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**LOW FLOW ESTIMATION IN
ARTIFICIALLY INFLUENCED
CATCHMENTS**

TRAINING COURSE

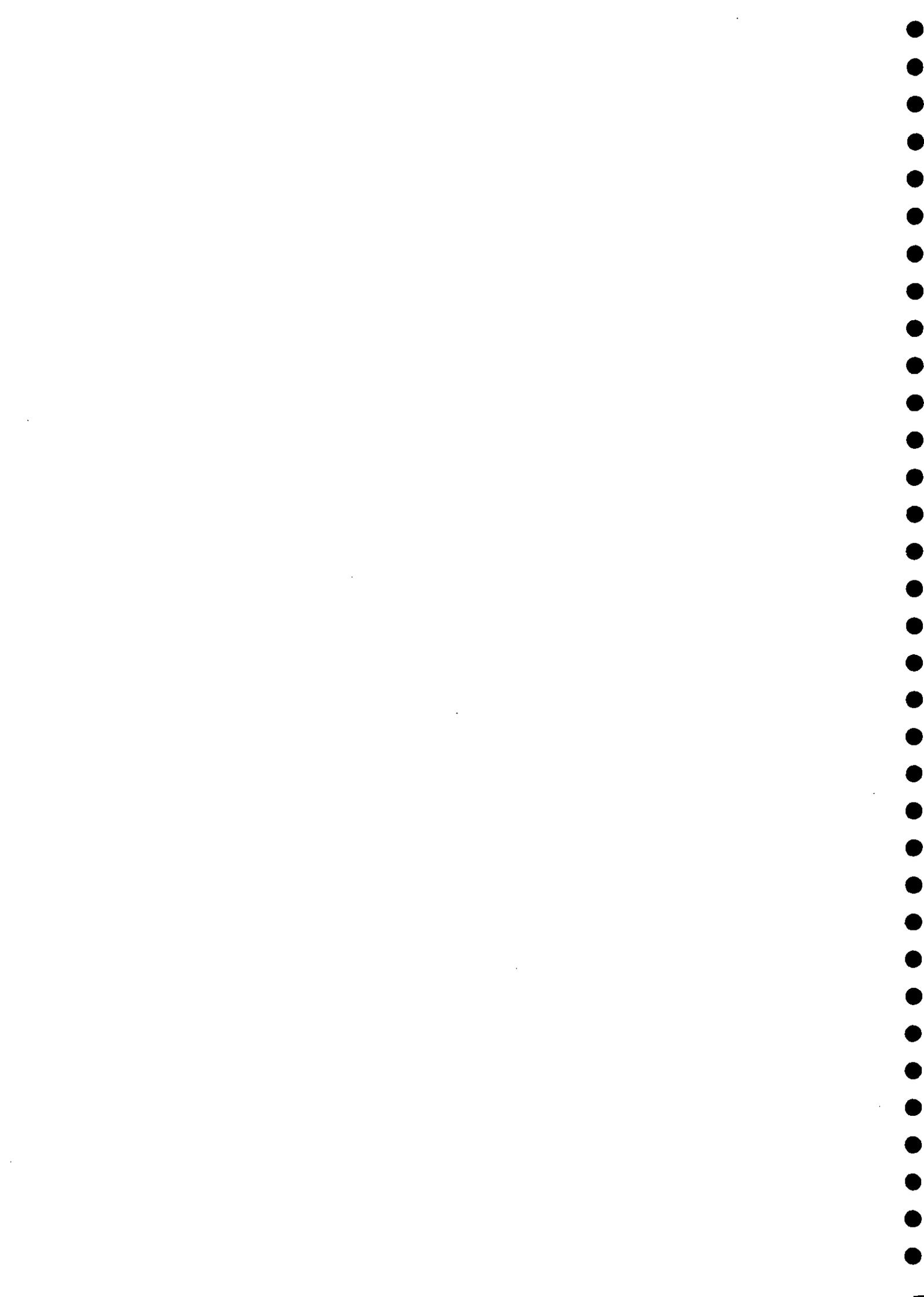
Report 4

Micro LOW FLOWS V2.1



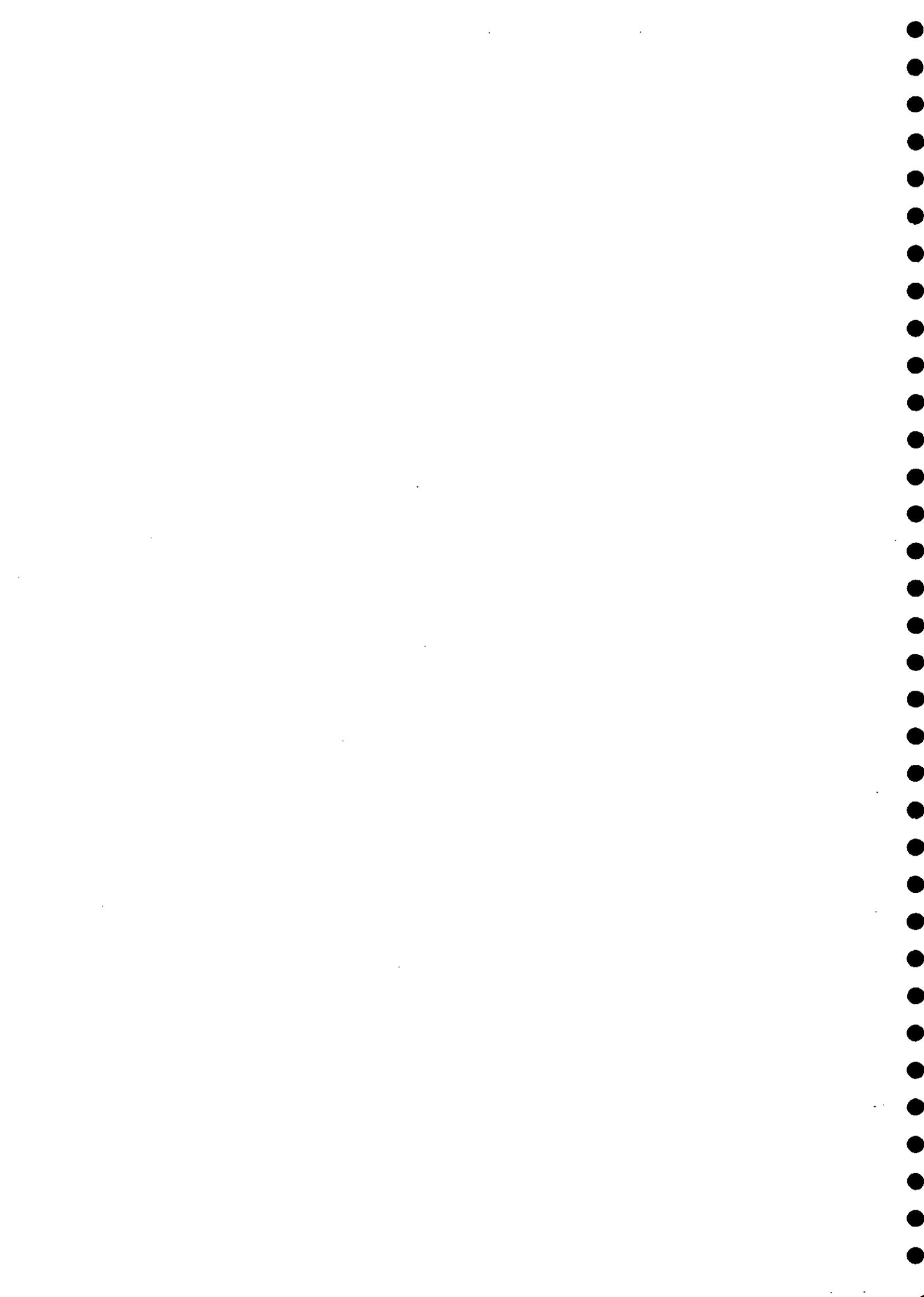
Preface

There are a variety of low flow measures which describe and quantify different properties of flow regimes and these have different applications in the water industry. This Manual describes the Micro LOW FLOWS V2.0 software which incorporates procedures for automatically estimating key low flow statistics at ungauged sites within natural catchments based on catchment characteristics and adjusts the low flow statistics to take into account the impact of artificial influences, including abstractions, discharges and impounding reservoirs.



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1. Introduction

Micro LOW FLOWS is a PC based interactive software package for the rapid estimation of low flow statistics from catchment characteristics at gauged and ungauged sites.

National methods (Gustard *et al.*, 1992) for the estimation of the mean flow, the mean annual minimum flow (MAM) and the 95 percentile exceedence (Q95) flow at ungauged sites are calibrated using catchment values of catchment area (AREA), standard annual average rainfall (SAAR), potential evaporation (PE) and the fractions of hydrological response (HOST) classes.

Based on a river network database, synthetic catchment boundaries are generated, which are then superimposed upon gridded databases of Q95 and MAM(7) (derived from the HOST classes), SAAR, and PE to derive mean catchment values of these characteristics above each river stretch. These catchment characteristic values are used for estimating the flow statistics associated with each stretch.

Micro LOW FLOWS provides database facilities for archiving information on abstraction licences, consents to discharge and reservoir outflows. These data are combined with natural flow statistics to estimate artificially influenced low flow statistics (Bullock *et al.*, 1994).

Micro LOW FLOWS also provides access to observed flow statistics at established gauging stations and facilities for the calculation of flow duration curves from databases of occasional current meter flow gaugings.

A mouse driven interactive roam capability within Micro LOW FLOWS allows the user to access flow estimates at river stretches by moving a cursor around a graphics display of the vectored river network.

1.1 HARDWARE AND SOFTWARE REQUIREMENTS

Micro LOW FLOWS requires the following:

- i) A DOS system computer with an Intel 486 processor or greater.
- ii) DOS 5.0 or above.
- iii) 3Mb of RAM with a minimum of 580Kb of system memory available for application programs and 100Mb of hard disk space.
- iv) EGA graphics card or better.
- v) A mouse.

The speed at which Micro LOW FLOWS executes is considerably enhanced by a maths co-processor.

Micro LOW FLOWS supports the following hard copy devices:

- i) HP LaserJet
- ii) HP7475
- iii) Paintjet

1.2 ABOUT THIS MANUAL

This Micro LOW FLOWS Technical Manual and User Guide represents a complete reference manual to accompany the software. Chapter 2 provides details of the estimation procedures used within Micro LOW FLOWS. Chapter 3 describes in detail the operation of the software through each of the menu options and a structured Tutorial exercise is provided in Chapter 4 to allow the user to become familiar with the main features of the software.

1.3 CONVENTIONS USED IN THE MANUAL

Within Chapter 3, using Micro LOW FLOWS, the following conventions are used to indicate inputs by the user:

- i) Keys on the computer keyboard are shown in small capital letters. For example, the Escape key is shown as ESC. The RETURN or ENTER key is shown as ↵.
- ii) Any input that the user is required to type is represented by bold characters. For example to start the Micro LOW FLOWS program the user can type **microlfs**. Input is always shown in lowercase letters unless the use of uppercase letters is indicated.
- iii) Places where a substitution can be made are shown in *italics*. For example *feature* can be substituted by gauging station, reservoir, abstraction site, discharge site, or spot gauge.
- iv) Micro LOW FLOWS is controlled by selecting choices from menus displayed on the screen. Menu choices are indicated in the manual by square brackets. The phrase "From menu 1 select [Low flow analysis]" means move the selection bar over the menu item [Low flow analysis] by pressing UP ARROW or DOWN ARROW and then press ↵ to initiate.

2. Technical Reference

2.1 THE RIVER NETWORK DATABASE

Micro LOW FLOWS has been designed around the generation of synthetic catchment boundaries based on digitized river networks and the capability to 'travel around' the networks to identify and quantify upstream spatial and point data. The original source of the river network database is the set of 1:50 000 Ordnance Survey maps. The basic component of the digitized river network is a river stretch, generally defined as the link of river between two confluences, and therefore devoid of inflow tributaries. In practice, a proportion of basic stretch units are broken and subdivided at map boundaries. The direction of flow within a stretch is known because each stretch is archived according to its upstream and downstream coordinates. In addition, several (but a variable number of) coordinate points along each river stretch are archived. Each stretch is identified by a Line Identifier (LID) assigned to that stretch which is unique to each individual river stretch within a single hydrometric area, but may be repeated in other hydrometric areas.

At confluences, the upstream and downstream end points of stretches meet where they have identical coordinates. As a result it is possible to travel upstream or downstream within a structured archiving file by identifying linked stretches. Travelling up a river is achieved by firstly obtaining the upstream coordinates of the selected stretch, and then searching the database for stretches which have these coordinates as their downstream point. The process is continued fan-wise until all upstream stretches are located, in which case all first-order 'source' reaches have been identified. This travelling capability makes possible the identification of associated stretches within a river basin and enables the automatic identification of all features (spatially distributed or point values) upstream of any stretch. In order to achieve this travelling capability, a simple branching structure has been imposed upon the network by editing braids, cross-channels and artificial drainage lines, including canals.

2.2 AUTOMATIC DERIVATION OF CATCHMENT CHARACTERISTICS

Catchment characteristics within Micro LOW FLOWS V2.1 are automatically calculated via the generation of a synthetic catchment area for each stretch and the accumulation of these synthetic catchment areas above each stretch. In the calibration procedure a computer generated grid of cell size 0.5 x 0.5 km is overlaid onto the digitized river network. Each cell within this grid is assigned to a stretch using a shortest-distance algorithm, subject to the constraints of digitized coastlines, hydrometric boundaries and sub-catchment boundaries. By travelling down the river networks, from the sources to the mouths, the array of cells above each stretch is identified and archived for that stretch. The overall methodology is detailed in Sekulin *et al.* (1992).

The standard period (1941-1970) average annual rainfall (SAAR) and annual average potential evaporation (PE) databases are both archived at a grid resolution of 1 km². The databases are derived from the Meteorological Office standard period (1941 - 1970) 1:625 000 rainfall and 1:2 000 000 average annual potential evaporation (provisional version) maps. The values of PE and SAAR are held with a depth resolution of 10 mm and 1 mm respectively. Gridded SAAR is held to an accuracy in the order of 10% of SAAR recorded at raingauges.

Two gridded databases of key low flow statistics are stored at a grid resolution of 0.25 km², notably Q95(1) (as a % of mean flow) and MAM(7) (as a % of mean flow). The origins of these two databases are described in detail below. Each 0.25 km² grid square in the United Kingdom has been assigned numerical values from the SAAR, PE, Q95(1) & MAM(7) gridded databases. As the array of grid squares above any stretch is known, taking the average of all the individual grid square values allows calculation of catchment average values of SAAR, PE, Q95(1) & MAM(7) above each stretch, thus providing estimates of catchment characteristics automatically, rapidly and consistently at any ungauged site. Catchment area is calculated directly from the number of accumulated grid cells. These values are used in the estimation of natural low flow statistics for that catchment, as described in detail below.

2.3 ARTIFICIAL INFLUENCES

The principal advance of Micro LOW FLOWS V2.1 from V1.31 is the ability to incorporate upstream artificial influences such as surface water abstractions, groundwater abstractions, discharges to surface water and impounding reservoirs into the low flow estimation procedures (Bullock *et al.*, 1994). The key step in implementing this is the construction of a monthly artificial influence profile based on data of water use upstream of an ungauged location. This comprises three stages:

- i) identification of all occurrences of artificial influences upstream of the ungauged site. This is implemented by attaching artificial influence features to river stretches, which can be identified as occurring upstream of a river stretch by the method described above;
- ii) quantification of monthly abstraction, discharge and reservoir impacts for each artificial influence. The feature archive of Micro LOW FLOWS V2.1 enables the storage of feature details for surface and groundwater abstractions, discharges and impounding reservoirs. Actual monthly data for an individual feature can be loaded, archived, edited and retrieved where available. Original data sources are National Rivers Authority archives of abstraction licences and discharge consents, and details of compensation flows are derived from Gustard *et al.* (1987). When actual monthly data are not available, Micro LOW FLOWS V2.1 offers the capability to 'predict' monthly values for abstractions and discharges. For abstractions this is achieved by applying uptake factors and minimum monthly factors to annual licensed totals, according to abstraction purpose and location within the United Kingdom. For discharges, the design dry weather flow discharge is assumed. In the case of groundwater abstractions, a Theis analytical solution is applied to distribute the impact of the abstraction upon river flow throughout the year depending on aquifer properties, distance of the abstraction from the stream and the rate of abstraction;
- iii) summation of individual upstream impacts to create a net monthly artificial influence profile. In the case of a catchment containing only abstractions (ABS) and discharges (DIS), the monthly artificial influence profile (IP) can be simplified to:

$$IP_k = DIS_k - ABS_k$$

where k = months 1 to 12

and DIS_k is indexed by:

$$\sum_{i=1}^n SCAMTH(i,k)$$

or $\sum_{i=1}^n SCPMTH(i,k)$

where:

$SCAMTH(i,k)$ = actual monthly discharges for month (k) at site (i)

$SCPMTH(i,k)$ = predicted monthly discharges for month (k) at site (i)

and ABS_k is indexed by

$$\sum_{i=1}^n SACTMTH(i,k)$$

or $\sum_{i=1}^n SPREMTH(i,k)$

where:

$SACTMTH(i,k)$ = actual monthly abstraction quantities for site(i) in month(k)

$SPREMTH(i,k)$ = predicted monthly abstraction quantities for site(i) in month(k)

for all (n) occurrences upstream.

However, in the case of a catchment containing an impounding reservoir, influences above the reservoir site are excluded, and the monthly reservoir release profiles (RR_k) replace the natural or artificial flow regime at the reservoir site.

2.4 LOW FLOW ESTIMATION

The estimation of natural low flow statistics is based on techniques developed and described in Gustard *et al.* (1992). Further development of these methods to estimate artificially influenced low flow statistics is described in Bullock *et al.* (1994). In summary, the overall methodology for the estimation of artificially influenced low flow statistics at an ungauged site comprises four principal steps, as follows:

- i) estimation of natural low flow statistics at the ungauged site, specifically mean flow, monthly mean flow, twelve monthly flow duration curves and twelve mean monthly minima, as described in subsequent sections;
- ii) construction of twelve monthly artificial influence profiles at the ungauged site which represent the net impact of all major upstream artificial influences, as described above;

- iii) combination of the estimated natural low flow statistics with the monthly artificial influence profiles to estimate artificially influenced monthly low flow statistics, as summarised in subsequent sections;
- iv) aggregation of monthly artificially influenced statistics to produce annual artificially influenced low flow statistics for design purposes.

2.4.1 Estimation of natural mean flow

The method for the calculation of the natural mean flow (MF) at the ungauged site is a water balance procedure (Gustard *et al.*, 1992) in which the average annual runoff depth (AARD in mm) is the difference between the rainfall and evaporation (Equation 2.1).

$$AARD = SAAR - AE \quad (2.1)$$

For catchments with rainfall in excess of 850 mm, actual evaporation is equal to potential evaporation as a result of relatively short periods when evaporation is limited by soil moisture deficit. Where evaporation is limited by rainfall being less than 850 mm, an adjustment factor dependent on the rainfall is applied to the potential evaporation. The adjustment factor is given by Equation 2.2 and the losses (actual evaporation) are calculated by Equation 2.3.

$$r = 0.00061 \times SAAR + 0.475 \quad (2.2)$$

$$AE = r \times PE \quad (2.3)$$

The average annual runoff depth in millimetres over the catchment is converted to mean flow in $\text{m}^3 \text{s}^{-1}$, as defined by Equation 2.4.

$$MF = AARD \times AREA \times 3.17 \times 10^{-3} \quad (2.4)$$

2.4.2 Estimation of artificially influenced mean flow

The artificially influenced mean flow is estimated in five stages:

- i) calculation of the natural mean flow (MF in $\text{m}^3 \text{s}^{-1}$) as described above;
- ii) estimation of the natural monthly runoff volumes which requires an estimated catchment value of the natural Q95 (as a % of MF) to determine the appropriate method required for the estimation. Constant values of monthly runoff volume (i.e. no spatial variability) are used for catchments in Northern Ireland (Table 2.1) and also in Great Britain where the Q95 is greater than 30% of the mean flow (Table 2.2).

For regions of the United Kingdom where the Q95 is less than 30% of the mean flow then 1 km^2 gridded databases of monthly runoff volumes (expressed as a % of MF) have been constructed. Two sets of grids are used: first for catchments with Q95 < 15% of the mean flow and second for catchments where the Q95 is between 15% and 30% of the mean flow. Each set comprises one grid per month. This method is based on the recognition that catchments within Great Britain with a Q95 of less than 30%

display significant regional variations in monthly runoff volumes (Institute of Hydrology, 1980 and Gustard *et al.*, 1987) and that the nature of this variability can be linked to Q95;

Table 2.1 Monthly runoff volume for Northern Ireland catchments

Monthly runoff volume (% ARV)											
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
16.8	12.3	8.7	5.3	3.9	2.7	2.4	3.4	5.9	9.9	12.9	16.0

Table 2.2 Monthly runoff volume for catchments in Great Britain with Q95 > 30% MF

Monthly runoff volume (% ARV)											
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
11.8	14.2	13.0	10.3	8.1	6.4	5.0	4.6	4.5	5.3	7.0	9.8

- iii) conversion of the monthly runoff volumes to monthly mean flows (MMF in $m^3 s^{-1}$) is achieved by Equation 2.5.

$$MMF = \frac{MRV \times MF}{(100/12)} \quad (2.5)$$

- iv) combination of the twelve natural MMF values with the appropriate monthly artificial influence profiles. Depending on the sign of the net artificial influence (which may vary between months), the MMF for each month may be reduced (if abstractions dominate) or increased (if discharges dominate). The influenced mean monthly flows $Inf_k MF_{DS}$ (where $k = 1$ to 12) are calculated using Equation 2.6.

$$Inf_k MF_{DS} = (Nat_k MF_{DS} - Nat_k MF_{RS}) + RR_k + (DIS_{kDS} - DIS_{kUI}) - (ABS_{kDS} - ABS_{kUI}) \quad (2.6)$$

where:

DS = design site

RS = reservoir site

RR = reservoir release

UI = upstream influence

- (v) the artificially influenced mean flow (in $m^3 s^{-1}$) is calculated as the average of the twelve influenced monthly mean flows, weighted by the number of days per month.

2.4.3 Estimation of natural Q95 and flow duration curve

The procedure for estimating the natural Q95 in ungauged catchments follows the method developed by Gustard *et al.* (1992). This method is based on the relationship between the standardised low flow statistics and the hydrological characteristics of soils represented by the Hydrology Of Soil Type (HOST) classification (Boorman & Hollis, 1990; Boorman *et al.*, 1991) and Low Flow HOST Groups. The HOST classification scheme is based on the assignment of soil series into 29 HOST classes according to physical properties of the soil and underlying solid and drift geology. Two further classes have been assigned to urban (in England and Wales only) and lake. HOST classes have been grouped into 12 Low Flow HOST Groups, for which estimates of standardised Q95 have been calculated (Table 2.3).

Based on this analysis, a gridded database of dominant HOST class within 1 km² grid squares has been converted to a gridded database of standardised Q95 .

Table 2.3 Q95 estimates for Low Flow HOST Groups

Low Flow HOST Grouping	Q95 parameter	standard error of parameter
LFHG1	40.8	1.7
LFHG2	31.9	2.6
LFHG3	65.7	2.9
LFHG4	25.0	3.0
LFHG5	49.0	6.8
LFHG6	6.5	5.6
LFHG7	10.7	0.8
LFHG8	1.1	2.0
LFHG9	15.0	2.2
LFHG10	6.8	1.5
LFHG11	29.4	2.1
LFHG12	65.1	25.8

The natural flow duration curve for a site can be constructed based on the selection of the appropriate curve from a family of 20 type curves (Gustard *et al.*, 1992). These type curves represent typical flow duration curves for different geological conditions. Selection of the

appropriate type curve is determined by the estimated value of Q95, whereby the curve corresponding to a Q95 value is calculated by:

$$\text{curve number} = \text{nearest integer} \times (10 \times \log Q95)$$

A comparison of the estimated Q95 and the Q95 for the selected type curve from Table 2.4 identifies the adjacent curve. Interpolation between these two curves enables a flow duration curve to be generated which passes through the estimated value of Q95.

Table 2.4 Flow duration type curves (as percentage of mean flow)

Type curve	0	1	2	3	4	5	6	7	8	9
Percentile 2	975.70	904.17	838.77	776.04	719.91	667.48	618.22	572.53	520.00	472.29
10	577.26	534.08	511.37	480.48	452.42	425.82	400.44	376.64	350.65	326.46
50	20.49	22.69	25.10	27.86	30.82	34.11	37.81	41.82	45.10	48.64
80	3.70	4.42	5.27	6.33	7.54	9.00	10.77	12.86	15.20	17.98
90	1.73	2.13	2.62	3.25	3.99	4.92	6.07	7.47	9.16	11.22
95	1.00	1.26	1.58	2.00	2.51	3.16	3.98	5.01	6.30	7.94
99	0.38	0.51	0.67	0.88	1.16	1.53	2.02	2.65	3.46	4.52
Type curve	10	11	12	13	14	15	16	17	18	19
Percentile 2	428.96	389.60	353.86	321.39	291.65	264.89	240.09	206.89	178.28	153.69
10	303.93	282.96	263.44	245.26	228.19	212.45	197.49	176.99	158.62	142.20
50	52.46	56.57	61.01	65.79	71.00	76.57	82.60	89.91	97.86	106.49
80	21.25	25.13	29.71	35.12	41.58	49.16	58.08	67.82	79.21	92.46
90	13.75	16.86	20.66	25.32	31.09	38.10	46.67	56.95	69.50	84.77
95	10.00	12.57	15.83	19.93	25.13	31.64	39.81	50.13	63.12	79.43
99	5.89	7.69	10.03	13.08	17.11	22.32	29.13	39.00	52.22	69.85

2.4.4 Estimation of artificially influenced Q95 and flow duration curve

The artificially influenced flow duration curve at a site is estimated in four stages, as follows:

- i) At a site, the natural Q95 is estimated using the method described by Gustard *et al.*, 1992. From this the annual flow duration type curve is derived, as described above. It has been established in Report Low Flow Estimation Artificially Influenced Catchments (Bullock *et al.*, 1994) that, for a given range of Q95 values, annual type curves can be assigned to each month, referred to hereafter as the monthly type curve. Table 2.5 shows the relationships between the monthly and annual type curves.

- ii) The 12 monthly type curves need to be individually adjusted so that the curve created by combining them coincides with the natural annual curve.

This is done by interpolating flow values from each monthly type curve at 30 percentile points equally distributed in log space. These 30 'flows' each carry a flag to indicate which month they belong to. The resultant 360 'flows' are used to derive a composite annual flow duration curve (CURVEM) by ranking them from highest (rank 1) to lowest (rank 360) and then calculating a probability of exceedence (P_n) for each of the 360 flows using Equation 2.7:

$$P_n = X_n \times \frac{100}{360} \quad (2.7)$$

where X_n = rank

Table 2.5 Matrix of type curves for monthly pooled flow duration curves

Q95 class (% of MF)	Annual type curves											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0-2.5	10	11	11	10	8	8	8	6	6	5	7	9
2.5-7.5	12	12	12	12	10	10	11	9	9	9	10	11
7.5-12.5	13	13	13	14	13	13	13	12	12	11	12	12
12.5-17.5	14	14	14	15	15	15	15	14	13	12	13	13
17.5-22.5	14	15	15	15	16	16	16	15	15	13	14	14
22.5-27.5	15	15	15	16	16	16	16	16	16	14	15	14
27.5-32.5	15	16	16	16	16	17	17	16	17	16	15	15
32.5-37.5	16	16	16	17	17	17	17	17	17	16	16	15
37.5-42.5	16	16	17	17	17	18	18	17	18	17	17	16
42.5-47.5	17	17	17	17	17	18	18	18	18	17	17	17
47.5-52.5	18	17	18	17	18	18	18	18	18	18	18	18
52.5-57.5	18	18	18	18	18	18	18	18	18	18	18	18
57.5-62.5	18	18	18	18	18	18	18	19	18	18	18	18
62.5-67.5	18	18	18	18	18	18	18	19	19	19	19	18
72.5-77.5	18	19	19	19	19	19	19	19	19	19	19	18

A composite flow duration curve is derived from the annual flow duration curve (CURVEA) comprising flow values for the 360 percentiles, P_n . At this stage, each of the 360 percentiles (P_n) is associated with a flow value from the CURVEA and a flow value from CURVEM (with the flag identifying the month of origin). A comparison is then made between the two sets of flows for each percentile and the individual flow values from CURVEM are set to equal the corresponding flow values from CURVEA if the two are different.

- iii) The influence profile for each month (as described in Section 2.3) is used to adjust the flows for the corresponding month in CURVEM (identified using the month flag). The 360 resultant influenced flows are ranked and the influenced annual flow duration curve calculated as previously using Equation 2.7.
- iv) If there are reservoirs upstream of the site of interest, the artificial influences upstream of the reservoir and the natural monthly flow duration curves at the reservoir site are replaced by the monthly reservoir releases profiles. Therefore, an estimated composite annual flow duration curve (CURVER) at the reservoir site is calculated from the 12 monthly type curves as described in (i) to (ii) above.

At the site of interest, the natural composite annual flow duration (CURVEM) is calculated as before. The 360 flow values are adjusted by the corresponding flow values from CURVER and the influence profiles and ranked as described in (iii) above to produce the influenced annual flow duration curve.

2.4.5 Estimation of natural MAM(7) and low flow frequency curve

In common with the estimation of the natural Q95 in ungauged catchments, the procedure for estimating the natural MAM(7) in ungauged catchments follows the method of Gustard *et al.*, (1992), using values of MAM(7) derived from the HOST classification and Low Flow HOST Groups (Table 2.6) for individual soil associations. The catchment estimate of MAM(7) is subsequently used to derive the mean monthly minima.

Annual minima of durations other than 7 days can be estimated using the natural MAM(7) value (Gustard *et al.*, 1992). A variable (GRADMAM) which represents the rate of change of MAM(D)/MAM(7) with duration (D), is derived using the Equation 2.9 and the annual minima can be derived from Equation 2.10.

$$\text{Log GRADMAM} = \text{SAAR}^{(0.6226)} \times \text{MAM}(7)^{(-1.0186)} \times 2.1213 \times 10^{-3} \quad (2.9)$$

$$\text{MAM}(D) = \text{MAM}(7) \times (1 + (D - 7) \times \text{GRADMAM}) \quad (2.10)$$

A family of 12 standardised type curves have been developed (Gustard *et al.* 1992) to represent frequency relations of typical curves for different geological conditions and different durations of minimum flows. The selection type curve is dependent on the magnitude of MAM(D) and the specified duration. The natural flow frequency curve is derived by applying a factor to the appropriate type curve.

Table 2.6 MAM(7) estimates for Low Flow HOST Groups

Low Flow HOST Grouping	MAM(7) parameter	standard error of parameter
LFHG1	50.8	1.9
LFHG2	40.3	2.8
LFHG3	71.3	3.3
LFHG4	25.7	3.3
LFHG5	53.4	7.5
LFHG6	1.4	6.2
LFHG7	12.4	0.9
LFHG8	0.1	2.3
LFHG9	14.4	2.4
LFHG10	5.9	1.7
LFHG11	33.8	2.4
LFHG12	49.6	28.7

2.4.6 Estimation of artificially influenced MAM(7)

The estimation of the mean monthly minimum is based on statistical relationships between observed mean monthly minima, MAM(7) and catchment characteristics. Values of the parameter estimates are shown in Table 2.7, for the following general relationship given by Equation 2.11:

$$MMM(7)_{MON} = a \times MAM(7)^b \times SAAR^c \times AREA^d \quad (2.11)$$

These equations provide estimates of natural mean monthly minimum at ungauged sites for the adjustment by artificial influences on a monthly basis. However, unlike the flow duration curve method, techniques have not been developed to recombine the 12 values of MMM(7) to estimate MAM(7).

If an estimate of the artificially influenced MAM(7) is required, then in the absence of more complex solutions involving time series simulations, MAM(7) is assumed to equal the lowest of all 12 values of artificially influenced MMM(7). In all circumstances, adoption of this assumption will overestimate the true value of MAM(7) (because in time series, the MAM(7) represents the mean of minima occurring in different months, which must by definition be less than the mean of minima selected from the same month).

Table 2.7 Parameter estimates for mean monthly minimum equations

MMM(7)	Parameter estimates		
	a const	b MAM(7)	c SAAR
JAN	15.52	0.314	0.038
FEB	39.32	0.303	-0.084
MAR	36.25	0.323	-0.079
APR	31.35	0.359	-0.066
MAY	17.99	0.337	0.035
JUN	39.04	0.398	-0.107
JUL	101.80	0.380	-0.238
AUG	50.04	0.414	-0.157
SEP	55.76	0.446	-0.197
OCT	19.99	0.385	-0.029
NOV	8.82	0.349	0.105
DEC	11.77	0.344	0.059

2.5 RETRIEVAL OF LOW FLOW ESTIMATES IN MICRO LOW FLOWS

Micro LOW FLOWS V2.1 generates estimates of low flow statistics (natural and artificial) of two general types: i) as estimates pertaining to a single stretch of river, termed single stretch estimates; ii) as residual flow diagrams which graphically represents the accumulation of flow estimates along the profile of a river.

2.5.1 Single stretch estimates

Micro LOW FLOWS V2.1 allows, in principle, natural and artificially influenced low flow statistics to be estimated at over 150 000 individual stretches of river in England and Wales, as defined by the river network digitized from 1:50 000 topographic maps. Micro LOW FLOWS (V1.31 & V2.1) is set up on a regional basis as defined by the administrative regions of the National Rivers Authority, and the number of river stretches varies between these regions, up to a maximum of 30 000 in a region.

Micro LOW FLOWS V2.1 generates estimates of the following low flow statistics and measures:

NATURAL**ARTIFICIAL**

Mean flow (MF) (in $\text{m}^3 \text{s}^{-1}$)	Mean flow (MF) (in $\text{m}^3 \text{s}^{-1}$)
Flow duration curve (as % of MF)	Flow duration curve (as % of influenced MF)
Q95 (in $\text{m}^3 \text{s}^{-1}$ and as % of MF)	Q95 (in $\text{m}^3 \text{s}^{-1}$ and as % of influenced MF)
Other percentiles (in $\text{m}^3 \text{s}^{-1}$)	Other percentiles (in $\text{m}^3 \text{s}^{-1}$)
MAM(7) (in $\text{m}^3 \text{s}^{-1}$ and as % of MF)	MAM(7) (in $\text{m}^3 \text{s}^{-1}$ and as % of influenced MF)
MAM(D) (in $\text{m}^3 \text{s}^{-1}$)	MMM(7) (in $\text{m}^3 \text{s}^{-1}$)
Low flow frequency curve (in $\text{m}^3 \text{s}^{-1}$)	

Natural and artificially influenced estimates of mean flow, flow duration curve, Q95 (and other percentiles) and MAM(7) are presented simultaneously on screen and hardcopy outputs. Micro LOW FLOWS V2.1 has full capabilities for generating tabular and graphical outputs to peripheral devices. In addition, monthly artificial influence profiles are displayed numerically on screen. In all cases, stretch estimates and influence profiles correspond to the downstream end of river stretches.

2.5.2 Residual flow diagrams

A residual flow diagram represents a hydrological 'snapshot' of the total quantity of water in a river or stream for any location on the river for a chosen flow condition. The diagram illustrates the natural low flows, artificially influenced low flows and the artificial flow component, enabling interpretation of the relative composition of flow at any point along a river profile. Micro LOW FLOWS V2.1 provides full flexibility in the selection of the upstream and downstream points for residual flow diagram construction and in selecting the mean flow or any flow percentile as the flow condition.

The principal structure of the residual flow diagram comprises a vertical axis which represents the line of the principal channel. Distance from source, or any other starting point, is measured downwards from the top of the axis. The horizontal axis represents the total flow of the river (measured in Mld^{-1} , or $\text{m}^3 \text{s}^{-1}$).

Residual flow diagrams may be constructed within Micro LOW FLOWS V2.1 for different low flow statistics, and are constructed as follows, using the example of the Q95 statistic:

- i) the natural Q95 is estimated for each river stretch;
- ii) the artificially influenced Q95 is estimated for each river stretch. This may also be termed the 'residual flow Q95';
- iii) the artificial flow component is calculated as the artificially influenced Q95 minus the natural Q95. Hence, the artificial flow component is positive where the artificially influenced Q95 exceeds the natural Q95 (in the case of discharge impacts being greater than abstraction impacts upstream) and negative when the artificially influenced Q95 is less than the natural Q95 (that is where abstraction impacts are greater than discharge impacts upstream). Clearly, the artificial component can be zero when there are no upstream influences or the impacts of the influences balance to zero;

- iv) plot natural Q95, artificially influenced Q95 and artificial component against distance downstream.

It should be noted that this method of construction differs from the traditional method discussed above, where the traditional method equates to Equation 2.12 on the basis that the artificial component for a *given flow condition* could be quantified.

$$\text{Residual flow Q95} = \text{natural Q95} + \text{artificial components} \quad (2.12)$$

However, this is rarely ever the case and previously represented a major limitation of this type of diagram. In comparison, and as stated, the modified residual flow diagram construction method in this report estimates the artificially influenced or residual flow Q95 directly, as well as the natural Q95, and the artificial component is calculated as the difference between the two. Hence, the artificial flow component will vary with flow condition.

3. Using Micro LOW FLOWS

It is assumed that Micro LOW FLOWS has already been installed. If this is not the case refer to Appendix A for the installation procedure. Micro LOW FLOWS is set up to provide regional coverage based on administrative units of the United Kingdom water industry.

3.1 STARTING MICRO LOW FLOWS

To start Micro LOW FLOWS first change to the directory containing the Micro LOW FLOWS files by typing `cd microlfs ←` and then type `microlfs ←`.

The screen illustrated in Figure 3.1 will be displayed where the user is requested to enter a database update password. This must be a 4 digit number eg 1234. The password may be skipped by pressing ESC in which case low flow analysis can be undertaken but changes to the database will not be allowed.

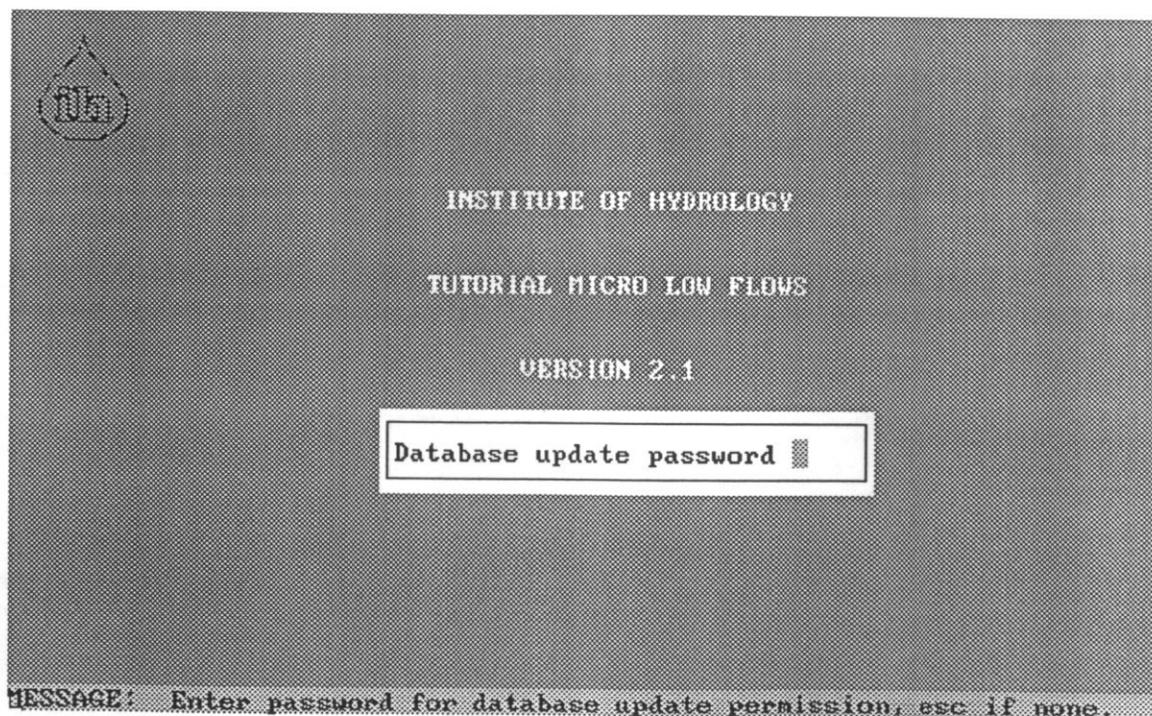


Figure 3.1 Micro LOW FLOWS entry screen

On entry of the correct password the following screen will be displayed where the user is requested to select either a LIVE or a TEMPORARY session (Figure 3.2). In a LIVE session the database will be updated at the end of a session whereas in a TEMPORARY session the database will be temporarily updated but changes will not be preserved at the end of a session.

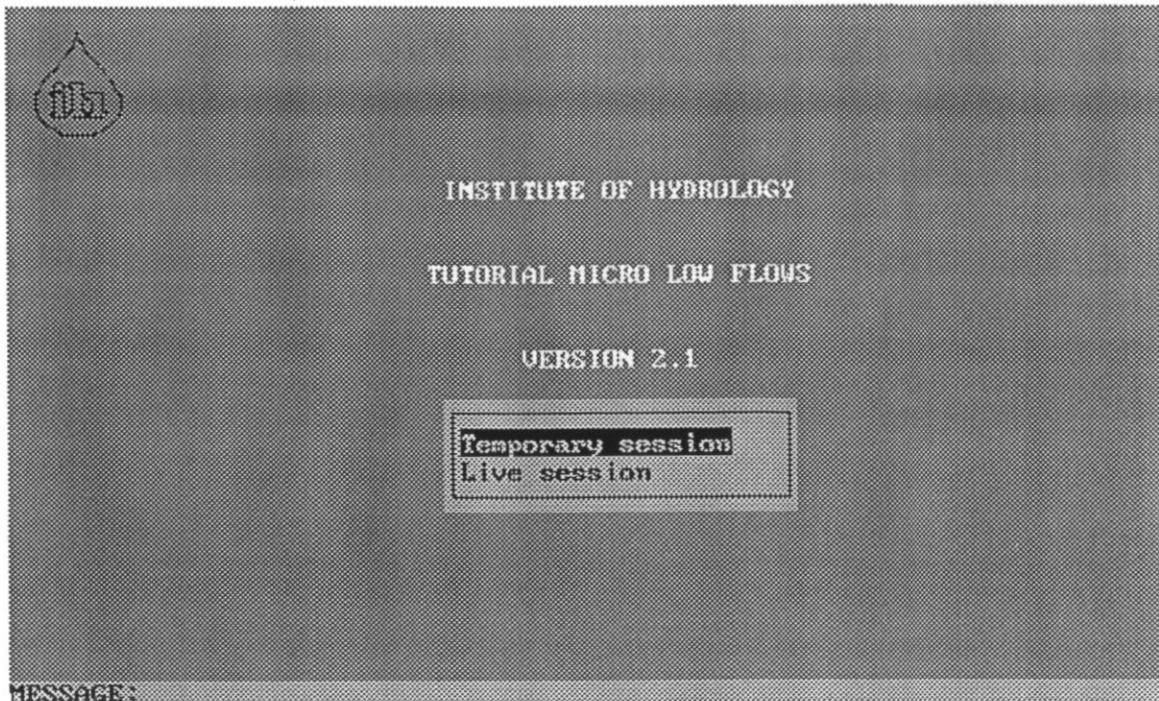


Figure 3.2 Session status

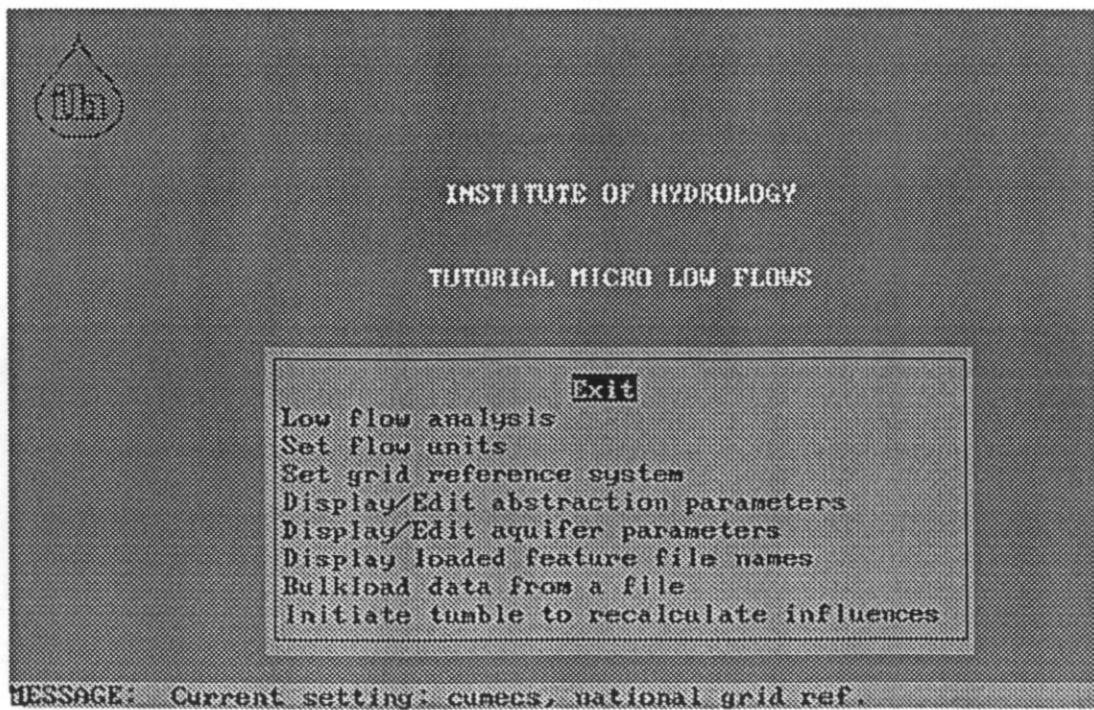


Figure 3.3 Menu A, Initial menu

From Menu A (Figure 3.3) select one of the following options:

Use this option	To do this
Exit	Return to the DOS environment
Low flow analysis	Begin low flow analysis. This is described in "Low flow analysis - overview", below.
Set flow units	*Set the units for flow rate. Either cumecs ($m^3 s^{-1}$) or Mld^{-1} can be selected.
Set grid reference system	*Set the grid reference system. Either eastings/northings (4 figures) or National Grid coordinates (2 letters and 6 figures) can be selected.
Display/Edit abstraction parameters	Access the abstraction licence global parameters. These parameters are explained in "Editing the global parameters", later in this chapter.
Display/Edit aquifer parameters	Access the aquifer global parameters. These parameters are explained in "Editing the global parameters", later in this chapter.
Display loaded feature file names	Display feature datasets which have been loaded.
Bulkload data from a file	Load feature data from a file into the Micro LOW FLOWS database. This is explained in "Bulkloading feature data", later in this chapter.
Initiate a tumble to update influences	Rebuild influence profiles following a change to the database.

3.2 LOW FLOW ANALYSIS - OVERVIEW

Low flow analysis involves the following steps:

1. Selecting the hydrometric area of interest and loading the data for this area into Micro LOW FLOWS.
2. Accessing the required river network.
3. Obtaining the low flow statistics for the selected river stretch.
4. Moving around the network to examine other stretches.
5. Using the feature editor to make changes to the database.

* ensure that the current settings are filled by reference to the message at the bottom of the screen.

3.3 SELECTING A HYDROMETRIC AREA

Having selected [Low flow analysis] from Menu A, the next step is to select the hydrometric area. If Micro LOW FLOWS is configured for only one area, this area is selected automatically. Otherwise the user can select the required area from those displayed.

Wait a few moments while the area data is loaded before model of entry menu is displayed (Figure 3.4).

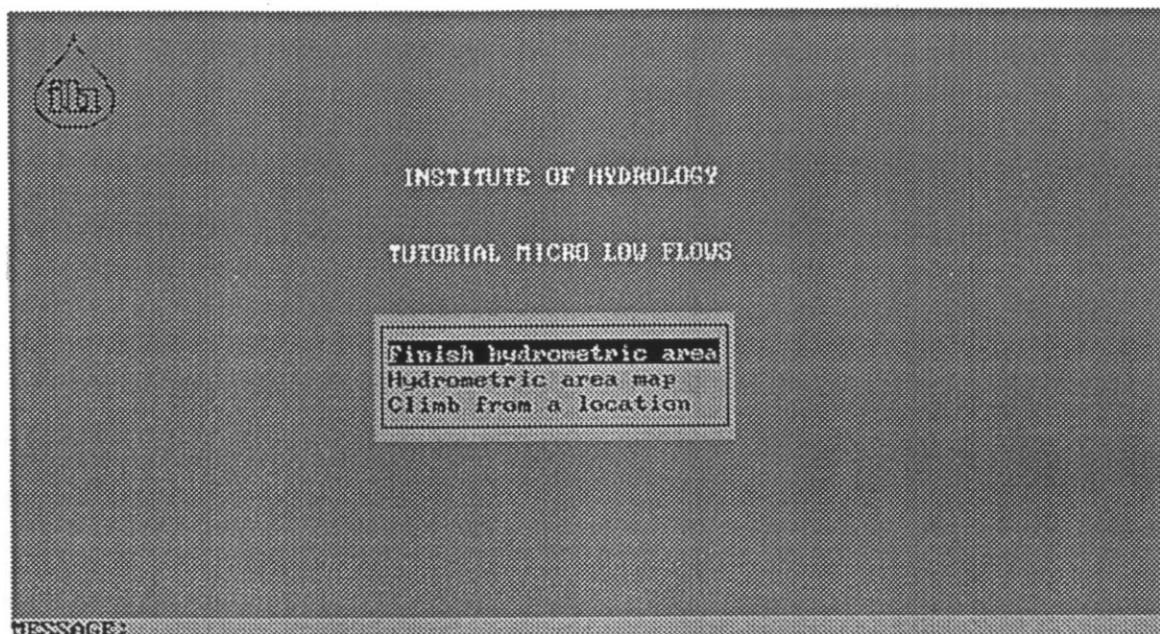


Figure 3.4 Mode of entry

3.4 ACCESSING A RIVER NETWORK

Micro LOW FLOWS provides two options for accessing a river network:

1. A single stretch in the river network may be selected from a map of the networks, termed the HYDROMETRIC AREA MAP option.
2. Multiple stretches may be selected through climbing from a known location, termed the CLIMB FROM A LOCATION option.

3.4.1 To select the HYDROMETRIC MAP option

1. Select [Hydrometric area map].
2. A list of hydrological features is shown:

- i) Reservoirs
- ii) Abstraction sites
- iii) Discharge sites
- iv) Spot gauges

These features can be selected for display by pressing Y or N against each feature. Note that gauging stations are always selected for display. However, when the river network is displayed initially, it is necessary to toggle on the icons. See 'using the Feature editor'. Press ESC to accept the settings and continue.

The boundary of the selected hydrometric area is displayed.

3. Select one of the following options.

Use this option	To do this
Finish hydrometric area	Return to Menu A.
Zoomin (with stretches)	Magnify a region of the map by selecting 2 points on the map with the mouse at opposite corners of the square of interest. If the points are less than 1 km apart, the magnification is set at x2; otherwise a square of side equal to the maximum of the X-Y distances selected is used to delineate the magnified region. The river networks within the zoomin window are plotted.

4. Select one of the following options:

Use this option	To do this
Display different part	Go to another region of the map, see "Moving around the river network" later in the chapter.
Select a stretch	Select a stretch for analysis with the mouse. Once selected the details, catchment characteristics and low flow estimates generated for that stretch are displayed.

3.4.2 To select the CLIMB FROM LOCATION option

1. Select [Climb from a location].
2. Select one of the following options for identifying an initialising river stretch.

Use this option	To do this
Finish hydrometric area	Return to Menu A.
Gauging station	Specify a gauging station. Enter the IH Surface Water Archive number for the gauging station required.
Line ID (LID)	Specify the Line Identification number of the stretch.
Grid reference	Specify the Grid Reference of the stretch. Enter either two 4 digit numbers or a 2 letter and 6 digit number.
River name	Specify a river. Select the river name from a list rivers within the hydrometric area. The initialising stretch in this case is the stretch furthest downstream on the nominated river. Certain named rivers may be tributaries of larger named rivers.

3. A list of hydrological features is shown. Mark the ones that are to be displayed by pressing Y or N against each feature. Press ESC to accept the settings.

The river network is plotted upstream of the requested initialising stretch; no hydrological features apart from gauging stations are shown at this point. The initialising stretch is marked red and the estimated values for this stretch are displayed (Figure 3.5).

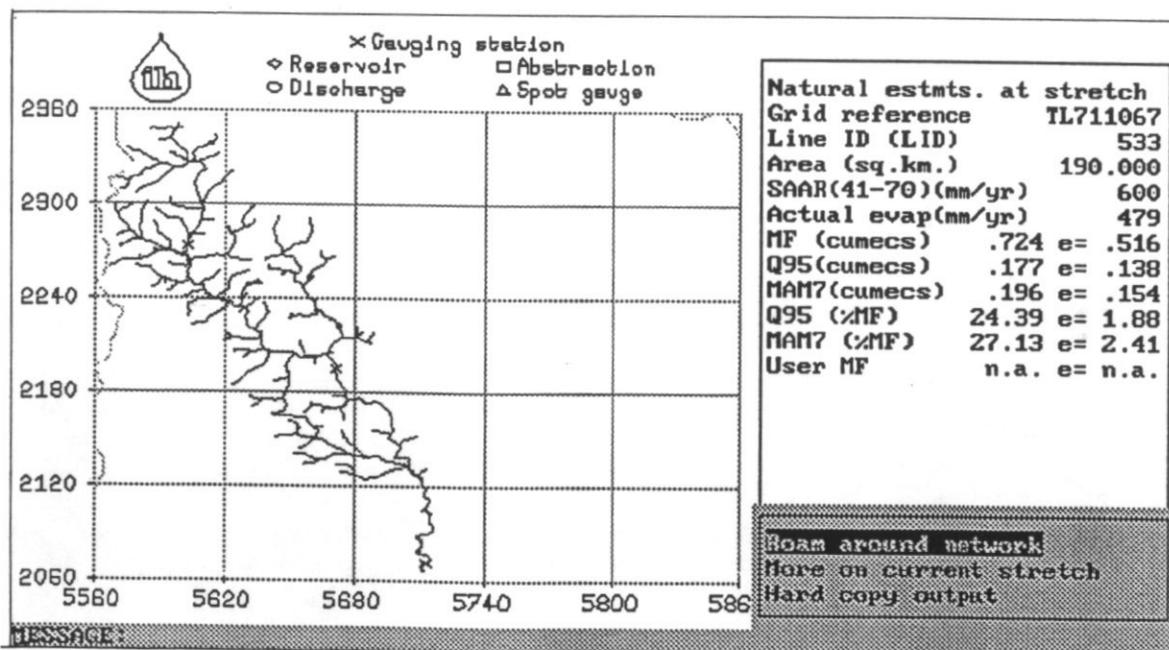


Figure 3.5 Catchment estimates for selected river network

3.5 OBTAINING THE RESULTS OF LOW FLOW ANALYSIS

The following can be obtained for the currently selected river stretch:

- i) Natural and influenced estimates of mean flow.
- ii) Natural and influenced flow duration curve.
- iii) Natural and influenced MAM(7) and natural flow frequency curve of different duration.
- iv) Residual flow diagram based on mean flow or selected flow duration percentile (only available within the CLIMB FROM A LOCATION option).
- v) Notes about the stretch.
- vi) River name (only available within the CLIMB FROM A LOCATION option).
- vii) Toggle markers on/off where features have been selected for display.

3.5.1 To obtain results

Select [More on current stretch] to list more detailed analysis options (Figure 3.6).

Note: Some of the analysis options are not valid within the HYDROMETRIC AREA MAP option and are therefore not displayed when this option is selected.

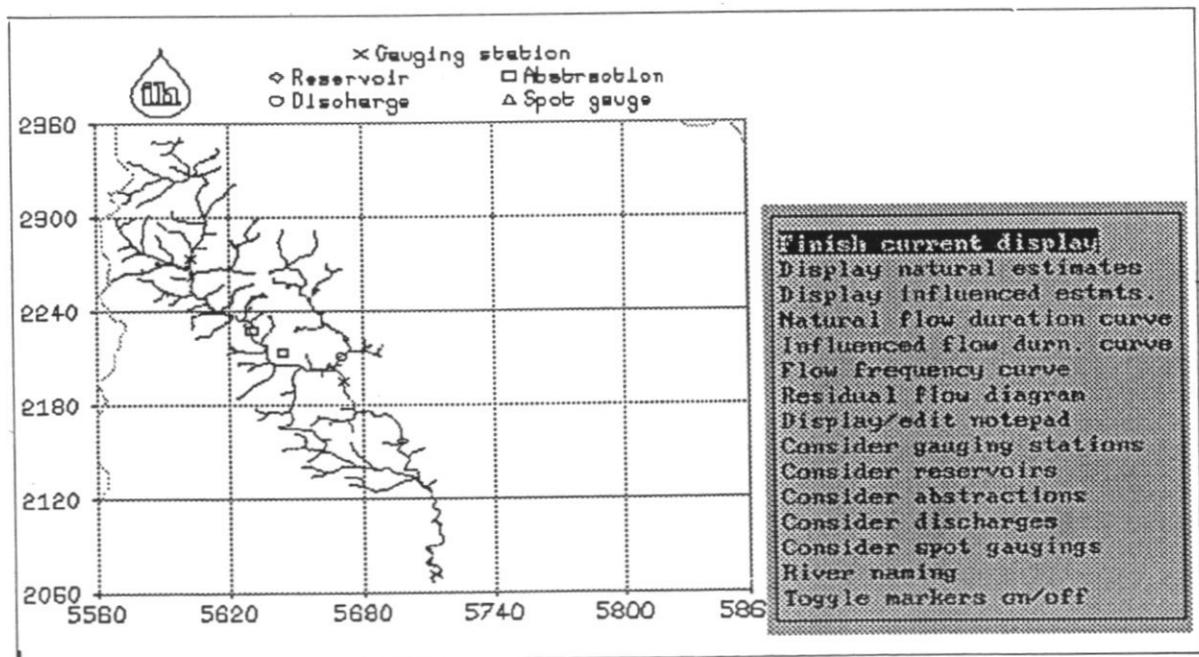


Figure 3.6 Analysis options menu

3.5.2 Stretch estimates

To obtain the natural estimates

From the analysis option menu, select [Display natural estimates].
The estimates will be shown in the display panel.

Estimate	Comments
SAAR (41-70) (mm/yr)	Estimated standard period (1941-70) annual average rainfall over the estimated catchment area.
Actual evap (mm/yr)	Estimated annual average actual evaporation over the estimated catchment area.
MF (selected units)	Estimated mean daily flow at the downstream end of the current stretch.
Q95 (selected units)	Estimated 95 percentile exceedence flow of one day duration.
MAM7 (selected units)	Estimated mean annual minimum flow of seven days duration.
Q95(%MF)	Estimated 95 percentile exceedence flow of one day duration expressed a percentage of mean flow.
MAM7(%MF)	Estimated mean annual minimum flow of seven days duration expressed as a percentage of mean flow.
User MF	User defined mean flow which you are allowed to edit. This value is used in place of MF above if it exists.

To obtain the influenced estimates

From the analysis option menu select [Display influenced estmts.].

As well as the estimates of MF, Q95 and MAM(7) the twelve monthly values of mean monthly minima (MMM(7)) and net influence at the site are displayed.

3.5.3 Flow duration curve

To obtain the natural flow duration curve

1. Select [Natural flow duration curve].
2. The flow duration curve and menu panel are displayed from which the following options can be selected.

Up to 10 values of estimated exceedence/flow will be stored and plotted on the hard copy. Values out of range will not appear on the hard copy.

Use this option	To do this
Finish requests	Get a hard copy plot of the flow duration curve and/or return to analysis options menu. If a hard copy of the flow duration curve is requested you have to specify the output device and supply a title for the plot.
Get exceedence from flow	Get the estimated exceedence percentile corresponding to a flow. Enter required flow.
Get flow from exceedence	Get the estimated flow corresponding to an exceedence percentile. Enter required percentile.

To obtain the influenced flow duration curve

1. Select [Influenced flow dur. curve].
2. The user is then requested to select
 - i) the natural and influenced flow duration curves
 - ii) the spot gauge scatterplot
3. Follow step 2 for the natural flow duration curve above (Figure 3.7).

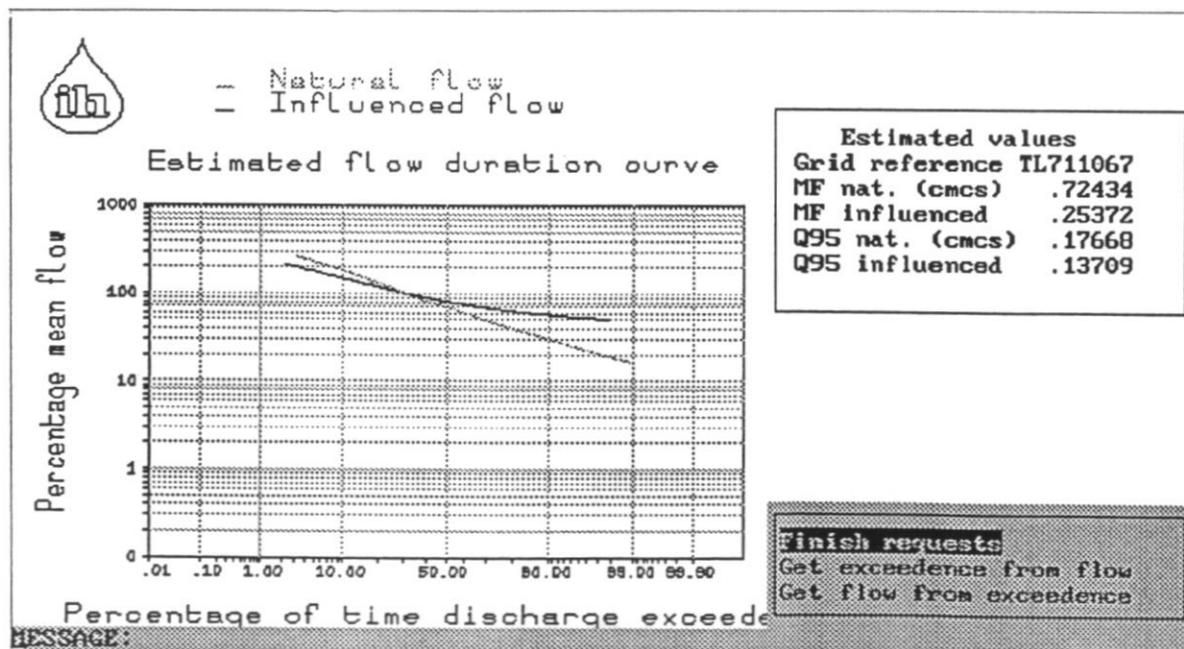


Figure 3.7 Influenced flow duration curve

3.5.4 Flow frequency curve

To obtain the flow frequency curve

1. From the analysis options menu select [Flow frequency curve].
2. Select the appropriate duration from the list.

The flow frequency curve will be displayed (Figure 3.8).

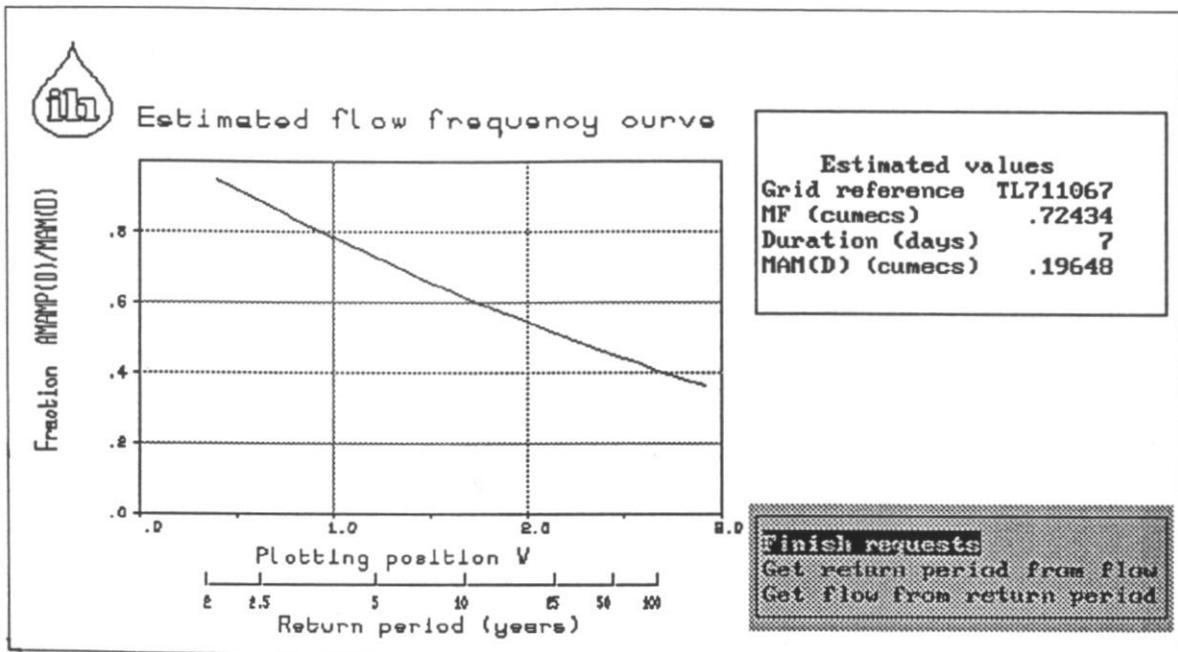


Figure 3.8 Natural flow frequency curve

3. Select one of the following options:

Use this option	To do this
Finish requests	Get a hard copy plot of the flow frequency curve and/or return to analysis options menu. If a hard copy is requested specify the output device and supply a title for the plot.
Get return period from flow	Get the estimated return period corresponding to a flow.
Get flow from return period	Get the estimated flow corresponding to a return percentile. Enter required percentile.

Up to 10 values of estimated return period/flow will be stored and plotted on the hard copy.

3.5.5 Residual flow diagram

The residual flow diagram presents a hydrological snapshot of a river for a particular flow condition. Each influence on a river is quantified and an overall picture of the total flow at any point on the system is presented. The diagram can show how the flow at any point on the system is composed in terms of its natural and artificial components.

The principle components of the residual flow diagram are:

- i) The vertical axis representing the line of the principal channel. Distance from source, or any other starting point, is measured downwards from the top of the axis.
- ii) The horizontal axis representing the flow of the river measured in cumecs or Ml/d. The flow is separated into three components; the natural flow, artificial flow and the residual flow. The natural and residual flow are always positive or zero, the artificial component may be positive or negative.

To obtain the residual flow diagram

Note: This is only available within the CLIMB FROM A LOCATION option.

1. From the detailed analysis options menu either.
 - i) Select [Finish residual flows] and return to the analysis options menu, or
 - ii) Select [Select U/S stretch]. Click on an upstream stretch with the mouse. The length of river from this stretch to the initialising stretch will be indicated in red.

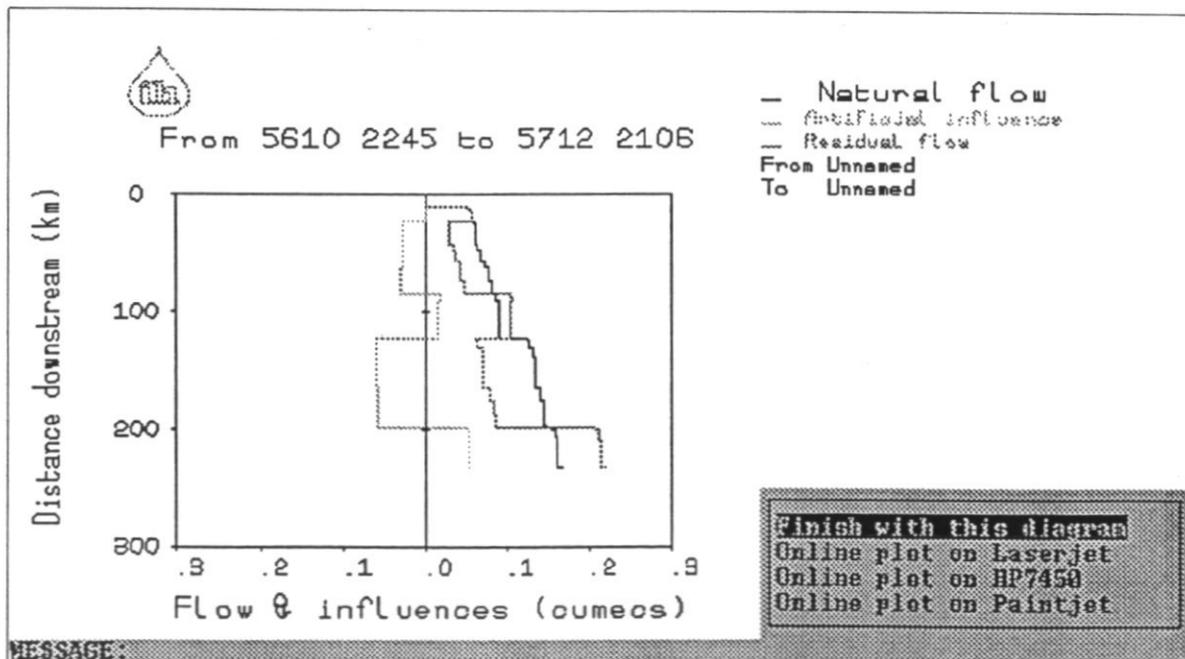


Figure 3.9 Residual flow diagram

2. Specify the statistic to be used to represent the natural flow component.
 - i) Use mean flow. The residual flow is represented by the artificially influenced mean flow.
 - ii) Use flow percentile (this may take a very long time to derive). Supply a value for the flow percentile.

The residual flow diagram will be displayed (Figure 3.9). A hard copy of the diagram may be requested. Alternatively, return to the [residual flow diagram] option and replot with a new statistic.

3.5.6 Notes about the stretch

The user can display and edit additional information regarding the current stretch. There is space for up to 297 characters.

To obtain notes on the currently selected stretch

1. From the detailed analysis option menu select [Display & edit notepad].
2. The notes are displayed. Text can be inserted, deleted and edited. To exit press ESC twice.

3.5.7 River name

Within the CLIMB FROM A LOCATION option it is possible to display and edit the river name assigned to the network above the current stretch. The river name appears on all hard copy output.

To obtain the river name

1. From the detailed analysis option menu select [River naming].
2. The river name is displayed which can be edited if required.

3.6 OBTAINING HARD COPY OUTPUT OF DATA FOR AN IDENTIFIED RIVER STRETCH

Micro LOW FLOWS provides a number of reports about the currently selected river stretch. It is possible to output the reports to either a printer or a file. If a filename is supplied, the extension .MLF is added automatically. It is important to note that if the filename is used more than once the subsequent output data sets will overwrite the first. These MLF files are written to the C:\MICROLFS directory.

To obtain hard copy output

1. From the river network menu select [Hard copy output]
2. Select one of the following options:

Use this option	To do this
Finish current hard copy	Return to the river network display.
Print stretch values	Print parameter estimates for the currently selected stretch. Supply a title for the print and select the required combination of stretch attributes to print: <ul style="list-style-type: none">● all stretch information● flow estimates only● estimates and catchment characteristics● other information
Print upstream estimates	Print parameter estimates for all stretches upstream of the current stretch. The network upstream of the stretch is plotted and the current stretch marked in red. Note: this can only be selected within the CLIMB FROM A LOCATION option.
Print upstream <i>feature</i>	Print data for all features of that type upstream of the current stretch. Note: this can only be selected within the CLIMB FROM A LOCATION option.
Plot network&natural estimates.	Output the currently displayed portion of the river network, with the natural estimated parameters for the current stretch and the contents of the notepad.
Plot network&influenced estimates	Output the currently displayed portion of the river network, with the artificially influenced estimated parameters for the current stretch and the contents of the notepad

3.7 MOVING AROUND THE RIVER NETWORK

Micro LOW FLOWS provides various options for moving around the network to access information for other stretches.

- i) Within the HYDROMETRIC AREA MAP option it is possible to move to a different part of the map prior to selecting a stretch.

- ii) Having selected a stretch and obtained results for that stretch it is possible to move to a new part of the map and select another stretch.

To roam around the network prior to stretch selection

1. From the river network menu select [Roam around network].
2. Select [Display a different part].
3. Select one of the following options:

Use this option	To do this
Finish hydrometric area	Return to Menu A.
Zoomin (with stretches)	Further magnify a region of the map. The network is then replotted at the new scale. Manipulate the display further or select a new stretch within the current ZOOMIN window. Once a stretch has been selected the estimates generated for the stretch are displayed.
Zoomout to pre-zoomin state	Replot the displayed networks as they were displayed before the previous zoomin. If only one zoomin has been made the original boundaries are replotted.
Plot hyd.area boundaries	Replot the original boundaries for the currently selected hydrometric area.

To roam around the network having already selected a stretch

1. From the river network menu select [Roam around network].
2. Select one of the following options:

Use this option	To do this
Finished hydrometric area	Return to Menu A.
Choose another stretch	Select another stretch for analysis. Click on a stretch with the mouse. Once selected the parameter estimates generated for that stretch are displayed.
Zoomin (with stretches)	Further magnify a region of the map by selecting opposite corners of a square. The network is replotted at the new scale. Manipulate the display further or select a new stretch within the current ZOOMIN window. Once a stretch has been selected the estimates generated for the stretch are displayed.
Zoomout to pre-zoomin state	Replot the network as it was before the last zoomin took place.

Use this option	To do this
Climb from selected stretch	<p>Plot the river network upstream of the currently selected stretch. The parameter estimates for the stretch are displayed.</p> <p>This option can be used to jump from the HYDROMETRIC AREA MAP option to the CLIMB FROM A LOCATION option. A climb from the currently selected stretch occurs and subsequent menus operate in the CLIMB FROM A LOCATION mode. This jump between options is one way; to return to the HYDROMETRIC AREA MAP it is necessary to return to Menu A the initial menu to reselect the hydrometric area.</p>
Restore original climb	<p>If using the CLIMB FROM A LOCATION option, replot the network as it was originally displayed when first selected. The parameter estimates for the initial stretch are displayed.</p>
Replot original boundaries	<p>If using the HYDROMETRIC AREA MAP option, replot the original boundaries.</p>

3.8 USING THE FEATURE EDITOR

The Micro LOW FLOWS feature editor allows the user to display and edit the data relating to features on the currently selected stretch. The following features can be associated with a stretch:

- i) Gauging stations
- ii) Reservoirs
- iii) Abstraction sites
- iv) Discharge sites
- v) Spot gauges

Within a hydrometric area there will be a significant number of abstraction licences, discharge consents, spot gauging sites and reservoirs. When the river network is initially displayed, no artificial influences are indicated. Therefore, it is necessary to toggle on the icons. This is most beneficial following the selection of the **ZOOMIN** or **CLIMB FROM A LOCATION** options.

Features are indicated on the display map by coloured icons. It is possible to control the way in which these icons appear.

- i) When the hydrometric area is selected, the user is also given the option to select the feature icons to be displayed within that area. By default gauging stations are always selected but the other features to be displayed can be selected by entering Y or N against each feature.

- ii) The user can also turn on/off the display of all feature icons by selecting [Toggle markers on/off] from analysis option menu.

The following procedures explain the editing facilities in detail. Note that the procedures for abstraction and discharge sites are different from the other types of feature. Each site has to be linked to a licence and in order to edit the site data you must first access the licence.

To set the edit password

The edit password is set outside of Micro LOW FLOWS by running SETPASS. The user is prompted to enter a four digit number for the password. This number can be updated at any time by running SETPASS.

To edit existing gauging stations, reservoirs or spot gauges

1. From the detailed analysis option menu select [*Consider feature*].

If no features of this type exist on the stretch the user will be asked to add a new one or to abandon the action.

2. Select [*Consider existing feature*].

The data held on the feature is displayed in the panel. Move the cursor to the relevant item and enter the new value. Press ESC to finish edits.

3. Select one of the following options:

Use this option	To do this
Continue	Update the feature archive and continue. If there is more than one feature of this type proceed to step 4, otherwise return to the analysis options menu.
Move to new location	Move the feature to a new location on the map. Click on the new location with the mouse and then confirm the action. The feature is moved to the new location and you return to the analysis options menu.
Delete from archive	Delete the feature from the archive. Confirm the action. The feature is removed from the stretch and you return to the analysis options menu.

4. Select one of the following options:

Use this option	To do this
End <i>feature</i> on this stretch	Return to the analysis options menu.
Next <i>feature</i> on stretch	Display the next feature on the stretch (if there is one).
Previous <i>feature</i> on stretch	Display the previous feature on the stretch (if there is one).

To add new gauging stations, reservoirs or spot gauges to the stretch

1. From the analysis options menu select [*Consider feature*].
2. Select [*Add a new feature*].
3. With the mouse, select the point on the current stretch where the new feature is to be located. The feature icon is shown in yellow.

Note that these features will be assigned a position on the stretch. Reservoirs are always considered to lie at the downstream end of a stretch, and any other features on the stretch are deemed to be upstream of the reservoir.

4. Enter the data relating to the feature in the data panel.

To edit existing abstraction or discharge sites

1. Select [*Consider feature*].

If no abstraction or discharge licences exist on the stretch the user will be asked to add a new one or to abandon the action.

2. Select [*Consider licences on stretch*].

If the stretch has more than one licence associated with it a list of the licence numbers will be displayed. The user may scroll through the licences, and the sites belonging to the licence are shown yellow. Select the one you want to edit. If the stretch has only one licence this is selected automatically.

The licence information is displayed in the panel and can be edited as required. Press ESC to finish edits.

3. Select one of the following options:

Use this option	To do this
Finished with this licence	Return to step 2.
Consider sites for licence	Examine the sites associated with the licence. Select [Consider existing site]. The information for the first site is displayed and can be edited. When finished proceed to step 4.
Remove licence & its sites	Delete the licence and its sites. You have to confirm the action. The licence and its sites are removed from the stretch and the user returns to analysis options menu.

4. Select one of the following options:

Use this option	To do this
Continue	Update the archive and continue. Proceed to step 5.
Move site to new location	Move the site to a new location on the map. You can either specify a grid reference or click on the new location with the mouse. The site is moved to the new location and you return to analysis options menu detailed and is options menu.
Delete site from archive	Delete the site from the archive. Confirm the action. The site is removed from the stretch and you return to analysis options menu.

5. Select one of the following options:

Use this option	To do this
End sites for licence	Return to step 3.
Next site for licence	Display the next site for the licence (if there is one).
Previous site for licence	Display the previous site for the licence (if there is one).

To add new abstraction or discharge sites to an existing licence

1. From analysis options menu select [Consider *feature*]. Detailed and options menu.
2. Select [Consider licences on stretch].

If the stretch has more than one licence associated with it you see a list of the licence numbers will be displayed. It is possible to scroll through the licences. The sites

belonging to the licence are shown yellow. Select the appropriate licence. If the stretch has only one licence this is selected automatically.

3. Select [Consider sites for licence].
4. Select [Add a new site].
5. Specify the location of the site. You can either specify a grid reference or point to the location with the mouse
6. Enter the appropriate data for the site. When you have finished you are returned to analysis options menu.

To add new abstraction or discharge sites to a new licence

1. From analysis options menu select [Consider *feature*].
2. Select [Add a new licence].
3. Enter the details for the licence.
4. Specify the location of the site and confirm the site is correct; when all details have been entered the user is returned to analysis options menu.

Note that the alteration of an abstraction, discharge or reservoir results in an immediate update of the influence on all stretches downstream of the feature.

3.9 FORMAT OF EDIT PANELS

This section describes the format of the feature edit panels. Example data panels are shown with explanations of the data items. If the edit password was correctly entered, it is possible to edit the contents of the panel by moving the cursor to the relevant item and entering the required edit; press ESC to finish the edit.

Micro LOW FLOWS treats negative values and blanks as missing data.

3.9.1 Gauging stations

Gauging station data is displayed in a single edit panel.

Gauging station number	26005
Easting	5135
Northing	4677
Start year of flow record	1981
End year of flow record	1991
Area (km ²)	240.00
Mean flow (cumecs)	.192
Q95(1) (cumecs)	-1.000
MAM(7) (cumecs)	.004

Gauging station edit panel

where:

Data item	Comments
Gauging station number	Surface Water Archive gauging station number
Easting/Northing	Grid reference can be shown as either easting/northing or National Grid co-ordinates
Start year	Start year of record
End year	End year of record
Area	Catchment area km ²
MF	Recorded mean flow m ³ s ⁻¹ or Mld ⁻¹
Q95	Daily flow exceeded 95% of the time m ³ s ⁻¹ or Mld ⁻¹
MAM (7)	Mean annual 7 day minimum m ³ s ⁻¹ or Mld ⁻¹

The shaded items cannot be edited.

3.9.2 Reservoirs

Reservoir data is displayed in two edit panels.

Reservoir number	540035
Grid reference	SE828427
Type of reservoir	18
Date of impoundment	1891
Total area (km ²)	94.25
Natural area (km ²)	73.7
Gross capacity (m ³)	59700.
Net capacity (m ³)	55148.
MF recorded (Mld ⁻¹)	
MF estimated (Mld ⁻¹)	309.98
Compcode	8
Compensation flow (Mld ⁻¹)	22.7
Natural yield (Mld ⁻¹)	207.3

(a) Reservoir information edit panel

Monthly releases	
Jan	.864
Feb	.864
.	
.	
Dec	.864

(b) Reservoir release values edit panel

where:

Data item	Comments
Reservoir number	HI reservoir number (Gustard et al, 1987)
Grid reference	Grid reference can be shown as either easting/northing or National Grid co-ordinates
Type of reservoir	Indicates primary function: 1 Hydroelectric with compensation 2 Hydroelectric with no compensation 3 Compensation only 4 Supply and compensation 19 Supply only 16 Pumped storage 18 Regulating
Date of impoundment	Date of impoundment of the reservoir (year)
Total area	Total area draining to dam (km ²)
Natural area	Natural catchment area (km ²)
Gross capacity	Gross reservoir capacity (m ³)
Net capacity	Net reservoir capacity (m ³)
MF recorded	Recorded daily flow at dam (m ³ s ⁻¹ or Mld ⁻¹)
MF estimated	Estimated mean flow at dam (m ³ s ⁻¹ or Mld ⁻¹)
Compcode	Release policy category: 0 Constant discharge 7 days/week 1 Constant discharge 6 days/week 2 Seasonally varying releases 3 Seasonally varying releases & freshnets and/or block grant allowance 4 Constant discharge & freshnets or block grant 5 Constant discharge over variable period 6 Constant discharge which varies weekly/daily 7 Constant discharge from 1 or more reservoirs 8 Variable discharge based on natural flow 10-18 As above but for maintained flow downstream 19 Seasonally varying releases and constant maintained flow downstream
Compensation flow	Compensation flow (m ³ s ⁻¹ or Mld ⁻¹)
Natural yield	Net yield after compensation (m ³ s ⁻¹ or Mld ⁻¹)
Monthly releases	12 monthly release flows

The shaded items cannot be edited.

3.9.3 Abstraction sites

Each abstraction site (for both surface water and groundwater abstractions) has an overall licence edit panel and two site edit panels.

Abstraction licence:

IH number	260002	Type	S
NRA number:			
Licence holder:			
Date of issue:		1994	
Revocation date:		1995	
Number of sites:		3	
TOTALS		Annual	Daily
		(cumecs)	
Licensed Abstraction:	1.000		.100
Actual Abstraction:	1.000		.100

Abstraction licence edit panel

where:

Data item	Comments
IH number	IH licence number
Type	Indicates (S) surface or (G) ground water licence (NB type of licence needs to be entered upper case)
NRA number	NRA licence number
Licence holder	Name and address of licence holder (max 28 chars)
Date of issue	Date of issue of licence (year)
Revocation date	Revocation date of licence (year)
Number of sites	Number of sites for this licence
Total licenced abstraction - annual	Total licenced annual quantity ($\text{m}^3 \text{s}^{-1}$)
Total licenced abstraction - daily	Total licenced daily quantity ($\text{m}^3 \text{s}^{-1}$)
Total actual abstraction - annual	Total actual annual quantity ($\text{m}^3 \text{s}^{-1}$)
Total actual abstraction - daily	Total actual daily quantity ($\text{m}^3 \text{s}^{-1}$)

The shaded items cannot be edited.

Site:

IH abstraction number 260002 Site 1			
Easting	4881	Northing	4422
Name:			
GW unit	CH	Stream dist.	183.37
S=	.010	T=	.020 %return 3.
MRF:	.040	Thresh. (cumecs)	.050
Max.Lic.annual	.060	daily	.070
Purpose	Lic.annual	Lic.daily	dates
	(cumecs)		(mths)
SI	.050	.005	1 2

(a) Abstraction licence/location panel

Monthly Values			
	Site	Actual Licence (cumecs)	Predicted Site
Jan	.010	.011	.012
.			
.			
Dec	.040	.040	.000

(b) Abstraction return and predicted values edit panel

where:

Data item	Comments
IH abstraction no.	IH licence number
Site	Which site this is
Easting/Northing	Grid reference can be shown as either easting/northing or National Grid co-ordinates
Name	Name of site
*GW unit	Groundwater unit if applicable (groundwater licence only): CH Chalk UG Upper Greensand LG Lower Greensand JL Jurassic Limestones TS Permotriassic Sandstone ML Magnesium Limestone CL Carboniferous Limestone SG Sands and Gravels
Stream dist.	Distance to nearest stream
*S	Storativity (%) (groundwater licence only)
*T	Transmissivity (ms^{-1}) (groundwater licence only)
%return	Percentage return if applicable
MRF	Minimum required flow
Thresh.	Threshold flow
Max.lic.annual	Max licenced annual abstraction rate for site
Max lic. daily	Max licenced daily abstraction rate for site
**Purpose	Indicates abstraction purpose: SI Spray irrigation CO Cooling water IP Industrial processing PS Public water supply BW British Waterways GA General agriculture PW Private water undertaking FF Fish farming MD Mine drainage UD Undefined (NB use uppercase letters)
**Lic.annual	Licenced maximum annual abstraction rate for purpose ($\text{m}^3 \text{s}^{-1}$)
**Lic.daily	Licenced maximum daily abstraction rate for purpose ($\text{m}^3 \text{s}^{-1}$)
**Dates	Authorised start and finish months of abstraction for purpose
Month actual site	Actual monthly abstracted quantity for the site ($\text{m}^3 \text{s}^{-1}$)
Month actual licence	Actual monthly abstracted quantities for the overall licence ($\text{m}^3 \text{s}^{-1}$)
Month predicted site	Predicted monthly abstracted quantities for the site ($\text{m}^3 \text{s}^{-1}$)

The shaded items cannot be edited.

* Values are required for groundwater sites only. Default values are used in the absence of data here. See 'editing the global parameters'.

** Values are required for the abstraction to be included in calculations.

3.9.4 Discharge sites

Each discharge site has an overall licence edit panel and a site edit panel.

Discharge consent:

IH discharge number:	260001	Type
NRA number:		
Licence holder:		
Date of issue:		1992
Review date:		1994
Number of sites:		1
Consented av. discharge (cumecs):	1.000	
Consented max. discharge (cumecs):	1.000	
Population equivalent:	30000.	

Discharge licence edit panel

where:

Data item	Comments
IH discharge number	IH consent number
Type	Consent type CS Crude sewage S Screened sewage SS Settled sewage TS Treated sewage SW Storm water overflow MD Mine drainage CW Cooling water FE Farm effluent TE Trade effluent FF Fish farm effluent
NRA number	NRA consent number
Licence holder	Name and address of consent holder
Date of issue	Consent issue date
Review date	Consent review date
Number of sites	Number of sites for this consent
Consented av. discharge	Consented average discharge rate (m ³ s ⁻¹)
Consented max. discharge	Consented maximum discharge rate (m ³ s ⁻¹)
Population equivalent	Population equivalent

The shaded items cannot be edited.

Site:

IH discharge number	260001	Site	1
Easting	4857	Northing	4444
Name:			
Receiving river:			
Consented av. discharge (cumecs):			.050
Consented max. discharge. (cumecs):			.050
Measured DWF (cumecs)			.060
Monthly values			
	Actual	Predicted	
	(cumecs)		
Jan	.100		.06
Feb	.100		.06
Mar	.100		.06
Apr	.100		.06
May	.100		.06
Jun	.100		.06
Jul			.06
Aug			.06
Sep			.06
Oct			.06
Nov			.06
Dec			.06

Discharge site information panel

where:

Data item	Comments
IH discharge number	IH consent number
Site	Which site this is
Easting, Northing	Grid reference can be shown as either easting/northing or National Grid co-ordinates
Name	Name of site
Receiving river	Receiving river
Consented av. discharge	Average discharge rate for site ($\text{m}^3 \text{s}^{-1}$)
Consented max. discharge	Consented maximum discharge rate ($\text{m}^3 \text{s}^{-1}$)
*Measured DWF	Dry weather flow ($\text{m}^3 \text{s}^{-1}$)
*Monthly actual	Actual monthly discharge ($\text{m}^3 \text{s}^{-1}$)
Monthly predicted	Predicted monthly discharge ($\text{m}^3 \text{s}^{-1}$)

The shaded items cannot be edited.

* Actual monthly discharge on measured DWF are required for the discharge to be considered in the calculations.

3.9.5 Spot gauges

Spot gauge data is displayed in a single edit panel.

IH Spot gauge number:	260063			
Easting:	4870			
Northing:	4447			
TOWTHORPE BECK	NURSERY BRD			
Date	Time	Flow Pcntl. (cumecs)	Info.	FDC?
820902	11.30	.013	STEADY	N
820806	8.45	.014	STEADY	N
820723	11.45	.018	STEADY	N
820708	13.00	.020	STEADY	N
820624	10.15	.053	STEADY	N
820610	9.50	.028	STEADY	N

Spot gauges edit panel

where:

Data item	Comments
IH Spot gauge number	IH spot gauge number
Easting/Northing	Grid reference
Text	Two lines of user defined text
Date	Date of reading (YYMMDD)
Time	Time of reading (HH.MM)
Flow	Measured flow ($m^3 s^{-1}$)
%	Percentile assigned to flow
Local reference	Reference text
FDC?	Y or N flag for incorporation into flow duration curve scatterplot.

The shaded items cannot be edited.

3.10 BULKLOADING FEATURE DATA

Micro LOW FLOWS has the facility for loading feature data from an ASCII file. This provides an alternative to using the feature editor for entering data into the database. The data has to be organised into datasets of the same feature type and same hydrometric area. A separate file is required for each dataset. The format for these datasets is described below.

To bulkload a dataset

1. From Menu A select [Bulkload data from a file]. Enter the filename of the dataset to be loaded.
2. Select one of the following options:

Use this option	To do this
Exit	Return to Menu A.
Replace all <i>feature</i> data already loaded	Remove the existing dataset for the feature and replace with the new dataset.
Append data for <i>feature</i> already loaded	Append the new dataset to the existing dataset for the feature.

Micro LOW FLOWS checks the dataset for errors and any that are found are logged to a file called LOADLOG.MLF. All errors need to be corrected before the dataset can be loaded.

If no errors are found then the loading process begins. This can take several hours! A summary of the data being loaded will appear in the display panel. When it has finished the user is returned to Menu A.

3. It is now necessary to perform a 'tumble' operation to rebuild the influence profiles with the new data. From Menu A select [Initiate a tumble to update influences].

Note: If several datasets are to be loaded, all the loading should be undertaken before selecting the tumble operation.

3.10.1 Format of feature datasets

This section gives the format of each feature dataset. The following general rules apply:

- i) Datasets have to be of the same feature type and same hydrometric area.
- ii) A separate file is required for each dataset.
- iii) Character fields must be delimited by NEWLINE. Numeric fields can be delimited by SPACE, COMMA OR NEWLINE.
- iv) All fields must be filled. Unassigned character fields must be blank, and unassigned numerical fields must be entered as -999.
- v) The 6-digit grid reference, 4-digit grid reference and National Grid reference are accepted.
- vi) Flow data is expected in $\text{m}^3 \text{s}^{-1}$.

Gauging stations

```
GAUGING STATIONS
26
    26001
West Beck at Wansford Bridge
506445 455925
2.512 .695 .507
-999.000    192.000
1953.000    1974.000
-1
    26002
Hull at Hempholme Locke
507865 449947
3.637 .877 .552
-999.000    378.100
1961        1991
-1
```

The dataset format is as follows:

1. Feature type = "GAUGING STATIONS"
2. Hydrometric area number
3. *Gauging station records*

Each gauging station record has the following format:

1. Gauging station number
2. 32-character name
3. 32-character description
4. Grid reference
5. MF
6. MAM(7)
7. Q95(1)
8. Q50 (Not generally used)
9. Area
10. Start year
11. End year
12. End of station marker = -1

Reservoirs

```
RESERVOIRS
27
John O'Gaunts
27206
  422103      454639
3. 1890. -999. .079 -999.
-999. 555. .035 3.
-999. -999. -999. 851. 450.
1. -999. 3. -999. 5. -999. 7.
-999. 9. -999. 11. -999.
-1
Beaverdyke
27006
  422824      454569
4. 1836. -999. -999. 0.
.004 555. .035 3.
2.75 -999. -999. 851. 450.
1. -999. 3. -999. 5. -999. 7.
-999. 9. -999. 11. -999.
-1
```

The dataset format is as follows:

1. Feature type = "RESERVOIRS"
2. Hydrometric area number
3. *Reservoir records*

Each reservoir record has the following format:

1. Reservoir name
2. Reservoir number
3. Grid reference
4. Type of reservoir
5. Date of impoundment
6. Total area
7. Natural yield
8. Comcode
9. Compensation flow
10. Net capacity
11. MF estimated
12. Authority (Not used)
13. Natural area
14. Gross capacity
15. MF recorded
16. SAAR (Not used)
17. AE (Not used)
18. Twelve monthly release values
19. End of reservoir marker = -1

Abstraction sites

```

ABSTRACTIONS
26
NRA NUMBER
NRA HOLDER
G
1968 1972
2
10. 5.
10.1 5.1
-1
505200 439000
First site
Gwul
1. 2. 3. 4. 5. 6. 7.
.1 .2 .3 .4 .5 .6 .7 .8 .9
1. 1.1 1.2
SI 1.01 1.02 1 12
CO 1.11 1.12 2 12
IP 1.21 1.22 3 12
PS 1.31 1.32 4 12
BW 1.41 1.42 5 12
GA 1.51 1.52 6 12
PW 1.61 1.62 7 12
FF 1.71 1.72 8 12
MD 1.81 1.82 9 12
UD 1.91 1.92 10 12
-1
505300 440000
Second site
Gwul
1. 2. 3. 4. 5. -999. 7.
.1 .2 .3 .4 .5 .6 .7 .8 .9
1. -999. 1.2
SI 1.01 1.02 1 12
MD 1.11 1.12 2 12
CO 1.21 1.22 3 12
PS 1.31 1.32 4 12
BW 1.41 1.42 5 12
-1

```

The dataset format is as follows:

1. Feature type = "ABSTRACTIONS"
2. Hydrometric area number
3. *Abstraction licence records*

Each abstraction licence record has the following format:

1. 16-character NRA number
2. 28-character Licence holder
3. Type (G for ground, or S for surface)
4. Date of issue
5. Revocation date
6. Number of sites
7. Total licenced annual abstraction
8. Total licenced daily abstraction
9. Total actual annual abstraction
10. Total actual daily abstraction
11. End of licence marker = -1
12. *Abstraction sites records*

Each abstraction site record has the following format:

1. Grid reference
2. 28-character Name of site
3. GW unit, if applicable (blank if not)
 - CH Chalk
 - UG Upper Greensand
 - LG Lower Greensand
 - JL Jurassic Limestones
 - TS Permotriassic Sandstone
 - ML Magnesium Limestone
 - CL Carboniferous Limestone
 - SG Sands and Gravels
4. Storativity
5. Transmissivity,
6. %return
7. Minimum required flow
8. Threshold flow
9. Maximum licenced annual abstraction
10. Maximum licenced daily abstraction
11. Twelve monthly returns for the site
12. *Abstraction site purpose records*
13. End of site marker = -1

Each abstraction site purpose record has the following format:

1. Purpose:
 - SI Spray irrigation
 - CO Cooling water
 - IP Industrial processing
 - PS Public water supply
 - BW British Waterways
 - GA General agriculture
 - PW Private water undertaking
 - FF Fish farming
 - MD Mine drainage
 - UD Undefined
2. Licenced maximum annual abstraction rate for purpose
3. Licenced maximum daily abstraction rate for purpose
4. Start month
5. End month

Discharge sites

```
DISCHARGES
26
NRA NUMBER
NRA HOLDER
SS
1968 1972
2
5. 10.
10000.
-1
505200 439000
First site
First river
1. 2. 3.

.1 .2 .3 .4 .5 .6 .7 .8 .9 1. 1.1 1.2
-1
505300 440000
Second site
Second river
1. 2. 3.
.1 -999. .3 .4 .5 .6 .7 .8 .9 1. 1.1 1.2
-1
```

The dataset format is as follows:

1. Feature type = "DISCHARGES"
2. Hydrometric area number
3. *Discharge licence records*

Each discharge licence record has the following format:

1. 16-character NRA consent number
2. 28-character Licence holder
3. Consent type:
4. CS Crude sewage
S Screened sewage
SS Settled sewage
TS Treated sewage
SW Storm water overflow
MD Mine drainage
CW Cooling water
FE Farm effluent
TE Trade effluent
FF Fish farm effluent
5. Date of issue
6. Review date
7. Number of sites
8. Consented average discharge rate
9. Consented maximum discharge rate
10. Population equivalent.
11. End of licence marker = -1
12. *Discharge site records*

Each discharge site record has the following format:

1. Grid reference
2. 28-character Name of site
3. 20-character Receiving river
4. Average discharge rate
5. Consented max.
6. Dry weather flow
7. Twelve actual monthly discharges for the site
8. End of site marker = -1

Spot gauges

```
SPOTGAUGES
26
515100.  448200.
  1
CATFOSS BECK
U/S STW
811021 .000 -999. -999.

N
-1
505300.  439100.
  6
BEVERLEY & SKIDBY DRAIN
STW
810813  10.150 .044 -999.
STEADY
N
810709  10.150 .177 -999.
STEADY
Y
810626  11.300 .128 -999.
STEADY
Y
810611   11.300 .132 -999.
STEADY
N
810529   11.300 .162 -999.
STEADY
N
810415   11.000 .178 -999.
STEADY
N
-1
```

The file format is as follows:

1. Feature type = "SPOTGAUGES"
2. Hydrometric area number
3. *Spot gauge records*

Each spot gauge record has the following format:

1. Grid reference
2. Number of readings
3. 32-character name
4. 32-character description
5. *Spot gauge readings*
6. End of spotgauge marker = -1

Each spot gauge reading has the following format:

1. Date of reading
2. Time of reading
3. Measured flow
4. Percentile
5. 12-character Reference text
6. Y or N flag to indicate inclusion (or not) in the scatterplot

3.11 EDITING THE GLOBAL PARAMETERS

3.11.1 Abstraction parameters

Purpose	Percentage Uptake Factor (0-100)	Minimum Monthly Factor (0.-1.)
SI Spray Irrigation	58	0.
CO Cooling Water	25	1.
IP Industrial Proc	23	1.
PS Public Supply	65	1.
BW British Waterway	50	1.
GA Gen. Agriculture	28	1.
PW Private Water	50	1.
FF Fish Farming	55	1.
MD Mine Drainage	50	1.
UD Undefined	78	1.

Abstraction parameters edit panel

These parameters define the percentage uptake factors and minimum monthly factors for each abstraction licence purpose. They are used for predicting return values for abstraction licences. The uptake factor represents the average percentage of the authorised quantity actually abstracted for each purpose. The percentage uptake may also vary throughout the year, therefore the minimum monthly factor represents the lowest fraction of the monthly abstraction which is taken up. Therefore, a minimum monthly factor of 1 indicates that the predicted licensed volume is constant over the licensed period for the purpose. Otherwise the predicted volume will be assumed to be distributed over the seasons as a triangle with the peak assumed to occur in the middle of the period. When [Display/Edit abstraction parameters] is selected from Menu A the current values are displayed. If these values are changed then Micro LOW FLOWS has to tumble down all the hydrometric areas to rebuild the influence profiles with the new predicted values.

Aquifer parameters

Aquifer unit	Transmissivity m/s (.00001-.3)	Storativity (%) percent (.1-10)
CH Chalk	.01	1.
UG Upper Ground	.01	1.
LG Lower Ground	.01	1.
JL Jurassic Limestones	.01	1.
TS Permotriassic Sandstone	.1	1.
ML Magnesium Limestone	.01	1.
CL Carboniferous Limestone	.01	1.
SG Sands and Gravels	.01	1.

Aquifer parameters edit panel

These parameters define the default values of Transmissivity and Storativity for principal aquifer units. When [Display/Edit aquifer parameters] is selected the current values are displayed. If any of these values are changed Micro LOW FLOWS has to tumble down all the hydrometric areas to rebuild the influence profiles with the new groundwater influences.

4. Micro LOW FLOWS Tutorial

Micro LOW FLOWS incorporates a Tutorial module which allows the user to become familiar with the software through a structured example based on the River Chelmer. The tutorial module contains the entire river network for Drainage Area 37, with test databases of artificial influences comprising 2 abstractions, 1 discharge consent, 1 spotgauge, 1 reservoir and all gauging stations already loaded for the Chelmer catchment.

The databases are also held in directory C:\TUTORIAL\SYSTEM in compressed backup file called ORIGINAL.ZIP. This enables the user to restore the original data at any stage by typing PKUNZIP -O ORIGINAL in that directory.

These artificial influences have been invented to demonstrate the impact on the flow regimes and in no way reflect the policy or intention of the National Rivers Authority or other concerned bodies.

4.1 STARTING MICRO LOW FLOWS

From directory C:\TUTORIAL, start Micro LOW FLOWS by typing TUTORIAL. Throughout the software there are clear instructions on the MESSAGE line at the bottom of the screen. To select an option from a menu, press the up-arrow and down-arrow keys until the required option is highlighted in black.

Enter a password for editing to be allowed. This is 1111 for the TUTORIAL. If you press ESC. or an incorrect password, the database can be interrogated but not altered.

Now select either [Temporary session] or [Live session]. If a temporary session is selected, a copy of the current database is made and at the end of the session this is restored. However, copying the databases may take some considerable time. A live session retains any edits made.

A panel with multiple choices is displayed. Selecting [Exit] terminates the session and if it was temporary, the original data base is restored.

4.2 MOVING AROUND THE NETWORK

Select [Low Flow Analysis] to enter the main part of the package. A suggested route to follow is to select [Climb from a location] followed by [River name]. Choose the river Chelmer (number 40 on the second page of river names) and select markers to be displayed by setting all influences to Y.

Wait a few moments while the network is plotted (Figure 4.1). Only gauging stations will be marked at this point.

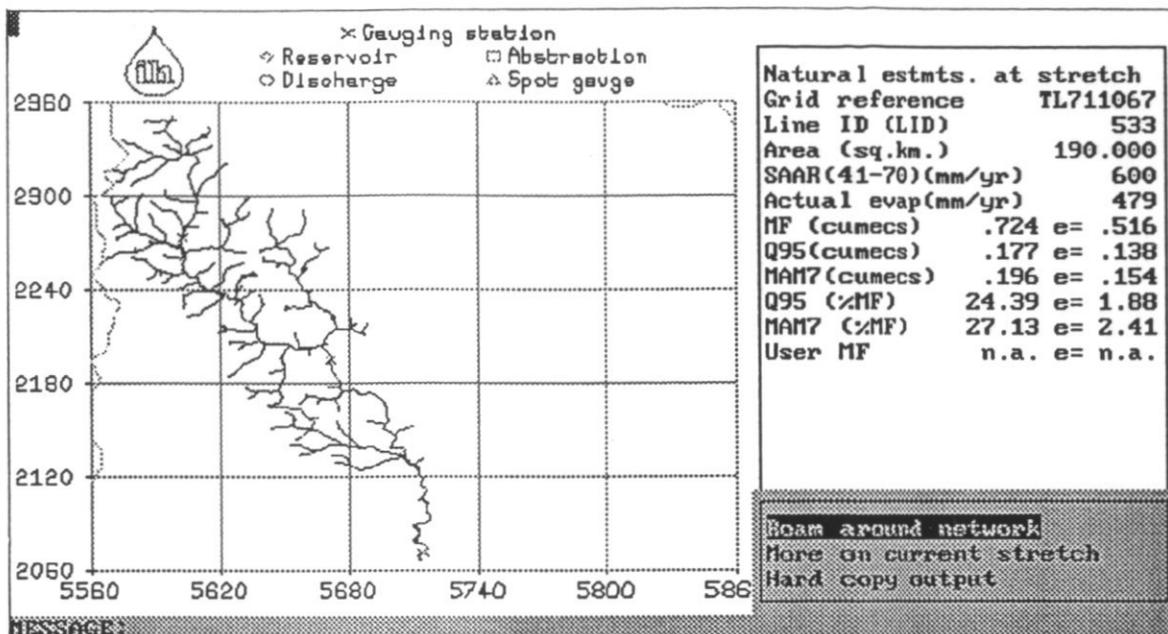


Figure 4.1 The River Chelmer network

Turn on the influence marker icons by selecting [More on current stretch] and then [Toggle markers on/off]. The location of the artificial influences are now displayed. Zoom in to magnify the area of interest.

Select [Finish current display] followed by [Roam the network] and [Zoom in with stretches].

Choose a zoom-in window by clicking the mouse at two opposite corners of the square of interest e.g. at grid references 5740,2120 and 5602,2240.

Select a stretch by moving the cursor to the appropriate point and click on it with the mouse; the selected stretch will turn red and the natural estimates for that stretch will be displayed. By selecting [More on current stretch] then [Toggle markers on/off] you can turn on the icons again. Select [Finished with this stretch] and then [Roam about network].

4.3 INVESTIGATING THE IMPACT OF ABSTRACTIONS

Select [Choose another stretch] and select a stretch where an abstraction licence exists, e.g. at grid reference 5630,2220. This stretch will be highlighted red for as long as it is the current stretch.

For the first investigation it is probably unwise to alter anything even if the password is set. Select [Consider abstractions]. Guidance through the ensuing menus and panels is provided by messages at the bottom of the screen.

Select [Consider licences]. The icon for the abstraction turns yellow, and the licence data is displayed. All the data in this display is for information only except 'Type' which is set to 'S' for surface water abstractions in this case (Figure 4.2).

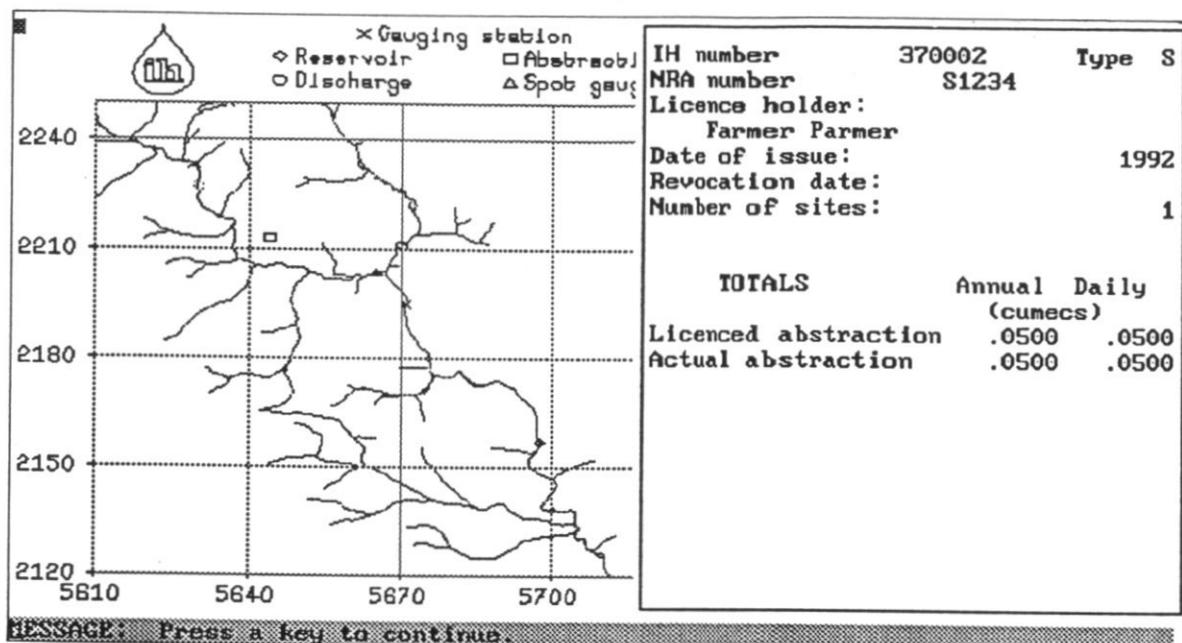


Figure 4.2 Abstraction licence data for site

Select [Consider sites], followed by [Consider existing sites]. The icon at the site turns red and the site data is displayed. This site is licenced for spray irrigation (purpose SI) with an annual extraction rate of $.005 \text{ m}^3 \text{ s}^{-1}$ from June to September (months 6 and 9). Press ESC to get the monthly data. No actual data is loaded so predicted values are calculated from the uptake and multiplier factors (see 'editing the global parameters').

Predicted extractions are.

	Actual Site	Monthly Values	
		Licensed so far (cumecs)	Predicted Site
Jan		0.	0.
Feb		0.	0.
Mar		0.	0.
Apr		0.	0.
May		0.	0.
Jun		-.00435	-.00435
Jul		-.0130	-.0130
Aug		-.0130	-.0130
Sep		-.00435	-.00435
Oct		0.	0.
Nov		0.	0.
Dec		0.	0.

Abstraction licence and predicted values edit panel

Press ESC followed by [Continue], [Finish with this licence] and [Finish with abstractions].

Note that there are no influences upstream of this abstraction so the net effect of it on the flow regime is simple.

Select [Display influenced estimates] to view the impact of the abstraction on the flow estimates (Figure 4.3), the ESC to return to the [More on current stretch] menu.

Select [Influenced flow duration curve] followed by [Flow duration curve]. The estimated natural flow duration curve is plotted together with the influenced curve (Figure 4.4). Note that the influenced curve is below the natural curve and the Q95 is reduced from .064 to .055 $\text{m}^3 \text{s}^{-1}$. Interpolate some other percentile flows by selecting [Flow from percentile]. Also, identify the exceedence probabilities for other flows using [percentiles from flow]. A hardcopy of the plot including the requested flows/percentiles can be obtained by selecting the output device appropriate to your installation.

Now repeat the exercise for a stretch downstream of the other abstraction to show the effect of accumulation of abstractions. Note that this is a groundwater abstraction and requires an aquifer unit (GWU) to be supplied, and in this example is 'CH' for chalk. The 'Storativity' and 'Transmissivity' for chalk are taken from the default 'Aquifer parameters' (See 'editing global parameters'). The abstraction is for Public Supply (PS) which occurs all year round (months 1 and 12). Predicted abstractions for this licence are $-0.064 \text{ m}^3 \text{ s}^{-1}$ in each month.

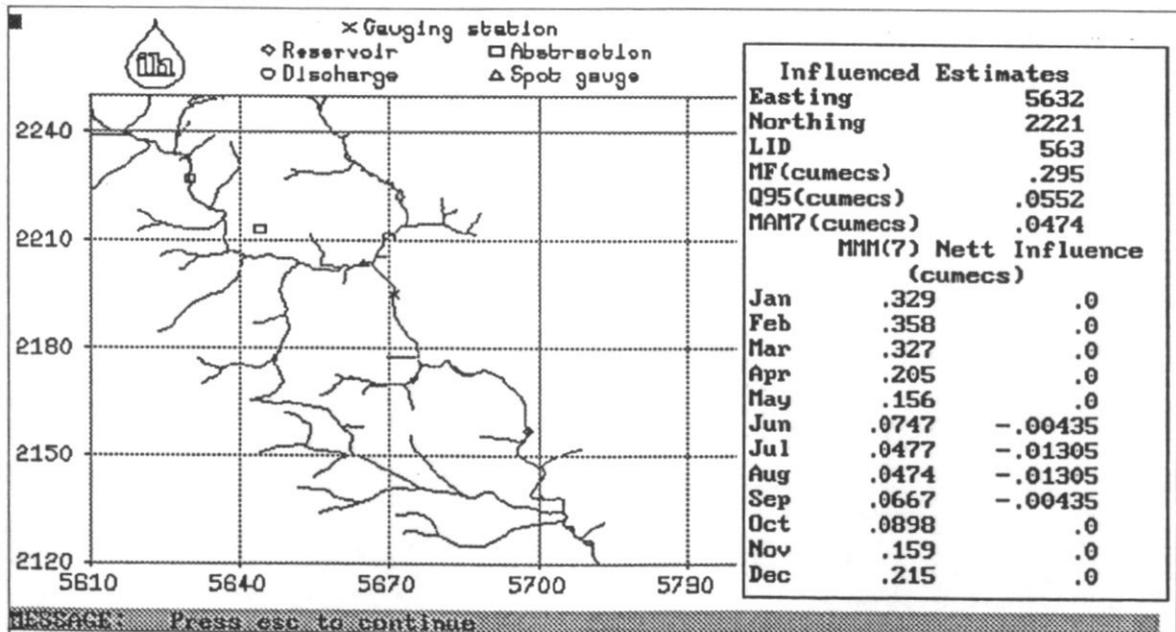


Figure 4.3 Influenced flow statistics

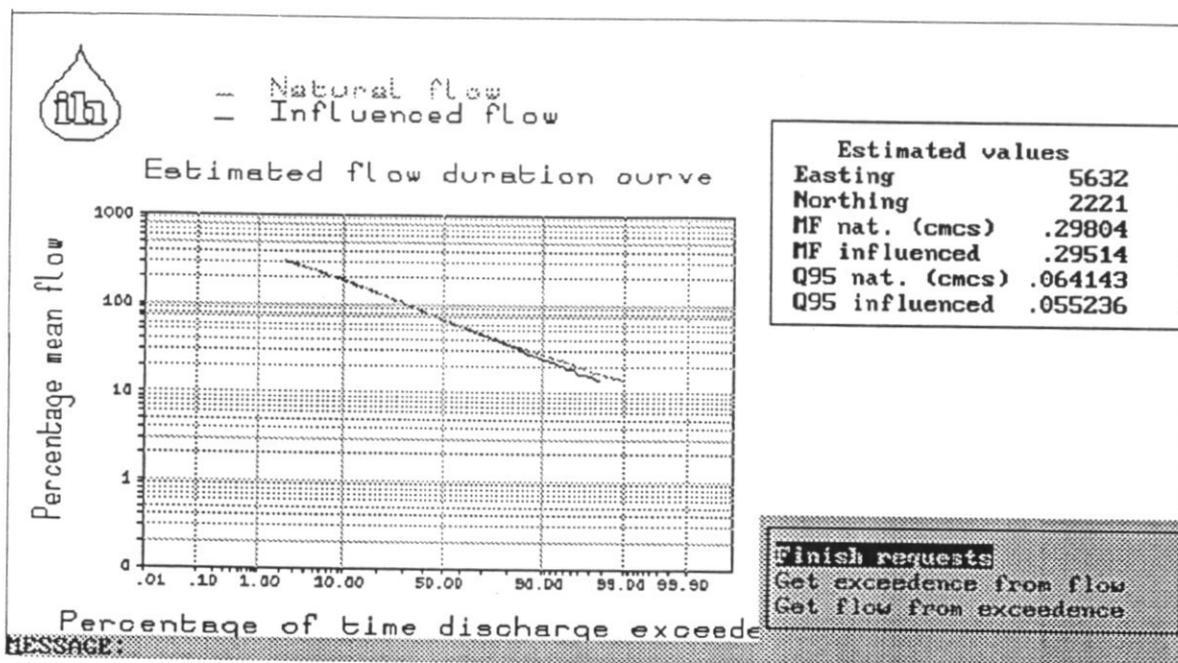


Figure 4.4 Influenced flow duration curve

4.4 INVESTIGATING THE IMPACT OF DISCHARGES

By selecting the stretch with the discharge located at approximately 5670,2210 and stepping through the displays in exactly the same way as for the abstractions detailed above, you will see that the discharge has actual values of $.01 \text{ m}^3 \text{ s}^{-1}$ every month. There are no influences upstream of this discharge so the direct effect of it on the regime can be investigated.

Now select a stretch downstream of the confluence to investigate the effect of the accumulated influences.

4.5 USING SPOT GAUGING DATA

To examine the spotgauge data, select the stretch where spot gauging has been undertaken (at approximately 5660,2200) and select [Consider spot gauges]. The flow readings at given dates and times are shown. If the corresponding percentile exceedence is supplied and is considered suitable for inclusion in the flow duration scatter plot, 'Y' appears in the final column (Figure 4.5). Exit from spotgauges by selecting [Finished spotgauges] and select [Influenced flow duration curve]. The scatterplot of spot gauge readings can be superimposed on the estimated curves for this stretch (Figure 4.6).

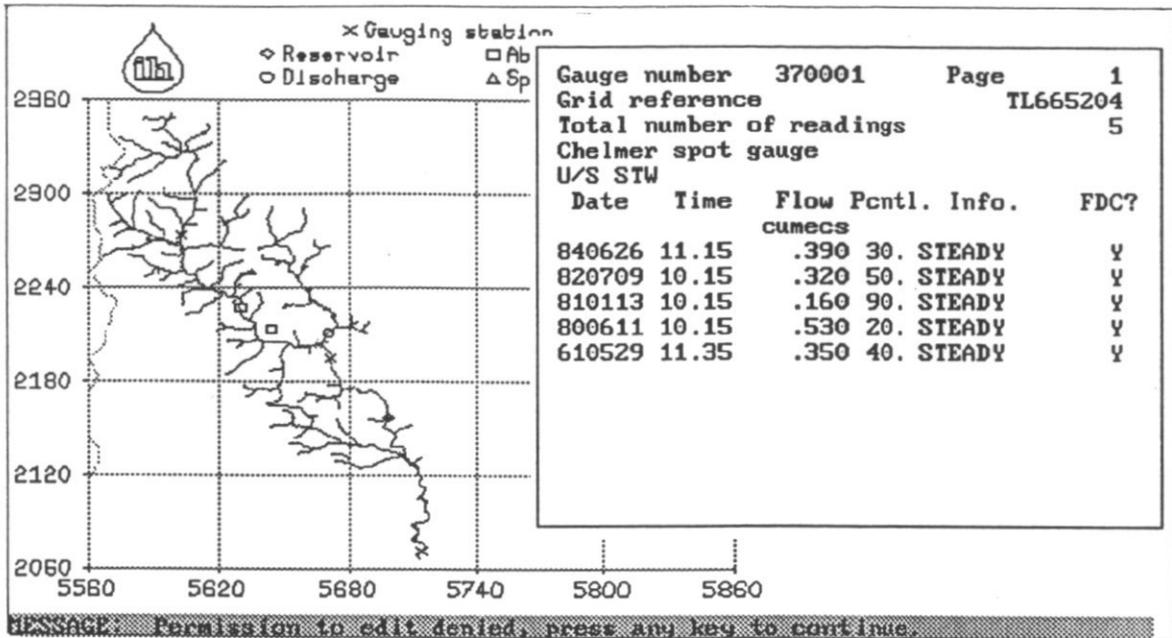


Figure 4.5 Spot gauges

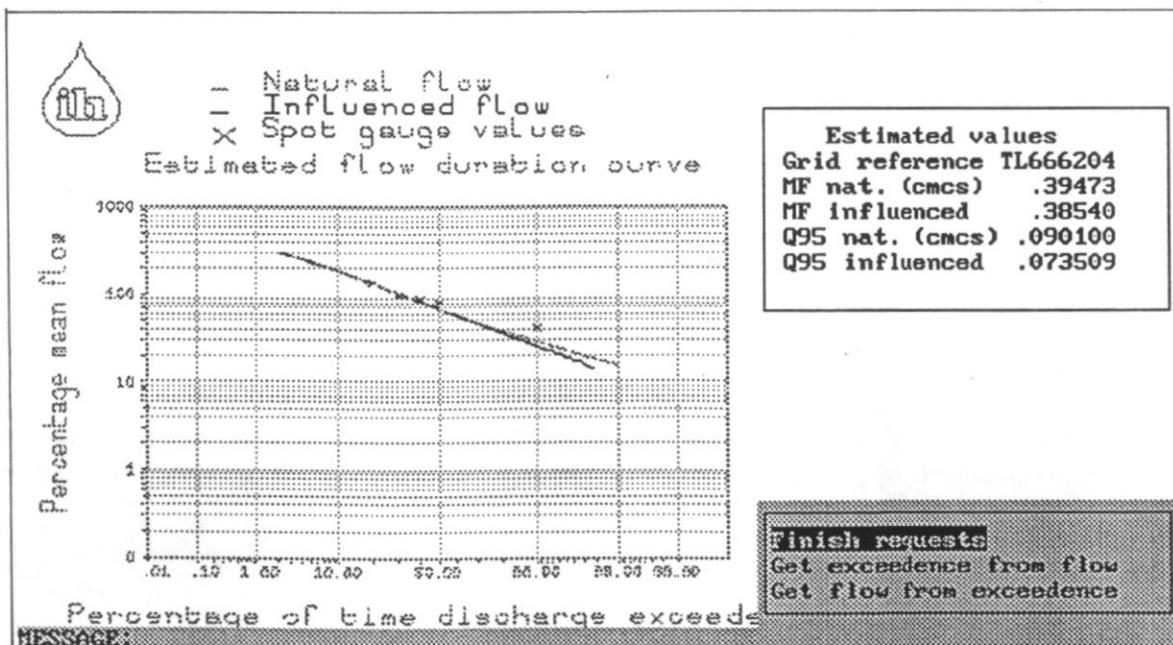


Figure 4.6 Spot gauge data superimposed on the flow duration curve

4.6 INVESTIGATING THE IMPACT OF RESERVOIRS

What happens to these influenced estimates and flow duration curves on the stretch with the reservoir? Find out by clicking on the stretch containing the reservoir. The monthly releases can be viewed by selecting [Consider reservoirs]. In the example they are all $.1 \text{ m}^3 \text{ s}^{-1}$. Select [Influenced flow duration curve] and notice that the influenced curve is a straight line at $.1 \text{ m}^3 \text{ s}^{-1}$ (Figure 4.7). Selecting [Display influenced estimates] will confirm that this is because the natural flow profile at the reservoir site and the effect of all upstream abstractions and discharges have been replaced by the reservoir release profile.

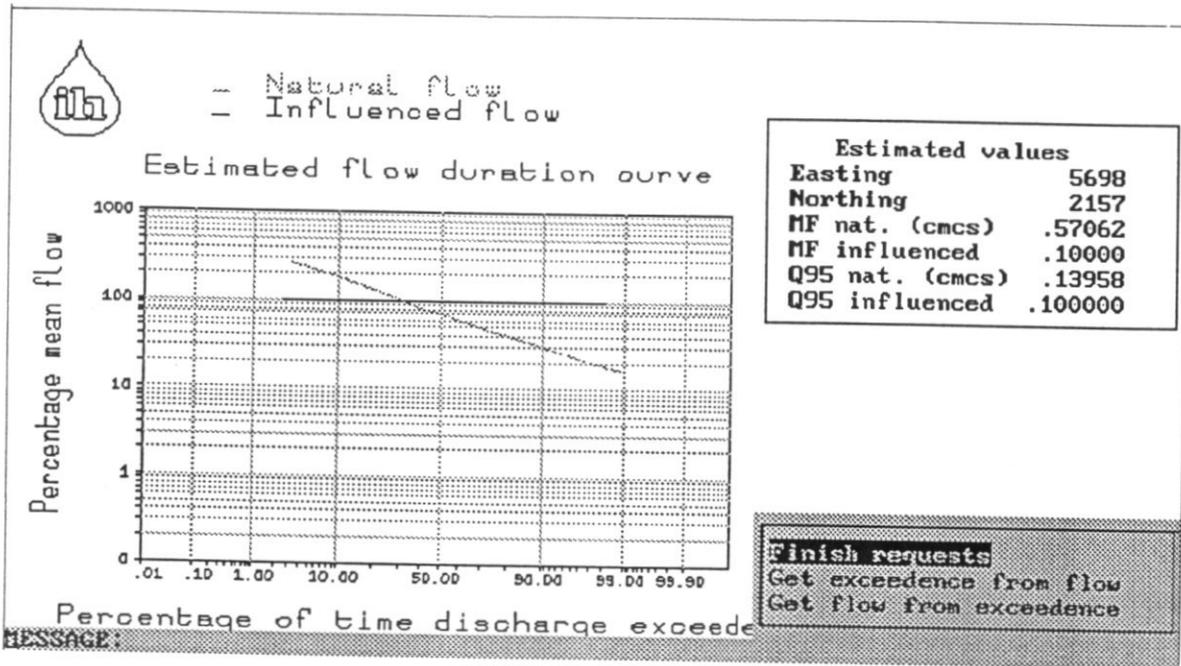


Figure 4.7 Flow duration curve at reservoir site

4.7 THE RESIDUAL FLOW DIAGRAM

To investigate the residual flow diagram, choose a stretch downstream of all the influences and select [Residual flow diagram] from the [More on current stretch] menu. Select an upstream stretch using the mouse. The main channel connecting the chosen upstream and downstream stretches is shown in red. After a pause options of [mean flow] or [flow percentile] are offered. Choose the mean flow option to start with (flow percentile is slow as there are a lot of calculations to do).

A plot of the stream profile of the natural flow together with artificial flows and the net (or residual flow) is displayed with the X-axis showing length downstream and the Y-axis the flows (Figure 4.8). The points where the abstractions, discharge, reservoir and adjoining tributary join the main channel are evident. A hardcopy of this can be obtained. Notice that the tributary 'Chelmerette' is named.

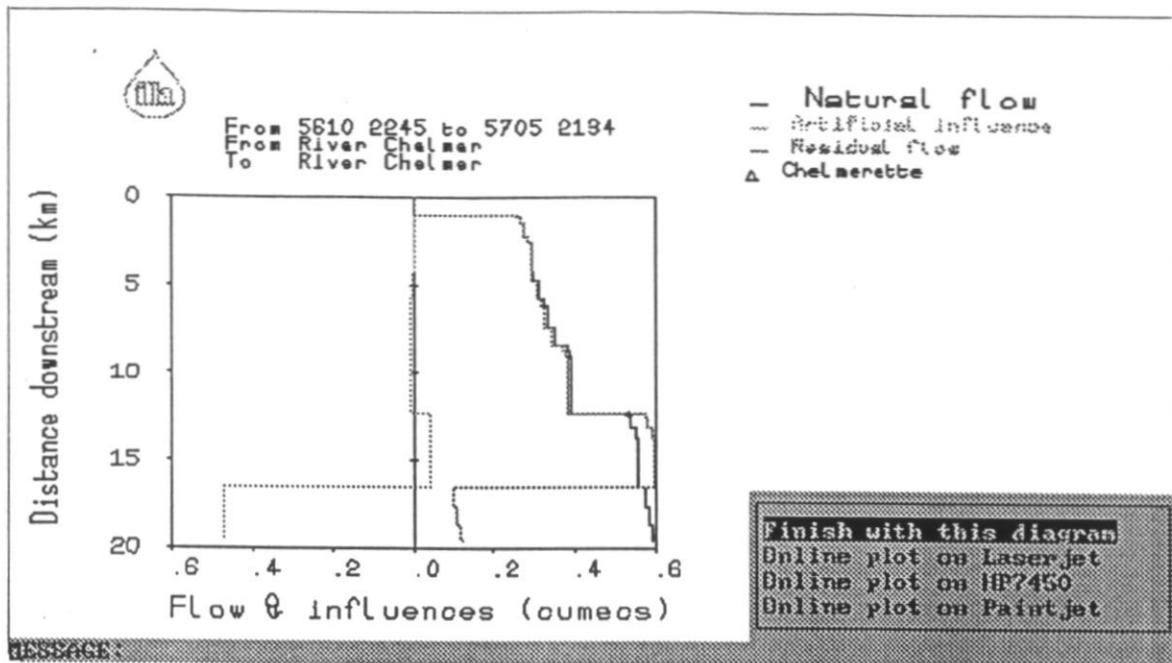


Figure 4.8 The residual flow diagram for selected stretch

4.8 NAMING RIVER STRETCHES

To investigate the naming of the rivers, choose a stretch of interest at a confluence and select [River naming]. Two names appear, one is the name of the current stretch and the second is the name of any adjoining stretch at a confluence. If the current stretch is renamed, all stretches upstream bearing the original name will also be renamed to the new name. It is also possible to 'Unnamed' the stretch if preferred.

4.9 EDITING THE DATA

Now is probably a good time to try editing some data values to see how the influences affect the profiles downstream of them, therefore return to the main menu to continue.

Some of the other options are explained here in the following sections.

The [Set flow units] option offers the user a choice between $\text{m}^3 \text{s}^{-1}$ and Mld^{-1} as working units, and similarly [Set grid reference system] offers a choice of grid reference units. Change these as required.

In order to predict surface water abstraction rates in the absence of actual data, Micro LOW FLOWS uses uptake factors and minimum monthly factors. The uptake factor represents the average percentage of the licenced quantity actually abstracted. For example, if the uptake

factor is assumed to be 100%, then the full licensed quantity is taken, e.g. for spray irrigation. An uptake factor of 50% could indicate that only half the licence is taken or that some water is returned (unless covered by a separate discharge consent), therefore the net impact of the abstraction is only 50%, e.g. for Cooling Water.

The uptake may vary throughout the year, therefore the minimum monthly factor represents the lowest uptake in any month (expressed as a fraction rather than a percentage). These factors can be viewed and altered (if password permission given), by selecting [Display/edit abstraction parameters].

Similarly the storativity and transmissivity parameters, used to predict the impact of groundwater abstractions in the absence of measured abstraction rates for groundwater sites, can be viewed and altered by selecting [Display/edit aquifer parameters] (see 'editing the global parameters'). If any these parameters are altered the artificially influenced low flow estimates need to be recalculated, therefore a reminder to 'tumble' the data is issued.

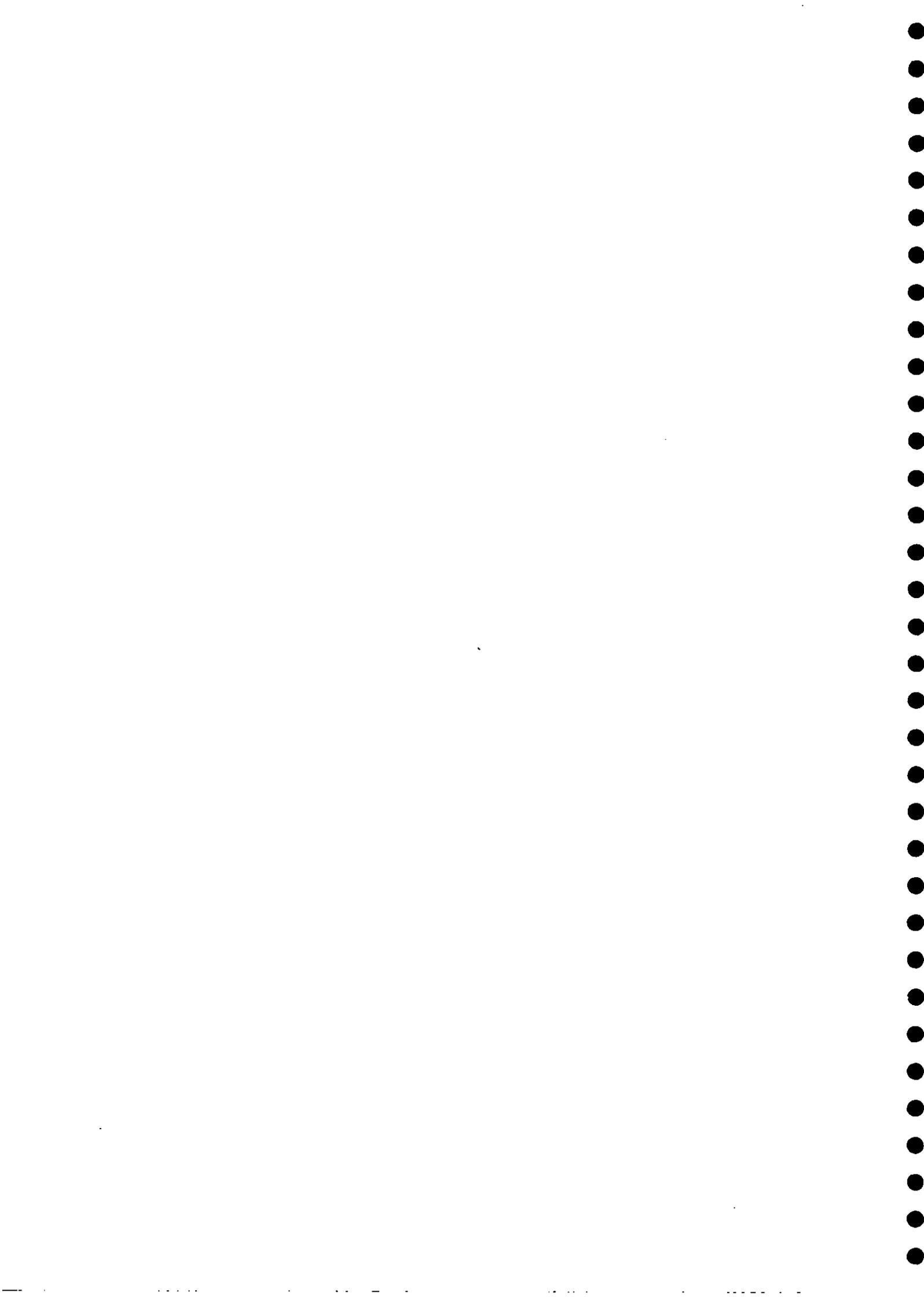
Select [Bulkload data from a file] investigate the option to load files of artificial influence data. Datasets of abstraction, discharge, reservoir and spotgauge data have been supplied in files ABSTUT.DAT, DISTUT.DAT, SPOTUT.DAT, and RESTUT.DAT respectively (note, no gauging stations supplied). If the abstraction, discharge or reservoir data are bulk loaded, a reminder to 'tumble' the data is issued in order to incorporate the new information.

Select [Initiate tumble to update influences] if the warning message 'Need to tumble' appears. Only do this when all bulkloading and parameter changes have been done. It is not necessary if online edits have been made to individual sites as the influence is updated in situ. Tumbling takes some time. The program calculates the effect of the influences loaded on all stretches downstream of them, meanwhile displaying a plot of the network which slowly turns red as the stretches are dealt with.

A log file LOADLOG.MLF records all transactions.

References

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- Gustard, A., Cole, G.A., Marshall, D.C.W. and Bayliss, A.C. (1987). A study of compensation flows in the United Kingdom. Institute of Hydrology Report No. 99.
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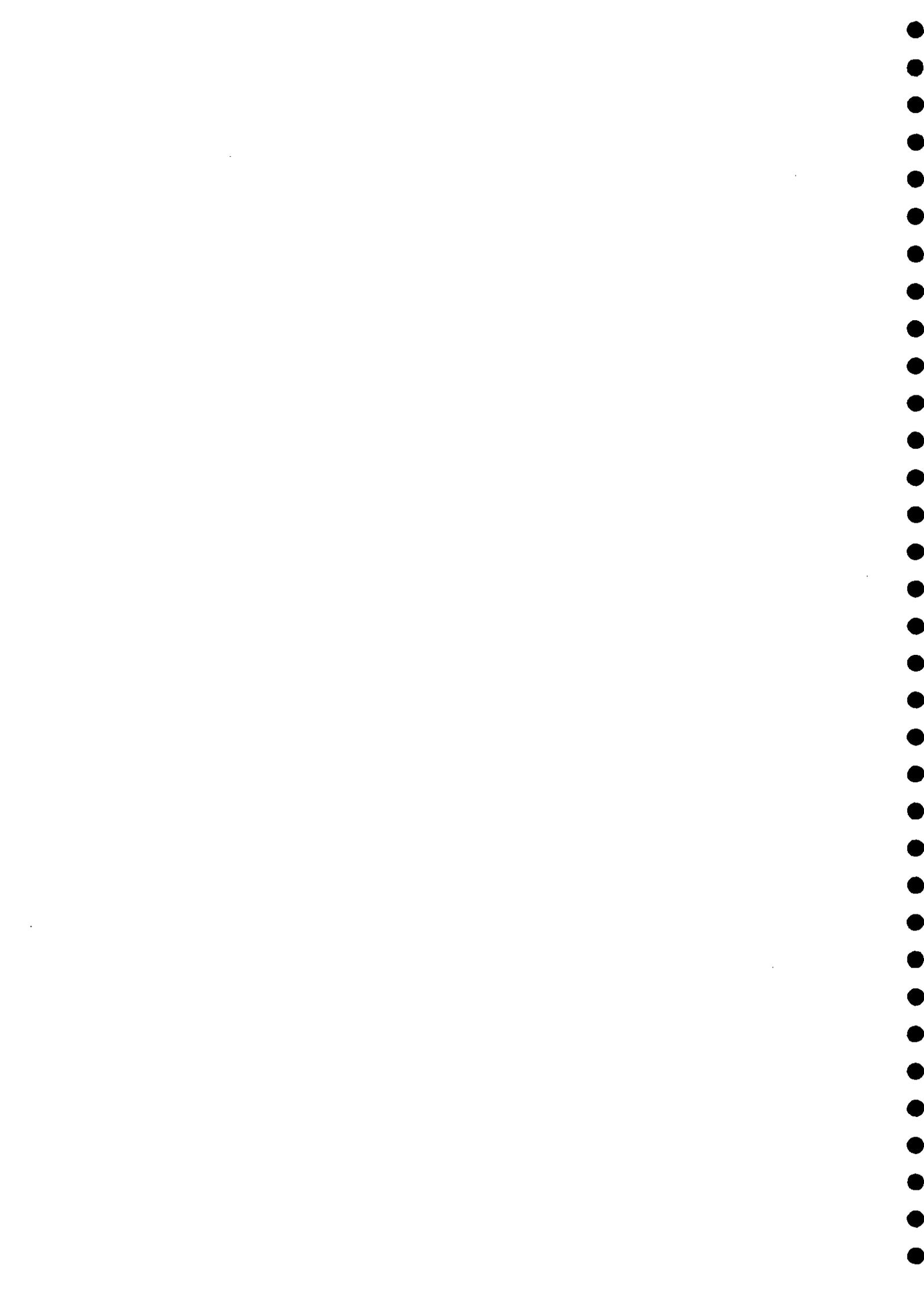


**LOW FLOW ESTIMATION IN
ARTIFICIALLY INFLUENCED CATCHMENTS**

TRAINING COURSE

Syndicate Exercise

**Estimating artificially influenced flows
using Micro LOW FLOWS V2.1**



Estimating Artificially Influenced Flows using Micro LOW FLOWS V2.1

1. DEFINITION OF THE PROBLEM

Due to the pressures of increased demand for water, a new impounding reservoir is to be constructed in the catchment of the River Trump above the town of Trumpton in Hydrometric Area 37; illustrated in Figure 1. Trumpton is sited some distance below the confluence of the Trump and the Trumpette (Geddit!). A few kilometres downstream of Trumpton is Trumpton Marsh. The water levels in this marsh are sustained by flows from the Trump. The Marshes are home to the endangered Great Raft Spider and have thus been designated a Site of Special Scientific Interest. The Trump is gauged below Trumpton at Club's Bridge (the puns get worse!), located just above the Marsh. The Environment Agency has set a Minimum Acceptable Flow Regime (MAFR) condition, for the Trump monitored at Club's Bridge. This MAFR is designed to maintain the minimum habitat requirements of the spider population within the Marsh. The flow regime at Club's Bridge and the MAFR are summarised in Annex 1.

Above Trumpton there are three abstractions:

- (i) A public water supply abstraction licence, owned by Trumpton Water Company. This abstraction is a surface water abstraction that is used by TWC, in conjunction with another source outside of the catchment, to supply the town with potable water. Following the designation of the SSSI, summer demand has been switched to the other source by TWC during the summer months as part of a PR exercise by TWC to demonstrate their environmental credentials. A typical abstraction profile for this licence has been provided by TWC;
- (ii) A Fish Farm owned by Captain Bird's Eye. Water is diverted from the Trump via a penstock to meet the requirements of this fish farm. Water is returned to the Trump immediately downstream of this penstock. It is estimated that 98 percent of the diverted water is returned in this manner. The diversion is operated at 83% of the allowed annual limit set on the licence;
- (iii) A groundwater abstraction for spray irrigation purposes. This spray irrigation licence is owned by Farmer Palmer and is thought to be 90 percent consumptive; although there are no reliable return data for the licence.

Historically there has been a low flow problem within the catchment as a result of the abstractions in the catchment. Sewage from Trumpton used to be treated at an obsolete plant sited some distance downstream of the Marshes. As part of their capital works programme, TWC, who owned the plant, have constructed a new plant which has a modern tertiary treatment facility. To alleviate the low flow problem the high quality effluent from this plant is now discharged upstream of the Marshes to augment flows at the MAFR control point.

The information held for these influences and the gauging station at Club's Bridge are detailed in Annex 1.

Micro LOW FLOWS V1.31 has been extensively validated within the Trump catchment by the Anglian Region of the Environment Agency, who are confident that the natural flow estimates are within the confidence limits of both Micro LOW FLOWS and natural/naturalised flow records for the region. The Region has recently upgraded the software to V2.1 and have loaded up their licence database.

However, the estimates produced by Micro LOW FLOWS show the Trump drying up during most of the year. This is thought to be due to following:

- (i) The representation of licences has been restricted to the information available from the licence database. Actual data, where these are available, have not been used and returns to the river that are not covered by a discharge consent) have not been taken into account;
- (ii) The discharge consent for the new treatment plant has not been loaded onto the system.

2. OBJECTIVES

The design specification for the reservoir stipulates that the impounded area should be between 130 and 140 km² and that compensation flow release policies are restricted to constant releases of either 20%, 55% or 90% of the natural Q95 flow at the dam site.

The objectives of the syndicate exercise are to identify suitable sites and evaluate the likely impact of the proposed reservoir development from the perspective of different interested parties. These parties are:

Group A: The developers - The MacAlpen Construction Group

The reservoir is to be developed by the MacAlpen Construction Group. The objective of the Group is to identify the site(s) which maximises the value of the reservoir scheme whilst meeting the minimum environmental requirements. The value of the scheme is directly proportional to the difference between mean flow and compensation flow. The chairman of the group, Lord MacAlpen is a major contributor to the political party in government and will not hesitate to use this lever to bring pressure to bear on the Environment Agency to re-evaluate downstream licences that are not fully utilised.

Group B: The Anglian region of the Environment Agency

The objective of this Group is identify a suitable site(s) and operating conditions for the proposed reservoir, whilst ensuring the needs and statutory rights of the downstream water users and the Great Raft Spider are met. The objective of this Group is not to unduly obstruct the development.

Group C: Lime Green Consultants

Following their successful campaign to protect the aquatic environment within the Roman River, Lime Green Consultants have been hired by the wealthy philanthropist, Peter Parker, to show that the reservoir development scheme is unacceptable, on environmental grounds, due to the potential threat to the colony of Great Raft Spiders. Their brief is to shadow the developers by identifying possible reservoir sites, modelling the impact of reservoirs at those sites upon the inflow to Trumpton Marsh and constructing an argument as to why the MAFR conditions may be violated if the development goes ahead.

Group D: Hydro International

Hydro International are bidding for an NFFO contract based on constructing a low head small hydro-power turbine sited immediately above the Club's Bridge gauge. This hydropower scheme will be totally non-consumptive and, as it is only at the proposal stage, HI are not applying to the Environment Agency. The index used to estimate whether the scheme is viable is based on the following ratio:

$$\text{(Mean Flow - Q95)/Q95}$$

The higher the ratio the better the site.

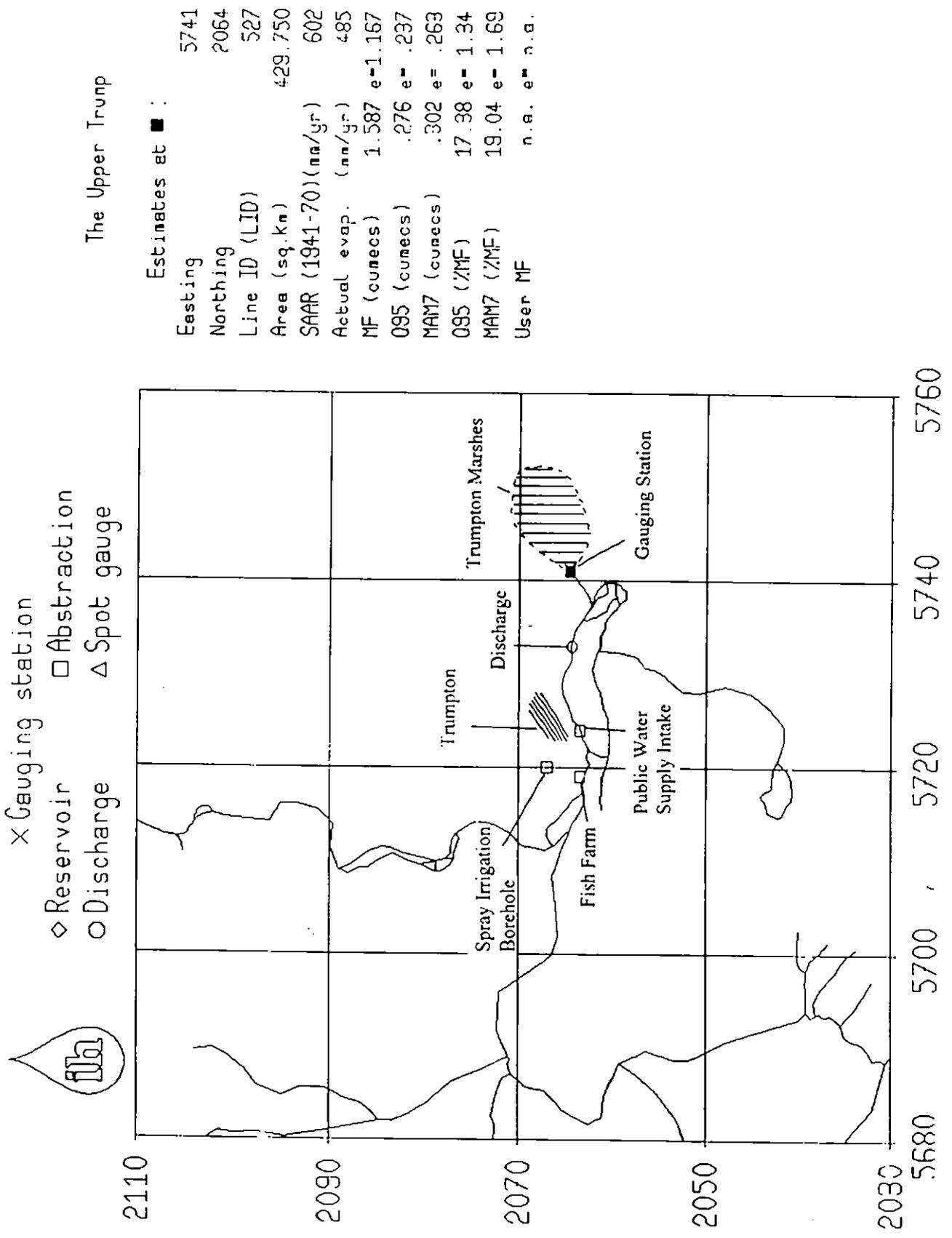
The HI objective is to evaluate the possible range of this ratio following construction of the reservoir. This range will be determined by the siting of the reservoir and the possible operating conditions.

3. APPROACH

The tool to be used by all groups to evaluate the impact of the reservoir development is Micro LOW FLOWS V2.1. However, before the software can be used to evaluate this impact the existing artificial influences have to be correctly set up within the software so that the mean flow and Q95 estimated by Micro LOW FLOWS at the site of the Club's Bridge gauge approximate to the gauged estimates. The accepted degree of fit between observed and estimated should be commensurate with the predicted accuracy of the natural flow estimates generated by Micro LOW FLOWS and the error inherent in the gauged flow record. Once Micro LOW FLOWS has been calibrated the software can then be used to predict the impact of the reservoir under the alternative siting and operating options.

4. TIME TABLE

Configuration of influences predicted flow statistics	35 mins
Presentation of calibrations	10 mins
Evaluation of the impact of reservoir construction	2 hrs
Presentation of preferred option(s) - site compensation release policy Representation of existing influences Impact of development on the MRF	



The Upper Trump

Estimates at ■ :

Easting	5741
Northing	2064
Line ID (LID)	527
Area (sq.km)	429.750
SAAR (1941-70)(mm/yr)	602
Actual evap. (mm/yr)	485
MF (cuneecs)	1.587 e=1.167
095 (cuneecs)	.276 e=.237
MAM7 (cuneecs)	.302 e=.263
095 (%MF)	17.38 e= 1.34
MAM7 (%MF)	19.04 e= 1.69
User MF	n.a. e= n.a.

Figure 1

ANNEX 1



GAUGING STATION AND MRF

Trump At Club's Bridge		
Location	{Easting	5741
	{Northing	2064
at	{Line ID (LID)	527
Catchment area (sq km)		429.75
MAFR (cumecs)		.276
Mean daily flow (cumecs)		1.487
Q95 (cumecs)		0.341
MAM7 (cumecs)		0.369

MAFR - Value below which Q95 must not fall.

DISCHARGES

IH discharge number: 370000 Type TS
 NRA number: TWC*001
 Licence holder:
 Trumptonshire Water Company
 Date of issue: 1996
 Review date: 2010
 Number of sites: 1
 Consented av. discharge (cumecs): .300
 Consented max. discharge (cumecs): .400
 Population equivalent:
 IH discharge number 370000 Site 1
 Easting 5733 Northing 2064
 Name: New Works Outfall
 Receiving river: The Trump
 Consented av. discharge (cumecs): .300
 Consented max. dischrge. (cumecs): .400
 Measured DWF (cumecs) .210

	Monthly values (cumecs)	
	Actual	Predicted
Jan	.210	.210
Feb	.210	.210
Mar	.210	.210
Apr	.210	.210
May	.210	.210
Jun	.210	.210
Jul	.220	.210
Aug	.220	.210
Sep	.210	.210
Oct	.210	.210
Nov	.210	.210
Dec	.210	.210

ABSTRACTIONS

(i) Public Water Supply

IH number 370004 Type S
 NRA number: S037*002
 Licence holder:
 Trumpton Water Company
 Date of issue: 1964
 Revocation date: 2010
 Number of sites: 1

TOTALS	Annual	Daily (cumeecs)
Licenced Abstraction:	.350	.900
Actual Abstraction:	.350	

IH abstraction number 370004 Site 1
 Easting 5724 Northing 2063
 Name: Trumpton Intake
 GW unit Bore dist.
 %S= T= %return
 MRF: Thresh.(cumeecs)
 Max.Lic.annual daily

Purpose	Lic.annual (cumeecs)	Lic.daily (cumeecs)	dates (mths)
PS	.350	.900	1 12

	Monthly Values		
	Actual Site	Licence so far (cumeecs)	Predicted Site
Jan	.670	.670	.0
Feb	.650	.650	.0
Mar	.580	.580	.0
Apr	.370	.370	.0
May	.100	.100	.0
Jun	.100	.100	.0
Jul	.100	.100	.0
Aug	.100	.100	.0
Sep	.100	.100	.0
Oct	.150	.150	.0
Nov	.300	.300	.0
Dec	.400	.400	.0

(ii) Fish Farm

IH number 370003 Type S
NRA number: s037*001
Licence holder:
Captain Bird's Eye Inc.
Date of issue: 1972
Revocation date: 2010
Number of sites: 1

TOTALS	Annual (cumeecs)	Daily
Licenced Abstraction:	.250	.250
Actual Abstraction:	250	

IH abstraction number 370003 Site 1
Easting 5719 Northing 2063
Name: Fish Farm Intake
GW unit Bore dist.
%S= T= %return 98.
MRF: Thresh.(cumeecs)
Max.Lic.annual .250 daily .250

Purpose	Lic.annual (cumeecs)	Lic.daily (cumeecs)	dates (mths)
FF	.250	.250	1 12

	Monthly Values		Predicted Site
	Actual Site (cumeecs)	Licence so far	
Jan	.250	.250	.00275
Feb	.250	.250	.00275
Mar	.250	.250	.00275
Apr	.250	.250	.00275
May	.250	.250	.00275
Jun	.250	.250	.00275
Jul	.250	.250	.00275
Aug	.250	.250	.00275
Sep	.250	.250	.00275
Oct	.250	.250	.00275
Nov	.250	.250	.00275
Dec	.250	.250	.00275

(iii) **Spray Irrigation**

IH number 370005 Type G
NRA number: G037*001
Licence holder:
Farmer Palmer
Date of issue: 1964
Revocation date: 2010
Number of sites: 1

TOTALS Annual Daily
(cumeecs)
Licenced Abstraction: .0100
Actual Abstraction:

N.B. not the original data

IH abstraction number 370005 Site 1
Easting 5720 Northing 2067
Name: Cold Comfort Farm
GW unit CH Bore dist. 486.055
%S= T= %return 10.
MRF: Thresh.(cumeecs)
Max.Lic.annual daily

Purpose Lic.annual Lic.daily dates
(cumeecs) (mths)
SI .0100 .0100 3 9

	Monthly Values		
	Actual Site	Licence so far (cumeecs)	Predicted Site
Jan		.000504	.000504
Feb		.000435	.000435
Mar		.00782	.00782
Apr		.00822	.00822
May		.00839	.00839
Jun		.00848	.00848
Jul		.00854	.00854
Aug		.00859	.00859
Sep		.00862	.00862
Oct		.00121	.00121
Nov		.000787	.000787
Dec		.000607	.000607