NRA Southern 134

NRA

National Rivers Authority

RIVER DARENT
LOW FLOW ALLEVIATION

ANNEX III

'Plan for the Darent',
Report of the Joint
NRA/TWUL Project Team
(November 1992)

National Rivers Authority
Southern Region

July 1994

PLAN FOR THE DARENT

REPORT OF THE JOINT NRA/TWUL PROJECT TEAM

30 November 1992

LIST OF CONTENTS

REFERENCES

Ref. 1 - Sir William Halcrow, May 1987. Study of Alleviation of Low River Flows Resulting from Groundwater Abstraction. Annex A. River Darent Case Study.

Ref. 2 - Groundwater Development Consultants, November 1991. Darent Cachment Investigation. CWP/8709 Pre-Feasibility Report.

Ref. 3 - W S Atkins, R Darent: 1990 Drought - Ecology Suvey and Environmentally Acceptable Flow Regime Study. Job Number K0756.

EXECUTIVE SUMMARY

(i) This report has been produced by the joint NRA/Thames Water Utilities Project Team for the River Darent.

(ii) The Joint Team was tasked to prepare by 30th November 1992 a plan to "return flow to the River Darent while safeguarding drinking water supplies to Thames Water's customers" This report constitutes the plan, which provides for early progress to secure flows in the Darent, while allowing flexibility for and review of future arrangements, which will develop in the context of knowledge and information being acquired over the next 8 years.

(iii) In outline the plan provides for

(a) water supply infrastructure changes, as a basis for a more "river friendly" configuration of abstractions.

(b) a "resource-neutral" plan for changing licences, and both normal and drought abstractions, to secure water supplies while contributing to better natural river flows

(c) two river augmentation schemes, one using water from the Blue Circle Industries site at Northfleet, the other providing local "topping up" artificial springs

(d) reservation until 2000 of a licence capacity for a new source at Northfleet, to be available to meet future demands if the need is proven after committed work on leakage control and demand management in the area.

(e) agreement to collaboration on water management issues in the area, culminating in a review by the year 2000 and appropriate subsequent steps.

(iv) Implementation of the immediate Plan will require significant capital expenditure, and some extra operating costs at times. Detailed estimates will only be available after more consideration, but it appears likely that extra costs to solve the Darent problems will (in approximate NPV terms) be of the order of

(a) for intrastructure changes, any new boreholes, and altered operations, perhaps

£4.6m combined NPV

(b) for artificial springs

£1.7m combined NPV

(c) for new BCI source and pipeline to augment at 15 Ml/d

£5.3m combined NPV

(v) In return for this investment, flows in the Darent in a 1-in-20-year drought could be sustained from west of Sevenoaks, down to Dartford, at flows and quality sufficient to maintain an amenity and a healthy ecology. The flexibility of the scheme means that flows in worse droughts could also be significantly helped.

RECOMMENDATIONS

(vi) This report is written for the Directors and Boards of the NRA and of TWUL. In summary, we recommend acceptance and joint implementation of this plan as the most appropriate and cost-effective means of alleviating the low flow problems in the Darent before and by 1998.

(vii) In specific terms we recommend the following:-

A. agreement to the integrated strategy proposed here, and commitment to the challenge of implementing it;

B. discussion leading to the agreement of the NRA and TWUL as to how the plan will be financed;

C. appointment of a joint steering group to provide a detailed project plan, to arrange and monitor management of relevant aspects of the development, and to coordinate communications with local people including DRPS, the Darent River Preservation Society.

D. announcement as soon as possible, on a joint basis, of decisions about the Plan.

(viii) In practice a proposed Joint Steering Group will have much work to do, and will need to be empowered to overcome obstacles. We recommend an appropriate level of seniority be considered (such as Regional General Manager/Director of NRA, Director of TWUL) while day-to-day work and negotiations can be carried out at an executive level reporting to the Steering Group.

1. INTRODUCTION AND BACKGROUND

The River Darent is probably the most well-known, and the worst affected, of all the rivers identified nationally by the NRA in 1990 as suffering from over-abstraction. The Darent was one of six studied on behalf of Thames Water Authority by Halcrows, in the late 1980s.

The extent of the problem is indicated in one respect by the statistics of the abstractions from the two aquifers which feed the Darent, the Lower Greensand and Chalk, see Map 1. Average abstractions as a percentage of average annual recharge, are about 83% and 87% respectively; as a percentage of the 1-year-in-5 recharge, these percentages are 100% and 120%. The maximum licensed abstractions are some 40% higher.

The problem is manifest, of course, in the state of the river. Mainly because of the abstractions, the river dries up in the middle and lower reaches, from Lullingstone to Hawley, whenever a dry winter produces less than normal recharge and groundwater levels. The Darent valley is a notable amenity to the outside of S. E. London, with riverside footpaths, villages and recreational sites, and it used to be a thriving trout fishery. The loss of flows means that there is frequently a dry bed with obvious loss of amenity, and results in damage to the ecology of the river system, as species have to compete to recover after the dry spells.

There is an active, well-informed, well-organised and well-supported campaign in the valley, seeking the restoration and preservation of the river.

That the problem stems from the level of licensed abstraction is not in doubt. The previous Thames Water Authority acknowledged it and planned to take alleviative action.The recent drought has further emphasised the problem and Thames Water Utilities Ltd (TWUL) had agreed to restraining abstraction to 70%. Both the NRA and TWUL have agreed that the situation is undesirable and have held meetings with local people (both the pressure group, DRPS, and local authorities) over what should be done and when.

This report is produced by a Joint Project Team which was set up with the support of the Directors of both NRA and TWUL, to develop a cost-effective plan based on agreed technical assessments, for the recovery of the Darent before or by 1998.

2. STATUTORY RESPONSIBILITIES

Both the National Rivers Authority (NRA) and Thames Water Utilities Ltd (TWUL) have duties and obligations under the Water Resources Act 1991 and the Water Industry Act 1991 respectively which have direct bearing on the River Darent situation.

In essence the NRA has a general duty to conserve, augment, redistribute and secure proper use of water resources. In addition the NRA have a general duty to have particular regard to the duties imposed on water undertakers. These duties and powers do not relieve any water undertaker of its statutory responsibility to develop water resources in line with its general duty to develop and maintain a water supply system. The water undertaker has a primary duty to make water available to persons for domestic and industrial use as demanded. Both NRA and TWUL have duties to enhance the environment whilst carrying out primary functions in relation to water resources and water supply.

The principal relevant responsibilities and duties are summarised in Appendix 1.

3. AIMS OF JOINT STUDY

The joint study arose directly from agreement of a Memorandum of Understanding between the NRA and TWUL. The aim is to "return flow to the River Darent while safeguarding drinking water supplies to Thames Water's customers".

The project team, comprising 3 NRA and 3 TWUL managers, and a Director of Mott McDonald's Groundwater Development Consultants (GDC) to assist on groundwater modelling work, was tasked to "produce its report by 30 November 1992 with a view to TWUL and the NRA agreeing a solution by the end of 1992". The report was to "include

- proposals for varying the six Darent licences;
- a comprehensive technical solution; and
- the provision of appropriate replacement resources"

Any agreed solution is to be "implemented in stages with substantial improvement by 30 June 1996 and ... completed by 31 March 1998".

The Project Team found this statement very helpful in defining its aims. We agreed at our first meeting that any "solution" proposed must meet three criteria, namely

- to secure flows in the Darent
- to conserve the ecology of the Darent
- to maintain the security of public water supply.

In addition to meeting these criteria, the team perceived a need to

- identify target flow regimes, for the river;

- pay attention to overall costs of different options or combination of options; and

- seek solutions which provided a robust and flexible base for future water management as well as meeting the stated time horizons.

4. WATER EFFICIENCY AND MANAGEMENT

4.1 Introduction

A significant amount of groundwater is abstracted from the Darent catchment, predominantly for public water supply. Abstractions grew in the 1950's and 1960's with increasing demand, and the Darent wells have in the past supplied a substantial amount of water to South East London. Existing actual abstractions are close to the long-term mean recharge (85% for chalk; 80% for Greensand). TWUL have average annual authorised abtractions of 106.9 Ml/d from 10 sources or 78.6 Ml/day from the 6 sources. Over recent years the trend has been towards greater use being made of River Thames derived water. The current picture of distribution of Darent water is given in Fig 1, and identifies zones wholly reliant on groundwater and those served by both groundwater and surface water. The area dependent on the Darent supplies has reduced as a result of conjunctive use.

Thames Water Utilities Ltd is the largest of the five water company abstractors; Table 1 shows relevant abstraction licences for all five companies.

4.2 Demand Management

Both Thames Water and the NRA recognise the need for effective and prudent management of water. The recent drought has resulted in increased attention being paid nationally to leakage control and demand management. Nationally, initiatives and studies are underway to establish appropriate strategies and targets, sponsored by Regulators and Government and supported by the water industry. These studies will clarify substantial issues on metering, demand forecasting and leakage control and allow the benefits of such approaches to be built into future water resource strategies. At present there are widely differing views of the scale of benefit which could accrue. It should be possible to give to the Darent the appropriate benefits of demand management gains that are achieved.

Given the uncertainty which surrounds the projected benefits, the Project Team have adopted a staged approach to the solution for the River Darent. An initial stage seeks to benefit the River Darent from the existing situation and does not assume any specific contribution from demand management. A second stage allows for benefits of water efficiency to be taken into account in determining the package of measures necessary to protect both the River Darent and public water supplies. The introduction of this second phase will be after the results of national studies and debates, and thus be able to reflect national policies, agreed best practice and expectations.

4.3 Leakage

Both Thames Water and NRA are committed to water efficiency. Leakage control programmes in TWUL have reduced local leakage from 11.5 to 7.5 litres/property/hour. The programme continues with an overall local leakage aim of 4 l/p/h, which matches the NRA 'good housekeeping' target for local leakage which generally equates to 16-18% of total supply. Achievement of this target would make a significant contribution to the future water resource situation in the Darent. It would however, be unwise to develop strategies for the Darent which are dependent on savings which are yet to be demonstrated as achievable and sustainable or cost effective. The phased approach proposed for the Darent allows for full account to be taken of water efficiency savings if their certainty is demonstrated. TWUL are committed to achieving the lowest practicable leakage in South East London. The move towards metering will provide benefits for leakage control.

4.4 Water Consumption

A critical feature of water resource planning is the current level of water consumption and projected changes in future demand.
Thames Water have been assessing water consumption through a domestic water use study on selected properties across the ACORN range since 1976-7. The results of the study provide evidence for a current average per capita consumption of water at 155 l/h/d in the Thames Water region. This figure includes proper allowance for night consumpton. Studies by Southern NRA and Southern Region Water Companies have identified consumption in the Southern region of 143 l/h/d and NRA Southern Region claim a similar figure should apply to the Thames Region. None of the figures include supply pipe leakage.

Forecast growth in demand for water in the Thames Region is 0.5% per annum, with total demand rising by 12.5% over the 25 year planning period. In the short term, reductions in total supply are projected taking into account leakage control, recession etc. The overall prediction takes into account the 1989 update of projections of populations and households issued by the Office of Population Census, independent econometric forecasts of industrial growth, the effects of changes in water using appliance ownership and the achievement and maintenance of a local leakage rate of 6.28 l/property/h by 1996. Forecasts are reviewed annually to take into account the latest available information on the components making up the forecast.

4.5 **Metering**

Metering remains a substantial issue. Commercial metering proceeds apace in the Thames Region. In addition to normal industrial customers all pubs, hotels and restaurants are now metered. Doctors, dentists and hairdressers are currently part of the commerical metering programme. All new domestic and commercial properties are metered. TWUL has metered 14,000 commercial properties annually for the last two years. These programmes will continue to their economic limit. For the present Thames Water has decided against compulsory metering of all domestic customers. It has not decided how to replace the rateable value system as a basis for charging and whether domestic metering should be extended. National surveys suggest that up to two thirds of people questioned have indicated a preference for metering and this appears to be an approach the Government is supporting. There are, however, high costs and practical difficulties associated with metering in highly urbanised areas.

Thames Water has introduced trial metering areas and the River Darent catchment would be a potential candidate for such an exercise.

4.6 **Summary**

Both TWUL and NRA are committed to water efficiency measures. The extent of the benefits remains to be quantified, but whatever savings are achieved and can be reliably predicted to be achieved in the future will be accounted for in the second phase of the River Darent project. The debates and discussions on demand management and leakage control will continue at both national and regional level. During 1993 it is anticipated that national policies and practices will be introduced which encourage or require levels of action to achieve specific targets. The Project Team consider it is essential that any strategy proposed for the River Darent is sufficiently flexible to accommodate the results of these actions and that investment programmes should be capable of taking them into account.

5. RANGE OF OPTIONS CONSIDERED

5.1 **Choice of Options**

From a long list consisting of the original range of options studied by Halcrows (Ref 1) in the late 1980's, and by GDC in their 1991 Pre-Feasibility Report (Ref 2) a short-list was drawn up to which was added the Blue Circle Industries (BCI) chalk dewatering option identified by NRA Southern. The other options were rejected as being either infeasible or too costly. The finally agreed short-list was as follows:

A. <u>Sewage Effluent</u>

A1. River augmentation from a new sewage treatment works (STW) at Otford using treated "upstream" (Sevenoaks) effluent.

A2. River augmentation at Otford using appropriately treated effluent from Long Reach STW.

B. <u>River augmentation</u>

From a series of riverside boreholes referred to as "artificial springs".

C. <u>Demand Management</u>

C1. Leakage Control

C2. Metering

D. **Abstraction Reduction**

D1. Licence Variation
D2. Conjunctive Use Operating Agreement

E. **BCI Chalk Dewatering Water**

E1. Direct Public Water Supply
E2. River Augmentation
E3. River Augmentation with downstream surface water/groundwater abstraction in lower catchment

5.2 Methodology

Target Flows

The Project Team agreed that the primary parameter is river flow. A fully evaluated environmentally acceptable flow regime (EAFR) would not be available for at least two or three years, thus a practical substitute for this would be needed. For this and for other work associated with evaluating effects on river flows, the Team relied heavily, after suitable scrutiny, on the work of and model produced by GDC, see Appendix 2. GDC proposed and the Project Team agreed that a target flow criterion should be fifty percent of the 1 in 20 year minimum natural baseflow as estimated by the GDC groundwater model, (also in Appendix 2). Currently under typical low flow conditions an approximate additional 35 Ml/d is required to bring river flow up to the target flow throughout its longitudinal profile (Westerham to confluence with Cray, see Map 2). This figure was used as a preliminary yardstick to judge the effectiveness of individual options. The target flow is compatible with earlier recommendations by NRA consultants, W.S. Atkins (Ref. 3), which was derived from ecological surveys during the drought and analysis of the hydrological regime.

Key Criteria

The five short-listed options were evaluated against the following nine criteria:

- security of river flows (using 35 Ml/d as a yardstick)
- conservation of ecology
- effect on water utility (split into water resources and operations)
- cost estimates (capex/opex/combined NPV)
- elapsed time
- public acceptability
- risk of failure to implement
- operational security
- flexibility of options

5.3 Description of Options

A. **Sewage Effluent**

There has never been a modern sewage treatment works in the Darent Valley, sewage has always been directed towards Long Reach STW on the Thames Estuary. Option A1 would intercept all the sewage in the existing trunk main which runs down the Darent Valley to Long Reach and would involve the construction of a new works, probably just downstream of Otford. The present dry weather flow (DWF) in the trunk main at Otford is estimated at 8 Ml/d; allowing for future growth, this figure is unlikely to exceed 10 Ml/d over the next 10 years.

The DWF at Long Reach is 170 Ml/d and therefore has ample flow to meet the maximum requirement of 35 Ml/d. Option A2 would consist of tertiary treatment of 35 Ml/d, effluent pumping from Long Reach to discharge point at Otford and pipeline from Long Reach to Otford.

Maintaining the very high river quality standards is, of course, a primary consideration with respect to these options. Critical parameters would be ammoniacal nitrogen, copper (found in domestic sewage) and organic substances (Long Reach has a high proportion of trade effluent). A high level of treatment would be required for both options. For the purposes of costing it has been assumed that A1 would require tertiary treatment and A2 would require both tertiary treatment and advance treatment.

B. **Artificial Springs**

This option provides for groundwater to be pumped from a series of riverside boreholes thereby augmenting river flow in a manner which would simulate natural discrete spring discharges.

The main features of Option B are as follows:

(i) It assumes that streamflow at Shoreham will be at or above the target flow. (Model simulation (See Appendix 2) shows that the most effective way of achieving this is by minimising Lower Greensand abstractions.)

(ii) Augmentation boreholes will be constructed between Shoreham and Hawley with the aim of obtaining the desired target flow accretion profile between Shoreham and Hawley. For costing purposes it has been assumed that five or six boreholes each yielding 4 to 5 Ml/d will be adequate. Field trials would enable the actual performance of this option to be properly evaluated.

(iii) Augmentation will be seasonal as and when required by actual flows compared with river augmentation rules. This would be most satisfactorily implemented as part of a Water Resources Management Scheme (under Section 20 of the Water Resources Act 1991).

C. **Demand Management**

Significant reductions in demand would, of course, mean that groundwater abstraction could be similarly reduced thereby enabling more groundwater storage to be available for baseflow. Unfortunately, at present there are widely differing views of the scale of benefit from leakage control and metering. What is not in doubt is that some benefit will result. Pressure on existing and future water resources in the area mean it is essential to manage water efficiently.

D. **Abstraction Reductions**

In line with the Project Team's aims, a possible package of radical changes to the current groundwater abstraction regime in the Darent catchment has been examined against the benefits which accrue in terms of improved river flow, whilst concurrently securing public water supplies.

Two approaches have been looked at, namely licence variations (D1) and a conjunctive use operating agreement (D2). However, the option which has been put forward is a combination of the two (D3). This incorporates the most attractive aspects of each.

D1 <u>Licence Variation in its simplest form</u>

Fundamental to any variation of the existing abstraction regime is its effectiveness in improving river flow. The GDC model (see Appendix 2) has demonstrated that of the six Darent sources under consideration reductions from Brasted and Sundridge in the Lower Greensand (see map in Appendix 2) produce the greatest improvement in river flow. The chalk sources of Lullingstone and Eynsford in the southern-most of the upper part of the chalk catchment are next most effective, followed by Horton Kirby and Darenth respectively. Furthermore, significant increases in abstraction levels in the Lower Cray and Lower Darent (including the Darenth source) are shown by the model to produce little reduction in river flow, especially during the critical low flow periods. Therefore, the picture that has emerged from the modelling work is that a redisposition of abstraction from the upper catchment (primarily Brasted and Sundridge, but also the upper three chalk sources - Lullingstone, Eynsford and Horton Kirby) down to the lower catchment (Lower Darent, including the Darenth source, and Lower Cray) could provide maximum benefit to the river whilst maintaining the same water resources capability.

On this basis the Team has considered varying licences downwards in the upper catchment and making an equivalent variation upwards in the lower catchment to off-set the shortfall. Unfortunately, there are two difficulties with achieving this to the full extent: one is the high infrastructure expenditure, and the other is the significant risk of producing saline intrusion from the Thames estuary. Nevertheless, the Team has concluded that some moderate increases in the lower catchment, especially if such increases are aimed at meeting periods of overall resource shortage and not permanent long-term abstraction, would be entirely consistent wih sustainable and environmentally acceptable water resources management.

D2 <u>Conjunctive Use Operating Agreement</u>

It has been recognised for some time that there is scope for application of a modern conjunctive use water management scheme between the Darent Valley groundwater sources and the Lower Thames surface water system. The trunk distribution capacity required to enable such a scheme to be implemented is currently being enhanced by the construction of the London Water Ring Main due for completion in 1995. Some considerable relief has already been provided to the Darent catchment from operation of the first Phase of the Main. An eastward extension to Honor Oak is proposed to support increasing demand in South East London. The introduction of conjunctive use on this scale implies some advancement of this tunnel. There are also increased operating cost implications.

A conjunctive use operating agreement would take the form of a Water Resources Management Scheme (under Section 20 of the Water Resources Act 1991). In essence it would seek to minimise groundwater abstraction from the most sensitive Darent sources by replacing any shortfall with River

Thames derived supplies. TWUL has actually been voluntarily limiting abstractions from the Darent Valley by their conjunctive use for some months, demonstrating the general approach. Its systematic adoption would mean that for most of the time Darent sources would be being partially 'rested' compared with historic abstractions, with benefits to groundwater levels and hence to river flows. However, when a "Thames drought" saw reservoir levels dropping significantly in the Thames Valley, the extra demand put on the Thames surface water sources would cease, leaving the Darent sources to operate to licence. Historically, "Thames droughts" have been substantially less frequent than groundwater droughts affecting the River Darent.

D3 **Combination Licence Variation/Conjunctive Use Operating Agreement Proposal**

The Team has devised a hybrid of D1 and D2 which seeks to combine the most attractive features of both options. The two principal benefits of the proposal are:-

(i) substantial abstraction reduction in the upper and middle catchment achieved by licence variations and

(ii) preservation of resource neutrality and low infrastructure costs by a conjunctive use operating agreement and upward variations in licensed abstraction in the Lower Cray and Darent catchments.

Thus D3 has been analysed as the most practical, cost-effective approach to combine licence variation/Conjunctive Use.

E. **Blue Circle Industries (BCI) Chalk Dewatering**

The chalk quarries at Northfleet are said to be the largest excavations in Europe. Presently some 24 Ml/d of chalk groundwater are pumped from the Western and Eastern quarries to keep them from flooding. This water is either channelled to the Swanscombe salt marshes on the estuary or used to augment the Ebbsfleet stream. Being a dewatering operation BCI has no need of an abstraction licence although the NRA is requiring BCI to obtain discharge consents for the discharges to surface waters. BCI have put forward plans to further develop Eastern Quarry by excavating it to deeper levels, although immediate plans have been postponed as a result of the economic recession. However the recent GDC report indicates that the dewatering requirements would be little different from the present day total.

It can be concluded, therefore, that between 15 and 20 Ml/d of reasonable quality chalk groundwater could be available for direct supply or river augmentation.

E1. **Direct Public Supply**

For costing purposes it has been assumed that pesticide removal and high turbidity should be addressed; new local infrastructure and pumping equipment are also included.

E2. **River Darent Augmentation Scheme**

The basic scheme would be a pumping station at Northfleet to boost raw chalk groundwater up to Eynsford or Lullingstone via a pipeline running up the Darent valley.

E3. River Augmentation followed by Public Supply

The BCI resource has further potential as a combined river augmentation and water supply scheme in which a surface water or groundwater abstraction at the lower end of Darent would pick up the augmentation water put in over the middle reaches.

5.4 The Overall Solution

As discussed above under 5.1 the short-listed options were analysed using the nine criteria itemised in 5.2, see Options Matrix given in Appendix 3. This approach enabled the Team to scrutinise each option against its ability to achieve, in whole or in part, the aims set out in Section 3.

The following are the principal conclusions drawn by the Team:

(i) No single option scores sufficiently highly across all nine key criteria as to provide a convincing robust, flexible and cost-effective overall solution.

(ii) The options rank in the following descending order of overall merit:

B	**-**	**artificial springs**
D3	**-**	**abstraction reduction (optimal variant of D1 and D2)**
E2	**-**	**river augmentation using BCI water**
E1	**-**	**BCI water - direct supply**
A1	**-**	**sewage effluent - STW at Otford**
A2	**-**	**sewage effluent - using Long Reach**

Because of the widely differing views of the scale of benefit which could accrue from Option C - Demand Management, it was not possible to give this option a strict ranking. However, the Team agreed that a Demand Management Programme should form part of the final overall package.

(iii) From (ii), it was the Team's view that the overall solution should comprise the following components:

- **resource neutral abstraction changes as given in option D3.**
- **river augmentation using Option B - Artificial Springs with back up from Option E2 - River Augmentation using BCI water.**
- **demand management to underpin abstraction reduction and river augmentation.**

This threefold package could be implemented before 31 March 1998 to achieve the desired target flows and ecological improvements under all hydrological conditions at the least economic cost compared to any other single option or combination of options. The overall capital and operating cost is estimated to be in the order of £11m NPV. Furthermore, the package readily lends itself to development in stages such that substantial improvements by 30 June 1996 could be realised. Each component is both robust and flexible thus bestowing the overall package with those same desirable features.

6. PROPOSED STRATEGY

6.1 Introduction

The Project Team has identified a two-stage strategy to meet the objectives as they were set for or identified by the group.

The preceding section should indicate that this selection has not been easy. It should also be clear that the strategy is designed on the basis of:

- achieving specified river flow targets and
- seeking the most cost-effective combination of options

The aim of cost-effectiveness has meant that the simpler sweeping solutions that could have been possible have not found favour, being out-performed by more complicated solutions which seek to use various characteristics and opportunities offered by the natural and developed system in the area.

6.2 Structure and Concepts

In broad terms there are three elements to the strategy:

(i) <u>reduce key abstractions</u>

Licensed quantities in the relevant 6 boreholes would reduce to 70%, normal annual abstractions would be reduced to 50% of current licenses, abstraction balance would migrate from key Lower Greensand and middle catchment sources to lower-catchment sources, with increased licences where necessary, and for most winters, abstraction rates would be down to 40% of current annual licensed rates. The West Kent Water Company licence at Crampton Road would also be varied down by 24%.

(ii) <u>augment river flows</u>

Flows in the upper reaches will be much higher, as a result of (i); this will often but not always be true of middle reaches. To ensure target flows are maintained from Shoreham downstream, five or six chalk augmentation boreholes ("artificial springs") will be drilled, tested, and operated. Plans will be developed to supplement this with water from BCI, unless early experience of artificial springs makes this water unnecessary.

(iii) <u>arrange suitable resources beyond 1998</u>

Subject to the statutory application and advertisement process, a new licence will be granted to TWUL for review by the year 2000 against need for extra resources. In the meantime TWUL will continue development of monitoring, leakage control and demand management to provide a secure base for forecasting of future demands. By the year 2000 both public water supply needs and river health will be reviewed jointly.

The strategy has two stages, in seeking to develop towards efficient water management practices which better balance public-water-supply needs with those of the river environment.

Stage I will set out to meet the target river flows by 1996, by combinations of 6.2 (i) and (ii) above. Uncertainty about BCI augmentation could delay full achievement slightly.

Stage II will comprise the leakage control and demand management activity, so that a review of licence needs and perhaps balance of existing abstractions at the time, can be carried out jointly This review should be carried out as far as possible by 1998, in the context of AMP III proposals, but in any case should be completed by June 2000, with a view to deciding on the future of the new licence and on any other adjustments needed.

6.3 Formal Steps

A number of formal steps will be needed, to achieve this strategy. They include:

- **agreement over financing**

  Costs comprise:
  . public water supply infrastructure and operating costs (£3.6m capital, £100K pa operating,£4.3m combined NPV)
  . augmentation springs (c.£1m capital, £80K pa operating, £1.7m combined NPV)
  . augmentation from BCI (c.£5m capital, £80K pa operating, £5.3m combined NPV)
  . leakage control and metering (no cost estimate available)

  (NB Basis of NPV calculations are given in Appendix 3 - Options Matrix)

- **amendments to licences (see Appendices 4 and 6)**

  . reductions in some licences (upper catchment)
  . increases in some licences (lower catchment)
  . new licences for augmentation abstractions
  . new (conditional) licence for TWUL

- **"management schemes" (see Appendix 5)**

  Two Management Schemes under section 20 of the 1991 Water Resources Act, to ensure:

  . operation below licence of relevant abstractions in the valley, for most circumstances relying on conjunctive use, plus augmentation of the River, when circumstances require, to maintain at or above a target flow regime.

  . commitment to collaboration and joint review by the year 2000 of both the future need for extra water in the area, following practical measures to reduce or manage water consumption in the area, and of the adequacy of arrangements for the Darent.

6.4 Implementation

The two stages of the strategy will require continued collaboration and cooperation between NRA and TWUL, both to put 'flesh on the bones' and to confirm the key assumptions, and hence, needs. However it is clear what is needed in general terms. The steps include

<u>Within Stage I</u>

(a) to arrange to develop, test and operate 5 or 6 "artificial springs" in the stretch from Lullingstone to Horton Kirby, for augmentation of flows

(b) to arrange to modify water supply infrastructure locally and towards Honor Oak, to improve the security of supply from the Thames surface sources and from the northern part of the Darent catchment

(c) to close experimentally Brasted and Sundridge sources, to establish as far as possible the response of groundwater and river levels. Subject to joint review, to proceed with total closure.

(d) to implement licence variations and relevant management schemes and augmentation sources, to achieve river flow targets

(e) to plan and design BCI augmentation source and link, and to build subject to need (see (a) above).

Within Stage II

(f) in the context of national advances, TWUL to continue to develop leakage control activities, and to pursue demand management opportunities with a view to sensibly reducing future consumption.

(g) subsequently carry out joint reviews.

Most of the strategy design/operation parameters have been agreed by the Team, and appear in Appendices 4, 5 and 6. These appendices are an integral part of this report.

Appendix 4 sets out the proposed licence variatons in terms of quantities, and Appendix 6 sets out the philosophy of a possible new conditional licence.

Appendix 5 outlines the Management Schemes proposed.

Because of some limited uncertainties about system (aquifer/river/distribution) behaviour, there are some specific issues which may benefit from a joint review. The Team agrees that, while (a) to (g) above plus Appendices 4, 5 and 6 provide the essential basis, there should be during Stage I attention to, and scope for joint review of detail concerning:

(i) the extent to which the Lower Darent and Lower Cray sources could practically at limited extra expense, take more 'load' from the middle-Darent sources in a drought;

(ii) the adequacy of the artificial springs to meet anticipated augmentation requirements and the need for BCI augmentation to be developed; and

(iii) the immediacy of impact of starting or stopping Lower Greensand abstracting on the river; and the possibility that occasional peak-lopping could continue there without discernible harm to the River. The sources could, in such an event, also be considered for augmenting river flows in certain circumstances.

6.5 The Scheme in Practice

This section seeks to illustrate how the various steps proposed would help river flow improve.

Stage I is designed to ensure the river achieves a satisfactory flow as quickly as possible within the interim period (up to 30 June 1996).

First, the Lower Greensand sources are identified as critical to the river above Otford. Closing Brasted and Sundridge, and reducing Crampton Road (West Kent WCo) would substantially benefit the whole length of the river.

The marked reduction normally achieved in the three upper chalk sources is also expected to make a significant difference to the flows below Lullingstone. However this will not always be enough to meet the target flow regime. In very serious droughts, when supplies from the Thames reservoirs to London are threatened, rather more water can be taken from these upper chalk sources. In either of these cases, the flows below Lullingstone will tend to decrease, below the target flow regime.

It is primarily for these circumstances that augmentation will be used. The artificial springs, designed and landscaped so as to provide limited unobtrusive boosts to flow at about 6 locations, could be enough in most or even all events. If all events are provided for by artificial springs, an extra source at BCI would not be needed; otherwise it should be constructed and probably used more than the springs). A feature of major use of the 'springs' is that, while they will have no significant observable detrimental effect when used, they will tend to draw down levels in the chalk further than otherwise, resulting in a slower subsequent recovery of water table and hence of natural feed to the river. BCI in contrast would give the advantage of bringing new 'extra' water to the catchment when it is very dry.

The impacts on the public water supply system have been studied by the Team in terms of cost impacts, and ability to continue to meet normal, drought, peak and emergency demands. The proposed strategy should leave these latter essential capabilities unimpaired.

The Stage 2 activities are an essential and agreed part to re-establishing a satisfactory balance to water management in the area. They are fully consistent with TWUL's own plans and aspirations, with the NRA's approach to granting of new licences, and with various national initiatives and statements advocating particular regarding to managing demand in the more water-stressed parts of the country. The NRA plans to grant a new licence, for bringing in good-quality water from outside the Darent, whose activation is conditional as with all other licences on a demonstrated future need. This licence is then legally protected against derogation, and should provide TWUL with the longer-term security needed while water husbandry is investigated further.

The 2000 review will cover the issue of need for this licence, as well as the adequacy of the Stage I activities in terms of protecting the River Darent.

6.6 Summary of Strategy

In summary, the strategy involves two stages:

Stage I (up to 30 May 1996)

- resource neutral licence changes (varying down the Lower Greensand and middle catchment abstractions, varying up the lower catchment abstractions);
- application by TWUL for a licence to use BCI water for public supply.
- a Management Scheme for conjunctive use with Thames Valley surface sources and for augmentation of the Darent's middle reaches when necessary;
- construction of infrastructure to support a redistribution of public supply;
- construction of infrastructure for augmentation from artificial springs and the BCI site.

Stage II

- further study by NRA of the river and its relationship with groundwater and abstractions;

- work on leakage and appropriate demand management measures by TWUL;

- collaboration over the water efficiency measures culminating in a joint review of river and licence needs and any other necessary measures.

Stage II will run concurrently with Stage I and beyond, culminating in the review by the year 2000.

7. SUMMARY AND RECOMMENDATIONS

7.1 Summary of results

1. An intensive period of work by the members of the Joint Project Team, supported by vigorous scrutiny of options and their effects and costs by supporting staff, has led to a proposed plan which would secure flows and river ecology in the Darent while safeguarding medium-term and long-term water supplies.

2. Inevitably some details need exploring and 'honing' further, but the Team is confident that its proposals are both practical and cost-effective.

3. The technical conclusions of the Team, on the path to identifying a strategy, include the following statements:

    (i) the upstream Lower Greensand sources at Brasted and Sundridge are more harmful to river flows than are the chalk abstractions; and of the chalk ones, Lullingstone, Eynsford and Horton Kirby have more critical effect on low flows, than do those sources further down the catchment;

    (ii) securing a flow regime down the river system at half the level of a 1-in-20-year natural regime, appears likely to be adequate to protect the ecology of the river as well as providing a secure amenity;

    (iii) provision of a sewage treatment works at Otford, or further treatment and transfer of Long Reach sewage effluent upstream, would not make an economical contribution to solving the flow problem;

    (iv) it is feasible to develop a new source at (or near) the BCI site at Northfleet; it could produce between 15 and 20 Ml/d of reasonable water. It could be used to augment the Darent, or for treatment and supply, or one followed by the other.

    (v) development of artificial springs close to the river should be practical, should produce good "gain" to the river, and should not affect groundwater levels or river recovery unduly.

    (vi) reconfiguration of the supply system in S.E. London, securing normal, drought, peak and emergency supplies for a modified pattern of source use, is practicable and its cost has been estimaed.

    (vii) there appears to be scope for controlling present and future demands in the area, by increasing the leakage control activity and seeking effective demand management through metering of commercial and some domestic properties; although it is uncertain at present how much demand-saving would result. Treating the Darent area as a priority would potentially help TWUL, align well with policy statements by the DoE and the two (OFWAT, NRA) regulators, and help limit demands for future abstractions in the area.

4. The Team's proposals provide for early progress to secure flows in the Darent, while allowing flexibility for and review of future arrangements, which will develop in the context of knowledge and information being acquired over the next 8 years.

5. Features of the plan are set out in Section 6. In outline, it provides for

(i) water supply infrastructure changes, as a basis for a more "river friendly" configuration of abstractions

(ii) a "resource-neutral" plan for changing licences, and both normal and drought abstractions, to secure water supplies while contributing to better natural river flows

(iii) two river augmentation schemes, one using water from the Blue Circle Industries site at Northfleet, the other providing local "topping up" artificial springs

(iv) reservation until 2000 of a licence capacity for a new source at Northfleet, to be available to meet future demands if the need is proven after committed work on leakage control and demand management in the area

(v) agreement to collaboration on water management issues in the area, culminating in a review by the year 2000 and appropriate subsequent steps.

6. Implementation of the immediate Plan will require significant capital expenditure, and some extra operating costs at times. Detailed estimates will only be available after more consideration, but it appears likely that extra costs to solve the Darent problems will be of the order of

(i) for infrastructure changes, any new boreholes, and altered operations

£3.6m	capital
£100K	p.a. extra operating cost
£4.6m	combined NPV

(ii) for artificial springs

£1m	capital
£80K	p.a. operating cost <u>on average</u>
£1.7m	combined NPV

(iii) for new BCI source and pipeline to augment at 15 Ml/d

£5m	capital
£80K	p.a. operating cost <u>on average</u>

£5.3m combined NPV

7. In return for this investment, flows in the Darent in a 1-in-20-year drought could be sustained from west of Sevenoaks, down to Dartford, at flows and quality sufficient to maintain an amenity and a healthy ecology. The flexibility of the scheme means that flows in worse droughts could also be significantly helped.

8. The Joint Project Team was asked to produce a plan to return flow to the Darent while safeguarding drinking water supplies to Thames Water's customers. The report was to include

   - proposals for varying the six Darent licences
   - a comprehensive technical solution
   - the provision of appropriate replacement resources

   We believe the information in this report achieves the aims, and meets these three stipulations.

7.2 Recommendations

This report is written for the Directors and Boards of the NRA and of TWUL. In summary, we recommend acceptance and joint implementation of this plan as the most appropriate means of alleviating the low flow problems in the Darent before and by 1998.

In specific terms we recommend the following:-

A. agreement to the integrated strategy proposed here, and commitment to the challenge of implementing it;

B. Discussion leading to the agreement of the NRA and TWUL as to how the plan will be financed;

C. appointment of a joint steering group to provide a detailed project plan, to arrange and monitor management of relevant aspects of the development, and to coordinate communications with local people including DRPS, the Darent River Presevation Society.

D. announcement as soon as possible, on a joint basis, of decisions about the Plan.

In practice a proposed Joint Steering Group will have much work to do, and will need to be empowered to overcome obstacles. We recommend an appropriate level of seniority be considered (such as Regional General Manager/Director of NRA, Director of TWUL) while day to day work and negotiations can be carried out at an executive level reporting to the Steering Group.

The Project Team wishes to acknowledge the freedom with which it has been allowed to work, and considers the resulting Plan provides a sound and acceptable basis with which to address and solve the current problems of the River Darent.

7.3 Project Team Sign-off

RIVER DARENT JOINT PROJECT TEAM

G W Phillips	-	Chairman (NRA Thames Region)
B J Connorton	-	Secretary (TWUL)
P W Herbertson	-	(NRA Southern Region)
G D Warren	-	(NRA Southern Region)
I H Bensted	-	(TWUL)
R J Oake	-	(TWUL)
T Evans	-	(Mott MacDonald)

Signed on behalf of the Project Team:

.... Chairman

.... Secretary

APPENDICES

APPENDIX 1 - RELEVANT LEGISLATION

The relevant legislation pertaining to the Darent issues are summarised below:

i) **NRA**

Water Resources Act 1991.

Section 19(1)a

: conserving, redistributing or otherwise augmenting water resources in England and Wales.

Section 19(1)b

: securing the proper use of water resources in England and Wales.

Section 15(1)

: to have particular regard to the duties imposed on water undertakers under the Water Industry Act 1991.

Section 16(1)

: to further the conservation and enhancement of natural beauty, flora, fauna and geological or physiographical features of special interest.

Section 20(1)a

: enter into and maintain arrangements with water undertakers for securing proper management or operation of waters which are available.

Section 52(1)

: powers to revoke or vary abstraction licences.

Section 61(1)

: provides for compensation to be paid in the event of losses sustained by water undertakers where the abstraction licence is modified by the Secretary of State following the NRA's proposals.

ii) **TWUL**

Water Industry Act 1991

Section 37

: developing and maintaining an efficient and economical water supply to persons on demand.

Section 38(1)

: meeting standards of performance, including availability and constancy of supply in accordance with the requirements of the Director General or included within the water undertakers licence.

Section 3(2)

: to further the conservation of natural beauty, flora, fauna and geological or physiographical features of special interest.

APPENDIX 2 GDC GROUNDWATER MODEL, KEY ASSUMPTIONS AND FINDINGS

1. INTRODUCTION

During the period that the Joint NRA/TWUL Darent Working Group were sitting, 16 October 1992 to 30 November 1992, use was made of an integrated river flow and groundwater catchment model of the River Darent and River Cray to study various options for improving the flow in the River Darent, as requested by the Working Group. This model was prepared for the NRA (Southern Region) as part of an existing investigation of the River Darent (GDC, 1991).

Modelling work carried out in connection with the activities of the Joint Working Group included:

- Improving calibration of the Lower Greensand aquifers.
- Deriving naturalised river flows (1970-1990) (ie flow without groundwater abstractions).
- Deriving 'Target Flows' based on naturalised conditions.
- Studying the effect of pumping all wells at 100% of licence values.
- Comparing the relative merits of reducing flow in the Chalk or the Lower Greensand.
- Investigating the effect on flows of weighting Chalk abstractions from mid to lower catchment.
- Simulating the TWUL conjunctive use scheme.
- Comparing seasonality of river flows.
- Studying the response time for increased or decreased abstractions in the Lower Greensand aquifers.
- Comparing computer runs for options covering the range of abstractions sought by TWUL and NRA.
- Simulating the artificial springs augmentation scheme and calculating the frequency of operations and amount of abstractions required.

Some of the more important results are presented.

2. MODEL DESCRIPTION

The model used for this investigation is an integrated groundwater and river flow catchment model. This simulates flows in the aquifers and river system, and the interaction between surface water and groundwater flow components. The basis for the model is described in the Pre-Feasibility Report (Ref.2). It uses the integrated finite difference method and incorporates an iterative solution technique based on a backward difference approximation.

The regional geology is shown in Map 1 in the main text of this report. The principal aquifers of the Darent catchment are the Chalk and Lower Greensand, separated by impermeable Gault Clay. Six geological layers are included in the catchment model. The Chalk is represented as a single layer whilst the Lower Greensand is divided into three layers with Hythe Bed and Folkestone Beds aquifers separated by the Sandgate Beds aquitard.

The model grid covering the Darent catchment comprises a network of 619 polygons produced by subdivision of a regular mesh of squares. The grid area is 527 km^2 with polygon sizes ranging from 0.27 to 4.4 km^2. Groundwater conditions can be represented more accurately by increased subdivision of polygons giving a dense network of small polygons in specific areas of particular interest. The highest density of polygons occurs along river valleys and in areas of high groundwater abstraction.

The river system is represented by a set of 99 river elements which are located along the interfaces between specified polygons. The elements range from 0.5 to 1.0 km in length depending on location. Representation of lakes is also fully integrated within the model. Inflow and outflow to the lakes are balanced by lake bed leakage.

3. MODEL CALIBRATION

This was carried out in the two stages of steady state and transient state calibration. Steady state calibration, in which recharge is simulated as a constant long term mean value, is used to define approximately aquifer transmissivities and leakage parameters controlling flows between aquifers. Calibration was achieved by a reasonable matching of simulated groundwater levels against levels estimated for pre-development conditions.

Aquifer recharge and abstraction conditions for the period 1970 to 1990 were simulated in transient state calibration. Recharge values were derived from daily rainfall using a separate lumped parameter hydrological model, the Stanford Watershed Model. This is recognised as one of the most conceptually complete representations of the hydrological cycle. It distributes rainfall between evaporation, surface runoff, interflow and recharge on a subcatchment basis and was used in an initial water balance assessment in the Darent Pre-Feasibility study. Data on actual abstractions in the period 1970 to 1990 were obtained from licence returns.

For transient calibration the catchment model was operated using a monthly time step. Calibration was achieved mainly by variation of the values for parameters which control groundwater storage and the hydraulic resistance of the river and lake beds. Following model runs, comparison was made between simulated groundwater levels and river flow and observation well level data, gauged river flow accretion profiles and river flow gauging station records.

A comparison of final calibration river flow results and gauging station records for the gauging stations at Otford in the upstream Chalk and Lower Greensand subcatchment and at Hawley at the downstream end of the main central Chalk subcatchment are shown in Figure A2.1 a) and b). At both locations observed flows are simulated accurately throughout much of the period of record and the calibration is excellent. Simulation of both the high levels of peak winter flows and, more critically for the purposes of this investigation, the low flows in summer and extended drought periods have been achieved in modelling. Model calibration of the aquifer system is however still at an early stage. The model may be subject to variation at a later stage as a result of incorporation of groundwater information being collected from a Well Construction and Testing Contract currently underway in the catchment.

4. DERIVATION OF TARGET FLOWS

Following completion of preliminary calibration work the catchment model was used to simulate naturalised catchment conditions by operation with all abstractions set to zero. The results of this model run were used to derive a target river flow accretion profile (see Figure A2.2).

Simulated naturalised river flows were analysed for five key sites along the river at Otford, Lullingstone, Horton Kirby, Hawley, and just upstream of the confluence of the Darent with the River Cray. A statistical distribution of annual minimum monthly flows was used to derive the 1 in 20 year monthly low flow for each site. It was found that these 1 in 20 year flows were approximately equal to the naturalised flows for August 1976. One in 20 year low flows were then derived for each river element as a product of the August 1976 flow for the element and the ratio of the 1 in 20 year low flow to the August 1976 flow for the nearest key site.

Finally a target flow profile was built up taking 50% of the 1 in 20 year low flow for each of the river elements. The target flow profile is shown in Figure A2.3 and in Table A2.1.

A frequency analysis was also undertaken for individual months and their target flows collated. It is intended at a later date to extend the annual minimum flows to target flows for individual months

Table A2.1
Target Flow Values

Location	1 m in 20 yrs Naturalised Flow in Drought Year (Ml/d)	Target Flow (Ml/d)
Otford	37	18.5
Lullingstone	49	24.5
Horton Kirby	54	27.0
Hawley	58	29.0
Cray Confluence	65	32.5

5. CHALK VERSUS LOWER GREENSAND ABSTRACTION

The calibrated catchment model was used to simulate the effects on river flows and groundwater levels of more than 30 strategies with reductions to existing groundwater abstraction licences. The simulations involved variations in total abstraction, testing the effects of changes to location of abstraction and changes in normal operation and peak period water requirements. The effectiveness of flow augmentation with river support pumped from wells and acting as artificial springs was also assessed.

At an early stage the investigation was concentrated on the effects of reducing Chalk abstraction from Chalk sources close to the river. Abstractions from Lullingstone and pumping stations downstream of Lullingstone were targeted in simulations. However the effect of reducing abstraction from the Lower Greensand was also checked and found to be a much more effective means of maintaining higher river flows particularly in drought periods.

The river above Otford is almost always influent in character with springs and Lower Greensand aquifers feeding the river. During the Working Group review the Lower Greensand aquifer's response to abstractions was investigated further and it was confirmed that changes in borehole abstractions produced a rapid response in river flow. Reductions in abstractions appeared as increasing model river flows over a five month period following the reduction. Reductions in abstractions from the Lower Greensand therefore presented one of the most immediate beneficial measures available to improve river flows.

Below Otford the river passes through the Chalk outcrop of the North Downs. The river over the middle to lower reaches of the catchment is often perched with the groundwater table lying well below the river bed. In such conditions there is leakage from the river bed which on average between Lullingstone and Hawley is of the order of 1.0 Ml/d per km. Reduction in abstraction from the Chalk aquifer has relatively little effect on river flows during drought periods. In addition,the model also indicates that if the Chalk abstractions are reduced substantially then the groundwater catchment reduces significantly with the influence of abstractions in adjacent catchments. For example a reduction of 15 Ml/d in Chalk abstraction is likely to result in only a 10 Ml/d increase in river flow at Hawley. Figure A2.4 demonstrates the benefits to the river of reducing abstractions from the Lower Greensand relative to the Chalk.

In the two simulations (references PR15 and PR16) the reductions in existing licensed abstraction is approximately equal. The simulations were run with constant abstractions at the sources indicated, with total simulated abstraction amounting to just over 50% of total licensed abstraction in each case. In PR15 the reduction in abstraction was spread equally between the Chalk and Lower Greensand sources; in PR16 Lower Greensand sources were reduced to zero abstraction with the balance of the reduction taken from the main Chalk sources.

Figure A2.4 shows simulated river flow profiles for the drought period in August 1976. By concentrating the reduction in abstraction on the Lower Greensand sources the river benefits by an additional 7.5 Ml/d over its length from a point midway between Westerham and Otford down to Lullingstone within the main Chalk valley. Below Lullingstone there is a gradual, slight reduction in benefit reducing to about 6.0 M/d just upstream of the Cray confluence.

The greater abstraction from the Chalk in simulation PR16 has very little effect in increasing the length of river which is perched above the water table. Very little additional loss in flow therefore results from greater Chalk abstraction in PR16 whilst the contribution of additional groundwater from the Lower Greensand to the river is, in comparison, very large. The slight convergence in benefits to river flow from the two strategies below Lullingstone results from greater leakage to groundwater with the higher flows in simulation PR16.

6. LOCATION OF REDUCTION IN CHALK ABSTRACTION

Having established the benefits of discontinuing abstraction from the Lower Greensand, further simulations were used to assess the effects of varying the locations at which reductions in Chalk abstraction could be made. The model indicates that in general the location of Chalk abstraction would make little difference in drought years. However in years of near average or above average flow there would be additional benefits to river flow by concentrating abstraction at the downstream end of the catchment. At these times the length of the river perched above the water table is considerably reduced. This is demonstrated in Figure A2.5.

Simulations PR25 and PR26 included a total abstraction under normal operating conditions of about 40% of the Lower Greensand and Chalk licences considered in Figure A2.4. In PR25 the reduction in abstraction is distributed evenly over four Chalk sources. In PR26 there is a greater reduction in abstraction from the three upstream sources at Lullingstone, Eynsford, and Horton Kirby with much higher abstraction maintained at Darenth. The river flow profiles shown are for August 1984 in a period of normal operation in which naturalised flows in the summer months are all close to the median naturalised values for those months. The additional benefits to river flow from concentrating abstraction further downstream are evident from a point about 4 km upstream of Lullingstone. The difference in flows reaches a maximum of 5 to 6 Ml/d between Horton Kirby and Hawley. Much of this improvement is maintained downstream to the confluence with the Cray.

7. AUGMENTATION ABSTRACTIONS

The model was run for a few different scenarios to investigate the number of 'artificial springs' required to increase the River Darent flows to their target values, to determine the frequency of their operation and to calculate the volume abstracted from the Chalk.

Figure A2.6 demonstrates the operation of the augmentation system. River support wells (artificial springs) are switched on to provide augmentation when the river flow drops below the target flow at the point of support. In Figure A2.6 five out of six sources, each providing

4 Ml/d of river support are in operation.

Analysis of results for two strategies are presented in Figures A2.7 and A2.8. Figure A2.7 represents how TWUL state they are likely to operate a conjunctive use system with abstractions from Lullingstone, Eynsford, and Horton Kirby being reduced in average years to 31.4 Ml/d and abstractions weighted in favour of sources down river, eg. 0 Ml/d at Lullingstone to 20 Ml/d at Darenth.

The abstractions for river support would amount to an average of 2.3 Ml/d over the period 1970 to 1990 with the maximum in any one year averaging 8.4 Ml/d. The river support scheme would be operated in 11 years out of 21.

The model also demonstrates that if conjunctive use is not in operation and abstractions are not weighted towards the lower catchment then the frequency of river augmentation can increase significantly. For example, even if the lower levels of abstraction proposed in the licence variation were operating continually on an annual basis, the frequency of river augmentation increases to 17 years out of 21 (Fig A2.8).

It is intended to incorporate monthly target flows at a later date which will have the effect of slightly increasing the frequency of operation of the augmentation wells and the volume abstracted.

Several important conclusions can be deduced:

(i) The conjunctive use operation (Figure A2.7) is beneficial.

(ii) It is important to reduce the abstractions from the four sites at Lullingstone, Eynsford, Horton Kirby and Darenth to 32 Ml/d - the value stated by TWUL as their likely normal abstraction rate.

(iii) It is important to reduce abstractions from the more upstream Chalk wells in the catchment in order to reduce the augmentation requirement, ie reduce abstractions at Lullingstone to a minimum whilst maintaining Darenth at a maximum.

8. OTHER GENERAL OBSERVATIONS

(i) Effect of Pumping Source at 100% of Licence Values

The effect of pumping all sources within the Darent and adjacent catchments at their licensed values was found to dry up the river in an average year over its whole length apart from the reach between Otford and Horton Kirby (15 km). The maximum August discharge was reduced to 8 Ml/d (100 l/s). However, if the Lower Greensand abstraction were eliminated under such conditions, then target flow could be met to a point between Lullingstone and Horton Kirby with the flow reducing from 28 Ml/d to 12 Ml/d at the Cray confluence.

(ii) Conjunctive Use Runs

A number of model runs were undertaken to simulate river flows when abstractions were increased under drought conditions as specified under TWUL's conjunctive use operating agreement (D2). In general, increases in abstractions during drought periods (conditions 'y' and 'z') had a small effect on flows due to the dominating influence of the increased river flows from the Lower Greensand. However, the beneficial influence of weighting the abstraction in the Chalk from mid to lower catchment was demonstrated (Figure A2.5).

(iii) **Range of Darent Flows**

A brief review of the range of naturalised and observed flows in the River Darent was made. As with many rivers supported predominantly from groundwater, seasonal variations are not large. For example at Otford the range was from 50 to 100 Ml/d for an average year, increasing to between 80 to 150 Ml/d at Hawley. In low rainfall years the range diminishes to 20 Ml/d and 30 Ml/d respectively, with maximum flows of 60 Ml/d and 90 Ml/d.

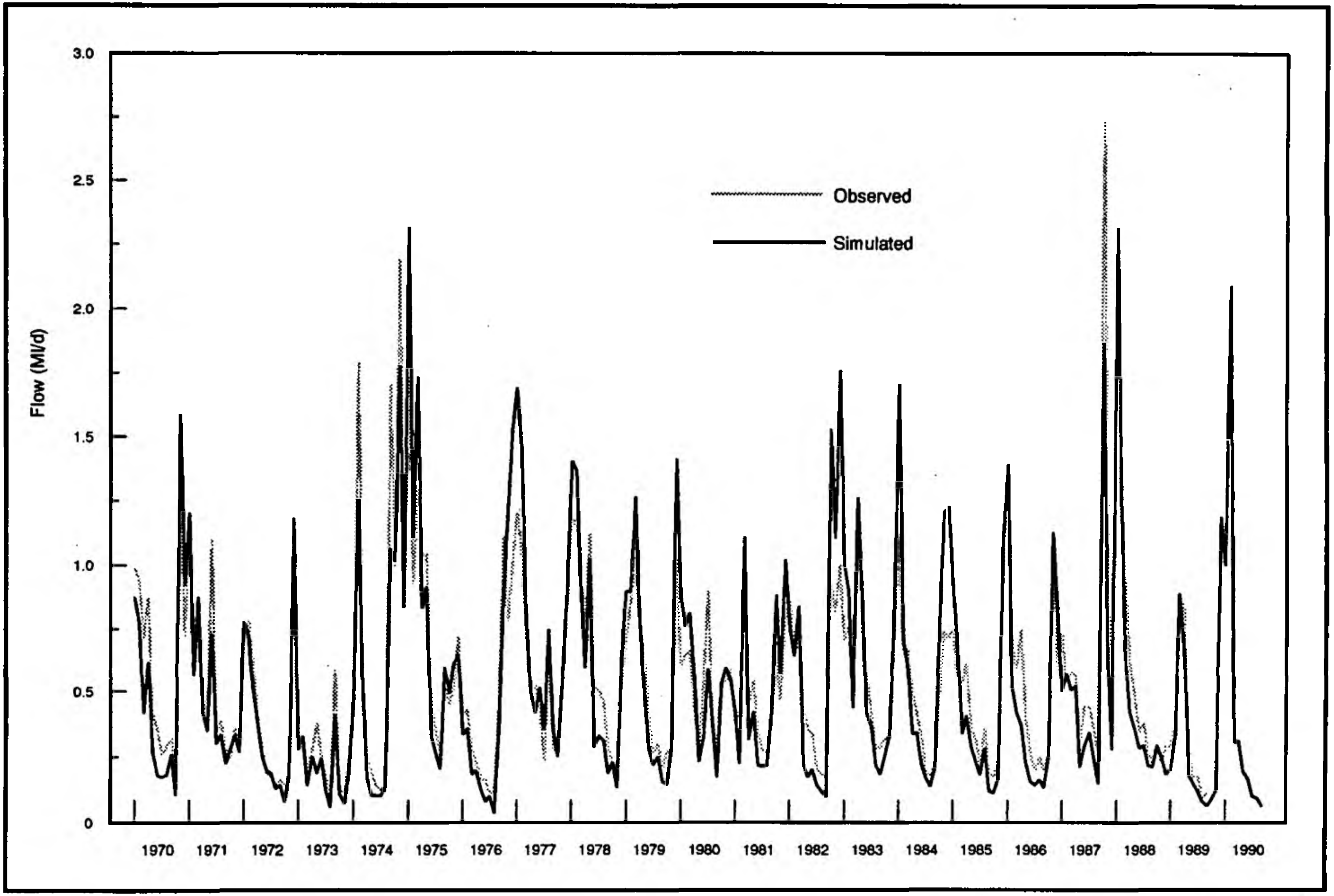


Figure A2.1a
Simulated Flows at Offord

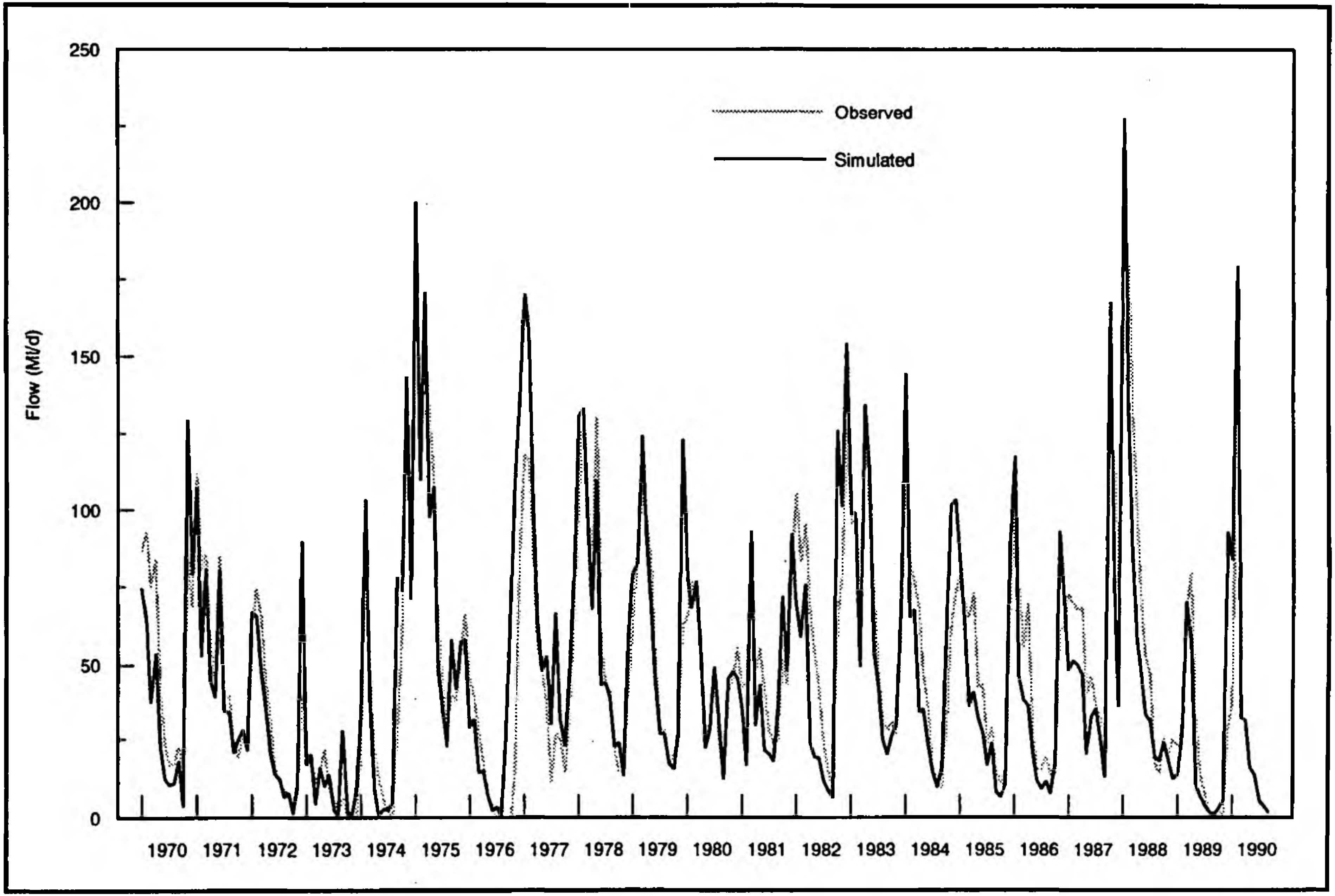


Figure A2.1b
Simulated Flows At Hawley

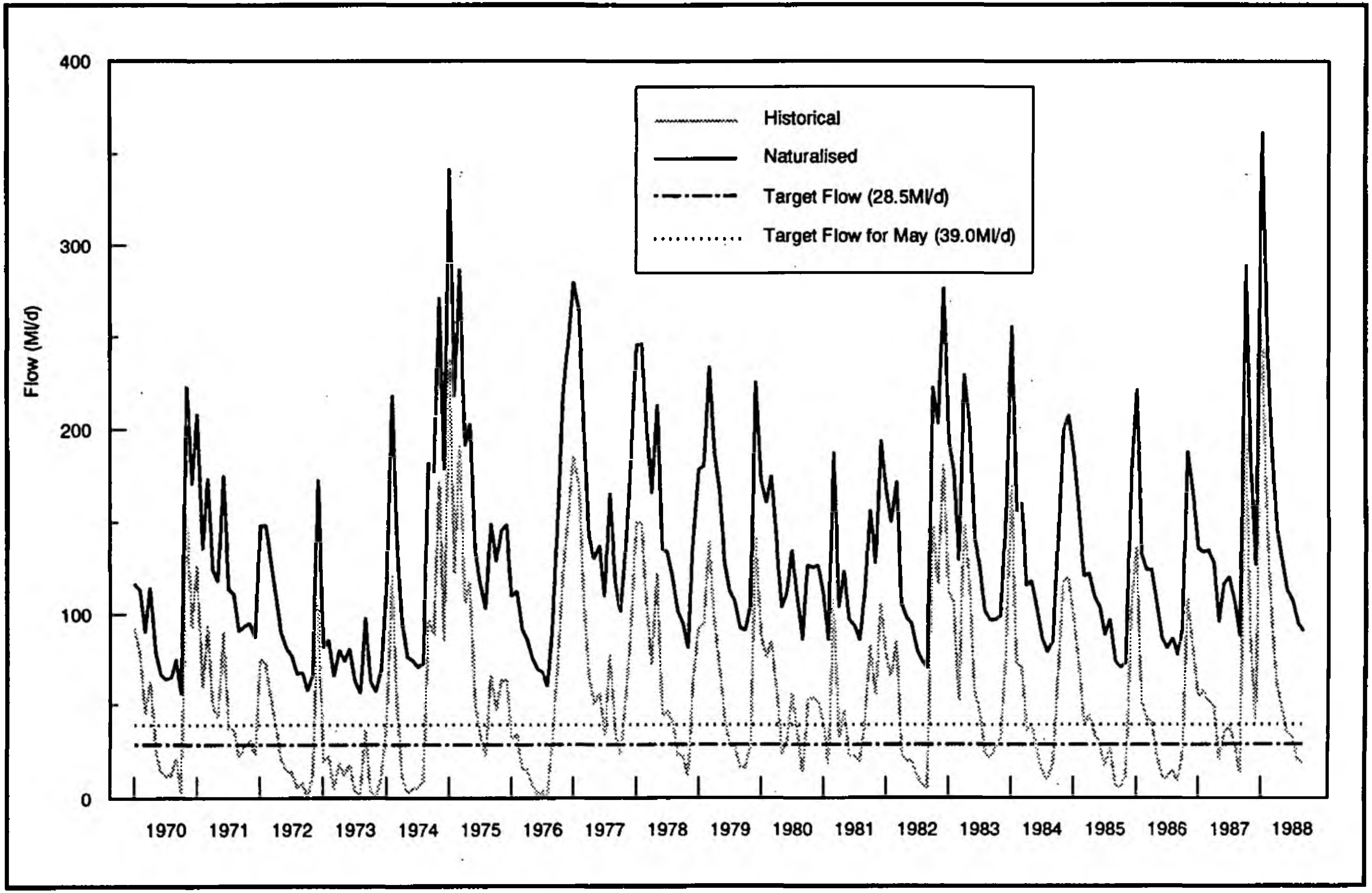


Figure A2.2

Naturalised River Flow at Hawley

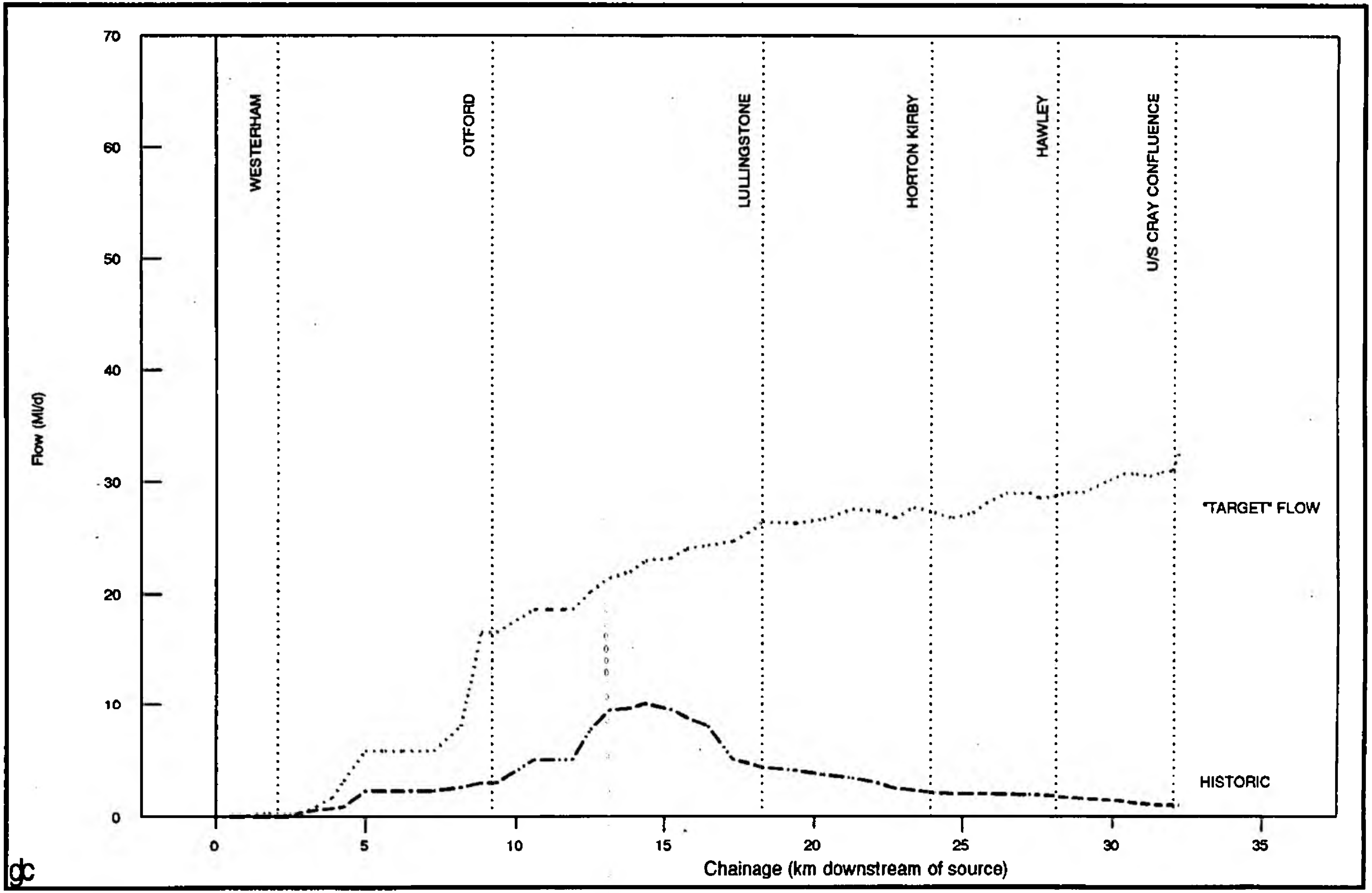


Figure A2.3
Simulated Accretion Profile for August 1976

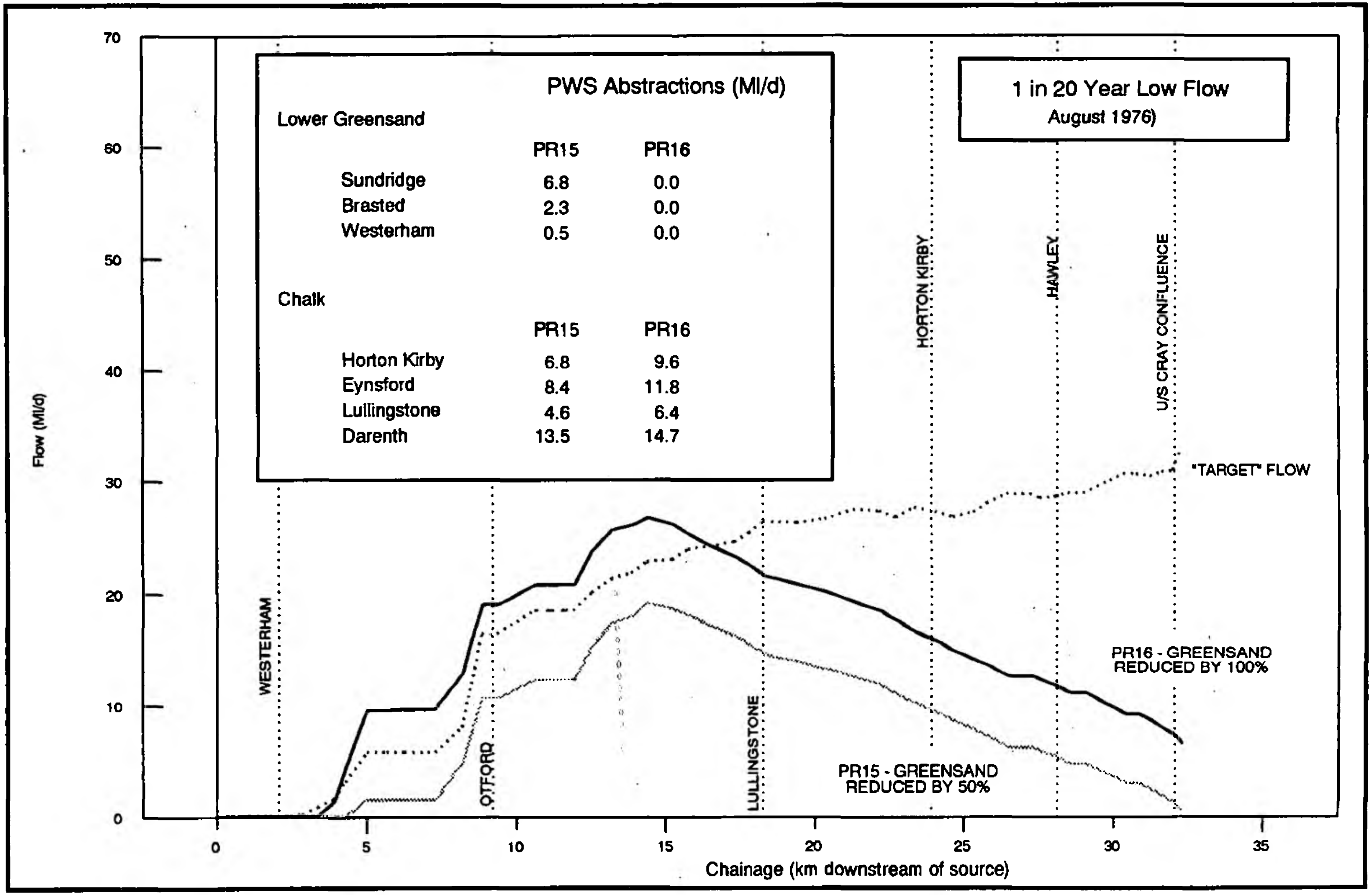


Figure A2.4
Comparison of Reduction in Abstraction from Chalk & Lower Greensand

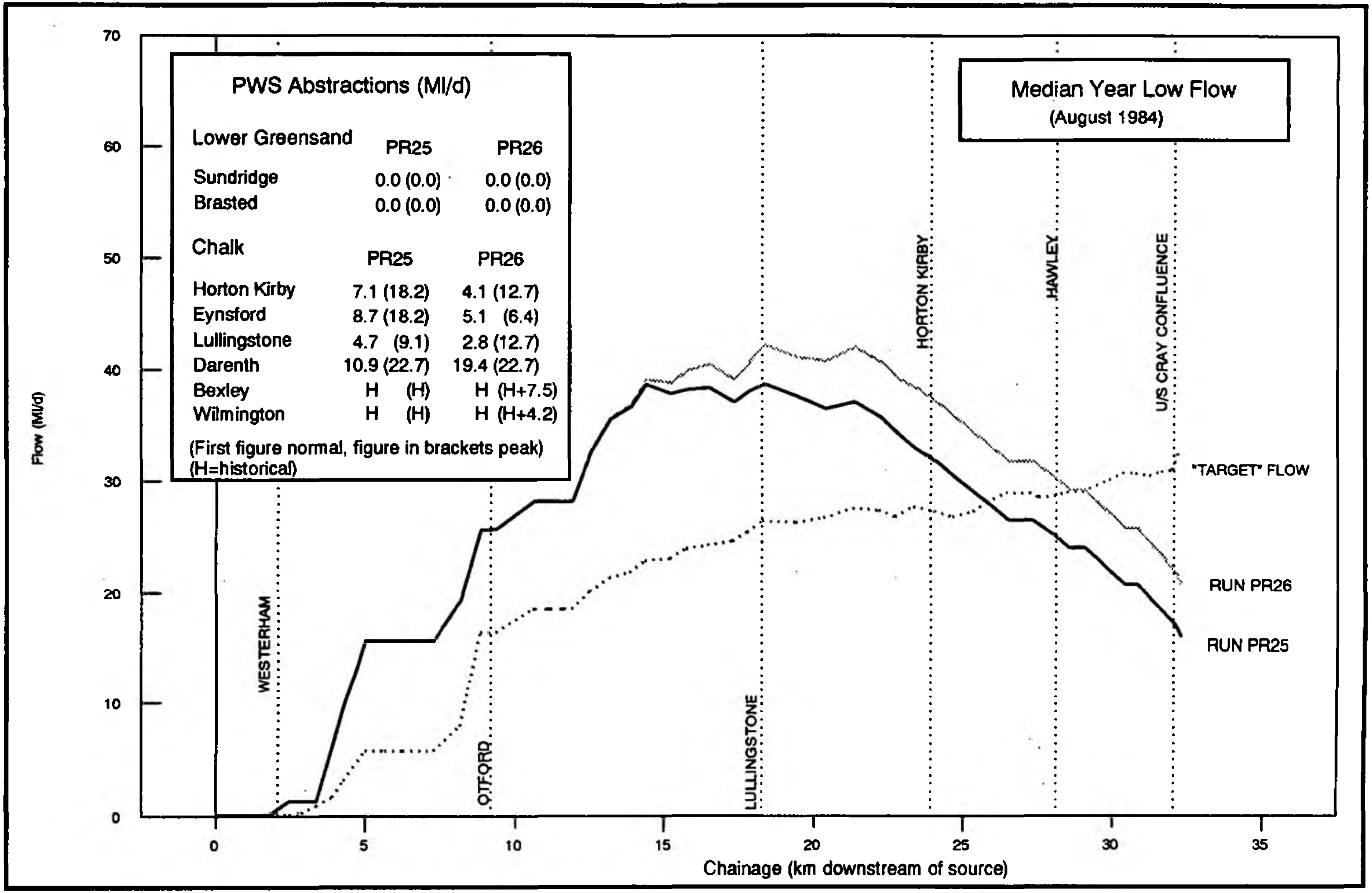


Figure A2.5
Effect of Location of Chalk Abstractions

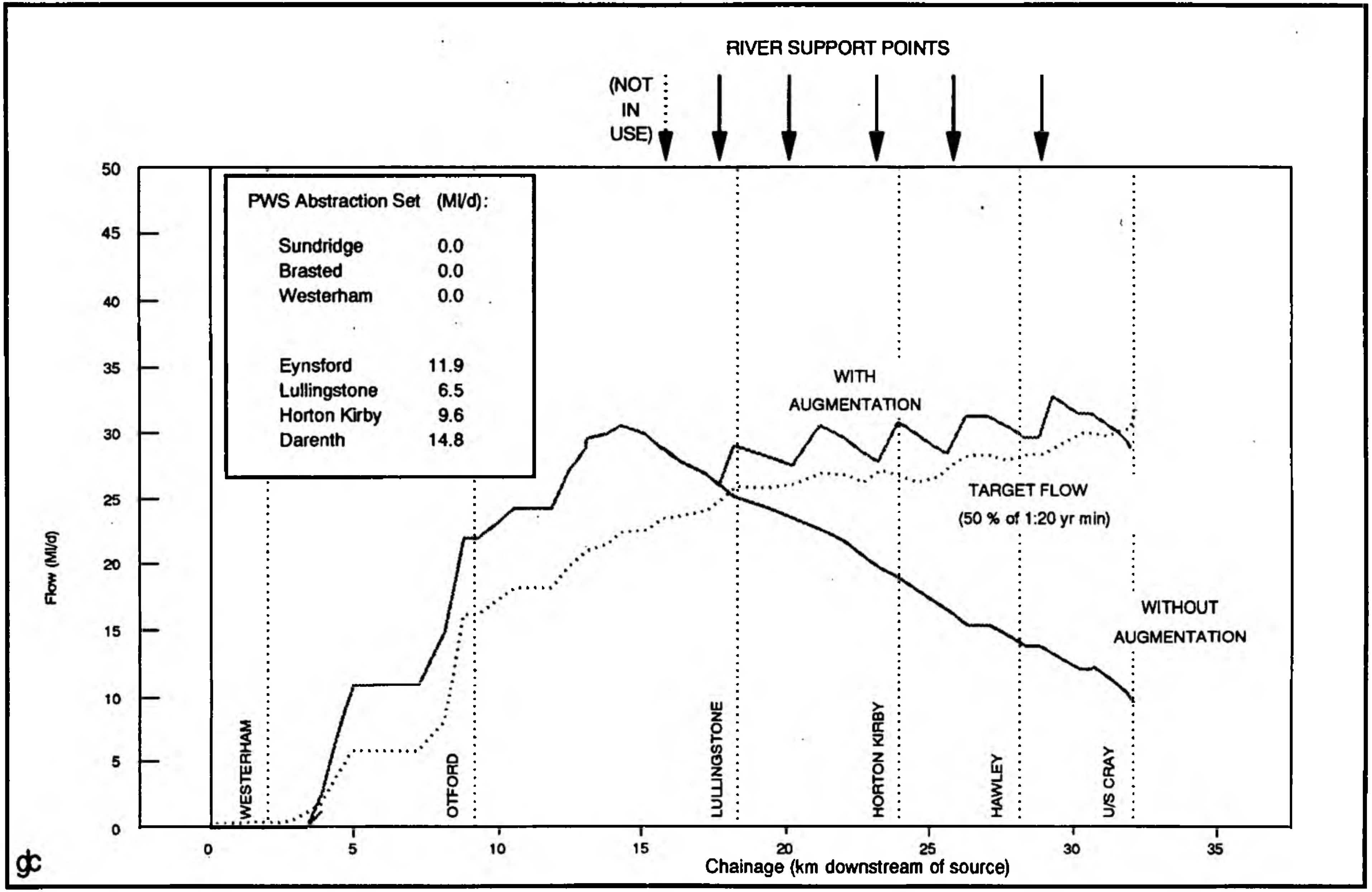
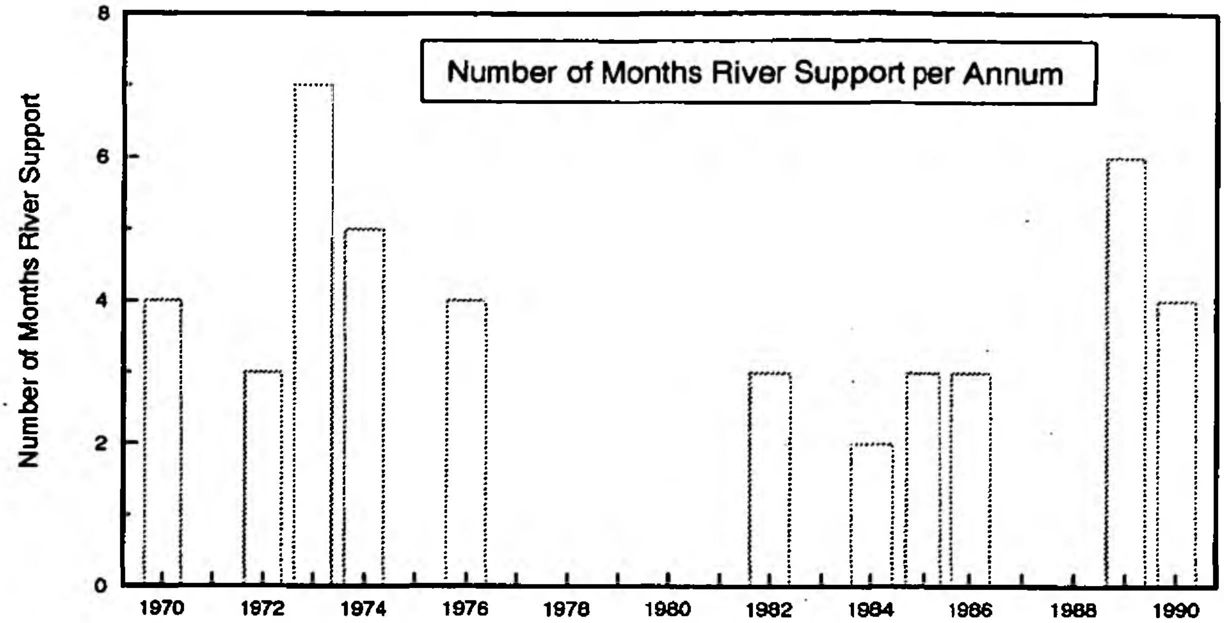
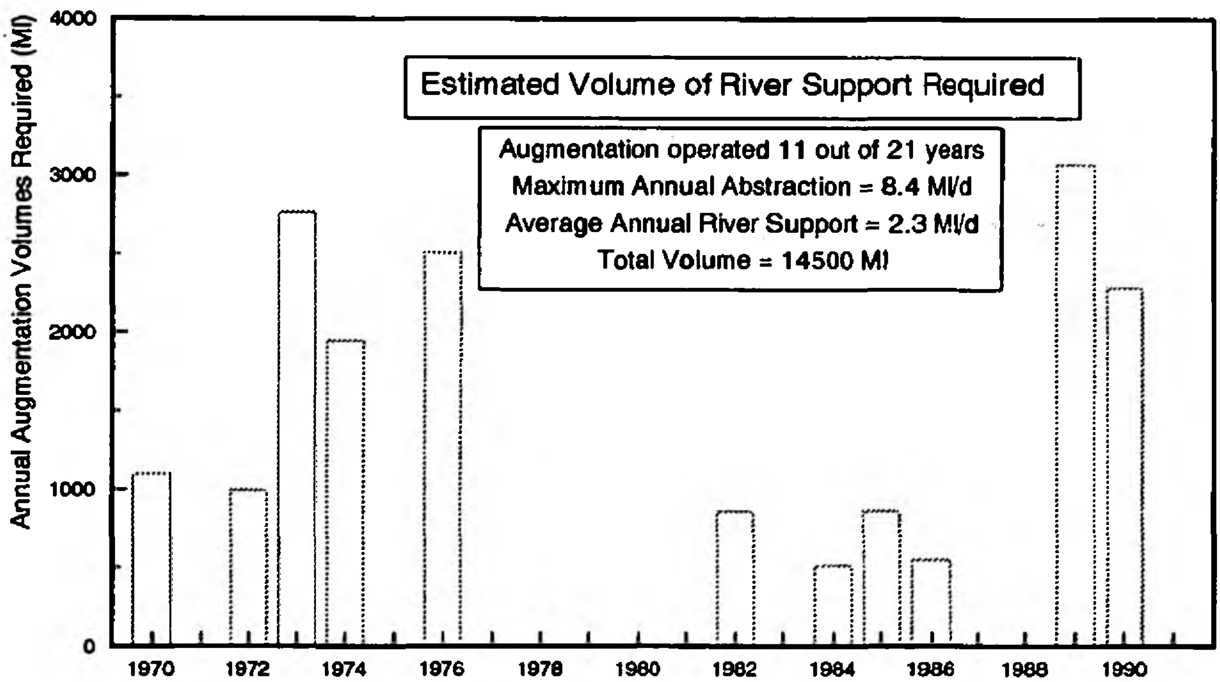


Figure A2.6
River Support

Figure A2.7

Augmentation Requirements: Conjunctive Use in Operation





PWS Abstractions Assumed (Ml/d):

	Normal	Peak
Sundridge	0.0	0.0
Brasted	0.0	0.0
Horton Kirby	6.4	18.18
Eynsford	5.0	18.18
Lullingstone	0.0	9.09
Darenth	20.0	22.73
Bexley	Historical	40.00

Periods of Peak Abstraction

May 1976 - Oct 1976

Sep 1984

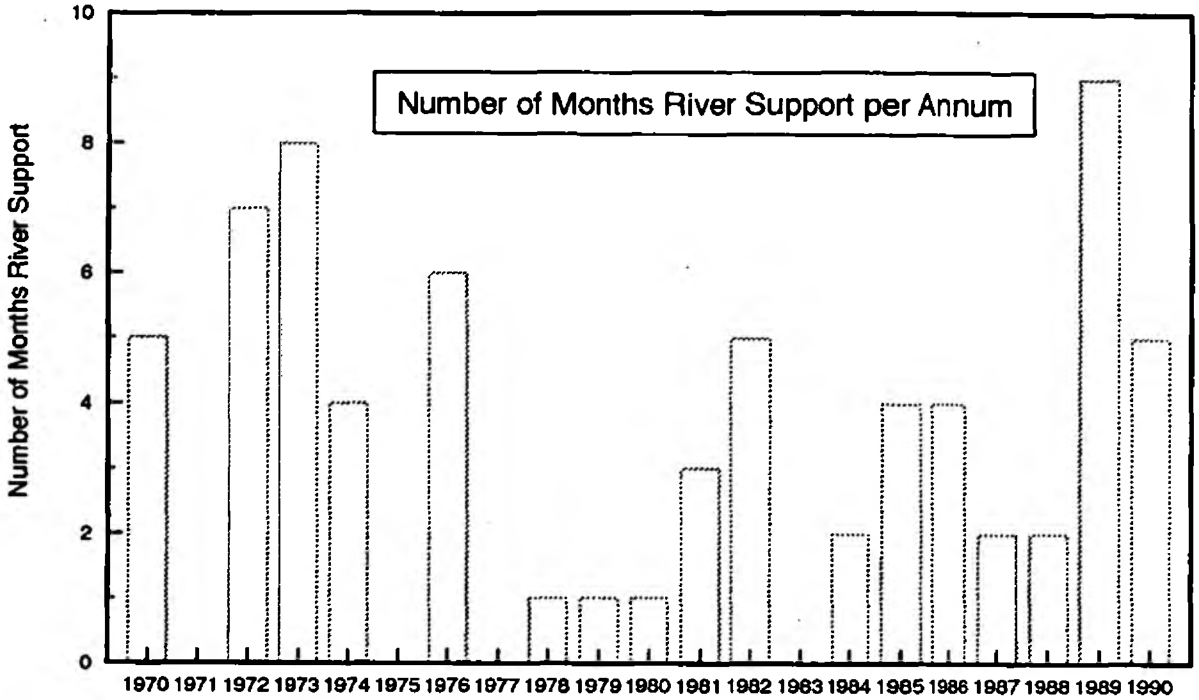
Jul 1989 - Dec 1989

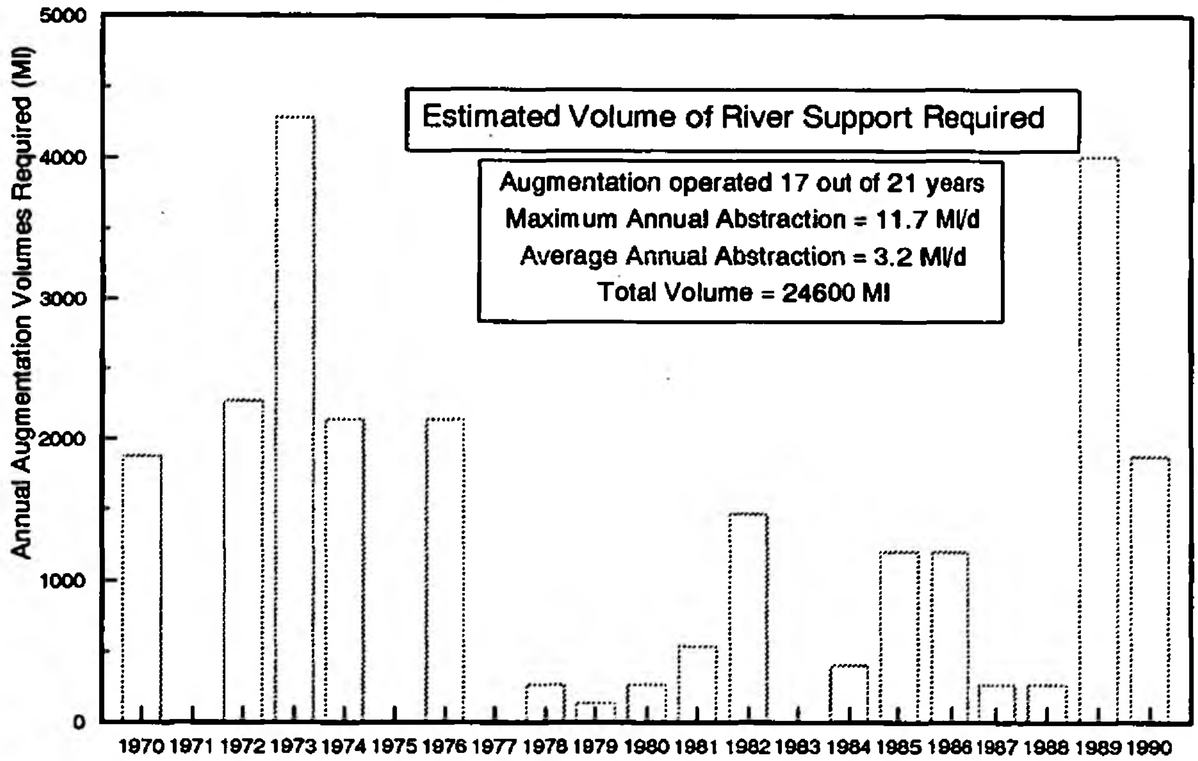
Jul 1990 - Sep 1990

Note. Chalk abstractions weighted to Lower Catchment

Figure A2.8

Augmentation Requirements: No Conjunctive Use





PWS Abstractions Assumed (Ml/d):

	Normal	Peak
Sundridge	0.0	0.0
Brasted	0.0	0.0
Horton Kirby	9,6	9,6
Eynsford	11.8	11.8
Lullingstone	6.4	6.4
Darenth	14.7	14.7
Bexley	Historical	Historical

Periods of Peak Abstraction

May 1976 - Oct 1976
Sep 1984
Jul 1989 - Dec 1989
Jul 1990 - Sep 1990

Note. Chalk abstractions not weighted to Lower Catchment

APPENDIX 3 OPTIONS MATRIX

APPENDIX 3

OPTIONS MATRIX

Options	Key criteria	Secure river flow Option contribution Ml/d / 35 Ml/d yardstick	Conserve ecology	Effect on water utility supply: Water Resources	Effect on water utility supply: Operations	Costs: CAPEX (£M)	Costs: OPEX (£k pa)	Costs: COMBINED £M NPV	Elapsed time (Years)	Public acceptability	Risk of failure to implement	Operational security	Flexibility	Other comments
A. Sewage Effluent	A1.STW at Otford	9/35 = 26%	•	Neutral	Extra OPEX for S&ST	>12[1]	340	>14.3	2-5	••	••	•••	•	[1]Copper removal not included
	A2.Long Reach Effluent augmented at Otford	> 35/35 = 100%	•[1]	Neutral	Extra OPEX for S&ST	>50	1500	>60.5	>5	••	••	•••	•••	[1]Assumes effluent suitably treated for ecological requirements
B. Artificial Springs		16/35 = 46%[1]	•••	Neutral	Neutral	<1	80	<1.7	1-2	••	•••	•••	•••	[1]Could be greater, requires further evaluation
C.	C1.Leakage Control reducing to 10%	SEE COMMENT		Benefit equivalent to savings	Some OPEX savings likely	1	negative expenditure	<1	3-4	•••	•	••	•	To be assessed in STAGE II proposals, see Appendix 5 RDMS2 (item 3)
	C2.Metering				Increase OPEX	29	800	23	2-3	••	•••	••	•	
D. Licence Variation & Conjuctive use	D3.Licence Variation/ Conjunctive Use Operating Agreement	20/35 = 57%	•••	Neutral	Extra OPEX	3.6[1]	100	4.3	0	••	•••	••	•••	[1]Full security requires bringing forward Brixton-Honor Oak by 3 years and infrastructure improvements
E. BCI	E1.Direct Supply	15[1]+NG/35 = <43%	•/••	If straight replacement: neutral. If additional: sig. benefit	Increase operating cost	9	200	10.1	3-4	•••	••	••	•••	Up to 20 Ml/d could be available
	E2.River Augmentation	15[1]/35 = 43%	•••	See comment	Neutral	5	80	5.3	2-3	••	••	•••	•••	Potential for further surface water abstraction (see Option E3 under 5.3)
Definitions		Assume quantity requirement for river is 35 Ml/d during extreme low flows periods (NG = Net Gain)	••• is equivalent to baseflow (LGS or CK); emphasis on water quality		Include total TWUL operations implications	'CAPEX' & 'OPEX' are given in 1992 prices. 'Combined NPV' assumes: - Capital asset life 60 years with 8% discount rate - Capital expenditure over 2 years starting 93/94 - Operating expenditure starts 95/96 - Zero energy growth					Measure of risk of failure to implement eg Planning permission refused, costs escalating	Measure of confidence that option will always work in practice	Measure of degree to which option can be adjusted at design stage or cope with changing river needs/water supply scenarios	

APPENDIX 4 PROPOSED LICENCE VARIATIONS (TWUL)

(1) Lower Greensand

	Existing Average Annual	Existing Peak	Proposed Range Average Annual	Proposed Range Peak
	(a)	(b)		
Brasted	4.56	6.82	0	0
Sundridge	13.60	18.20	0	0
Sub-total	18.16	25.02	0	0

(2) Chalk-Middle Catchment "4"

	(a)	(b)	(c) or	(d)	(e) or	(f) see (iii) and (iv) below
Lullingstone	9.09	9.09	4.50	4.54	6.14	6.36
Eynsford	16.82	18.18	11.60	8.39	18.18	12.73
Horton Kirby	13.64	18.18	13.60	6.80	18.18	12.73
Darenth	20.91	22.73	20.90	20.90	22.73	22.73
Sub-total	60.46	68.18	50.60	40.63	65.23	54.55

(3) Total for (1) + (2)

	78.62	93.20	50.60	40.63	65.23	54.55
	100%	100%	65%	52%	70%	58%

(4) Chalk-Lower Catchment*

	(c)	(d)	(e)	(f)
Proposed range of increase from Lower Darent and/or Lower Cray	4.4	14.4	13.4	24.08

(5) Total for (3) and (4)

	(c)	(d)	(e)	(f)
	55.0	55.0	78.63	78.63
	70%	70%	84%	84%
			100% of existing average annual	

* Lower Darent : Darenth, Wilmington and Dartford
Lower Cray : Bexley**, Crayford and Wansunt
** Assumes time-limited condition and flow constraint condition is relaxed

Key Points

(i) The proposed licence variations as given in columns (c) to (f) inclusive represent the maximum permitted entitlements. A fundamental part of the licence variation proposals is that the adoption of the conjunctive use operating agreement (see WRMS1, Appendix 5) will mean in practice that these maximum abstraction rates will be used no more frequently than one year in ten on average i.e. during a "Thames drought". For most of the time abstraction levels will be substantially lower at about 32 Ml/d (40%) from the Middle Catchment "4". Furthermore, the weighting applied to the "4" during these "normal" periods will be biased down-catchment, with the Darenth source taking over 60% of that abstraction.

(ii) The resource neutral position (i.e. London's present deficit is not increased) for the proposed conjunctive use mode of operation is for a maximum take from the original "six" (see columns a and b) during an extreme "Thames drought" of 55 Ml/d (70%) average annual and a peak capability of 78.6 Ml/d (100% of original "six" over the critical months of low reservoir storage.) This has been achieved by off-setting the proposed range of downward variations in the upper and middle catchments by upward variations in the lower catchment (c.f. totals under (3) and (5) for columns (c),(d),(e) and (f)).

(iii) The figures given under columns (c) and (e) for proposed annual average and peak use are directly compatible with the costings given for Option D3 (see Appendix 3). They represent TWUL's best estimate of the maximum upward variation from the lower catchment sources without incurring significant extra costs over and above Option D3.

(iv) An early requirement within Stage I will be for the NRA to review the benefits to river flow of moving a greater proportion of "Thames drought" additional abstractions to the lower catchment. In order for the cost-benefit to be assessed, TWUL will review the level of infrastructure costs needed to provide for an increase of lower catchment abstractions towards the upper range (as given under 4 (d)/(f)).

APPENDIX 5 OUTLINE MANAGEMENT SCHEMES

Two Section 20 Water Resources Management Schemes (WRMSs) are proposed. Their substance is outlined below.

WRMS1 - To secure conjunctive use of River Thames reservoirs and Darent groundwater sources, and associated augmentation of the River Darent

This scheme will secure commitments to conjunctive use and to augmentation, as follows:

(A) Conjunctive Use

It will commit TWUL to reduce abstraction from the Darent/Kent sources when Thames Reservoir storage is maintained at normal levels while permitting TWUL to increase abstraction from the Darent when Thames reservoir storage is below normal.

It will specify three modes of operation, following the definitions contained in the S20 WRMS registered in the 'Privatisation' Transfer Scheme as Agreement A2, "Lower Thames Abstraction Scheme". This Agreement includes an Operating Strategy Diagram (OSD) which relates water-saving measures (such as hosepipe bans) and protected residual flows in the River Thames at Teddington, to storage in the London reservoirs and to time of year. Figure A5/1 shows an adapted version of this diagram for use with the Darent.

Usually storage can be kept full or nearly full. (Condition X). Only in a significant drought does it fall far enough to invoke two specific triggers identified for this MS1 purpose. The triggers are

(Y) when River Thames target residual flows are dropped to 600 Ml/d
(Z) when hosepipe bans are to be imposed to reduce demand or when the OSD allows for them to be imposed, whichever is the later. TWUL retain freedom to make decisions, with the OSD as "guidance"; so WRMS1 allows for some conjunctive use to continue, if TWUL delay hosepipe bans, until the reservoir situation is recognised by TWUL as sufficiently serious.

WRMS1 will stipulate three zones of Thames reservoir storage, X, Y and Z. X is the normal one, around 90% of the time, when the Thames flow target is retained at its usual 800 Ml/d. Y and Z come in during drier conditions and a drought.

The Scheme will indicate that when a severe drought, with Thames storage in Zone Z, occurs, the full annual average licensed quantities in the Darent will apply until Zone X is regained. However normally (zone X) and sometimes (zone Y), abstractions will be restricted to follow the following amended figures for annual average, whilst Thames reservoir storage levels remain the relevant zone:

4 Middle Catchment Chalk Sources	ZONE		
	X Ml/d	Y Ml/d	Z Ml/d
L + L + HK	19.6	23.1	29.7
Darenth	20.9	20.9	20.9
TOTAL	40.6	44.0	50.0

L = Lullingstone, E = Eynsford, HK = Horton Kirby

Peak day abstractions will be unaffected.

WRMS1 will also require TWUL to use "best endeavours" to keep winter abstractions from October to March inclusive down to less than 32 Ml/d, from the 4 middle chalk sources combined whilst Thames reservoirs remain in Zone X. It is recognised that there is a practical the need to abstract much less than the annual average allowed, from October to March, to allow for possible peak demands later in the year. Minimising winter abstraction has the added benefit of significantly reducing the frequency of river augmentation.

(B) **Augmentation**

It will commit the NRA to ensuring by providing monitoring and augmentation, that target river flow regimes at different locations throughout the year are met. The monthly river flow targets will be specified in the Scheme, as recommended by GDC consultants and agreed by the Team.

The Scheme will also include management consultation arrangements, to seek to resolve where possible any differences of opinion or shortcomings by either side.

WRMS2 Review of river and public water supply needs

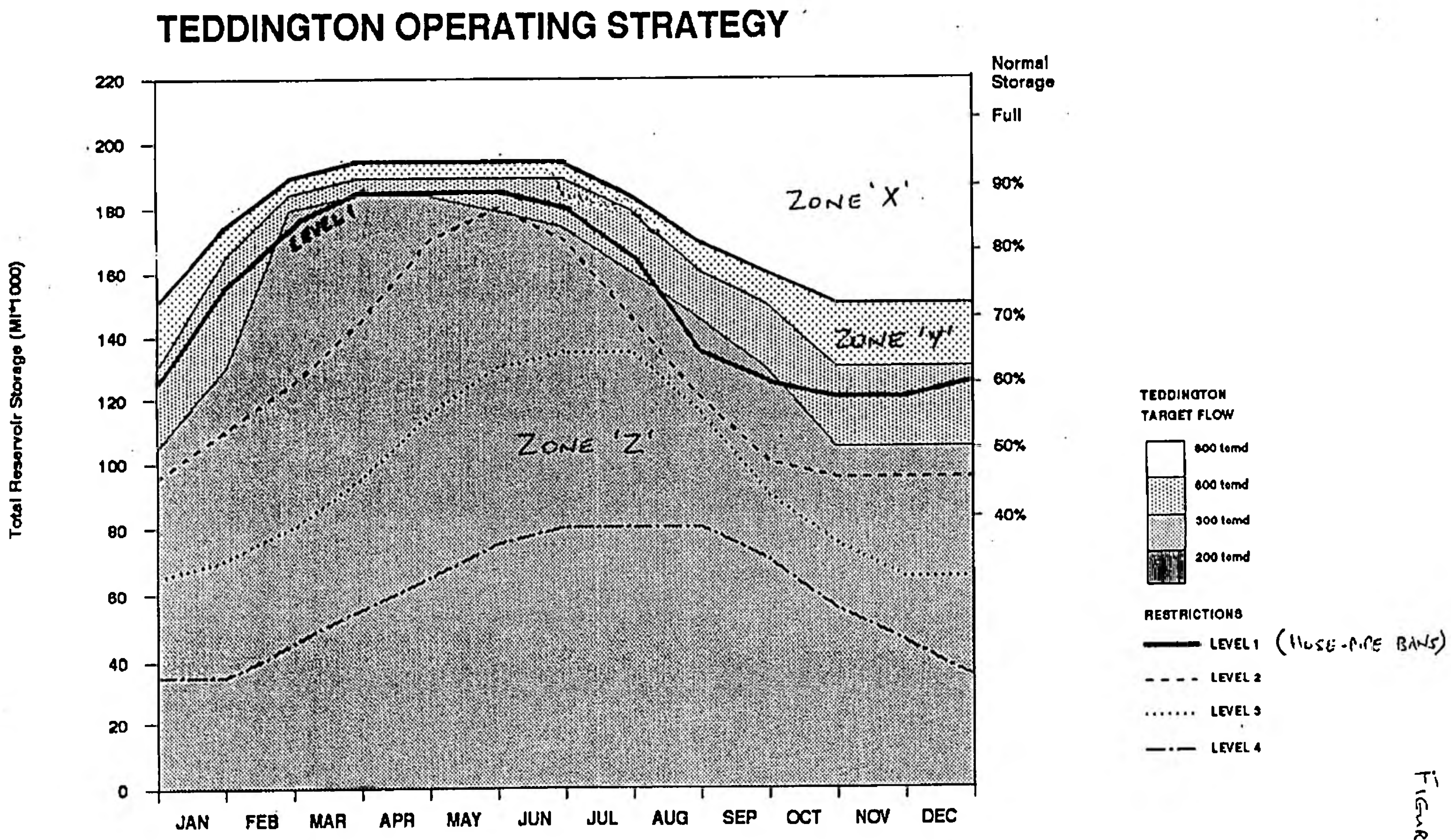
1. This scheme will commit NRA and TWUL to collaboration and actions to enable review both of river needs and of public water supply needs in the future.

2. It will commit the NRA to collecting data, and refining models, which will ensure confidence about the relationship between the River Darent and various associated groundwater levels and abstractions. The NRA will also be committed to assessing the overall health of the river under Stage I arrangements and considering the adequacy of the target flow profile and the acceptable frequency of augmentation.

3. It will commit TWUL to a continuing programme of leakage control and appropriate demand management measures with a view to demonstrating future needs for water in the area.

4. It will commit both bodies to a joint review to establish the future need for water from the proposed conditional BCI licence, and to establish further steps (should they prove necessary) to safeguard the Darent.

5. The joint review should be carried out as far as possible by 1998, in the context of AMPIII proposals, but in any case should be completed by June 2000.



TEDDINGTON OPERATING STRATEGY
Total Reservoir Storage (Ml*1000)
220
200
180
160
140
120
100
80
60
40
20
0
Normal Storage
Full
90%
80%
70%
60%
50%
40%
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
LEVEL 1
ZONE 'X'
ZONE 'Y'
ZONE 'Z'
TEDDINGTON TARGET FLOW
800 tcmd
600 tcmd
300 tcmd
200 tcmd
RESTRICTIONS
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4

FIGURE A5-1

APPENDIX 6 STAGE II CONDITIONAL LICENCE FOR PUBLIC WATER SUPPLY (BCI CHALK DEWATERING)

In Stage II it is proposed that TWUL apply for a licence for public water supply which would permit re-abstraction of augmentation water at the bottom of the Darent, or take water direct from BCI quarries. The licence would include the condition that utilisation of authorised quantities will be dependent on TWUL demonstrating need according to pre-determined methodology contained within the licence.

If abstraction is proposed from BCI then the total quantity taken, together with augmentation on an annual basis is not expected to exceed 20 Ml/d, which is the current estimate of available quarry water of reasonable quality.

Thus the issue of the licence would allocate a resource, but its utilisation would depend on demonstrating need and securing the proper use of water resources.

TABLES

TABLE 1

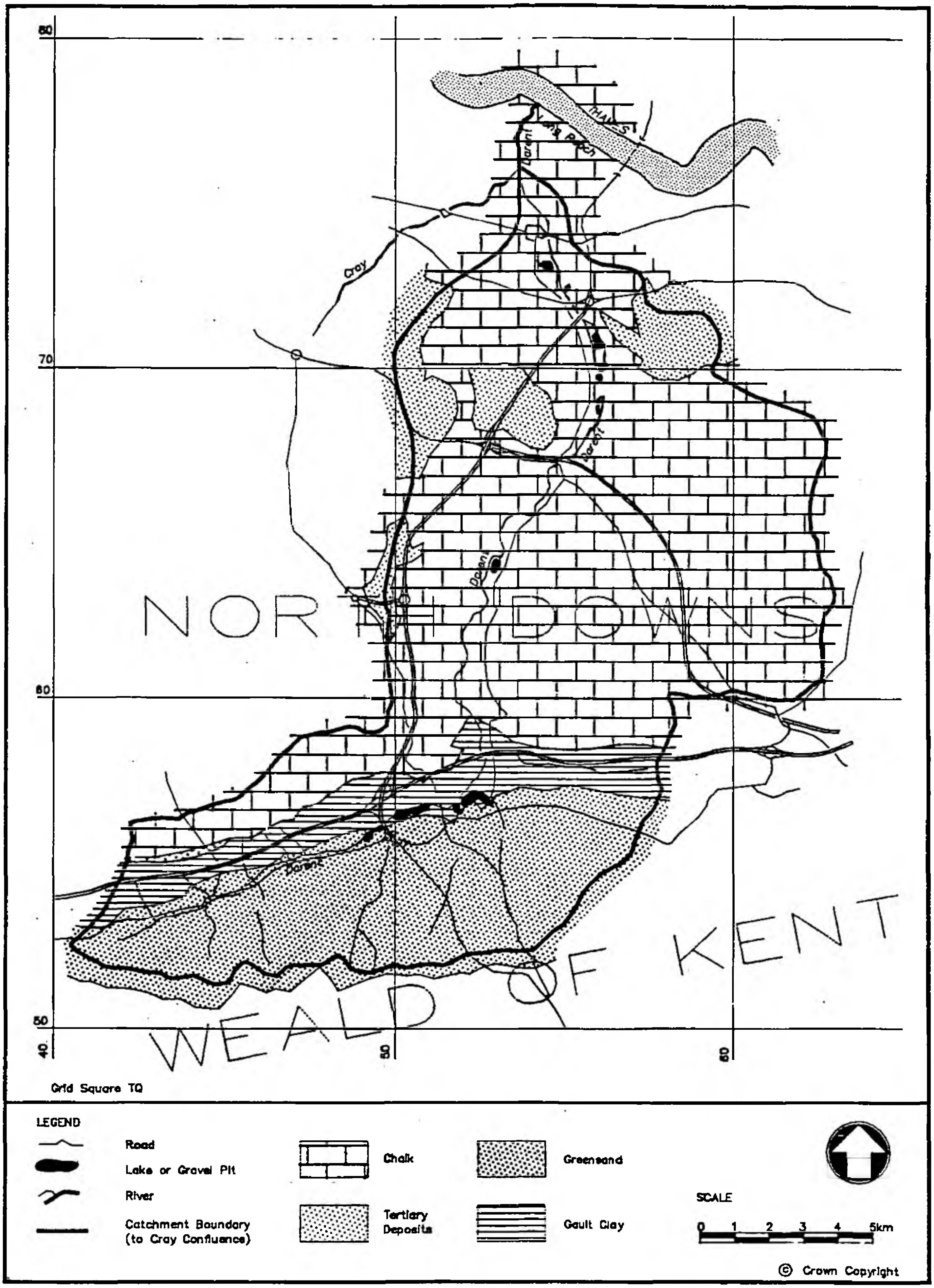
ABSTRACTIONS FOR PUBLIC WATER SUPPLY

Abstractor	Number of Sources	Licensed average	Average abstractions for 1985 to 1989 (Ml/d)
Thames Water	10	106.9	81.0
West Kent Water	3	23.1	18.8
Mid Kent Water	3	12.5	5.4
Southern Water	1	6.8	6.1
East Surrey Water	1	5.6	1.9
TOTAL	18	154.9	113.2

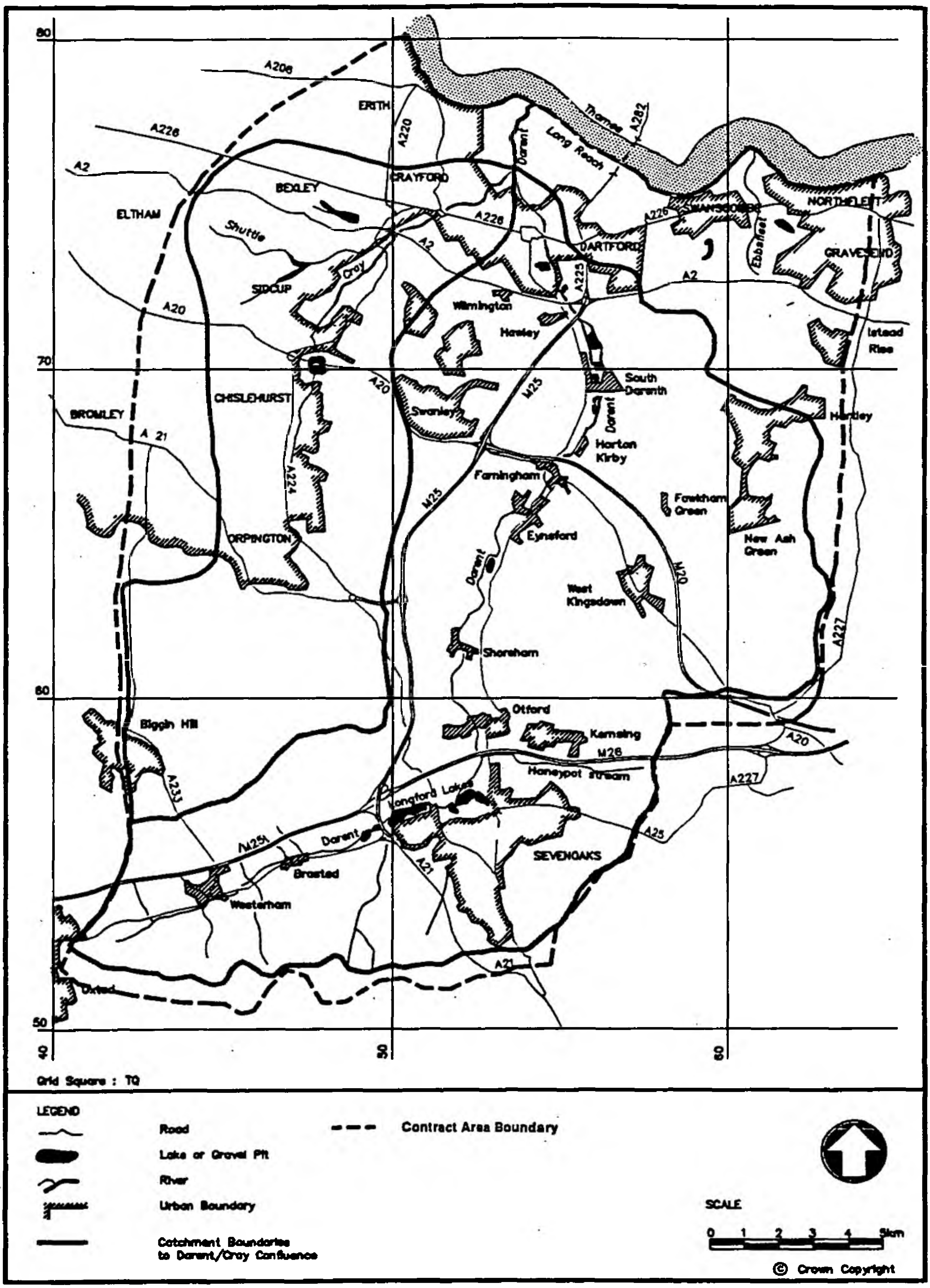
NOTES:
(1) Licensed average abstraction is the licensed annual abstraction divided by 365 days.
(2) Source: TWU Database and water companies' data.

MAPS

Solid Geology

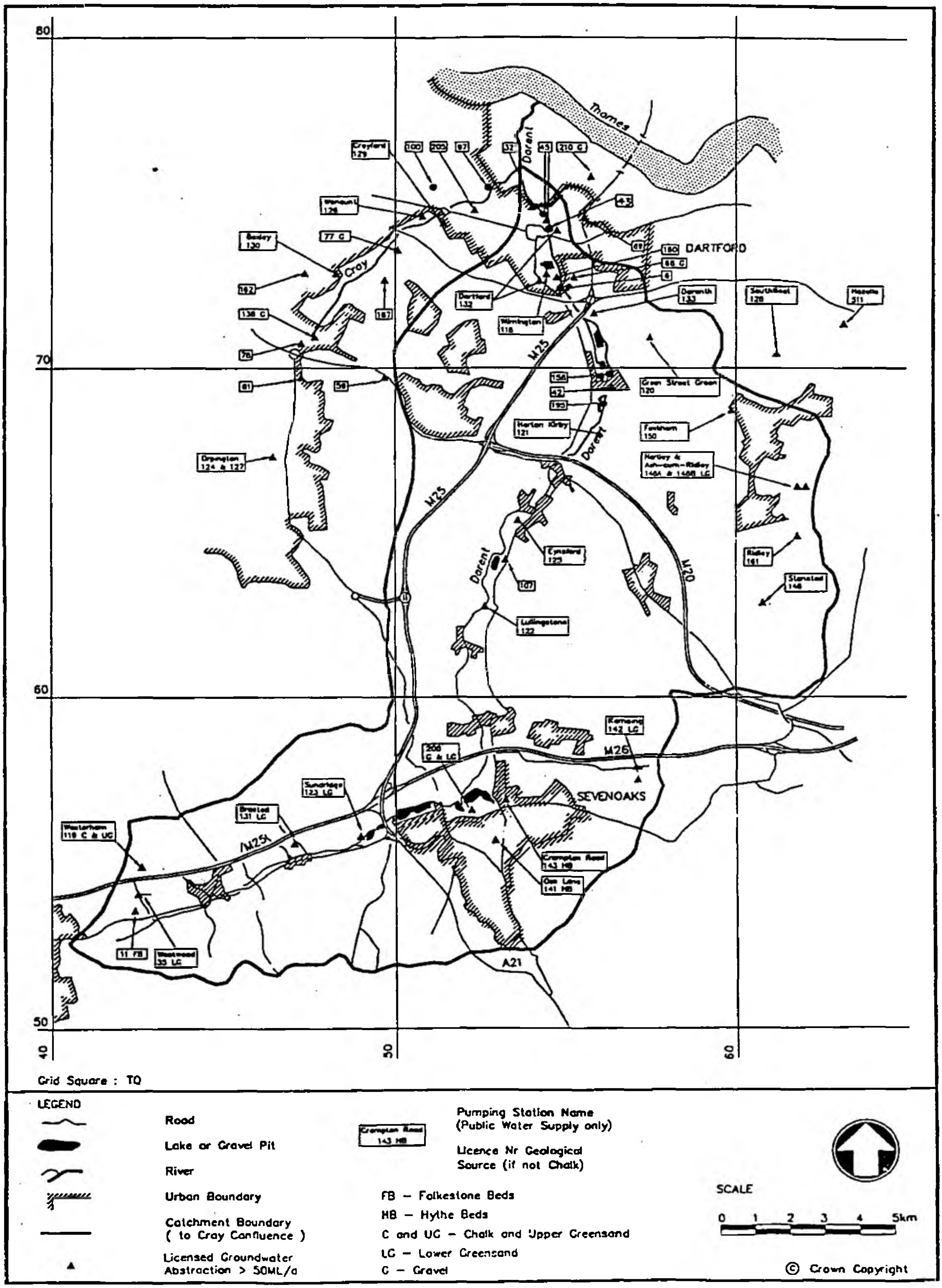


Location


A206
ERITH
A226
A2
A220
Thames
A282
Long Reach
Darent
BEXLEY
CRAYFORD
ELTHAM
Shuttle
A226
NORTHFLEET
SWANSCOMBE
A226
DARTFORD
A2
Ebbsfleet
GRAVESEND
SIDCUP
Cray
A225
A2
A20
Wilmington
Hawley
Istead Rise
CHISLEHURST
A20
South Darenth
BROMLEY
M25
Swanley
Darent
Hartley
A 21
Horton Kirby
Farningham
A224
M25
Fawkham Green
ORPINGTON
Eynsford
New Ash Green
Darent
M20
West Kingsdown
A227
Shoreham
Otford
Biggin Hill
Kemsing
M26
Honeypot stream
A20
A233
Longford Lakes
A227
M25
Darent
A25
A21
SEVENOAKS
Brasted
Westerham
A21
Oxted
80
70
60
50
40
50
60
Grid Square : TQ
LEGEND
Road
Lake or Gravel Pit
River
Urban Boundary
Catchment Boundaries to Darent/Cray Confluence
Contract Area Boundary
SCALE
0 1 2 3 4 5km

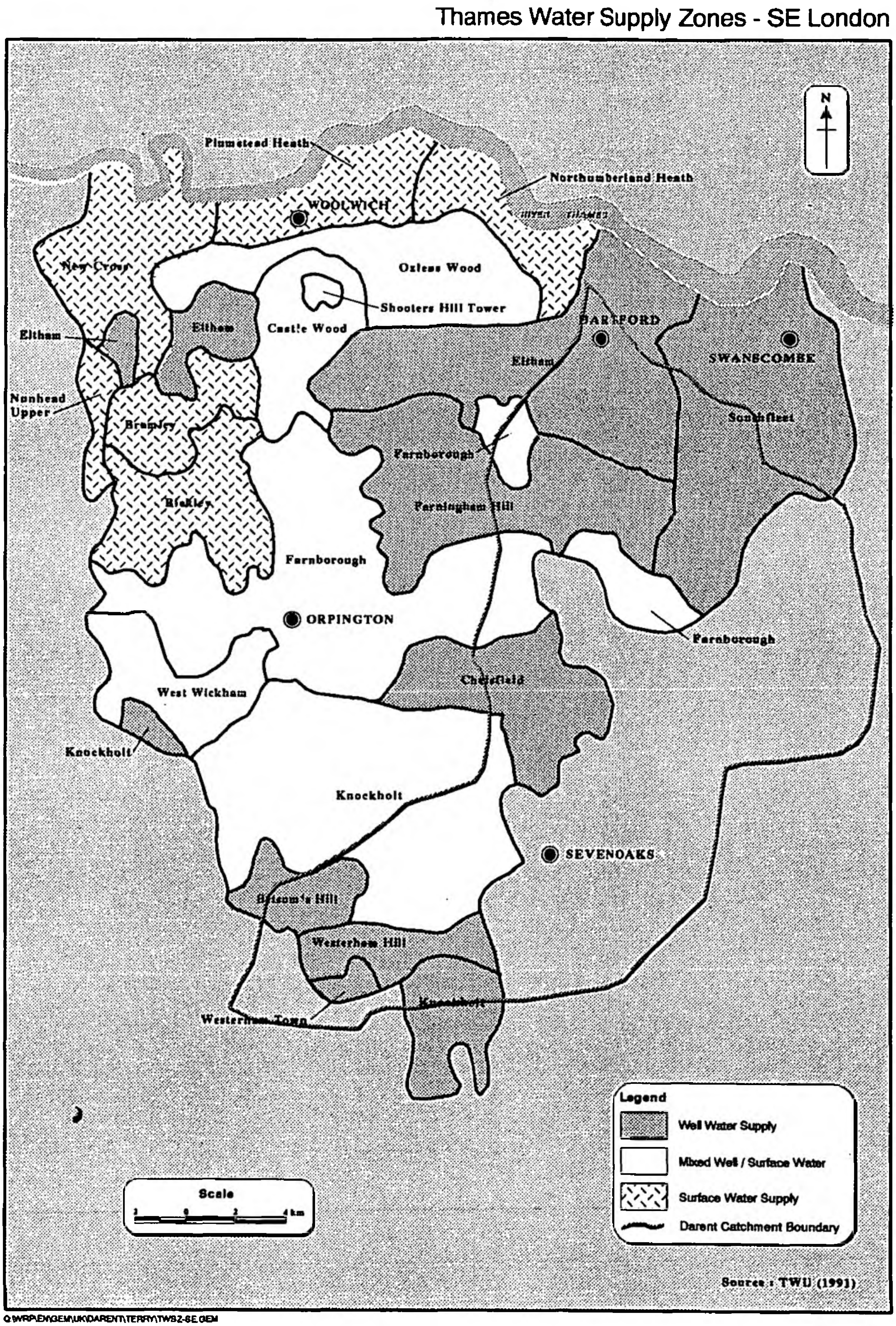
MAP 3

Abstraction Sources



FIGURES

FIGURE 1 CURRENT DISTRIBUTION OF SUPPLIES FROM DARENT SOURCES



Q:\WRP\ENGEM\UK\DARENT\TERRY\TWSZ-SE.GEM