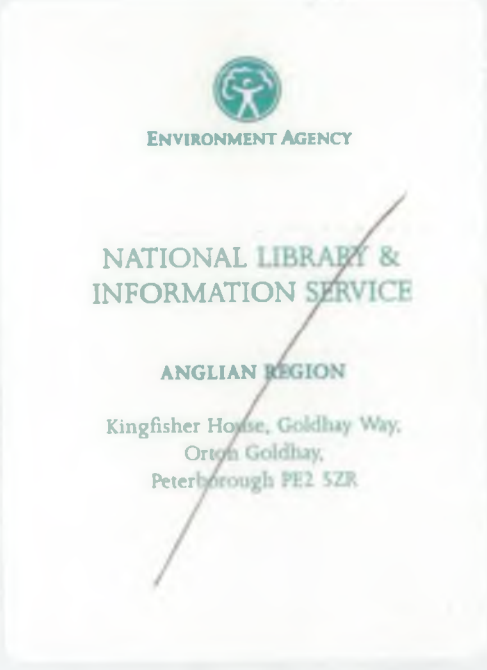
National Rivers Authority
Anglian Region

THE MANAGEMENT OF THE WATER RESOURCES OF THE LITTLE OUSE GROUNDWATER UNIT



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1	Feb 1993	Consultation Draft
2	August 1993	Sections about Great Ouse Groundwater Scheme changed.

SUMMARY

This report recommends a strategy for the management of the water resources of the Little Ouse groundwater unit.

The Little Ouse groundwater unit covers parts of several river catchments, including those of the Little Ouse, Thet, Sapiston (Black Bourn) and Cut-Off Channel (see Figure 1).

The current issues in the Little Ouse catchment include; the increasing demand for water abstraction, the protection of wetlands, the protection of river levels and flows, the protection of river water quality and the future use and development of the Great Ouse Groundwater Scheme.

This unit is part of the "Ely Ouse Catchment Management Plan".

The water in the river system is derived in four ways;
- rainfall runoff, predominately from areas of Boulder Clay cover in the upper part of the catchment,
- baseflow from the Chalk aquifer, which underlies the whole catchment, and from minor sand and gravel deposits,
- artifical augmentation using groundwater, and
- effluent discharges.

During the recent drought, the river flows were sustained by groundwater using the Great Ouse Groundwater Scheme and by effluent discharges.

There are twenty three water dependent S.S.S.I.s in the unit and over fifty wetland Wildlife Trust sites. Part of the Little Ouse unit is included in the Breckland Environmentally Sensitive Area.

The long term average available water resource is allocated firstly to meet environmental needs and secondly for abstraction purposes. It is shown that the water resources of the Little Ouse unit are fully committed. This conclusion is sensitive to the amount allocated to the river, which is provisional and requires further investigation. However, for the present, future applications for additional groundwater abstraction will not be recommended.

Several options are examined to address the current issues in the unit. Recommendations are made for further studies.

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WATER RESOURCES OF THE LITTLE OUSE GROUNDWATER UNIT

1. INTRODUCTION

1.1 Purpose of Report

The purpose of this report is to review the water resources of the Little Ouse Groundwater Unit. In particular how the water resources are currently used and managed, to identify the future needs both environmental and human, and to make recommendations to optimise future water resource management in this unit.

1.2 Location

Figure 1 shows the area of the Little Ouse Groundwater Unit (Unit 9). The western boundary has been defined by the base of the Totternhoe Stone horizon within the Lower Chalk. The remaining boundaries are groundwater divides derived from the minimum groundwater heads shown on the "Hydrogeological map of Northern East Anglia" (1976) and the "Hydrogeological map of Southern East Anglia" (1981).

The Unit covers all or part of the following surface water catchments; the River Thet (6/33/44), the Little Ouse (6/33/42, 6/33/43, 6/33/45 and 6/33/46), the Sapiston (6/33/41), the River Lark (6/33/37 and 6/33/39), the Cut Off Channel (6/33/56), the River Wissey (6/33/48), the River Waveney (7/34/16) and small parts of the River Tiffey (7/34/13) and the River Gipping (7/35/8) and a tributary of the Yare (7/34/13).

1.3 Sub-unit divisions

The unit has been divided into four sub units in order to examine the utilisation of water resources in more detail.

The divisions were made with regard to surface hydrology and groundwater flows. Figure 2 shows the definition of the sub units; A covers the Thet, B is the Upper Little Ouse, C is the Sapiston and D is the Lower Little Ouse.

1.4 Current issues

a. Increasing Demand for Water Abstraction

This groundwater unit has been perceived to have surplus water resources available for abstraction and hence the area has become a focus for the water companies and other abstractors seeking water supplies.

The N.R.A. needs to re-evaluate the availability of water resources in order to address the increasing demand.

b. Protection of Wetlands

There are twenty three S.S.S.I. wetland sites and over 50 wetland sites managed by the Wildlife Trusts. There are licensing policies in force to protect wetlands but these may need to be reviewed, and elsewhere more hydrogeological information is needed.

c. Protection of River Levels and Flows

The levels and flows required in the river system to satisfy the ecology need to be identified in order to successfully manage the system and devise an appropriate licensing policy. An "in river needs" appraisal (a detailed study of ecology, water quality and quantity : see section 5.6.2) has not been carried out for the Little Ouse or it's tributaries.

d. Protection of River Water Quality

In general, the quality of the river system is good. However, problems can occur in the headwaters of the tributaries.

e. Future Development of The Great Ouse Groundwater Scheme

The unit contains boreholes drilled under the Great Ouse Groundwater Scheme in order to augment the river and to provide extra exports to Essex via the Ely Ouse to Essex transfer scheme. The operation and possible future development of the Great Ouse Groundwater Scheme needs to be considered.

f. Licensing Policy

The policy followed by the N.R.A. regarding the issue and variation of abstraction licences needs to be reviewed.

1.5 Ely Ouse Catchment Management Plan

This unit is included in the "Ely Ouse Catchment Management Plan".

2. DESCRIPTION

2.1 Geology and Hydrogeology

The surface geology is shown in Figure 3 and described below in order of importance with respect to water resources.

The principal aquifer which underlies the whole unit is the Chalk. This is a fine grained, fissured, white limestone with bands of flint nodules. The Chalk outcrops in the west of the unit and along the majority of the main river valleys. The Chalk transmits water effectively with the majority of the water flow occurring through fissures.

The eastern part of the unit is covered by Boulder Clay. To the north of Thetford, the Boulder Clay is a pale grey/blue type consisting of pebbles of Chalk flint and other rocks in a sandy Chalk matrix. This has been called Chalky Boulder Clay. The rest of the Boulder Clay area consists of a darker type with Chalk and other pebbles in a matrix of sand and Jurassic Clay. This type is referred to as Chalky Jurassic Boulder Clay. Both types are semi-permeable.

There are several deposits of Sands and Gravels in the unit. Firstly, Glacial Sands and Gravels in the upper part of the catchment occurring beneath and on top of the Boulder Clay and at outcrops along the valley sides. Crag, consisting of unconsolidated or poorly consolidated ferruginous sands and gravels with shells, occurs beneath the Boulder Clay to the south east of the unit. The third type of Gravels are the Valley Gravels. These occur along the river valley sides and can be important local aquifers.

The majority of the rivers run in a bed of Alluvium. This consists of silts, clays and some sand layers. The majority of the rivers run along lines of buried channels. The exceptions include the River Little Ouse between Blo Norton and Euston and the River Thet between East Harling and Thetford. The buried channels can be 30 metres deep filled with sands and silts, and are semi-permeable.

The general direction of Chalk groundwater flow in the unit is South-East and East to West. The Boulder Clay limits the recharge into the chalk aquifer and encourages surface water runoff. Interflow from within the Boulder Clay as well as outflows from the Chalk appears as spring flows. The groundwater levels are given in Figures 4 and 5, and Table 1.

The change in groundwater levels between April 1988, when the levels were at their highest, to September 1991, when levels were very low due to the intervening drought, shown in Figures 4 and 5. The groundwater levels in the Sapiston sub catchment have remained similar between 1988 and 1991. However, the levels within the Little Ouse and Thet sub catchments have been lowered by up to 5 m. The gradient in the upper reaches has steepened whereas the gradient elsewhere has become less.

2.2 Hydrology

The river flow regime for the Little Ouse can be examined using available records from gauging stations, current metering and analysis using the Great Ouse Resource Model (G.O.R.M.). The principal river is the River Little Ouse and the tributaries are the Rivers Thet and Sapiston (also known as The Black Bourn). The Cut Off Channel, constructed between Denver and Mildenhall as a flood relief channel, cuts across the western part of the unit.

The River Waveney drains the eastern part of the groundwater unit. The Chalk aquifer is believed to have produced more spring flow into the Redgrave and Lopham Fen (see Figure 23) prior to the location of the abstraction borehole at Redgrave (see Figure 20).

2.2.1 Gauging Stations

There are nine gauging stations in the Little Ouse unit (shown in Figure 6). Table 2 gives the details. The flow statistics are given for two periods, from beginning of 1970 to end of 1991 (except at Knettishall where the record did not begin until 1980) and for beginning of 1970 to end of 1988. This second period ends before the current drought and before the significant operation of Great Ouse Groundwater Scheme boreholes (see Figure 21) to augment the rivers Thet and Little Ouse. The flow duration curves for the period 1970 to 1991 are given as Figures 7 to 15.

The nearest gauging station on the River Waveney is at Billingford Bridge near Diss.

The flows recorded at the gauging stations are unnatural since they have been changed by abstractions from and discharges to the river. In addition, some of the river is affected by the use of the Great Ouse Groundwater Scheme boreholes (see section 5.5). Comparison of the records between 1970 and 1988 (pre recent drought and river augmentation - although this period does include the drought of 1976 and the testing of the scheme in 1970s) with the records between 1970 and 1991 reveals the following :

a. The non -augmented parts of the river (i.e. the flow recorded at Stonebridge and Euston 1 : Rectory Bridge) show that the Average Flow has reduced by 8 % and the 95 %ile has been reduced by 25 % (Stonebridge).

b. The rivers that were augmented show a 6% reduction in Average Flow but the 95%ile flows were reduced between 0.4 % (Thetford 1 : Melford Bridge).

The Base Flow Index (BFI) is the ratio of the flow in the river derived from the aquifer to the total river flow. Rivers with a high baseflow component will have a high BFI. The index ranges from zero (no baseflow) to one (all baseflow). The BFI given in Table 2 has been calculated using the Institute of Hydrology "Low Flow Studies Report" (1980) method of hydrograph separation.

The BFI indicates that the River Little Ouse has a high contribution from groundwater compared to runoff, approximately 70 : 30 %. This is to be expected in a catchment where the Chalk aquifer is at or near the surface.

The gauging records also reveal that there is a major gain of flow between County Bridge, Melford Bridge and Rectory Bridge (i.e the sum of the tributary flows) and Abbey Heath (the main river below Thetford). In Average Flow conditions, the gain is 58.73 tcmd and in 95 %ile conditions, the gain is 41.4 tcmd. The artificial discharges made to the system total only 5.57 tcmd (The Dry Weather Flows from Thetford and Barnham Sewage Treatment Works and the Industrial effluent from Thermalite). The explanation could be that the Chalk is effluent to the river along this stretch. The Chalk is known to have high Transmissivity in the area between the rivers Thet and Little Ouse and the river may act as the line of discharge from the aquifer system where the ground level and the water table are probably coincident.

TABLE 2 Flow Measurement in the Little Ouse Unit.

Name of Station	National Grid Reference	Period of Record	Average Flow (tcmd)	95%ile (tcmd)	Base Flow Index
Knettishall * (River Little Ouse)	TL956 807	1.1.80-31.12.91	38.62	10.80	0.70
		1.1.80-31.12.88	44.67	13.74	0.68
Euston 2 * - County Bridge (River Little Ouse)	TL892 801	1.1.70-31.12.91	39.74	7.52	0.75
		1.1.70-31.12.88	42.68	10.28	0.74
Thetford 2 * - Abbey Heath (River Little Ouse)	TL851 844	1.1.70-31.12.91	316.48	97.63	0.80
		1.1.70-31.12.88	335.84	113.79	0.80
Stonebridge (Larling Brook)	TL927 907	1.1.70-31.12.91	4.67	0.78	0.82
		1.1.70-31.12.88	5.01	1.04	0.82
Quidenham * (River Wittle)	TM027 878	1.1.70-31.12.91	10.63	1.21	0.64
		1.1.70-31.12.88	11.40	1.64	0.64
Shropham * -Redbridge (River Thet)	TL996 923	1.1.70-31.12.91	71.37	11.40	0.64
		1.1.70-31.12.88	75.95	11.66	0.63
Bridgham * (River Thet)	TL957 856	1.1.70-31.12.91	130.29	33.09	0.75
		1.1.70-31.12.88	137.98	33.70	0.74
Thetford 1 * - Melford Bridge (River Thet)	TL880 830	1.1.70-31.12.91	158.20	41.47	0.76
		1.1.70-31.12.88	166.67	41.64	0.77
Euston 1 - Rectory Bridge (River Sapiston)	TL896 791	1.1.70-31.12.91	59.79	7.26	0.63
		1.1.70-31.12.88	64.89	13.05	0.63

Notes: The 95%ile is the flow that is exceeded for 95 per cent of the time.

* shows where the flows have been augmented since 1988.

2.2.2. Current Metering

The following sites are current metered on a regular basis. There are records for 33 other sites which have been current metered in the past. The location of the sites are given in Figure 6. The sites were chosen to monitor the effects of the operation of the Great Ouse Groundwater Scheme boreholes.

TABLE 3 Current Metering Sites

Ref.	Site Name	Grid Ref
334207	Hopton Fen	TL989 807
334208	Euston Weir	TL894 804
334301	Dog Kennels	TL992 808
334202	Gasthorpe Bridge	TL975 806
334303	Knettishall Park	TL956 808
334304	River Little Ouse	TM004 802
334305	Blo Norton	TM012 791
334306	Rushford Bridge	TL925 812
334307	Wymers Farm	TM027 789
334401	New Buckenham	TM082 904
334402	Trib. River Thet	TM073 903
334403	Railway Crossing	TM022 913
334404	Hall Farm	TM025 918
334405	A11 Bridges	TM026 929
334406	A11 Old Bridges	TM026 928
334407	Swangey Ford	TM006 945
334408	Mount Pleasant	TL993 945
334411	Larling Bridge	TL973 907
334412	East Harling	TL989 869

2.3.2. Great Ouse Resource Model

The Great Ouse Resource Model (G.O.R.M.) was developed by Anglian Water Authority (later NRA) and Water Research Centre between 1987 and 1990. The model has been updated for this unit ("Procedure Adopted for Revision of Input Data for the Little Ouse Catchment" by A. Turner and G. Watts, 1994).

The whole of the Great Ouse river system has been divided into reaches defined by nodes at the end of each reach. The model calculates the flow at every node at weekly time intervals using information about recharge and aquifer characteristics as well as abstractions and discharges.

The inflow to a reach can be given as:

runoff + baseflow + effluent returns - surface water abstractions

The inflow is then added to the flow from the upstream node, progressively adding the flows downstream. Account is taken of aquifer storage and transmissivity values as well as groundwater abstractions when the model calculates the baseflow element.

The recent work has meant that the model has been calibrated with abstraction and discharge data for the period 1971 to 1992. The original abstraction monthly return data was used, where available, or, where absent, returns estimated from annual figures or comparison with similar licences. The effluent returns to the river were calculated using population figures and per capita consumption figures.

In addition, the recent work tested the model against gauging stations throughout the catchment. The work has resulted in a greater confidence level for the model and produced a "reasonable simulation with good agreement of modelled and gauged flow duration curves". The flows below Abbey Heath gauging station have not been calibrated as there is not a suitable gauging station. However, the model takes into account the extra area and type of the contributing aquifer and is expected to produce flows to equal accuracy as the model above Abbey Heath.

The model has been used to calculate the "naturalised" flow duration curves for the rivers. This is possible by using the model without any abstraction or effluent data and producing the flow characteristics for so called natural conditions. These curves were produced for the period 1961 to 1990 in order to match the period of resource calculation. This was achieved by using calibration for the period 1971 to 1992 and extending the model using the available effective rainfall data.

3. WATER RESOURCES

3.1 Surface water resources

As indicated in section 2.2.1, the river system in this catchment has a high contribution from groundwater compared to runoff. Only 30 % of the total annual river volume is direct rainfall runoff and this is available at a very variable rate and mostly in winter.

During most summers, the river flows are sustained by groundwater springs and effluent discharges. During droughts additional river support is obtained from the Great Ouse Groundwater Scheme boreholes (see section 5.5).

3.2 Groundwater resources

The groundwater resources represent the reliable source of water and contribute 70 % of the total river volume.

"Wright's method", adopted in the Cambridge Water Plan 1985, has been used to estimate the gross groundwater resource. This method is given in the paper by C.E. Wright, "Combined use of surface and groundwater in the Ely Ouse and Nar Catchments", Water Resources Board, March 1974.

Wright looked at the relationship of infiltration and rainfall. He did this by using known factors of geology, rainfall and river flows to produce the following relationships by multiple regression analysis. He gave two different equations depending on the type of Boulder Clay. The Chalky Jurassic Boulder Clay extends over most of the unit changing to the more sandy Chalky Boulder Clay in the northern part of the unit.

The infiltration through Chalk : $I = 0.81 \times R - 308$ (mm/a)
The infiltration through Jurassic Boulder Clay over Chalk: $I = 0.202 \times R - 77$ (mm/a)
The infiltration through Chalky Boulder Clay over Chalk: $I = 0.202 \times R - 70$ (mm/a)

where R = average annual rainfall (mm/a)

The gross resource calculated in this way is then reduced by 20 per cent to reflect the inadequacy of the Chalk storage to fully even out the year to year fluctuation in recharge (drought years to wet years) and becomes the "effective" resource. The 20 per cent is unreliable for abstraction but instead contributes to river flow in the wetter years. Another separate allocation is also made for the river (see section 5.6.2).

3.2.1 Cambridge Water Plan (1985) Assessment of Resources

The following assessment was made in the Cambridge Water Plan, 1985 (using Wright's method with 1916 to 1950 rainfall records):

TABLE 4 : Little Ouse Resources: 1985 Calculations					
Sub Catchment	Chalk Area (km2)	I (mm/a)	Boulder Clay Area (km2)	I (mm/a)	Recharge (tcma)
41	19	183	180.5	48	12140
42	31	201	123.5	49	12280
43	48.5	185	12.5	47	9560
44	65.5	200	251.5	58*	27690
45	85	211	14.5	53	18710
46	36.5	198	-	-	7230
56	75	198	5	47	15090
Gross Resource = 102700 tcma (or 281.4 tcmd)					

* This Boulder Clay has been taken as Chalky Boulder Clay.

The effective resource, therefore, was estimated as 82160 tcma or 225 tcmd.

3.2.2. Current Assessment of Resources

The following calculations update this analysis using 1961 to 1990 rainfall figures, the following areas of geology for the unit and the Wrights equations. The relationships identified in these equations may not hold true for the 1961 to 1990 conditions but they represent the best available method.

TABLE 5 Areas of Geology			
Area	Total Area (km^2)	Chalk Area (km^2)	Boulder Clay Area (km^2)
Whole Unit	970	434	536 (part 237*)
Sub Unit A (Thet)	309	72	237*
Sub Unit B (Upper Little Ouse)	171	76	95
Sub Unit C (Sapiston)	209	46	163
Sub Unit D (Lower Little Ouse)	281	240	41

* This Boulder Clay has been taken as Chalky Boulder Clay.

Rainfall figures from individual records have been weighted by the fraction of the area represented by the gauges and then summed. The areas were determined by the technique of Theissen polygons. The following table summarises this analysis:

TABLE 6	Rainfall Analysis		
Station No.	Proportion of total area	Annual Average Rainfall (mm/a) 1961 - 1990	Rainfall Weighted by area (mm/a)
204304	.013	640	8.320
204688	.065	611	39.715
205443	.007	647	4.529
209525	.067	603	40.401
209624	.066	608	40.128
188370	.060	638	38.280
221558	.004	557	2.228
221741	.025	578	14.450
188598	.037	581	21.497
226016	.002	589	1.178
185848	.002	552	1.104
188832	.068	574	39.032
189014	.064	651	41.664
190532	.079	608	48.032
191188	.055	570	31.350
187228	.012	545	6.540
191130	.020	557	11.140
191769	.033	572	18.876
190539	.033	635	20.955
189346	.057	616	35.112
190118	.114	585	66.690
188013	.077	598	46.046
192957	.014	626	8.764
		Total	586.031

Therefore, using R = 586 mm/a and the appropriate areas of geology in Table 5, the revised recharge or groundwater resource for the whole unit and the four sub units is given below.

TABLE 7 Little Ouse Resources - 1993 Calculations		
Area	Gross Resource (tcmd)	Effective Resource (tcmd)
Whole Unit	263.44	210.75
Sub Unit A	64.14	51.31
Sub Unit B	45.47	36.38
Sub Unit C	39.39	31.51
Sub Unit D	114.44	91.55

The effective groundwater resource for the whole of the unit is 210 tcmd (15 tcmd less than assumed in the Cambridge Water Plan, 1985). The reduction mostly reflects the change in rainfall period used, from 1916 - 1950 to 1961 to 1990.

4. WATER QUALITY

4.1 Surface water

River water quality is assessed against four criteria:

a. EC Directives

The following stretches of the Little Ouse river system are designated under the EC Fishery Directive as a Coarse Fishery:

60 km of the Little Ouse from Broom Hills Botesdale to the Ely Ouse River and 34 km of the River Thet from Portwood Brook (north of Attleborough) to the Little Ouse River.

The EC Directive sets water quality criteria for Dissolved Oxygen, pH, Ammonia, Zinc, Biological Oxygen Demand and Copper.

b. River Quality Objectives

The river is classified according to River Quality Objectives (1986). The river has been divided into a series of stretches and the uses of the river have been listed (see Table 8). The uses of the river determine the quality that should be maintained.

c. National Water Council Classification

The river can also be classified according to the National Water Council Classification. The categories are given in Table 9 and Figure 17 shows the results for 1991.

d. Biological standards

Biological Standards are derived using a model (Rivpacs) which uses details about the physical features of the river channel (width, depth and type of substrate) to predict the type of invertebrates that should be in evidence. The comparison of modelled against actual offers another type of river classification.

The rivers in the Little Ouse unit are generally of good quality, with most of the lengths being Class 1B in the NWC classification. There are no failures of any EC Directive. Figure 18 and Table 10 give the location of major discharges made to the Little Ouse river system. The operation of the Great Ouse Groundwater Scheme boreholes (see section 5.5) during the drought period probably avoided additional failures. Hence, the only problems experienced are in the upper reaches:

i) River Sapiston

The headwaters are affected by effluents from a factory and a sewage treatment works. Significant improvements have been made to the quality of the effluents; however, the quality problems have persisted. This has been attributed to the lack of dilution caused by low flows during the drought.

ii) Stowlangtoft Stream (tributary of River Sapiston)

Low dissolved oxygen levels in 1991 caused a downgrading in NWC class. This was interpreted as being due to the loss of dilution (during drought conditions) for a sewage treatment works effluent.

iii) Larling Brook

There has been deterioration of quality but pollutant levels have remained the same. The water quality problems have, therefore, been attributed to low flows during the drought.

4.2 Groundwater

In general, the quality of the Chalk groundwater is suitable for abstraction and environmental demands. The following may need to be considered.

The infiltration of Nitrate has occurred across the Chalk aquifer outcrop as elsewhere.

Solvent contamination of the Chalk aquifer is known to exist near to Honington, Brandon and Watton airfields.

The NRA "Policy and Practice for the Protection of Groundwater" sets out policy with respect to future protection of the aquifer and the potable sources. The associated maps are still to be produced.

5. WATER USE IN THE CATCHMENT

Figure 19 and Table 11 show the increase in licensed abstraction in this unit according to different uses. The sections below describe this increase in more detail. Table 14 shows the applications that await determination.

5.1 Public Water Supply

5.1.1 PWS Abstractions

Figure 20 shows the location of the public water supply boreholes operated by Anglian Water Services Ltd., Cambridge Water Company and Suffolk Water Company. There is no surface water intake directly from the river for public water supply. Table 12 below gives the licence details for these sources and the actual abstraction figures for 1993. Overall the actual abstraction was 43.32 % of licensed quantity.

The quantity of groundwater licensed for Public Water Supply (including any aggregate limitations) in 1966 was 4175 tcma. The quantity in 1993 is 20006 tcma. Figure 19 and Table 11a show the history of licensed abstraction.

TABLE 12 Public Water Supply Licence Details

Source	Actual Abstraction 1993 (tcma)	Licensed Abstraction (tcma)
Anglian Water Services Ltd.		
Brandon 2 - TL795 862	617.440	750
Croxton - TL873 864	0	15.91 Sold
Old Buckenham - TM085 935	0	272.7 Disused
Quidenham-TM020 876 & TM024 874	652.100	1410
Two Mile Bottom - TL854 864	1590.830	1659) Common
Barnham Cross - TL870 816	100.560	1000) Agg.=
Nunnery Lodge - TL879 823	980.760	1561) 4073
Riddlesworth - TL955 815	0.0	696.8
Ixworth - TL940 698	2253.980	2953.33
Cambridge Water Company		
Brettenham - TL9105 8236	1.200	4138 (to reduce to 1460 tcma in 2003)
Euston - TL9033 7977	1038.336	2920 (to reduce to 2190 tcma in 2003)
Rushford - TL9344 8142	1.500	1460 (to reduce to 730 tcma in 2003)
Suffolk Water Company		
Rickinghall - TM045 746	364.166	454.6
Redgrave - TM046 792	1066.005	862.1
TOTAL	8666.616 tcma	20006.44 tcma
or	23.74 tcmd	54.81 tcmd

5.1.2 Public Water Supply Transfers into and out of the Catchment

Some boreholes are used to supply the population centres within the unit, the main population being in Thetford. Other boreholes are used to supply areas outside the catchment, to Cambridge in particular. Similarly boreholes outside the unit supply some areas within this catchment. These exports and imports are as follows:-

Imports

There is provision to import water from the east into Attleborough but this is balanced by another supply back to the east.

Exports

The total quantity of the three Cambridge Water Company licences is allocated to supply Cambridge up to 8518 tcma or 23.33 tcmd.

In addition, there is a small export from Ixworth, estimated as 0.36 tcmd in 1991 in the Cambridge Water Plan 1985). (The 'export' listed in the Cambridge Water Plan 1985 from Quidenham and Riddlesworth (0.65 tcmd in 1991) is considered to supply villages within this unit and hence has not been included as an export).

The source at Redgrave supplies the area of south of the River Waveney. An estimated one third of the quantity abstracted supplies villages within this unit which implies a 1991 export of 1.62 tcmd.

5.1.3 Public Water Supply: Return of Effluents

The quantity of the public water supply returning to the river via the sewage treatment works as effluents can be estimated by three methods. These methods calculate the reliable effluent which will return to the catchment. Future effluents may not be returned to this catchment.

Firstly, the quantity abstracted minus exports and loss in use plus imports, must return to the catchment. The quantity abstracted in 1991 was 20.70 tcmd. The quantity exported for 1991 is estimated as 2.63 tcmd (0.36 + 0.65 + 1.62, see above). Therefore, the effluent return (neglecting evaporative loss in use) would be 18.07 tcmd.

A second method uses the quoted "Dry Weather Flows" from the sewage treatment works. These flows are calculated from an estimate of the population served multiplied by a factor of water use. These estimates have not been revised since the early 1980s. The sum of Anglian Water Sewage Works dry weather flows equates to 14.1 tcmd (see table 10). However, some of the non - AWS and Industrial discharges would have been derived from public water supply sources. This increases the total effluent to 15.73 tcmd.

A third method uses the population figures from the 1991 Census multiplied by the predicted level of water use for 1991. For 87,190 people using 0.145 m^3/d/person this gives 12.64 tcmd. If the Industrial discharges from mains are added, the total increases to 14.17 tcmd.

The sum of dry weather flows is used in the resource balance calculations - see section 5.6.2.

5.1.4 Public Water Supply: Proposed Developments

Table 13 indicates the current issues in the unit regarding public water supply.

TABLE 13 Proposed Public Water Supply Developments in the Unit

Anglian Water Services Ltd. have indicated that they wish to increase the licensed quantity at Ixworth in order to supply Bury St. Edmunds (possibly an extra 2.9 tcmd average).

Cambridge Water Company already have the three licences for their boreholes at Thetford. However, the licensed quantities will reduce in year 2003.

Brettenham will reduce from 4138 to 1460 tcma in 2003, Euston (works 13) will reduce from 2920 to 2190 tcma and Euston (works 15) from 1460 to 730 tcma i.e. a total reduction of 4138 tcma or almost 50 %.

Cambridge Water Company have indicated that they wish the full quantity of 8518 tcma (23.3 tcmd) to remain permanently. In addition they may seek increased quantities by year 2015. The company have commissioned Mott MacDonald to examine the water resource availability on their behalf (due to report in 1994). A distributed groundwater model has been written and calibrated for the catchment.

Suffolk Water Company in conjunction with the NRA are looking to relocate the Redgrave source (licensed for 3.6 tcmd) away from Redgrave and Lopham Fen RAMSAR wetland site. The new location may be within this unit or be moved to the Dove catchment.

5.2 Private Water Undertaking

The quantity of groundwater licensed for this purpose in 1966 was only 0.16 tcma whereas in 1993 the figure was 326.76 tcma. The increase is largely explained by the licensing of chalk boreholes to supply the new Center Parcs Holiday Centre near Thetford (licence No. 6/33/43/25).

There are "Crown Exempt" abstractions, ie. abstractions which do not require a licence under the Water Resources Act, within this unit. This includes water supply to the Airfields. There is little information about the sources of water to these sites. One example is R.A.F. Lakenheath which is known to be supplied by two boreholes and recent correspondence has suggested that the average abstraction is 1.3 tcmd. A total of 1.5 tcmd has been included in the resource balance assessments in this report to cover the "Crown Exempt" abstraction from groundwater.

5.3 Agriculture

The quantity of groundwater licensed for general agricultural use has increased from 537 tcma in 1966 to 1030 tcma in 1993. The corresponding figures for spray irrigation use are 547 tcma in 1966 and 5666 tcma in 1993. The quantity licensed for spray irrigation peaked at 7103 tcma in 1990. A separate quantity of 11.9 tcma is licensed for Anti-Frost spray irrigation.

5.4 Industry

The quantity of groundwater licensed for industrial purposes has increased from 94 tcma in 1966 to 1801 tcma in 1993. Industrial uses are mainly food processing, including a bacon factory, vegetable washing plants, a soft drink company and chicken farms. Water for cooling is licensed in the unit, 153 tcma for non-consumptive cooling (95% is assumed to return to resource) and 216 tcma for consumptive cooling. Sand and Gravel Washing is licensed as a separate use as the majority (assessed as 95 %) of water is recycled. There have been only two licences for this use in the catchment, one ceased in 1980 and the second ceased in 1987.

5.5 Raw Water Transfer : The Great Ouse Groundwater Scheme

There are 27 chalk boreholes operated by the NRA in the unit during periods of low recharge in order to supplement river flows and to maintain the export of water to rivers in Essex. The augmented flow can be transferred from the River Little Ouse to the Cut Off Channel at Hockwold (TL732 870) where three pipes have a total capacity of 68 tcmd.

In addition, there is a requirement in the abstraction licence held by Anglian Water at Stoke Ferry on the River Wissey to maintain river flows. Water is transferred from the Cut Off Channel, which is supported by the River Little Ouse at Hockwold, into the River Wissey. In the drought year of 1990 this demand represented 12 tcmd or 25% of the 46 tcmd transferred at Hockwold from the River Little Ouse. (from unpublished Drought Report:Central Area).

5.5.1 The Great Ouse Groundwater Scheme Boreholes

The boreholes were developed in the 1970s as part of the Groundwater Development Scheme. The Scheme was authorised by the Anglian Water Authority (Great Ouse Groundwater Development) Order 1976 following a Public Inquiry. Abstraction licences were issued under the Water Resources Act 1963.

Details of the sites, licences and operational status are given in Figure 21 and Table 15. The licences contain all sites authorised by the Order but not all the boreholes exist or are operational. Figure 22 shows the borehole at Roudham and its associated discharge to the Larling Brook.

The quantity licensed (600 day limit divided by 600) for each sub unit is : 36.3 tcmd for the Thet, 29.28 tcmd for the Little Ouse and 13.18 tcmd for the Sapiston.

The current installed capacity of the boreholes is 129 tcmd (112 tcmd in the Thet and 17 tcmd in the Little Ouse sub units).The boreholes in the Sapiston are presently not drilled. The installed capacity exceeds the quantity that can be transferred at Hockwold (68 tcmd) to account for recirculation losses after prolonged pumping, occasional pump failures and other problems.

Total actual abstractions during the recent drought are given per licence in Table 15.

The net gain, which is the quantity pumped from the Chalk that will reach Hockwold after recirculation losses, varies between about 80% near the start of support pumping down to 30% at the end of a long period of support pumping (4th Progress Report by Binnies about the Groundwater Pilot Scheme tests 1971). The net gain was also estimated in 1989 when only the boreholes

in the Thet catchment were pumped and hence a comparison could be made against the unsupported flows in the Little Ouse catchment. Net gain was found to be 40% at the end of pumping.

5.5.2 The transfer at Hockwold

During 1976, it was shown that the supported flows entering the South Level System were being used by abstraction and evaporation demands in the Fens. The Hockwold transfer was constructed to allow the net gain of pumping the Great Ouse Groundwater Scheme boreholes to be transferred from the Little Ouse river to the Cut Off Channel (which is 5 km from Blackdyke) and hence transferred to Essex.

An Abstraction Licence (No 6/33/45/50/10) allows the NRA to abstract up to 68 tcmd or 24820 tcma from the River Little Ouse into the Cut Off Channel at Hockwold (TL 732 870), subject to the following conditions:-

i) When GOGW scheme is operational:-

the abstraction must not exceed the net gain in flow (as assessed at Abbey Heath) up to the maximum of 68 tcmd.

ii) When GOGW scheme is not operational:-

the abstraction may not take place when either

- the level at TL 732 870 is at or below 1.74 m ODN and the flow Abbey Heath is less than 27 tcmd; or

- the flow at Denver is less than the prescribed rate of flow (presently 114 tcmd March to August and 318 tcmd September to February).

5.6 Environmental Water Needs

The environmental 'demand' for water consists of three elements; the level and flow needed to maintain wetland sites of conservation interest, the inflow to the Cut Off Channel and the 'in river needs'.

5.6.1 Wetland SSSI's and other Sites of Conservation Interest

Details of the 23 SSSI sites and over 50 Wildlife Trust sites are given as Appendix 1. The detail includes the geological information from the work carried out by Birmingham University in 1989 ("The Hydrodynamics of Fen Systems) and indication of the current licensing practice.

The wetland sites exist, in certain cases, because of the supporting groundwater levels and flow. Therefore, the need to protect wetlands will require the prohibition and/or management of abstraction in the immediate surrounding areas. Ideally, there will be defined protection or catchment zones around all wetland sites. There are policies in practise to protect the Breckland Meres, Lakenheath Poors Fen and Pashford Poors Fen (see Appendix 1).

Figure 23 shows the location of wetland sites of conservation interest. The SSSI sites are under the control of English Nature whereas the Wildlife Sites are under the supervision of Suffolk Wildlife Trust or Norfolk Wildlife Trust. The future licence policy has to take account of these sites. Figure 24 shows two of the Breckland Meres described in Appendix 1.

5.6.2 Cut Off Channel

The Cut Off Channel was constructed for the purpose of diverting flood waters from the Rivers Lark, Little Ouse and Wissey away from the Fens and into the Relief Channel at Denver. The Channel was completed in 1964.

In 1971 the Ely Ouse to Essex Water Transfer Scheme was completed and the Cut Off Channel is used to transfer surplus water from the Ely Ouse system to Essex.

The Cut Off Channel is constructed into the Chalk aquifer and acts as a drainage level for the groundwater levels. A study of this groundwater baseflow element of the Cut Off Channel (north of the Little Ouse) showed that the baseflow could vary from 100 tcmd in April 1991 to 10 tcmd in September 1991 (1991 being a drought year). (R.J. Hillier, February 1993 "Mass Balance of the Cut Off Channel (Downstream of Little Ouse Syphon) to evaluate Baseflow.")

This baseflow element is another demand upon the groundwater resource of the Little Ouse unit.

5.6.3 In River Needs

The "in river needs" are the flow, level and quality of water necessary to satisfy:-

a) the aquatic and riparian ecological communities,
b) the requirement for effluent dilution,
c) navigation,
d) flushing of silt.

An extensive ecological and hydrological study, to examine the existing ecology of the river system and define the minimum water level, flow and quality required to maintain the system is ideally needed for this unit. National NRA research is in progress to define the scope and methods of such a study.

There is, however, a need to define the quantity that should be reserved for the river system from the groundwater resource. In the absence of an extensive ecological study, current practise is to use the natural 95 percentile flow (ie that which would have occurred before abstractions and discharges existed) as a first approximation to the river need in the fluvial sections of river. Different considerations apply in the 'fen' river below Hockwold.

The quantity of water between the 'gross resource' and the 'effective resource' described in section 3.2. has already been allocated to the river. An additional quantity of groundwater to be reserved for the river (RA) is assessed as:-

$$RA = Z - E$$

Where Z = the naturalised 95 percentile flow (from Great Ouse Resource Model. see 2.3.2)

E = sum of effluents reliably discharged to the river

(Note : This calculation does not allow for abstractions direct from the river, which are accounted for in chapter 6).

A consistent approach toward the calculation of effluent returns has been adopted for the Anglian Region, N.R.A. (the factors used have been adopted from several studies across the region including section 14 reports and the Cambridge Water Plan 1985). This calculates the reliable effluent that is expected to return to the catchment in dry condition.

This effluent return is given as the sum of the following elements:

75 % of the sum of all Dry Weather Flows from Discharge Consents to the catchment (PWS and Industry),
75 % of water licensed for Private Water Undertaking,
95 % of water licensed for non-consumptive Cooling Water, and
90 % of water licensed for Agriculture and other Miscellaneous Uses.
(Spray Irrigation is considered to be entirely consumptive)

For the whole of the Little Ouse Unit:

Z = 141.70 tcmd (output from G.O.R.M.s model node 4601 near Lakenheath) plus 3 tcmd (an estimated natural flow for the Waveney : taken from the actual 95 %ile at Billingford Bridge Gauging station minus the effluent from Diss Sewage Treatment Works). A Total of 144.70 tcmd.

E = 0.75 x (14.1 tcmd PWS + 3.80 tcmd Industry & Non AWS + 0.90 tcmd Private W.S.) plus 0.90 x (2.82 tcmd Agriculture) = 17.04 tcmd

RA = 144.70 - 17.04 = 127.66 tcmd

The "RA" quantity is carried forward to Chapter 6 where the overall balance of water resources is discussed.

TABLE 16 River Allocation - tcmd
(based on Great Ouse Resource Model)

Sub Unit	A Thet	B Upper Ouse	C Sapiston	D Lower Ouse	Whole Unit
Z	54.43	14.23 (5)	13.82	62.22 (6)	144.70 (5)
E	3.03 (1)	0.83 (2)	3.93 (3)	9.25 (4)	17.04
RA	51.40	13.40	9.89	52.97	127.66

Notes :

(1) 0.75 x (1.47 PWS + 1.23 Industry + 0.07 Non AWS + 0.05 Private W.U.) + 0.90 x 1.02 Agriculture.

(2) 0.75 x (0.14 PWS + 0.20 Industry + 0.04 Non AWS) + 0.90 x 0.60 Agriculture.

(3) 0.75 x (4.05 PWS + 0.72 Industry) + 0.90 x 0.39 Agriculture.

(4) 0.75 x (8.44 PWS + 1.54 Industry + 0.85 Private W.U.) + 0.90 x 0.81 Agriculture + 0.95 x 0.42 Non-Consumptive Cooling.

(5) Includes 3 tcmd to the Waveney.

(6) The protected flow for unit D is based on the naturalised flows from zones A,B and C i.e. Whole Unit - (A + B + C).

5.6.4 Breckland Environmentally Sensitive Area

Figure 23 also shows that the western part of the area is within the Breckland Environmentally Sensitive Area. The Breckland area is distinguished by light sandy soils , belts of Scots Pine and areas of heathland with a rich variety of flora and fauna. The Ministry of Agriculture, Fisheries and Food operates a scheme whereby farmers can come to an agreement (in exchange for a grant) to farm in such a way as to preserve the Breckland landscape. The river valleys are considered to be an integral part of the landscape and farmers can agree "to maintain wet grassland", ponds and ditches.

5.7 Navigation

The river Little Ouse is presently navigable from it's confluence with the River Ely Ouse to Brandon Staunch (TL780 867), a distance of some 20 km. This is maintained by N.R.A. as required under the Anglian Water Act 1977. The navigation used to extend to Thetford in the past and there are plans to extend into Brandon Town Centre.

5.8 Fisheries

The fish stocks of the Rivers Little Ouse, Sapiston and Thet are monitored approximately every three years.

The River Thet between Shropham and Thetford was last surveyed in July 1988. The population was dominated by pike, roach and dace and the results were similar to the previous survey in 1986.

The River Little Ouse is surveyed in two sections; one between Blo Norton and the confluence with the River Sapiston near Barnham, and the other between Barnham and Brandon Creek where the river joins the Ely Ouse. Above Barnham the river channel is characterised by a series of riffles and pools over a predominantly gravel substrate and this is reflected in the fish species present, with the population dominated numerically by dace and gudgeon.

The Lower Little Ouse is an important Coarse Fishery with populations of roach, bream and pike. As the river goes across the fenland, it slows and becomes more eutrophic. However, the level of water is more important than flow to these fish species since they spawn on plants and do not rely on clean gravels in the channel.

The River Sapiston shows similar physical channel characteristics to the upstream section of the River Little Ouse and in the 1988 survey, roach, dace and chub were the dominant species and the river supported a good fishery.

The operation of the Great Ouse Groundwater Scheme boreholes (see section 5.5) since 1989 in the Thet catchment has resulted in higher river flows and the maintenance of habitat for the fish. In particular, dace which rely on clean gravels for spawning were able to survive the drought conditions.

No part of the Little Ouse system supports a natural population of brown trout which is an anomaly if compared to other tributary systems of the Ely Ouse. The reason for this is unclear and perhaps due to a degradation of habitat in the past. The population would not naturally re-establish since other populations are isolated in the upper reaches of other rivers.

6. BALANCE OF RESOURCES AND DEMANDS

6.1 Whole catchment

Table 17 compares groundwater resources with the demands upon them for the whole of the Little Ouse Unit.

TABLE 17 Balance of Groundwater Resources and Demands : Whole Unit

Groundwater Resource	Gross (tcmd)	Effective (tcmd)	
1985 Cambridge Water Plan	281.4	225.12	
Current Assessment	263.44	210.75	
ADOPTED FIGURE OF EFFECTIVE RESOURCE (X)			210.75
Abstraction Demand			
Groundwater abstraction licensed (Y) (includes 1.5 tcmd for Crown Exempt abstraction)		81.53	
Surface water - summer spray irrigation(Y2)		5.23	
Environmental Demand			
River Allocation (RA) from T16		127.66	

Therefore Deficit or Surplus (X - Y - Y2 - RA) = -3.67 nominal deficit

This balance excludes Great Ouse groundwater scheme licences (see section 6.4)

6.2 Sub Units

Table 18 below shows the same assessment for each sub unit.

TABLE 18 Balance of Resources and Demands per Sub-Unit
(all figures in tcmd unless otherwise indicated)

	A	B	C	D	
	Thet	Upper Lt Ouse	Sapiston	Lower Lt Ouse	Whole Unit
Resource					
Gross Resource	64.14	45.47	39.39	114.44	263.44
Effective Resource (X)	51.31	36.38	31.51	91.55	210.75
Total Abstraction Demand					
Groundwater Licensed (Y)	12.28	31.58	19.41	18.26	81.53
Surface water Licensed (Summer SI only)(Y2)	2.24	0.39	0.78	1.82	5.27
River Allocation					
RA	51.40	13.40 (1)	9.89	52.97	127.66 (1)
Surplus/Deficit					
D/S	-14.61	-8.99	1.43	18.50	-3.67

Note (1) this figure includes 3 tcmd for the River Waveney

The tributaries or sub units A and B are in deficit whereas sub units C and D are in surplus.

The method is sensitive to the amount allocated to the river. This is more sensitive where the available resource equates to the river allocation and hence does not allow any abstraction. This is the case for sub unit A.

6.3 Allocation of Little Ouse Groundwater Resources

The gross average groundwater resource in the Little Ouse Unit has been allocated as follows:

TABLE 19 Allocation of Groundwater Resource (all figures in tcmd)		
Unreliable resource (20 %)		52.69
Licensed Abstraction	Public Water Supply	54.81
	Spray Irrigation	15.56
	Industrial	4.93
	Cooling	1.01
	Agricultural	2.82
	Private Water Undertaking	0.90
	Crown Exempt	1.50
	Summer SI (Surface Water)	5.23
River Allocation - allowing for reliable effluents of 17.04 tcmd.		127.66
Deficit		-3.67
Total Gross Resource		263.44

6.4 Balance including the Great Ouse Groundwater Scheme

The analysis so far has not included the allocation for the Great Ouse Groundwater Scheme (as described in section 5.5). The effect of the scheme is to redistribute the rivers' baseflows in order to sustain low flows:

a) to meet in-river needs and/or
b) to meet export needs at Denver, (via Hockwold)

The balance in section 6.1 and 6.2 has been made on the basis that the scheme will be operated to sustain natural 95 percentile flows in the rivers, and that Essex may take, when required, any excess which this produces over the mrf at Denver. (The transfer at Hockwold is an expedient to avoid losses in the Ely Ouse pond and is not relevant to consideration of the manipulation of the groundwater resource of the Little Ouse).

If the balance had shown any additional resource over and above net abstractions plus that needed to sustain the 95 percentile flows, then it would have been possible to consider either:

a) additional net abstraction within the catchment or
b) additional river support pumping to sustain higher flows for transfer to Essex.

However there is no such surplus, and the catchment must be regarded as fully committed, on the basis of 95 percentile allocation to the fluvial rivers.

Figure 25 shows diagrammatically the rivers, the major abstractions and transfers, and the reliable (95 percentile) flows which could theoretically be sustained by river support pumping.

7. ISSUES AND OPTIONS

This section reviews the issues and discusses the options available to answer them.

7.1 The Increasing Demand for Water Abstraction

Section 5 describes the present demands for water in the Little Ouse Unit and the current applications for more water.

Demands will continue to increase, both for public supply and for use within the catchment, for groundwater for export from the catchment and for surface water to increase the transfers to Essex.

7.1.1 Increasing Demand for Direct Water Use

This is primarily for irrigation, for which there is a potentially large unsatisfied demand particularly in the Breckland area. It is virtually wholly consumptive, and the groundwater resource has been shown to be fully committed. The remaining options are:-

a) **Winter Storage**

Where feasible, abstractors may be encouraged to build their own reservoirs to store winter surface water. Abstraction charge tariffs are set to encourage this.

b) **Strategic Sources**

The Region's draft Water Resources Strategy (currently at public consultation) recommends a major reservoir, primarily for public supply, either in or near to this catchment. If such a reservoir is built, part of its yield should be considered for allocation to direct users.

c) **Groundwater Abstraction**

Increased groundwater abstraction cannot be considered unless either:

i) the resource assessment were to be re-evaluated upwards

ii) the river allocation were to be re-evaluated downwards or

iii) river flows were to be supported in some other way (e.g. water transfer from adjacent catchments) - for which there are no apparent options.

7.1.2 Increasing Demand for Public Supply

Abstractions for public supply within the catchment are partly consumptive, and abstractions for use in other catchments (eg to Cambridge or Suffolk Water Companies) are wholly consumptive as far as the donor catchment is concerned. Options for public supply therefore include a, b and c above and also

d) **Demand Management**

This unit is a resource sensitive area where leakage control and consideration of metering should have high priority.

e) **Use of surface water flows**

It might be possible to operate a public water supply intake at the bottom of the Little Ouse system similar to the Stoke Ferry Intake on the Wissey, with the conjunctive use of the Great Ouse Groundwater Scheme to support the intake during periods of low flow. The "in river needs" below the intake would need to be determined in order to define the minimum required flow condition. Any 'loss' to Essex would have to be compensated from elsewhere.

7.1.3 Demands Beyond the Little Ouse Catchment

Water leaving the catchment into the Ely Ouse contributes to meeting abstractive demands from the Ely Ouse pond, to the residual flow to the estuary and to Ely Ouse - Essex transfers. The transfer at Hockwold meets the residual flow to the estuary, the public water demands at Stoke Ferry and to Ely Ouse - Essex transfers.(see figure 25).

'Returning' uses within the catchment, and river support pumping all contribute to these needs by sustaining low flows. Non returning uses reduce the amount available for them. The only 'options' arising are:-

a) To regard these downstream entitlements as sacrosanct and therefore contemplate no further abstraction of any kind within the catchment or

b) to recognise that there are other, strategic, options available to those uses and accept that, where possible, reasonable local needs have first call on local resources.

The Regional Water Resources Strategy should ensure there is scope for the second option.

7.2 The Environmental Needs for Water

7.2.1 River Needs - Fluvial Rivers

Subject to discussion of Great Ouse Groundwater Scheme capacity below, adequate groundwater resources have been allocated to sustain flows to at least the natural 95 percentile level. In a naturally high based flow river this is probably a conservative allowance. There is a need to refine this first approximation to the in-river needs, probably by means of a detailed study on the lines of others carried out recently at the Wissey and the Babingley. Comparison of ecological records before and after the recent experience of river support by the Great Ouse Groundwater Scheme could contribute to this assessment.

7.2.2 River Needs - the Fen River

The character of the 'fen' river below Hockwold is totally different from the fluvial tributaries. Its flow need has been assessed as 27 tcmd (as specified in the Hockwold licence) which is pro-rata by area to the summer mrf at Denver. This mrf can be critical to the operation of the Hockwold/Ely Ouse/Essex transfer and should be reviewed on completion of the current review of the Denver mrf.

7.2.3 Wetland Needs

The N.R.A. has a general duty under the Water Resources Act 1991 to conserve and enhance flora, fauna and geological or physiographical features of special interest. The protection of wetlands, in particular, is important.

There is a need to understand the hydrology and hydrogeology of many of the wetland sites. This has already been addressed to some extent by a Birmingham University study commissioned by Anglian Water Authority (The Hydrodynamics of Fen Systems, 1989) and by continuing discussions with English Nature about monitoring.

Furthermore the NRA has recently engaged the Bristol Geological Survey, in collaboration with the Institute of Hydrology, to investigate various hydrogeological ways to protect wetlands. Middle Harling Fen is to be studied within phase 1 and East Harling and Swangey Fen within phase 2.

Wetlands in this catchment will continue to be controlled by restrictions on licensing as specified in the Regions Licensing Manual.

Special cases such as the Brecklands Meres, Lakenheath Poors Fen and Pashford Poors Fen should continue to be afforded special protection.

7.2.4 Cut Off Channel Baseflow

The Cut Off Channel acts as a drainage level for the Chalk groundwater levels. The resulting baseflow in the Channel provides water for abstractions and fisheries.

The quantity of water required from the groundwater resource needs to be identified.

7.3 River Water Quality

There are few particular problems with river water quality. As well as continued vigilance against pollution events, some options for improvement are:-

a) To impose more stringent conditions in discharge consents

This would have the effect of improving the treatment of effluent and hence there would be less need for dilution.

The method of defining consent conditions is based on the long term flow characteristics of the river, usually represented by the mean and 95 percentile flow. Future discharge consent conditions could be more stringent following the recent drought since the long term statistics for the river will be reduced.

b) To introduce structures in the river

The introduction of "wing dykes" or weirs which only go across part of the channel might be locally beneficial in terms of mixing flow.

c) To provide augmentation water from boreholes or inter basin transfers

The surface water quality problems in Section 4 were experienced along stretches of river not augmented by the Great Ouse Groundwater Scheme boreholes. At present, there are no plans to provide augmentation water to the heads of these tributaries. As a generalisation, it is almost always more economic to improve effluent treatment than to provide additional dilution flow.

7.4 Future Management of the Great Ouse Groundwater Scheme

7.4.1 The Net Gain of the Scheme

The actual percentage (called Net Gain) of the quantity pumped that reaches Hockwold, allowing for recirculation to ground, is not clearly understood. It is believed to vary between 80% and 30%. The operation of the Hockwold licence depends upon this knowledge (see section 5.5). During the recent drought, current metering of flows took place and there may be scope to assess the Net Gain using this data and inter basin regression analysis and/or using the Great Ouse Resource Model. Further study of net gain is recommended to refine operation of the Great Ouse Groundwater Scheme.

7.4.2 Licensed Quantities for River Support

The water balance calculations have shown that there is sufficient groundwater resource to meet current licensed entitlements, and to sustain the 'natural' 95 percentile flow in the river, but no more. The theoretical quantities for river support pumping can be shown for a peak (or daily) basis and for an average basis.

a. Peak Licensed Quantities

The peak pumping capacity is that needed to meet the maximum shortfall between the natural 95 percentile flow and the lowest anticipated actual flow (which includes effluents). Figures 26 to 28 show how the peak deficit in flows is calculated from the natural 95 percentile flow minus the actual 99.9 percentile flow (which includes forecast abstractions to the year 2011). The flows were calculated using the Great Ouse Resource Model (see section 2.3.2). The peak pumping capacity results from the peak deficit divided by a minimum net gain. The table 20 shows the results.

The final column of the table shows the total capacity for the scheme which would be available at the confluence of the tributaries. The peak licensed quantity for the Thet compares well with the required capacity. However, the Upper Little Ouse appears to be over licensed but has nearly the correct installed capacity and finally, the Sapiston is over licensed and obviously has insufficient installed capacity.

The total peak deficit is given as 41 tcmd is less than the quantity that can be transferred at Hockwold, which is 68 tcmd.

It is recommended that the installed peak capacity for the Upper Little Ouse and the Sapiston is increased to allow the 95%ile to be supported (ie. 40.30 tcmd).

Table 20 Required River Support Pumping Capacities - tcmd				
	A Thet	B Upper Lt Ouse	C Sapiston	Totals
1. Q95 natural	54.43	11.23	13.82	
2. Q99.9 actual	31.10	5.18	1.73	
3. Peak Deficit	23.33	6.05	12.09	41.47
4. Assumed minimum net gain	0.3	0.3	0.3	
5. Required capacity (3 ÷ 4)	77.77	20.17	40.30	138.24
6. Present installed capacity	112	17	0	129
7. Present Peak Licensed Quantity	74.88	62.40	55	192.28

b. Average (600 day) Licensed Quantities

The quantity that needs to be licensed on an average basis is given as the difference in volume between the required regulated duration curve and the unregulated curve divided by average net gain. This concept is illustrated in Figures 26 to 28 and the results given in Table 21. The accepted licensing period for the scheme is 600 days.

The table shows that the scheme is adequately licensed to meet the local needs of the river (which are judged to be the naturalised 95 percentile). It should be remembered that the scheme was originally licensed as a scheme to export water from the catchment to meet the needs in Essex.

Table 21 - Required 600 day River Support Licensed Quantities - tcm.				
	A Thet	B Upper Lt Ouse	C Sapiston	Whole Unit
1. Required Support Volume	2,071	381	1,934	6,496
2. Average Net gain	0.55	0.55	0.55	0.55
3. Therefore required licensed Volume (1 ÷ 2)	3,765	692	3,516	11,810
4. Actual Licensed Volume	21,780	17,570	7,910	47,260

7.4.3 The 'Cambridge Reduction'

At the time the boreholes (works Nos 2, 13 and 15) were sold to Cambridge Water Company and the corresponding licences issued (see Section 5.1), it was stated that "the existing Great Ouse Groundwater Scheme licence, held by NRA, will be reduced by an equivalent quantity".

This would affect the licences for the Great Ouse Groundwater Scheme boreholes in the Thet (Licence No 6/33/44/137) and the Little Ouse (Licence No 6/33/42/74).

Table 22 demonstrates the resulting changes to the licences, assuming the total quantity licensed to Cambridge Water Company at present is re-allocated.

Table 22 - Potential Changes to the Great Ouse Groundwater Scheme Licences

Licence Number	Present Quantities			Proposed Quantities		
	tcmd	tcma	tcm/600	tcmd	tcma	tcm/600d
6/33/44/137	74.88	13070	21780	59.88	8932	14977.8
6/33/42/74	62.40	10550	17570	47.40	6170	10370.0

When the statement was made it was perhaps not appreciated that the quantity was being re-allocated from an intermittent use and part of the River Allocation to an abstractive or consumptive use. In addition, it is not clear whether (a) the total quantity, (b) just the permanent element of the Cambridge Water Company licences or indeed (c) just the reference to the sites and the associated daily and annual quantities should be re-allocated from the Great Ouse Groundwater Scheme licences.

The potential reduction would undermine the ability, on a daily basis, of the Great Ouse Groundwater Scheme both to fully support the river and to supply the transfer demand at Hockwold.

It is recommended that the legal status of this potential reduction be reviewed. One solution would be to remove reference to the individual sites, their daily and annual quantities but to maintain the total quantities on the licences.

7.5 Licensing Policy

The policy followed by the N.R.A. regarding the issue and variation of abstraction licences in the Little Ouse Unit needs to be reviewed and reissued. The following options are available.

a. Total embargo of the Little Ouse Unit

The water resources of the unit have been shown to be scarce. It has also been shown that some areas of the unit are over licensed. It would be prudent, therefore, to prevent any increase in water abstraction from the unit at least until research has proved the resource calculations to be different or circumstances change.

b. Revocation of Licences

The NRA has the authority to revoke abstraction licences under the Water Resources Act 1991. If the source has not been used for seven years, the revocation is without compensation.

In general, a "review and revoke" policy could release water for more genuine needs.

c. Encourage use of Storage

Abstractions which rely on water stored from periods of high (winter) flow should be encouraged.

d. Encourage use of Surface Water

The abstractions from surface water can be permitted if above the minimum flow for the river. The cessation flow/level would need to be calculated to protect downstream users as well as the minimum flow for the environment. Licences could also be permitted during the periods of operation of the Great Ouse Groundwater Scheme if there was spare capacity over existing requirements of abstraction and the environment.

The present National Abstraction Charges Scheme allows for extra charges to be made if the river is supported. The surface water abstractions above Hockwold come into the supported category because of the Great Ouse Groundwater Scheme and hence pay three times as much compared to unsupported rivers.

The needs of these customers should be considered when the Great Ouse Groundwater Scheme is operated. In drought conditions, these abstractions should not be restricted unless the Great Ouse Groundwater Scheme is operating at full capacity.

e. Future assessment of resources

The assessment of available resources used in this report is still simplistic with arbitrary assumptions. There is a need to refine the method of calculation.

It is suggested that research be completed with respect to:

- the calculation of recharge to the Chalk,
- the storativity of the Chalk (how much of the store is available),
- the limitations imposed by the need to protect wetlands,
- the naturalisation of river flows,
- the interaction of groundwater abstraction and river flows (using the Regional Groundwater Model, Flowpath and G.O.R.M. could be used)
- establishing the critical flow, level and quality of the river (both for the full flowing river above Hockwold and the fen river below Hockwold) that should be maintained (i.e. a in-river needs study).

Such future assessment may indicate more water available for abstraction.

8. CONCLUSIONS

8.1 Geology and Hydrogeology

Chalk underlies the whole of the unit and acts as the principal store of water. The upland areas to the west are covered by Boulder Clay which is semi permeable. There are several areas of Sands and Gravel in the unit which can store water. The river runs on a bed of Alluvium and/or a line of a buried channel. However, there are some stretches, in particular along the river Thet where the river runs close the Chalk aquifer outcrop.

8.2 Hydrology

The river Little Ouse system has a high contribution from groundwater compared to runoff, approximately 70 : 30 %.

The river can be augmented with groundwater by using the boreholes drilled under the Great Ouse Groundwater Scheme.

8.3 Groundwater Resources

The groundwater resource has been calculated using the Wright Equations and the rainfall figures for 1961 to 1990. The Gross Resource is given as 263 tcmd and the Effective Resource is 210 tcmd.

8.4 Water Quality

The rivers in the Little Ouse unit are of good quality with only a few problems in the upper reaches where discharges were insufficiently diluted during the drought years.

In general, the groundwater quality is suitable for abstraction and environmental needs. However, Nitrate infiltration has occurred across the Chalk outcrop and solvent contamination is known to exist near the airfields.

8.5 Water Abstraction

Water is abstracted to meet the needs of public water supply, agriculture including spray irrigation, industrial uses such as food processing, cooling and sand and gravel washing. Total licensed abstraction has increased from 6173 tcma in 1966 to 29758 tcma in 1993.

The NRA is licensed to abstract from boreholes in order to support the river flow (the Great Ouse Groundwater Scheme) and to transfer water from the River Little Ouse to the Cut Off Channel at Hockwold.

8.6 Environmental Water Needs

There are 23 Sites of Scientific Interest and over 50 wildlife trust sites, all recognised wetland sites to be protected in this unit.

The unit is part of the Breckland Environmentally Sensitive Area.

The quantity identified to be reserved from the groundwater resource to meet river needs has been based on the 95%ile flow of the river.

8.7 Navigation

The river Little Ouse is presently navigable from it's confluence with the River Great Ouse to Brandon Staunch, some 20 km.

8.8 Fisheries

The Little Ouse river system supports a reasonable population of fish and the Lower Little Ouse is a recognised important coarse fishery.

8.9 Water Resources and Demands

It has been shown that the water resources of the unit are fully committed. The total gross resource has been allocated between an "unreliable" volume, licensed abstraction and a river allocation volume. There is a deficit of 3.67 tcmd.

8.10 Future Management of the Great Ouse Groundwater Scheme

The Scheme can be managed to support the river to achieve the natural 95%ile flow conditions at all times. The capacity of the scheme to achieve this support has been examined for both peak and average licence quantities. The scheme is adequately licensed overall to meet the local needs of the river. However, the installed peak capacity should be increased in the Upper Little Ouse and the Sapiston sub units.

9. RECOMMENDATIONS

The recommendations have been divided into investigation work that should be carried out in the next five years and an interim licensing policy that will be used until the further investigations have been completed. The groundwater embargo should remain in force unless and until the investigations detailed in the next section show that additional water is available.

9.1 Interim Licensing Policy

The following are recommended. These are in addition to any statutory requirements under the Water Resources Act 1991 and the Manual of Licensing.

a. Surface Water

Some winter water is available during periods of high flow and abstractors are encouraged to store this water in reservoirs for summer use. Summer water is not available.

b. Groundwater

The groundwater resources of the Little Ouse are fully committed.

Applications for increase of annual groundwater abstraction will not be recommended with the exception of the following cases; the abstraction is small (less than 20 cubic metres per day) for which no alternative supply is available, or the abstraction is part of an arrangement which provides for overall net benefit to the environment.

Renewals of time-limited licences for the same quantities should be for ten years duration.

c. Current and Anticipated Future Licence Applications

i. There are insufficient water resources to meet the needs described by the licence applications listed in Table 14. The total quantity represented by these applications is 1.17 tcmd.

ii. The current licences held by Cambridge Water Company contain a "temporary" element whereby the quantities are reduced in year 2003. This report indicates that there may be sufficient water resources within the Little Ouse Unit as a whole to allow the temporary element to be renewed. However, the renewal should not be automatic and should be supported by evidence that the water resource is available, nearby protected rights to abstract will not be affected, and rivers and wetlands are not adversely affected. The company should consider relocating the points of abstraction to areas of surplus resource (unit D) and to less environmentally sensitive areas, i.e. away from the Breckland Meres or any wetland site.

The future proposals, by Cambridge Water Company, to increase licensed abstraction by a further 24 tcmd to meet the needs beyond 2015 can not be recommended given the present view of resources. (The proposed investigations over the next five years by NRA might change this view of resources.)

iii. Anglian Water Services Ltd. have indicated that they wish to increase their licence at Ixworth beyond 2953.33 tcma. This is not recommended given the current view of

resources. The company should be encouraged to seek supplies from elsewhere to meet the demands in Bury St. Edmunds and/or to enhance demand management in the town to control the need for the water.

iv. Suffolk Water Company in conjunction with the NRA are looking to relocate their abstraction at Redgrave away from Redgrave and Lopham Fen. There are no objections, on water resources grounds, if the abstraction is relocated to the Little Ouse unit provided that the quantity does not exceed 862.5 tcma (or 2.36 tcmd average) since this is the quantity that has been allocated for Redgrave in this unit.

9.2 Further Investigations

The following investigations should be carried out within the next five years. The work comprises of investigation which will enable better assessment of the groundwater resource and consideration of the future management of the Great Ouse Groundwater Scheme. An indication of when the work should be done is given in brackets.

a. Reassessment of the Groundwater Resource

i. Revocation of Licences. There should be a positive initiative to examine the scope of unused allocations with a view to revoking or reducing licences. This would release water for other uses. (1994)

ii. "In River Needs" study should be undertaken to identify the needs of the river system (for both the full flowing river and the fen part of the river) in order to better identify the quantity of water required to be reserved from the total groundwater resource.(1996 - 1997)

iii. Effluent Return information should be updated and reviewed. This is necessary to identify the reliable quantity of water which returns to the river. (1994 - 1995)

iv. Definition of Wetland Catchment Areas. This may reduce the quantity of groundwater resource available for abstractive use. (1994 - 1998)

v. Reassess the licensing policies with respect to wetland sites, in particular the policy for the protection of the Breckland Meres. Experience may have been gained from the recent drought. (1994 - 1996)

vi. Identify the groundwater resource needed to maintain the baseflow to the Cut Off Channel. This may reduce the quantity available for abstraction. (1995)

vii. Development of the Groundwater Model. Once calibrated, the model can be used to examine the recharge mechanisms, the interaction of groundwater and surface water and the role of aquifer storage. The model can, therefore, be used as a means of reassessing the resource and as a tool for the future management of the resource. (1994 - 1997)

b. Future Management of the Great Ouse Groundwater Scheme

i. The net gain of the Great Ouse Groundwater Scheme should be determined by analysis of the operational pumping during 1989 to 1992. (1995)

ii. The peak capacity of the Great Ouse Groundwater Scheme boreholes in the Upper

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Little Ouse and Sapiston sub units should be increased to support the river to the naturalised 95 %ile flow. The location of the boreholes under the scheme should be chosen to best meet the identified river needs. (1995-1997)

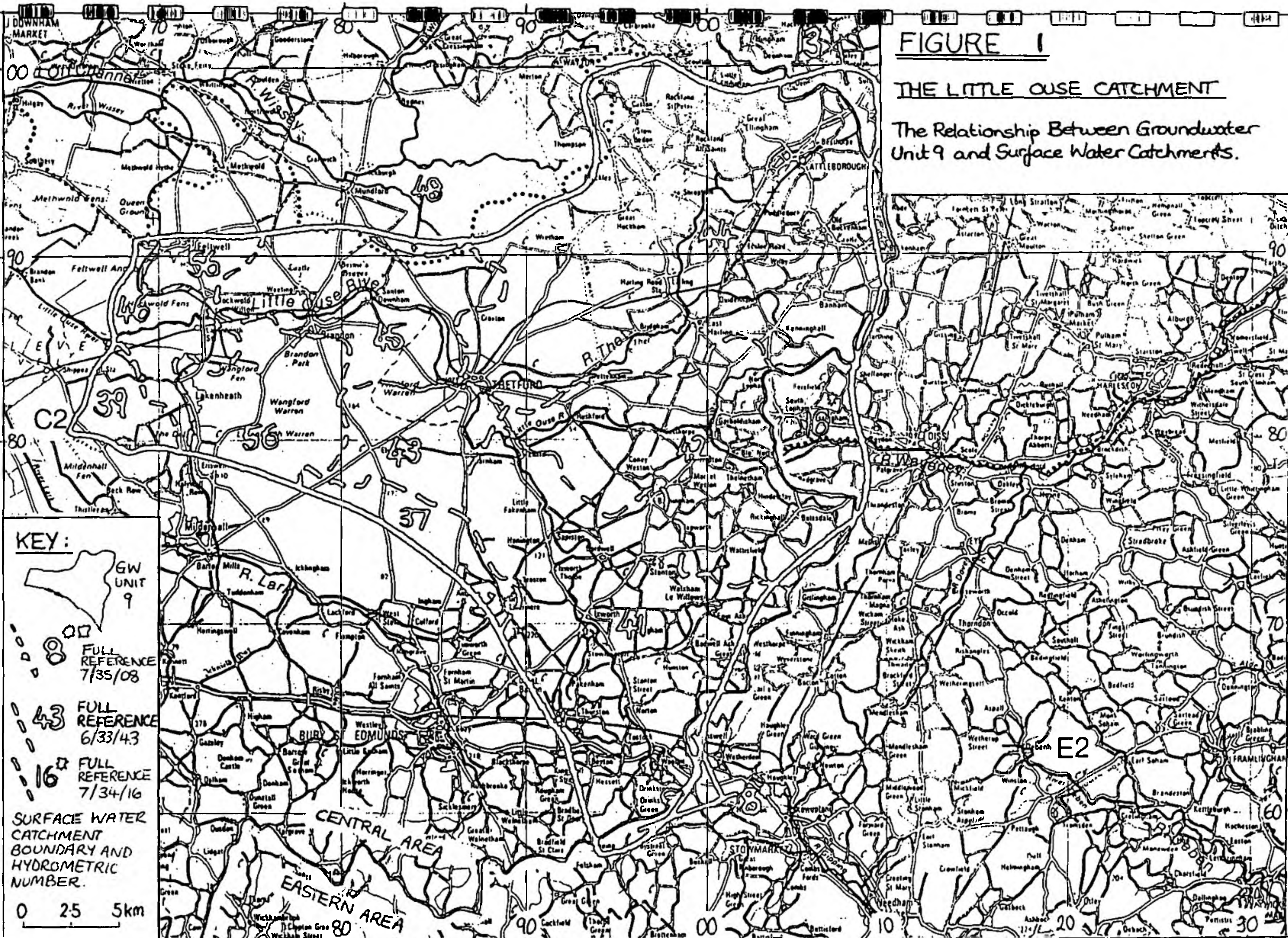
iii. The legal status of the 'Cambridge reduction' should be reviewed. (1994)

iv. The management of the Great Ouse Groundwater Scheme should be reviewed. This would follow the acquisition of information gained from the "In River Needs" study, analysis of net gain and interpretation from the regional groundwater model. (1998)

FIGURE 1

THE LITTLE OUSE CATCHMENT

The Relationship Between Groundwater Unit 9 and Surface Water Catchments.



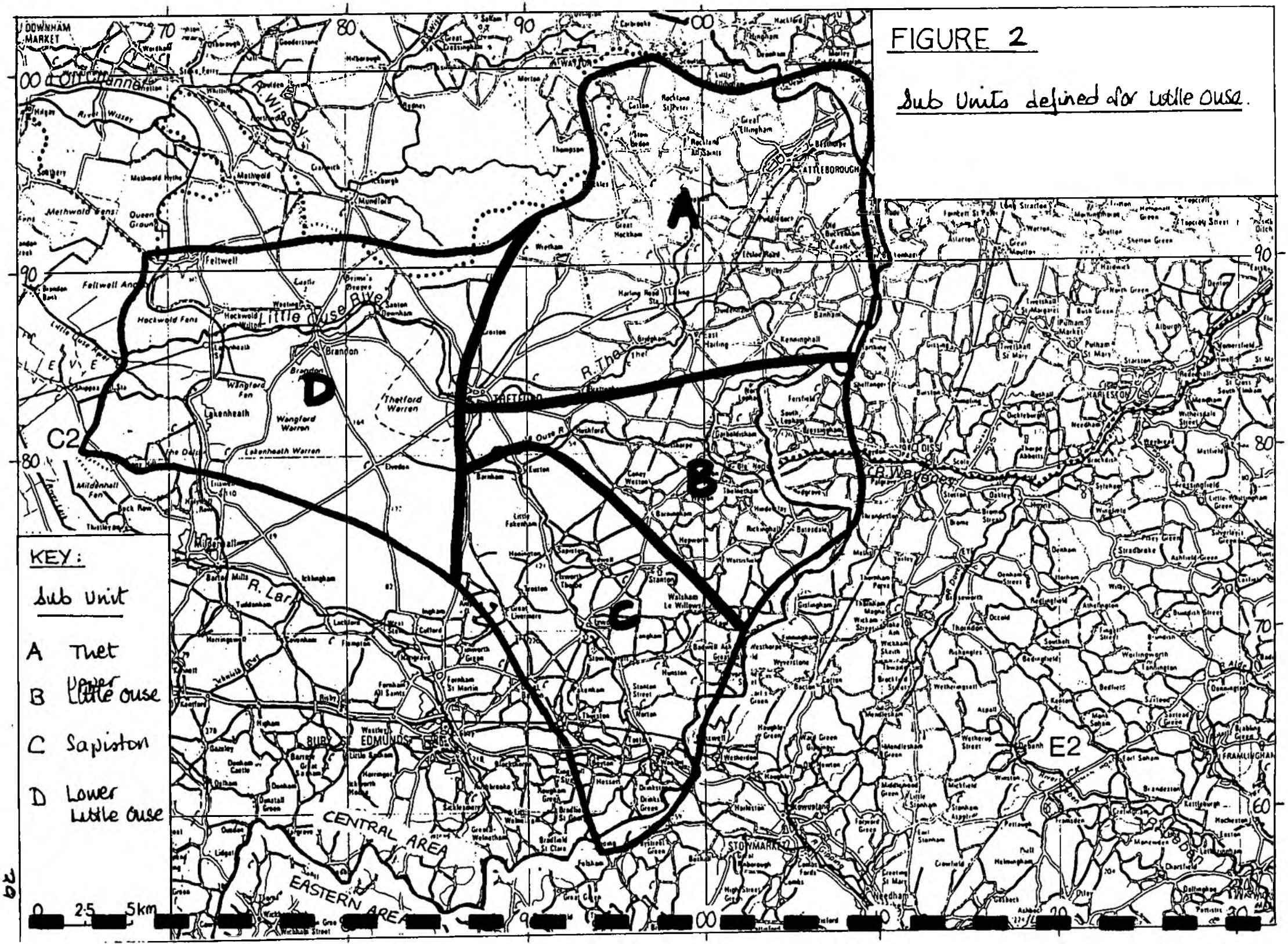


FIGURE 2
Sub Units defined for Little Ouse.
KEY:
Sub Unit
A Thet
B Lower Little Ouse
C Sapiston
D Lower Little Ouse
Little Ouse River
R. Thet
Brandon
Thetford
Lakenheath
Wangford Warren
Thetford Warren
Lakenheath Warren
Hockwold Fens
Feltwell Anchor
Methwold Fens
Mundford
Feltwell
Ouse R.
R. Lark
R. Waveney
DISS
HARLESTON
ATTLEBOROUGH
BURY ST EDMUNDS
STOWMARKET
FRAMLINGHAM
CENTRAL AREA
EASTERN AREA
C2
E2
0 2·5 5km

FIGURE 3

GEOLOGY

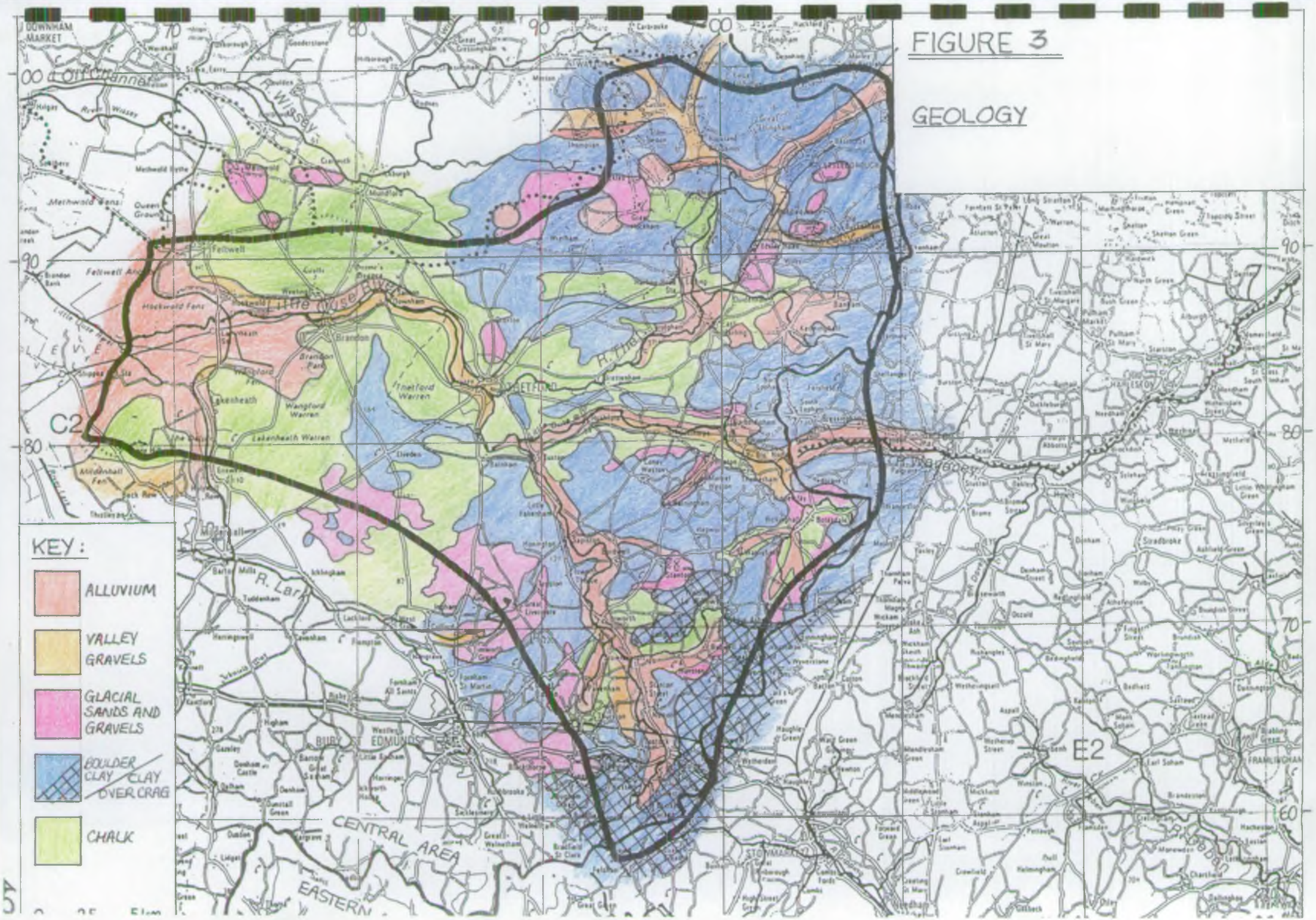


TABLE 1 : LITTLE OUSE GROUNDWATER CATCHMENT - WATER LEVEL DATA

Well Reference	National Grid Ref.	Water Level Apr '88	Water Level Sep '91	Well Reference	National Grid Ref.	Water Level Apr '88	Water Level Sep '91
TM 05/49/30	TM 0439 5902	28.95	28.34	TL 89/12	TL 875 948	25.75	
TM 05/96/00	TM 0901 5600	23.45		TL 89/14	TL 898 948	28.46	26.82
TM 06/02/88	TM 008 628	41.87	40.94	TL 89/15	TL 853 949	21.97	19.46
TM 15/26/01	TM 1201 5618	26.12	25.04	TL 89/17	TL 862 948	21.22	20.06
TM 15/53/24	TM 1528 5349	32.25	31.26	TL 89/18	TL 864 963	21.39	20.42
TM 15/54/81	TM 1580 5415	36.15	34.88	TL 89/19	TL 878 978	28.29	23.23
TM 15/85/72	TM 1871 5522	32.15	32.32	TL 89/20	TL 889 930	28.80	22.98
TM 16/51/38	TM 1537 6180	47.06	45.75	TL 89/25	TL 851 908	29.12	
TM 16/72/96	TM 179 626	31.40	30.14	TL 99/02	TL 958 941	35.10	
TM 16/74/62	TM 1764 6427	31.72	31.37	TL 99/03	TL 999 939	29.96	23.67
TM 16/74/62	TM 1746 6427	32.07		TL 99/04	TL 918 968	34.06	29.93
TM 16/82/13	TM 181 623	34.14	30.19	TL 99/05	TL 924 994	45.60	39.82
TM 26/32/36	TM 233 626	27.64	25.96	TL 99/06	TL 935 918	31.97	31.62
TM 26/40/96	TM 2490 6065	32.12	28.47	TL 99/07A	TL 937 983	47.25	41.83
TM 26/41/60	TM 2461 6109	24.27	22.18	TL 99/07B	TL 937 983	47.39	43.92
TM 26/51/16	TM 2510 6164	26.49	23.51	TL 99/08	TL 943 964	39.83	36.26
TM 26/73/89	TM 278 639	27.30	26.72	TL 99/09	TL 960 975	38.13	35.75
TL 68/01	TL 661 880	-1.17	-3.94	TL 99/10	TL 954 926	37.44	33.11
TL 69/04	TL 608 957	-.22	-.50	TL 99/13A	TL 970 921	26.12	26.08
TL 69/13	TL 699 955	-1.12	-1.15	TL 99/13B	TL 970 921	27.74	25.02
TL 69/18	TL 697 949		-.64	TL 99/15	TL 960 932	37.95	33.07
TL 69/18A	TL 693 943		-1.53	TL 99/16A	TL 923 927	34.75	31.19
TL 69/19A	TL 676 936		-1.53	TL 99/16B	TL 923 927	34.56	32.33
TL 79/02	TL 764 913	10.63	2.39	TL 99/17A	TL 915 976	40.68	39.98
TL 79/03	TL 799 914	14.23	5.32	TL 99/17B	TL 915 976	48.08	45.93
TL 79/04	TL 765 956	7.34		TL 99/18	TL 929 911	31.11	26.90
TL 79/05	TL 722 925	6.05		TL 99/19	TL 995 910	22.60	17.89
TL 79/07	TL 753 946	7.50		TL 99/20	TL 981 921	24.58	21.51
TL 79/08	TL 771 933	12.21		TL 99/21	TL 973 907	23.22	14.90
TL 79/10	TL 793 909	13.15	4.72	TL 99/22	TL 963 924	34.44	28.99
TL 79/11	TL 720 916	5.26	.28	TL 99/23	TL 954 916	27.35	22.90
TL 79/12	TL 709 918	2.05	-.18	TL 99/24	TL 930 923	34.29	30.21
TL 79/13	TL 708 944	-.03	-.30	TL 99/25	TL 973 934	33.68	31.71
TL 79/14	TL 719 941	2.83	.13	TL 99/26	TL 921 905	29.57	24.85
TL 79/18	TL 739 921	8.02		TL 99/27	TL 916 973	40.33	35.40
TL 79/20	TL 760 934	10.93	3.73	TL 99/28	TL 949 902		23.17
TL 79/21	TL 764 914	10.42	2.23	TL 99/29	TL 941 907		21.20
TL 79/24	TL 766 993	7.01	6.19	TL 99/30	TL 938 900		22.22
TL 79/31	TL 799 935	12.78	8.82	TL 99/31	TL 937 931	34.55	31.90
TL 79/76	TL 708 948	-.24	-.26	TL 99/32	TL 940 944	36.13	32.69
TL 79/95	TL 793 973		16.53	TL 99/34	TL 914 946	31.32	27.81
TL 79/128	TL 700 950		-.12	TL 99/147	TL 967 994		44.03
TL 89/01	TL 817 900	13.74	6.08	TM 17/26/88	TM 129 769		30.04
TL 89/02	TL 835 945	13.62	12.45	TM 17/33/00	TM 130 730		30.60
TL 89/03	TL 813 967	15.97		TM 17/50/76	TM 157 706	30.75	30.32
TL 89/04	TL 836 921	20.92	13.43	TM 17/69/70	TM 167 790	25.73	
TL 89/05	TL 819 991	20.02		TM 17/33/00	TM 130 730	33.39	
TL 89/06	TL 813 949	11.39		TM 18/93/25A	TM 192 836		19.54
TL 89/07	TL 837 917	21.90		TM 18/93/46A	TM 195 836	18.07	18.48
TL 89/08	TL 813 949	32.86	25.76	TM 18/94/38	TM 193 848		14.11
TL 89/11	TL 886 952	26.25		TM 18/96/80	TM 198 860	35.65	33.38

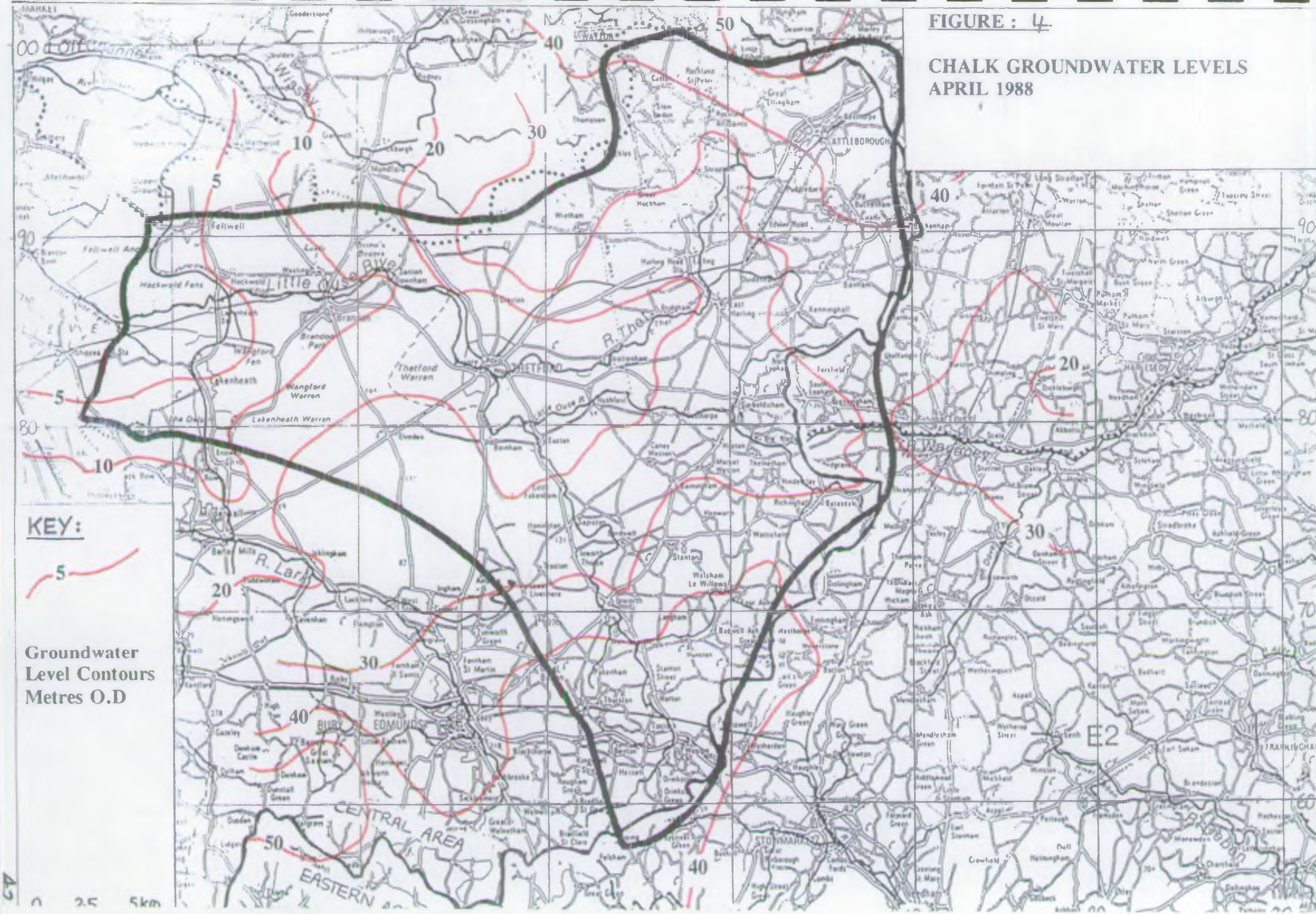


FIGURE : 4

CHALK GROUNDWATER LEVELS
APRIL 1988

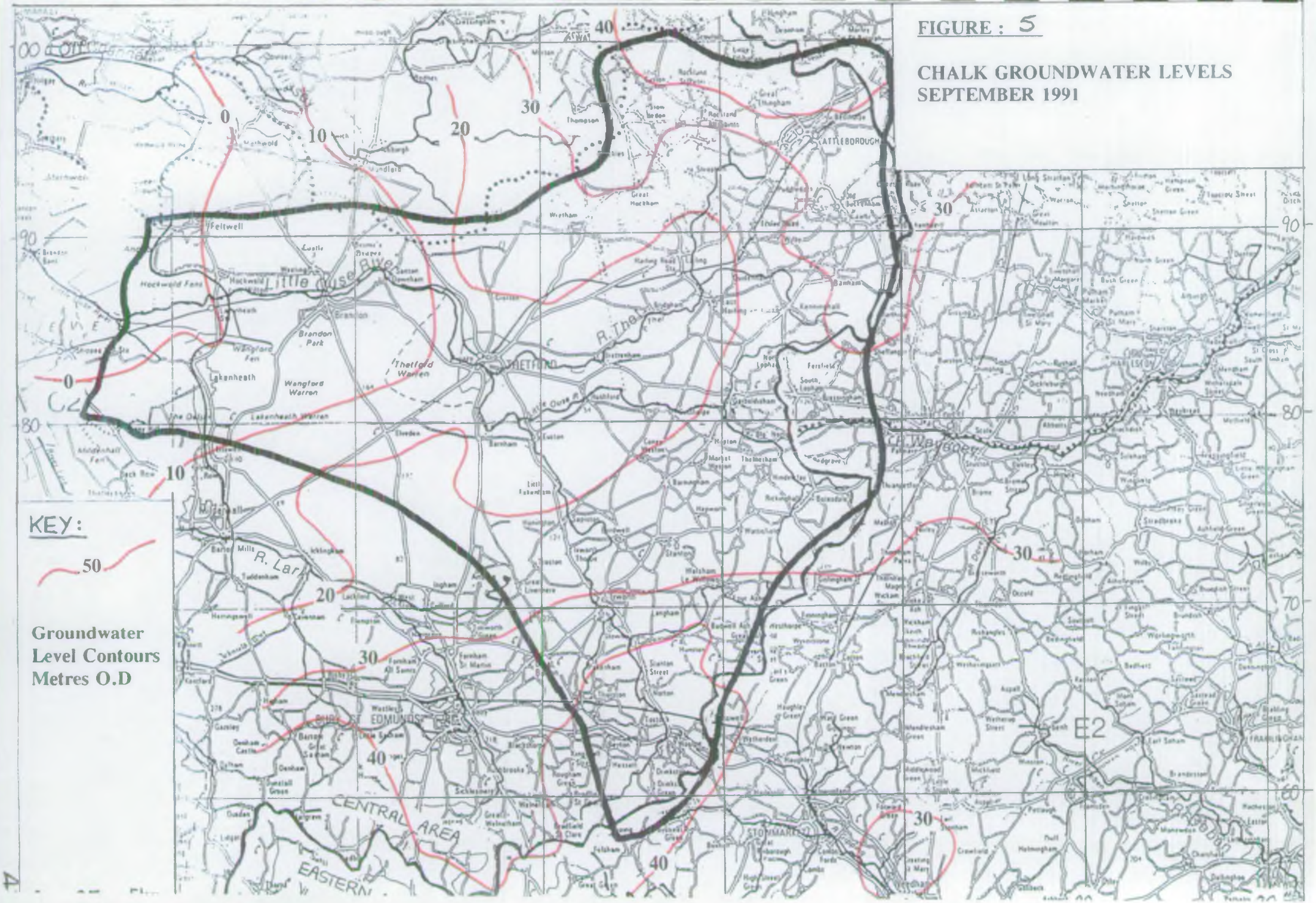


FIGURE : 5
CHALK GROUNDWATER LEVELS
SEPTEMBER 1991
KEY:
50
Groundwater
Level Contours
Metres O.D
0
10
20
30
40
THETFORD
ATTLEBOROUGH
Brandon
Wangford Warren
Lakenheath
Feltwell
Mildenhall
BURY ST EDMUNDS
CENTRAL AREA
EASTERN
R. Lark
R. Thet
Little Ouse
E2

FIGURE 6

Gauging Stations and Current Metering Sites

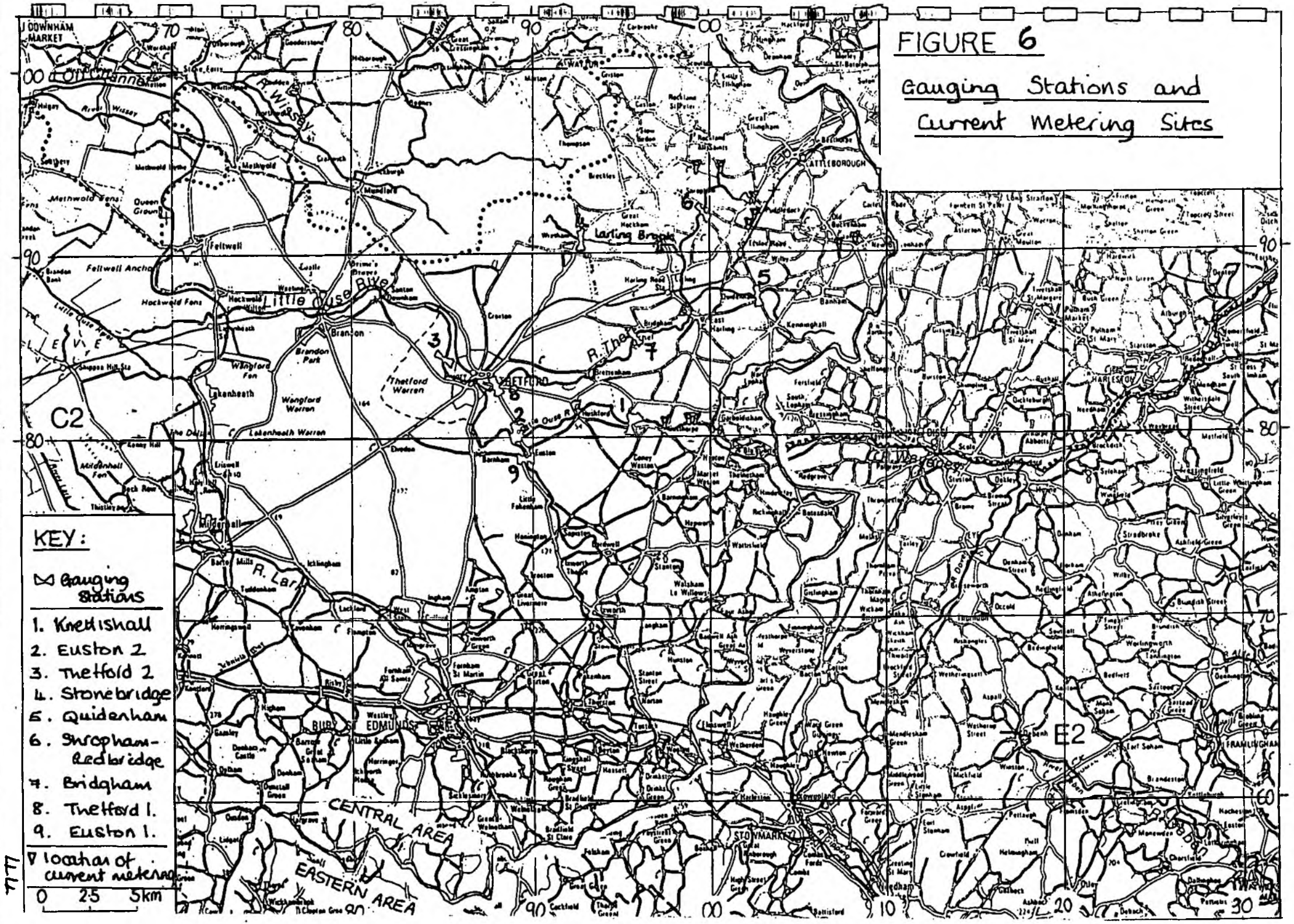


FIGURE 7 : FLOW DURATION CURVE

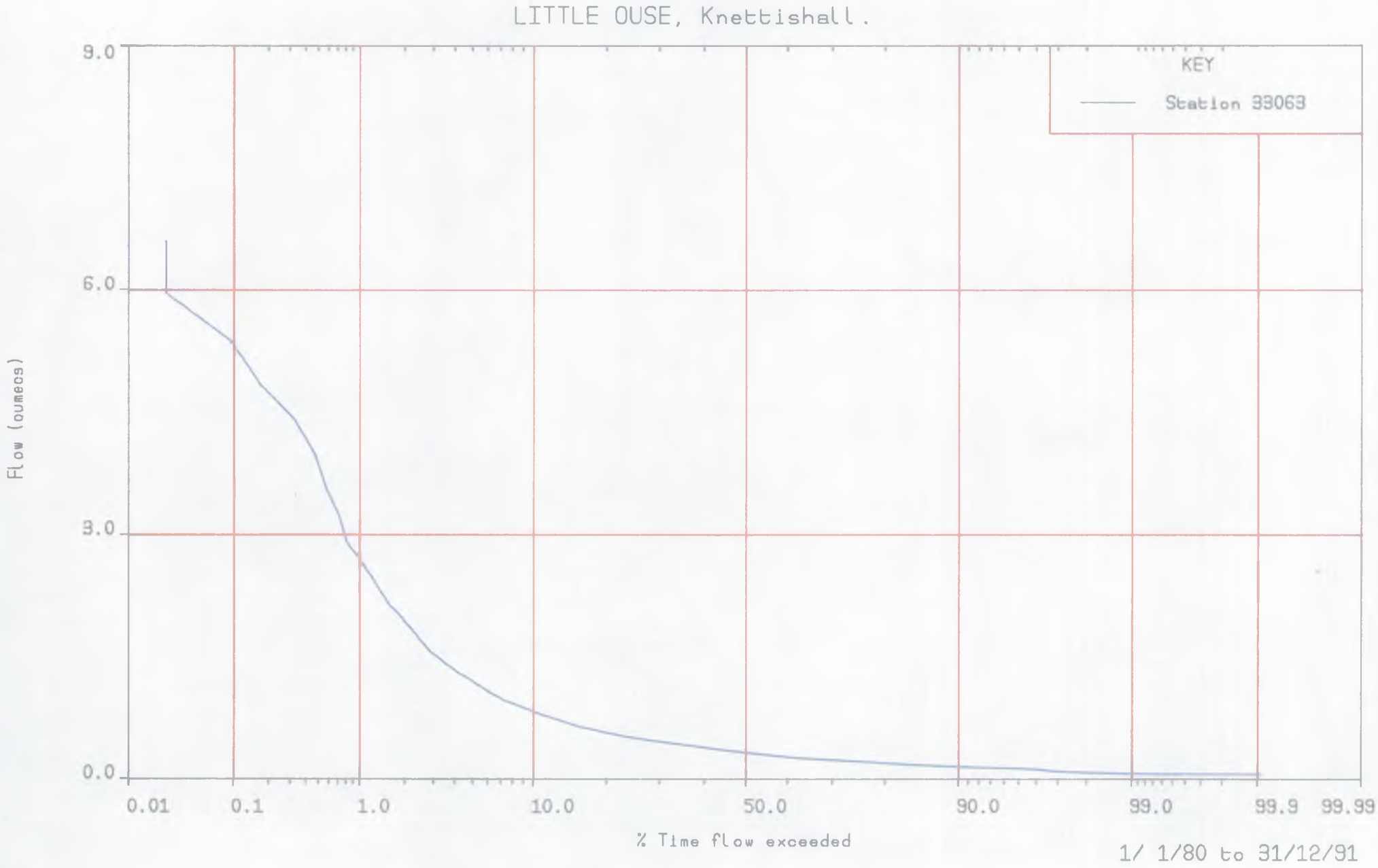


FIGURE 8 : FLOW DURATION CURVE

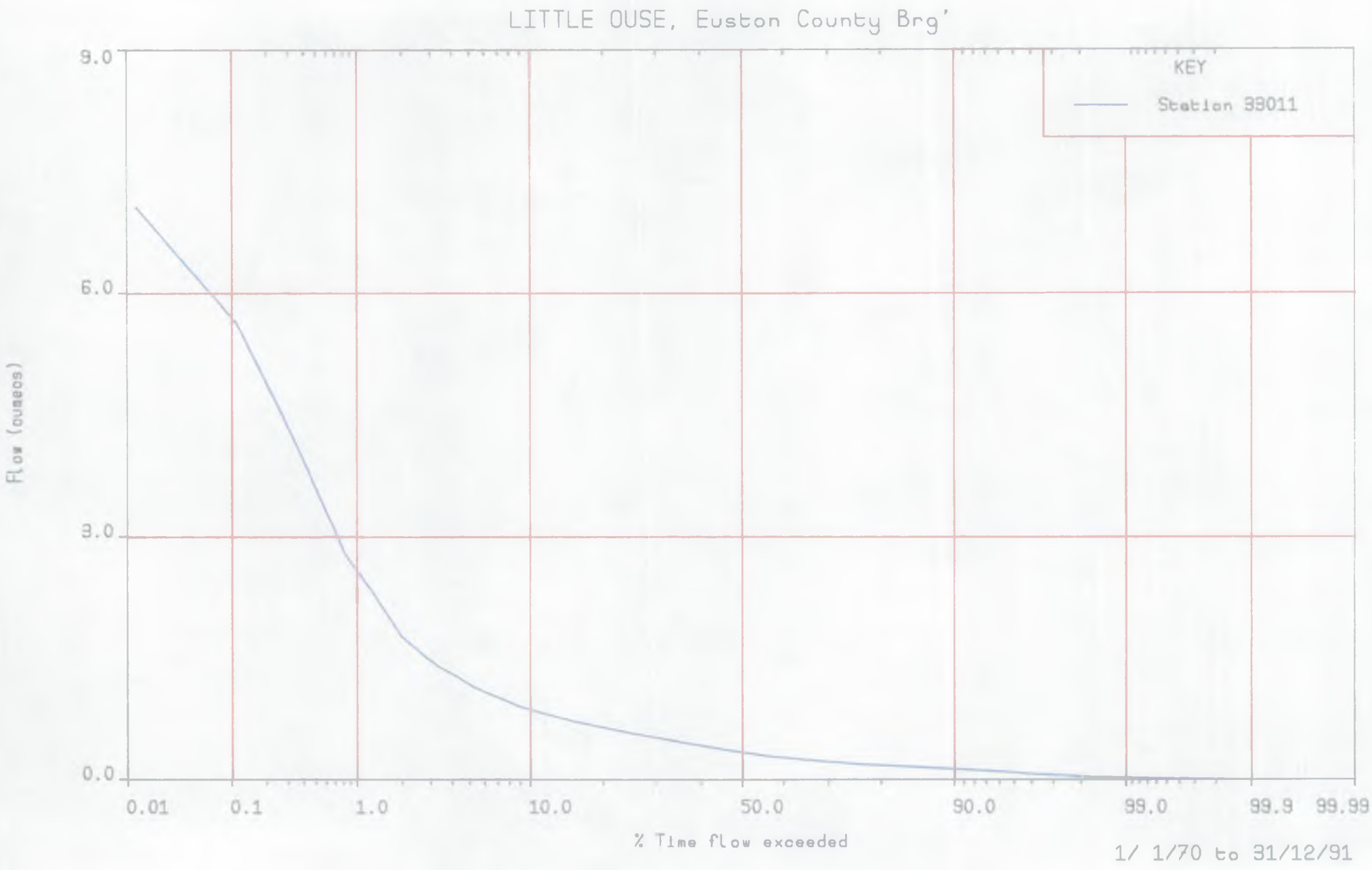
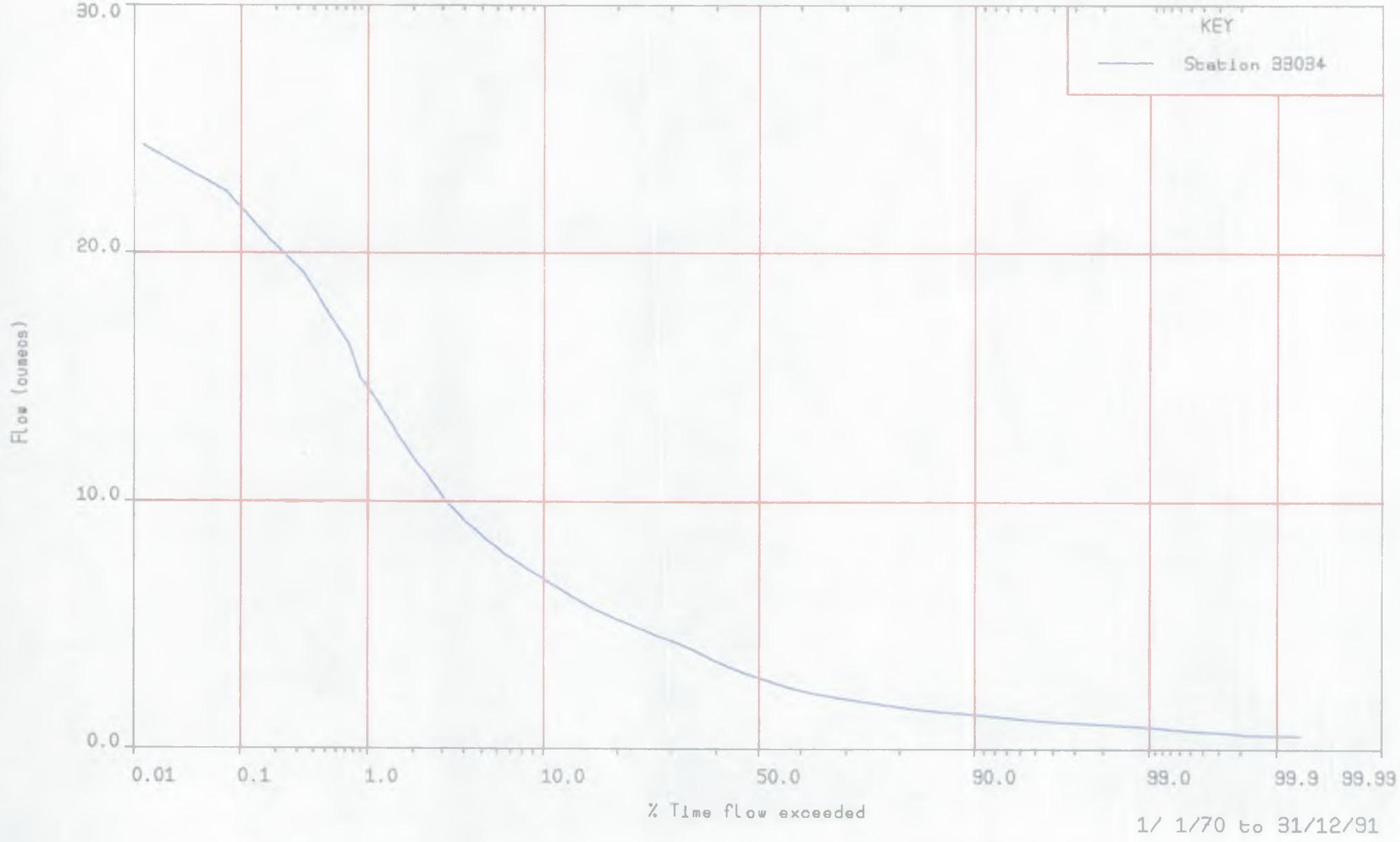


FIGURE 9: FLOW DURATION CURVE

LITTLE OUSE, Abbey Heath.



1/ 1/70 to 31/12/91

FIGURE 10 : FLOW DURATION CURVE

LARLING BROOK, Stonebridge.

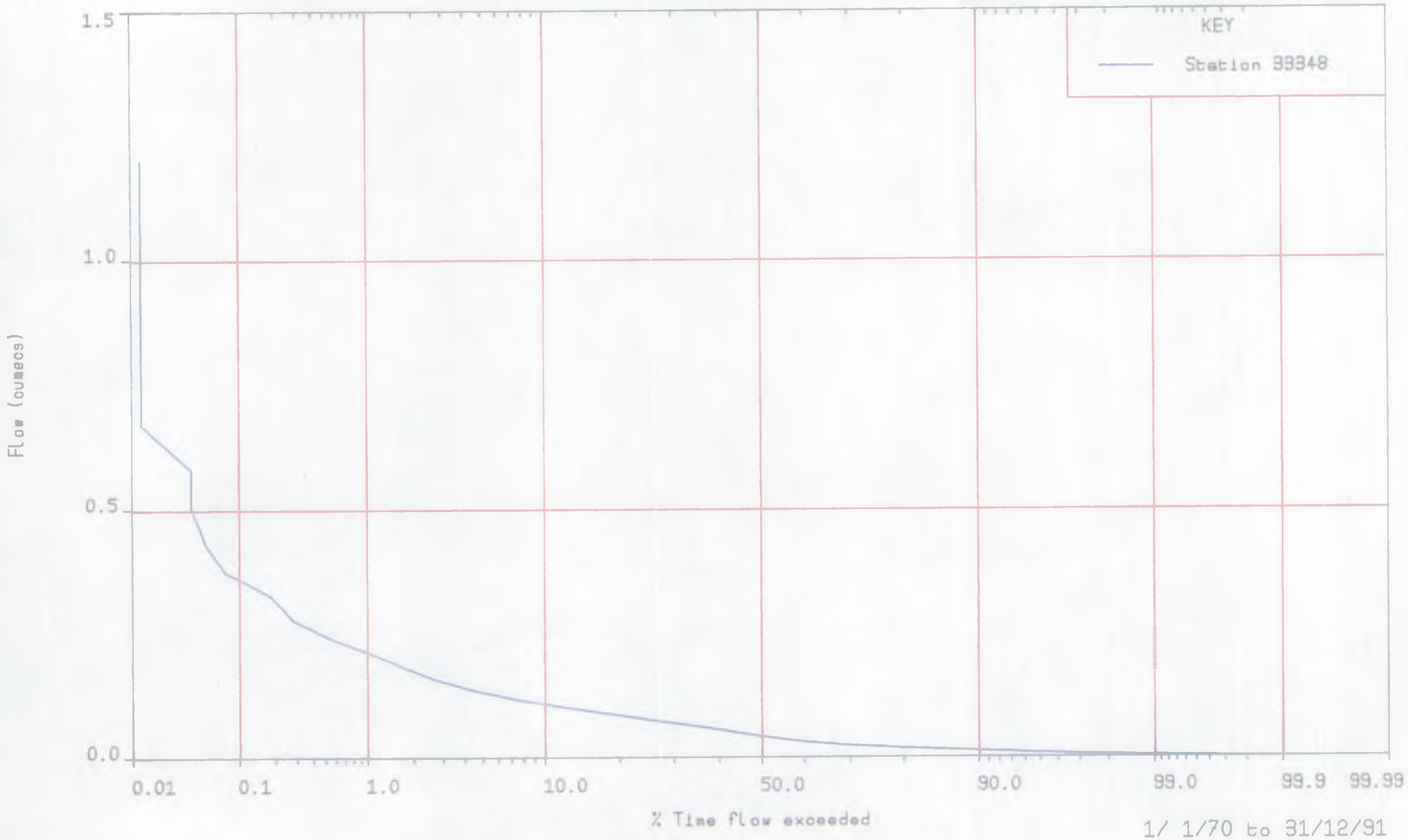
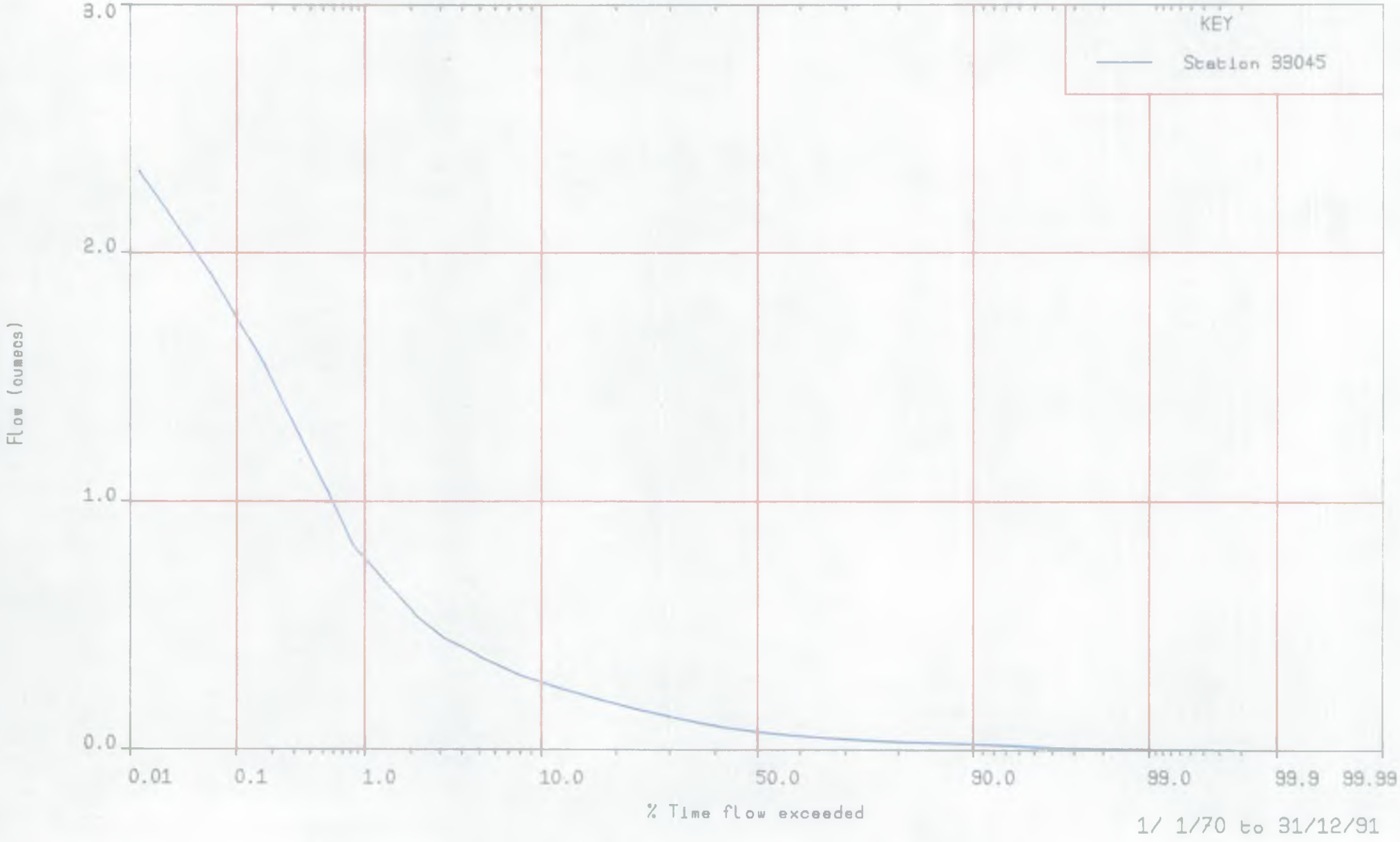


FIGURE 11 : FLOW DURATION CURVE

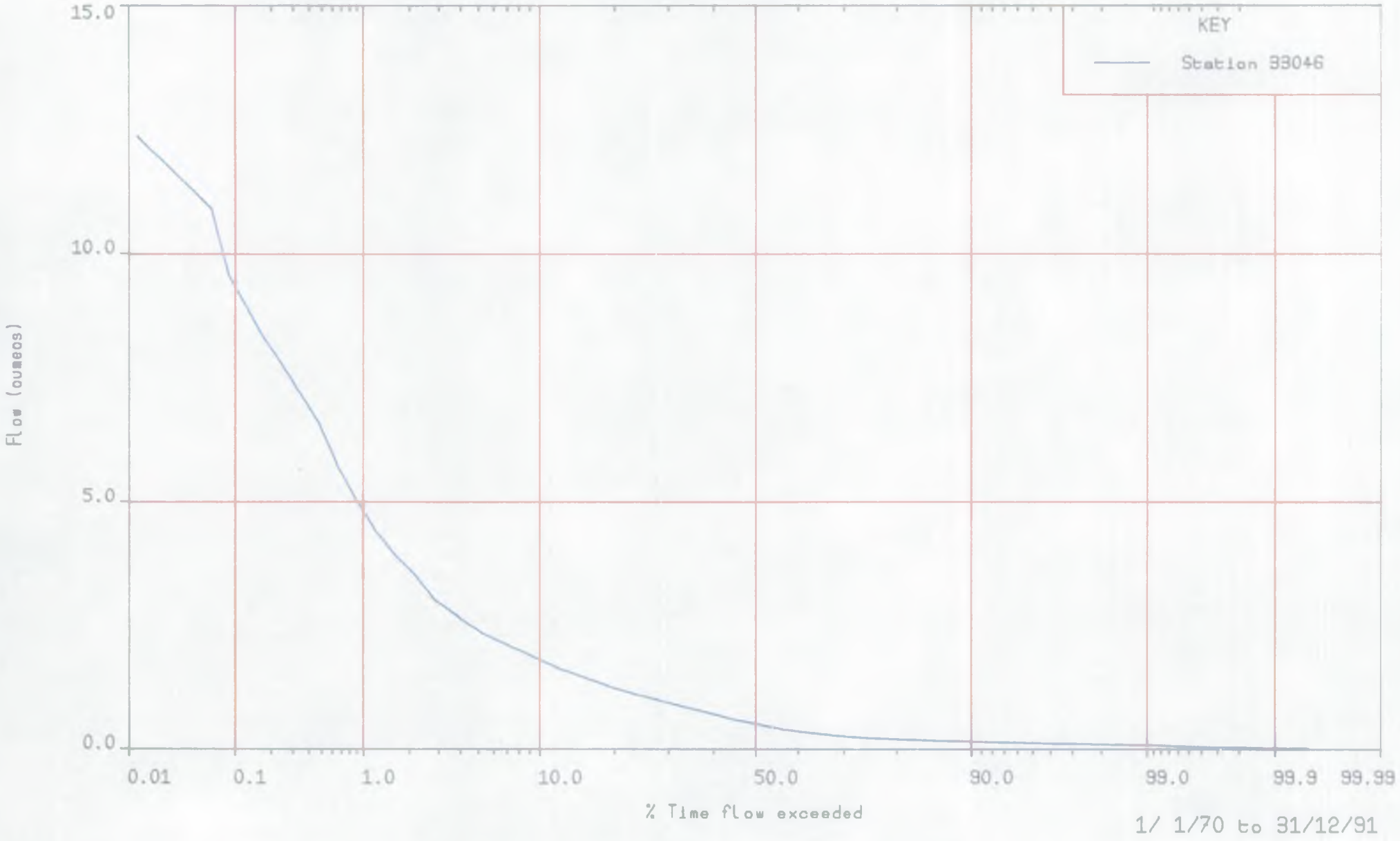
R. WITTLE, Quidenham.



1/ 1/70 to 31/12/91

FIGURE 12 : FLOW DURATION CURVE

R. THET, Redbridge.



1/ 1/70 to 31/12/91

FIGURE 13 : FLOW DURATION CURVE

R. THET, Bridgham.

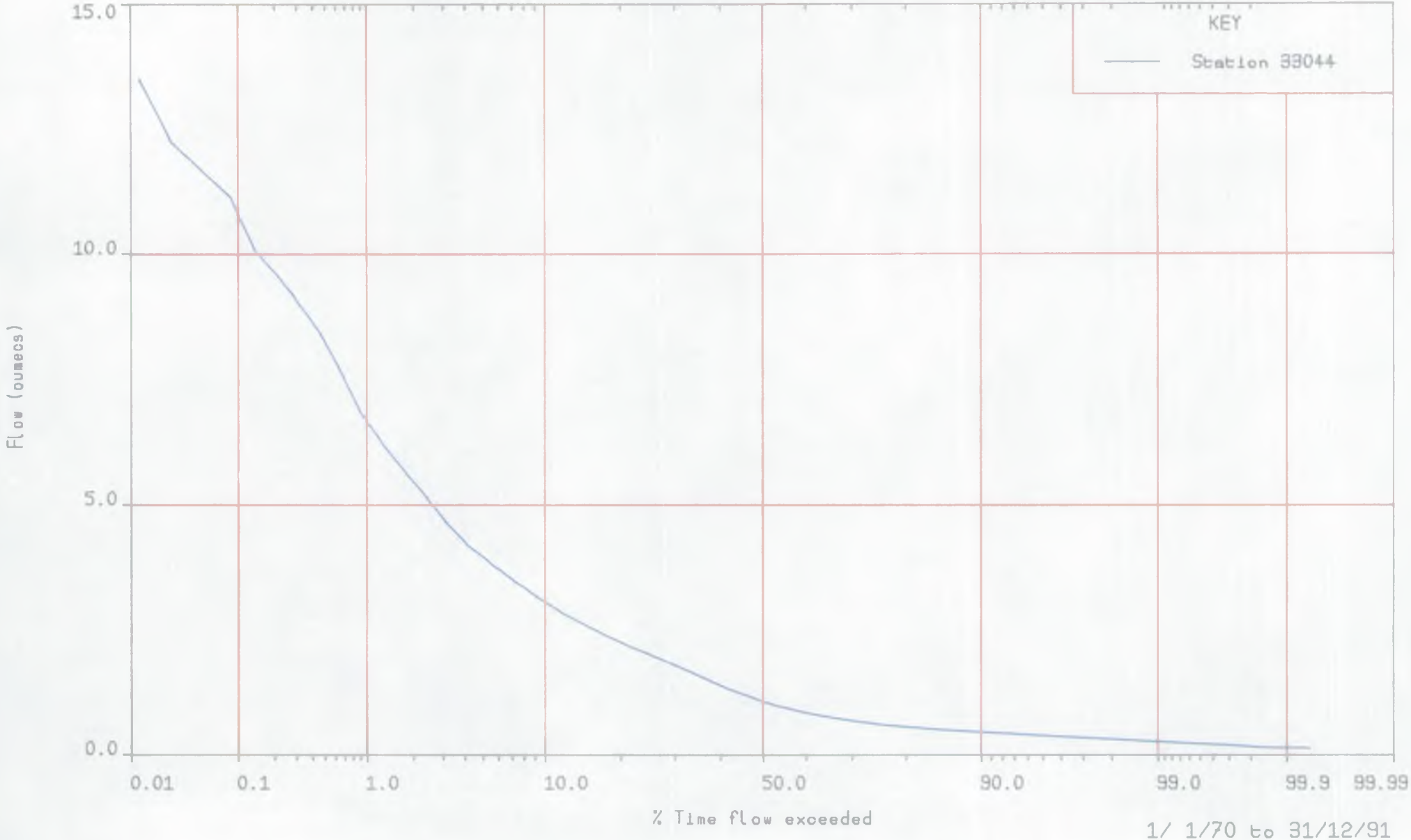


FIGURE 11.1 : FLOW DURATION CURVE

R. THET, Melford Bridge.

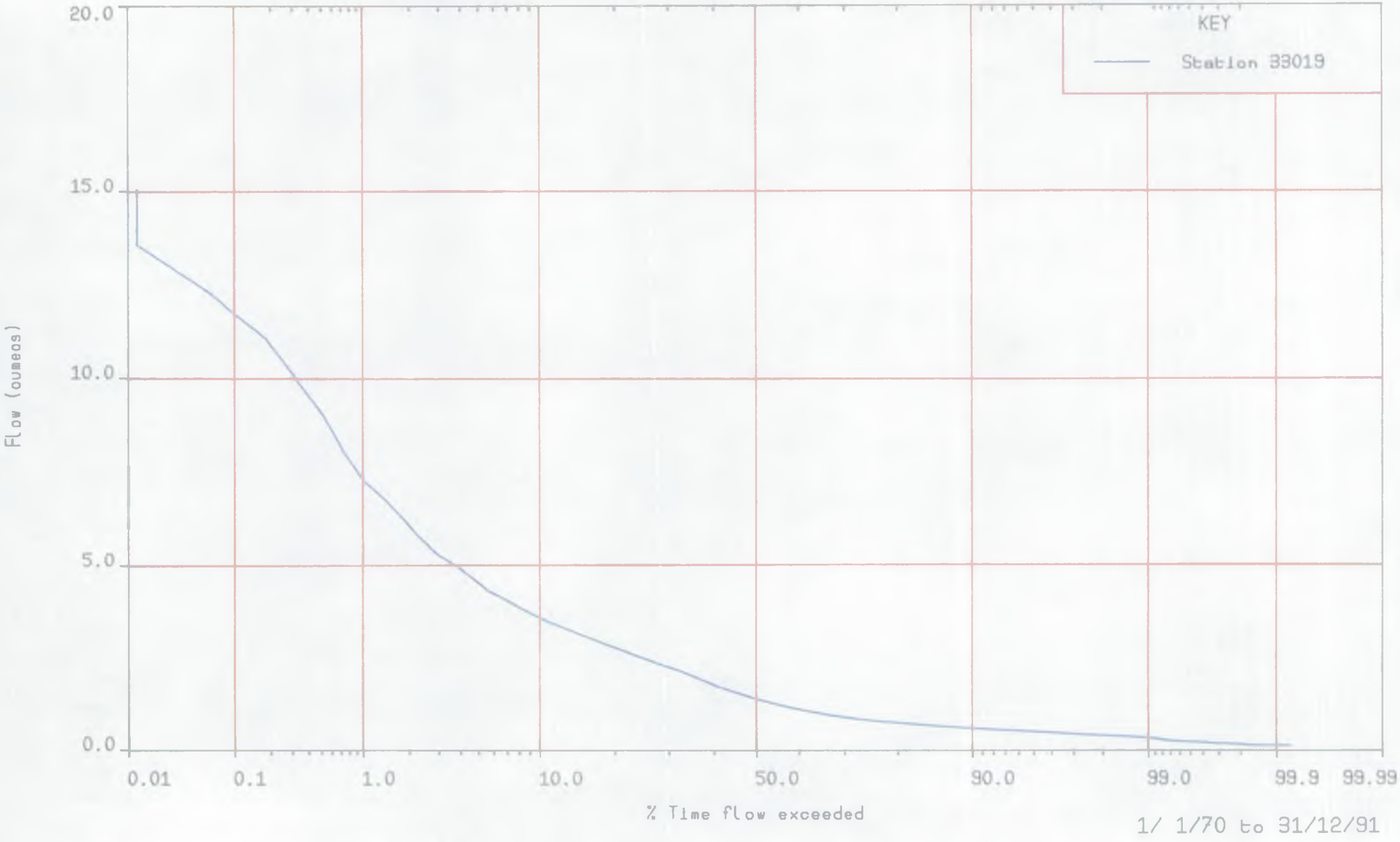
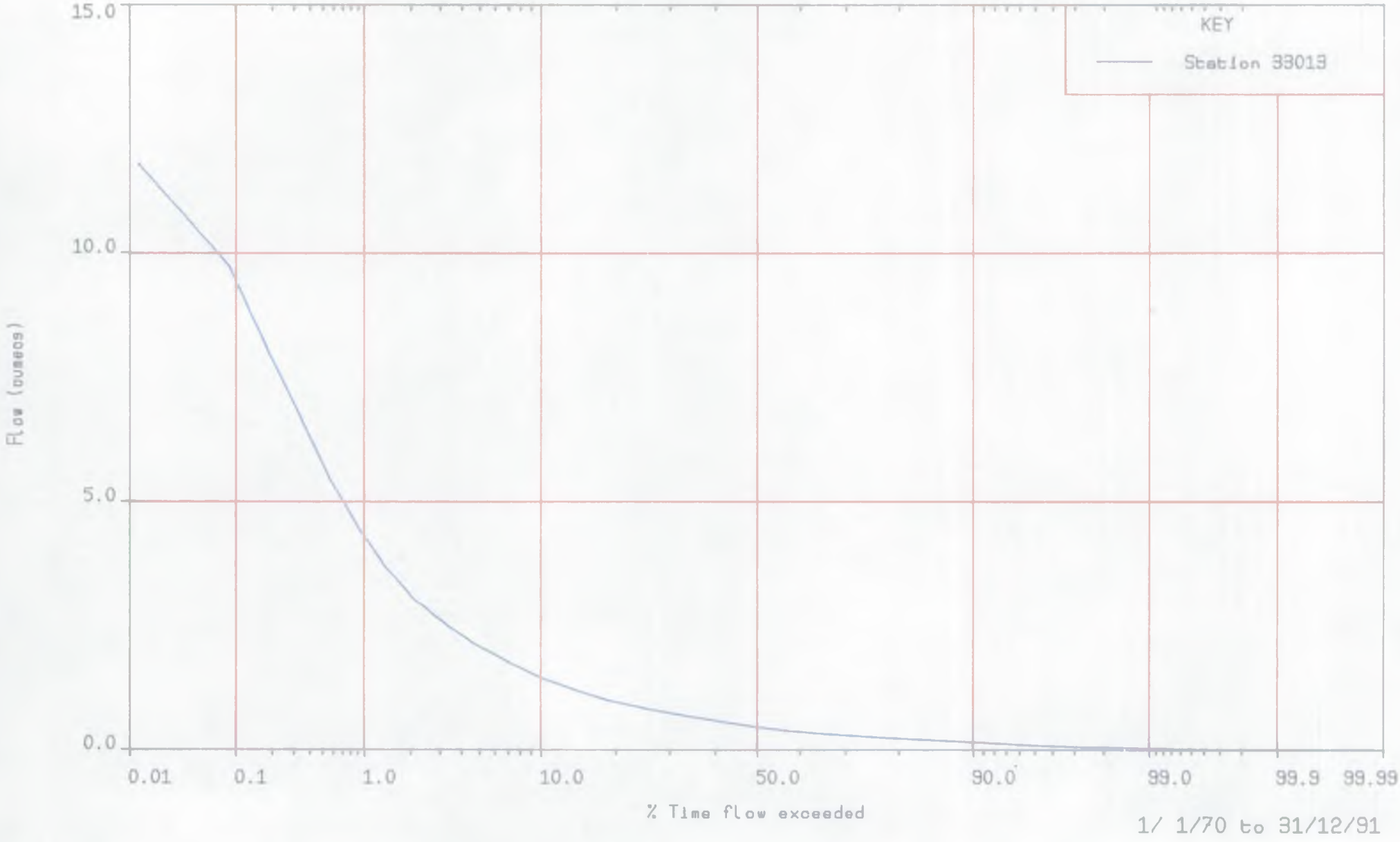


FIGURE 15 : FLOW DURATION CURVE.

R. SAPISTON, Rectory Bridge.



1/ 1/70 to 31/12/91

FIGURE 16

ABBEY HEATH GAUGING STATION

(Daily Flow at the time = 5.58 cumecs = 482 cumd)

Looking Upstream TL 851 845 November 1992

Looking Downstream TL 851 845 November 1992.

TABLE 8

RIVER QUALITY OBJECTIVES

RIVER	STRETCH	STRETCH LENGTH (km)	RECOGNISED RIVER USES
Sapiston River and Tributaries			
Elmswell Tributary	Headwaters - Norton/Thurston Road Bridge	6	SI,LW,MA
Trib R.Sapiston	Hardings Farm - R.Sapiston	3	LA
Sapiston River	Norton/Thurston Road Bridge - Stowlangtoft Stream	2.5	F_2,SI,LW,MA
Stowlangtoft Stream	Walsham le Willows - Hunston/Langham Road Bridge	5	SI,LW,MA
Stowlangtoft Stream	Hunston/Langham Road Bridge - Sapiston River	3	F_2,SI,LW,MA
Sapiston River	Stowlangtoft Stream - Pakenham Stream	1.5	F_2,SI,LW,MA
Pakenham Stream	Pakenham Stream	5	F_2,SI,LW,MA
Tributary of Pakenham Stream)	Thurston - Pakenham Stream	1.5	SI,LW,MA
Sapiston River	Pakenham Stream - R.Little Ouse	15	F_2,SI,LW,MA
Stanton Tributary	Stanton Tributary	4.5	SI,LW,MA
Trib Stanton Brook	Headwaters - Stanton Brook	4	MA
Botesdale Brook	Headwaters - Broom Hills, Botesdale	2	SI,LW,MA
Little Ouse River and Botesdale Brook (part of)	Broom Hills, Botesdale - Knettishall Heath Road Bridge	11	F_2,SI,LW,HA
Grundle Beck	Grundle Beck	3.5	SI,LW,MA
Weston Fen Beck	Weston Fen Beck	4	SI,LW,HA
Little Ouse River	Knettishall Heath Road Bridge - Sapiston River	8	F_2,SI,LW,MA
R.Little Ouse	Sapiston River - R.Thet	6	F_2,SI,LW,HA
Hunwell Brook	Hunwell Brook	3	SI,LW,MA
River Thet and Tributaries			
R.Thet	Attleborough - Portwood Brook	4	SI,LW,MA
Portwood Brook	Portwood Brook	3.5	SI,LW,HA
Trib Portwood Brook	Headwaters - Portwood Brook	1	MA
R.Thet	Portwood Brook - R.Whittle	9	F_2,SI,LW,HA
Melsop Stalland River	Melsop Stalland River	14	SI,LW,MA
Trib Melsop Stalland River	Frostrow Farm - Melsop Stalland River	1	LA
Trib Melsop Stalland River	Caston - Melsop Stalland River	1	MA
Cranberry Carr	Cranberry Rough-Melsop Stalland River	4.5	SI,LW,HA
Trib Melsop Stalland River	Rocklands - Melsop Stalland River	2	MA
Buckenham Stream	Buckenham/Attleborough-Pettle Bridge, Attleborough	11	SI,LW,MA
Buckenham Fen Brook	Bunn's Bank Attleborough - Pettle Bridge Attleborough	6	SI,LW,MA
Buckenham Stream	Pettlebridge, Attleborough - R.Thet	2	F_2,SI,LW,MA
Larling Brook	Mickle Mere, Wretham - Knights Fen, Hockham	8	SI,LW,MA
Larling Brook	Knights Fen, Hockham - R.Thet	2	F_2,SI,LW,MA
R.Whittle	Headwaters - Quidenham	8	SI,LW,MA
R.Whittle	Quidenham - R.Thet	4.5	F_2,SI,LW,MA
R.Thet	R.Whittle - R.Little Ouse	15	F_2,SI,LW,HA
R.Little Ouse	R.Thet - Brandon	13	F_2,SI,HA
R.Little Ouse	Brandon - Little Ouse Syphon	6	F_2,SI,LW,MA
Tributary of Little Ouse	Weeting - R.Little Ouse	1.5	LA
R.Little Ouse	Little Ouse Syphon - Ten Mile River	16	F_2,SI,LW,HA
Twelve Foot Drain	Headwaters - Railway Bridge	2.5	SI,MA
Twelve Foot Drain	Railway Bridge - R. Little Ouse	1.5	F_2,SI,HA

KEY :

F_1	fisheries supporting a breeding population of trout/grayling
F_2	fisheries supporting a breeding population of non-salmonid fish
IWS	industrial water supply
SI	spray irrigation
LW	livestock watering
HA	high amenity
MA	Moderate amenity
LA	low amenity

TABLE 9 : National Water Council River Quality Classification

National Water Council River Quality Class	Summary Description	Full Description
1A	Good Quality	Water of high quality suitable for potable supply abstractions, high class fisheries (trout) and high amenity value.
1B	Good Quality	Water of less high quality than Class 1A but usable for substantially the same purposes as Class 1A.
2	Fair Quality	Waters suitable for potable supply after advanced treatment but supports a reasonable coarse fishery.
3	Poor Quality	Waters which are polluted to an extent that fish are absent or only sporadically present; may be used for low grade industrial abstraction purposes.

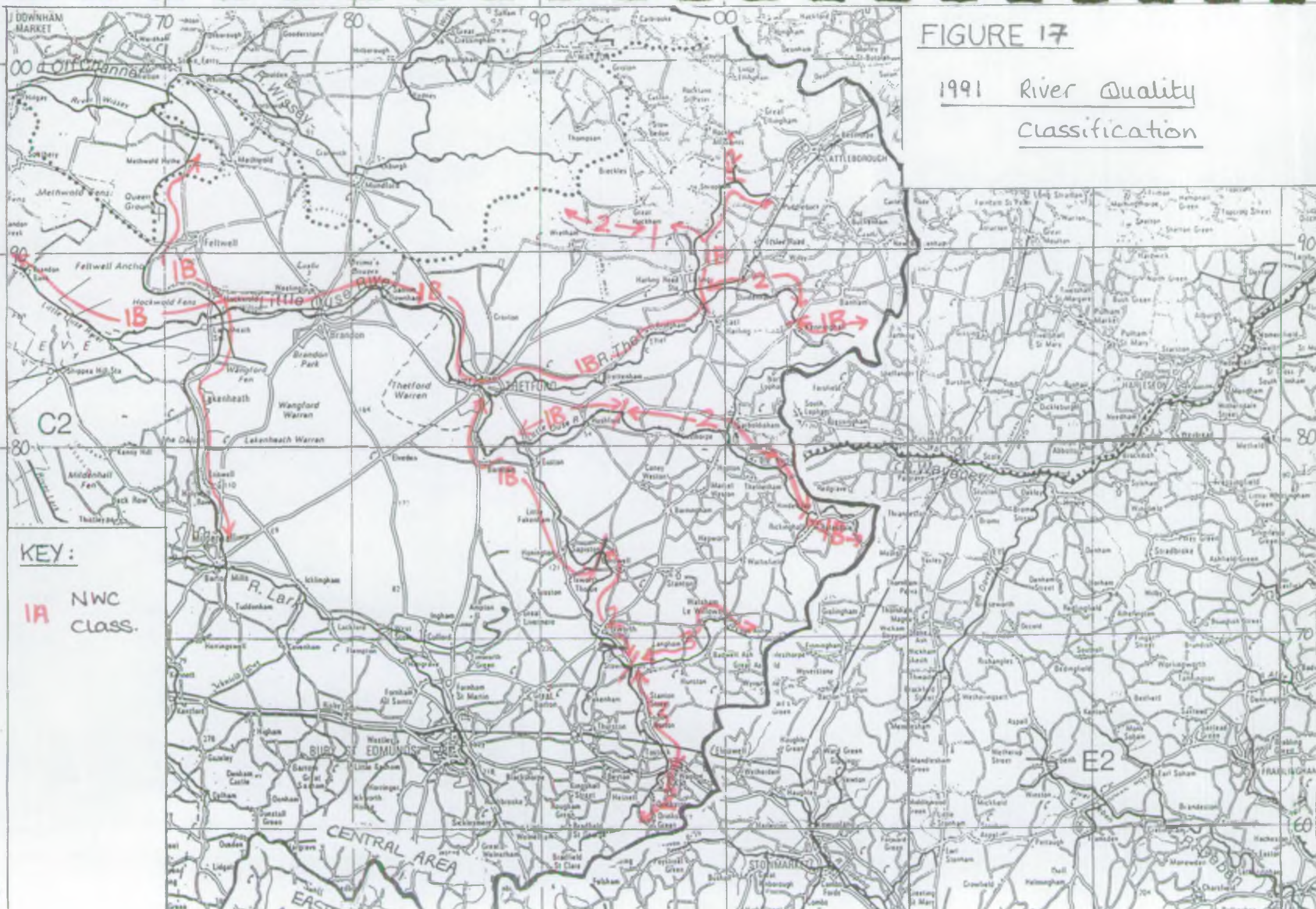


FIGURE 17

1991 River Quality Classification

TABLE 10 : Discharges Made to the Little Ouse System

Map Ref.	Site Name	Nat. Grid Ref.	Dry Weather Flow (m^3/d)
A. Sewage Treatment Works (Anglian Water Services Ltd.)			
1.	Attleborough	TM 041 937	0.0
2.	Hockham	TL 951 916	75.0
3.	Old Buckenham	TM 061 904	550.0
4.	East Harling	TM 009 881	410.0
5.	Great Ellingham	TM 023 978	110.0
6.	Besthorpe (Bunwell Road)	TM 072 957	0.0
7.	Besthorpe (Norwich Road)	TM 072 975	0.0
8.	Bridgham	TL 961 859	0.0
9.	Little Ellingham	TM 004 991	0.0
10.	Caston	TL 962 976	15.0
11.	Kenninghall	TM 039 865	0.0
12.	Griston	TL 943 997	0.0
13.	Griston Longmeadow	TL 943 988	0.0
14.	Kenninghall School	TM 037 858	22.0
15.	Quidenham	TM 037 858	0.0
16.	Rocklands (Rectory Road)	TL 988 962	0.0
17.	Rocklands (Wayland Road)	TL 993 973	0.0
18.	Rouldham	TL 977 879	0.0
19.	Scoulton	TL 983 934	0.0
20.	Snetterton	TL 996 921	0.0
21.	Stow Bedon Mere	TL 949 965	0.0
22.	Stow Bedon Station	TL 944 963	0.0
23.	Badwell Ash	TL 992 698	290.0
24.	Elmswell	TL 978 663	1100.0
25.	Honington	TL 915 748	99.0
26.	Norton	TL 951 670	154.0
27.	Stanton	TL 920 736	1500.0
28.	Thurston	TL 917 668	1200.0
29.	Barnham	TL 871 795	136.0
30.	Lakenheath	TL 708 840	760.0
31.	Bressingham (School Road)	TM 077 813	0.0
32.	Fersfield	TM 067 833	0.0
33.	North Lopham (Kings Head Lane)	TM 034 833	0.0
34.	North Lopham (The Street)	TM 038 829	0.0
35.	South Lopham (Blo Norton Road)	TM 038 811	0.0
36.	South Lopham (Church Road)	TM 042 817	0.0
37.	Weeting	TL 769 877	420.0
38.	Brandon	TL 776 965	2006.0
39.	Thetford	TL 835 835	5250.0
40.	Croxton (Church Avenue)	TL 872 872	0.0
41.	Croxton (Breckworth House)	TL 872 872	0.0
42.	Two Mile Bottom	TL 853 864	0.0

TABLE 10 : Discharges Made to the Little Ouse System

Map Ref.	Site Name	Nat.Grid Reference	Dry Weather Flow (m^3/d)
B. Trade Effluents.			
1.	Bayer Uk Ltd. Thurston	TL 941 659	0.0
2.	Hardings Farm Pigs Ltd. Norton	TL 984 657	4.1
3.	Nebbitts Fm Gt Ashfield Bury St Edmunds	TL 996 668	1.0
4.	Shepherd Grove Mushrooms Ltd. Stanton	TL 991 739	36.0
5.	Farm Kitchen Foods (Possible new owner)	TL 987 643	700.0
6.	Woolpit Heath Bungalow B.Squirrel	TL 987 615	0.0
7.	Mid Suffolk Daisy Green Great Ashfield	TM 007 676	0.0
8.	B.J Harper Wrens Hall Barn Farm	TL 984 720	0.0
9.	Beyton School Pool	TL 940 630	7.5
10.	Shepherd Grove Mushrooms Ltd. Stanton	TL 992 739	170.0
11.	Charrington Solid Fuels Ltd. Thurston	TL 915 668	0.0
12.	McGregor Warehousing Ltd. Stanton	TL 994 735	5.0
13.	Mid Suffolk DC N.Delight Rd. Rickinghall	TM 050 723	0.0
14.	Banham Poultry Produce Ltd	TM 062 937	410.0
15.	Buxtead Duckling Ltd	TM 012 994	218.0
16.	Breakland Lodge Motel	TM 025 929	35.0
17.	Frostrow Farm Hingham Shingfield	TM 007 007	59.0
18.	Watton Produce Co Ltd. Redbridge Shropham	TL 996 923	182.0
19.	Norfolk Area Health, Wayland Hospital	TM 028 962	0.0
20.	Mr Armitage, White Lodge Attleborough	TM 027 929	19.8
21.	Happy Eater A11 Besthorpe	TM 071 971	0.0
22.	DES.Banham Road Kenninghall	TM 038 862	0.0
23.	DES.Heath Farm Cottage Banham	TM 082 873	0.0
24.	Bay Cottage,Mkt Place Kenninghall	TM 038 861	3.0
25.	C.J.Wright Double Banks Fm Carleton	TM 091 936	12.0
26.	THF Ltd. Happy Eater A11 Besthorpe	TM 050 971	15.0
27.	Penwood Country Chickens Bunwell	TM 091 936	273.0
28.	Foulger Transport at Quidenham	TM 020 905	0.0
29.	Little Chef A11 Attleborough	TM 072 971	0.0
30.	Abbey Farm Ind Estate Thetford	TL 860 833	0.0
31.	Thermalite Ltd. Two Mile Bottom	TL 851 867	181.0
32.	Crown Estate Brandon Road, Thetford	TL 854 834	0.0
33.	Freedom Farm Hockwold Trevor Cobbold	TL 714 864	1363.0

TABLE10 : Discharges Made to the Little Ouse System

Map Ref.	Site Name	Nat.Grid Reference	Dry Weather Flow (m^3/d)
C. Sewage Treatment Works (Non Anglian Water Services Ltd.)			
1.	PSA DOE Wretham Camp STW O/F	TL 923 907	65.0
2.	F.P Bradshaw, Flaxmoor House Caston STW	TL 956 976	1.5
3.	St Edmundsbury B.C. Theltenham STW O/F	TM 012 784	0.0
4.	PSA DOE Barnham Camp STW O/F	TL 865 803	42.0

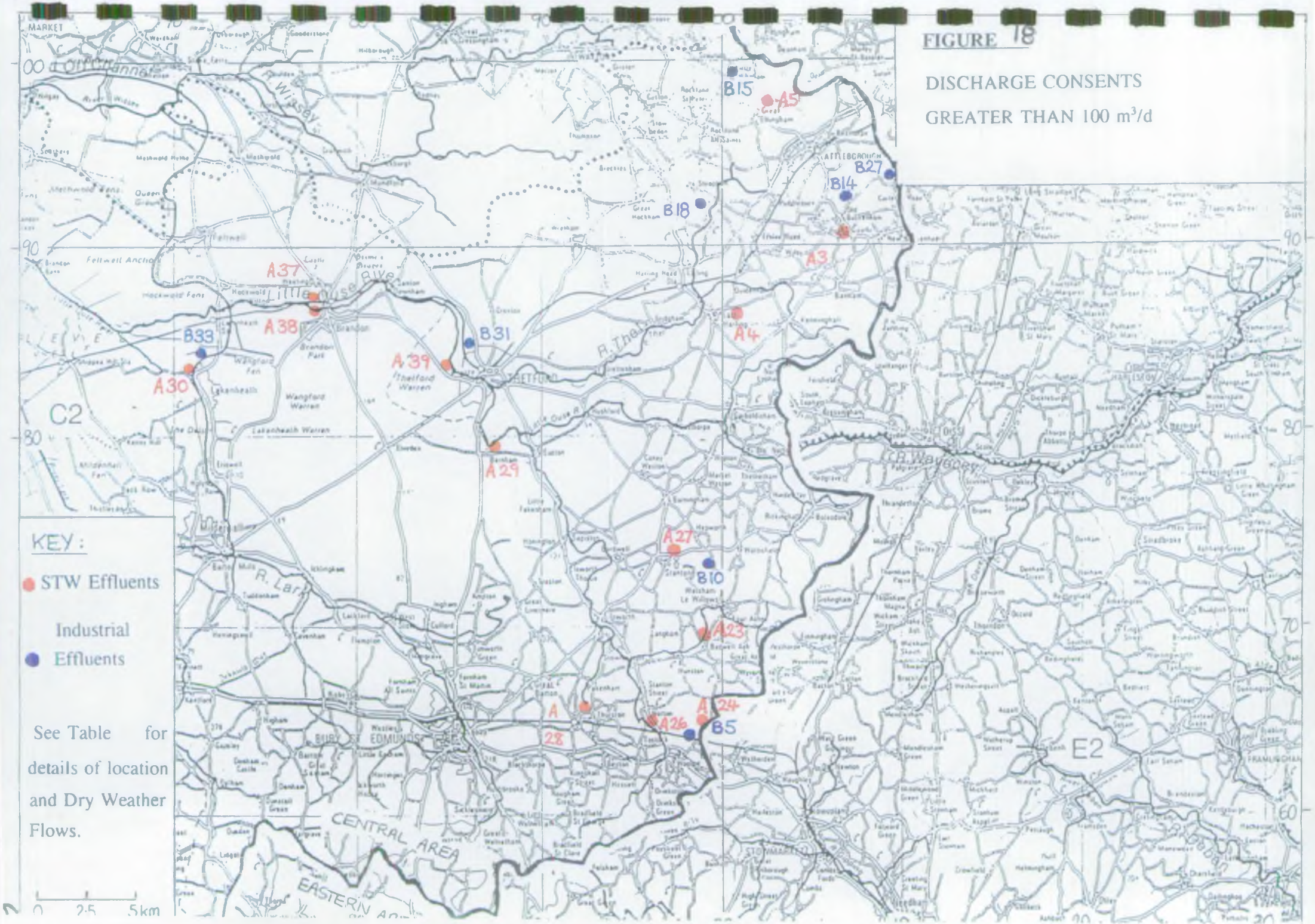


FIGURE 18
DISCHARGE CONSENTS
GREATER THAN 100 m³/d
KEY:
STW Effluents
Industrial Effluents
See Table for details of location and Dry Weather Flows.
0 2.5 5km
A5
B15
B27
B14
B18
A3
A4
A37
A38
B33
A30
B31
A39
A29
A27
B10
A23
A24
A26
B5
A28
C2
E2
R. Lark
R. Thet
R. Wissey
CENTRAL AREA
EASTERN AREA

TABLE IIa: HISTORY OF LICENSED GROUNDWATER ABSTRACTION 1966-93

	Spray Irrigation	Agric.	Total PWU & Domestic	Crown Exempt (1.5 tcmd)	Industrial	Consum. Cooling	Non Consump Cooling	Sand & Gravel Washing	PWS (inc eggs)	TOTAL LICENSED QUANTITY
1966	547.19	536.60	.00	547.50	93.97	.00	.00	272.73	4175.15	6173.13
1967	406.55	700.40	.75	547.50	161.76	54.55	.00	272.73	4175.15	6319.38
1968	445.93	730.90	.75	547.50	162.94	54.55	.00	272.73	6974.46	9189.76
1969	621.72	787.30	.75	547.50	162.94	54.55	.00	272.73	7601.36	10048.84
1970	671.23	822.00	.75	547.50	162.94	54.55	.00	272.73	7601.36	10133.05
1971	529.32	751.80	.70	547.50	162.94	90.95	.00	272.73	7601.36	9957.29
1972	692.64	751.90	.70	547.50	163.03	90.95	.00	272.73	7601.36	10120.80
1973	705.31	875.60	.70	547.50	200.07	90.95	.00	272.73	8851.36	11544.22
1974	973.44	844.10	.70	547.50	245.53	90.95	.00	272.73	9047.36	12022.30
1975	1167.98	912.20	.70	547.50	249.08	90.95	.00	272.73	9047.36	12288.49
1976	1216.30	912.20	.68	547.50	249.08	90.95	.00	272.73	9047.36	12336.79
1977	1728.05	920.40	.68	547.50	247.90	306.63	.00	772.73	9047.36	13571.24
1978	2072.09	991.00	.68	547.50	247.90	306.63	.00	772.73	9047.36	13985.88
1979	3075.82	991.00	.23	547.50	281.24	306.63	.00	772.73	9047.36	15022.50
1980	2917.09	992.70	.23	547.50	279.93	306.63	.00	272.73	9204.26	14521.06
1981	2971.36	1011.60	14.13	547.50	397.54	306.63	.00	272.73	9204.26	14725.74
1982	2950.09	1019.80	42.13	547.50	661.34	306.63	.00	272.73	9598.11	15398.32
1983	1925.75	1024.80	42.13	547.50	671.72	306.63	.00	272.73	9598.11	14389.36
1984	5187.94	1030.90	42.13	547.50	701.59	306.63	152.70	272.73	9598.11	17840.22
1985	6376.32	1042.70	42.13	547.50	723.66	215.68	152.70	272.73	9779.71	19153.12
1986	6453.66	1049.90	42.13	547.50	723.66	215.68	152.70	272.73	9779.71	19237.66
1987	6862.79	1020.50	42.13	547.50	803.06	215.68	152.70	.00	9779.71	19424.06
1988	6970.94	1024.60	348.49	547.50	1293.94	215.68	152.70	.00	9779.71	20333.56
1989	6584.53	1024.60	320.49	547.50	1535.94	215.68	152.70	.00	10010.80	20392.24
1990	7114.94	1004.60	320.49	547.50	1535.94	215.68	152.70	.00	20090.53	30982.38
1991	6532.24	1002.90	320.49	547.50	1535.94	215.68	152.70	.00	20090.53	30397.98
1992	6354.30	1004.70	326.79	547.50	1574.04	215.68	152.70	.00	20090.53	30266.24
1993	5677.57	1030.20	326.79	547.50	1801.04	215.68	152.70	.00	20006.44	29757.93

Yearly quantities as on 30 December

TABLE 11b : LICENSED QUANTITIES FOR SUB UNITS A,B,C AND D 1993
All figures in TCMA

Use/Unit	A	B	C	D
Public Water Supply	1698.61	10083.50	5873.33	2351.00
Agriculture	370.72	220.43	143.88	295.20
Spray Irrigation including Anti-Frost	1592.85	1006.59	531.39	2546.70
Private Water Undertaking	16.90	0.0	0.0	309.89
Crown Exempt	0.0	0.0	0.0	547.50
Industrial	801.23	0.68	535.48	463.66
Consumptive Cooling	0.0	215.68	0.0	0.0
Non Consumptive Cooling	0.0	0.0	0.0	152.70
Sand and Gravel Washing	0.0	0.0	0.0	0.0
TOTAL LICENSED QUANTITY	4480.31	11526.88	7084.08	6666.65

Allocation for Public Water Supply (site and licensed quantity in tcma):

Unit A
Old Buckenham, 272.7
Quidenham, 1410.0
Croxton, 15.91

Unit B
Rushford, 1460.0
Nunnery Lodge, 1507.0
Brettenham, 4138.0
Rickinghall, 454.6
Barnham Cross, 965.0
Redgrave, 862.1
Riddlesworth, 696.8

Unit C
Ixworth, 2953.33
Euston, 2920.0

Unit D
Two Mile Bottom, 1601.0
Brandon, 750.0

TABLE 14 Current Abstraction Applications in the Little Ouse Unit

A. Existing Licence Quantity in tcma.
B. Quantity applied for in tcma.
C. Difference between A. and B. ALL FIGURES ARE GIVEN IN TCMA.
D. Further Impact on Resource.

Date of Application	Application Number	Name (Use)	Licence Number	A.	B.	C.	D.	Comments
11.12.91	CN/479	T.C. Cobbald	-	0.0	125.0	125.0	125.0	Spray Irrigiation
21.9.92	CN/673	A. J. Edwards & Son	41/182	90.9	90.9	0.0	0.0	Renewal
14.9.92	CN/666	Elvedon Farms	56/113	1432.0	1432.0	0.0	0.0	Renewal
		Elveldon Farms	-	0.0	22.8	22.8	22.8	To Fill Reservoir in Nov/Dec.
1.5.90	R/62	Button Poultry	-	0.0	374.4	374.4	125.0	Original application to be Refused - alternative proposals to 125 tcma under consideration
1.5.90	R/63	Button Poultry	-	0.0	318.5	318.5		
14.4.93	CN/740	AWS (Ixworth)	41/8 & 41/109	2953.0	3000.0	47.0	47.0	
24.9.93	CN/834	Sovereign Chicken Ltd.		0.0	105.0	105.0	105.0	Previous Licence expired 1985
31.12.93	CN/854	AWS (Two Mile Bottom)	45/16	1659.0	1659.0	0.0	0.0	To include extra borehole
12.10.93	CN/855	R.G. Abrey Farms	44/178	240.9	240.9	0.0	0.0	
25.8.93	CN/886	Ennemix	-	0.0	30.88	30.88	3.0	Mineral Washing - 90% recirculation
11.10.93	CN/915	Banham Poultry Ltd.	44/230	189.1	189.1	0.0	0.0	To include extra borehole
9.11.93	CN/930	Duke of Grafton	41/149	193.2	193.2	0.0	0.0	River Support purposes
9.11.93	CN/932	JA & PE Wright	44/192	114.97	114.8	-0.17	-0.17	Slight reduction to Agric Use.
13.12.93	CN/942	AE Sexton	44/191	68.2	68.2	0.0	0.0	
TOTALS				6941.27	7964.68	1023.41	427.63	

NOTE : Impact upon Resource = 427.63 tcma which is equivalent of 1.17 tcmd

FIGURE 19

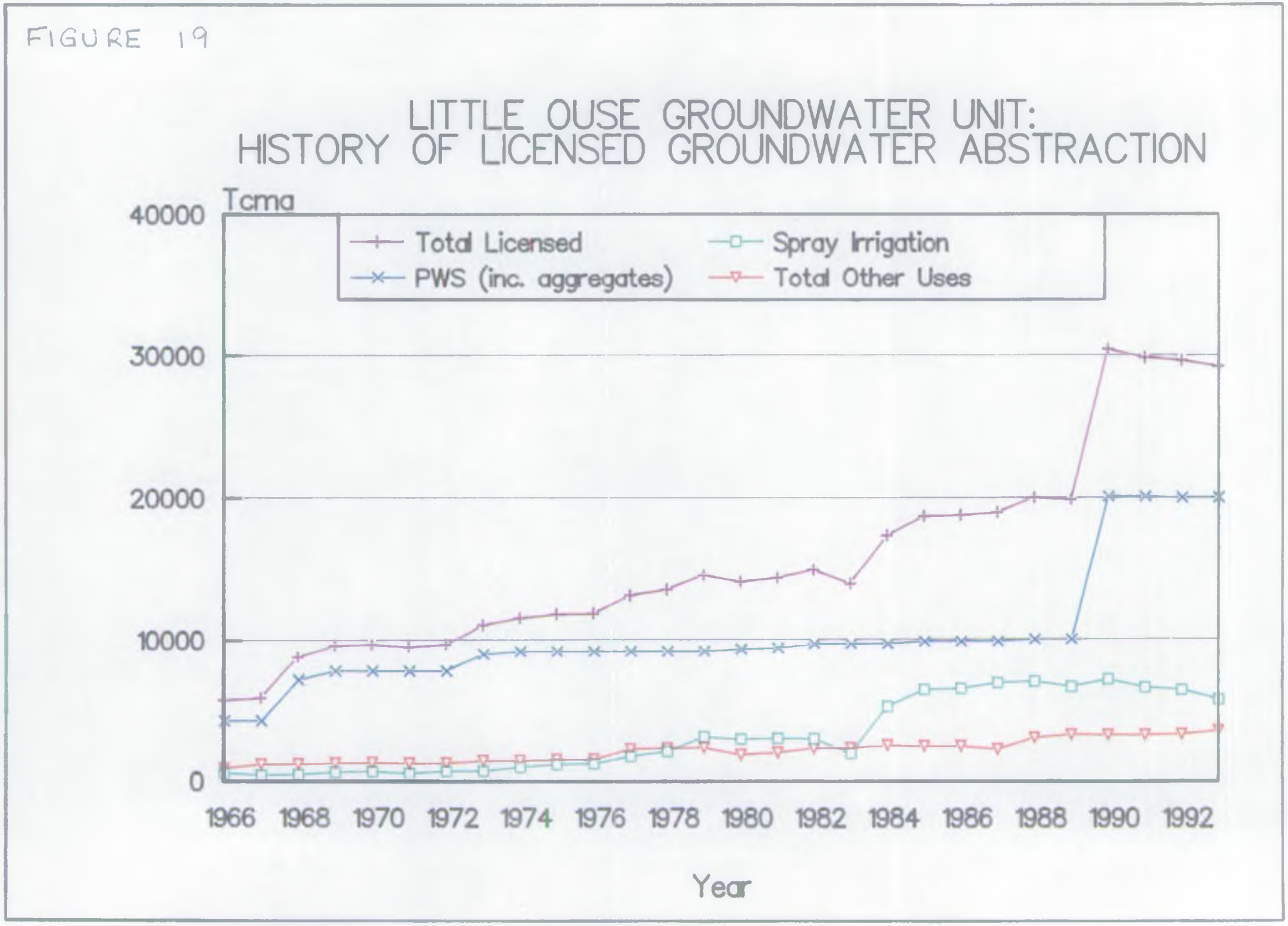
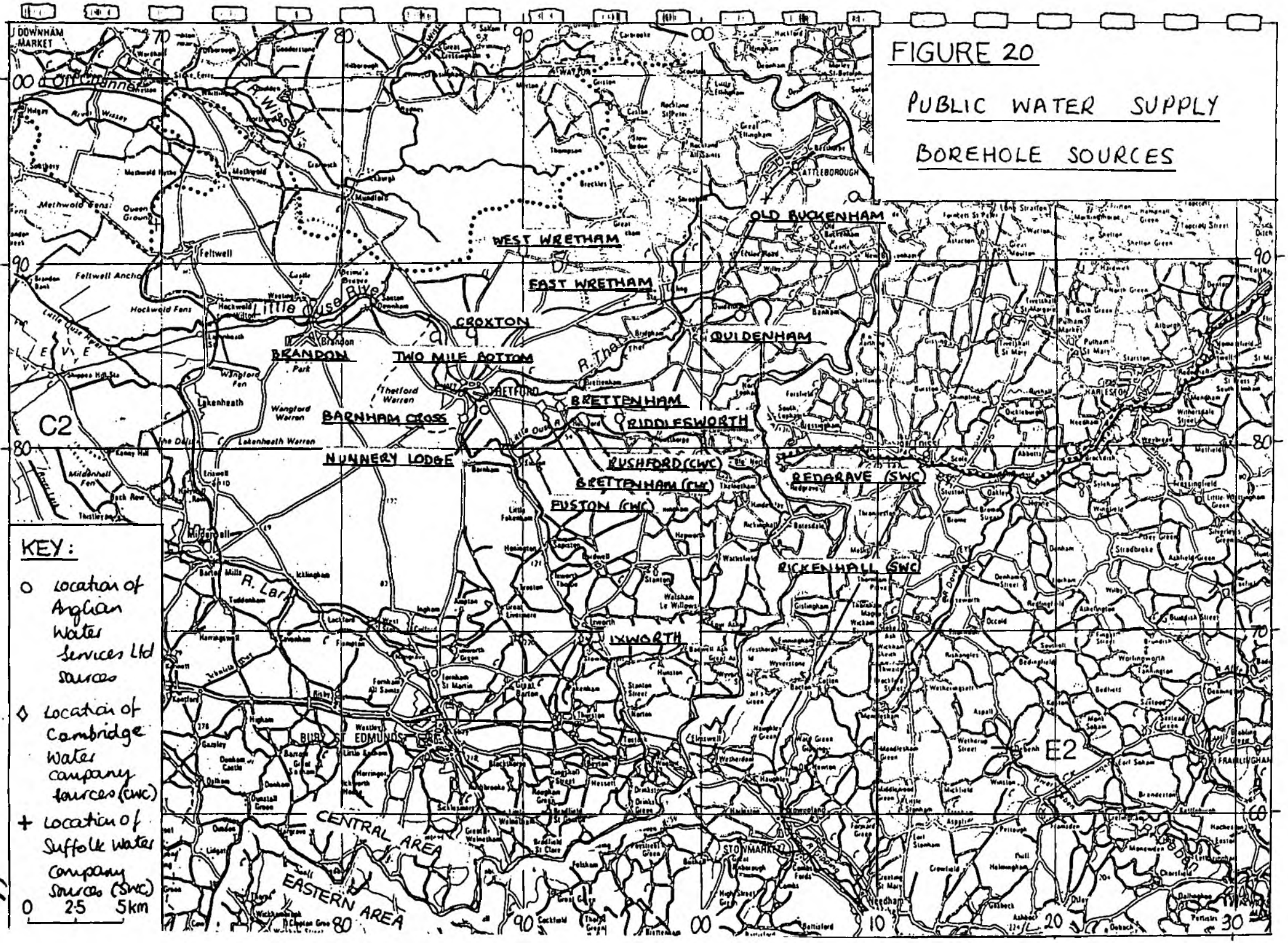

LITTLE OUSE GROUNDWATER UNIT:
HISTORY OF LICENSED GROUNDWATER ABSTRACTION
Tcma
40000
30000
20000
10000
0
Total Licensed
Spray Irrigation
PWS (inc. aggregates)
Total Other Uses
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
Year

FIGURE 20

PUBLIC WATER SUPPLY BOREHOLE SOURCES



The Great Ouse Groundwater Development Scheme Boreholes

a. Licence 6/33/41/128

Each source is licensed for 500 m^3/hr, 11 tcmd and 3000 tcma with an overall aggregate of 2500 m^3/hr, 55 tcmd, 4750 tcma or 7910 tcm in any period of 600 days from 1st April in any year.

Site No.	Site Name	National Grid Ref.	Drilled Y/N	Operational Y/N	Actual Abstraction (tcma) 1989 1990 1991 1992
14	Sapiston	TL9262 7607	N	N	nil
16	Ixworth	TL9376 7193	N	N	nil
19	Bardwell	TL9480 7372	N	N	nil
22	Stanton	TL9757 7252	N	N	nil
23	Hepworth	TL9782 7429	N	N	nil

contd.

b. Licence 6/33/42/74

Each source is licensed for 500 m^3/hr, 11 tcmd, 3000 tcma with an aggregate of 5200 m^3/hr, 62.4 tcmd, 10550 tcma or 17570 tcm in 600 days from 1st April in any year.

Total Abstracted during 1990 : nil, 1991 : 2188.21 tcma
and 1992 : 1498.84 tcma

Site No.	Site Name	National Grid Ref.	Drilled Y/N	Operational Y/N	Actual Abstraction (tcma) 1989 1990 1991 1992
4	Harling	TL9716 8298	Y	Y	nil nil 243.84 166.87
5	Riddlesworth	TL9855 8176	Y	Y	nil nil 381 260.83
6	Garboldisham	TM0011 8198	Y	Y	nil nil 1014.73 695.30
7	Blo' Norton	TM0163 8022	N	N	nil
9	Garboldisham	TM0251 8361	Y	Y	nil nil 548.64 375.84
13	Euston	TL9033 7977	Y	Sold to C.W.Co.	
15	Euston	TL9344 8142	Y	Sold to C.W.Co.	
17	Euston	TL9383 7943	N	N	nil
18	Bardwell	TL9423 7722	N	N	nil
20	Knettishall	TL9577 7946	N	N	nil
21	Barningham	TL9616 7749	N	N	nil
24	Hepworth	TL9915 7646	N	N	nil

25	Wattisfield	TL9983 7250	N	N	nil
26	Thelnetham	TM0009 7792	N	N	nil
27	Rickinghall Inferior	TM0166 7290	N	N	nil
28	Hinderclay	TM0223 7568	N	N	nil
29	Hinderclay	TM0283 7714	N	N	nil
30	Rickinghall Superior	TM0499 7349	N	N	nil
31	Botesdale	TM0539 7568	N	N	nil
32	Burgate	TM0699 7453	N	N	nil

c. Licence 6/33/44/137

Each source is licensed for 500 m^3/hr, 11 tcmd, 3000 tcma with an aggregate of 6240 m^3/hr, 74.88 tcmd, 13070 tcma or 21780 tcm in any period of 600 days from 1st April in any year.

Total Abstracted during 1990 : 7089.14 tcma, 1991 : 11819.96 tcma
and 1992 : 3326.0 tcma

Site No.	Site Name	National Grid Ref.	Drilled Y/N	Operational Y/N	Actual Abstraction (tcma) 1989 1990 1991 1992
1	Brettenham	TL8890 8281	Y	Y	468 1212 2004 1044
2	Brettenham	TL9109 8233	Y	Sold to C.W.Co.	
3	Harling	TL9612 8369	Y	Y	828.12 667.32 1342.68 nil
8	Quidenham	TM0214 9168	Y	Y	nil 683.6 272.25 nil
10	Banham	TM0509 8710	Y	Y	nil 840.24 1299.26 677.0
11	Kenninghall	TM0713 8562	Y	Y	nil 451.83 132.8 nil
12	Old Buckenham	TM0835 9100	Y	Y	nil 806.4 1286.4 835

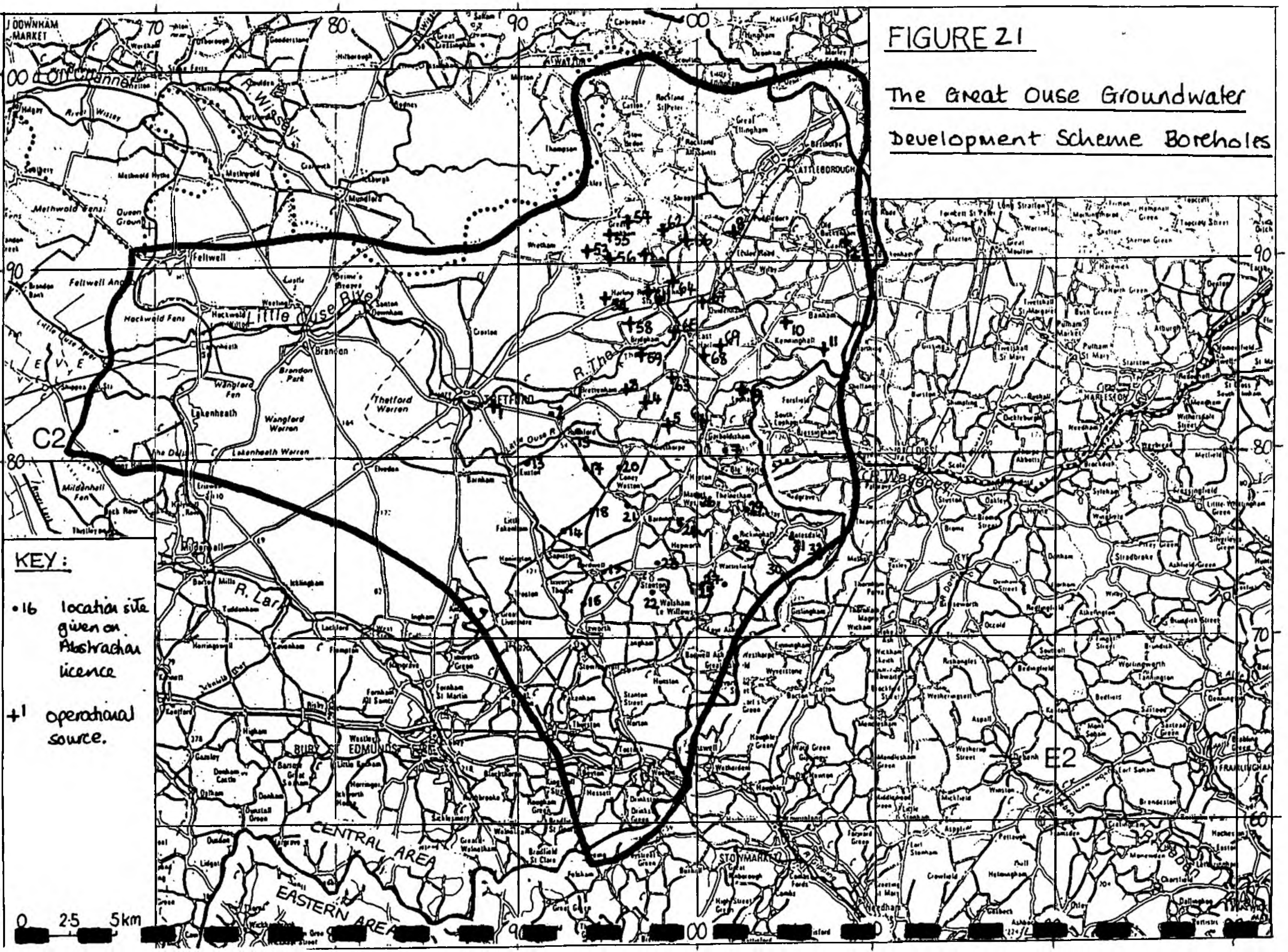
53	Hockham	TL9393 9060	Y	Y*	nil nil 684.7 nil
54	Roudham	TL9492 8851	Y	Y*	nil nil 36.33 nil
55	Hockham	TL9515 9150	Y	Y*	nil nil 224.11 nil
56	Wretham	TL9512 9013	Y	Y*	nil nil 135.77 nil
57	Hockham	TL9629 9215	Y	Y*	nil nil 200.1 nil
58	Roudham	TL9637 8723	Y	Y (iron)	418.28 nil nil nil
59	Harling	TL9694 8550	Y	Y	422.3 496.1 684.7 nil
60	Roudham	TL9714 9047	Y	Y	165.13 456.84 706.41 368.0
61	Roudham	TL9737 8883	Y	Y	560.63 239.36 nil nil
62	Shropham	TL9810 9179	Y	Y	242.62 37.32 nil nil

63	Harling	TL9863 8424	Y	Y	nil nil 169.34 nil
64	Snetterton	TL9877 8944	Y	Y	388.0 456.17 629.59 nil
65	Bridgham	TL9885 8674	Y	Y	311.47 nil 504.34 nil
66	Snetterton	TL9941 9120	Y	Y	180.26 498.96 771.54 402.0
67	Quidenham	TM0017 8837	Y	Y	nil nil 194.65 nil
68	Harling	TM0018 8541	Y	Y	nil nil 165.24 nil
69	Harling	TM0113 8595	Y	Y	231.34 243 375.75 nil

* These sites are close to the Breckland Meres and an undertaking was given at the Public Inquiry (1976) that these boreholes would only be used at the end of a critical drought.

FIGURE 21

The Great Ouse Groundwater Development Scheme Boreholes



KEY:

- •16 location site given on Abstraction licence
- +1 operational source.

THE GREAT OUSE GROUNDWATER DEVELOPMENT SCHEME

Roudham (No 60) Pumping Station + Borehole
TL 971 LL 9047 November 1992

Augmentation of Larling Brook : Discharge from
Roudham (No 60) borehole TL970 907
November 1992

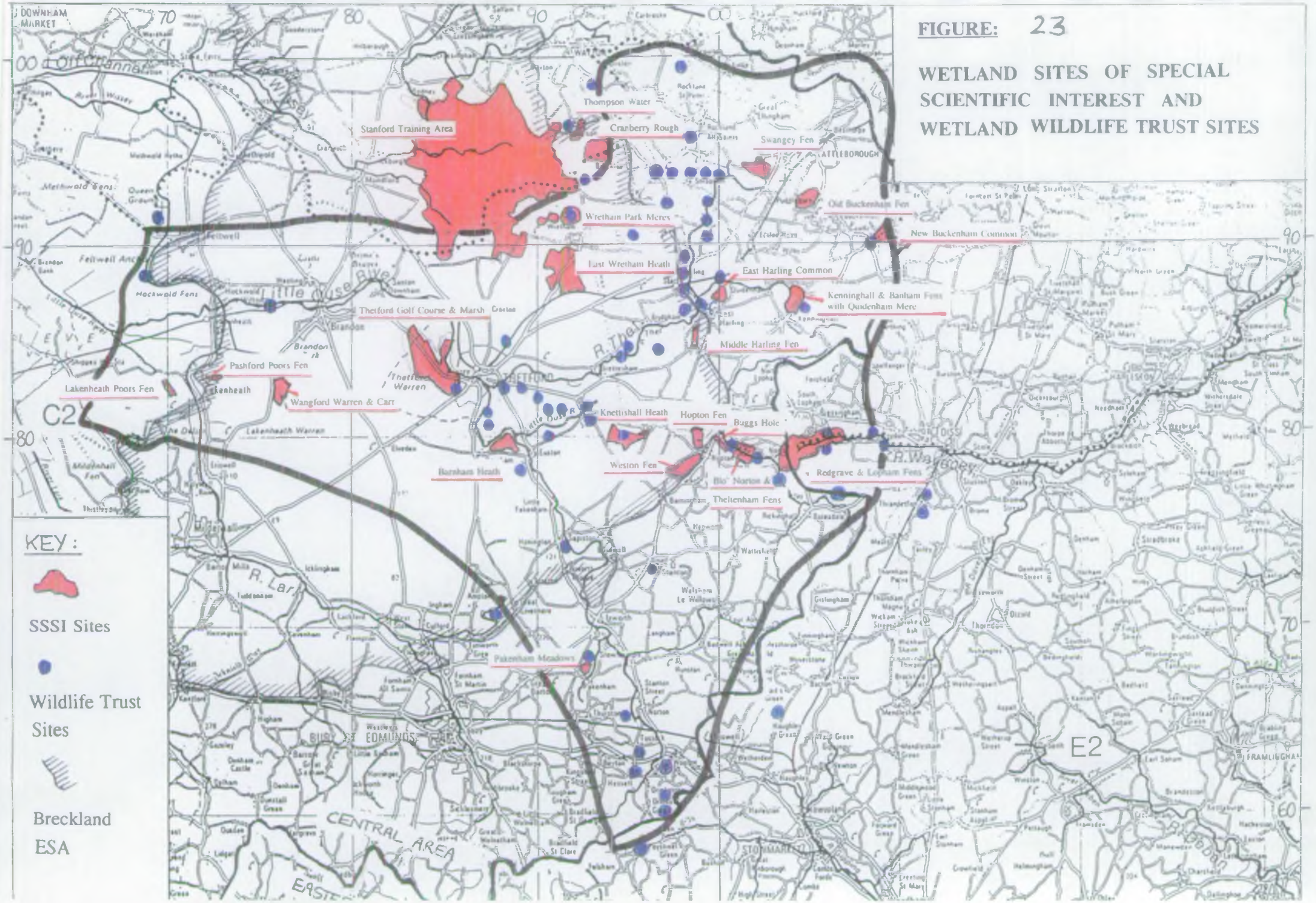


FIGURE: 23
WETLAND SITES OF SPECIAL SCIENTIFIC INTEREST AND WETLAND WILDLIFE TRUST SITES
Thompson Water
Cranberry Rough
Stanford Training Area
Swangey Fen
Old Buckenham Fen
New Buckenham Common
Wretham Park Meres
East Wretham Heath
East Harling Common
Kenninghall & Banham Fens with Quidenham Mere
Middle Harling Fen
Thetford Golf Course & Marsh
Pashford Poors Fen
Lakenheath Poors Fen
Wangford Warren & Carr
Knettishall Heath
Hopton Fen
Buggs Hole
Weston Fen
Redgrave & Lopham Fens
Thelnetham Fens
Barnham Heath
Pakenham Meadows
KEY:
SSSI Sites
Wildlife Trust Sites
Breckland ESA
CENTRAL AREA
EASTERN AREA
E2
C2

Ringmere TL910 879 November 1992

Langmere TL905 885 November 1992.

FIGURE 25: SCHEMATIC MAP OF THE LITTLE OUSE

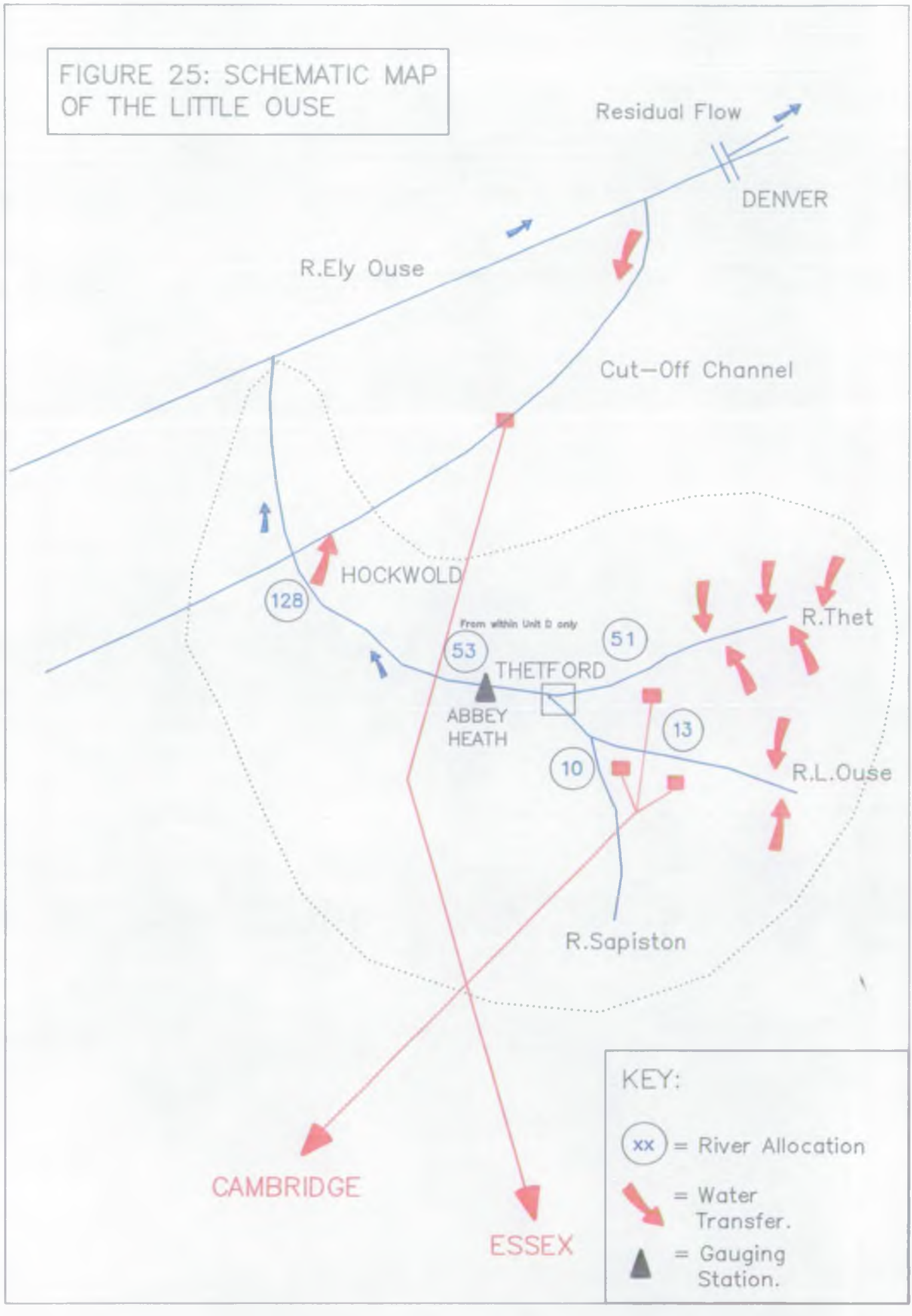
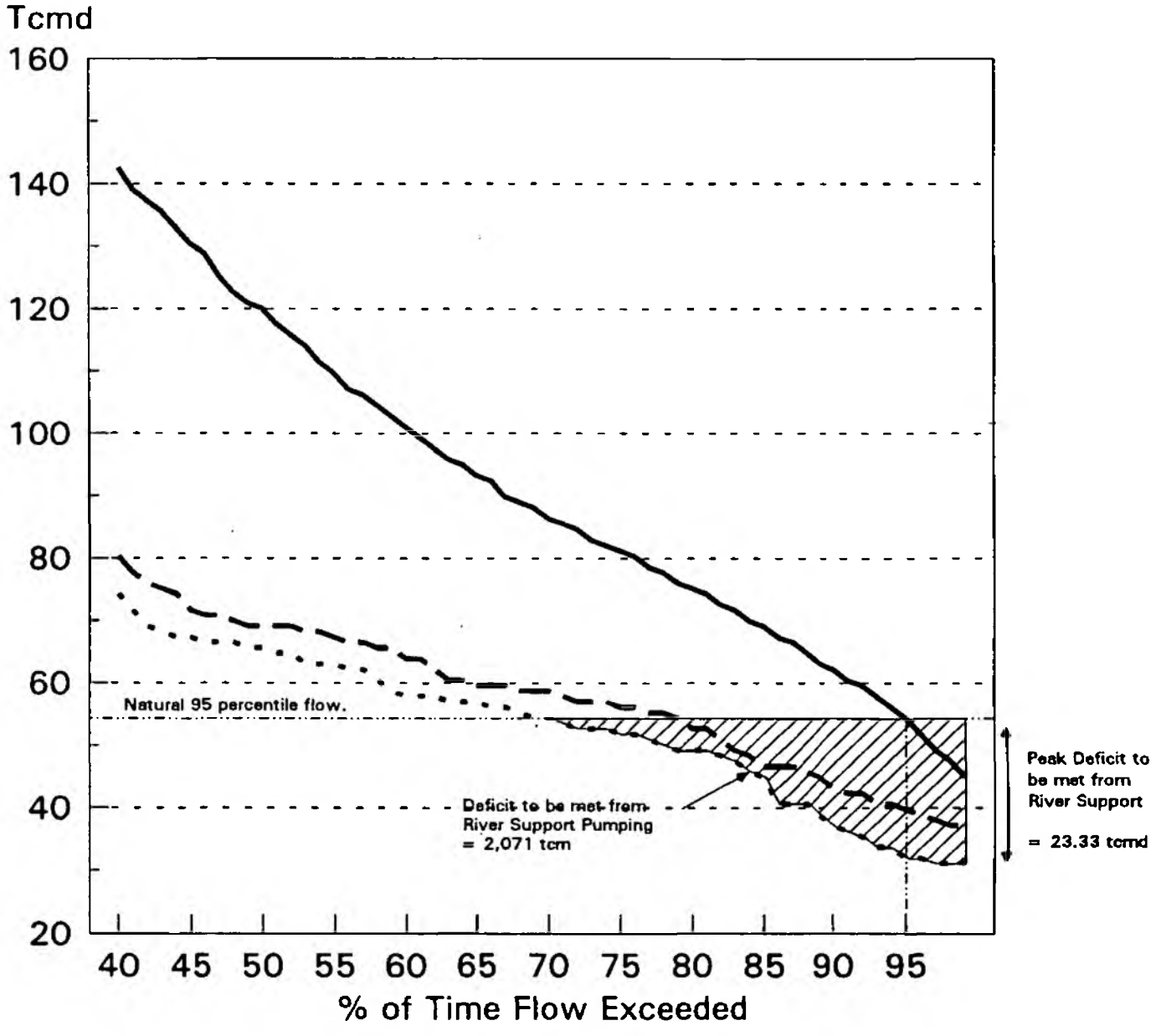


Figure 26

Thet Groundwater Sub-Unit
7 Day Flow Duration Curves

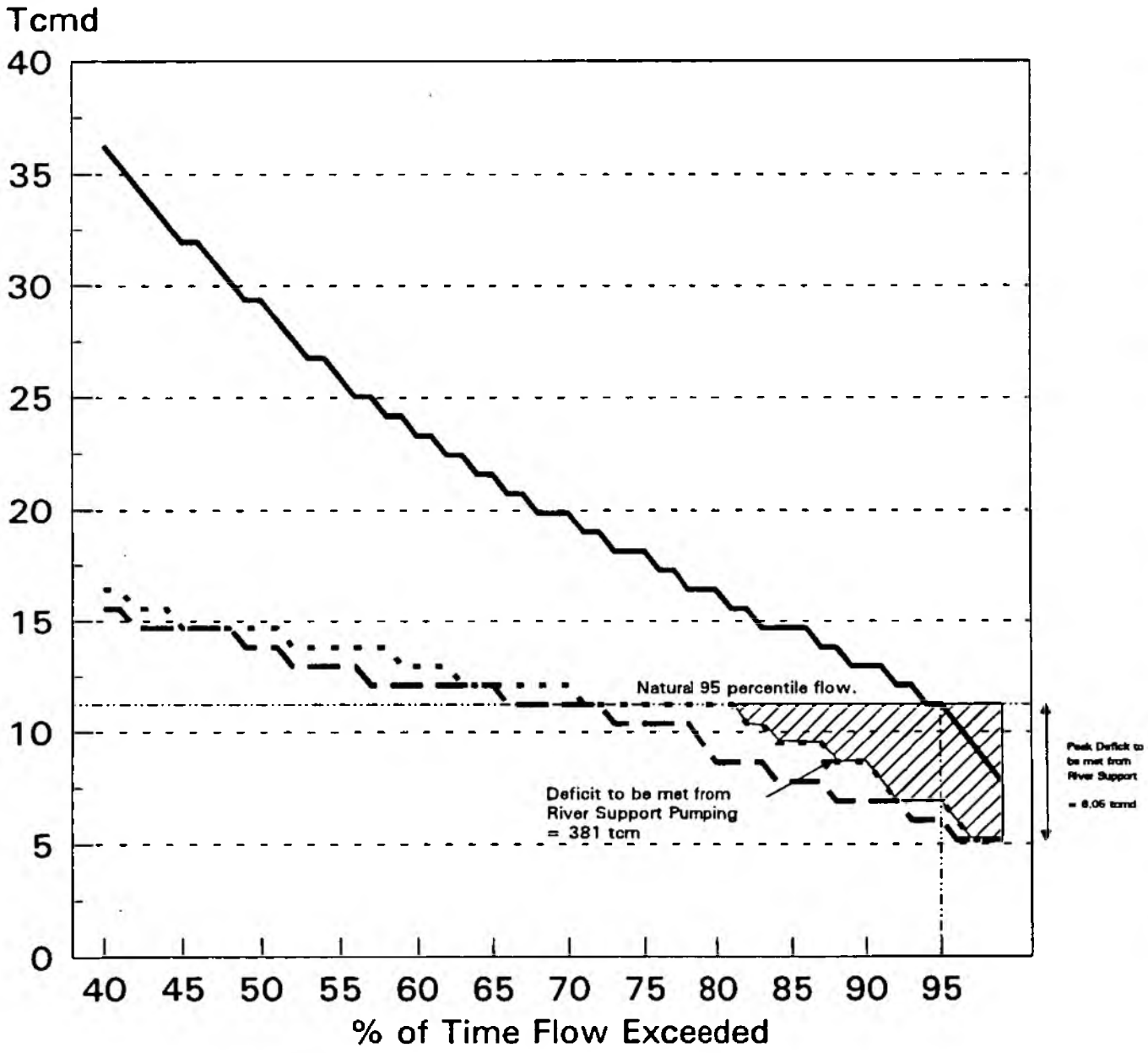


Long Term Naturalised Flows
'Minimum 600 Day' Naturalised Flows
'Minimum 600 Day' Flows with 2011 Abstraction Conditions

'Minimum 600 Day' Period taken as 85 weeks from April 1972.
(A 600 day aggregate applies to the GOGWS licences).
NB. The minimum 600 day period was identified from simulated 2011 flows.

Figure 27

Upper Little Ouse Groundwater Sub-Unit
7 Day Flow Duration Curves

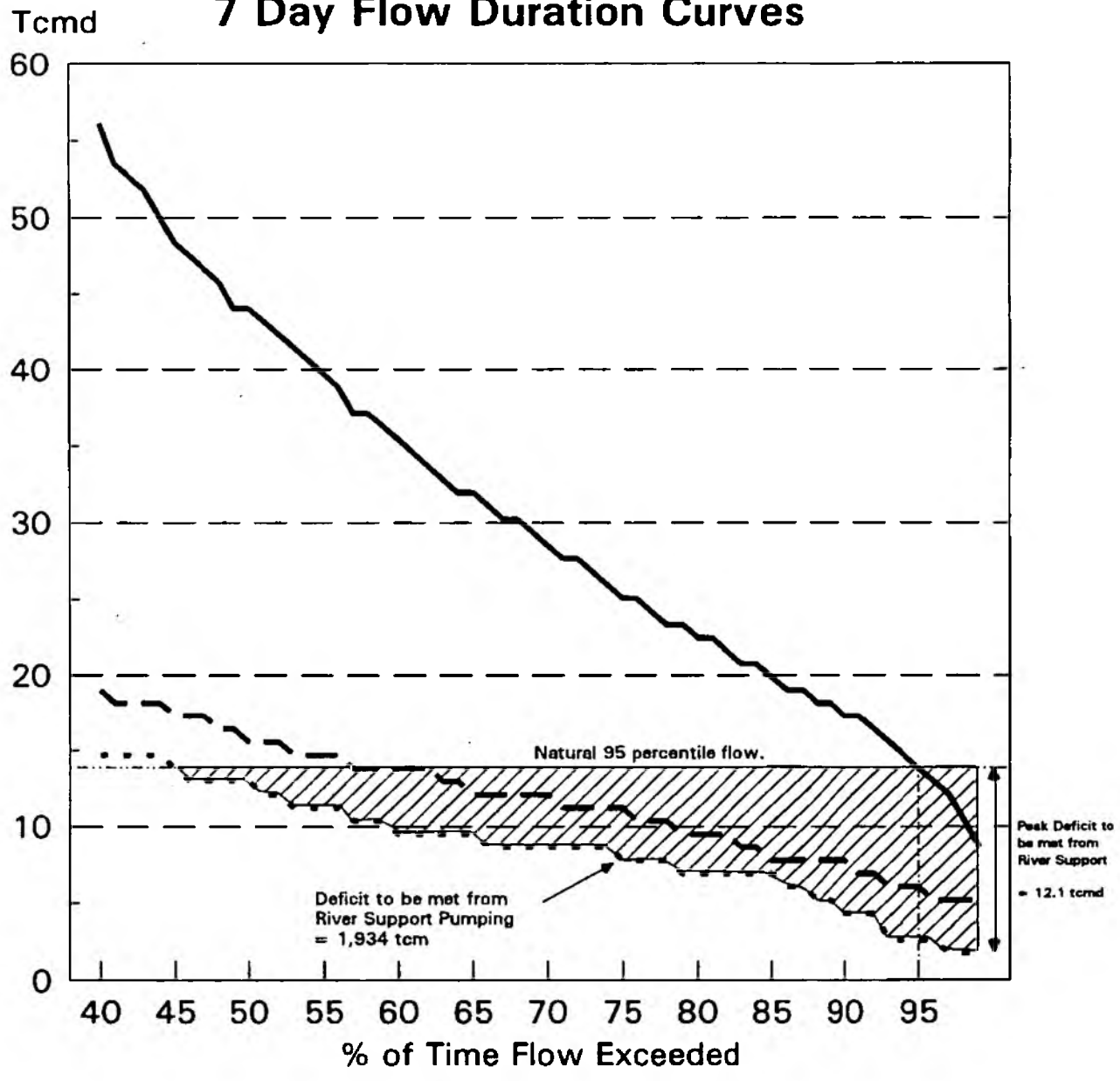


——— Long Term Naturalised Flows
– – – – 'Minimum 600 Day' Naturalised Flows
····· 'Minimum 600 Day' Flows with 2011 Abstraction Conditions

'Minimum 600 Day' Period taken as 85 weeks from April 1972.
(A 600 day aggregate applies to the GOGWS licences).
NB. The minimum 600 day period was identified from simulated 2011 flows.

Figure 28

Sapiston Groundwater Sub-Unit
7 Day Flow Duration Curves



Long Term Naturalised Flows

'Minimum 600 Day' Naturalised Flows

'Minimum 600 Day' Flows with 2011 Abstraction Conditions

'Minimum 600 Day' Period taken as 85 weeks from April 1972.
(A 600 day aggregate applies to the GOGWS licences).
NB. The minimum 600 day period was identified from 2011 simulated flows.

APPENDIX 1

S.S.S.I. Sites

Figure 23 shows the location of the following wetland sites of conservation interest. The S.S.S.I. sites come under the control of English Nature. The following details have been taken from the formal notification documents issued by English Nature and the work produced by Birmingham University about the hydrogeology (The Hydrodynamics of Fen Systems) presented to Anglian Water Authority in 1988.

The following gives an indication of why the site is important and the general information about hydrogeology. Reference to original documentation and monitoring data should be made when dealing with particular licence applications.

a. Blo' Norton and Theltenham Fens. TM 017 790.

The site is of interest mainly because of the plant communities associated with the remaining areas of open fen. Additional interest is provided by the areas of carr woodland and by some of the meadows adjacent to the fen. In order to provide some control over the water table in the fen areas the site boundary also encompasses several small fields and ditches. These are of some interest in their own right.

The site is on Alluvium with Glacial Sands along the slopes. The sand layers probably form a connection between the underlying Chalk and the site hence water can be derived from the Chalk as well as surface water runoff.

b. Bugg's Hole Fen. TM 006 792.

Bugg's Hole is a small, spring fed calcareous fen situated in the valley of the Little Ouse River. A wide range of habitats occur from mown grassland on the driest soils to tall fen vegetation on shallow fen peats. The tall fen vegetation occupies the low-lying northern part of the site.

The Chalk Aquifer is probably discharging to the valley via sands along the valley sides. The site is isolated from the main river except during flood events.

English Nature are to monitor water levels on the site starting 1992.

c. Cranberry Rough. TL 934 936.

Cranberry Rough is a basin mire which has developed on the site of a former lake. It is now occupied by swamp woodland of Alder, Willow and Birch, tall fen, grassland and a network of ditches and pools. The site's high and stable water level and lack of pollution mean that it contains an exceptionally wide range of wetland plants, butterflies and other insects.

The geology is Upper Chalk covered with Glacial Sands and Boulder Clay. Groundwater issues from the shallow Sands and the connection to the Chalk is not confirmed. The source of water is mostly surface run off.

d. Hopton Fen. TL 990 800.

Hopton Fen is one of a series of valley fens spanning the watershed between the headwaters of the Waveney and Little Ouse. It supports a variety of tall fen communities and is floristically rich. The site contains areas of reed-dominated fen and on the higher ground are small seepage areas dominated by Black Bog Rush, Blunt-flowered Rush and Purple Moor-grass.

Hopton Fen is in a shallow valley of the tributary of the Little Ouse. The geology is Chalk overlain by Glacial Sands, river Gravels and Alluvium. The hydraulic connection with the Chalk is unclear but probable via the Sands and Gravels.

English Nature intend to monitor water levels on the site starting 1992.

e. Lakenheath Poors Fen. TL 701 827.

Lakenheath Poors Fen is an area of species-rich fen meadow with areas of damp calcareous and neutral grassland. It lies on the transition between the Breckland sands and the fen basin. Although a relatively small fragment, it represents a once extensive tract of similar vegetation that is now lost to arable cultivation. The rich flora includes one rare and one uncommon species, whilst the dykes and ditches support a good variety of aquatic plants.

The site lies on the Sands and Silts of an Alluvium filled embayment into the Chalk. The water may exist because of poor drainage and a high groundwater level. Spring flows have not been identified but are possible.

Nearby licensed abstraction is limited by cessation levels in the Fen.

f. Old Buckenham Fen. TM 048 920.

This site is a valley fen which is underlain by clays of a buried channel. The central part of the site consists of a species-rich, managed reed bed surrounding a small , natural mere. Around the margins of the fen basin are areas of species-rich scrub, drier fen and cattle grazed meadows containing wet hollows and calcareous flushes. The meadows are divided by a network of dykes and are used by wading birds.

g. Pakenham Meadows. TL 934 686.

The meadow is unusually species rich, unimproved and poorly drained, and forms one of the best examples of its kind in the county. The small-scale complex mosaic of vegetation types present reflects the variation in soils from loam to peat. The meadow is also herb rich and contains a number of uncommon

species, and the dykes provide a valuable additional habitat for invertebrates.

h. Pashford Poors Fen. TL 732 835.

A small area of lightly grazed fen, acid and calcareous grassland and wet birch woodland. The fauna and flora are exceptionally good and largely dependant upon the continuance of existing management.

The site also lies on the boundary between Breckland and the Fens. Chalk is overlain by Sands, Silts and Peats. The Melboun Rock band in the Chalk occurs beneath the area and the associated spring contributes to the site. Surface runoff is important in winter and may recharge the Chalk.

Nearby licensed abstraction is limited by cessation levels in Wangford Drain which contributes to Pashford Poors Fen.

i. Redgrave and Lopham Fens. TM 050 797.

This site consists of an extensive area of spring fed valley fen at the headwaters of the River Waveney. It supports several distinct fen vegetation types. There are small areas of wet heath, Sallow carr and Birch woodland. The invertebrate fauna is extensive and well studied and the site is the only British locality for the Fen Raft Spider.

The site is a RAMSAR site of international importance.

j. Swangey Fen. TM 015 932.

The site contains an area of species rich, spring-fed fen of a type that is otherwise largely restricted to the Norfolk Broads. Wet woodland and grassland surround the fen, increasing the interest of the site and helping to maintain a high water table. The River Thet passes through the site.

The Chalk is covered by Alluvium and Glacial Sands. The hydraulic connection between the water on the site and that within the Chalk is unclear. The site is dominated instead by winter flooding of the river Thet and surface water runoff.

k. Thompson Water, Carr and Common. TL 930 955.

This site comprises a mosaic of habitats supporting a wide range of plant communities developed in response to variations in topography, soil type and wetness. Although lying at the northern edge of Breckland, its position on a tributary of the River Wissey has lent the site more of a damp lowland grassland character than a typical breck heath. The diversity of the grassland communities is enhanced by the presence of damp and water filled "pingos", formed at the end of the last glaciation, where various open water and fen communities have developed. Scrub, woodland and an artificial lake (Thompson Water) further contribute to the site's variety, which as a whole supports an exceptional number of plant and animal species, several of them rare, and including an invertebrate fauna of considerable

national importance.

The geology consists of blown Sand, Sands and Boulder Clay over Chalk. The impermeable based hollows may be fed by runoff or spring water from adjacent Sandy Boulder Clay.

l. Weston Fen (or Market Weston Fen) TL 981 787.

This site contains a very valuable example a species rich, spring-fed valley fen with areas of grassland scrub and woodland communities. Of all the fens in the Waveney/Ouse valley it has been least affected by drainage or water abstraction. The water table remains high and stable throughout the year and this is reflected in the rich and varied flora of the site.

The springs probably form part of the regional discharge from the Chalk aquifer so it does not dry up as often as perhaps a sand controlled system.

Suffolk Wildlife Trust plan to carry out monitoring of the site from 1992.

m. East Harling Common. TM 000 879.

East Harling Common, situated on chalk on the eastern edge of the Norfolk Breckland is of great importance for its system of periglacial ground ice depressions (pingos) retaining a relict community of aquatic beetles which, together with that of a few other Norfolk pingo systems, is unique in Britain. This includes species which are nationally scarce or rare. Floristically rich fen, a declining habitat, has developed in and around many of the depressions, and surrounding chalk grassland supports a diversity of plants , several of which are uncommon locally.

n. Stanford Training Ground. TL 870 940.

This is the last really extensive example of Breckland grassland and heath that has survived. Included within the site are wetlands and many springs, streams and standing water (including Fowlmere and Homemere). These benefit from the large acreage of the SSSI because they are largely unaffected by drainage, pollution, eutrophication or water abstraction. Many of them are consequently extremely species rich.

o. Wretham Park Meres TL902 918

Wretham Park Meres consist of four natural lakes: Rush Mere, Hill Mere, West Mere and Mickle Mere. Aquatic plants are generally sparse but there is good fringing vegetation which provides an important nesting habitat for wildfowl.

p. East Wretham Heath TL910 882

East Wretham Heath is the oldest established Breckland nature reserve. Its principal scientific interest lies in the two fluctuating meres, Ringmere and Langmere, and in the areas of Breckland grassland. In addition to the fluctuating meres, the site contains several small water bodies, including Fenmere,

whose water levels remain more constant.

The meres are directly influenced by the chalk water table and are known to dry in dry years. These conditions have enabled the development of an unusual series of aquatic and periodically inundated plant and animal communities. Plants are tolerant of alternate flooding and drying.

East Wretham Heath lies in an area of Boulder Clay over Chalk. However, in areas across the site the Boulder Clay cover is absent. The fluctuating meres represent a connection with the underlying Chalk in an area covered by a veneer of sand and the clayey deposits of the Lowestoft Till.

Both water levels in three observation boreholes (TL98/37,TL98/36 and TL98/29) and water levels in Ringmere and Langmere are recorded monthly.

A licensing policy has been established in order to protect the Breckland Meres including Fowl mere, Home mere, Langmere and Ringmere. A cessation level of 27.5 m AOD has been determined at Ringmere. If the water level falls to this level, abstractions are reduced or ceased. Licence No. 6/33/44/221 held by Cambridge Water Company for their Public Water Supply source at Brettenham (TL9105 8236) contains a similar clause whereby the abstraction is restricted to 5 tcmd (from 10 tcmd) according to the level at Ringmere.

q. <u>New Buckenham Common TM094 908</u>

New Buckenham Common is a large area of unimproved grassland containing a sizeable pool, called Spittle Mere.

There is a Great Ouse Groundwater Scheme borehole at TM084 910. The water area of Spittle Mere was considered not to be at risk since the water level in the mere is perched by 24 m of Boulder Clay above the Chalk aquifer.

r. <u>Kenninghall and Banham Fens with Quidenham Mere TM041 875</u>

This complex site occupies a section of the valley of the River Whittle. It has areas of tall fen, calcareous grassland and a deep natural mere (Quidenham Mere). The level in the Quidenham Mere does not fluctuate significantly.

The site is on an area of Upper Chalk overlain by glacial deposits, dominantly consisting of Lowestoft Till. This Till consists of sand lenses in a tenacious clay. Chalk springs supply water to rich-fen areas and hence these areas may be vulnerable any nearby groundwater abstractions. The level of Quidenham mere is relatively stable and hence is probably maintained by surface water inputs (some of which may be spring fed) and direct rainfall.

s. Middle Harling Fen TL989 852

Middle Harling Fen is a small calcareous valley fen situated at the head of a tributary of the River Thet. The site contains a number of chalk springs, drain systems and ponds.

The site lies in an area of Chalk with Lowestoft Till covering the south-east but elsewhere the cover consists of thin peats. Chalk springs are reported to emerge as part of the regional discharge of the Chalk aquifer to the River Thet. The surface catchment to the site is large and hence surface water input may be significant together with poor drainage of the site. The site would be vulnerable to groundwater abstractions which may cause a depletion of spring flows and improved drainage.

English Nature have agreed with NRA to set up a programme of botanical and dip-well monitoring during 1992 and 1993.

t. Thetford Golf Course and Marsh TL845 838

This site is mostly an area of Breckland heath known as Thetford Warren. However, the site includes a strip of land adjacent to the River Little Ouse including the assocated wet soils and drain network.

u. Wangford Warren and Carr TL758 833 & TL757 841

The site contains a system of active sand dunes in Breckland. In addition, the north of the site preserves the transition of soils between Breckland and fen. The fen area is maintained by a drain system.

v. Barnham Heath TL882 800

Barnham Heath is another area of Breckland Heath. The areas adjacent to the Rivers Little Ouse and Black Bourn (Sapiston) are damp grassland.

w. Knettishall Heath TL950 805

Knettishall is predominantly heath but contains wet hollows on low-lying ground which support fen vegetation.

The Chalk is unconfined at the site and covered by a thin layer of sands. The southern and northern margins are covered by areas of Lowestoft Till and the course of the River Little Ouse contains deposits of river gravel and alluvium.

The hydrology of the site is poorly understood and hence the vulnerability to groundwater abstraction is uncertain.

WETLAND WILDLIFE TRUST SITES
FOR THE LITTLE OUSE GROUNDWATER CATCHMENT

NGR	SITE NAME
TL 940 733	Bardwell Meadows
TL 864 799	Barnham Meadow
TL 898 785	River Blackbourne Meadow
TL 877 710	Great Livermere Lake
TL 917 745	Honington Meadows
TL 932 677	Pakenham Fen Meadows
TM 123 791	Laurie's Hayrattle Meadow
TM 112 769	The Marsh
TM 115 773	Railway Meadow (Not SSSI)
TM 026 788	Hinderclay Fen
TM 057 767	Redgrave Lake
TM 088 795	Hall Farm Meadow
TM 089 774	The Marsh, Wortham
TM 088 760	Hill House Meadows
TL 947 655	Grove Farm Meadow, Thurston
TL 963 607	Pumping Station Meadow, Drinkstone Green.
TL 961 622	Drinkstone Meadow
TL 953 634	Tostock Village Pond
TL 950 612	Drinkstone Lake
TM 030 643	The Cricket
TM 959 583	Coronation Meadow
TL 940 810	Little Ouse River (Also at the locations below)
	TL 9182
	TL 9282
	TL 9580/9680/9780/9880/9980
	TL9181/9180/9080/9281/9381/9281/7687/7587/7886/7786/7986/7987
	TL 8880/8781/8782
TL 900 830	River Thet (Also at the locations below)
	TL 9585/9685/9785/9885/9886/9887/9888
	TL 9991/9992/9993 (Shropham Fen)
	TL 9584
	TL 8883/8983
	TL 8583/8781/8782
	TM 0680
	TM 0094
	TL 895 837/900 834
TL 920 820	Lake on Shadwell Park
TL 980 890	River Thet including Larling Fen, Larling Carr and Hassocks Fen
TL 950 900	Pond near Mill Farm
TL 990 920	Lakes east of the River Thet
TL 970 930	Lake South of Shropham Hall
TL 960 940	River habitat near Breckles Hall
TL 970 940	River habitat south of Lower Stow Bedon

TL 980 940	River habitat south of Fen Street
TL 950 910	Pond near Watergate Plantation
TL 920 920	Pond north west of Breckles Heath
TL 920 960	Pond near Hallfield Farm
TL 920 960	Pond near school at Thompson Village
TL 930 980	Pond south west of Griston Hall
TL 980 950	Pond south west of Fen Street
TL 970 990	Pond near Scoulton Hall
TL 680 880	Cut-off Channel (Also includes locations below) TL 6990/6989/6988/7088/7188/7287 TL 6992/6993/7091
TM 000 870	Land adjacent to East Harlington
TM 040 870	Quidenham Mere
TM 080 800	River Waveney (Also includes locations below) TM 0579/0479/0378/0278/0079/0080/0179