAlity Simulation Along Rivers) model has been applied to the lower Thames from Cookham to Teddington and extended to simulate the proposed flood relief channel (FRC). The RPS Clouston Groundwater model has been used to simulate groundwater movement and quality. A dissolved daily oxygen model developed by the Institute of Freshwater Ecology has been adapted to assess oxygen cycles and a model of algal growth has been applied to assess algal concentrations.

4. Initially the FRC will resemble a series of long gravel pits but it is considered that this will change as soon as it is used for flood relief. The influx of nutrient rich water from the main river and the high loads of silt deposited in the FRC channel will ensure the FRC assumes the characteristics of a river system.

5. The quality of water in the channel and the main river will depend on the operating strategy adopted for the channel. Essentially three main scenarios have been explored; these being 1) equal flow (i.e. 50:50 split) in both chanel and main river; 2) zero flow along the channel except under flood conditions; 3) sweetening flows under low flow conditions.

6. Scenario 1) appears impractical under most summer low flow conditions when there is a need to maintain flow in the main river.

7. Under scenario 3) the quality of the channel in terms of nutrients (N and P) rapidly assumes the quality of the main river as sweetening flows increase to 5 m^3s^{-1} (432 Mℓ/d).

8. With low sweetening flows under scenario 3) algal concentrations are likely to be high since N and P will not be growth limiting and long residence times will ensure ideal conditions for algal growth. Sweetening flows of at least 5 m^3s^{-1} (432 Mℓ/d) are required to reduce residence times sufficiently to control algal growth. A sweetening flow of 10 m^3s^{-1} (864 Mℓ/d) is preferred.

9. Under scenario 2) the channel will assume the quality of the groundwater in terms of nutrients i.e. high N and low P. This would be ideal if phosphorus levels were sufficiently low to limit algal growth. Unfortunately this may not be the case because the sediments may recycle phosphorus into the water column; only very low concentrations are required

for algal growth. Certainly during the first three years of operation nutrient levels are likely to be high and not limiting for algal growth.

10. Lining the channel would reduce the nitrogen levels under scenario 2) but not sufficiently for nitrogen to become growth limiting for algae.

11. Under 1976 type summer conditions water quality conditions would deteriorate with algal blooms and large variations in dissolved oxygen concentrations will occur. Even under medium flow conditions DO levels are likely to fluctuate.

12. It is recommended that two continuous monitoring stations be installed on the channel to monitor water quality and a weekly spot sampling programme for water quality and algae be initiated to provide information for management.

13. In order to control macrophyte growth it is suggested that surges of flow are allowed through the channel at least once a year.

14. The impact of the channel on bird life is expected to be small and indeed there will be benefit in providing attractive new habitats for bird life.

15. The channel will provide considerable potential for fishing, with substrata for spawning and refugia suitable for coarse fish nurseries.

16. The new channel is unlikely to favour salmoid species unless it is operated partly as a put-and-take trout fishery with attendant risks of mortality and loss due to floods and oxygen deficiency.

17. The recommended operating strategy is scenario 3) with sweetening flows of at least 5 m^3s^{-1} (432 Mℓ/d) and preferably 10 $m^3 s^{-1}$ (864 Mℓ/d).

2. Introduction and objectives

2.1 INTRODUCTION

2.1.1

The purpose of the proposed flood relief channel (FRC) scheme for Maidenhead, Windsor and Eton is to provide alleviation of flooding from the River Thames. This will be achieved by the construction of a new channel to carry excess flood water along the left bank of the river (Figure 2.1.1). In order to provide an adequate level of protection the channel would need to be of a similar size to the river itself.

2.1.2

The FRC will traverse the shallow gravel aquifer enclosed by a loop of the River Thames between Maidenhead and Eton. Water will be retained within the channel by means of retention structures or weirs. The open water of the channel will be in direct contact with groundwater, with the possible exception of a stretch of the channel adjacent to Manor Farm where the channel may be lined. The flow of groundwater is from north to south across the line of the channel. This will constantly introduce water into the channel through the north bank; flow from the channel through the south bank is predicted and will recharge the aquifer.

2.1.3

It is intended that the channel should contain water at all times. Unless the channel is lined, local groundwater conditions mean that there will be constant seepage from groundwater into the channel. The seepage water is of poor quality, with high nitrate levels especially near the upstream end of the channel. Concern has been expressed that when there is no flow into the FRC from the Thames, the seepage of nitrate rich groundwater into the channel may pose water quality problems. The main purpose of this study is to examine the effects of the flood relief channel on water quality.

2.2 OBJECTIVES

2.2.1

The way in which the FRC is operated, both in its role as a flood relief channel and during other times of year when flows are low, will have a major influence on water quality. The objective of this study is to model the effects of the FRC on the aquatic environment under different operating scenarios and hydrological conditions.

2.2.2

Various models have been used in order to predict the eventual water quality in the FRC and the River Thames downstream of the intake of the new channel. Firstly, a groundwater model was used to simulate the aquifer flows and the quality of groundwater seeping into the channel. These flows along the channel were then incorporated into a surface water model that simulates the changes in key water quality determinants as water moves along the channel and back into the river. The predicted output from the surface water quality model was then used as input data to a model of algal growth, and a model of diel growth and dissolved oxygen.

2.3 SCOPE OF THE WORK

2.3.1

This Final Report presents all the work carried out to meet the Brief for the study which is reproduced as Appendix 1. The work has been carried out in distinct parts; the Institute of Hydrology (IH) have carried out the surface water modelling and have been responsible for drawing the elements of the study together; RPS Clouston have carried out the groundwater modelling; aspects of freshwater ecology, including algal blooms and macrophyte growth were covered by two laboratories of the Institute of Freshwater Ecology (IFE); ornithological aspects have been covered by the Institute of Terrestrial Ecology (ITE).

2.3.2

The main text of the report summarises the work undertaken, and presents recommendations for suitable operating strategies designed to cause the least possible impact on the aquatic environment. More technical details of the work are given in the Appendices.

Location map

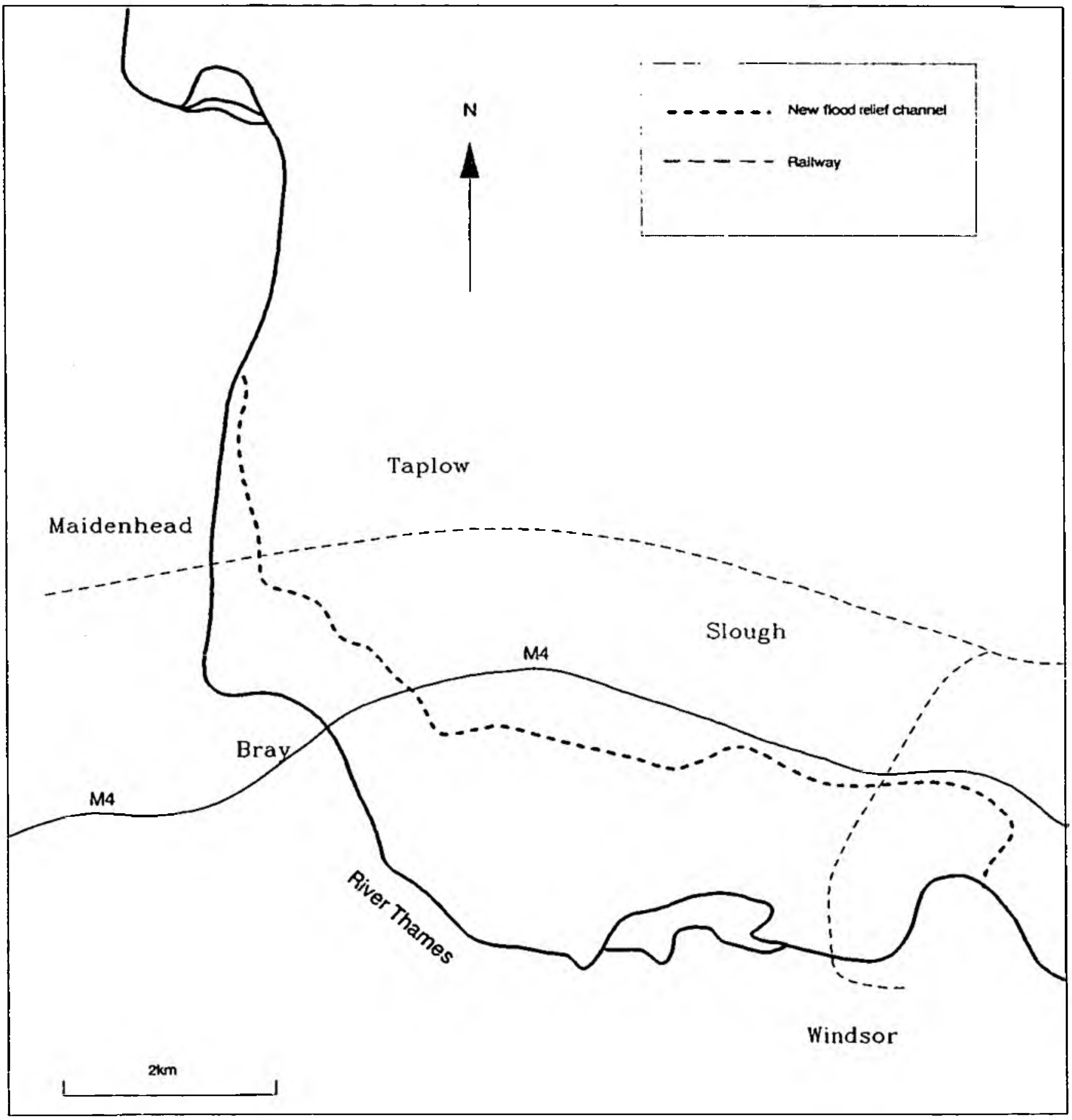


Figure 2.1.1

3. Modelling methodology

The project brief (Appendix 1) specified that existing models should be used and extended. The surface water and groundwater models were available in-house at IH and RPS Clouston respectively;

- The water flow and quality model developed by IH has already been used for water quality studies on the lower Thames (Warwick, 1984).

- The Thames Water Quality Model (TWQM) was developed for the Thames Water Authority. The TWQM simulates various key water quality variables for the entire non-tidal Thames down to Teddington (Whitehead *et al.*, 1981). For the present study, a further development of TWQM called QUASAR (Quality Simulation Along Rivers) was used.

- Diel variations in quality have been assessed using a model developed at the Institute of Freshwater Ecology. The term diel refers to the variation of oxygen through the day and night. (Note Diurnal is often used incorrectly in this situations - diurnal is the opposite of nocturnal).

- Simulation of algal growth was carried out using a simplified capacity model (Reynolds, in Warwick, 1984).

- The groundwater flow and quality model for the aquifer system around the lower Thames developed by RPS Clouston had been used to predict channel water quality around Manor Farm.

The modelling studies were carried out using existing data; there was no opportunity for the collection of additional data. The project brief also restricted the environmental effects to be considered to the aquatic environment of the flood relief channel and the main river, and to fish and bird communities. Other environmental effects, such as plant and animal communities around the proposed development were not considered.

3.1 SURFACE WATER QUALITY MODEL

3.1.1

The existing Thames water quality model (TWQM) was developed to predict changes in the flow, velocity and water quality conditions under different strategies for water abstraction above Teddington (Warwick, 1984). The TWQM was adapted for the present study to include the following;

- additional water quality determinands such as phosphate;
- the location of the flood relief channel offtake and outlet; and
- representation of the flood relief channel itself.

3.1.2

The previous study was concerned with the river downstream of Maidenhead. Calibration of the TWQM for BOD, DO, temperature and flow was for these lower reaches. However, in an earlier study a model for the whole Thames was calibrated for nitrate and chloride. To model phosphate, a loss term with first order kinetics has been built into the model. The updated model was revalidated for the determinands of interest, namely nitrate, ortho-phosphate, dissolved oxygen and BOD. Details of the validation are given in Appendix 3.

3.1.3

The most appropriate way of including the flood relief channel was to consider it as a dummy abstraction at the point where the relief channel leaves the river (Figure 3.1.1); similarly the outflow at the downstream end of the FRC was represented as a tributary input at the point where the channel rejoins the main river. The flood relief channel is represented in a new sub-model as a number of reaches so that spatial changes in water quality along the channel can be properly represented. This division into reaches also allows for the input of groundwater flow (and associated water quality) to be distributed along the channel. A schematic diagram of the QUASAR reach structure is given in Figure 3.1.2.

3.1.4

The flow into the flood relief channel is determined by the operating conditions laid down for the channel and the quality of the inflow is that of the Thames at that point. The quality and rate of groundwater flow into the channel were provided by the output from the groundwater model. The flow rate and quality of the outflow from the flood relief channel as it rejoins the main river were determined by the new sub-model.

3.1.5

The flow and quality equations used in the channel sub-model are the same as those in the TWQM. A relationship between the flow and residence times in each of the main reaches of the channel was provided by Lewin Fryer and Partners from runs of their hydraulic model (see Table 3.3.1). The input of water from the Thames into the top reach of the model was determined by the operating scenarios laid down for the flood relief channel.

3.1.6

Previous simulation studies meant that a complete data set for the period January 1974 to December 1976 was available at IH. This data set did not include ortho-phosphate. Additional data for the periods 1983 to 1984 and 1989, together with ortho-phosphate data for the earlier (1974 to 1976) period were provided by Thames NRA.

3.2 GROUNDWATER QUALITY MODEL

3.2.1

The solid geology of the area is shown in Figure 3.2.1. The flood relief channel crosses outcrops of the Upper Chalk, Reading Beds (variegated clay, locally sandy), and London Clay. The chalk outcrop occupies rising ground to the north and along the edge of the Thames at Taplow. An inlier of chalk and Reading Beds occurs at Windsor, and the downstream (eastern) end of the channel crosses from the London Clay back onto the Reading Beds for a short section adjacent to the Thames. The chalk outcrops to the southeast here.

3.2.2

Erosion by the River Thames has created a wide flood plain south of a line between Maidenhead and Slough, and this stretch of nearly flat ground is covered in sand and gravel deposits of recent origin to a depth of up to 7 m. The Thames, whose level is regulated throughout the study area by weirs, is in hydraulic connection with the gravel aquifer which crosses beneath the river. The gravel aquifer is very permeable, and the water table to the north is partially controlled by river levels. This aquifer is used for public abstraction at Dorney, although a proportion of this water is drawn from the Thames.

3.2.3

The main inputs of water to the aquifer arise from infiltration plus flow out of Thames around locks and weirs, which on the level open ground will account for a high proportion of total precipitation. Relatively little flow appears to arise from the rising ground to the north where the gravels thin out on the outcropping chalk and Reading Beds. Urbanisation in the areas of Maidenhead, Slough and Eton will reduce infiltration by intercepting rainfall and diverting this to the drain system.

3.2.4

The channel will pass through Manor Farm which is associated with Slough Sewage Treatment Works and has been receiving sewage sludge for many decades. Effluents and leachates from the sludge beds pass quickly into the ground, and the aquifer is locally polluted by nitrate and ammonia. More widespread contamination by nitrate has resulted from the intensive arable and vegetable farming.

3.2.5

The aquifer is shallow and lies in a fairly homogeneous granular matrix, making it suitable for modelling using Darcy's Law and in two dimensions. The AQUA computer program was used to simulate steady-state groundwater flows and chemical transport within the aquifer, both under the existing situation and with the channel in place.

3.2.6

The central section of the aquifer, based upon Manor Farm has been previously modelled, but it was not possible to extend the model westwards and eastwards to cover the respective ends of the channel due to the physical limitations of the programme. Separate models were therefore created for the west and east sections, directly abutting the central section. The areas of the three models are shown on Figure 3.2.2: more details of its structure and validation are given in Appendix 4.

3.2.7

The channel is modelled as a 50 m wide high transmissivity zone whose south bank has a head level fixed to that of the weir downstream. Retention levels are given in Table 3.2.1. The AQUA model cannot simulate open water flows and therefore it is assumed that there is no flow into the channel from the river, and there is virtually no flow over weirs. The change in head across the weir structures may be up to 2 m and this will induce substantial groundwater gradients in the surrounding aquifer, introducing a component of flow to the east which cuts across the more general north-south groundwater movement.

3.2.8

Boundary conditions are divided into those which apply to the River Thames (used as one boundary of all the groundwater models), and those which apply to the inland edges of the models. Along mutual boundaries, the outflows from one model have been used to define inflows on the adjacent model. The abstractions at Dorney have also been included in the model as a sink. Other abstractions at Taplow and Datchet draw water largely from the chalk aquifer and have not been simulated.

3.2.9

Chemical transport modelling has placed emphasis on nitrate, which is assumed to behave conservatively i.e. is not subject to chemical or biological removal. Main nitrate sources are infiltration water, particularly beneath intensively farmed areas, the River Thames, and Manor Farm. Figure 3.2.3 shows the nitrate inputs to the aquifer which have been assumed. These are based upon known groundwater and river concentrations, and estimates of the infiltration concentrations likely to be found.

3.2.10

Ortho-phosphate was not modelled since other studies have indicated that it is strongly bound in aquifers, probably in calcium compounds. Groundwater concentration are generally below 0.1 mg l^{-1}, and average between 0.01 and 0.001 mg l^{-1}.

3.2.11

Ammonium was modelled in the vicinity of Manor Farm, although some uncertainty exists due to the strong adsorption of ammonium to the aquifer and retention interchange with nitrate. Ammonia concentrations are in a pH-mediated equilibrium with ammonium, and are estimated to be less than 1 mg l^{-1} in the alkaline groundwater.

3.2.12

In some areas, the channel will descend to the base of the aquifer, and will thus intercept all groundwater flowing into the open water body. If silting occurs within the channel then the resulting loss of permeability of the channel bed may restrict the extent of recharge to the aquifer. The result would be to divent the general pattern of north-south groundwater flow into the channel flow from west to east. This phenomenon has been modelled by applying a reduced transmissivity layer to the south bank of the central channel model. The transmissivity reduction was in the order of 0.02 times that of the adjacent aquifer block in a layer modelled as being 25m wide.

3.2.13

In other areas the groundwater flow will remain able to pass beneath the channel in undisturbed alluvium. Lining of the channel to prevent the ingress of polluted groundwater has been examined and this could be adopted in the areas of Manor Farm and the agricultural land to the west. It is necessary to leave a sufficient depth of material with high permeability beneath the channel to transmit the water and prevent damming of the groundwater and consequent possible surface flooding upstream.

3.2.14

The main body of polluted groundwater lies directly to the south of the channel at Manor Farm, and this has been shown to be displaced southwards with the general groundwater flow over a matter of months. There is some field data from Manor Farm which may support this prediction.

3.3 SURFACE WATER QUALITY - DIEL CHANGES

3.3.1

The proposed physical conditions for the channel will primarily dominate the biotic condition of the channel and govern important factors such as oxygen exchange across the stream surface ie reaeration coefficient. The proposed gradient for the channel is 1:1000 for the initial stretch of about 1 km around Taplow before becoming 1:2000 for the remaining 10 km. Water level retention structures, weirs, are proposed at six sites downstream spaced at intervals of 1.2 to 2.4 km apart. The residence times in each of the reaches for a range of flows are given in Table 3.3.1. The fall over these weirs varies from 0.7 to 1.5 m with a higher value of 2.5 at the upstream and inlet structure above Taplow. Reaeration coefficients for weirs in flow are generally considered to be high and values of 0.5 to 2 were tested in the diel growth and dissolved oxygen model (Table 3.3.2).

3.3.2

The model used to simulate diel dissolved oxygen changes is based on the stepwise progression of segments (0.25 hour in this case) down the channel. The model incorporates photosynthetic oxygen production, total respiration and then corrects for the surface reaeration coefficient. Real or simulated light and water temperatures or dissolved oxygen input levels with or without biological oxygen demand, can also be used. The model itself embodies a 3 day long array of elements and parameters which may alter down the channel; this allows the position of weirs to be incorporated.

3.3.3

The oxygen demand of water entering the FRC may vary from having a BOD 5 of 1 to 8.5 mg l^{-1} with a mean around 2.4 mg l^{-1}, although at Boveney a lower level of 1.2 to 1.6 mg l^{-1} is the range. If there is a substantial change in velocity in the river, phytoplankton may very well exert an oxygen demand almost immediately as it dies or settles to lower levels in the water when flows are reduced.

3.3.4

Assumptions about the possible submerged plant biomass which might develop are prone to problems but some average possible values were used up to 500 grams m^{-2} dry weight.

3.3.5

To investigate the oxygen levels in the FRC models of extreme dissolved oxygen and oxygen demand were tested. The lowest maintained dissolved oxygen level at which fish can maintain normal life cycles under otherwise favourable conditions is generally considered to be 5 mg l^{-1} for salmonids and a little lower, 3 mg l^{-1} for coarse fish such as carp. Of course, the minimum levels of dissolved oxygen and hence the major risk is attained just prior to dawn. The Thames Region river water quality standards for freshwater classifies the River Thames as 1B and this implies a minimum dissolved oxygen concentration at the 50 percentile of 9 mg l^{-1} and a minimum dissolved oxygen saturation at the 95 percentile of 60% of air saturation.

3.4 SURFACE WATER QUALITY - ALGAL GROWTH

3.4.1

In comparison with the majority of UK rivers, the production, species, composition and abundance of phytoplankton in the River Thames has a substantial history of study, and a good body of data has been accumulated. Details of the algal growth model and a review of the major factors controlling algal growth is given in Appendix 5. Even so it is difficult to predict with any precision, the characteristics of phytoplankton in the proposed channel, owing to insufficient detail of past data and to the present debates about which of the key factors will actually regulate the assembly of suspended biomass.

3.4.2

The work described here is based on the assumption that nutrients scarcely limit concentrations while biotic influences such as grazing and parasitism act at best spasmodically (Warwick, 1984; Whitehead and Hornberger, 1984). This assumption is supported by the results of the modelling work (see section 5.2). The only circumstances in which nutrients limit algal growth would be in the case of FRC behaving as a gravel pit. This is extremely unlikely given the initial disturbance during construction and the subsequent inputs of high nutrient river water and sediments as soon as the channel is used to divert flood water. Thus the only ultimate limit to supportable biomass is likely to be the underwater light availability and the rate of its attainment will be influenced by temperature, turbidity and the rate of downstream displacement and dilution. Indeed this upper carrying capacity for phytoplankton can be modelled from first principles with reasonable accuracy and is of value in defining a 'worst-case' scenario, that is to say "the plankton supported will not exceed ....".

By ascribing growth rates to phytoplankton in the channel under different model flows and travel times with different turbidity loads, it is possible to determine output concentrations at the downstream end, against given intake concentrations at the upstream end. This has been archieved using the model described in Appendix 5.

Table 3.2.1 Channel retention levels

Reach		Level (m O.D.)
1	Thames - Taplow Mill	23.45
2	Taplow Mill - Marsh Lane	21.00
3	Marsh Lane - Dorney	20.30
4	Dorney - Manor Farm	19.50
5	Manor Farm - Slough Road	18.50
6	Slough Road - Black Potts Viaduct	17.00
7	Black Potts Viaduct - Thames	16.12

Table 3.3.1 Characteristics of the FRC as length, minimum mean depth and residence time of water flowing down over a range of discharges between sections divided weirs.

Reach	length km	depth m	Discharges (m^3s^{-1}) 5	10	20	50	100
			Residence times (hours)				
7	1.4	2.3	8.2	4.2	2.2	1.0	.60
6	1.1	2.7	8.6	4.3	2.2	.93	.51
5	2.0	3.2	12.4	6.3	3.2	1.4	.80
4	1.2	3.4	7.7	3.9	2.0	.86	.48
3	2.3	3.2	14.3	7.3	3.7	1.59	.88
2	2.4	3.8	12.8	6.5	3.4	1.46	.83
1	1.2	3.2	5.8	2.9	1.5	.58	.29
Overall	11.6	3.1	69.8	35.4	18.2	7.8	4.4
Mean velocity (ms^{-1})			.05	.09	.18	.41	.73

Table 3.3.2 The water velocity and reaeration coefficients for the Thames at Teddington together with those predicted for the downstream section 7 of the flood relief channel (from IH model)

Reaeration Coefficients, K_2		Discharge, m s^{-1}							
Reach	Depth	10		20		50		100	
	m	V	K_2	V	K_2	V	K_2	V	K_2
FRC reach 7	3.2	.08	.11	.15	.17	.35	.30	.64	.45
Thames at Teddington	2.44	.05	.14	.11	.23	.27	.42	.54	.68

Flood relief channel: reach structure

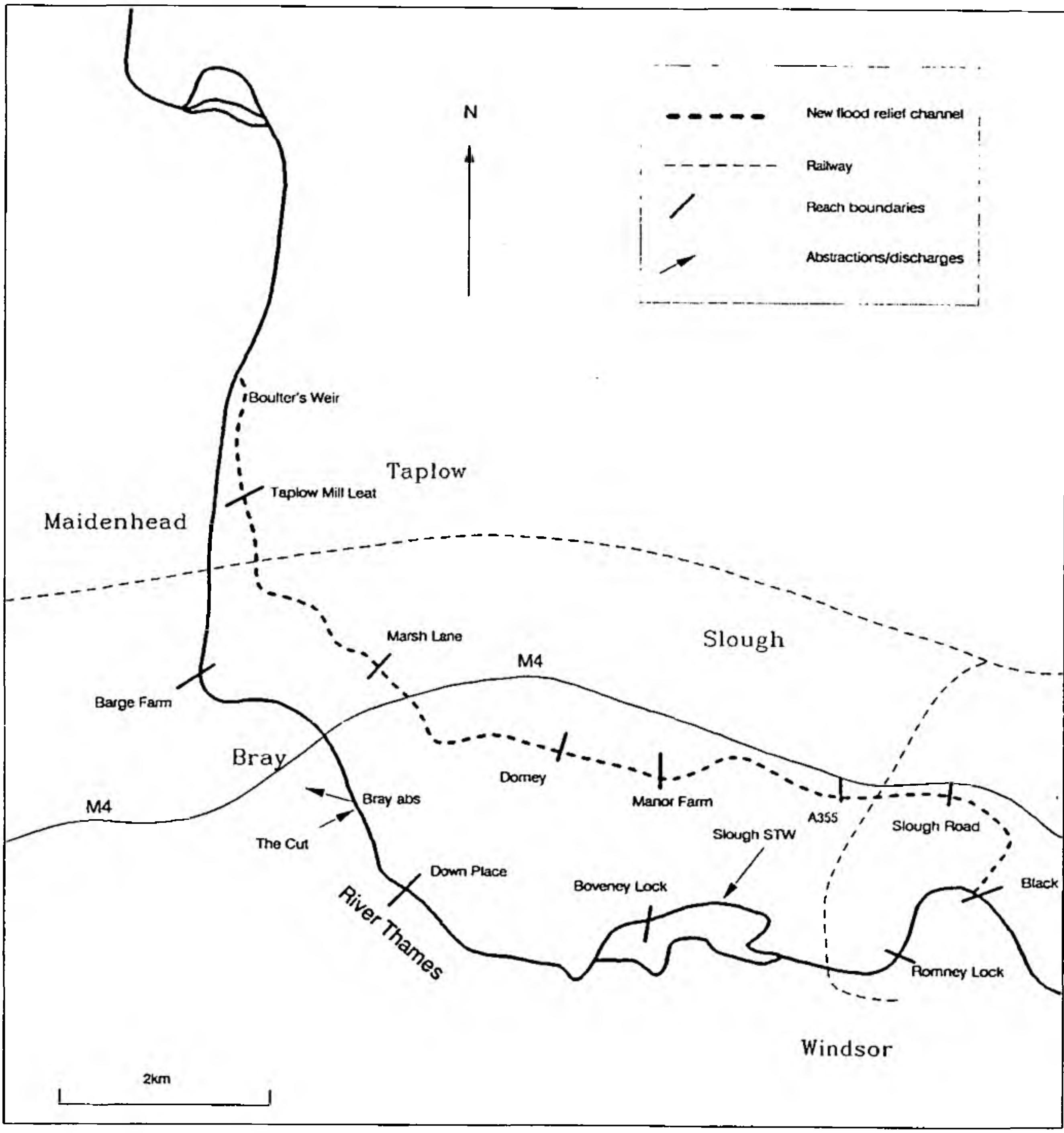


Figure 3.1.1

Schematic diagram of QUASAR reach structure

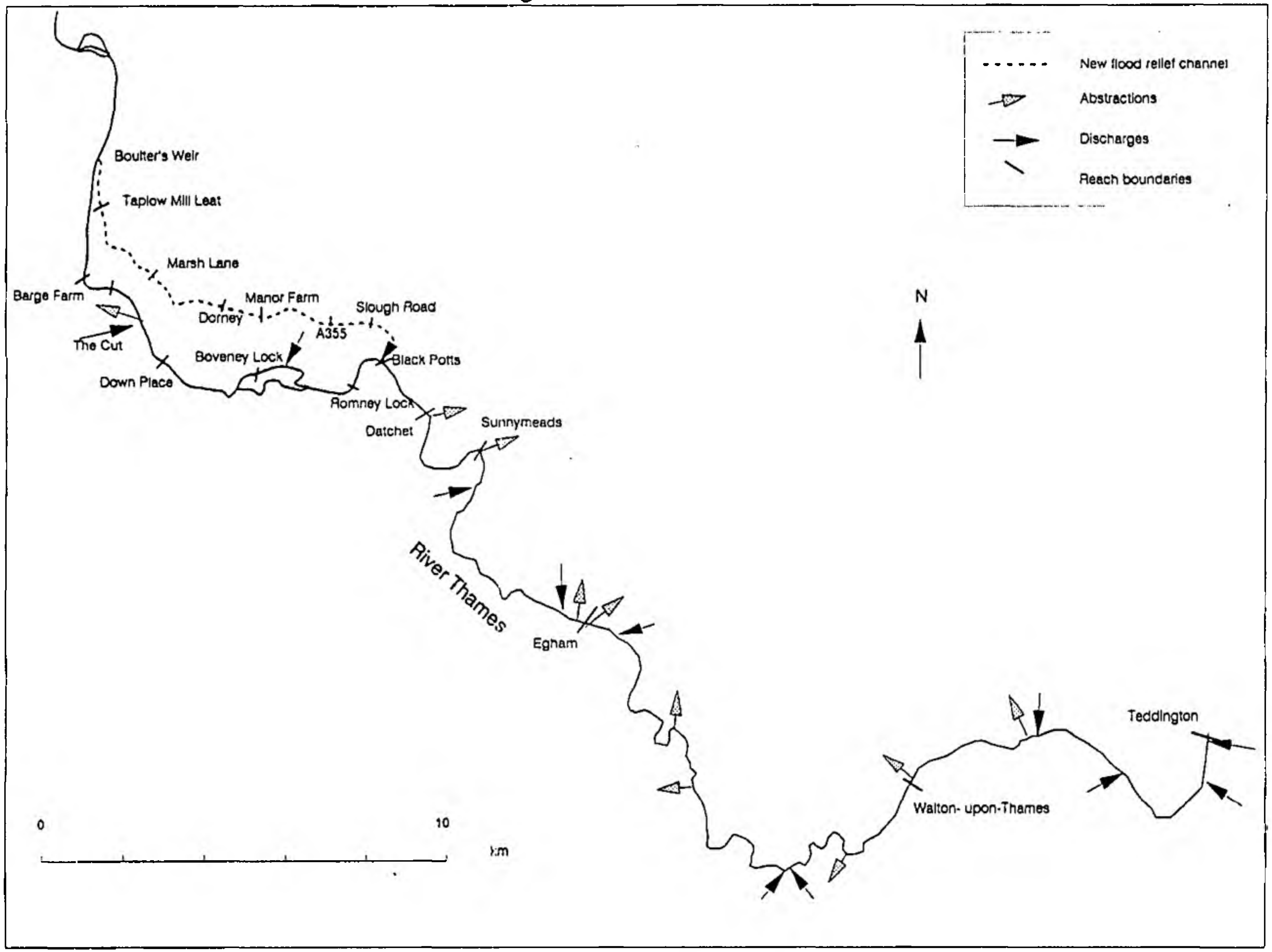


Figure 3.1.2

Geological map

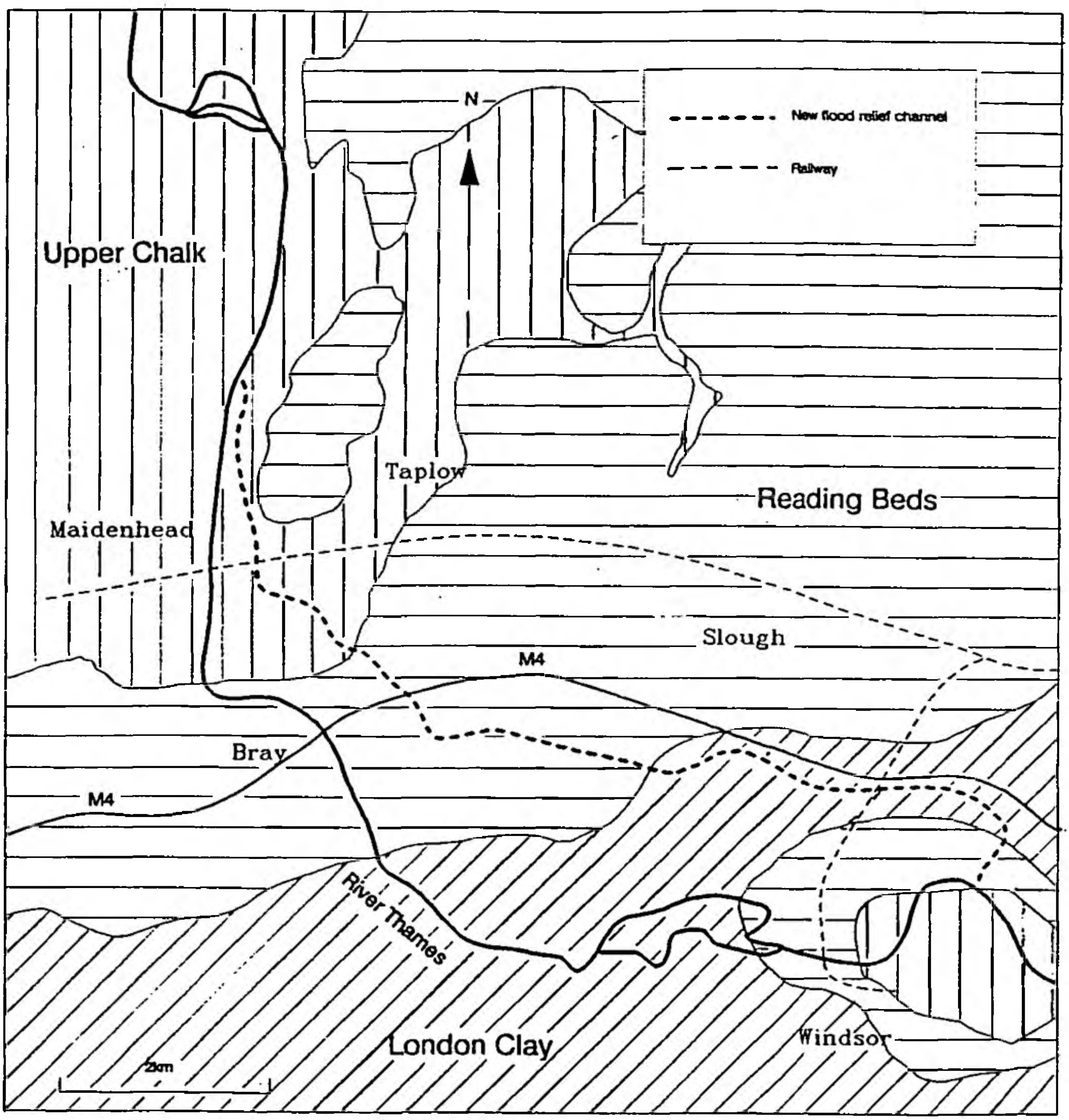


Figure 3.2.1

Areas of the Groundwater Model

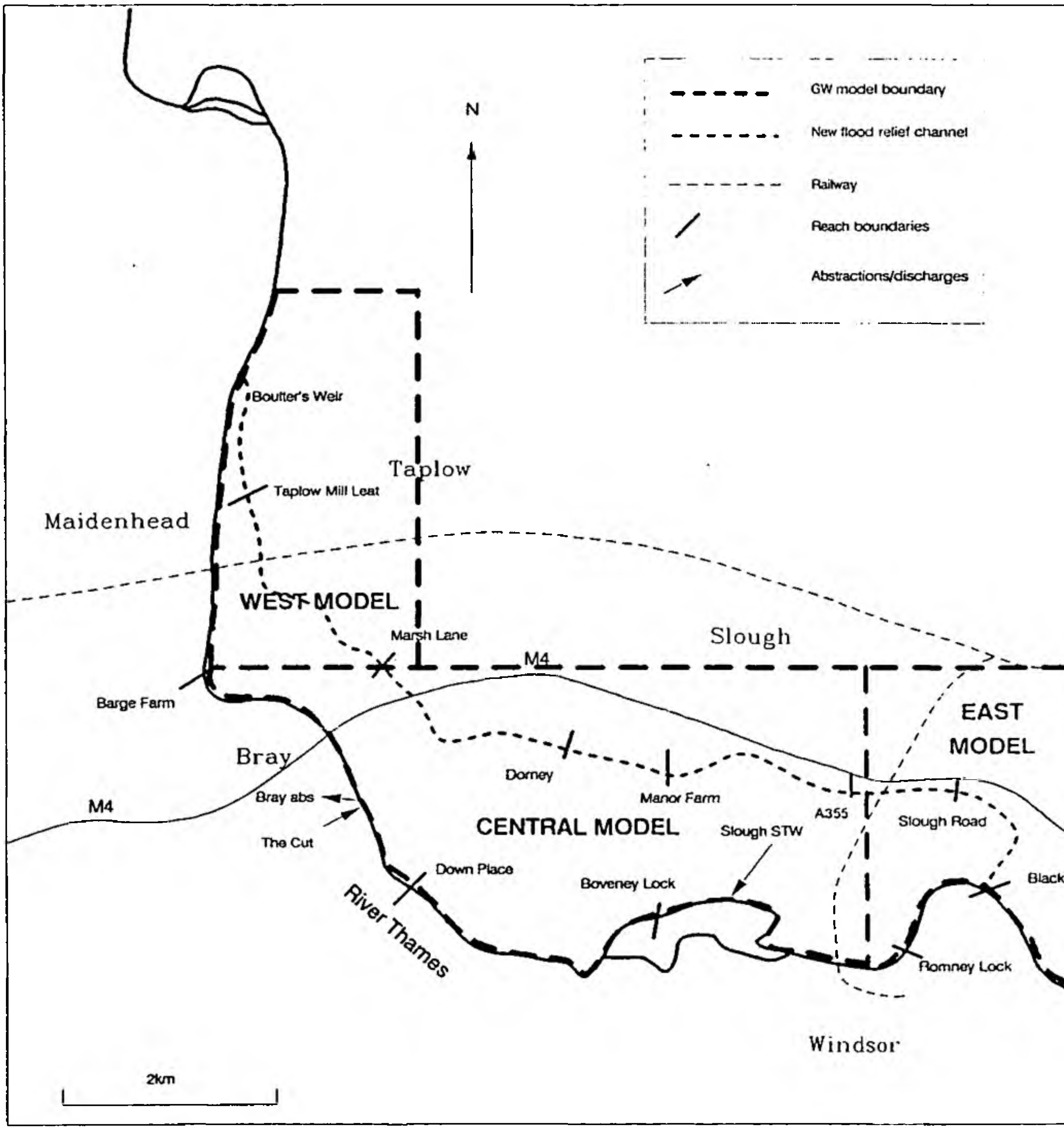
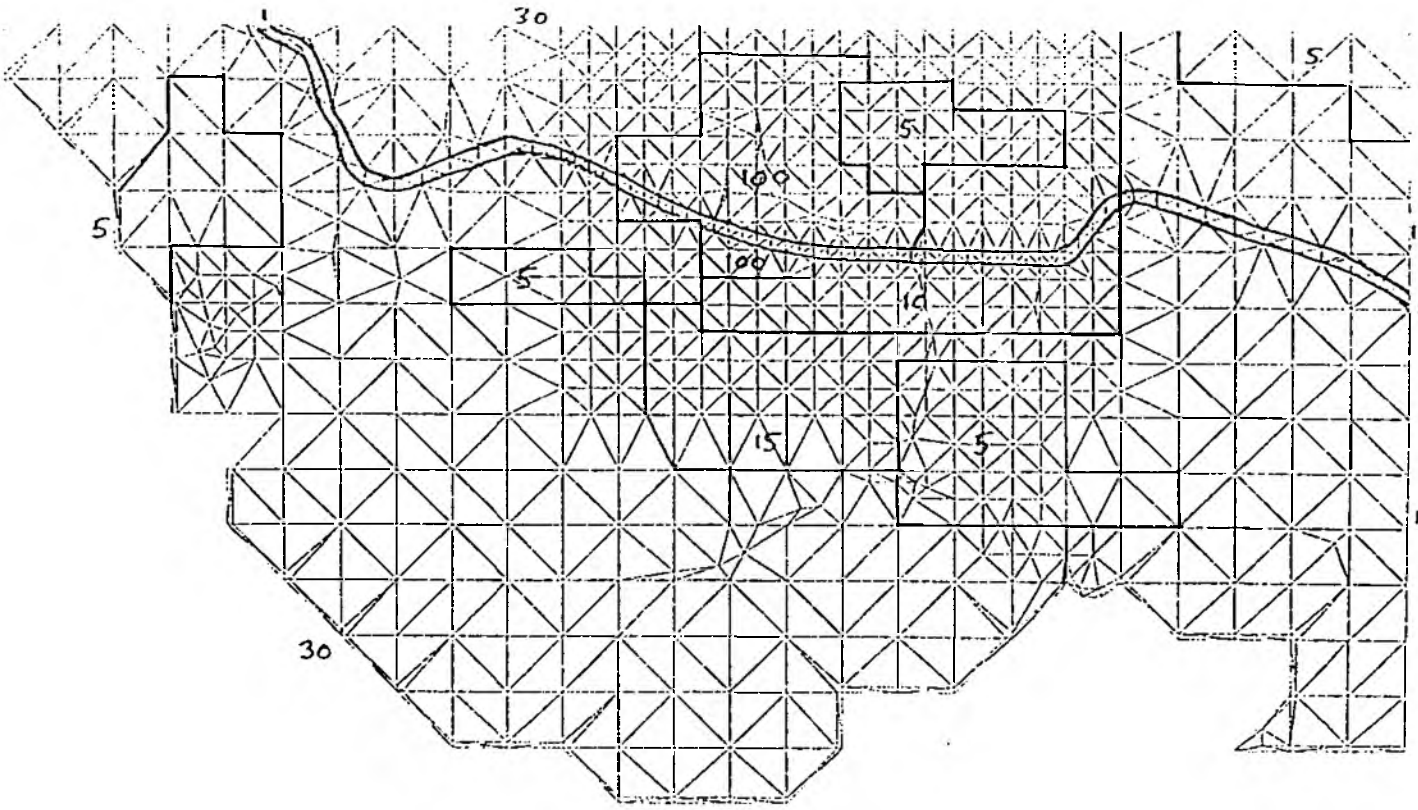


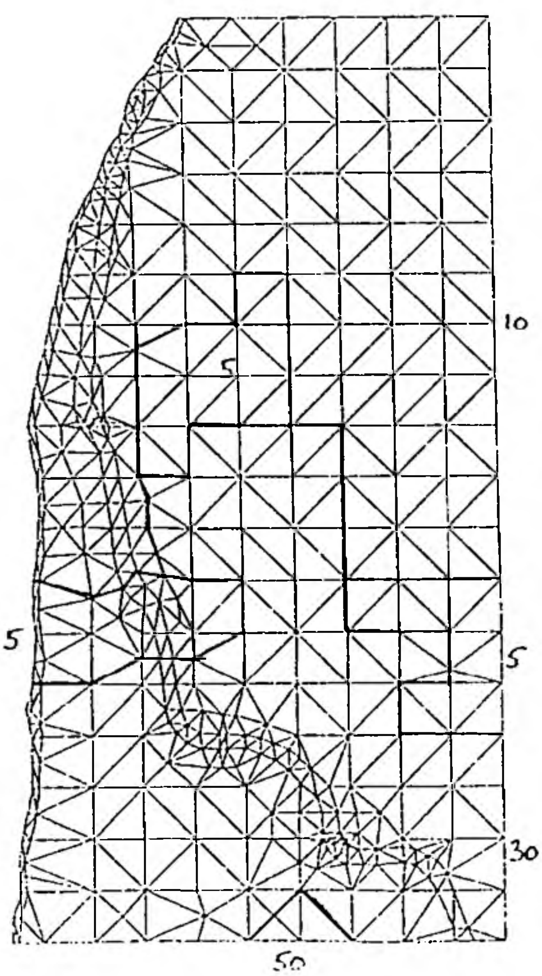
Figure 3.2.2

3.2.3 . Nitrate Infiltration Rates for Aquifer Model

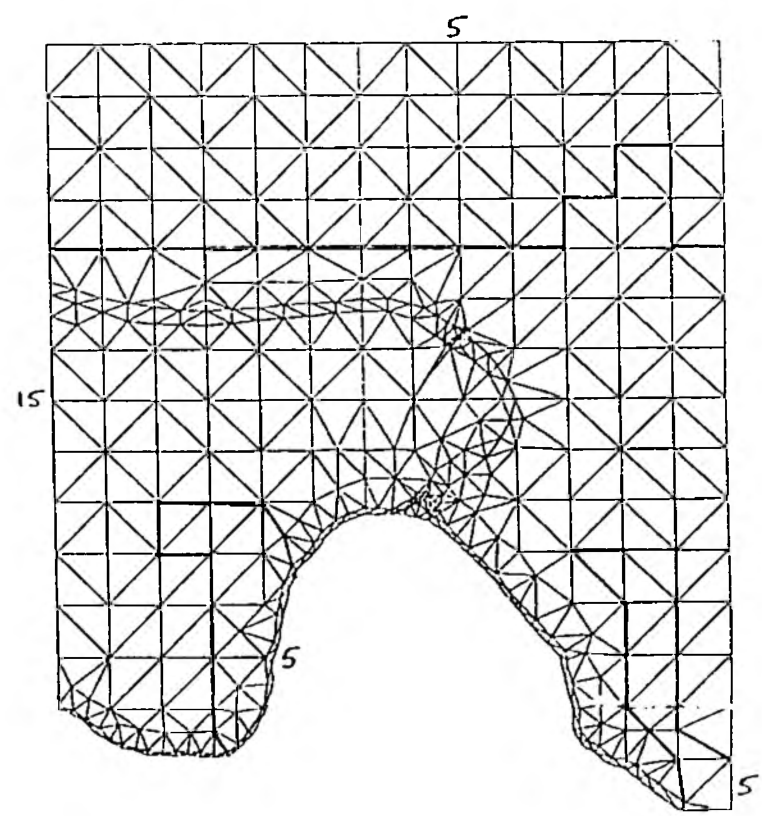
CENTRAL SECTION



WEST SECTION



EAST SECTION



4. Operating Scenarios

4.1

The scenarios were chosen to represent the range of ways in which the flood relief channel could be operated. These ranged from only using the channel when the River Thames came close to bankfull, to diverting half the Thames flow down the channel at all times. In between these extremes come any number of scenarios which involve keeping a flow down the flood relief channel at all times; a 'sweetening flow'. Preliminary work showed that sweetening flows of a little as 5 m^3s^{-1} were sufficient to make the quality of the flood relief channel resemble the River Thames. Flow rate of less than 5 m^3s^{-1} in the channel were likely to result in ideal conditions for rapid algae growth and were therefore not considered (except in the extreme scenario of only using the channel to alleviate floods).

4.2 SUMMARY OF SCENARIOS

4.2.1 Scenario 1 - 50%

Flows are are always split 50/50 between the channel and the River Thames.

4.2.2 Scenario 2 - FNS (Floods No Sweetening)

The channel is used only for the diversion of floods in the main river of over 200 m^3s^{-1}.

4.2.3 Scenario 3 - FS5 (Floods Sweetening 5 m^3s^{-1})

The channel receives a sweetening flow of 5 m^3s^{-1} when the Thames flow is above 10 m^3s^{-1} otherwise it receives half of the Thames flow. In addition all flood flows of greater than 200 m^3s^{-1} are diverted down the channel.

4.2.4 Scenario 4 - FS10 (Floods Sweetening 10 m^3s^{-1})

The channel receives a sweetening flow of 10 m^3s^{-1} when the Thames flow is above 40 m^3s^{-1} otherwise it receives one quarter of the Thames flow. In addition all flood flows of greater than 200 m^3sec^{-1} are diverted down the channel.

5. Water quality results

The discussion in this section of the report is based on the predictions of the groundwater quality model AQUA, and the water quality model QUASAR. The calibration and validation of these models for the Ribver Thames below Cookham and the aquifer in the vicinity of the flood relief channel are given in Appendix 3 and Appendix 4 respectively. The same surface water model is assumed to be valid for the flood relief channel but obviously this cannot be proved until the scheme is commissioned and routine monitoring undertaken. However since the channel is to be constructed to similar dimensions as the Thames this assumption is considered to be valid especially as the model has been applied successfully to the main river under extreme low flow conditions.

5.1 GROUNDWATER

The AQUA model was used to simulate each aquifer section under normal steady state conditions. The degree of matching of levels between the west and central sections is good, but between the central and east sections is poor, reflecting the difficulty experienced in calibrating the east section with the limited data available.

5.1.1 Channel effects on groundwater

The changes to the groundwater flow patterns caused by placing a fixed head channel are illustrated in Appendix 4. The groundwater movements are locally influenced by the weirs. Calculations of the estimated flows across the channel banks were made, and for this purpose the channel was divided into reaches between weirs based upon whether the flows across each model node were into or out of the channel. The net flows are out of the channel immediately upstream of weirs, and into the channel downstream. Table 5.1.1 gives a summary of the total predicted groundwater flow into and out of each reach of the model. Within each reach, where flows in exceed those out of the aquifer then the channel is behaving as a source of water recharging the aquifer. Over the channel as a whole, the net inflow is 1.319 m^3s^{-1} whilst the net loss of water from the channel is 1.02 m^3s^{-1}, giving an increase in channel flow along its length of about 0.3 m^3s^{-1}.

5.1.2 Nitrate fluxes

The nitrate loadings to each section of the channel were calculated as the product of the concentration and the groundwater flow. This will be a worst case estimate since a proportion of groundwater will flow beneath the channel without entering the open water. It is also considered that biological activity within the channel water and silt zones will serve to reduce nitrate concentrations in recharge water to the aquifer where the groundwater nitrate is naturally at a higher concentration than in the Thames intake. Thus, if sweetening flows are maintained from the Thames, nitrate levels could be reduced in parts of the aquifer being recharged towards the level of about 7 mg/l normally found in river water.

Table 5.1.1 Calculated groundwater flows (m^3s^{-1}) across FRC boundaries.

		Inflow	Outflow
West model			
	North bank	.188	.182
	South bank	.122	.156
Central model			
	North bank	.389	.112
	South bank	.146	.285
East model			
	North bank	.280	.105
	South bank	.194	.180
	Total	1.319	1.020

5.1.3 Effect of silting

The consequence of silting is difficult to predict accurately due to the problems of modelling the interaction between open water and groundwater systems and the limitations of a groundwater model in this province. The simple consequence of reducing transmissivity of the southern bank of the channel is to divert water flowing in from the north along the channel to the east. As a result groundwater levels and gradients to the south will drop and flows reduce. In practice, silting might be most likely towards the upper end of the channel and in the areas where recharge to the aquifer occurs, particularly just upstream of weirs. The most noticeable effect will be where the groundwater flow is perpendicular to the channel flow, the central section being most important in this respect. The compensating effect of drainage through the aquifer beneath the channel also means that the impact of silting should be small in the aquifer south of the channel. If there were no recharge to the aquifer due to heavy silt accumulations, then the additional flow along the channel resulting from groundwater inputs would be less than the predicted inflow assuming no silting, that is 1.319 m^3s^{-1}.

5.1.4 Effect on abstractions

The major abstractions taking water from the shallow aquifer are located at

Dorney, at least 1 km from the channel route. No significant physical effect of the channel upon the groundwater levels at the abstractions is predicted, nor are significant chemical changes predicted. However, these assessments do not allow for silting effects as the likely rate of accumulation of silt and the effect that this would have on the permeability of the channel bed have not been studied.

5.1.5 Impact of channel lining

The possibility of lining the flood channel to prevent the entry of nitrate contaminated groundwater has been raised. This would require the construction of sub-channel drains, or retention of alluvium beneath the channel base. Model predictions are that groundwater levels upstream would not be significantly raised if a minimum 1 m thick deposit of sand/gravel were retained. The minimum transmissivity would need to be 0.04 ms^{-1}. and while this is typical of clean granular alluvium such as that found in the study area, silting could reduce this over time leading to rises in groundwater levels to the north of the central section of the channel. Rises of 0.5 m in winter could lead to flooding. In terms of chemical improvements to the channel water, if substantial sweetening flows occur the dilution effects would be so large as to make the groundwater contribution negligible.

5.1.6 Assumed groundwater quality for the flood relief channel

The flow and quality of the groundwater to the flood relief channel is assumed to be constant throughout the year and for all the scenario years. The groundwater flowrate into and out of the channel and the nitrate concentrations vary down the length of the channel (Table 5.1.2) while the other determinands are constant (Table 5.1.3)

Table 5.1.2 Groundwater flow rates and Nitrate concentrations

Reach	Flow In (m^3s^{-1})	Flow Out (m^3s^{-1})	Nitrate (as N) (mg/ℓ)
Boulters Weir	0.31	0.34	21.5
Taplow Mill leat	0.01	0.04	20.0
Marsh Lane	0.18	0.18	17.5
Dorney	0.09	0.14	12.7
Manor Farm	0.26	0.04	6.0
A355	0.21	0.21	6.0
Slough Road	0.27	0.27	8.0
Black Potts			

These totals have ben calculated from values in Table A4.5.4 and rounded.

Table 5.1.3 Groundwater concentrations of other water quality variables used in the model

Dissolved Oxygen	5.0 mg/ℓ
Ammonia (as N)	0.1 mg/ℓ
BOD	2.0 mg/ℓ
O-phosphate	0.1 mg/ℓ
pH	8.5 mg/ℓ

5.2 SURFACE WATER

5.2.1 Flow implications

The QUASAR model has been applied to the main river and the FRC to simulate flow and water quality behaviour. Detailed descriptions of the model and the calibration procedure are given in Appendices 2 and 3 respectively. Detailed results of all model runs are given in Appendix 7. It should be emphasised that QUASAR has been developed and applied as a river system model. Its application to the FRC assumes that river type processes are still operating. This is a reasonable assumption given that the characteristics of the channel will rapidly resemble those of a river as soon as Thames river water enters, as during construction, testing and operation of the FRC. The model has been run for the years 1974, 75, 76, 83/84 and 89 and used to simulate flow, nitrates, orthophosphate, ammonia, unionised ammonia, dissolved oxygen and biochemical oxygen demand (BOD).

5.2.1.1

The flow patterns for each of the 5 years chosen (1974, 75, 76, 83/84, 89) differ considerably from year to year. (Summaries of the main flow statistics are given in Tables A7.1, A7.8, A7.15, A7.22 and A7.29 in Appendix 7). The first year, 1974, (see Figure A3.1) was fairly normal - the majority of the rain is in the winter, early spring and late autumn with 3 peaks above 200 m^3s^{-1}. 1975 had plenty of rain in the early part of the year, with 4 peaks over 200 m^3s^{-1}. In the second half of the year the flow remained below 50 m^3s^{-1}, but never fell below 10 m^3s^{-1}. 1976 was the worst case with flow remaining below 30 m^3s^{-1} right until the end of the year, with a prolonged period below 10 m^3s^{-1} in the summer.

5.2.1.2

The pattern of 1983/4 (October 1983 to September 1984) was similar to 1974, but scaled down. Flows stayed in the range 20 - 180 m^3s^{-1}. 1989 was again different; the majority of the winter rains took place in March and April and there was little rain after this until the middle of December. These five years then give a good spectrum of average to very dry years upon which to base the water quality implications of the flood relief channel.

5.2.1.3

The QUASAR model simulates well the hydrological behaviour of all 5 years. In the case of the main river, velocity flow information was obtained from Thames water and is given in the report by Warwick, 1984. For the FRC the velocity flow information presented in Table 3.3.1 has been used.

5.2.1.4

In order to assess the mixing of channel flows and the River Thames downstream of the confluence two tracer experiments were conducted on the River Thames. In these experiments a known mass of sodium iodide was released at the proposed confluence and the iodide concentrations monitored at 3 sites downstream. Transects across the river indicated that within 700 metres of the confluence mixing had occurred. The flow rates at the time of the experiment was 22 m^3s^{-1}. Whilst this is not the lowest flow conditions it represents a flow at which poor quality water from the channel may be flushed into the main river. The potential problem of this poor quality water hugging the bank and entering the Dachet abstractions for public water supply appears to have been disproved by the iodide tracer experiments. The abstraction site is approximately 1200 metres downstream of the confluence and hence adequate mixing of channel and main river water will have occurred.

5.2.2 Nitrate (as N)

5.2.2.1

Nitrate concentrations in the Thames vary considerably with generally low values in mid summer and high values in winter or during high flow conditions. In general nitrate levels are always well above the concentrations required to limit algal growth. As with the flow, the nitrate concentrations (see Tables A7.2, A7.9, A7.16, A7.23 and A7.30 of Appendix 7 for a summary of these statistics) found in the River Thames range widely over the selected years, from a 95% concentration of about 7 mg ℓ^{-1} in 1975. Despite this variation the predicted effects of the flood relief channel on the nitrate concentrations was consistent for all the years selected.

5.2.2.2

The 50%, FS5 and FS10 scenarios all showed comparable nitrate concentrations in the flood relief channel (FRC) which were similar to the concentrations predicted in the River Thames; this was the same for all years. This is because even compared with the smallest sweetening flow of 5 m^3s^{-1} the groundwater inputs are insignificant. Under the FNS scenarios, however, groundwater is the only flow into the channel. Thus the channel shows a nitrate concentration close to that of the groundwater for much of the time except when flood water is routed down. Figure 5.2.3 emphasises both the high levels of nitrate in the channel under the scenario and the dilution effect of the flood waters (25 January 1975 and 15 March 1975). These concentrations do not persist down the channel (Figure 5.2.4) under low flow conditions in the channel due to a long residence times allowing denitrification to occur to a signficant extent.

Table 5.2.1 Effect of lining first 3 reaches of FRC on predicted Nitrate concentrations using 1976 as an example.

		Lined Mean	95%	5%	Unlined Mean	95%	5%
Marsh	FS5	7.0	14.1	4.1	8.6	15.5	6.0
Lane	FNS	8.1	9.5	6.6	18.6	20.9	15.3
Black	FS5	6.7	12.2	4.8	7.9	12.6	5.8
Potts	FNS	6.9	7.8	5.6	8.3	9.3	5.7
Datchet	FS5	7.4	14.2	4.8	7.6	14.2	5.7
	FNS	7.6	14.3	4.8	7.6	14.2	5.1

5.2.2.3

All the scenarios show little effect on the nitrate of the River Thames either below the discharge of the Cut at Romney or at Datchet below where the channel will rejoin the Thames (e.g. Figs. 5.2.1 and 5.2.2). This is not surprising given that nitrate levels are generally high both in the river and the FRC. The FRC will, however, raise nitrate slightly in dry periods under the 50%, FS5 and FS10 scenarios due to the input of additional nitrate from groundwaters (see Table A7.2). All years show a similar response with a 0.1 mg/ℓ increase in nitrate. This is a very small increase compared with mean nitrate levels of the order of 7-8 mg/ℓ.

5.2.3 Ortho-phosphate

5.2.3.1

Ortho-phosphate levels in the Thames are high and again do not limit algal growth. The ortho-phosphate concentrations at the key Main River locations of Boveney, Romney and Datchet are largely unaffected by any of the operating scenarios for any of the selected years and may even reduce the concentrations due to the increased residence times, (e.g. Figure 5.2.16).

5.2.3.2

Under all the scenarios the FRC shows orthophosphate concentrations lower than in the River Thames. However, concentrations do not become low enough to limit algal growth; to limit algal growth concentrations of 10 $\mu g/\ell$ are required. Simulated FRC levels are well above this limit even under the FNS scenario. Moreover the model does not account for the additional P that may be recycled via the sediments. The extent of recycling is extremely difficult to quantify and little research has been undertaken in this area. Recycling would effectively provide an additional source of P which would add to the relatively high levels being estimated. It is not considered that P would ever be limiting to algal growth in the FRC even under the FNS scenario.

5.2.4 BOD (ATU)

5.2.4.1

Summaries of the predicted BOD levels are given in tables A7.4, A7.11, A7.18, A7.25 and A7.32 of Appendix 7. The BOD concentrations in the critical reaches at Boveney, Romney and Datchet are unaffected by any of the scenarios for all years except 1976. In 1976 (Figure 5.2.9) the 95% BOD at Datchet is increased from 6.4 mg ℓ^{-1} to over 9 mg ℓ^{-1} as a result of water of high BOD's concentration entering from the FRC. The BOD levels in the FRC are influenced by algae concentrations and under low flow conditions the algae concentrations can be expected to increase markedly along the channel. This in turn leads to an increase in BOD concentrations along the channel, (Figure 5.2.11). Figure 5.2.12 shows a peak in BOD at Black Potts on the FRC during the summer months.

5.2.4.2

High algal populations in the FRC may be flushed into the main river at the end of drought periods and this may give rise to high levels of BOD in the river downstream (see section 5.2.5.2 and 5.2.5.3 for DO effects).

5.2.5 Dissolved oxygen

5.2.5.1

Dissolved oxygen levels in the main River Thames are generally high and close to saturation. There are problems at times caused by the presence of algal blooms which contribute to BOD on algal death. In addition algae generate oxygen by photosynthesis during the day and remove oxygen at night by respiration. This diel pattern is a common feature of many lowland U.K. river systems. All the scenarios for all the years simulated show no deteriation in the oxygen levels in the Thames at the control reaches of Boveney, Romney and Datchet. (e.g. Figs. 5.2.5 and 5.2.6).

5.2.5.2

The dissolved oxygen levels in the FRC are close to those in the River Thames under most situations. However when flows fall below 10 m^3s^{-1}, there may be low DO levels due to the presence of large algal blooms. This is demonstrated in Fig. 5.2.7 for 1976 where flows fall significantly in the severe drought period and the large algal blooms give rise to high levels of BOD (see section 5.2.5 and Figure 5.2.12). Thus oxygen problems may arise in severe drought years or under the FNS scenario.

5.2.5.3

A further oxygen problem may arise in the Thames Tideway if large algal populations are suddenly flushed out of the channel and into the main river. Algal deaths are unlikely to occur immediately downstream of the FRC but would occur in the saline sections of the river below Teddington. The additional BOD load created may cause some additional oxygen problems in the tideway.

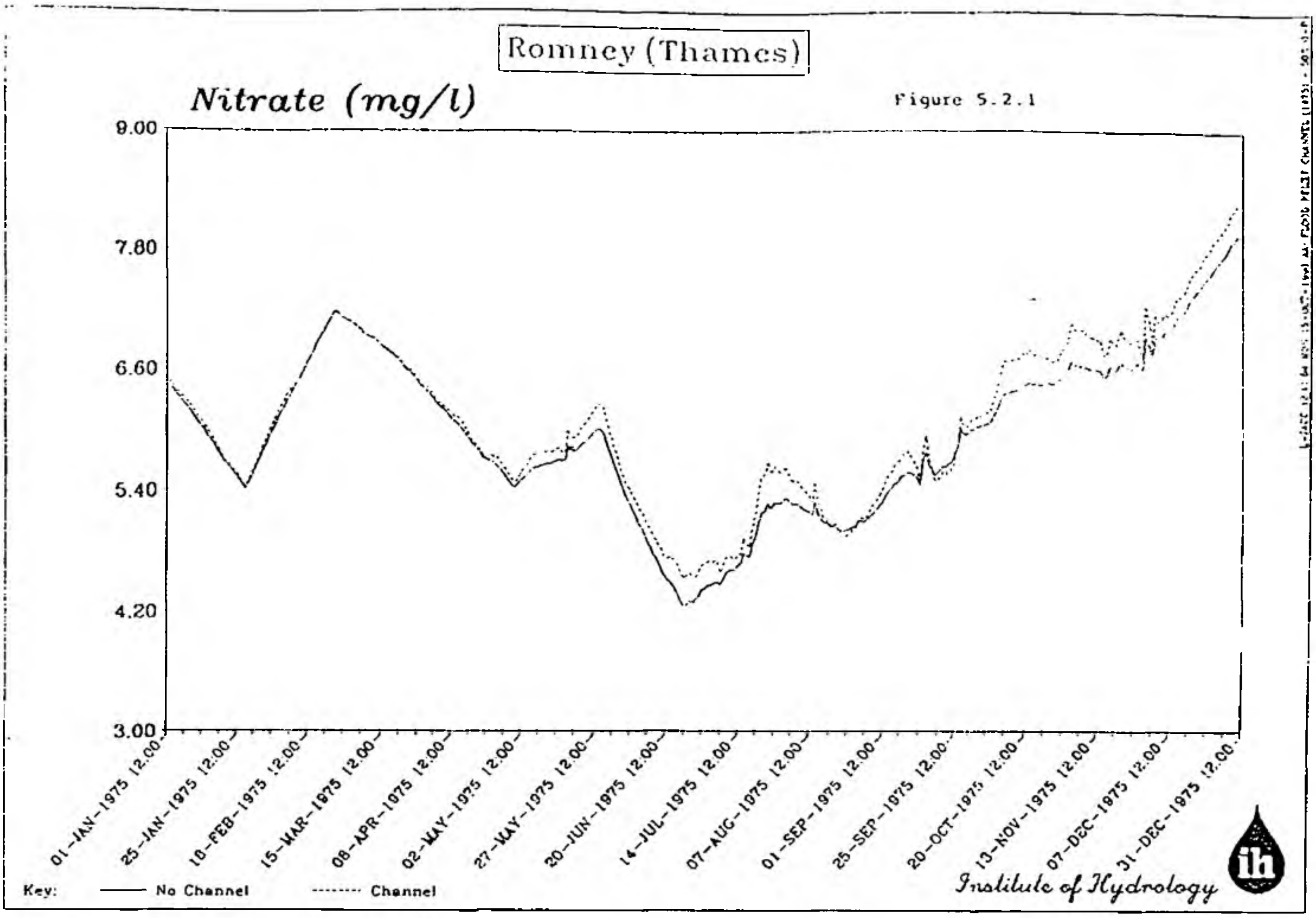
5.2.6 Ammonium + Unionized Ammonia

5.2.6.1

The ammonium and hence the unionized ammonia concentrations in the River Thames (summarised in Tables A7.5, A7.7, A7.12, A7.14, A7.19, A7.21, A7.26, A7.28, A7.33, A7.35 of Appendix 7) are unaffected by any of the operating scenarious for the FRC in any of the selected years (Figure 5.2.13, 5.2.14, 5.2.15).

5.2.6.2

The low concentrations in the groundwater and the long residence times in the channel mean that the ammonium and unionized ammonia concentrations are always low in the channel compared with the River Thames.



Romney (Thames)
Nitrate (mg/l)
Figure 5.2.1
9.00
7.80
6.60
5.40
4.20
3.00
01-JAN-1975 12.00
25-JAN-1975 12.00
18-FEB-1975 12.00
15-MAR-1975 12.00
08-APR-1975 12.00
02-MAY-1975 12.00
27-MAY-1975 12.00
20-JUN-1975 12.00
14-JUL-1975 12.00
07-AUG-1975 12.00
01-SEP-1975 12.00
25-SEP-1975 12.00
20-OCT-1975 12.00
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31-DEC-1975 12.00
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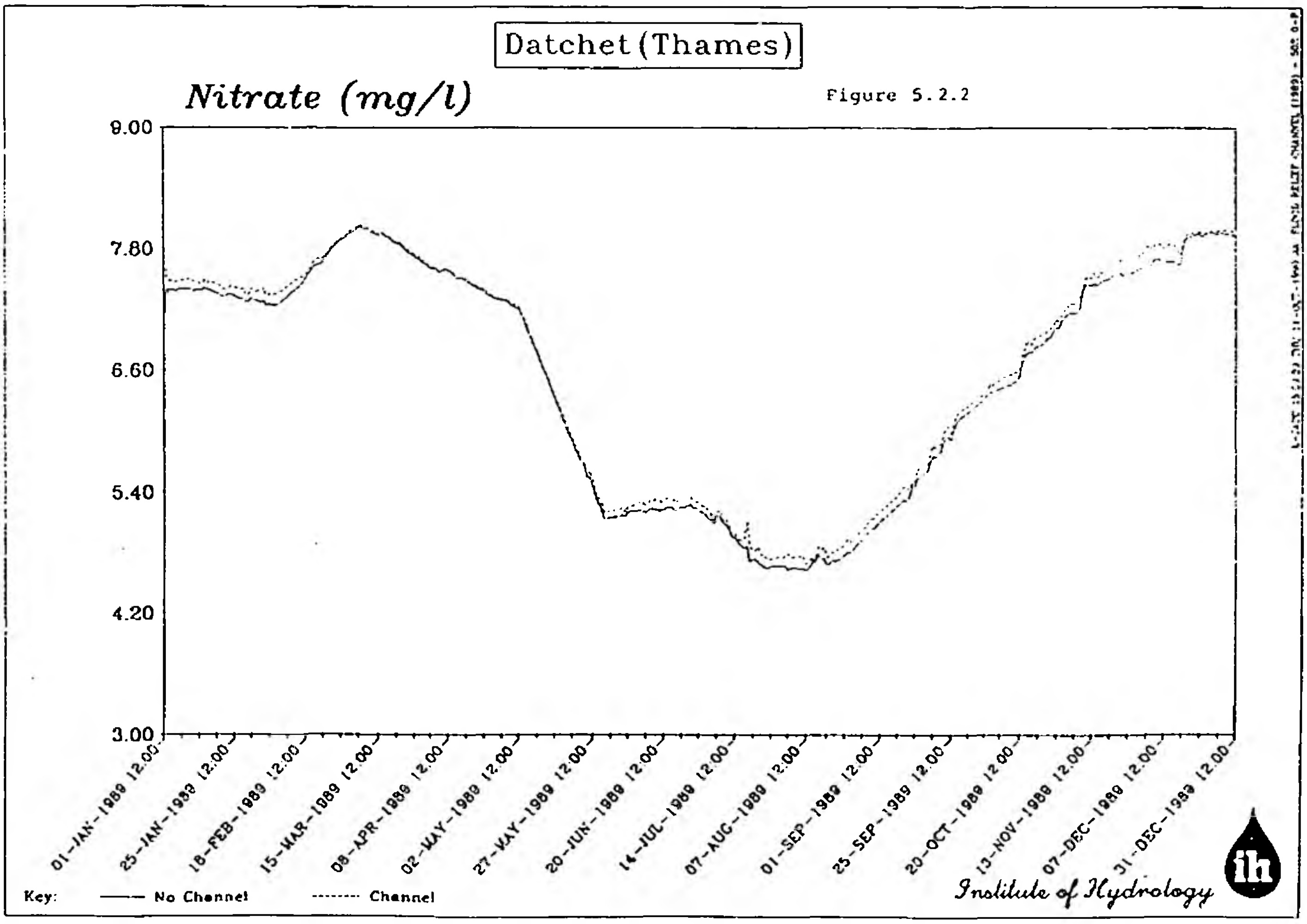
Channel
Institute of Hydrology



Datchet (Thames)
Nitrate (mg/l)
Figure 5.2.2
9.00
7.80
6.60
5.40
4.20
3.00
01-JAN-1989 12.00
25-JAN-1989 12.00
18-FEB-1989 12.00
15-MAR-1989 12.00
08-APR-1989 12.00
02-MAY-1989 12.00
27-MAY-1989 12.00
20-JUN-1989 12.00
14-JUL-1989 12.00
07-AUG-1989 12.00
01-SEP-1989 12.00
25-SEP-1989 12.00
20-OCT-1989 12.00
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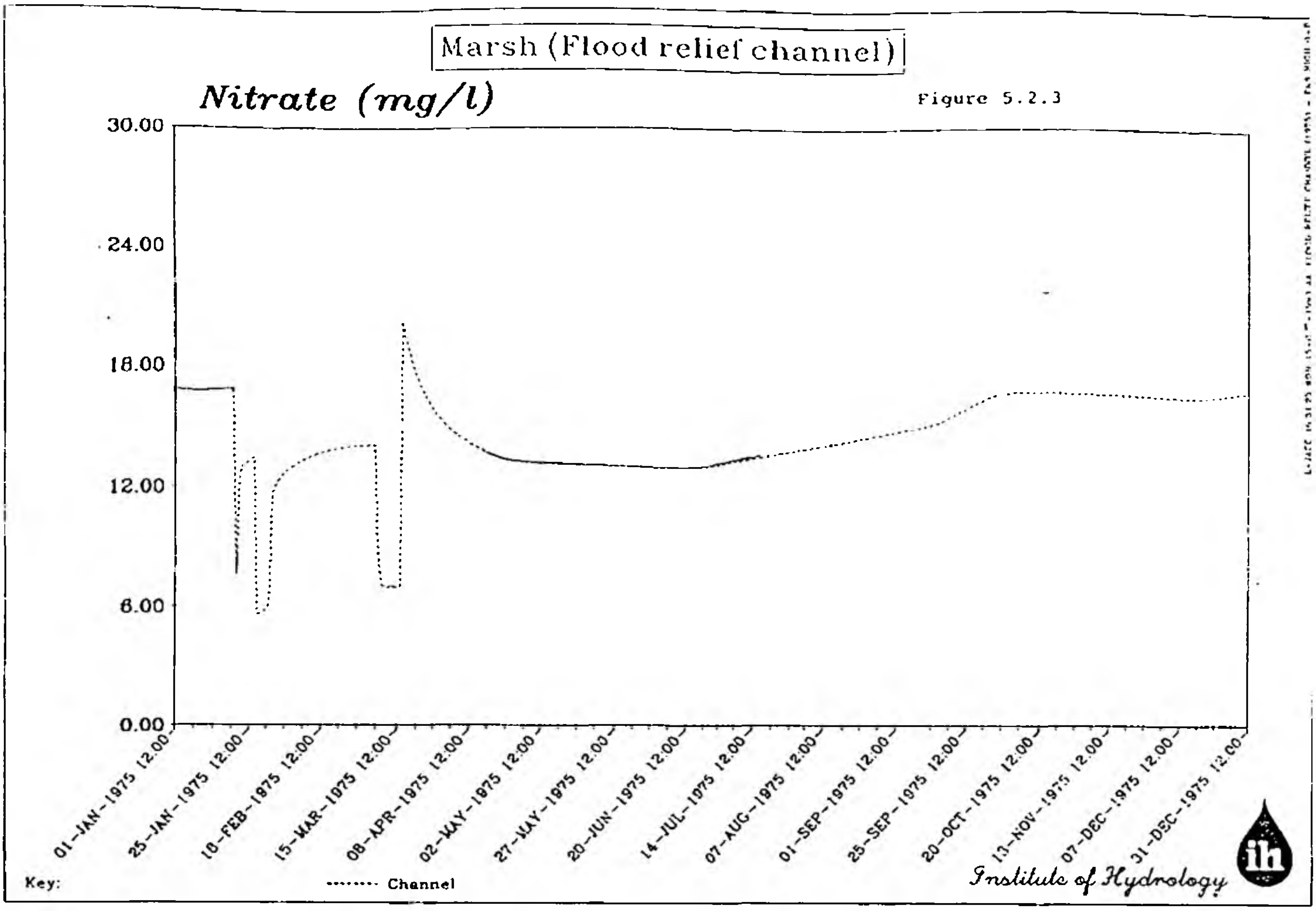

Marsh (Flood relief channel)
Nitrate (mg/l)
Figure 5.2.3
30.00
24.00
18.00
12.00
6.00
0.00
01-JAN-1975 12.00
25-JAN-1975 12.00
18-FEB-1975 12.00
15-MAR-1975 12.00
08-APR-1975 12.00
02-MAY-1975 12.00
27-MAY-1975 12.00
20-JUN-1975 12.00
14-JUL-1975 12.00
07-AUG-1975 12.00
01-SEP-1975 12.00
25-SEP-1975 12.00
20-OCT-1975 12.00
13-NOV-1975 12.00
07-DEC-1975 12.00
31-DEC-1975 12.00
Key:
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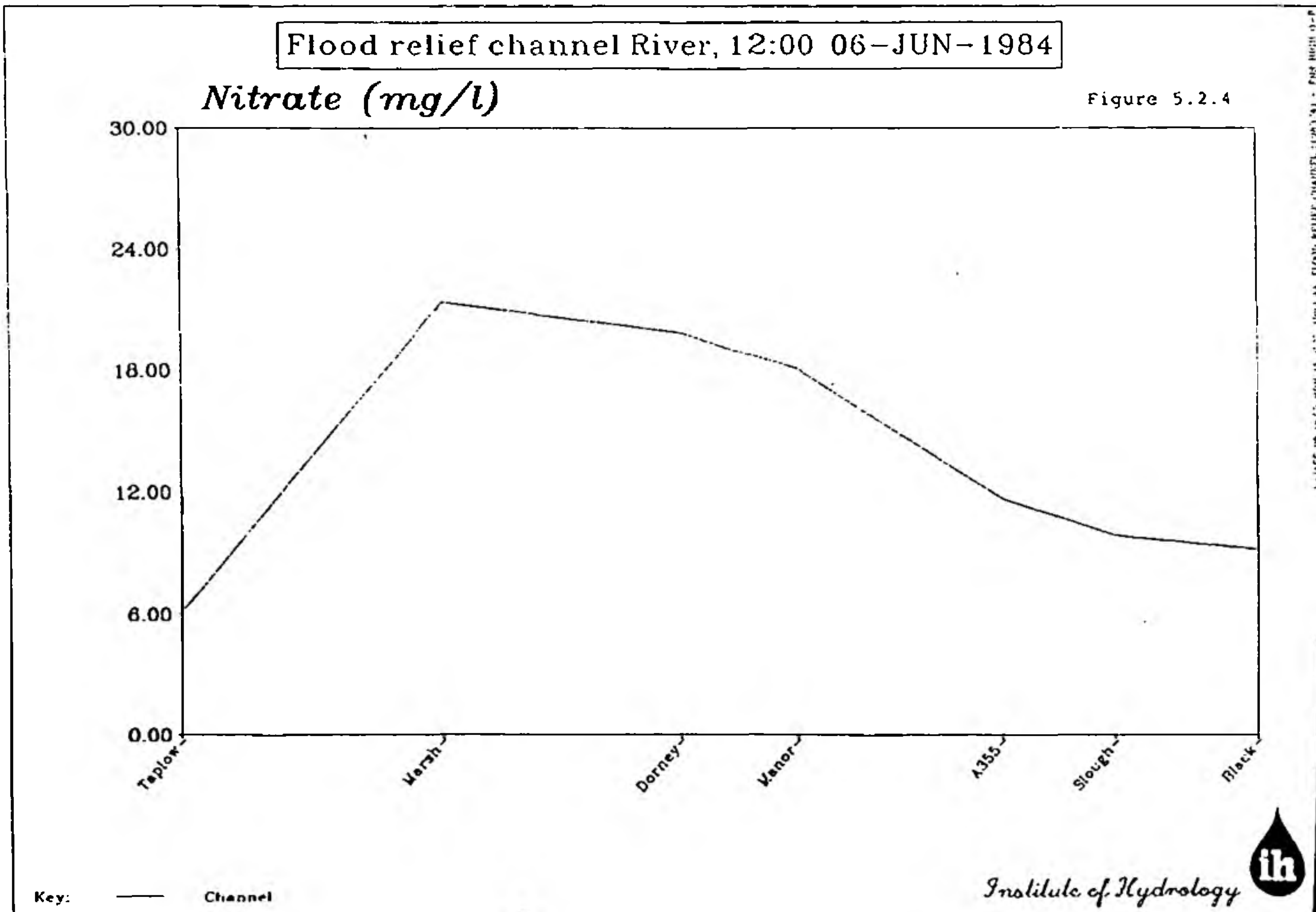
Institute of Hydrology
ih



Flood relief channel River, 12:00 06-JUN-1984
Nitrate (mg/l)
Figure 5.2.4
30.00
24.00
18.00
12.00
6.00
0.00
Taplow
Marsh
Dorney
Manor
A355
Slough
Black
Key:
Channel
Institute of Hydrology
ih

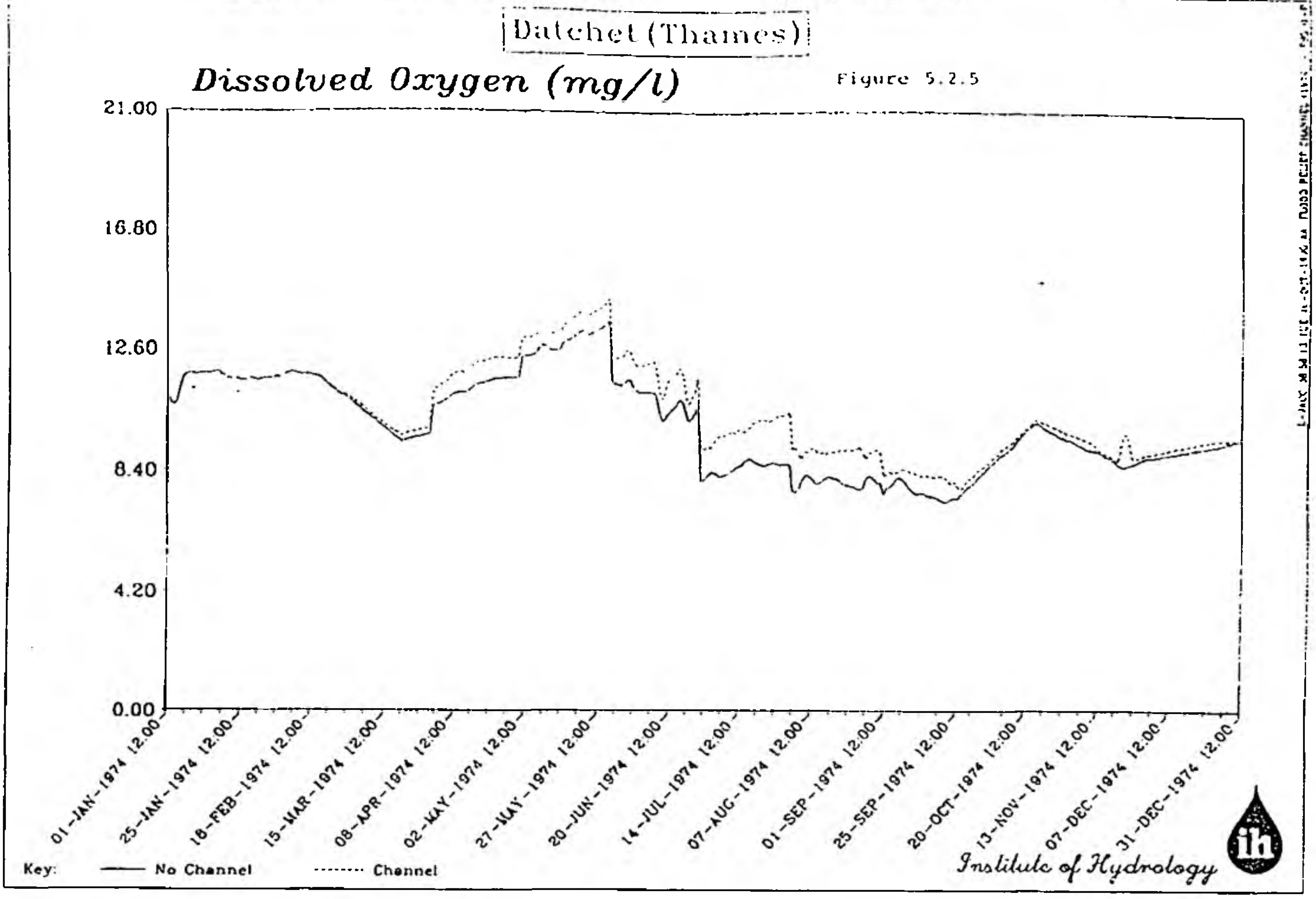


Figure 5.2.5

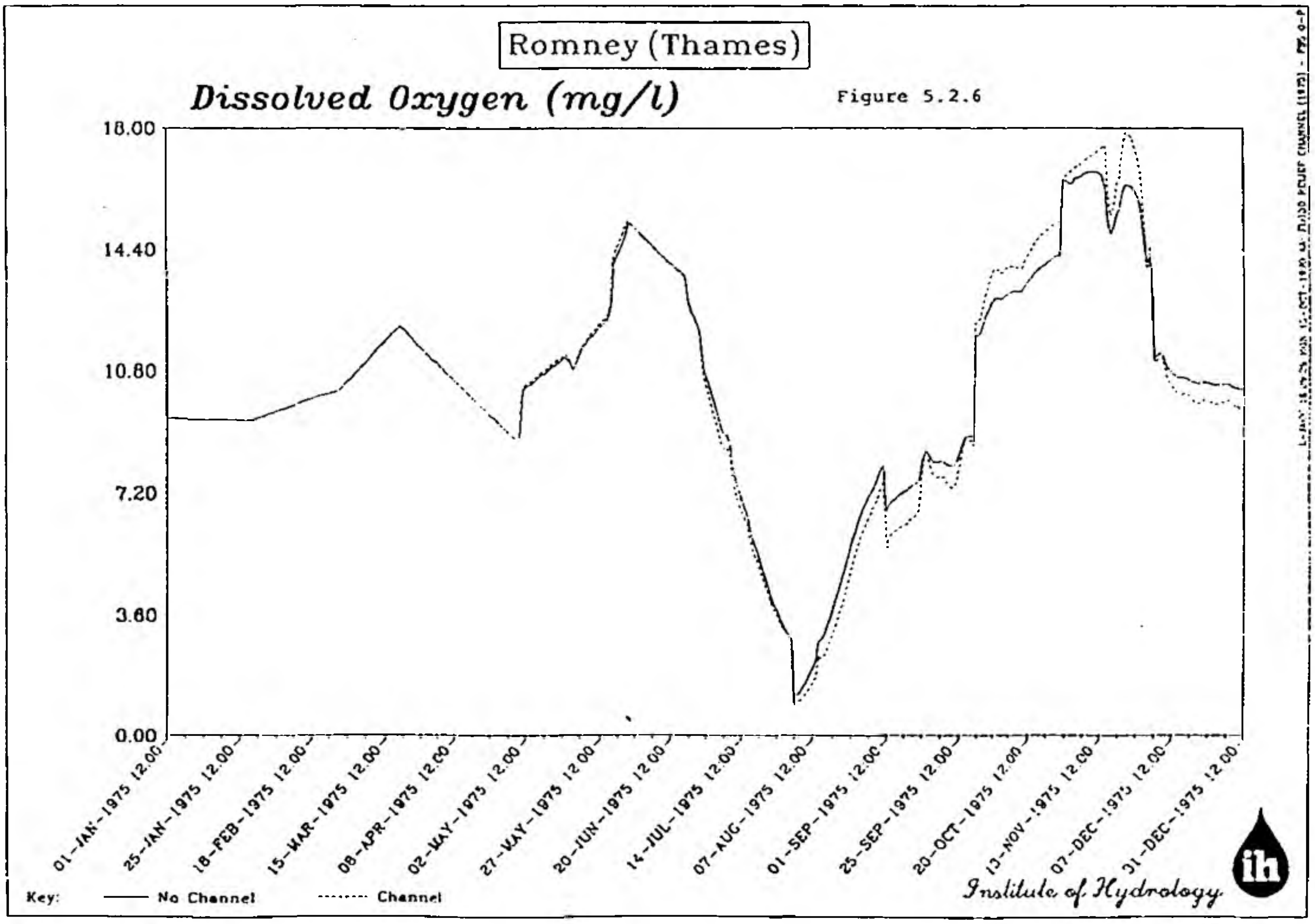
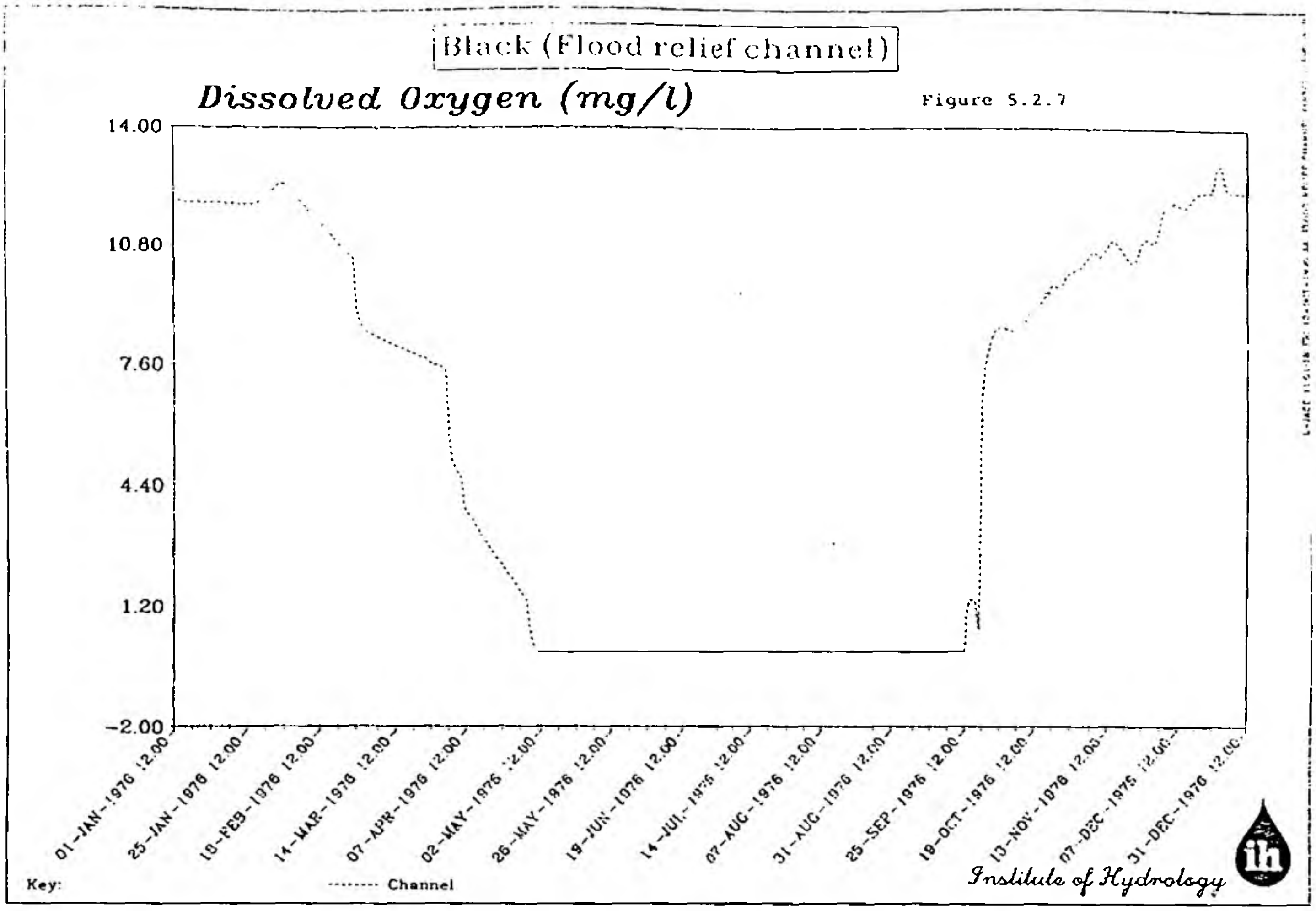


Figure 5.2.6


Black (Flood relief channel)
Dissolved Oxygen (mg/l)
Figure 5.2.7
14.00
10.80
7.60
4.40
1.20
-2.00
01-JAN-1976 12.00
25-JAN-1976 12.00
18-FEB-1976 12.00
14-MAR-1976 12.00
07-APR-1976 12.00
02-MAY-1976 12.00
26-MAY-1976 12.00
19-JUN-1976 12.00
14-JUL-1976 12.00
07-AUG-1976 12.00
31-AUG-1976 12.00
25-SEP-1976 12.00
19-OCT-1976 12.00
13-NOV-1976 12.00
07-DEC-1976 12.00
31-DEC-1976 12.00
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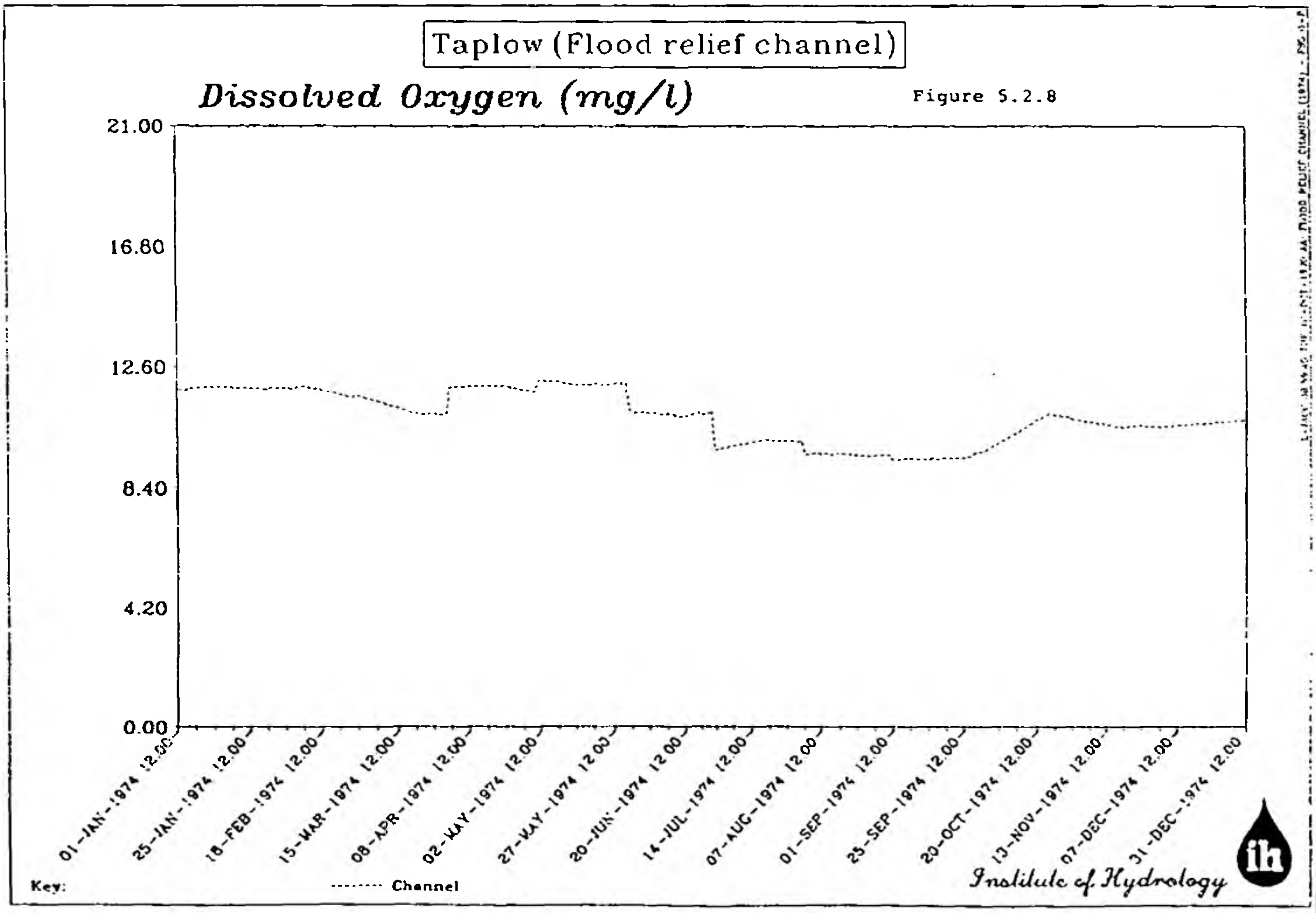
Channel
Institute of Hydrology


Taplow (Flood relief channel)
Dissolved Oxygen (mg/l)
Figure 5.2.8
21.00
16.80
12.60
8.40
4.20
0.00
01-JAN-1974 12.00
25-JAN-1974 12.00
18-FEB-1974 12.00
15-MAR-1974 12.00
08-APR-1974 12.00
02-MAY-1974 12.00
27-MAY-1974 12.00
20-JUN-1974 12.00
14-JUL-1974 12.00
07-AUG-1974 12.00
01-SEP-1974 12.00
25-SEP-1974 12.00
20-OCT-1974 12.00
13-NOV-1974 12.00
07-DEC-1974 12.00
31-DEC-1974 12.00
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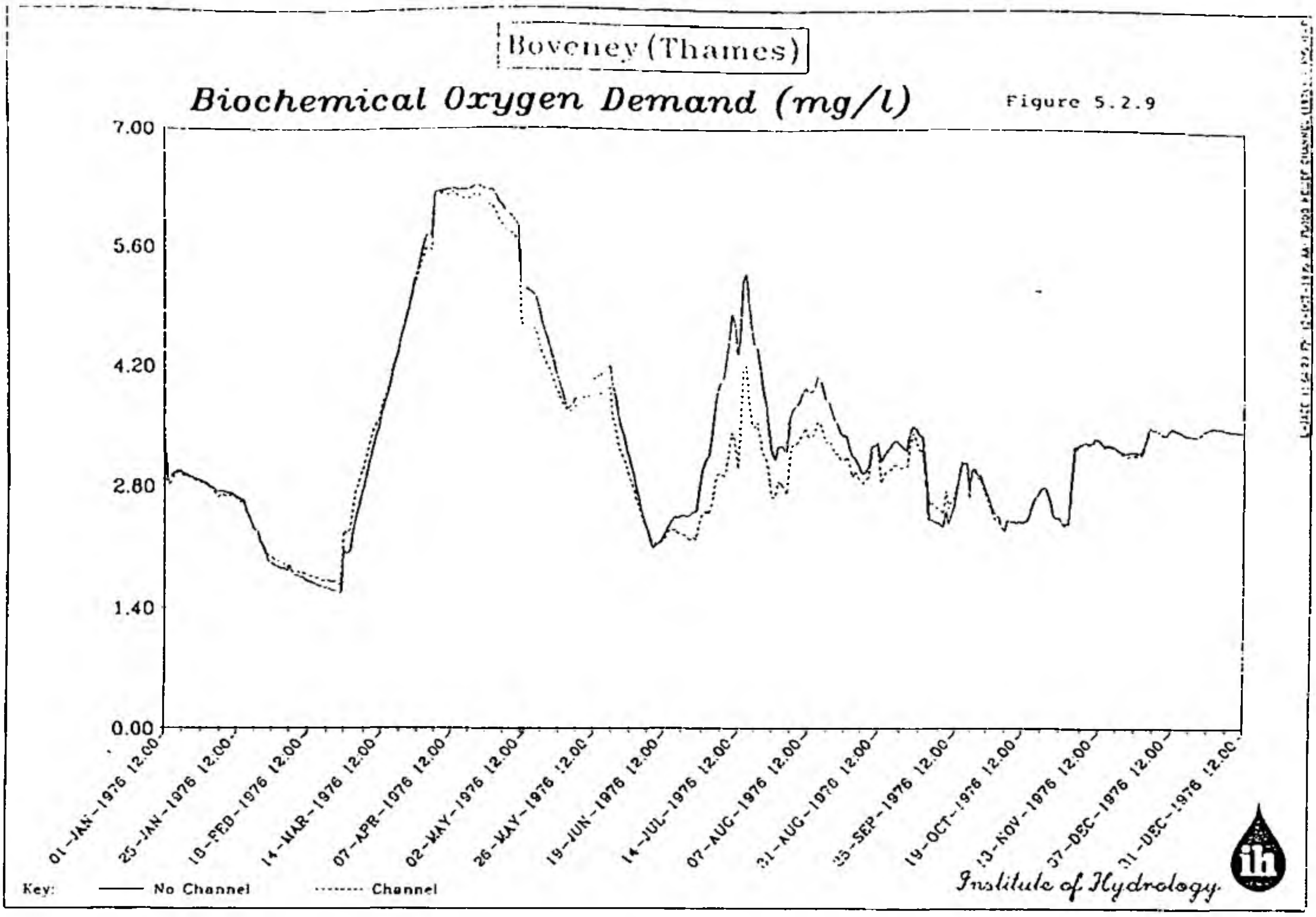
Boveney (Thames)
Biochemical Oxygen Demand (mg/l)
Figure 5.2.9
7.00
5.60
4.20
2.80
1.40
0.00
01-JAN-1976 12.00
25-JAN-1976 12.00
18-FEB-1976 12.00
14-MAR-1976 12.00
07-APR-1976 12.00
02-MAY-1976 12.00
26-MAY-1976 12.00
19-JUN-1976 12.00
14-JUL-1976 12.00
07-AUG-1976 12.00
31-AUG-1976 12.00
25-SEP-1976 12.00
19-OCT-1976 12.00
13-NOV-1976 12.00
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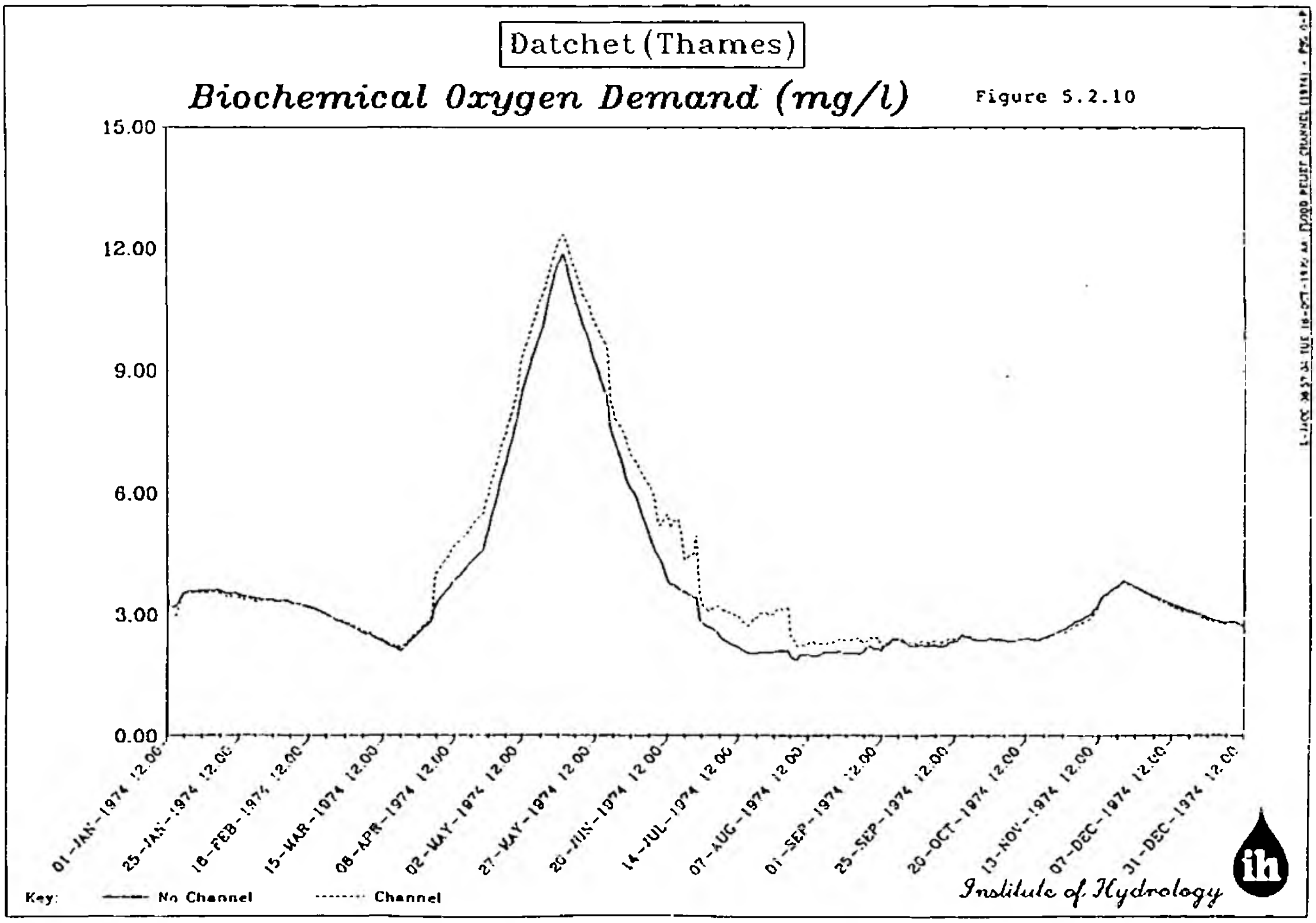
Datchet (Thames)
Biochemical Oxygen Demand (mg/l)
Figure 5.2.10
15.00
12.00
9.00
6.00
3.00
0.00
01-JAN-1974 12.00
25-JAN-1974 12.00
18-FEB-1974 12.00
15-MAR-1974 12.00
08-APR-1974 12.00
02-MAY-1974 12.00
27-MAY-1974 12.00
20-JUN-1974 12.00
14-JUL-1974 12.00
07-AUG-1974 12.00
01-SEP-1974 12.00
25-SEP-1974 12.00
20-OCT-1974 12.00
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31-DEC-1974 12.00
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Channel
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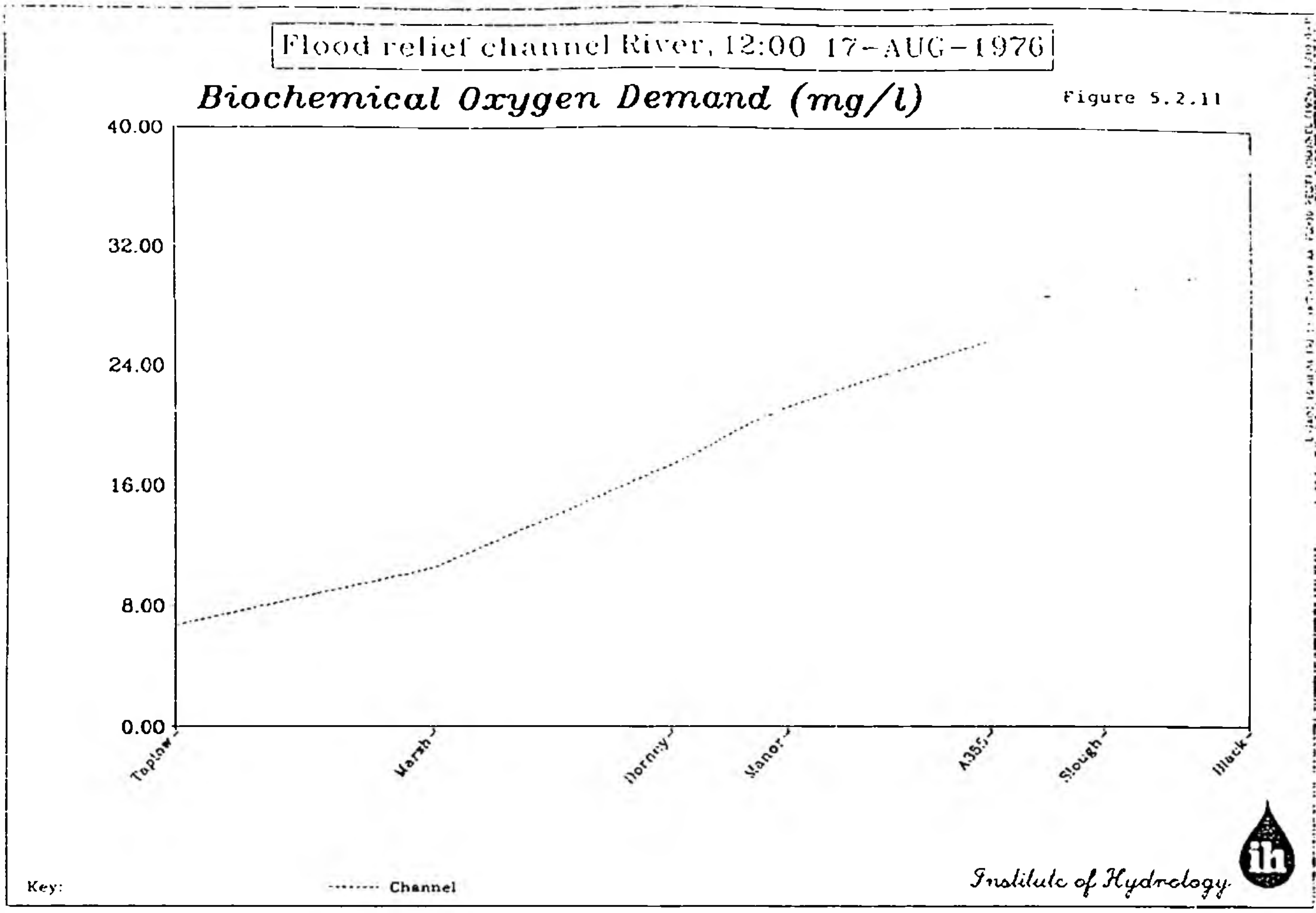
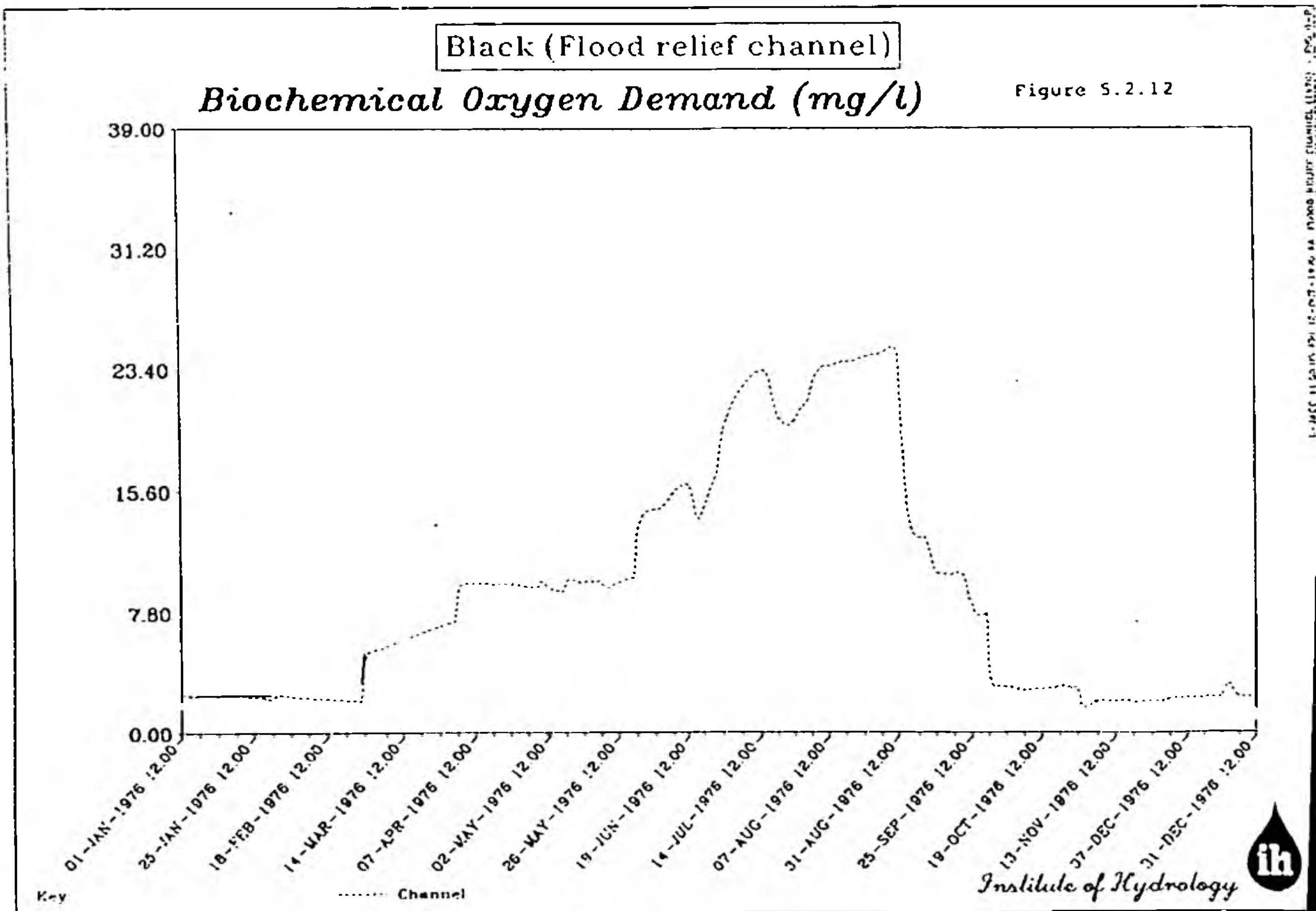

Flood relief channel River, 12:00 17-AUG-1976
Biochemical Oxygen Demand (mg/l)
Figure 5.2.11
40.00
32.00
24.00
16.00
8.00
0.00
Taplow
Marsh
Dorney
Manor
A355
Slough
Black
Key:
Channel
Institute of Hydrology


Black (Flood relief channel)
Biochemical Oxygen Demand (mg/l)
Figure 5.2.12
39.00
31.20
23.40
15.60
7.80
0.00
01-JAN-1976 12.00
25-JAN-1976 12.00
18-FEB-1976 12.00
14-MAR-1976 12.00
07-APR-1976 12.00
02-MAY-1976 12.00
26-MAY-1976 12.00
19-JUN-1976 12.00
14-JUL-1976 12.00
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25-SEP-1976 12.00
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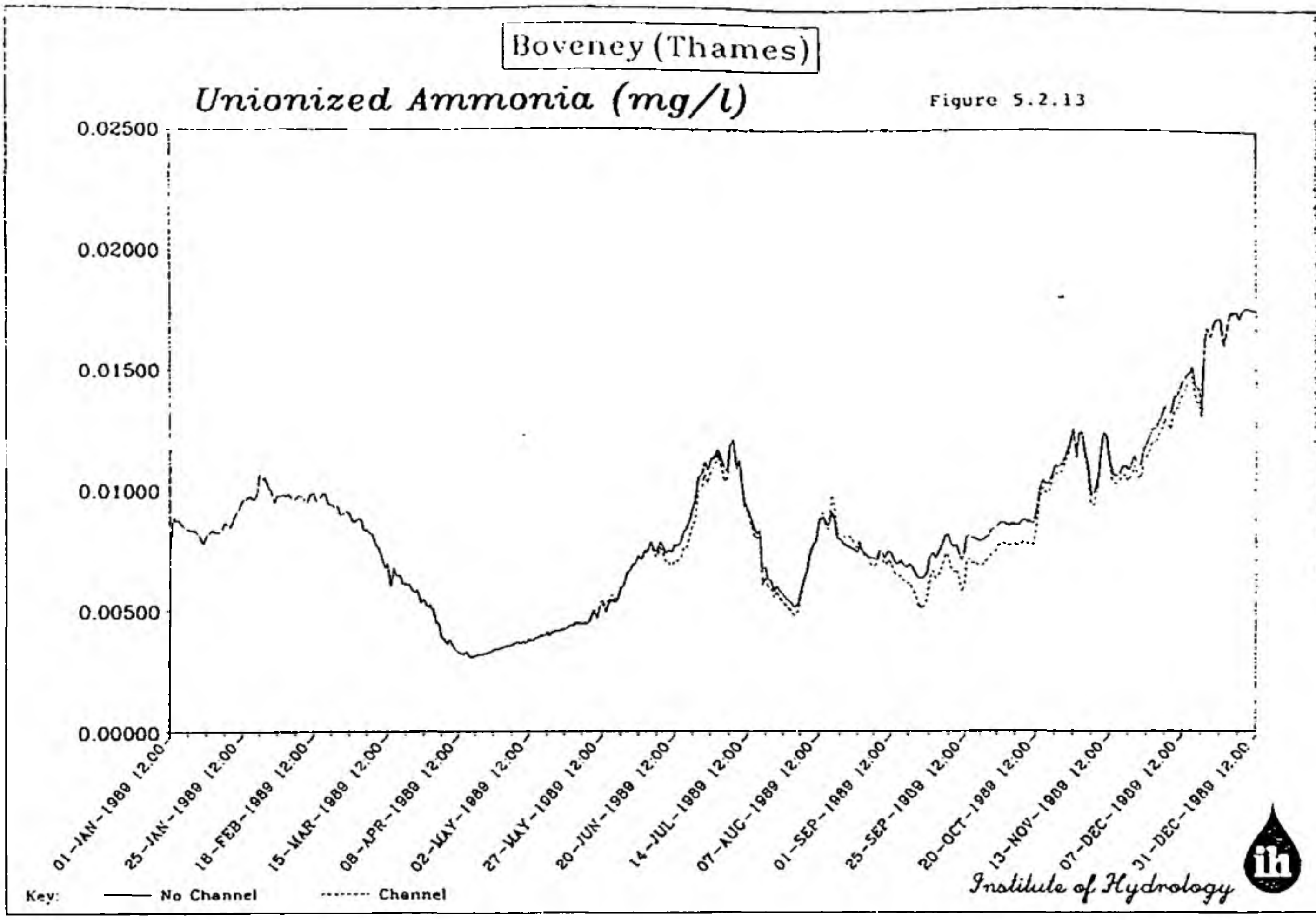
Key
Channel
Institute of Hydrology


Boveney (Thames)
Unionized Ammonia (mg/l)
Figure 5.2.13
0.02500
0.02000
0.01500
0.01000
0.00500
0.00000
01-JAN-1989 12:00
25-JAN-1989 12:00
18-FEB-1989 12:00
15-MAR-1989 12:00
08-APR-1989 12:00
02-MAY-1989 12:00
27-MAY-1989 12:00
20-JUN-1989 12:00
14-JUL-1989 12:00
07-AUG-1989 12:00
01-SEP-1989 12:00
25-SEP-1989 12:00
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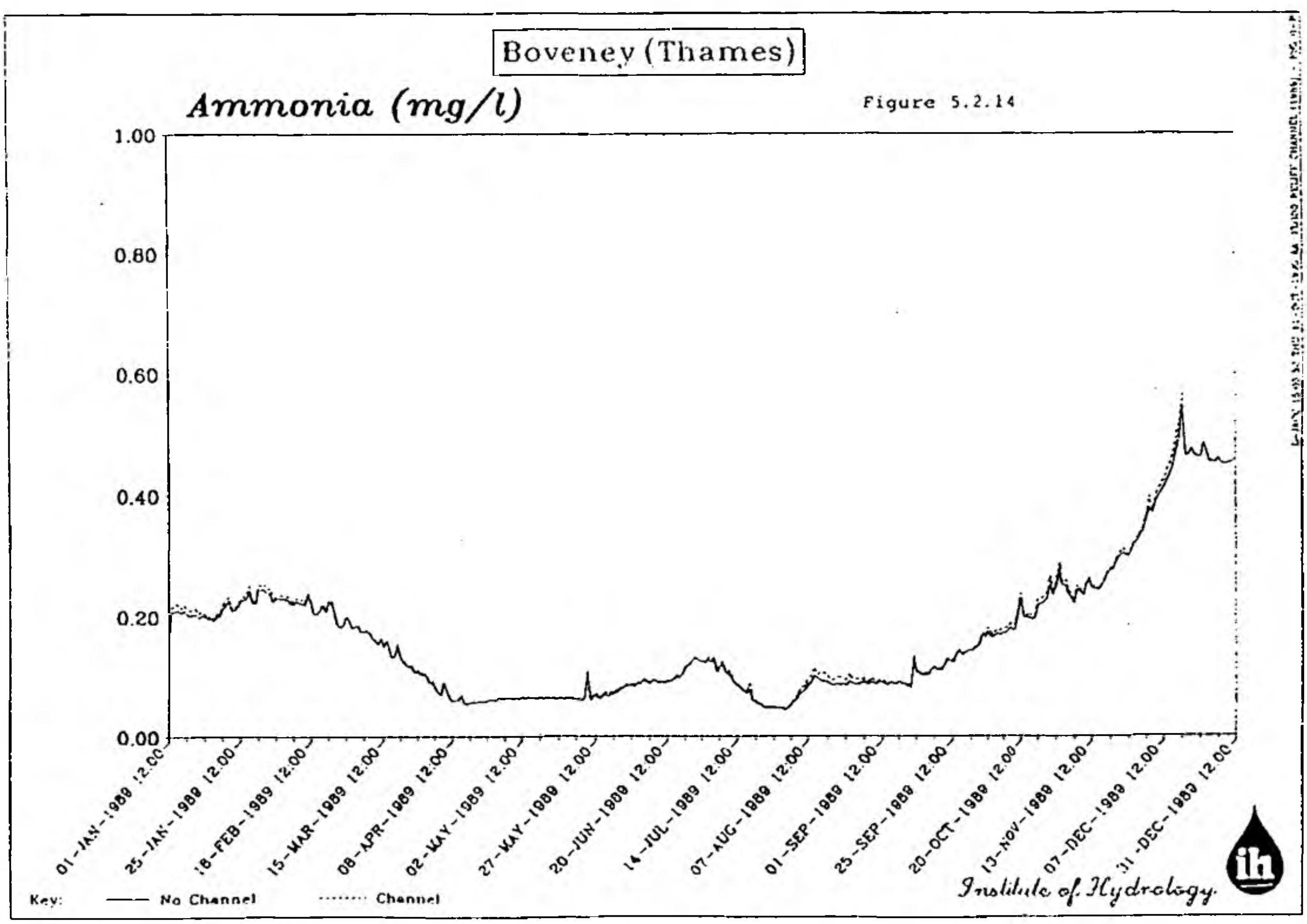
Boveney (Thames)
Ammonia (mg/l)
Figure 5.2.14
1.00
0.80
0.60
0.40
0.20
0.00
01-JAN-1989 12:00
25-JAN-1989 12:00
18-FEB-1989 12:00
15-MAR-1989 12:00
08-APR-1989 12:00
02-MAY-1989 12:00
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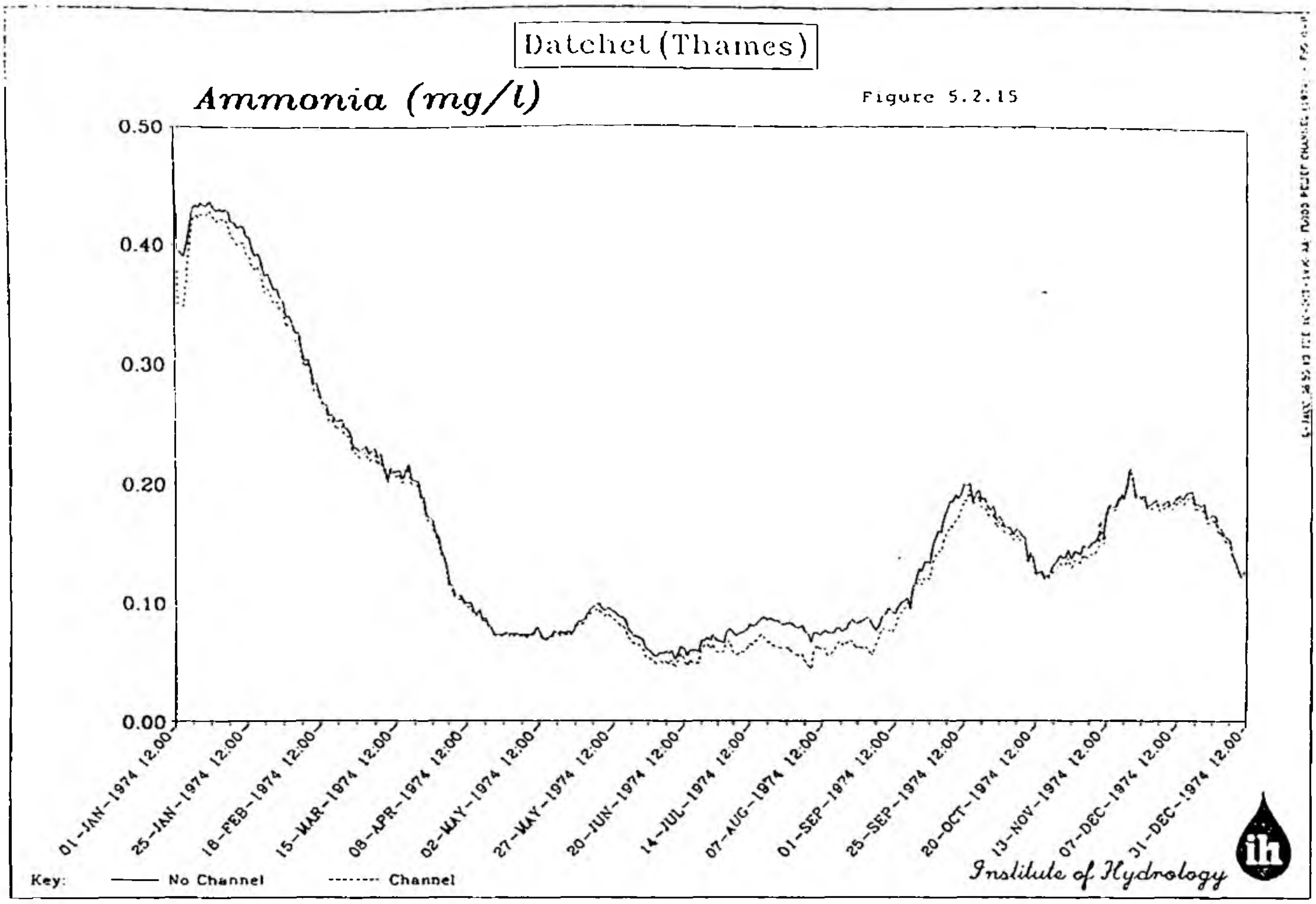
20-JUN-1989 12:00
14-JUL-1989 12:00
07-AUG-1989 12:00
01-SEP-1989 12:00
25-SEP-1989 12:00
20-OCT-1989 12:00
13-NOV-1989 12:00
07-DEC-1989 12:00
31-DEC-1989 12:00
Key: No Channel
Channel
Institute of Hydrology



Datchet (Thames)
Ammonia (mg/l)
Figure 5.2.15
0.50
0.40
0.30
0.20
0.10
0.00
01-JAN-1974 12.00
25-JAN-1974 12.00
18-FEB-1974 12.00
15-MAR-1974 12.00
08-APR-1974 12.00
02-MAY-1974 12.00
27-MAY-1974 12.00
20-JUN-1974 12.00
14-JUL-1974 12.00
07-AUG-1974 12.00
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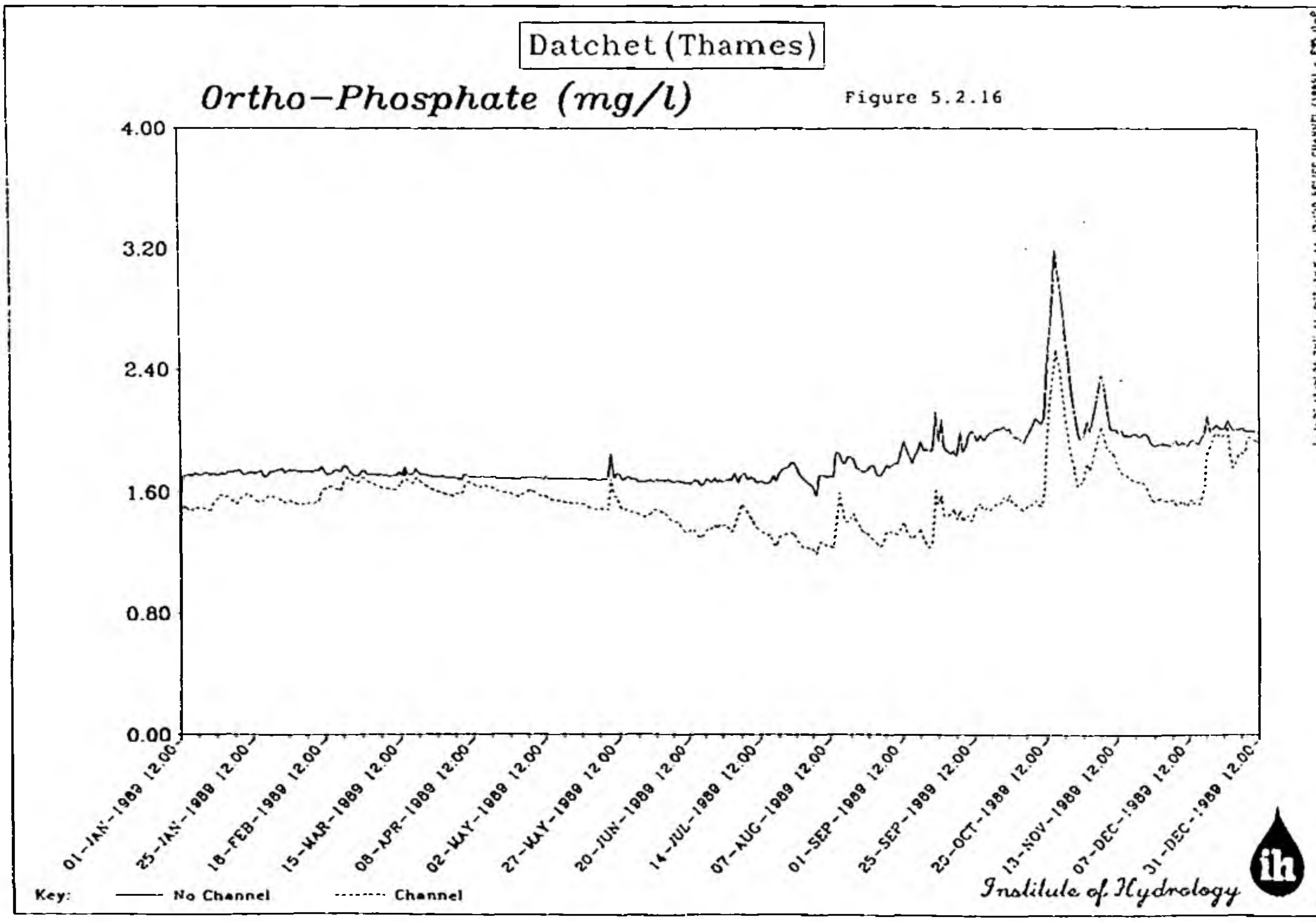
Key: No Channel Channel
Institute of Hydrology



Datchet (Thames)
Ortho-Phosphate (mg/l)
Figure 5.2.16
4.00
3.20
2.40
1.60
0.80
0.00
01-JAN-1989 12.00
25-JAN-1989 12.00
18-FEB-1989 12.00
15-MAR-1989 12.00
08-APR-1989 12.00
02-MAY-1989 12.00
27-MAY-1989 12.00
20-JUN-1989 12.00
14-JUL-1989 12.00
07-AUG-1989 12.00
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25-SEP-1989 12.00
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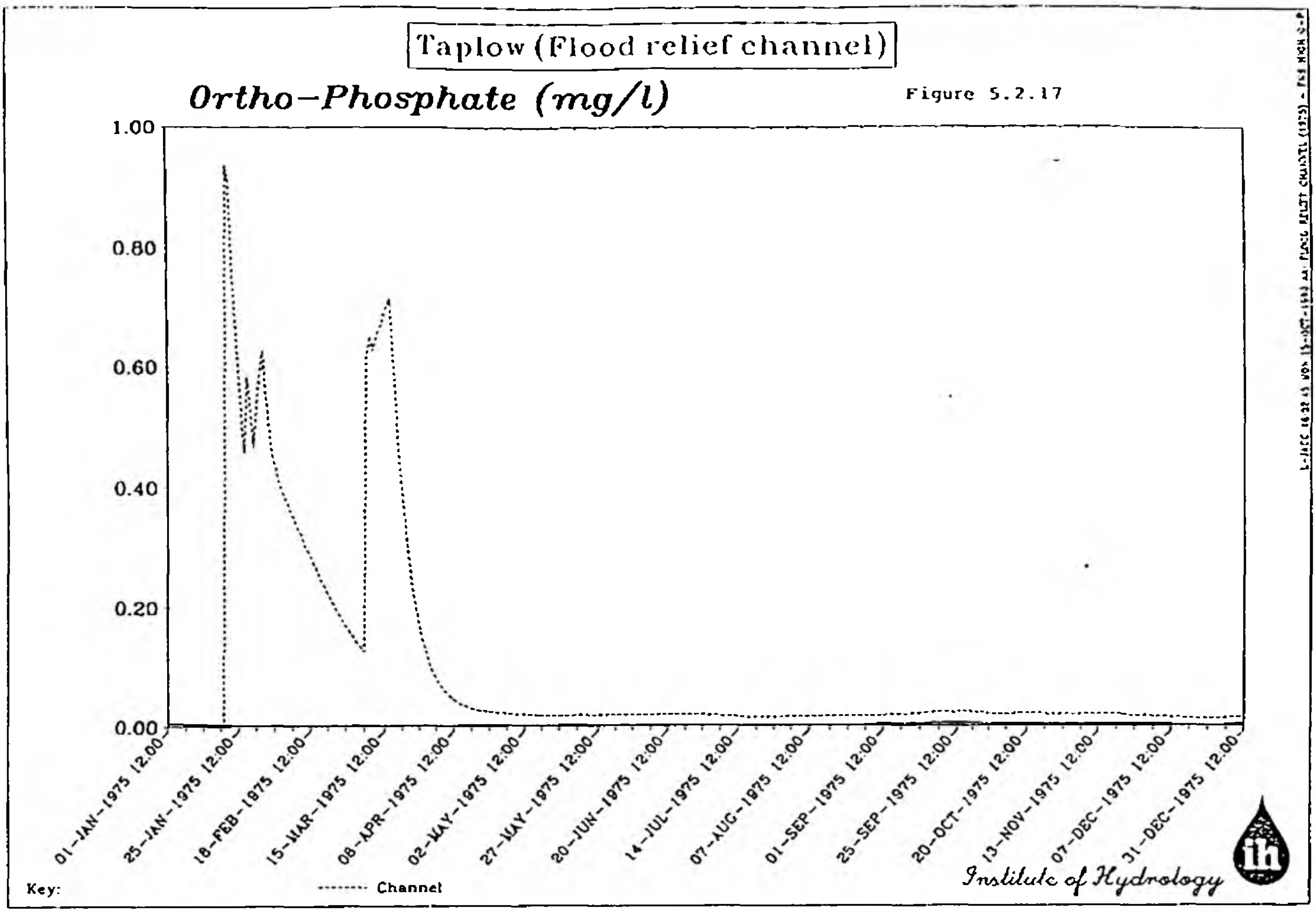
31-DEC-1989 12.00
Key: No Channel Channel
Institute of Hydrology



Taplow (Flood relief channel)
Ortho-Phosphate (mg/l)
Figure 5.2.17
1.00
0.80
0.60
0.40
0.20
0.00
01-JAN-1975 12:00
25-JAN-1975 12:00
18-FEB-1975 12:00
15-MAR-1975 12:00
08-APR-1975 12:00
02-MAY-1975 12:00
27-MAY-1975 12:00
20-JUN-1975 12:00
14-JUL-1975 12:00
07-AUG-1975 12:00
01-SEP-1975 12:00
25-SEP-1975 12:00
20-OCT-1975 12:00
13-NOV-1975 12:00
07-DEC-1975 12:00
31-DEC-1975 12:00
Key:
Channel
Institute of Hydrology

6. Environmental implications

6.1 DIEL CHANGES

6.1.1

Under normal conditions if any submerged plants grow in the central portion of the channel they are soon likely to be covered by epiphytes etc., because of the availability of excessive quantities of plant nutrients, and are unlikely to grow with any vigour. In abnormally dry years submerged plants apart from water lily, may become established but they are not likely to survive for more than a few seasons. It is possible that floating species such as Lemna and Azolla may appear from time to time. Large stands of floating plants (esp. Lemna and Azolla) may occur but these are considered unlikely to cause a problem due to a relatively short development time between flow events under the recommended sweetening flows. If the channel is static for more than 6 months and an innocula of floating plants is available in the margins or backwaters then a problem may develop; a dense surface cover of plants may cause deoxygenation.

6.1.2

When factors for biochemical oxygen demand or low oxygen input concentrations were introduced, dissolved oxygen equilibrated to normal and moderate diel curves occurred at discharges higher than 5-10 m^3s^{-1}. Under a variety of more extreme conditions including BOD 5 to 10 mg l^{-1} (to allow for the effects of incoming algae dying), the dissolved oxygen levels reduced to 1 mg l^{-1}. It is recommended that the three proposed sloping weirs (1:5) are replanned to be similar to the three proposed straight-fall weirs if practicable as this will enhance reaeration. Structures recommended to enable acceptable reaeration or weir-type values should, for example, be broad-crested straight-sloped or vertical-faced weirs; flumes or low gradient weirs are to be avoided.

6.1.3

It is recommended that some flow is always maintained in the channel throughout the year to ensure that the weirs return the dissolved oxygen concentration towards air equilibrium.

6.2 MACROPHYTE GROWTH

6.2.1

The water depth of approximately 2 metres is likely to discourage the normal growth of submerged water plants. However during periods of low water level during particularly dry years submerged water plants may become established. This may occur through colonisation from fragments or clumps from upstream either by settlement in margins during normal operation of the channel or during flood events. Such settlement events may be further encouraged by the proposal to overdredge the channel by 0.5 m to reduce maintenance over its life. However this overdredging will encourage the settlement of much organic material which may or may not be subject to seasonal washout, and although giving a channel with a more unstable bed for plant colonisation, will further encourage the settlement of viable fragments which may grow despite the effects of deeper water on light absorption. The species of plants which develop will depend upon the flow scenarios but at even slight sweetening flows the naturally turbid nature and fine suspended organic material of the water resulting from algal growth is unlikely to allow much development. In addition, with the high levels of plant nutrients, particularly nitrate and phosphate, epiphytic overgrowth of submerged water plants is very likely to occur; this will also limit submerged plant growth. Chlorophyll levels were generally high during the potential plant growth season.

6.2.2

The growth of marginal emergent plants from the shallow margins is likely to predominate. Plants such as water lily are likely only to become common in the refugia or backwaters where organic muds accumulate and water flow is less rapid at high discharges. Invasion across the regularly flushed gravel beds of the main channel around Manor Farm and the central sections is unlikely under scenarios 2 and 3. Concrete lined sections of channel are only likely to be colonised by plants if excessive deposition occurs.

6.2.3

Many submerged and emergent species are available upstream for colonisation; during a brief visit to the area around Taplow lock, 15 aquatic and marginal species including two vigorous invasive species, were found.

6.3 ALGAE

6.3.1 Modelling results

6.3.1.1

The model was used to simulate the growth of different algae at different temperatures and light incomes. As an example, Figure 6.3.1 traces the 'worst case' effects of downstream increase of an inoculum, N_0, into the channel at Taplow by the time it is discharged back into the main river near Eton. Similar plots for different algae and different times of year could be generated, but they would show less extreme effects than this 'worse case'. What is clearly illustrated is that at channel flows of >50 m^3s^{-1}, the combination of low light penetration and the shortness of the travel period (<0.33 days) do not permit any significant downstream increases to occur; the output concentration is unchanged with respect to the input.

6.3.1.2

Populations greater that 300 mg Chl m^{-3} at discharges >100 m^3s^{-1}would be impossible to sustain in the main river and this would be true in the proposed relief channel. At low flows in the FRC even quite modest input concentrations (around 10 mg Chl m^{-3}) might increase fourfold at flows of <5 m^3s^{-1} and some thirty fold at flows of <2 m^3s^{-1}. When input concentrations are as high as 100 mg Chl m^{-3}, well within experienced values, maximum self-shaded populations of about 700 mg Chl m^{-3} are obtained within the length of the channel.

6.3.2 Effect of operating scenarios

6.3.2.1

As far as the channel itself is concerned, sustained flows of 10 to 20 m^3s^{-1} would be required at all times, if the chlorophyll content was to be maintained at a level comparable with that of the main river at Maidenhead. At 5 m^3s^{-1} some increase, up to four fold, is always likely. If flows of <2 m^3s^{-1} are sustained, then the channel is capable of achieving self-shaded populations; in other words, were chlorophyll content the only quality objective, it matters little whether the water is flowing or not. The flow is inadequate as a sweetener and then channel might as well be closed, pending the next available flood event to flush the channel.

6.3.2.2

The maintenance of a 10 to 20 m^3s^{-1} flow in the channel would seem to be counterproductive if the flow in the parallel river was depleted to levels prejudiced to its own quality. From approximations in Warwick (1984) it would appear prudent, from the point of view of algal chlorophyll, to contain these within 100-200 mg m^{-3} which would require normal flows of between 20 and 30 m^3s^{-1} throughout the year. When flows fall below this, chlorophyll could increase substantially in both river and channel. Where the two watercourses merged, the population would be higher than had only one channel been in operation. This is because the intercepting surface is increased with respect to the discharge volume. On the grounds of chlorophyll alone, the optimal strategy might be to maintain a flow >10 m^3s^{-1} in the channel at all times when there was sufficient flow in the main river to maintain a simultaneous residual flow of >30 m^3s^{-1} (the FS10 scenario).

6.3.3 Algal composition

6.3.3.1

Phytoplankton assemblages in UK rivers are remarkably similar, perhaps reflecting the strongly selective conditions under which they have to grow. In very broad terms, the deeper and lower gradient sections support diatoms (of which *Stephanodiscus* is a typical representative) while shallower, less turbid sections may support green algae such as *Chlorella*, *Scenedesmus* and *Ankistrodemus*. However in very slow-flowing sections or at times of low flows, the variety of planktonic algae may often increase abruptly, assemblages featuring many species from the plankton of rich ponds and shallow lakes. Of particular concern among this latter group are the bloom-forming blue-green algae or cyanobacteria. Given problems with blue greens in the past two years it is highly likely that blue-greens will appear in the FRC. Maintaining a flow of 10 m^3s^{-1} as in the FS10 operating strategy would minimise this problem.

6.3.3.2

Blue-greens are not normally considered components of river plankton but two types do seem to be recorded fairly frequently: the solitary filamentous forms of *Oscillatoria* and *Pseudanabaena* seem more frequently associated with natural, unregulated channels but with many backwaters. The bloom forming species of *Anabaena*, *Aphanizomenon* and *Microcystis* are more prevalent in larger regulated, navigable rivers at low flows when individual reaches behave like linked lakes.

6.3.3.3

The important feature of both types of situation is that downstream removal is severely truncated, giving this typically slow-growing and slow-infecting species an opportunity to reproduce *in situ*. In the Thames, *Microcystis* was recorded in the lower Thames during low flows of 1976, and we have observed (unpublished) *Aphanizomenon* in 1990, between Henley and Maidenhead, at a time when flows were also severely reduced.

6.4 BIRD LIFE

The assessment of the likely consequences of the FRC on bird-life, and in particular on the incidence of the disease botulism, has been based on a brief survey of the birds and the kinds of habitat in the vicinity of the channel. A fuller description of the survey is given in Appendix 6; some background on botulism and its occurrence in birds is also given in the Appendix.

6.4.1 Overview of field survey

The whole length of the FRC was walked, and the main habitat type encountered were marked on an ordnance survey map; any birds seen or heard were noted. The bird species were typical of the habitats encountered; it is considered that none of the species would be significantly affected by the channel. In fact, a number of species (particularly waterfowl) could benefit from an additional stretch of water, as refuges for them are proposed.

6.4.2 Landscape

6.4.2.1

The planting of trees along the channel route should be undertaken with care, especially if the channel is to be maintained in a stagnant state for lengthy periods. This is because the leaf-fall into the water increases the probability of anaerobic conditions developing in the mud. As discussed in Section 6.5 this provides one of the conditions that encourage the growth of the toxic bacterium *Clostridium botulinum* and the death of birds from botulism. A number of species known to be at risk to this disease were recorded during the survey, including coot, black-headed gull, mallard, mandarin duck, great-crested grebe and swan. The presence of refuse tips servicing the neighbouring towns of Maidenhead, Slough and Windsor could also facilitate an outbreak of this disease amongst the birds. In general the FRC channel is considered a neglible risk compared to rubbish tips and other standing water bodies in the area.

6.4.2.2

On the basis of the site visit, it is suggested that wherever possible, damage to mature trees and hedgerows should be avoided. They probably form important linear habitats across the valley along which wildlife can move and colonise new places. The flood channel could also contribute usefully to the network of linear sheltered habitats along which birds, and other wildlife, disperse and occupy new places. By providing a ribbon of trees, bushes and other vegetation, and by being itself sheltered, it should provide a useful route along which many species might disperse.

6.4.3 General effects on birds

6.4.3.1

The main concern is that the existing network of hedges and small woods might be interrupted, during and after construction. It is recommended that these are disturbed as little as possible. The channel could provide additional good habitat for waterfowl and other riverine species but this would depend on the water management. It is to be welcomed that special provision will be made to provide habitat for waterfowl and breeding kingfishers and sandmartins. It is suggested that the Wildfowl Trust be consulted on how the habitat could be made most attractive to waterfowl.

6.4.3.2

However during the field survey it was noted that one of the proposed waterfowl sites is too close to overhead power cables that are a hazard to flying waterfowl, particularly swans. It is recommended that the proposed refuge at this site is reconsidered.

6.5 BOTULISM

6.5.1

Botulism is a bacterial disease caused by several strains of *clostridium botolinum* (for more details of the bacterium see Appendix 6). The bacterium is a widespread soil-organism which thrives in anaerobic conditions, particularly where there is rotting vegetation and animal matter. Because of this, the organism can prosper in stagnant water and mud: type C, the commoner infective strain found in birds, seems to be particularly associated with mud. The juxtaposition of stagnant water and rubbish tips, along with high summer temperatures, would seem likely to raise the possibility of an outbreak occurring.

6.5.2

Botulism outbreaks have occurred on the Thames itself, in places not far from the flood relief channel. Because these outbreaks have occurred on the main river, where water-flow is expected to be generally faster than in the FRC, the risk has to be taken particularly seriously. Moreover the FRC is expected to attract high-risk species, such as mallards, swans, moorhens, coots and herring gulls, which are common in the area. In the case of herring gulls, there is an enchanced risk due to the presence of rubbish tips close-by.

6.5.3

Experience in the United States may provide a precedent of how best to minimise the risk of an outbreak of botulism occurring in the flood channel. It seems that by controlling the water level in the lake, anaerobic conditions and high temperatures in the water were reduced to a level which apparently eliminated the disease.

6.5.4

In principle it would also be possible for birds to take in a lethal dose of toxin by drinking which they do particularly in hot weather. The circumstances would probably have to be extreme. For example, a rapidly growing bacterial population in an evaporating, small stagnant pool might cause concentrations of the toxin in the water to increase so much that the ingestion of a small amount would prove to be lethal. Also infected microscopic invertebrates may be ingested as food or in drinking water.

6.5.5

There is a particular problem with gulls, mainly the herring gull, which frequently scavenges on rubbish tips during the day and roosts on, or by, water at night. These birds may transfer infected material from the tip to the water by carrying it in their beaks and in their crops from whence it might be ejected as undigested pellets. Furthermore, birds infected with a lethal dose are likely to die when on the water by drowning. The water could then become an additional focus for the transmission of the disease as the dead birds will themselves become carrion for other scavengers. Because mud is a source of botulism, mud-feeding birds, such as snipe and lapwing, or birds that forage on the bottom of infected waters, such as mallards, other ducks, geese, swans, rails, coots and moorhens, are also at risk.

6.6 FISHERIES

6.6.1 Background

6.6.1.1

The proposed flood relief channel is an example of the conflicting interests which may arise when the requirements of flood alleviation, land drainage, effluent disposal, conservation and fisheries must all be considered in relation to a single watercourse. Since the major source for the new channel will be the River Thames, and the objective of the scheme is to bypass the main river in times of flood, it is inevitable that, at some time (probably early in the operation of the channel), some fish from the Thames will enter all parts of the channel. Any management of the fishery within the channel will subsequently be subject to perturbation by such additions of stock at irregular and unpredictable intervals.

6.6.1.2

Clearly the impact of influxes of fish from the main river will, at least in the short term, depend on the species, numbers and age structure of the fish. This will, in turn, be a function of the degree of throughflow and the time of year since the various life stages of the fish concerned will vary in abundance and will have different degrees of mobility and susceptibility to flow.

6.6.1.3

In the longer term the nature of the fish community within each section of the new channel will depend on the suitability of the ambient conditions for spawning, as nursery areas, for growth and survival of all stages and on the interactions between species. It is, of course, possible to manage stocks to a greater or lesser degree by introduction of fish, culling and removal or habitat manipulation. Stocking and culling are both facilitated by a high degree of isolation from adjacent waters as envisaged in scenario 2. Clearly a 50/50 split of discharge between the main river and the channel would render compartmentalisation of management regimes virtually impossible.

6.6.1.4

The presence of particular species of fish in a body of water will influence the ecology of the system, not only by competitive and predatory interactions but by modifying the physical and chemical conditions of the water body. Bream and carp, for example, often feed by disturbing the bed sediments and thus increasing the turbidity of the water, reducing light penetration and at the same time removing plant cover. The "knock on" effects of such activities are to some extent unpredictable because of the complexity of the system.

6.6.2 Fish in the Thames

6.6.2.1

The River Thames supports a variety of fish species including anadromous forms such as salmon, catadromous forms like the eel and riverine species with a wide range of flow tolerances. At Reading, Williams (1967) recorded 16 fish species with bleak and roach dominant, predominantly as 0 group fish. These species attained very high densities and grew only slowly and it was suggested that reduction of stocks could enhance growth rates.

6.6.2.2

Improved treatment and disposal practices in the lower reaches of the Thames since the 1970's have resulted in restoration of stocks by natural immigration of fish from upstream and from tributaries (Mann 1989). Presumably the colonisation of the new channel at Maidenhead would be by fish from the main river no matter what subsequent management was undertaken and, depending on the time of year when the channel was filled, the initial species composition and age structure of the fish community would differ. Subsequent management of such communities could be expensive in terms of time and money if it is desired to substantially modify the status quo. Scenarios 2 and 3 would of course provide a greater degree of control over the fish communities in each section of the channel subject to the vagaries of floods and pollution problems which may occur.

6.6.3 Specific areas of concern

6.6.3.1

It is not possible to predict the likely direction of shift in fish communities without some knowledge of the probable degree and frequency of inputs to the new channel from the main river. The extreme cases would seem to be those of complete continuity with the River Thames on the one hand, and total isolation with little or no effective throughflow on the other; these conditions are represented by scenarios 1 and 2 respectively.

6.6.3.2

In the former case (Scenario 1) the result would simply be an increase in river bed area equivalent to the dimensions of the channel bed with resultant fish populations determined by the relative abundance of habitat types within the inundated area. In this instance the fish community would be dominated by the same riverine species which presently occur in the adjacent channel with the proviso that the slower flows (due to increased cross sectional areas) would favour those species (roach, bream, etc.) which flourish under such conditions and the increase in food supply generated by enhanced development of planktonic algae and benthic invertebrates could enhance growth rates. Recruitment should be improved by the considerable increase in marginal refugia.

6.6.3.3

In the case of no exchange of water (e.g. scenario 2) the FRC could be regarded as a chain of gravel pits filled by Thames water. Each pit could be managed more or less as a separate entity in accordance with the requirements of fishery interests. Stocking with carp, tench and similar "still water" species could be successful and might indeed prove beneficial to some management needs. The use of those sections of the channel which join the Thames as a form of massive "Off River Supplementation Unit" to generate young fish could generate large numbers of juvenile bream or roach provided that sufficient submerged vegetation was present to permit effective recruitment. However it has already been noted that recruitment of some species in the Thames could be regarded as excessive and that simply adding more fish may not improve the fishery.

6.6.3.4

Both of the above management regimes create effectively "stable" flow regimes in terms of the annual discharge pattern and as such are likely to maximise survival and recruitment of coarse fish. The introduction of an unpredictable element of flow due to the operation of the flood relief scheme would be a divergence from the stable condition. The main considerations seem to be the possibility of: -

a - Washout of juvenile or adult fish caused by rapid (over a few hours) increases of discharge (rises in water level and velocity) in the absence of suitable, accessible refugia. Such losses would be most likely to affect juvenile coarse fishes and as such would mainly operate in spring and summer.

b - Migrating game fish could be attracted into the new channel by high flows and could conceivably be trapped by falling water levels and lost to the system. The most likely season for this to occur would be Autumn when the secondary (spawning) run of salmonids to the spawning grounds normally takes place, often in association with high flow conditions.

6.6.3.5

All the above comments assume that conditions in the channel (and the main river) are capable of sustaining fish life. If high levels of pollution or low concentrations of dissolved oxygen were to cause fish mortality, the effect of fluctuations in flow would become less relevant.

6.6.3.6

An additional consideration should be the influence of species life histories on success or failure of particular populations. In the instance of populations regulated chiefly by factors associated with flow instability or other 'density independent' stresses at relatively frequent, for example yearly, intervals those species which are short lived and breed over long periods (e.g.) minnows may be disproportionately successful. In contrast the predominance of density dependent population control longer lived species such as chub will be favoured. In general terms low summer flows will adversely affect salmonid fishes and high winter flows will be deleterious to recruitment of coarse fishes.

6.6.3.7

It is in the summer months that water quality considerations are most likely to affect fish populations. Coarse fish are generally less sensitive to low oxygen concentrations than salmonids while both groups are probably equally susceptible to high ammonia concentrations. Although it is preferable to sustain high (>5 mg l^{-1}) concentrations of dissolved oxygen for growth and survival of all fish it has been suggested that minimum acceptable levels for coarse fish in the River Trent could even be as low as 1 mg l^{-1}. At pH values of about 8 concentrations of ammonia in excess of 0.5 mg l^{-1} are likely to produce lethal concentrations of un-ionised ammonia.

Worst case effects of downstream increase of inoculum, N_o

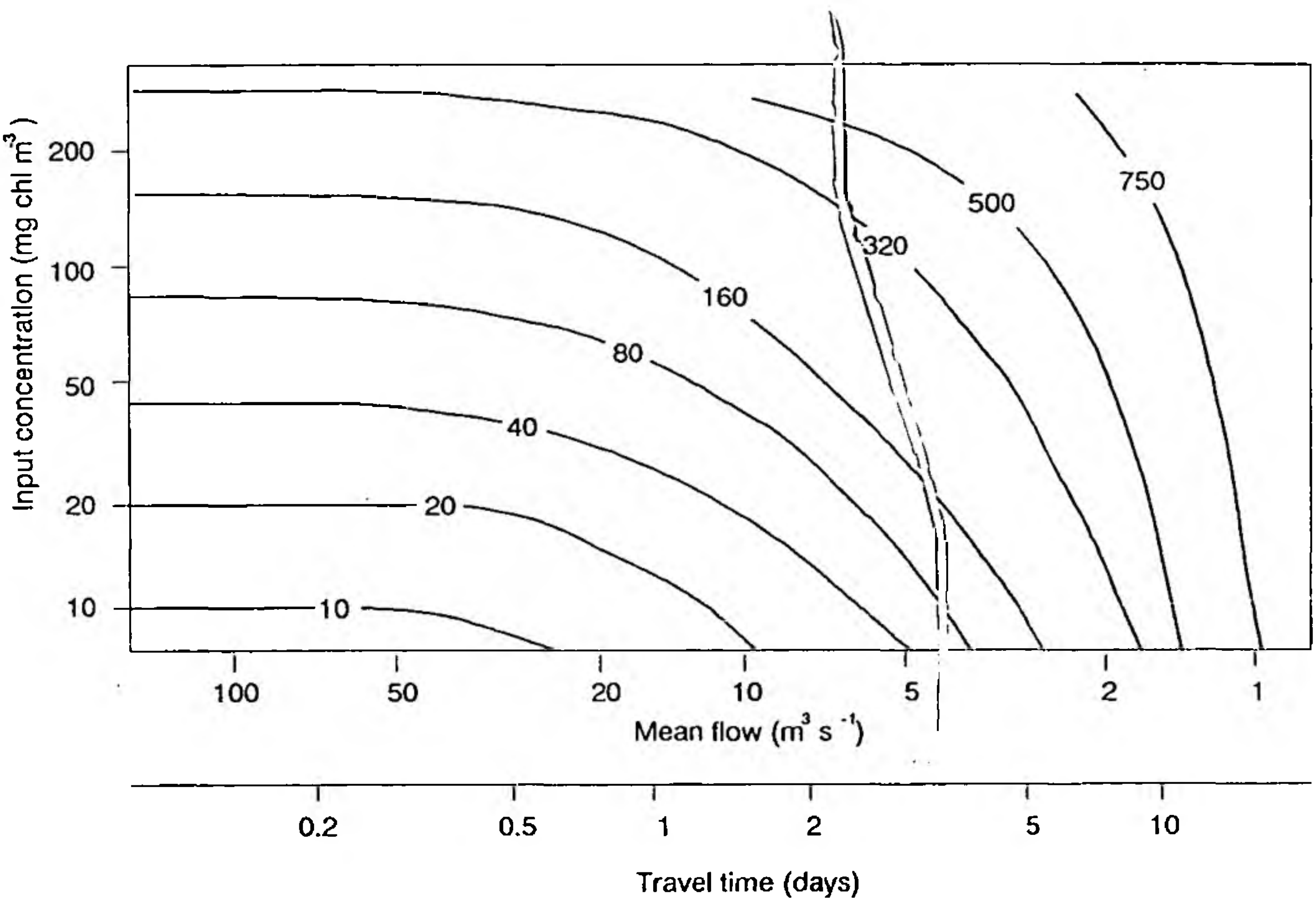


Figure 6.3.1

7. Conclusions

7.1 GROUNDWATER

7.1.1

The groundwater flows into the channel are generally of a small order and will only be significant if there is little or no flow directed into the channel from the River Thames. The largest flows are found in sections where the channel traverses the direction of groundwater movement at a large angle. This is seen primarily in the central section of the channel which runs west-east across a north-south groundwater flow.

7.1.2

The model predicts an approximate balance between groundwater inflows and outflows to the channel, with highest movements being seen around the weir structures where steep gradients are imposed upon the water table. Although surface water movements cannot be adequately simulated using this mode, it is predicted that silting of the outflow band of the channel will reduce recharge to the aquifer and increase the quantity of flow moving eastwards along the channel. This will have little effect upon the water quality of the channel especially if flows are introduced from the Thames.

7.1.3

Nitrate is the primary contaminant of concern, and is present in a concentrated plume across the western side of the central section, north of Dorney. A further nitrate plume is seen immediately south of the channel at Manor Farm. this latter is of greater concentration but of smaller areal extent and apparently more transient nature than the agricultural nitrate plume to the west. Maximum concentrations in the order of 20 mg l^{-1} nitrate are predicted to enter the channel from groundwater. The effects on water quality within the channel are principally a function of the nitrate concentration of the groundwater and the net inflow, and these areas of greatest nitrate accumulation will also have low flows into the channel.

7.1.4

Phosphate is not a major contaminant and is found at low concentrations within the aquifer due to its immobility. Maximum flows of 0.1 mg l^{-1} phosphate are predicted to enter the channel from groundwater. Note these levels are well above the levels required to limit algal growth in the FRC.

7.1.5

Ammonia is only of significance in the area of Manor Farm where concentrations in the order of 100 mg l^{-1} nitrate or 100 mg l^{-1} ammonium may be found depending upon the redox state of the groundwater. Under the reduced ammonium regime, the concentration of unionised ammonia is predicted to remain below 1 mg l^{-1}. Field data suggest that these concentrations are subsiding due to biological activity and dispersion of the pollution plume following the cessation of sewage spreading operations on Manor Farm. Transient modelling of the observed plume suggest that this will move southwards and away from the channel at over 1,000 m per year.

7.1.6

Lining of the channel in the areas of polluted groundwater would be technically feasible providing that adequate sub-channel drainage were provided. A risk of increased groundwater levels on the north bank and possible flooding would arise if reduction of the permeability of the drains were to occur through silting. There is no overriding argument for lining the channel if groundwater flows are substantially exceeded by inflows from the Thames.

7.1.7

The groundwater model predicts that there will be no significant impacts from the channel upon the quality or quantity of water at public abstractions.

7.2 SURFACE WATER QUALITY

7.2.1

The quality of the River Thames is likely to be altered little by the building of the flood relief channel except in the driest of years when the 50% and the FS scenarios may remove too much water to allow adequate dilution of effluents or sufficient oxygen reaeration. The FNS scenario presents no problems for the main Thames since it only removes water under high flow conditions.

7.2.2

The quality of the water in the channel is very much dependent on the operating scenario. Under the FNS scenario the concentrations of all the quality variables except nitrate fall when the channel is not in use. The groundwater moving in to the channel has a high nitrate concentration (up to 20 mg l^{-1}) and this level can be achieved in the channel. Under both the 50% and the FS scenarios the water quality of the channel begins to resemble the River Thames although the concentration of some variables is lower. Under these scenarios the channel may well behave like the River Thames with much reduced velocities especially under the FS scenario.

7.3 VEGETATION AND MACROPHYTES

7.3.1

For management of vegetation in the main body of the channel, it is recommended that periodic surges of flow are allowed through the channel at least once a year, to restrict the colonisation of the central channel and also reduce overgrowth from the margins. To minimise management decision on timing, a compromise position would seem to be that of allowing floods of a lesser magnitude to flow down the channel to ensure that at least one flood per year always occurred. This level may need further discussion but about 150 m^3s^{-1} would seem appropriate. Low flow during the spring and summer growth period will give rise to submerged plants tolerating low flows; these are likely to be more susceptible to high flow events. The static flows of the no-flow scenarios will encourage the overgrowth of floating stands from the margins and depending on the species may be more or less easily washed out, to become caught upon weirs downstream. Some periodic variation in low flows is to be encouraged (as in the 5 m^3s^{-1} sweetening flow scenario 2) although the overall variation in water velocity will be slight.

7.3.2

The general arrangement plans have been viewed and are likely to give a good habitat with acceptable variation, provided a positive approach to planting of suitable species is adopted. Advice on this aspect is recommended at an early stage. However concern is expressed over the presence of backwater and refugia on the outer corners of bends where erosion is generally considered to be greatest. Although it is suggested that the channel will only carry flow at velocities which might erode these areas 'at infrequent intervals', it is precisely at these times that major changes to the channel and the refugia will take place. Some redesign of these bends is recommended. The general arrangement plan emphasises the large amount of new waterside habitat but the above water observable habitats are only a part of a good aquatic environment. No plans with cross sectional detail have yet been seen and in consequence no erosional or depositional changes can be predicted.

7.4 ALGAE

The implications for the relief channel are fairly direct. At low ($<5m^3s^{-1}$) or zero discharges, water retention would allow for one or more divisions of *Aphanizomenon* or *Microcystis* populations to take place. At small inocula this might not present any serious problem. The scenario which might give rise to concern is the one where, under low flows, inocula of a few hundred cell m^{-3} are taken in at Maidenhead and where the retention time allowed some successional maturation, and as a result the blue-greens become established in the relief channel. Alternatively, at zero flow, this might occur spontaneously. The opposite view is that, in either case, the phase of blue-green algal abundance would be temporary and subject to termination at the next flushing opportunity. There would, in short, be little difference from the situation that presently obtains in the river generally, the 'risk' attaching primarily to the channel itself during prolonged periods (from 30 to 50 days) of isolation from the main river.

7.5 BIRD LIFE

7.5.1

Overall, any disbenefits to the terrestrial environment in the vicinity of the FRC are expected only to be minor as such a small part of the habitats encountered would be affected. To our knowledge, no endangered species depends on the habitat provided by the land that would be affected.

7.5.2

It seems likely that the proper choice of water management in the FRC may substantially reduce the possibility of a botulism outbreak. The most important requirement is to avoid the combination of high temperatures and anaerobic conditions, especially in alkaline environments, in which botulism flourishes. However, too rapid and frequent movement would reduce vegetation growth and diminish the attractiveness of the channel to both man and animals. Too sluggish a water movement would encourage the high-temperature anaerobic conditions favoured by the bacterium. There is also a danger that planting trees too close to the water would contribute to the development of anaerobic conditions.

7.5.3

In order to monitor the development of conditions that would favour the multiplication of the bacterium, it is proposed that a routine programme of water monitoring should be implemented. This should be based on monitoring oxygen content, temperature and levels of *C. botulinum*, particularly at times of high summer temperatures. Early symptoms should be looked for. Gallinaceous birds seem to be particularly sensitive to the toxin and may provide early indications of poisoning.

7.6 FISHERIES

7.6.1

The flood relief channel could interfere with upstream and downstream migration of fish in the event of sudden and erratic shifts from high to low flow at critical periods. The community structure of fish in the channel and the main river is likely to be biased towards species which favour slow flows except in the event of frequent, large and dramatic changes in discharge, lethal pollution or artificial stock manipulation.

7.6.2

If the channel is constructed so as to provide large areas of spawning substrata and marginal refugia suitable as nurseries for some coarse fish species and if the water quality is sufficiently nutrient rich to provide adequate planktonic food for fry, it may generate high densities of roach, bleak and other cyprinids having poor growth because of intense competition for food supplies in the later stages. The new channel is unlikely to favour salmonid species unless it is operated partly as isolated put-and-take trout fisheries with the attendant risks of mortality and loss due to floods, pollution incidents and oxygen deficiency.

7.6.3

In the event of heavy silting the channel is likely to favour the growth and development of adult bream feeding on chironomid larvae and oligochaete worms. However, juvenile bream are heavily dependent on planktonic crustaceans as food and these may be inadequate in conditions of high turbidity or nutrient deficiency. The species is also liable to be vulnerable to sudden strong flows in the absence of adequate refugia. Changes in the speed and intensity of water flow are not per se liable to adversely affect riverine fish species but in the absence of suitable bank profiles, vegetation and sudden increases in velocity could seriously affect recruitment as appears to be the case in some East Anglian rivers.

8. Recommended operating strategy

8.1

Following analysis of the flow and water quality simulation results and an assessment of algal growth along the FRC it is recommended that the FRC be operated using sweetening flows whenever possible. A sweetening flow of at least 5 m^3s^{-1} (432 Mℓ/d) and preferably 10 m^3s^{-1} (864 Mℓ/d) would ensure that residence times are sufficiently low to prevent major blooms of algae and would provide reaeration as water flows over the weirs. Water quality would be similar to the main river and the range of algal species would also be similar. This will minimise the impact below the confluence since waters of similar quality will be mixing upstream of the Dachet abstraction.

8.2

It is recommended that each year during winter months a surge of flow is allowed through the FRC to flush emergent macrophyte from the channel margins. This will provide a control on vegetation growth along the channel.

8.3

It is recommended that a monitoring system is established for the FRC such that information is available for management purposes. For example continuous water quality monitors should be installed at two locations such as upstream of the final weir and at a weir midway along the channel to monitor oxygen levels. In addition a continuous record of the upstream or downstream flows should be kept. Also a routine water quality, algal and fisheries monitoring system should be established with weekly information collected on water quality and algae (chlorophyll A + species).

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