INSTITUTE of
HYDROLOGY

Fm
1/8/89

Low Flow Study - 1989 Drought

Interim Report June/July 1989

R. P. C. Brown

Instute of Hydrology
Wallingford
Oxon
OX10 8BB
Tel: (0491) 38800
Telex: 849365 HYDROL G

Low Flow Study - 1989 Drought

Interim Report June/July 1989

INTRODUCTION

This report is the second in a series whose purpose is to provide monthly low flow estimates throughout the summer of 1989 to Department of the Environment. The estimates are based on two data sets: May daily flows to estimate June minimum flows, and June monthly flows to estimate July minimum flows.

2, CATCHMENTS STUDIED

The analysis and flow estimates centre on the same four surface water catchments as were used in the last report:

Thames at Kingston/Teddington (39001):	1881-1988 gauged flows
	1881-1987 naturalised flows
Medway at Teston (40003):	1956-1987 gauged flows
Sussex Ouse at Gold Bridge (41005):	1960-1987 gauged flows
Itchen at Highbridge (42010):	1958-1987 gauged flows

3. MONTHLY MINIMUM ANALYSIS

Revised tables showing monthly seven day minimum flows for the months April to October, for 10, 20 and 50 year return periods are given in Table 1.

Table 1. ***7 DAY MINIMA (cumecs)*** *(percentage of monthly average flow in italics)*

39001 THAMES at Kingston (gauged flows) Month	Monthly average flow m^3s^{-1}	Mean 7 day min m^3s^{-1}	%	Return Period (years) 10 m^3s^{-1}	%	20 m^3s^{-1}	%	50 m^3s^{-1}	%
March	104.9	69.1	*65.9*	29.4	*28*	22.0	*21*	13.6	*13*
April	75.5	52.7	*69.8*	24.9	*33*	20.4	*27*	15.1	*20*
May	54.0	37.1	*68.7*	15.7	*29*	11.9	*22*	8.1	*15*
June	37.5	24.3	*64.7*	10.1	*27*	7.9	*21*	5.6	*15*
July	23.7	17.2	*75.2*	7.3	*31*	5.5	*23*	3.1	*13*
August	22.1	15.5	*70.2*	6.6	*30*	4.6	*21*	2.4	*11*
September	23.6	15.7	*66.5*	7.1	*30*	5.2	*22*	3.1	*13*
October	39.0	21.6	*55.4*	8.2	*21*	6.2	*16*	4.3	*11*
November	73.3	39.3	*53.6*	15.4	*21*	12.5	*17*	8.1	*11*

39001 THAMES at Kingston (naturalised flows) Month	Monthly average flow m^3s^{-1}	Mean 7 day min m^3s^{-1}	%	Return Period (years) 10 m^3s^{-1}	%	20 m^3s^{-1}	%	50 m^3s^{-1}	%
March	115.9	80.3	*69.3*	40.6	*35*	34.8	*30*	26.7	*23*
April	86.5	64.1	*74.1*	36.3	*42*	31.1	*36*	25.1	*29*
May	65.3	48.6	*74.5*	26.1	*40*	22.9	*35*	18.3	*28*
June	49.0	36.0	*55.5*	21.6	*44*	18.6	*32*	15.7	*32*
July	35.2	28.7	*81.7*	15.1	*43*	13.4	*38*	12.0	*34*
August	32.7	26.0	*79.5*	14.1	*43*	11/8	*36*	10.5	*32*
September	34.4	26.3	*76.4*	14.8	*43*	12.7	*37*	11.4	*33*
October	50.1	32.5	*64.9*	17.5	*35*	15.5	*31*	14.0	*28*
November	84.1	50.6	*60.1*	22.7	27	20.2	*24*	18.5	22

42010 ITCHEN at Highbridge (gauged flows) Month	Monthly average flow m^3s^{-1}	Mean 7 day min m^3s^{-1}	%	Return Period (years) 10 m^3s^{-1}	%	20 m^3s^{-1}	%	50 m^3s^{-1}	%
March	7.0	6.5	*93.0*	4.6	*65*	3.9	*55*	3.2	*46*
April	6.5	6.1	*93.9*	4.6	*71*	4.1	*63*	3.4	*52*
May	5.8	5.4	*92.8*	4.1	*70*	3.6	*62*	3.1	*54*
June	4.9	4.6	93.2	3.4	*70*	3.0	*61*	2.6	*54*
July	4.2	3.9	*92.9*	3.2	*77*	3.1	*73*	2.9	*68*
August	3.9	3.6	*92.6*	3.0	*78*	2.9	*74*	2.7	*70*
September	3.7	3.4	*92.6*	2.8	*77*	2.7	*73*	2.5	*67*
October	4.2	3.8	*90.9*	2.9	*70*	2.7	66	2.5	*61*
November	4.9	4.4	*89.0*	3.0	*62*	2.8	*57*	2.5	*51*

Comment: Very stable flow - even a 1 in 50 year drought only causes flow in any month to be approximately halved.

Table 1. (Contd.)

41005 SUSSEX OUSE at Gold Bridge (gauged flows) Month	Monthly average flow m^3s^{-1}	Mean 7 day min m^3s^{-1}	%	Return Period (years) 10 m^3s^{-1}	%	20 m^3s^{-1}	%	50 m^3s^{-1}	%
March	3.09	1.68	54.5	.87	28	.68	22	.49	16
April	2.36	1.43	60.5	.80	34	.66	28	.52	22
May	1.71	1.05	61.6	.55	32	.41	24	.29	17
June	1.09	0.61	55.6	.29	27	.25	23	.20	18
July	0.67	0.44	65.5	.25	37	.21	32	.18	27
August	0.76	0.43	56.9	.22	29	.17	23	.14	18
September	1.06	0.47	44.0	.21	20	.18	17	.13	12
October	2.09	0.82	39.1	.25	12	.19	9	.17	8
November	3.42	1.29	37.6	.38	11	.31	9	.24	7

40003 MEDWAY at Teston (gauged flows) Month	Monthly average flow m^3s^{-1}	Mean 7 day min m^3s^{-1}	%	Return Period (years) 10 m^3s^{-1}	%	20 m^3s^{-1}	%	50 m^3s^{-1}	%
March	14.9	7.0	46.9	3.7	25	3.3	22	2.5	17
April	10.9	5.9	53.8	3.2	29	2.7	25	2.3	21
May	6.9	4.0	58.6	2.4	35	2.1	31	1.7	25
June	5.3	3.0	56.5	1.5	28	1.2	22	0.7	14
July	3.0	2.1	69.7	1.4	47	1.2	41	1.1	37
August	3.4	2.0	58.8	1.2	35	1.0	30	0.9	25
September	5.0	2.0	44.4	1.2	24	1.0	20	0.9	17
October	9.1	3.2	35.7	1.4	15	1.2	13	1.1	12
November	15.7	5.6	35.6	1.9	12	1.7	11	1.6	10

4. PREDICTING FUTURE MINIMUM FLOWS FROM REGRESSION

Regressions developed in the last report, were used to predict June seven day minima from May seven day minima. The results, with corresponding return periods, are given in Table 2.

Table 2 Predicted June 1989 seven day minimum flows (% - percentage of June mean flow T - return period in years)

Station	June mean flow	Recorded June 1989 mean flow		Predicted June 1989 7-day minimum flow			Actual June 1989 7-day minimum		
	m^3s^{-1}	m^3s^{-1}	%	m^3s^{-1}	%	T	m^3s^{-1}	%	T
39001(g)	37.5	14.5	38.7	16.5	43.9	< 5	-	-	
39001(n)	48.9	33.4	68.2	32.0	65.3	< 5	24.4	49.9	
40003	5.23	2.6	49.7	2.14	40.9	5			
41005	1.10	0.39	35.8	0.43	39.0	< 5			
42010	4.88	3.26	66.8	3.64	74.7	5-10			

It can be seen that in three of the five cases the recorded average June 1989 flow is less than the predicted seven day minimum.

Regressions were also developed to estimate July and August 7-day minimum flows from June average flows. These regressions are given in Table 3, and the results from implementing them on June 1989 mean flows are given in Table 4.

Table 3. Regressions to derive July and August 7-day minima from June mean flow

Station	Regression	
39001(g)	[JULY7DY] = 8.57 + 0.23 [JUNE30DY]	$R^2 = 0.405$
	[AUG7DY] = 7.43 + 0.22 [JUNE30DY]	$R^2 = 0.370$
39001(n)	[JULY7DY] = 15.64 + 0.27 [JUNE30DY]	$R^2 = 0.493$
	[AUG7DY] = 13.69 + 0.25 [JUNE30DY]	$R^2 = 0.467$
40003	[JULY7DY] = 1.88 + 0.05 [JUNE30DY]	$R^2 = 0.094$
	[AUG7DY] = 1.87 + 0.04 [JUNE30DY]	$R^2 = 0.021$
41005	[JULY7DY] = 0.35 + 0.09 [JUNE30DY]	$R^2 = 0.231$
	[AUG7DY] = 0.37 + 0.07 [JUNE30DY]	$R^2 = 0.053$
42010	[JULY7DY] = 1.25 + 0.54 [JUNE30DY]	$R^2 = 0.786$
	[AUG7DY] = 1.36 + 0.45 [JUNE30DY]	$R^2 = 0.528$

It is worth noting that confidence in a relationship between June 30-day flow and July and August 7-day minimum flows would only be justified for Station 42010 (Itchen at Highbridge), and possibly the Thames naturalised data (39001 (n)).

Table 4. Predicted July and August 7-day minimum flows (from June 1989 mean flow)

Station	Predicted July 7-day minimum			Predicted August 7-day minimum		
	m^3s^{-1}	% July mean	T(yrs)	m^3s^{-1}	% August mean	T(yrs)
39001(g)	11.91	50.3	< 5	10.62	48.1	< 5
39001(n)	24.66	70.1	< 5	22.04	67.4	< 5
40003	2.01	67.0	< 5	1.97	57.9	< 5
41005	0.385	57.5	< 5	0.398	52.4	< 5
42010	3.22	76.7	10	3.00	76.9	10-25

The revised estimate of July 7-day minimum for the naturalised Thames data, using recorded June 7-day minimum flow and the regression supplied on page 6 of the first report, is 21.8 m^3s^{-1}, or 62.0% of mean July flow. This would have a return period of less than 5 years.

A comparison between predicted May 7-day minimum flows from April mean and April 7-day minimum flows, and recorded May 7-day minimum flows is given in Table 5.

Table 5. Comparison of predicted and recorded May 7-day minimum flows.
(% - percentage of May mean flow
T - return period in years)

Station	Recorded			Predicted from April mean			Predicted from April 7-day		
	m_3s^{-1}	%		m_3s^{-1}	%	T	m_3s^{-1}	%	T
39001(g)	21.9	40.6	5	57.8	107.0	< 5	47.3	87.5	< 5
39001(n)	41.3	63.3	<5	53.8	82.4	< 5	57.0	87.3	< 5
40003	2.07	30.0	25	6.70	97.1	< 5	4.27	61.9	< 5
41005	0.63	37.0	5-10	1.08	63.2	< 5	1.16	67.8	< 5
42010	4.27	73.5	5-10	4.70	81.0	5	4.80	82.8	5

MINIMUM FLOW FROM DRY WEATHER FLOW RECESSIONS

Using the recession constants derived in the first report, and end-of-month daily flows, an end-of-following-month daily flow can be derived. This was done using 30 April recorded flow to predict 30 May flow, and 31 May recorded flow to predict 30 June flow. Predicted and recorded flows from 30 May are shown in Table 6 for comparison. 30 July and 31 August flows assume continuous recession throughout the whole of June and July, and June, July and August respectively. Return periods quoted assume that the flows quoted are the monthly minimum.

Table 6. Predicted end-of-month daily flows assuming constant recession

	30 May 1989 flow				30 June 1989 flow		30 July 1989 flow		31 August 1989 flow	
	Recorded		Predicted		Predicted		Predicted		Predicted	
Station	m^3s^{-1}	T	m^3s^{-1}	T	m^3s^{-1}	T	m^3s^{-1}	T	m^3s^{-1}	T
39001(g)	11.0	10	11.53	10	2.62	50	0.62	50-100	0.13	100
39001(n)	35.50	< 5	26.40	5	14.60	35	5.69	< 200	2.09	> 500
40003	1.993	5-10	2.110	5-10	0.639	25-50	0.16	≥ 500	0.04	> 500
41005	0.603	5	0.697	< 5	0.208	10-25	0.12	50	0.07	100
42010	4.147	5-10	3.997	5-10	3.196	10	2.37	200	1.76	> 500

It can be seen that 30 May 1989 flow was generally quite well predicted. On closer inspection of the May flow record, however, this is coincidental as no station experienced a continuous recession through the month. The recorded Thames naturalised flow for the 30 June was 31.60 m^3s^{-1}. A return period cannot be assigned to it as it is not the monthly minimum.. The revised estimates for 30 July and 31 August flows for the Thames (naturalised), based on recorded 30 June flows are: 12.32 m^3s^{-1} (T = 5 years), and 4.51 m^3s^{-1} (T = > 200 years) respectively.

6. CONTINUING DROUGHT FLOW TABLE

Predicted 7-day minimum monthly flows based on the return period of May 1989 7-day minimum flow, and assuming constant severity (or return period) throughout the rest of the year are given in Table 7.

Table 7. Predicted 7-day monthly minima assuming constant return period.

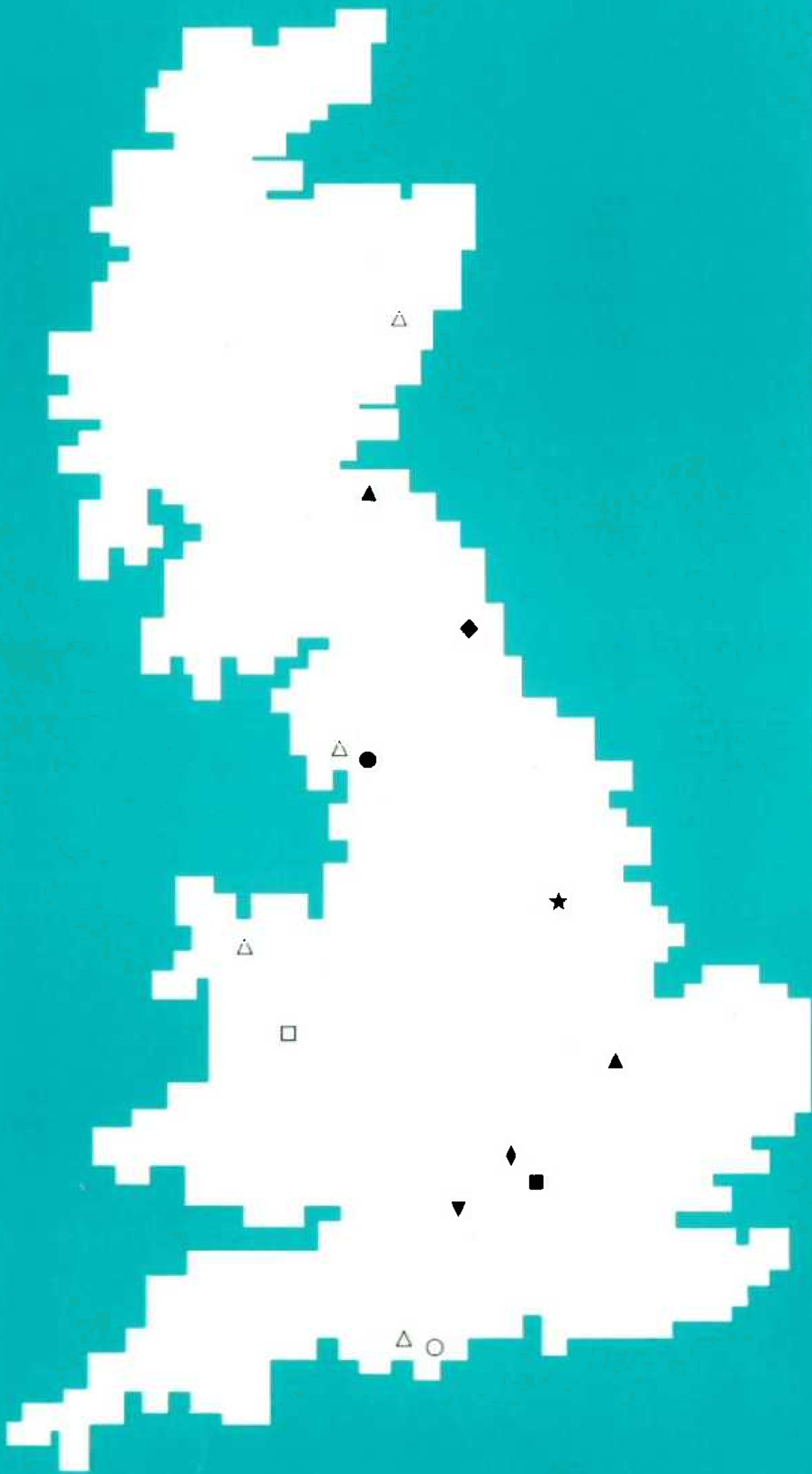
Station	May 1989	T (years)	June 1989	July 1989	August 1989	September 1989
	7-day monthly minima (m^3s^{-1})					
39001(g)	21.90	5	13.89	10.19	9.28	10.62
39001(n)	41.33	< 5	27.93	24.64	21.26	20.64
40003	2.069	25	1.060	1.230	0.900	1.000
41005	0.632	5-10	0.338	0.268	0.236	0.244
42010	4.265	5-10	3.626	3.360	3.081	2.886

INSTITUTE of HYDROLOGY

The **Institute of Hydrology** is a component establishment of the UK Natural Environment Research Council, grant-aided from Government by the Department of Education and Science. For over 20 years the Institute has been at the forefront of research exploration of hydrological systems within complete catchment areas and into the physical processes by which rain or snow is transformed into flow in rivers. Applied studies, undertaken both in the UK and overseas, ensures that research activities are closely related to practical needs and that newly developed methods and instruments are tested for a wide range of environmental conditions.

The Institute, based at Wallingford, employs 140 staff, some 100 of whom are graduates. Staff structure is multidisciplinary involving physicists, geographers, geologists, computer scientists, mathematicians, chemists, environmental scientists, soil scientists and botanists. Research departments include catchment research, remote sensing, instrumentation, data processing, mathematical modelling, hydrogeology, hydrochemistry, soil hydrology, evaporation flux studies, vegetation-atmospheric interactions, flood and low-flow predictions, catchment response and engineering hydrology.

The budget of the Institute comprises £4.5 million per year. About 50 percent relates to research programmes funded directly by the Natural Environment Research Council. Extensive commissioned research is also carried out on behalf of government departments (both UK and overseas), various international agencies, environmental organisations and private sector clients. The Institute is also responsible for nationally archived hydrological data and for publishing annually HYDROLOGICAL DATA: UNITED KINGDOM.



● **FRESHWATER BIOLOGICAL ASSOCIATION**
The Ferry House, Far Sawrey
Ambleside, Cumbria LA22 0LP
Tel: 09662 2468 Fax: 6914
Telex: 8950511 ONEONE G
REF 16173001

○ **The River Laboratory**
East Stoke, Wareham
Dorset BH20 6BB
Tel: 0929 462314 Fax: 462180
Telex: 8950511 ONEONE G
REF 16174001

■ **INSTITUTE OF HYDROLOGY**
Wallingford, Oxon OX10 8BB
Tel: 0491 38800 Fax: 32256 Telex: 849365

□ **Plynlimon Office**
Staylittle, Llanbrynmair
Powys SY19 7DB
Tel: 05516 652

INSTITUTE OF TERRESTRIAL ECOLOGY

▲ **Edinburgh Research Station**
Bush Estate, Penicuik, Midlothian EH26 0QB
Tel: 031-445 4343 Fax: 3943 Telex: 72579

△ **Banchory Research Station**
Hill of Brathens, Glassel
Banchory, Kincardineshire AB3 4BY
Tel: 03302 3434 Fax: 3303 Telex: 739396

△ **Merlewood Research Station**
Grange-over-Sands, Cumbria LA11 6JU
Tel: 04484 2264 Fax: 4705 Telex: 65102

▲ **Monks Wood Experimental Station**
Abbots Ripton, Huntingdon, Cambs PE17 2LS
Tel: 04873 381 Fax: 467 Telex: 32416

△ **Bangor Research Station**
Penhros Road, Bangor, Gwynedd LL57 2LQ
Tel: 0248 364001 Fax: 355365 Telex: 61224

△ **Furzebrook Research Station**
Wareham, Dorset BH20 5AS
Tel: 0929 51518 Fax: 51087

♦ **INSTITUTE OF VIROLOGY**
Mansfield Road, Oxford OX1 3SR
Tel: 0865 512361 Fax: 59962 Telex: 83147

★ **UNIT OF COMPARATIVE PLANT ECOLOGY**
Dept of Plant Sciences, Sheffield University, Sheffield S10 2TN
Tel: 0742 768555 Fax: 760159 Telex: 547216

◆ **UNIT OF WATER RESOURCES SYSTEMS RESEARCH**
Dept of Civil Engineering
Newcastle University
Newcastle upon Tyne NE1 7RU
Tel: 091-232 8511 Fax: 261 0191 Telex: 53654

▼ **DIRECTORATE OF TERRESTRIAL & FRESHWATER SCIENCES**
Natural Environment Research Council
Polaris House, North Star Avenue
Swindon SN2 1EU
Tel: 0793 40101 Fax: 511117 Telex: 444293

DIRECTORATE OF TERRESTRIAL & FRESHWATER SCIENCES

Natural Environment Research Council