NATIONAL RIVERS AUTHORITY

ANGLIAN REGION

WATER RESOURCES PLANNING:

DEBEN GROUNDWATER UNIT
WATER RESOURCES MANAGEMENT PLAN

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February 1995

DOCUMENT CONTROL SHEET

Project: **WATER RESOURCES MANAGEMENT PLANS**

Title: **DEBEN GROUNDWATER UNIT: WATER RESOURCES MANAGEMENT PLAN**

File Ref: 656/3/6

Document Approval and Amendment Record

Version No.: Final Report

Status: Internal working document.

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Drafts Checked By: Pauline Smith, David Evans, Gerard Stewart, Bob Hillier, Barry Barton, Alan Hull, Dave Clarke (part)

Approved:
Date: 15th February 1995

Purpose and Distribution: To refine and apply the principles of both the National and Regional Water Resources Strategies at a local scale, and to provide water resource input into Catchment Management Plans.

Document History

Previous Version Number	Date	Comments
Draft 1.0	Nov 94	For comment by Deben ALF Project Team members.
Draft 2.0	Jan 95	Final Draft.

DEBEN GROUNDWATER UNIT:

WATER RESOURCES MANAGEMENT PLAN

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FOREWORD

Water Resources Management Plans are a series of studies for specific catchments/aquifer units in which water resources issues are examined. Their purpose is to refine and apply the principles of both the National and Regional Water Resources Strategies at a local scale, and provide water resources input to Catchment Management Plans.

Water Resources Management Plans are the second of a three stage programme of resource assessment:-

- **Groundwater Balances** provide a first approximation of available groundwater resources (using historical information from existing reports, recent abstraction licence and discharge consents data) and make a provisional assessment of environmental requirements.

- **Water Resources Management Plans** build on, and refine the groundwater balance work. They update historical information, where relevant and make additional assessments of future needs, both for abstraction and the environment. They provide a structure for the integrated management of both groundwater and surface water resources.

- **Groundwater Modelling** through computer simulation aims to aid understanding and quantify estimates of recharge into aquifers; the subsequent storage and movement of water within aquifers; eventual discharges of water from aquifers, given various abstraction scenarios. These models enable more accurate assessment of aquifer yield and evaluation of options for water resources management.

This particular Water Resources Management Plan examines both the water resources and demands of the Rivers Deben, Fynn & Lark in Suffolk, and sets out a plan to achieve the twin objectives of water resources:-

secure water supplies and a better water environment

DEBEN GROUNDWATER UNIT:
WATER RESOURCES MANAGEMENT PLAN

1 SUMMARY

1.1 Area of Study

The Deben Groundwater Unit (Figure 1) includes the River Deben (7/35/6), the surface catchments of the Fynn & Lark (7/35/7) and part of the Felixstowe Peninsula (7/35/10). Whilst the Groundwater Unit forms the area of study for the Water Resources Management Plan, it should be noted that the area is greater in its extent than the area of study associated with the River Deben Alleviation of Low Flows (ALF) project.

The Chalk is the main aquifer, with overlying Crag also important in local areas.

The Deben is the principal river. Its flows have been gauged since 1964 at Naunton Hall. They are relatively flashy as a consequence of heavy boulder clay cover and limited direct interaction with the aquifers, especially in the headwaters. This gives a comparatively low baseflow index of 0.36 (Ref [1]) and results in naturally low flows during dry conditions.

The main uses of water in the Unit are for public water supply, and for spray irrigation.

1.2 Groundwater Balance

The gross (long term average) resource of the unit is 32.6 Ml/d. The effective resource (in a dry year) is taken as 80% of this (Ref [24]), and is currently allocated as follows:-

	Component	Ml/d ave.
1	Gross resource	32.6
2	Net resource (80% of 1)	26.1
3	Total groundwater abstraction licensed	12.5
4	Net environmental allocation	7.3
5	Surplus/Deficit (2-3-4)	+ 6.4

1.3 Current Issues

- **Abstraction Licensing Policy**
  In order to achieve secure water supplies and a better water environment, an appropriate abstraction licensing policy needs to be based upon assessments of available resources and current demands, both for abstraction and the water environment.

- **Protection and Improvement of the River Environment**
  In the River Deben, there is a history of low flow incidents and related public complaints during dry summers, particularly in the stretch of river around Wickham Market. The river has sometimes become stagnant, with zero flows, mill ponds have dried out and fish have been killed. Implementation of a package of measures to alleviate low flows is planned (Ref [13]).

- **Protection and Improvement of the Wetland Environment**
  The Deben Groundwater Unit contains several water dependent SSSI and other sites of nature conservation interest. A framework is required to enable the right balance to be achieved between their needs and the needs of abstractors.

- **Provision of Secure Water Supplies**
  There is a need to secure the supplies of existing abstractors and ensure if possible that future needs can be met in an environmentally sustainable manner.

- **Protection of River Water Quality**
  Although not the remit of the water resources function, an integrated policy to take account of water quality requirements is needed.

- **Appropriate River Channel Management**
  River flow objectives need to be defined in conjunction with both best practice river channel maintenance and with any opportunities for river channel improvements to optimise efficient use of water resources.

1.4 Recommendations

This report identifies that the Deben Groundwater Unit has a small nominal surplus (6.4 Ml/d) of resources over demands, after taking into account both environmental requirements and the needs of existing abstractors. It recommends an appropriate abstraction licensing policy based on these findings and a series of further measures in order to conserve and enhance important wetlands and the river environment, and to protect river water quality.

The following recommendations are made in accordance with the principles of **sustainability, demand management** and **precaution** (Ref [2]).

1.4.1 Licensing Policy

Surface Water

At present, no new summer surface water abstraction is permitted. Winter surface abstraction is only permitted subject to hands-off flows for the protection of existing abstractors and the environment. Where summer use is required, and winter surface abstraction is permitted, construction of bankside reservoirs is encouraged to enable stored winter water to be utilised during summer months. It is recommended that this policy continues.

Groundwater

The policy of considering only limited further **groundwater abstraction**, subject to local considerations and environmental impacts should continue in accord with the regional licensing guidelines.

1.4.2 River Flows and Environmental Needs

The 'In River Needs' of the Deben have been preliminarily identified as part of the Southern Science Environmental Appraisal for the River Deben Alleviation of Low Flows (ALF) project (Ref [13]). It is recommended that when current research (Ref [3]) to identify methodologies for evaluating river flow needs has been completed (due 1995), the methodology identified should be applied to the Rivers Fynn & Lark and used to refine the river flow needs of the River Deben.

In the interim, further work has been recommended to refine the naturalised flows for the River Deben through rainfall run-off modelling.

1.4.3 River Deben Alleviation of Low Flows

Due to its Clay catchment, flows in the Deben are normally low in dry summers. However, this situation is exacerbated by long established abstractions. A package of measures has been identified by the River Deben ALF Project Team (Ref [13]). All identified options have been subject to detailed feasibility and cost investigations in accordance with project management procedures. The following package of measures has been identified as the preferred option:-

River support from the Earl Soham augmentation borehole, to augment flows to a provisional target minimum of 7.6 Ml/d at Naunton Hall.

Re-allocation of 5 key surface spray irrigation licences to groundwater.

Revocation of 2 key surface spray irrigation licences.

Implementation of river channel improvements and revision of river channel maintenance practices.

The impacts of Anglian Water Services' proposed increases in groundwater abstraction are to be addressed through the licensing process, and may include requirements for minor river support.

1.4.4 Groundwater Modelling

It is recommended that the Deben Groundwater model is updated by the NRA either 'in- house', or through consultants, to incorporate any new monitoring data collected from proposed time limited licences for public water supply and/or from the Deben ALF scheme. Applicants would still be required to submit separate Environmental Assessments as specified by Area staff in support of any licence application.

A time variant Deben Groundwater Model should be developed following the availability of the new data.

The impact of seasonal abstractions on groundwater should be identified by modelling with the time variant model. The model should also be used in post project appraisal to review the effectiveness of the package of measures to alleviate the low flows of the River Deben.

2 INTRODUCTION

This report provides information on the water resources of the Deben Groundwater Unit and the demands placed upon them. It examines water resources issues, identifies appropriate options and makes recommendations, including a suitable licensing policy for the continuation of sustainable management of those resources to provide secure water supplies and a better water environment.

2.1 Location

The River Deben rises near Debenham in Suffolk and flows southeastward to the Deben Estuary near Woodbridge. General features are shown in **Figure 1**.

The Deben Groundwater Unit is currently based on the surface catchments of the River Deben (7/35/06) and the Rivers Fynn & Lark (7/35/07) and part of the Deben Estuary/Felixstowe Peninsula (7/35/10)

2.2 Current Issues

2.2.1 Provision of Secure Water Supplies

Public Water Supply

Latest regional public water supply forecasts (**Ref** [4]) to the 2021 planning horizon show a much smaller increase in demand than previous forecasts. This is largely due to a combination of factors including metering and leakage reduction programmes, and an increase in public awareness of the need to use water wisely. However, metering and leakage reduction programmes require approval, from OFWAT, of major expenditure which may or may not be forthcoming following the recent decision (**Ref** [5]) on water company K factors.

In the context of the Deben, much of the water used for public supply is exported out of the Unit to the major demand centre of Ipswich. Given that the A14 corridor is an area where future development may be attracted, this could prove to be a local exception to the 'flat' regional public water supply demand forecast. Applications from Anglian Water Services to increase the security of supply within the Ipswich Water Supply Zone are currently in hand.

Agriculture

The 'most likely' demand forecast for spray irrigation (**Ref** [6]) in England and Wales predicts an increase of 1.7% per year for the period 1996-2001 and 1% per year for the period 2001-2011. For Anglian Region, the forecast under the same scenario is 2% per year falling to 1.25% over the same periods. If reflected in the Deben Groundwater Unit there will be additional requirements for irrigation purposes.

Industry

New industrial demands are unpredictable; there is no particular evidence to suggest that large requirements will arise in the Deben Groundwater Unit. The most likely new demands to arise may be for sand and gravel washing works in the lower parts of catchments. Such abstractions would be unlikely to pose difficulties in terms of overall water resource availability as much of the water is returned to source after use, although local impacts would need to be addressed.

2.2.2 Protection and Improvement of the Water Environment

Designated Areas

There are 8 Sites of Special Scientific Interest (SSSI) and around 70 County Wildlife Sites within the area of study (**Figure 2**). Of these, 1 SSSI and 12 County Wildlife Sites in the River Deben catchment are considered to be water dependent (**Ref** [7]).

Parts of the Deben are also designated as an Area of Outstanding Natural Beauty (AONB), Special Landscape Area (SLA) and Environmentally Sensitive Area (ESA). There are several other sites of conservation value.

Wetlands

Investigations (**Refs** [8 & 9]) are currently being undertaken into 'wetland catchment areas' so that licensing policies may more effectively afford their protection.

Wetlands and many of the designated areas can be sensitive to the effects of abstraction and merit special consideration. The 'precautionary principle' (ie. where knowledge is incomplete, decisions should err on the side of caution) should therefore be practised in order to further protect their status.

Rivers

The River Deben has been identified as one of the NRA's National 'Top 40' low flow rivers and has been included in a programme of Alleviation of Low Flows (ALF's) (**Ref** [10]).

The river has a history of low flow problems around Wickham Market during dry periods. Unconstrained spray irrigation abstraction, direct from the river in summer months has been identified as the major cause of low flows by studies spanning from 1971 to 1993 (see Bibliography).

Water levels and flow regimes are required to satisfy the biology of a river. They need to be identified in order to achieve successful management and to determine an effective licensing policy. No standard methodology has been identified to date, although current studies (**Refs** [11],[12],[3]) may provide an approach which could be applied to other rivers in the future.

The NRA recently commissioned Southern Science to undertake an Environmental Appraisal (**Ref** [7]) into the low flows of the River Deben and to identify minimum flow requirements for key species. The findings of the report are elaborated upon later in this study.

2.2.3 Water Resources Management Policy

Abstraction Licensing Policy

Currently, additional summer surface water is not available for development. Additional surface water during the winter period, when flows are naturally higher may be granted, subject to availability and protection of both existing abstractors and the environment. This protection is usually in the form of a 'hands-off flow' (hof) condition incorporated into a licence which prohibits or restricts abstraction when flows or groundwater levels reach a critical value. Abstractors are also encouraged to store available winter water in reservoirs for summer use.

The Deben Groundwater Unit is currently designated as having a small 'nominal surplus' (R.Deben 4.2 Ml/d, R.Fynn & Lark 2.2 Ml/d) enabling groundwater abstraction licences to be issued subject to the usual considerations of local needs of existing abstractors and the environment. There is a need for a regular reassessment of the abstraction licensing policy in order to ensure that appropriate measures are taken in the future to maintain sustainability.

River Support

In order to remedy the low flow problems encountered in the Deben, river support has been identified (**Ref** [13]) as the preferred option in conjunction with a series of other measures. The use of river support in the catchment needs to be examined in the wider context to incorporate other issues in the catchment, therefore being part of an integrated water resources management policy.

Other Management Policies

Consideration of other activities such as river channel maintenance and the scope for improvements to the existing river channel need to be addressed in order to operate in harmony with both existing and future management activities.

3 DESCRIPTION

A detailed account of the hydrology and hydrogeology of the Deben Groundwater Unit is given in Hydrotechnica 1993 (**Ref** [14]).

3.1 Hydrogeology

Chalk is the main aquifer in the Unit. To the north of Debenham it is covered by a thick Crag (sand and gravels) aquifer, and in the south east is confined by London Clay. A separate shallow Crag aquifer overlies the London Clay. The Crag is of particular importance in terms of water resources in the following areas:-

- In a deep basin in the north west of the Unit (NW of Debenham)
- Downstream of Wickham Market where the Chalk becomes confined by the London Clay.

The Crag covering the Chalk has a high iron content and the Chalk itself in this area is ineffective as an aquifer due to saline water at depth.

3.2 Hydrology

Flows in the River Deben are relatively flashy due to the large proportion of clays within the catchment which restrict the interaction of surface and groundwater. This is reflected in the baseflow index of 0.36 at Naunton Hall gauging station (**Ref** [1], Plate 1)

There are two permanent gauging stations in the Deben Groundwater Unit:-

- Naunton Hall on the main River Deben (Station No 35002)
- Playford on the River Fynn (Station No 35325)

Details of the Naunton Hall record are given in **Table 1**. The Playford site is a low flow station, with an intermittent flow record. In addition there have been several temporary gauging sites in the catchments and several current metering readings. (**Figure 3**).

3.3 River Support

The NRA have a partially developed river augmentation scheme inherited from the then Anglian Water Authority. The scheme was started following recommendations of the East Suffolk & Norfolk Rivers Authority (ESNRA) in 1971 (**Ref** [15]), to alleviate the impact of peak summer irrigation abstractions on low flows and potentially provide additional water for spray irrigation abstraction.

However, the current implications of implementing river support in the Deben catchment are different to those considered in the past and have therefore been re-addressed.

Two main boreholes to provide augmentation have been considered in the past. Their locations are shown in **Figure 4**, and they are described below:-

Debenham (Crag) — This has a high yield of approximately 10 Ml/d, but the water is very high in iron. The borehole is not useable without additional treatment and is not currently being developed further. It was re-tested by the NRA in autumn 1990, and was aborted after 1 month as the test confirmed its unsuitability because of high iron content.

Earl Soham (Chalk) — The current yield is believed to be approximately 3 Ml/d. The borehole is currently unlicensed, but plans are now in progress to authorise its use. The NRA is currently undertaking research to evaluate the likely physical impact of pumping (**Ref** [16], Plate 2). This study will be used as a basis for the licence and discharge order application, and will include consultation.

Relevant reports on the augmentation boreholes are referenced in the bibliography at the back of the report.

3.4 Existing Models

Deben Groundwater Model

Groundwater models are tools which can be used to aid in the management of groundwater resources. They can be utilised for the following purposes:-

- to support abstraction licensing policy, by providing defensible estimates of reliable groundwater resources.
- to provide a framework for the evaluation of impacts of groundwater development proposals on existing abstractors and the environment.

Plate 1:
River Deben at Naunton Hall Gauging Station

Plate 2:
Cretingham Golf Course (Grove Farm); Water Dependent County Wildlife Site.

- to evaluate the impact of different water resources management scenarios (e.g river augmentation) on existing abstractors and the environment.

- to determine groundwater protection zones.

- for risk assessment of groundwater contamination.

A groundwater model has recently been developed for the Unit by consultants, Hydrotechnica, as part of a review of the resources of the Deben Groundwater Unit. It is a steady state 2 layer model based on the MODFLOW package. The model has recently been accepted by the NRA, and should be applied according to the recommendations made in this report. A time-variant version of the model is also available, but requires additional work to become a useful tool.

A more detailed description of the model is given in Hydrotechnica, 1993 **(Ref [14]).**

The model however, has limitations:

- It is only steady state.
- There is limited groundwater level and streamflow monitoring data for calibration (the Hydrotechnica report contains recommendations for further monitoring).
- Groundwater boundaries are uncertain.
- Sequences of boulder clay, critical in controlling aquifer recharge are not represented in the model.
- The conceptual model and recharge mechanisms may need improvement.

Despite these reservations it is expected that the model can be used to assess overall resources and abstraction impacts. The experience gained should be of value in any future modelling developments.

Micro Low Flows

Micro Low Flows (MLF) is an Institute of Hydrology computer software package which enables rapid estimation of flow statistics from catchment characteristics at both gauged and ungauged sites.

National methods for the estimation of **naturalised values** for mean flow, mean annual minimum flow and the 95 percentile exceedance flow at ungauged sites are calibrated using values of catchment area, standard annual average rainfall, potential evaporation and the fractions of hydrological response (HOST) classes for each catchment.

Based on a river network database, synthetic catchment boundaries are generated, which are then superimposed on gridded databases of Q95(1) (derived from HOST classes), standard annual average rainfall and potential evaporation to derive mean catchment values of these characteristics above each river stretch.

When applied to the River Deben at Naunton Hall, MLF estimates the natural 95 percentile flow and natural mean flow as 0.081 cumecs and 0.65 cumecs respectively. However, when MLF was applied to 35 rivers in Anglian Region, results indicated that MLF required further calibration. A calibration method was determined (**Ref** [17]) whereby the MLF flow duration curve is calibrated to the gauged mean flow. With recalibration, using the above method, the natural 95 percentile flow was reassessed to be 0.094 cumecs.

Results from Micro Low Flows for the main rivers in the Groundwater Unit are given in **Table 2**.

Table 2: Comparison of Calibrated and Uncalibrated Natural Q95 Flows from MLF (cumecs).

River Deben at N. Hall		River Fynn at TM 240 477		River Lark at TM 241 480	
(Gauged Q95 0.09 cumecs)					
Natural Q95 Uncalibrated	Natural Q95 Calibrated	Natural Q95 Uncalibrated	Natural Q95 Calibrated	Natural Q95 Uncalibrated	Natural Q95 Calibrated
0.081	0.094	0.034	0.041	0.026	0.031

Calibrations of the Fynn & Lark are based on that derived for the Deben.

4 WATER RESOURCES

Detailed information is available in **Ref [14]**.

4.1 Surface Water Resources

The rivers Deben and Fynn are the main surface resources. Utilisation of these resources is limited by distribution and seasonal variation. Most of the water is only available as unreliable peak winter flows and can only be effectively used if captured and stored in reservoirs for summer use. This is particularly so in the case of the Deben which has a relatively flashy flow regime and low baseflow index; summer flows in the Fynn are better sustained by groundwater baseflow from the Crag aquifer which has relatively large storage.

4.2 Groundwater Resources

4.2.1 Hydrotechnica Resource Assessment

Groundwater resources have been assessed by Hydrotechnica (**Ref [14]**), using a steady state groundwater model. The results are based on modelling for the period 1971-1990. This period was used as it provides adequate input and calibration data for the modelling, but note that overall it is a slightly drier than average period. A summary of the resources are presented in **Table 3 and Figure 5. Figure 6** shows the locations of the boundaries used in the model.

Table 3: Deben Groundwater Resource Estimations

Modelling Unit	Sub Catchment	Area	Aquifer	Average Recharge
		(km^2)		(Ml/d)
Upper Deben (Unit 1)	35/6	156	Chalk	22.2
Lower Deben (Unit 2)	35/6 & 35/10 part	67	Crag/Chalk	16.5
Upper Fynn (Unit 3)	35/7	25	Crag/Chalk	5.3
Lower Fynn/Lark (Unit 4)	35/7	54	Crag/Chalk	13.1
Total		302		57.1

These units were defined for mass balance assessment for the groundwater study and could be amended if chosen.

In the 'Upper Deben' unit of the model, the Crag and Chalk aquifers are considered to be in hydraulic continuity. Abstraction from the Chalk in this area is likely to induce recharge from the overlying Crag.

However, the movement and availability of water between the Crag and Chalk aquifers in the other units of the model are complicated by the presence of the London Clay which confines the Chalk aquifer. (**Figure 7**). The Chalk and Crag aquifers are therefore considered separately in these areas.

Table 4 gives the approximate distribution of recharge, to the Chalk and Crag aquifers. The figures presented for recharge to Crag are only for those areas which can be considered separate from the Chalk.

Table 4: Distribution of Groundwater Resources

Sub Catchment	Hydrotechnica Recharge (Ml/d)			NRA Effective Resource (Ml/d)
	Chalk	Crag	Total	(Recharge x 0.8)
35/6 & 10 (part) (Units 1 & 2)	24.2	14.5	38.7	31.0
35/7 (Units 3 & 4)	7.1	11.3	18.4	14.7
Total	31.3	25.8	57.1	45.7

4.2.2 Water Resources Strategy, Application of Resource Assessment

The Hydrotechnica resource assessment was used in water resource balance calculations as input to the Regional Water Resources Strategy (**Ref [4]**), (**see Section 7.2**). Two balances were calculated; one for the Deben catchment and the other for the Fynn & Lark catchment.

Due to the confined nature of the Chalk beneath the Eocene clays, the Crag component of the resource in the Lower Deben was excluded from the 'gross resource' (long term average annual recharge) figure used in the calculations.

Hydrotechnica estimated this by taking an intermediate baseflow value of 20.1 Ml/d at Naunton Hall and adding back groundwater abstractions to arrive at a 'gross resource' value of 25.5 Ml/d. Recharge to the Crag in the Upper Deben is therefore included in this figure. However, this figure is somewhat precautionary as groundwater flows may by-pass the gauging station at Naunton Hall from which the figure was derived, although the scope for this may be somewhat limited as the gauging station is near sea level.

In order to assess resources both available and reliable for abstraction and river flows, a standard factor of 0.8 is applied to the gross resource (**Ref [4]**). This gives the effective resource figure in the **Table 4.** (A more detailed explanation of the application of the resource estimates is given in **Chapter 7, and Ref [24]**)

In the longer term the use of the standard factor could be replaced by better understanding and management of the groundwater resources using the groundwater model. However, this is likely to need better development of a time variant model - either from the prototype produced by Hydrotechnica or an alternative.

5 WATER QUALITY

Water quality issues in the Deben Groundwater Unit are not addressed directly in this report, although some recommendations for example, river support, may have an inherent effect on surface water quality, for example by increasing dilution of effluents and increasing dissolved oxygen levels. Water quality is examined in greater depth by Southern Science (**Ref** [7]) following consultation with water quality staff from Peterborough and Ipswich.

5.1 Surface Water

Surface water quality in the Deben Groundwater Unit is assessed against four main criteria. In general terms the quality is good, but in times of low flow (due either to periods of dry weather and/or surface water abstraction) quality problems have occurred which have resulted in fish kills.

5.1.1 E.C. Fishery Directives

The reach of the River Deben from Kettleburgh (TM 2630 5970) to Melton (TM 2910 5010) has been designated as a cyprinid fishery. It therefore has to meet quality criteria for dissolved oxygen, Ph, ammonia, zinc, biological oxygen demand (BOD) and copper. The Rivers Fynn & Lark have no reaches which are designated under the Directive.

5.1.2 River Quality Objectives

Statutory river quality objectives have not been set for the Deben, Fynn or Lark to date. However, in the absence of NRA defined objectives, Hydrotechnica (**Ref** [14]) have defined the following reaches for the River Deben:-

Reach	Use
u/s Debenham (3km)	Low Amenity.
Debenham to Kettleburgh (13km)	Moderate Amenity, Cyprinid Fishery, Livestock Watering, Spray Irrigation.
Kettleburgh to Melton (17km)	Moderate Amenity, Cyprinid Fishery, Livestock Watering, Spray Irrigation.
Earl Soham (9km)	Moderate Amenity, Livestock Watering.

5.1.3 National Water Council Classification

The River Deben from Debenham to Cretingham has National Water Classification (NWC) class 2 (fair) grading for the surveys undertaken in 1980, 1985 and 1990. The River Deben from Cretingham to the tidal limit at Ufford, and the River Fynn were graded as class 1B (good quality). **Figure 8** shows the river water quality of the Deben Unit.

The general quality assessment (GQA) monitoring approach has recently been adopted whereby chemical water quality is only one of several 'windows' which describe the quality of water, the others will be developed in the future and will describe quality in terms of biology, nutrients and aesthetics.

5.1.4 Biological Standards

5 sites are routinely sampled between the source and Eyke Ford. Samples at these points provide an indication of the actual biological quality and are compared to the predicted quality of the same stretch as modelled by RIVPACS (River InVertebrate Prediction And Classification System).

Site	Grid References
u/s Debenham STW	TM 176 628
A1120 Road Bridge	TM 203 615
Kettleburgh Bridge	TM 263 593
Glevering Bridge	TM 295 566
Eyke Ford, nr. Ufford	TM 316 445

RIVPACS is a computer package which uses details about the physical features of the river channel (width, depth and type of substrate) to predict the types of invertebrates that should be in evidence.

This comparison enables compliances to be set and the biological quality to be monitored through time.

The data for the above sites indicate an increase in the diversity of invertebrates in the River Deben, at progressive downstream sampling points. There appears to be no marked trend or fluctuation that can be accounted for by periods of low or high flow. Data at Debenham indicate low diversity of habitat composition, giving rise to a low diversity of fauna. This may be due to a combination of occasional low flows coupled with the channelization of the reach.

5.1.5 General

NRA quality records are based on samples taken over the period 1976 to 1993, with general trends as stated below:-

- All sites show a general decrease in the amount of ammonia and BOD concentration, with the exception of Debenham where occasionally high ammonia concentrations still occur.
- There is an increase in the mean chloride concentration from 1989/90 to 1994.

5.2 Groundwater

Groundwater quality is, in general suitable for abstraction and environmental demands. However, there are some notable exceptions with variations in the iron content and the salinity of water throughout the catchment.

5.2.1 Groundwater Protection Zones (GPZ's)

The NRA has produced a policy (**Ref** [18]) for the protection of aquifers and potable sources in which a common framework is provided for the control of development around these sources. The Deben Groundwater Unit contains several abstractions which were originally identified as requiring GPZ's. These are listed below:-

Winston PWS
Tuddenham PWS
Pettistree PWS
Woodbridge PWS (now disused)
St Audreys Hospital, Ufford (ex. crown property, now revoked)

Draft GPZ's (**Figure 9**) were identified for the above sources by preliminary studies and where relevant are in the process of being refined by computer simulation models.

5.2.2 Nitrate Vulnerable Zones (NVZ's)

As a result of the 1991 EC Nitrates Directive, NVZ's are being created in relation to groundwater abstractions that have high nitrate concentrations. NVZ's are established where nitrate levels exceed, or are likely to exceed by 2010 (given rising trends) 50 mg/l. A 12 year timetable for the designation of sources is being operated, with the introduction of the code of good agricultural practice (**Ref** [19]) and additional measures to reduce nitrate leaching. By 1999, farmers in identified zones will be required to adopt these measures. In the Deben Groundwater Unit, there are currently no NVZ's.

5.2.3 Nitrate Sensitive Areas (NSA's)

NSA's provide farmers with the chance to adopt Good Farming Practices (Ref[19]), which reduce nitrate input into an area. Those who take up this option are given compensation payments.

There are no NSA's in the Deben Groundwater Unit, although the headwaters of the River Deben are adjacent to the proposed Waveney NSA (R.Dove).

5.2.4 Salinity

In the Stradbroke Depression north of Debenham, the Chalk below the Crag aquifer contains saline groundwater with over 250 mg/l chloride.

Towards the coast and around Ipswich there is a risk of saline intrusion, both from connate saline water from the coastal confined Chalk and by sea water through 'windows' in the London Clay in the estuary area around Woodbridge.

5.2.5 General

There is no known solvent contamination in the Groundwater Unit. However, the now disused airbases at RAF Bentwaters and RAF Woodbridge may be possible sources and caution should be expressed with any considerations for the future use of resources associated with these areas.

Groundwater in the Crag aquifer has a relatively high iron content of around 10mg/l.

The Tuddenham public water supply source is known to be prone to bacterial contamination.

6 WATER USE IN THE GROUNDWATER UNIT

6.1 Public Water Supply

6.1.1 Licensed Abstraction

Anglian Water Services (AWS) have Chalk groundwater sources in the Unit as given in **Table 5, their locations are given in Figure 10:**

Table 5: Current Licensed Abstraction - Public Water Supply

Site	Sub Catchment	Licensed Quantity*	
		Ml/d average	Ml/d peak
Pettistree	35/06	4.4	8.183
Winston	35/06	1.4	2.700
Tuddenham	35/07	1.7	3.092
Woodbridge	35/10	Source not in use	
Total		7.5	13.975

* Licensed quantity:

All these sources are part of a large group licence covering both Deben and Gipping abstractions (7/35/08/GS/152, and link to 7/35/08/*G/190) annual total 15251 Ml/a (41.78 Ml/d). The average quantities are pro-rata allocations of the group total between sources in active use.

In addition there is a licensed public water supply spring source at Tuddenham.

6.1.2 Actual Abstraction

Total actual abstractions **(Figure 11)** remained fairly constant at between 5 and 6 Ml/d average during the 1970's, taken equally from the Woodbridge, Tuddenham and Pettistree sources. In the 1980's abstraction increased, to fluctuate around a higher level of around 6-7 Ml/d, with the bulk of the water being abstracted at Pettistree from 1986 onwards.

The Woodbridge source has been disused since 1986 because of water quality concerns of pollution risk and rising salinity, although some water is pumped to maintain the plant.

The source at Tuddenham includes three boreholes and two springs. These have been prone to bacterial contamination; by 1983 abstraction at the springs had ceased and in 1991 no water was abstracted from the boreholes either.

In 1993 abstractions were close to the licensed group total of 41.78 Ml/d *(40.13 Ml/d in 1992)*, and abstractions within the Deben Chalk were close to the nominal share of this group total of 7.5 Ml/d *(6.54 Ml/d in 1992)*. However, in the Anglian Water Ipswich Water Resource Zone (WRZ 25), AWS still have spare licensed and sourceworks capacity from surface sources at Alton Water and Bucklesham intake. AWS regard the Bucklesham intake as an emergency source only. However, it can be used to provide additional Alton yields of about 6-7 Ml/d, with the water transferred by a pipeline installed during the 1988/92 drought.

6.1.3 Sourceworks Reliable Outputs (SRO's)

SRO's are an indication of the output that may be achieved from a source during drought periods after taking into account physical yields, treatment capacities, and existing licence entitlements. The figures have been discussed and, in general, agreed with the relevant water companies. These figures are termed '*Current SRO's*' (**Ref**[20]).

When possible future developments are taken into account, resulting in increased output capabilities, the SRO may be revised appropriately. The revised figures are termed *SRO's for Planning Purposes* and are used to evaluate the timing and need of any future resource development by comparison with demand forecasts. **(Figure 12)**

Table 6 identifies both the current SRO's and SRO's for Planning Purposes for the Ipswich Water Resources Zone (WRZ 25) which includes the Deben Unit. To be consistent with the SRO figures quoted in the Regional Water Resources Strategy, figures for Bucklesham and Newbourne should be excluded as they supplement Alton Water. However, in practice they may be used to provide direct supply in emergencies and are therefore quoted.

Table 6: Current SRO and SRO for Planning Purposes for WRZ 25.

Source & Licence Number	Licensed Quantity (Ml/d ave.)	Current SRO (Ml/d ave.)	SRO for Planning Purposes (Ml/d ave.)
Bucklesham & Newbourne (7/35/08/152)	11.15	within Alton figure*	within Alton figure*
Alton (8/36/19/099)	29.59	30.0	30.0
Tuddenham Springs (7/35/08/152)	41.80	41.80	41.80
Baylham (7/35/08/152)			
Bramford (7/35/08/152)			
Kirby Rise (Claydon) (7/35/08/152)			
Pettistree (7/35/08/152)			
Westerfield/ Whitton (7/35/08/152)			
Winston (7/35/08/152)			
Tuddenham (7/35/08/152)			
Woodbridge (7/35/08/152)			
Belstead (7/35/08/152)			

* Bucklesham SRO taken to be 6 Ml/d to Alton, essentially emergency use only. Licensed quantity has therefore been excluded from **Ref 20.**

6.1.4 Forecast Demand Growth

Abstraction is forecast to rise gradually over the next 20 years in response to demand growth. The rate of increase in demand is much slower than was predicted in 1990, as shown in **Table 7** for forecast average daily demand (Ml/d):

Table 7: Public Water Supply Demand Forecasts (WRZ 25)

Year	1990 Forecast	1992 Forecast	1994 Forecast
1996	81.3	67.3	67.3
2001	86.7	71.2	65.3
2006	91.0	74.7	64.6
2011	95.4	78.5	63.9
2015	n/a	82.1	63.7

N.B. 1994 figures = Regional forecast applied to 1992 base year.

The main reasons for the reduced forecast demands on a regional scale are:

- Higher proportion of domestic users metered than previously assumed, with lower per capita consumption than unmetered users.
- Lower leakage rates, down from 8 litres per property per hour to 4.8 l/p/h in 2011. This would represent about 8 Ml/d in the Ipswich Resource Zone.
- No growth in industrial demand (previously forecast to rise by about 2 Ml/d by 2011).
- Greater public awareness of the need to use water wisely.

The latest regional demand forecasts (**Ref[4]**) show an even lower rate of increase, but these are not yet broken down into trends for individual resource zones.

In very general terms, longer term demand in the Ipswich area may rise if broader planning policies continue to encourage economic growth in the A14 corridor between Newmarket and Felixstowe.

Plotting the demands against the current Sourceworks Reliable Output (SRO) for the Ipswich Zone (**Figure 12**) suggest that average daily demands will not exceed SRO's in the foreseeable future. Previously there was concern that new sources would be needed by 1995 to meet forecast average demands.

However, **Figure 12** shows that future demands are sensitive to several factors. Given the uncertainty resulting from political and financial influences on metering/leakage policies and programmes, these forecasts do not remove the need to establish a framework for resources management policies.

6.1.5 Proposed New Sources

AWS have been actively seeking new groundwater sources in the Deben Chalk, to meet possible future demand increases. The urgency is less than previously perceived as a consequence of the lower forecasts, but the applications are still proceeding.

Current proposals for additional groundwater abstractions in the Unit are given in **Table 8.**

These applications will not result in any additional water resource being licensed as they all fall under the Deben/Gipping aggregate of 15251 Ml/a.

Table 8: Current Licence Applications in the Deben Unit

Location	Current Ml/d	Current Ml/a	Proposed Ml/d	Proposed Ml/a
Winston	2.7	986	5.0	986 for 5 years, then 1500
Payford/Tuddenham	3.1	1129	6.0	1700
Tuddenham (to drill new standby borehole)	as above	as above	no increase	no increase
Pettistree (new borehole)	8.2	-	13.2	no increase

The NRA expect to grant licences for both the Playford and Winston applications shortly. These are likely to be time limited to 5 years, with requirements for monitoring and environmental appraisal of impacts, and possible river flow support in the case of Winston.

6.1.6 Implications of New Developments

As part of the new developments, the Gipping group licence total is to be divided between the Gipping and Deben Chalk. This is presented in **Table 9.** Recent work **(Ref [21])** concluded that the proposed aggregate (derived in 1991 from provisional actual abstraction returns) was still relevant based on more recent data.

Table 9: Revised Deben/Gipping Aggregate

Gipping Sources			Deben Sources		
Source	Licence 7/35/...	Quantity	Source	Licence 7/35/...	Quantity
Baylham	8/152	Aggregate = 12500 Ml/a	Pettistree	8/152	Aggregate = 2750 Ml/a
Belstead	8/152		Tuddenham	8/152	
Kirby Rise (Claydon)	8/152		Winston	8/152	
Westerfield	8/152		Woodbridge	8/152	
Whitton	8/152		Playford	8/152	
Bramford	8/190				

Playford and Tuddenham

The subdivision above assumes that abstraction at Playford and Tuddenham draws on resources in the Deben Chalk rather than the Gipping. Groundwater contours in the divide between these units show little gradient and the boundary may well move in response to abstraction.

The modelling study by Hydrotechnica (**Ref[14]**) predicts that up to 85% of the abstraction at Playford may be at the expense of baseflows in the lower Gipping (Bramford to the Orwell Bridge). Only 15% is predicted to be at the expense of baseflows in the Deben, Fynn and Lark. The London Clay limits interaction between the Chalk aquifer and the River Fynn. Baseflows in the River Fynn come mainly from the glacial sands and gravels and Crag aquifer overlying the London Clay.

However, the modelled prediction is dependant on aquifer parameters in the model, including a tunnel valley between Tuddenham and Whitton, for which the evidence is uncertain. The percentages above are a 'worst case' for impacts on the Gipping.

Hydrotechnica also point out that the risk of saline intrusion in the Gipping/Orwell Estuary area should be considered in the assessment of resources available for abstraction.

The NRA have considered these concerns, but feel that the modelling evidence is not strong enough to warrant outright refusal of the AWS application at Playford. Instead, the abstraction may be granted on a time limited basis. This will allow monitoring of potential effects, and further investigation of the sensitivity of the modelled predictions to aquifer parameters and assumptions built into the model.

It is particularly important to ensure that any long term, delayed effects are considered, since the aquifer system could take many years to reach a new equilibrium.

At the same time, if it appears that there is more leakage from the shallow sands and gravel aquifer than predicted, then the greater impacts on flows in the Fynn and wetland sites near Playford will need reconsideration.

Winston

A temporary licence may also be granted here. The main concerns are derogation of river and stream flows in the headwaters of the main River Deben, and impacts on nearby SSSI/conservation sites. AWS will be required to undertake an environmental assessment and identify the full impact on river/stream flows for subsequent consideration/protection in future licence conditions.

Protection of existing abstractors' rights will also require consideration.

Pettistree

This is the location the NRA initially expected AWS to favour for development (rather than Winston & Playford). It is still our favoured location. The Hydrotechnica study tends to confirm that it will be the least damaging option to develop further for PWS. It has the advantage of being near the limit of the London Clay - so that effectively it captures water near the 'downstream' end of the aquifer unit. However, it is in an area where low river flows are already an issue because of surface irrigation abstraction. Any increased impact on low river flows is likely to need compensation pumping by AWS. Preferably this would include mitigating existing impacts of Pettistree on low flows too. It is considered that saline intrusion is less likely to be an issue than at Playford.

The NRA should consider influencing AWS to relocate some or all of the temporary licensed increase at Winston and Playford to Pettistree at the end of the 5 year period, if it seems that the higher abstraction can be sustained overall.

Effect on Licensing Policy

The NRA has previously indicated to AWS its willingness to regard Playford as part of the Deben Groundwater Unit for planning purposes. Our letter of 9/5/91 recommended dividing the existing group licence total (with Tuddenham in the Deben Unit) as outlined in **Table 9**, ie:

Gipping unit 12500 Ml/a, Deben unit 2750 Ml/a

Until further confirmation of the Hydrotechnica modelling predictions, the NRA will use this split for planning purposes.

However, if fresh evidence shows that Tuddenham and Playford abstract mainly from the Gipping unit, NRA policy will need revision so that the group totals reflect this (eg Gipping unit 13000 Ml/a, Deben Unit 2250 Ml/a).

In the longer term, there is little scope for any further groundwater abstraction in this area and AWS should be encouraged to seek alternative sources or further develop their demand management policy if demands rise further.

Alternatives to meet the longer term future public water supply needs for Ipswich will be reviewed in the Gipping/Felixstowe Peninsula Water Resources Management Plan, scheduled to be produced during 1995/6.

6.2 Agriculture

Agriculture is the other main use of water in the Deben Unit, accounting for almost half of all licensed abstraction in sub-catchments 35/6 and 35/7. Most of this (85 %) is spray irrigation, two thirds of which is from groundwater. Licensed quantities are summarised in **Table 10** (all figures Ml/d average):

Table 10: Licensed Quantities - Agriculture

Catchment / Use	35/6 (Ml/d)		35/7 (Ml/d)		Total (Ml/d)	
	Surface	Ground	Surface	Ground	Surface	Ground
General Agriculture	-	0.4	-	0.7	-	1.1
Spray Irrigation	1.6	3.4	0.7	0.5	2.3	3.9
Total	1.6	3.8	0.7	1.2	2.3	5.0

6.2.1 Spray Irrigation

Spray irrigation abstraction can have a disproportionate impact on the water environment because water is taken at relatively high peak rates, usually during summer coinciding with low flow conditions and is consumed, rather than returned to the river.

Direct surface abstractions have the greatest immediate impact. The peak impact of seasonal groundwater abstractions is less due to time lag effects, but depends on local aquifer properties and may still be severe where water is taken from shallow sand and gravel aquifers close to the river. The Hydrotechnica groundwater model contains details of seasonal irrigation abstractions. However, further development of the distributed model would be needed to investigate the impacts of seasonal groundwater abstractions on river baseflows.

Actual abstraction in many cases is much less than licensed, and varies considerably from year to year, particularly for spray irrigation.

In the case of the River Deben, licensed peak rates of unconstrained surface abstraction are 75 % of the natural 95 percentile flow at Naunton Hall gauging station. Abstraction sites are concentrated in the stretch of river near Wickham Market, and this has led to identification of the River Deben as one of the NRA's top 40 National ALF sites for investigation and amelioration.

Details of actual spray irrigation abstraction in 1989 to 1991 have been analyzed by both the NRA (**Refs**[22&13]) and Hydrotechnica (**Ref**[14]). These illustrate that irrigation abstractions have a significant effect on low flows and that Section 57 irrigation bans led to a measurable improvement in flows during the severe drought conditions of 1990. **Ref**[13] identifies 8 key spray irrigation licences which are perceived to be the major contributors to the low flow problem, and makes the following recommendations to reduce their impact on flows:-

- the re-allocation of 5 key licences from surface water to groundwater sources, or where appropriate to bankside storage.

- the revocation of 2 key licences under Section 61(4) of the Water Resources Act 1991, for non use.

- determination of an application by the licence holder of one of the key licences to re-allocate voluntarily from surface water to groundwater.

Future demand for irrigation water is difficult to predict, and dependant on many external factors, such as agricultural and land use policies and possible climate change. Historically there has been continued demand for further irrigation water in the Deben catchment, especially in the lower Deben catchment and the Fynn and Lark catchments, on the light sandy soils overlying the Crag. Research (**Ref**[6]) has indicated that in Anglian Region under the 'most likely' scenario, spray irrigation demand will rise at a rate of 2% per year from 1996 to 2001 and at a lower rate of 1.25% per year from 2001 to 2021.

6.2.2 General Agriculture

General agriculture is a less consumptive use of water and a relatively minor part of total demand. For planning purposes the following assumptions are made:

- about 90% of the water is returned after use
- returns are close to the point of abstraction
- actual abstraction is approximately 50% of licensed quantity
- future demands are unlikely to rise substantially

All these factors indicate that general agriculture does not impose a significant impact on resources at the catchment planning level, although local impacts will always still be considered.

6.3 Industry

Industrial water use in the catchment is minimal. The only significant licensed abstraction is from glacial deposits for sand and gravel washing in the Fynn catchment. The water is largely recirculated after use, so overall impact is minimal. For planning purposes it is assumed that 90% of mineral washing water is returned after use, close to the point of abstraction.

New industrial demands are unpredictable; there is no particular evidence to suggest that large requirements will arise in the Deben catchment. The most likely new demands to arise may be for sand and gravel washing works in the lower parts of the catchment. Such abstractions would be unlikely to pose difficulties in terms of overall water resource availability, although local impacts would of course need consideration.

6.4 Environment

The water needs of the environment fall into two main categories: firstly 'In-River Needs' to maintain the aquatic ecology, and secondly the need to maintain groundwater levels and flows for wetland sites (Plates 2,3,4). In addition, the need to prevent saline intrusion is considered within the groundwater resource allocation.

Research has been undertaken on the environmental status and needs for water management in the Deben by the NRA and Suffolk Wildlife Trust (**Ref**[23]) which provided input to an environmental appraisal of the Deben by Southern Science (**Ref**[7]) as part of the River Deben Alleviation of Low Flows Project. This provides a review of the low flow problem, identification of 'in-river needs' for water and makes recommendations for meeting them. The study's main focus is on river needs, but also considers associated wetlands.

6.4.1 River Flows

To ensure that baseflows are protected, a portion of the groundwater resource is allocated to the environment. Where no special studies are available this has been based on the natural 95 percentile flow using the Micro Low Flows (MLF) software package. Details of river flow allocation from all major groundwater units in the region, including the Deben are stated in (**Ref**[24]) and summarised in (**Ref**[4]).

The natural 95 percentile figure derived for the Deben using MLF, and calibrated using the methodology stated in (**Ref**[17]) is 0.094 cumecs (8.2 Ml/d) at Naunton Hall and is very similar to the gauged 95 percentile flow of 0.1 cumecs (8.6 Ml/d). This may indicate that low flows are already supported to a significant degree by effluent discharges within the catchment, and is reiterated in the findings of Southern Science (**Ref**[7]).

It is assumed that flows downstream of Naunton Hall are met from the Crag aquifer, as the Chalk is confined by the London Clay.

Hydrotechnica suggested a target flow of 110 l/sec (9.5 Ml/d or 0.11 cumecs) at Naunton Hall (see **Ref**[14], **Appendix M**). However, this figure was derived primarily to allow assessment of flow augmentation requirements to meet summer spray irrigation abstractions. It did not independently assess environmental needs.

The Hydrotechnica study also indicates that flows in the Fynn and Lark are largely sustained by baseflows from the Crag aquifer. No specific allocation of groundwater resource to meet this has been made.

Southern Science (**Ref**[7]) suggest a minimum naturalised flow requirement of 0.076 cumecs (6.57 Ml/d) at Naunton Hall. This flow was determined by identification of the level and velocity requirements of key indicator species, at three sites in the Deben catchment, and expressed as an equivalent 'naturalised' flow at Naunton Hall.

However, the naturalisation exercise undertaken by Southern Science did not take account of test pumping discharges, groundwater abstractions, and spray irrigation abstraction was assumed to be over several months (in reality spray irrigation abstraction may have been concentrated over several weeks). Questions were also raised by the Quality Review Panel regarding the methods used. With these points in mind, refinement of the Southern Science work was undertaken (**Refs** [25&26]) and the minimum naturalised flow reassessed to be 0.088 cumecs (7.6 Ml/d).

It is recommended that further refinement of the work, using a rainfall runoff model is undertaken to incorporate groundwater abstraction data which has not previously been considered.

6.4.2 Wetland Sites

There are a number of water-dependent sites of conservation value in the catchment. The Hydrotechnica study included a brief review of hydrologically sensitive sites. It did not identify any wetland SSSI vulnerable to changes in groundwater flow within **underlying aquifers**. Some of the sites are wet meadows, thought to be dependant on shallow groundwater and poor drainage over boulder clay.

There are several water-sensitive county wildlife sites. These are reviewed in the Hydrotechnica report, and more detail is given in the Register of County Wildlife Sites by Suffolk Wildlife Trust. Some of these sites could be affected by changes in groundwater levels, especially in the Crag aquifer. All county wildlife sites in Suffolk are covered in a series of registers based on District Council areas; the relevant ones for the Deben, Fynn and Lark are Mid-Suffolk and Suffolk Coastal.

Plate 3:
River Deben at
Kettleburgh, 1991.

Plate 4:
Home Farm Meadow;
Water Dependent
County Wildlife Site.

The Deben valley from Debenham to Woodbridge is part of the Suffolk River Valleys Environmentally Sensitive Area (MAFF Guidelines for Farmers, Suffolk River Valleys ESA). Within the ESA some farmers have agreements to enhance the environment through management of shallow groundwater levels in drainage ditches and ponds. Additional information on ESA agreements is being sought as part of the Deben 'ALF' study, specifically for land covered by the surface spray irrigation licences.

6.4.3 Saline Intrusion

There is a potential risk of saline groundwater movement inland if abstraction increases (**Ref[14]**). A specific allocation of groundwater resource (1.1 Ml/d) has been made in previous reviews of the Deben Chalk to prevent both saline intrusion into groundwater and saline incursion into rivers. This has been applied to the Fynn & Lark catchment only.

6.5 River Support

Facilities already exist within the Unit to augment the flows of the River Deben. Two boreholes were partly developed by the then Anglian Water Authority during the 1970's, one is located upstream of Debenham, and the other at Earl Soham STW on the Earl Soham Watercourse, a tributary of the River Deben **(Figure 4).**

The scheme was originally intended to alleviate the impact of low flows in the River Deben during dry periods and to potentially provide additional water for licensed abstraction. Due to water quality problems encountered at the Debenham site, and re-organisation of the water industry, the two sites were never licensed.

As part of the River Deben Alleviation of Low Flows Project (Project Ref No 9090031), the NRA are currently proposing a package of measures to alleviate the impact of low flows. Part of the recommended package includes the licensing of the Earl Soham borehole (Plate 5), but with the objective of alleviating the impact of low flows only and not providing any additional water upon which new abstraction licences could be granted.

As part of the preparation for an application for an abstraction licence and discharge order, a physical impact study has been undertaken (**Ref[16]**) to form the foundation for an Environmental Impact Assessment. The Project Initiation document (PID) (**Ref[13]**) also addresses the financial, economic and business aspects of the proposal.

An additional part of the proposal is to write off the asset value of the Debenham borehole (c.£140 k) and salvage the pumps for re-use. The site would still be kept, and considered for use as, for example, a groundwater quality observation borehole.

6.6 Navigation

The Deben Estuary is popular for sailing, but navigation is not significant upstream of the tidal limit at Melton Mill. There is no statutory navigation on the River Deben.

6.7 Fisheries

The River Deben is a cyprinid (non salmonid) fishery; the Fynn and Lark are salmonid fisheries. The requirements of water for fishery purposes for the River Deben have been considered in the environmental appraisal. Fishing rights along the river are in the hands of riparian owners, other than the Woodbridge and District Angling Club who fish the river between Glevering Bridge and Wickham Market. Fish survey results are expanded upon in **Ref** [7].

6.8 Recreation and Amenity

The river valleys have general amenity value (Plates 6 & 7), providing recreational opportunities and riverside walks. Proximity to the large population centre of Ipswich increases this importance.

There are water mills at Ashe Abbey and Wickham Market: maintenance of water levels in the Mill Ponds is of importance for amenity and other reasons.

It is stated (**Ref** [7]) that the 'in river needs' for recreation can largely be met from adopting the flows recommended in the Southern Science Environmental Appraisal report (and then refined), which were derived to meet other requirements.

6.9 Effluent

Figure 13 shows the location of existing effluent discharges within the catchment. Effluent discharges have an important role to play with regard to water resources. Reliable effluent discharges effectively support the flows of river systems, and where of a suitable quality increase the reliability of surface abstractions with hands-off flows, and help sustain a healthy environment. However, water resources planners should not rely too heavily on a few effluent discharges within a catchment as a basis for granting new licences, as their locations and suitability in terms of quality may vary dramatically through time.

This is typified in the Deben catchment where the effluent from airbases is of major significance. RAF Bentwaters has recently been decommissioned, and therefore can no longer be counted as a reliable resource.

Plate 5:
Earl Soham River
Augmentation Works.

Plate 6:
River Deben at
Cretingham Bridge 1991.

Plate 7:
River Deben at
Easton Farm Park, 1991.

The standard required of effluent discharged to watercourses is determined by the range of flows that provide dilution. In the majority of cases it is almost always more economical to improve effluent treatment rather than increase dilution flows. It is therefore not normally water resources policy to increase flows purely for dilution purposes:

We will not, usually, allocate water specifically to the dilution of effluents; but rather we will set effluent consent conditions according to the anticipated regime of dilution flows.
(Water Resources in Anglia, 1994)

Estimates of 'reliable effluent' have been made for the subcatchments of the Deben Unit.

'Reliable effluent' is the minimum quantity of effluent considered likely to be returned to the environment under long term average conditions, given full licensed abstraction.

Reliable effluents for the Deben Unit have been based on a combination of dry weather flow values from water quality discharge consents for both public water supply and industrial use (excluding direct industrial abstractions), and percentages of licensed abstraction for other uses. These estimates are then applied to assess the sustainability of abstractions within the catchment (see Section 7.2).

The reliable effluents estimated for the Deben Groundwater Unit are given below.

Sub Catchment	Reliable Effluent (Ml/d)
River Deben (35/06)	2.6
Rivers Fynn & Lark (35/07)	1.1

Effluents discharged to tidal waters have been excluded.
Effluents not currently discharged have been excluded.

7 BALANCE OF RESOURCES AND DEMANDS

7.1 Surface Water

River Deben

The balance of licensed and actual abstractions and consented effluent returns for the main River Deben is discussed in an NRA file note (August 1992), and the summary during low flow conditions (approximately 92 percentile) shown in **Figure 14.**

The Deben suffers from low flows during dry periods. This has led to fish kills and quality problems in the past, resulting in complaints from both the public and pressure groups. The low flows are believed to be caused by a combination of problems:-

- Geological conditions, especially in the headwaters of the catchment leading to flows which are naturally low during dry periods.
- Unconstrained spray irrigation abstraction direct from the River (Peak daily licensed surface spray irrigation licences are similar to both the gauged and estimated natural 95 percentile flows at Naunton Hall.)
- Illegal abstraction.
- Environmentally unsympathetic channelization for land drainage purposes.
- Groundwater abstraction for public water supply.

Analysis has been undertaken, using the Alleviation of Low Flows (ALF) national methodology (**Ref**[27]). This led to confirmation of the problem, and establishment of a Project Team with capital budget to identify and implement a solution. Approvals have been given to implement a package of measures in order to alleviate the impact of low flows on the River Deben. These are summarised below and presented schematically in **Figure 15**:-

- River support from the Earl Soham augmentation borehole.
- Re-allocation of key surface spray irrigation licences to groundwater.
- Consideration of re-allocation to bankside storage of winter water where re-allocation to groundwater is unsuitable.
- Revocation of unused licences in the catchment.
- Improvements in river channel management.
- Environmentally sympathetic re-channelization.

During the 1988-92 drought, Section 57 irrigation bans were used to protect low flows. In 1990 a 100% ban on abstraction was implemented, and a significant recovery of flows resulted within 6 days. In 1991 a 50% ban was imposed, and no significant effect was evident. Further analysis of the effectiveness is given in (**Ref** [14]).

Rivers Fynn and Lark

There is less licensed abstraction from these rivers, and baseflows are relatively stronger during dry periods. Although the catchments as a whole are not perceived to be problematical, **Figures 16 & 17** show that if two or three key abstractors were to abstract at their full entitlement, problems may occur in isolated stretches. Examination of actual abstraction from these sources through the 1988-1992 drought, suggests that such a problem is not occurring in practice, but it should be noted that the potential certainly exists.

It is recommended to continue to monitor these abstractors to determine whether any future action should be taken.

7.2 Groundwater

Chalk Aquifer

The overall conclusion of the groundwater investigation by Hydrotechnica is that there is some small scope for additional licensed abstraction from the Chalk aquifer, if sensitively sited and with compensation for reduced river baseflows.

However, there are still uncertainties over the position of the groundwater divide between the Deben and Gipping Chalk around Tuddenham and Playford, and over the movement of water between the Crag and Chalk aquifers in the lower parts of the Unit near the London Clay boundary.

'Groundwater Balance Assessments' (see below) for the River Deben and for the Rivers Fynn & Lark can be found in **Tables 11 & 12** respectively.

Crag Aquifer

The Crag aquifer is relatively lightly exploited. This is mainly because it is a less suitable source both in terms of water quality and borehole engineering.

Although the abstractors ability to use the Crag aquifer may be limited, there is further potential for abstraction from the Crag in some parts of the catchment. These are:

- The Stradbroke Depression north of Debenham. The aquifer has high storage of water which might be exploited. However, water quality is a definite limitation, as experienced with the NRA borehole at Debenham.

- The Crag south of the London Clay boundary in the lower Deben and lower parts of the Fynn and Lark catchments.

A separate 'Groundwater Balance' (see below) sheet for the Crag aquifer does not exist; the resource in the Crag to the north of Debenham is implicitly included with the overall groundwater balance for the River Deben.

The recharge to the Crag to the south of the London Clay boundary is estimated at 25.8 Ml/d by Hydrotechnica (see S 4.2) and includes parts of subcatchments 35/06, 35/07 and 35/10. A moderate resource exists in subcatchments 35/6 and 35/7 (roughly 20 Ml/d average annual recharge) and is not accounted for in a groundwater balance calculation. The resource in 35/10 is relatively small and is covered by a separate groundwater balance for the Crag of the Felixstowe Peninsula.

Groundwater Balances

Groundwater resources are assessed by the method outlined in the Groundwater Balances Review 1992 (**Ref [24]**).

The gross resource (long average recharge) is calculated and factored by 0.8 to account for the following:-

"The total groundwater resource will rarely be fully exploitable, the non uniform availability of the resource within the groundwater unit may be a limitation affected by factors such as geology, pattern of development, avoidance of sensitive areas, storativity and transmissibility of the aquifer. Some allowance must also be made for uncertainties in estimation of resource, the degree to which storage can be used to overcome seasonal fluctuations, and imperfect manipulation of baseflow by river support schemes."

(1992 Groundwater Balance Review, 1994 Edition)

This leaves an effective resource from which quantities are allocated for licensed abstraction and the environment.

The environmental requirement for groundwater is assessed. This is primarily the minimum required river flow. The detailed study undertaken by Southern Science does this.

In practice, river flows are sustained by treated sewage effluents, and reduced by surface abstractions. These are quantified and the allocation to the river from groundwater is adjusted accordingly. Abstractions are taken as the annual average licensed quantity; and reliable effluents are taken as 75% of their normal dry weather flow, to account for reduced water usage in drought conditions.

The quantity allowable for abstraction is the effective resource minus the allocation of groundwater to the river.

The quantities thus allocated to the river are the natural 95 percentile flow plus the remaining 20% of the unreliable recharge, plus all surface runoff. This leaves a river with naturally varying flow characteristics.

Tables 11 and 12 show the components of the groundwater resource balances for the River Deben, and the Rivers Fynn and Lark respectively. Table 13 summarises their combined values and shows the balance for the Deben Groundwater Unit.

Table 11: Upper & Lower Deben - Chalk Groundwater Resource Balance

Catchment Characteristics

Catchment Area (km^2)	183.8
Chalk Recharge Area (km^2)	122.0
Gross Resource (Ml/d)	25.5 (Chalk, plus Crag upstream of London Clay)
Availability Factor	0.8
Available Resource - Net (Ml/d)	20.4

Licensed Demands (Ml/d average.)	Groundwater Licensed	Surface Water Licensed	Effluent Returns
Public Water Supply	5.8	*	2.2
Private Water Undertaking	0.0	*	0.0
General Industry	0.0	*	0.0
Industry- Mineral & Non Consumptive Cooling	0.0	*	0.0
General Agriculture	0.4	*	0.4
Spray Irrigation	3.4	1.6	0.0
Miscellaneous	0.0	*	0.0
Totals	**9.6**	**1.6**	**2.6**
Net Abstraction (-) or return (+)	**-9.6**	**1.0**	

Environmental Allocation

Gross Allocation (natural 95 percentile flow)	7.6
Net Allocation (allowing for net surface abstraction)	6.6

Resource Surplus/Deficit

(Net resource - total GW licensed - net environmental allocation.) **+4.2**

* Most large surface abstractions are controlled by hands-off flows as are more recently issued spray irrigation licences. In terms of the impact on the groundwater resource balance, the average annual licensed abstraction for summer spray irrigation has been used. This represents the maximum potential average depletion of flows by such abstractions that might have to be ameliorated using an equivalent volume of river augmentation.

Table 12: Fynn & Lark - Chalk Groundwater Resource Balance

Catchment Characteristics

Catchment Area (km^2)	78.8
Chalk Recharge Area (km^2)	25.0
Gross Resource (Ml/d)	7.1
Availability Factor	0.8
Available Resource - Net (Ml/d)	5.7

Licensed Demands (Ml/d average.)	Groundwater Licensed	Surface Water Licensed	Effluent Returns
Public Water Supply	1.7	*	0.5
Private Water Undertaking	0.0	*	0.0
General Industry	0.0	*	0.0
Industry- Mineral & Non Consumptive Cooling	0.0	*	0.0
General Agriculture	0.7	*	0.6
Spray Irrigation	0.5	0.7	0.0
Miscellaneous	0.0	*	0.0
Totals	**2.9**	**0.7**	**1.1**
Net Abstraction (-) or return (+)	**-2.9**	**0.4**	

Environmental Allocation

Gross Allocation (natural 95 percentile flow)	0.0 (see footnote)
To Prevent Saline Intrusion (0.5 l/s/km^2)	1.1
Net Allocation (allowing for net surface abstraction)	**0.7**

Resource Surplus/Deficit

(Net resource - total GW licensed - net environmental allocation.)	**+2.2**

* Most large surface abstractions are controlled by hands-off flows as are more recently issued spray irrigation licences. In terms of the impact on the groundwater resource balance, the average annual licensed abstraction for summer spray irrigation has been used. This represents the maximum potential average depletion of flows by such abstractions that might have to be ameliorated using an equivalent volume of river augmentation.

River baseflows are largely met from Crag resource, therefore no allocation has been made.

7.3 Summary of Water Resources and Demands

In summary, the combined resources and demands of the Deben Groundwater Unit result in a small nominal surplus of 6.4 Ml/d. This is accounted for in **Table 13.**

Table 13: Groundwater Balance Summary

	Component	Ml/d ave.
1	Gross resource	32.6
2	Net resource (80% of 1)	26.1
3	Total groundwater abstraction licensed	12.5
4	Net environmental allocation	7.3
5	Surplus/Deficit (2-3-4)	+ 6.4

NB. Figures are rounded.

8 ISSUES AND OPTIONS

This section takes the issues identified in Section 2.2, identifies the options available and presents a case for recommending implementation of selected options.

8.1 Increasing Demand for Water Abstraction, & Licensing Policy

8.1.1 Groundwater

When forecast increases in the demand for spray irrigation, for industry, and possible local increases in public water supply are considered in the context of limited resource availability for the Deben Groundwater Unit, the following options are available:-

Options

i) The current licensing policy of limited further abstraction should continue.
ii) No further licensing (for precautionary reasons).
iii) Only issue time limited licences.

If option i) is chosen, licensed abstraction will continue to increase subject to environmental considerations and the protection of existing users. However, as the quantity of available resource is only minimal, licensing should only continue until such time that the nominal surplus is zero.

If option ii) is chosen, following the principle of 'precaution', increased demands would not be met. This may be seen as an improper use of resources, as the best current estimates indicate that a nominal surplus is available.

Guidance (**Ref**[28]) for option iii), time limited licences, states that they should be considered as an option in catchments where groundwater resources are fully committed and actual use is significantly less than authorised abstraction. In this instance, a nominal surplus has been identified with the best available data. No further studies to refine the calculations are programmed at this stage. This option is therefore considered inappropriate. However, consideration should still be given to time limited licences where uncertainty of their impact exists.

Recommendations

It is recommended that option i) is chosen until the nominal surplus has been licensed. From then on, the Unit should have a 'no water available status'. ***Only applications which qualify as exceptions in Ref[4] should then be considered.***

8.1.2 Surface Water

With the River Deben especially, and to a lesser extent the Rivers Fynn & Lark, low summer surface flows are a problem. The following options for the further licensing of surface water are available:-

Options

i) No further licensing of summer abstraction.
ii) Licence winter flows with 'hands-off flow' conditions.
iii) Licence winter abstraction with storage for use in the summer months.

All options would provide a continuation of the current surface abstraction licensing policy and would prevent further impact on the low flows of the Deben experienced during dry periods in summer months.

Recommendations

It is recommended that options i) ii) and iii) are chosen.

8.2 Protection and Improvement of the Environment

The main concern is to alleviate the low flows of the River Deben. However, a wider understanding of the levels and flows of both groundwater and surface water within the Deben Unit is critical to maintaining the in-river environment, SSSI and other sites of nature conservation importance. In river needs for the River Deben have been identified as part of the work of the River Deben ALF Project Team.

Options

i) Do nothing/ minimum action.
ii) River support - transferring water into the river at times of low flow.
iii) Reduction of the impact of the peak surface spray irrigation abstractions.
iv) River channel management and restoration.

Studies Leading to Identification of Further Options

v) Identification of wetland water needs of catchment.
vi) Identify wetland needs as part of the licence application process.

Options i) to iv) have been examined in detail in **Ref**[13] and option i) has been discounted.

A combination of options ii) to iv) has been identified by Ref[13] as a package that would alleviate the low flows of the River Deben. **(Figure 15)**

With regard to wetlands, v) is already partly in progress with studies aiming to develop a methodology **(Refs [8,9])** which can be applied to other catchments, including the Deben. It would provide a comprehensive base for managing water resources for the environment.

Point vi) is attractive in passing the onus onto the applicant. However, it may lead to fragmented studies that do not cover the integrated needs of the environment, and would still require significant input from the NRA in order to specify the requirements of such investigations.

Recommendations

*It is recommended that options ii) to iv) are undertaken in accord with the detail outlined in **Ref**[13].*

It is recommended that vi) is carried out as far as possible, but this is not regarded on its own as an adequate policy for environmental protection. v) will identify the integrated needs of the Deben Groundwater Unit.

8.3 Protection and Improvement of River Water Quality

Although they are outside the immediate remit of the water resources function, water quality issues are inherently linked and are therefore of great importance.

There are some minor problems in isolated parts of the catchment. Although they are not a major issue at present, the maintenance of quality if abstraction increases will become more important.

Options

i) Improved standards of effluent treatment.
ii) Provision of higher flows to improve dilution etc.
iii) Restrict further abstraction throughout the catchment.
iv) Limit further abstraction in the headwaters only.
v) Tighter control of diffuse agricultural pollutants.

Option ii) is not normally considered policy by water resources as it is generally more cost effective to improve the standards of effluent by treatment than to increase flows for dilution.

Options iii) and iv) are not recommended in the licensing policies as they would conflict with the proper use of water resources. A nominal surplus has been identified and licensing policies are determined accordingly.

Recommendations

Of these options, i) and v) are current water quality related policies that should be continued and encouraged.

8.4 River Support

The further development or otherwise of the existing augmentation boreholes at Earl Soham and Debenham require consideration, in conjunction with the objectives of the River Deben ALF Project.

Options

i) Full implementation of the Earl Soham and Debenham boreholes.
ii) Earl Soham plus a new augmentation borehole in the Deben catchment.
iii) Earl Soham plus a transfer of groundwater from River Dove catchment.
iv) Increase capacity of Earl Soham borehole.
v) Earl Soham borehole at current capacity.
vi) Require Anglian Water Services to provide river support from their abstraction sites.
vii) Diversion of effluents from other catchments.

All the above options have been considered in detail in **Ref**[13].

Recommendations

It is recommended that options v) (Earl Soham at current capacity) is adopted, and option vi) is pursued as part of the current (and any future) licence applications by Anglian Water Services. However, any augmentation by AWS would only be required by the NRA to make good the impact of their own abstraction, and is not considered an appropriate mechanism for more general low flow alleviation.

8.5 Groundwater Modelling

The existing Deben groundwater model is a limited tool for effective use in the management of water resources. A general lack of confidence in output stems from poor model calibration, due to limited data availability within the catchment.

In order to use a model to address the medium and longer term water resources management issues in the catchment, most notably a review of time limited PWS licences (if granted) and a review of the effectiveness of the Deben ALF scheme, the following options are available:-

Options

i) Further develop and/or refine the existing Deben groundwater model.

ii) Develop a new, time variant Deben groundwater model. In the interim, limited use of the existing model could be made.

iii) Expand the existing Gipping groundwater model into the Deben catchment.

Assuming that temporary licences with effective monitoring of both groundwater levels and river flows are granted for public water supply within the Unit, the data gathered could be used to update the existing model and improve confidence (Option i).

Option i) could be achieved through several mechanisms:-

- Anglian Water Services could update the model in support of their licence application near the end of the temporary period (if granted), with an NRA audit of the work. However, with the existing uncertainties in the model further development by a third party could prove difficult.

- NRA could update the model 'in-house' either to assist in the determination of any such application for renewal, or to enable more effective use as a management tool (Section 3.4) if and when further data became available. This would enable the model to be used for other management purposes and would enhance the internal expertise in model application.

- As above, with consultants employed to undertake the work.

If Options ii) or iii) are followed, development should be within the framework of any regional modelling strategy. Output from other modelling studies undertaken for sourceworks within the Unit should also be considered.

The current area of uncertainty is focused on the Deben/Gipping boundary and is partly caused by the limited extent of the model area. Confidence could increase by redefining boundaries further afield. Option ii) could achieve this by extending the Deben model into the Gipping Unit, or option iii) could achieve this by extending the Gipping model into the Deben Unit.

It should be noted that the NRA only has an executable version of the groundwater model at present. This does not enable internal modification of the conceptual mechanisms, or the model boundary. Any fundamental changes to the source code would therefore require further work by Hydrotechnica.

For the recharge component of the model however, the NRA have the source code only and not an executable version of the program. This means that scenarios incorporating variations to the aquifer recharge cannot be explored at present.

Recommendations

It is recommended that option i) is adopted, with the work undertaken by the NRA either in-house or through consultants. (Separate local impact assessment as specified by Area staff should be commissioned by AWS in support of any application for renewal of the time limited licences - if granted). If the calibration is still unsatisfactory at that stage, consideration should be given to options ii) and iii).

9 CONCLUSIONS

9.1 Water Resources

The best estimate of the gross groundwater resource (long term average recharge) for the Deben Unit is 32.6 Ml/d

9.2 Water Abstraction Demands

The main abstractive demand for water is for public supply (60% of abstractive use). Spray irrigation and agriculture account for the remainder.

Demands for spray irrigation are expected to rise and applications are currently in hand to increase the security of supply (but not the total licensed quantity) of several public water supply abstractions in the Unit.

Several studies have indicated that peak spray irrigation abstractions from the River Deben are a major factor in exacerbating the effects of low flows during dry periods. A package of measures (**Figure 15**) including river support has been proposed by the River Deben ALF Project Team to alleviate the problem.

9.3 Environmental Water Demands

The minimum flow requirement of the River Deben has been assessed by Southern Science (and later refined by NRA) as 7.6 Ml/d at Naunton Hall. This is based on the requirements of key indicator species at 3 locations within the Deben catchment chosen for their diversity and conservation status, all upstream of the reaches affected by low flows. With consideration of the impact of effluents, the net environmental allocation of groundwater becomes 6.6 Ml/d.

The current environmental allocation from the Chalk for the Fynn and Lark catchments (1.1 Ml/d) is solely for the purpose of preventing saline intrusion. It is assumed that the environmental requirements of the rivers are met from the Crag resource which provides most of the rivers' baseflow. With consideration of the impact of effluents, an environmental allocation from groundwater becomes 0.7 Ml/d.

Figure 5 illustrates how the hydrogeological components of the unit interact and aids the reasoning of allocation of water for environmental purposes.

9.4 Balance of Resources and Demands

No additional summer surface water is available. There may however, be some scope for further abstraction of winter surface water subject to appropriate licence controls and consideration of both the environment and existing entitlements.

Groundwater resources are currently allocated as follows:-

Gross resource	**32.6 Ml/d**
Unreliable resource	6.5 Ml/d
Licensed abstraction	12.5 Ml/d
Net environmental allocation	7.3 Ml/d
Nominal surplus	**6.4 Ml/d**

N.B. Figures have been rounded.

The Deben Groundwater Unit therefore has a licensing policy which allows limited new groundwater abstraction (subject to licensing guidelines) until such time that the nominal surplus has been reduced to zero.

10 RECOMMENDATIONS

10.1 Licensing Policy

Surface Water

This study (and **Ref[13]**) confirms the existing abstraction licensing policy in the Rivers Deben, Fynn and Lark:-

- there is no additional summer surface water available for abstraction.
- there is some scope for using winter surface water.
- storage of winter water should be encouraged for summer use.
- any new winter licences should incorporate 'hands-off flows' conditions related to flows at Naunton Hall.
- any new licences should be subject to the usual considerations of the environment and of derogation.

Groundwater

There is limited groundwater available for abstraction within the Deben Groundwater Unit; 2.2 Ml/d is nominally available in the Fynn and Lark catchments and 4.2 Ml/d in the Deben catchment. Licensing should be undertaken in accord with the Regional abstraction licensing guidelines (**Ref[29]**). This policy should be undertaken until the nominal surplus is reduced to zero and/or 'in river needs' have been refined in accordance with these recommendations.

10.2 Actions & Investigations

River Flows and Environmental Needs

- Naturalised flows for the River Deben should be further refined by rainfall runoff modelling. Input data should include groundwater abstractions.

  The new output should then form the basis for the determination of operating rules for the Earl Soham augmentation borehole. The borehole should then be operated accordingly.

- The actual abstractions of surface abstractors on the Rivers Fynn and Lark should continue to be monitored to assess whether any action is required in the future to reduce their impact on low flows.

- When current research (Ref[3]) to identify methodologies for evaluating river flow needs has been completed (due 1995), the methodology identified should be applied to the Rivers Fynn and Lark and used to refine the river flow needs of the River Deben.

River Deben Alleviation of Low Flows

- The package of measures outlined in Section **7.1**, and detailed in **Ref[13]** should be implemented under the supervision and guidance of the River Deben ALF Project Team.

- The requirement for Anglian Water Services to make good any impact of their proposed groundwater abstractions through river support should be made through the licensing process.

Groundwater Modelling

- The Deben Groundwater model should be updated by the NRA either 'in-house', or through consultants, to incorporate any new monitoring data collected from proposed time limited licences for public water supply or from the Deben ALF scheme. Applicants would still be required to submit separate Environmental Assessments as specified by Area staff in support of any application to make temporary licences permanent.

- A time variant Deben Groundwater Model should then be developed.

- The impact of seasonal abstractions on groundwater should be identified by modelling with the time variant model, and used in post project appraisal to review the effectiveness of the package of measures to alleviate the low flows of the River Deben.

Deben Groundwater Unit: Water Resources Management Plan
Action Programme

ID	Name
1	Refinement of naturalised flows. (Rainfall-runoff modelling).
2	River Deben Alleviation of Low Flows: Main implementation phase.
3	River Deben Alleviation of Low Flows: Environmental monitoring.
4	River Deben Alleviation of Low Flows: Review of benefits.
5	AWS Temporary Licences: Environmental monitoring.
6	Determination of AWS licence renewal.
7	Groundwater Model: Re-calibration and evaluation.
8	Development of time variant groundwater model.
9	Deben Catchment Management Plan

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FIGURE 1: Deben Groundwater Unit

NRA

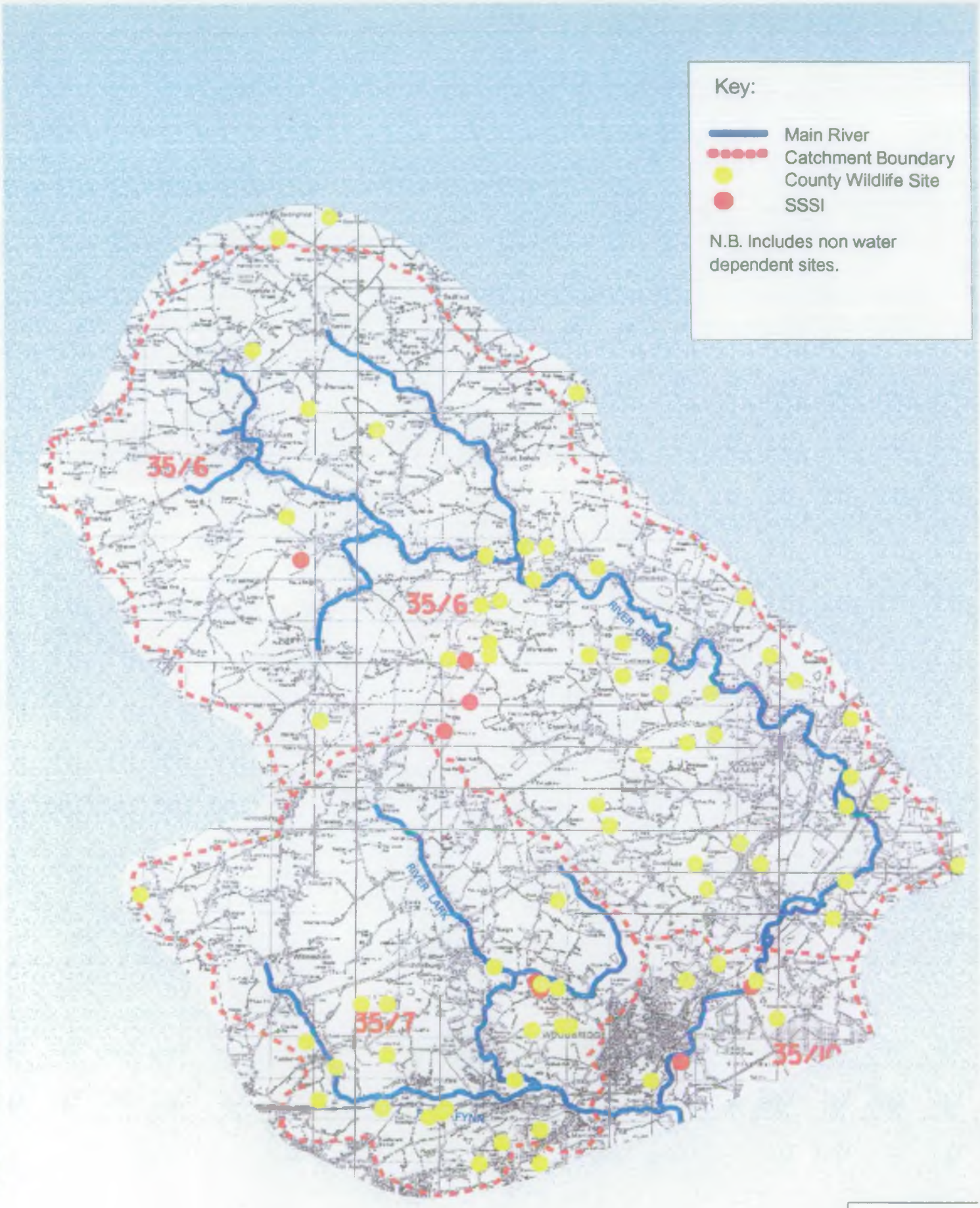


FIGURE 2: Nature Conservation Sites

NRA

FIGURE 3:
Gauging Stations and Current Metering Sites

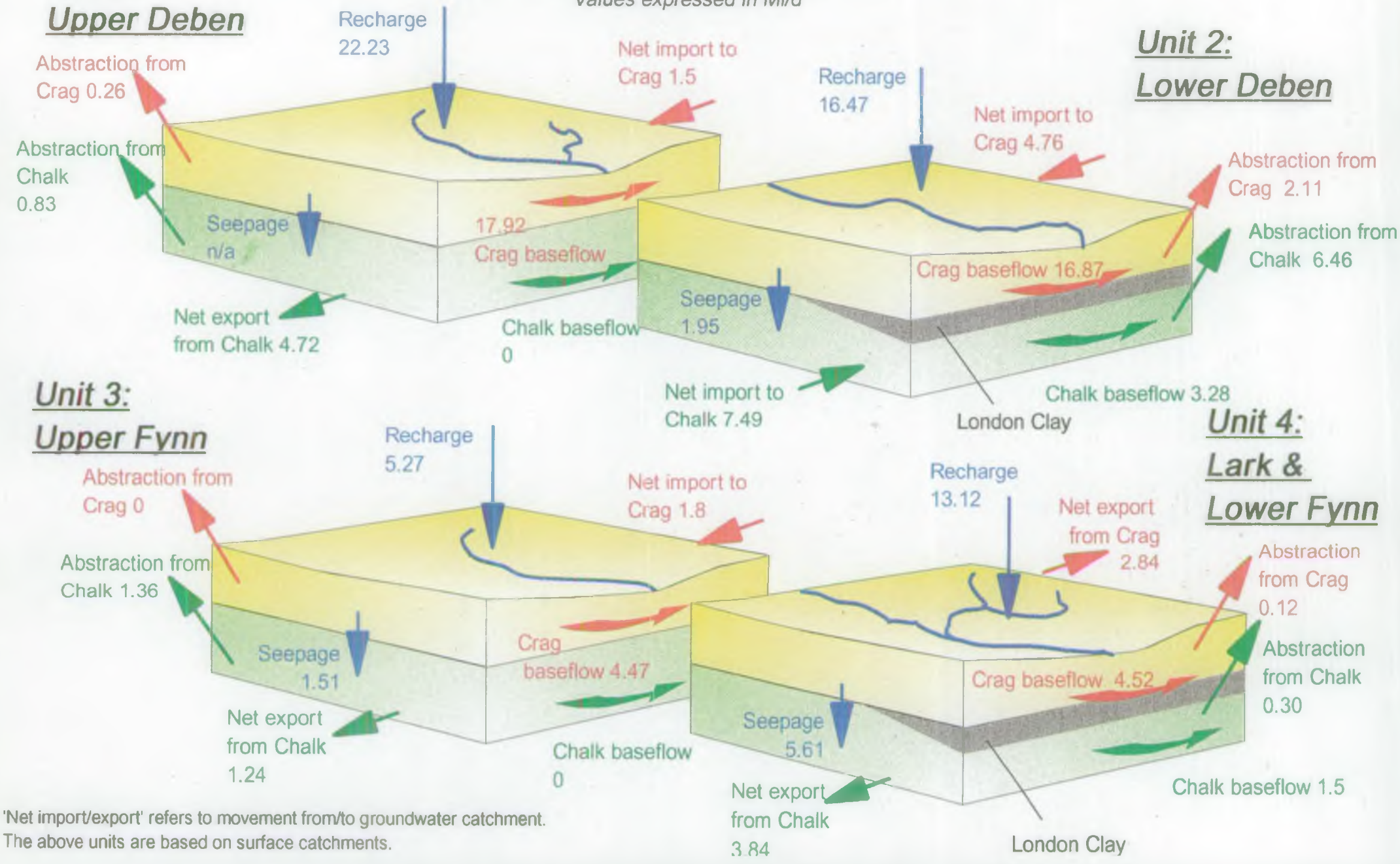
NRA

FIGURE 4: River Augmentation Boreholes

NRA

FIGURE 5: Deben Groundwater Model: Groundwater Balance Components

(Groundwater Components Only)
Values expressed in Ml/d



'Net import/export' refers to movement from/to groundwater catchment.
The above units are based on surface catchments.

FIGURE 6:
Resource Assessment Areas (Hydrotechnica)

NRA

FIGURE 7: Deben Groundwater Unit - Geology

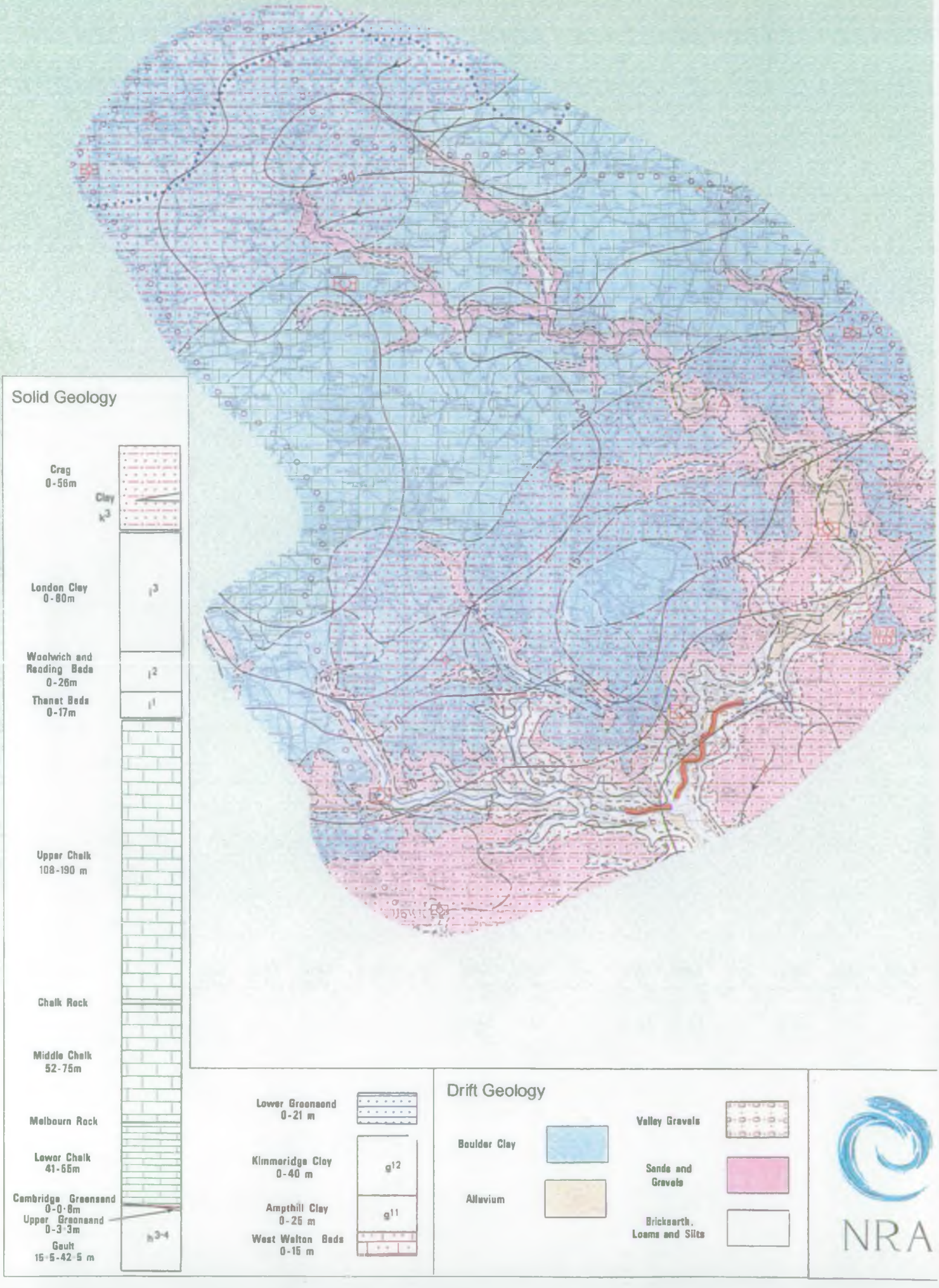


FIGURE 8: River Water Quality

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FIGURE 9: Groundwater Protection Zones

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FIGURE 10:
Public Water Supply Abstractions

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FIGURE 11: Public Water Supply Actual Abstraction

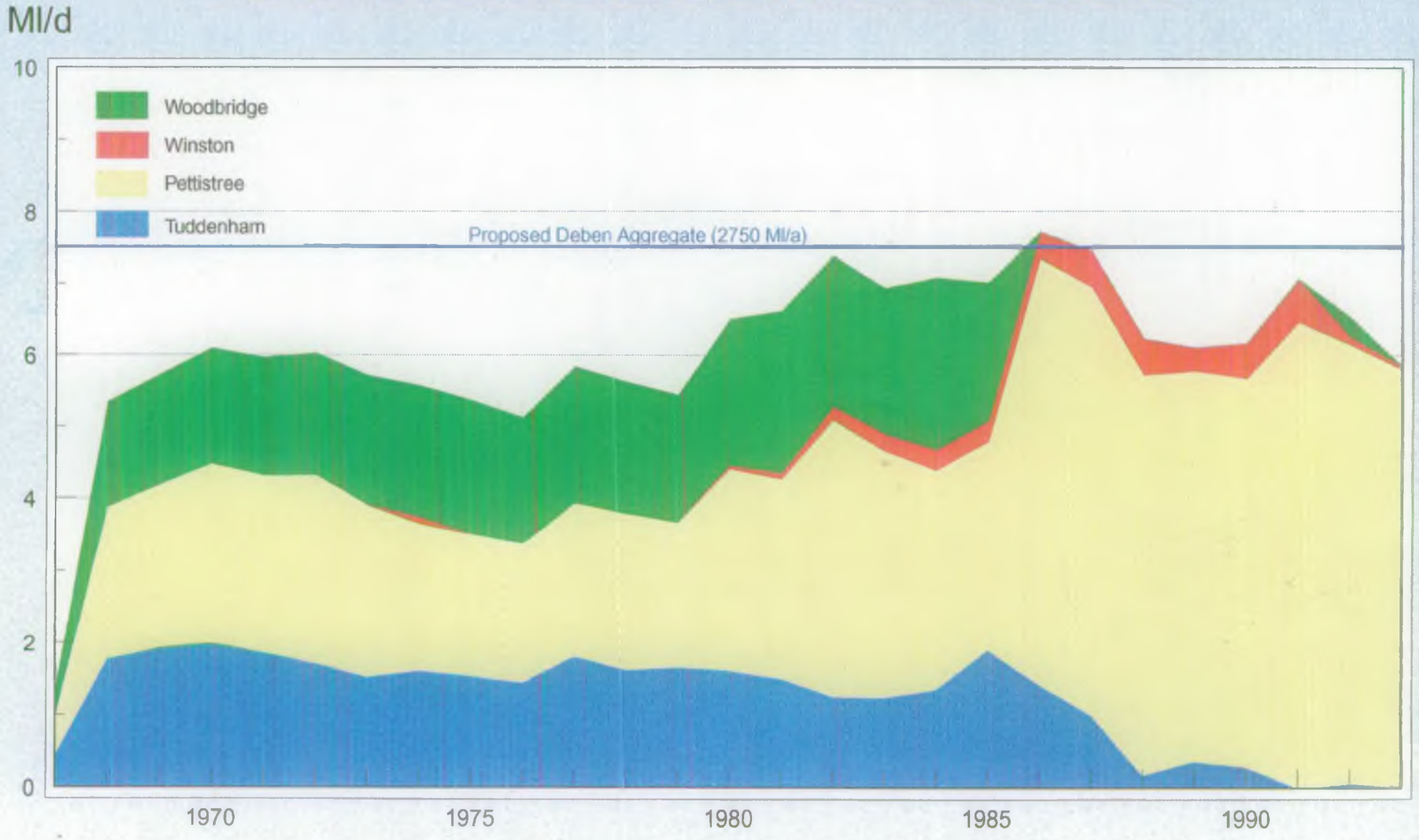

FIGURE 12: Public Water Supply Sourceworks Reliable Output versus Demand Forecasts for the Ipswich Water Resources Supply Zone (WRZ 25)

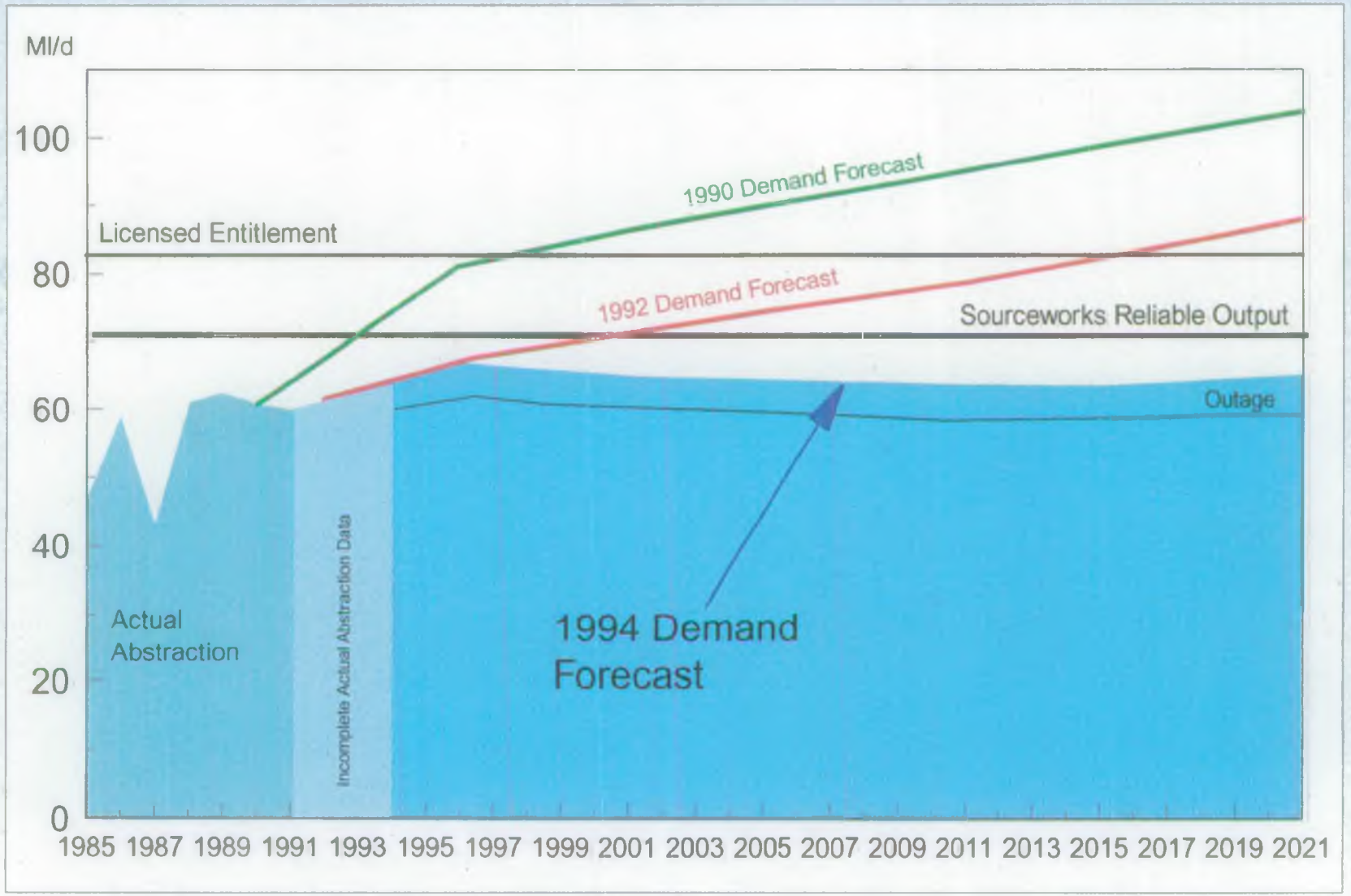

FIGURE 13: Effluent Discharge Points

NRA

FIGURE 14: R.Deben - Residual Flows at Q95

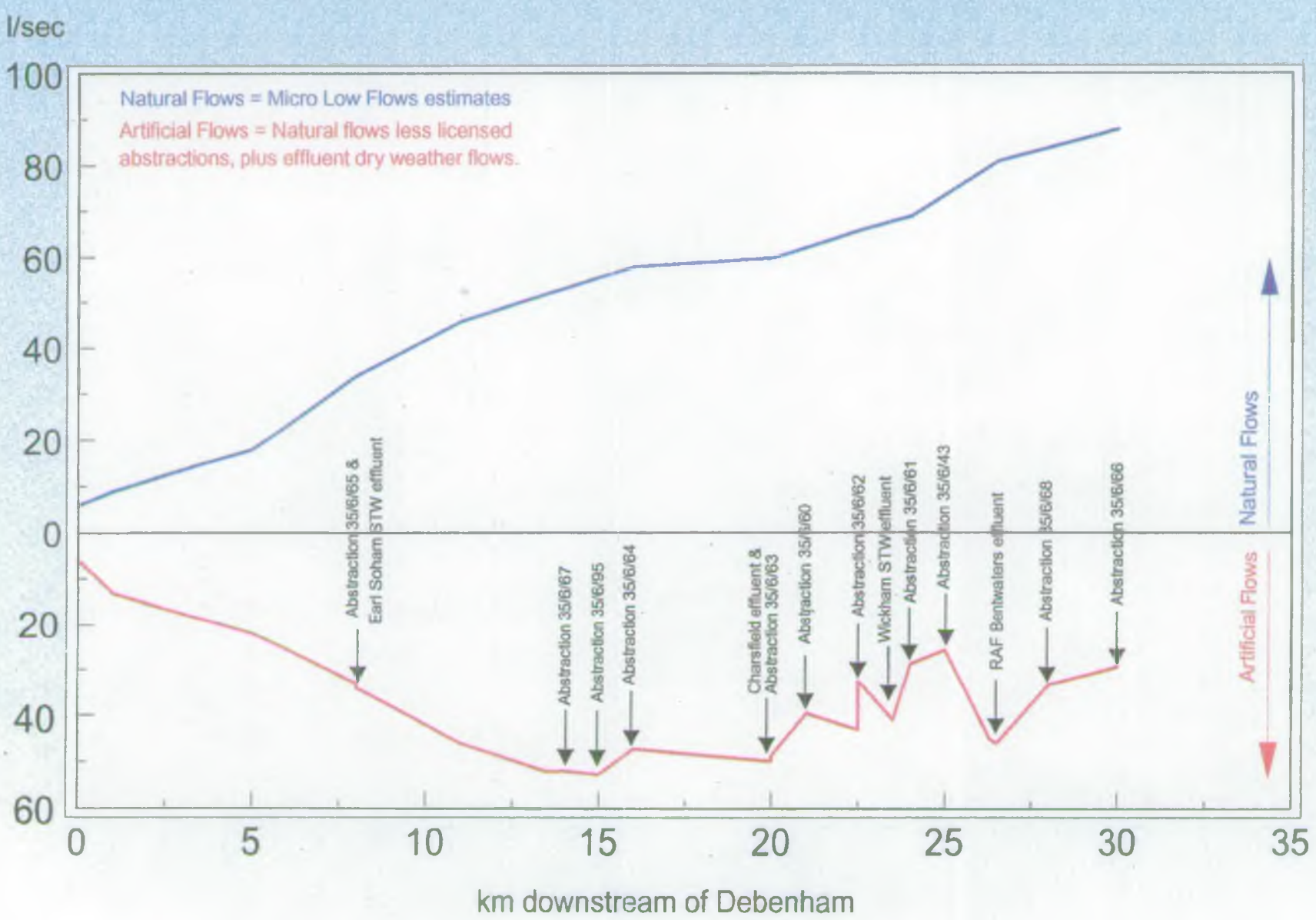

FIGURE 16: River Fynn - Residual Flows at Q95

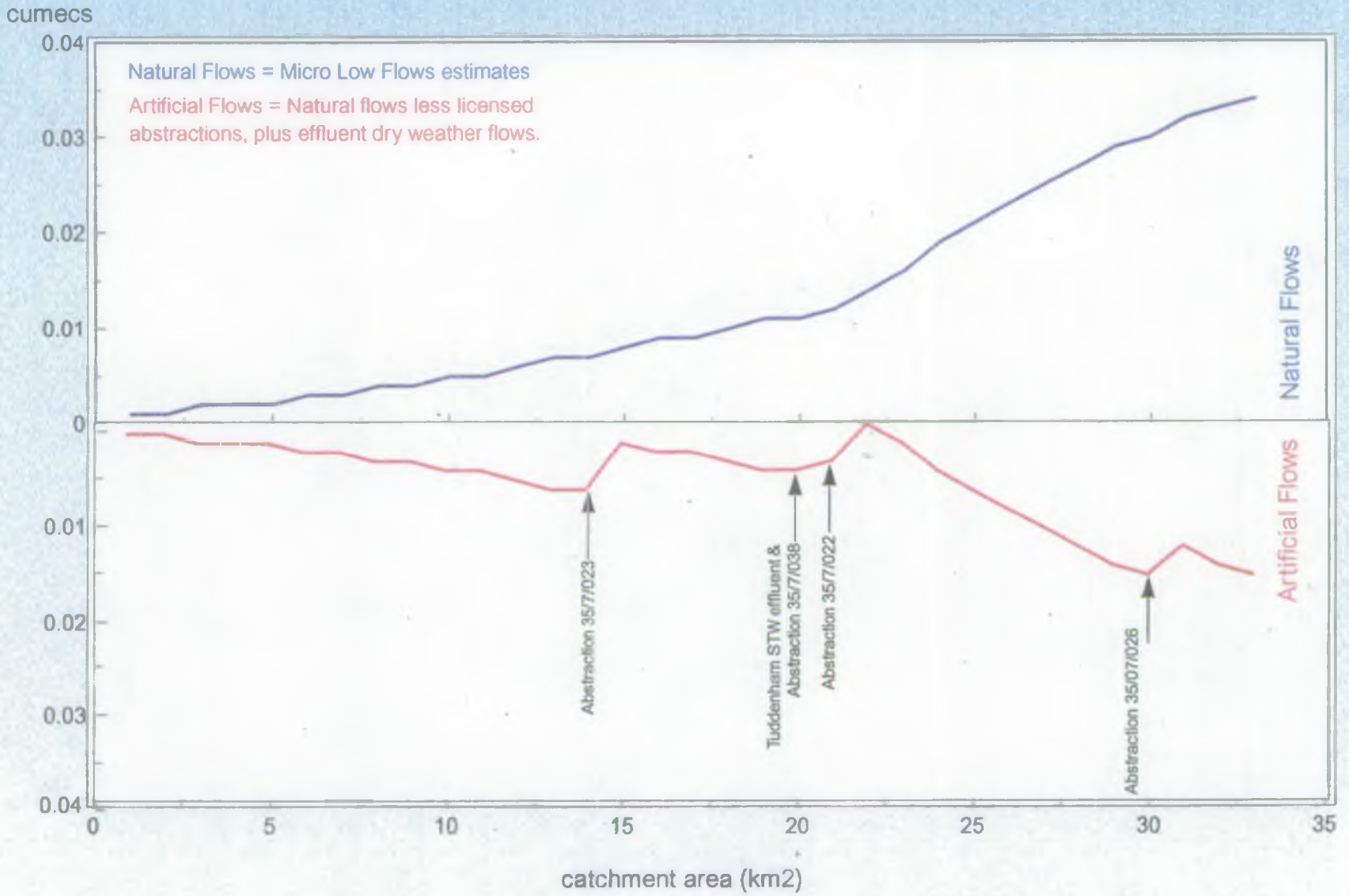

FIGURE 15: THE PRINCIPLES OF THE PROPOSED SOLUTION TO ALLEVIATE LOW FLOWS IN THE DEBEN

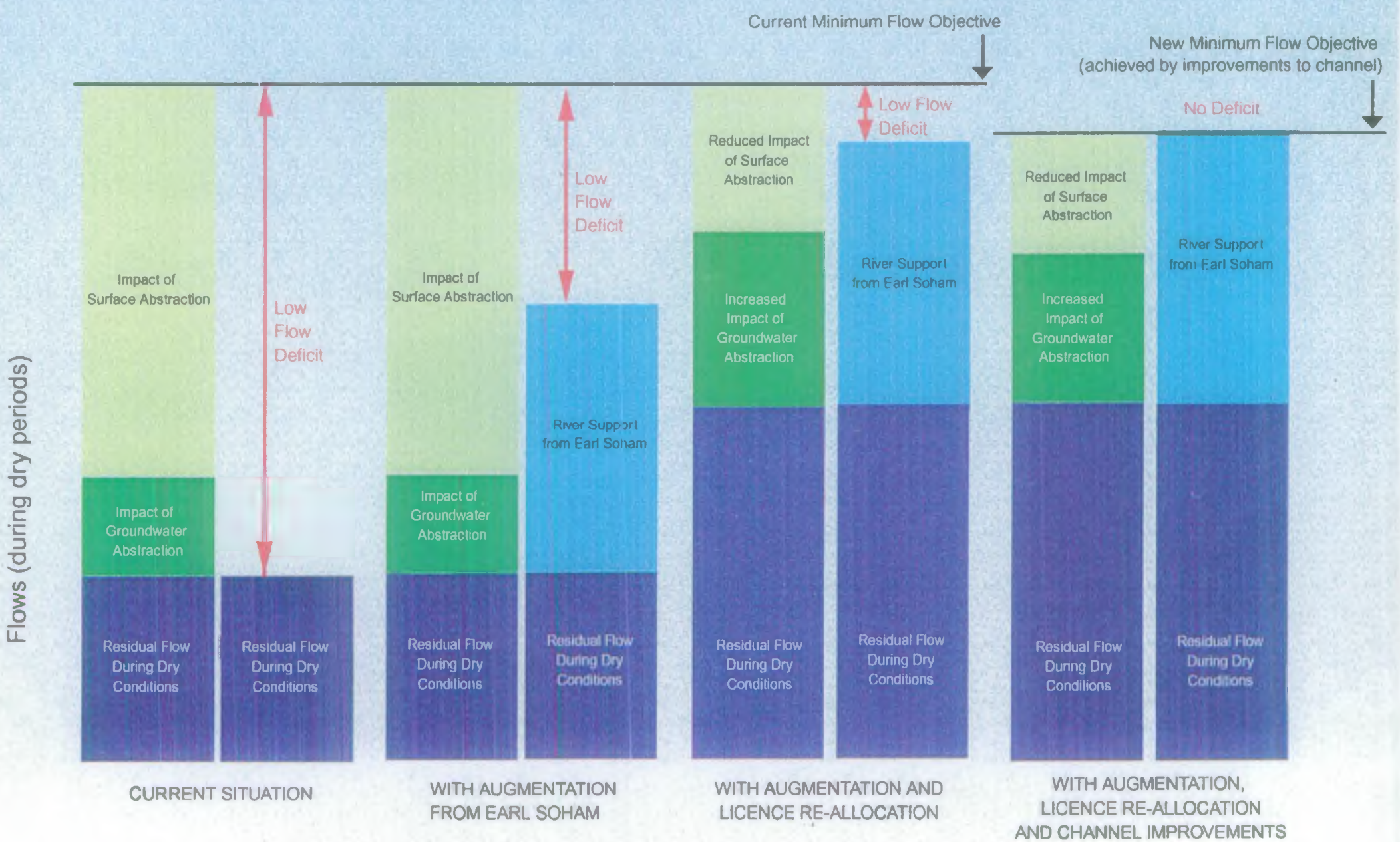

FIGURE 17: River Lark - Residual Flows at Q95