HYDROLOGICAL SUMMARY FOR GREAT BRITAIN - AUGUST 1990

Data for this review have been provided principally by the regional divisions of the National Rivers Authority in England and Wales, the River Purification Boards in Scotland and by the Meteorological Office. The recent areal rainfall figures are derived from a restricted network of raingauges (particularly in Scotland) and a significant proportion of the river flow data may be subject to revision following reviews of the low flow stage-discharge relations.

For a fuller appreciation of the water resources implications, this hydrological review should be considered alongside assessments of the current reservoir storage and water demand situations in each region.

Summary

A severe, or moderately severe, six-month drought extends across most of England and Wales following an exceptionally dry spring and a hot dry summer. Provisional data suggest that, for England and Wales, the March to August period ranks among the driest half dozen six-monthly sequences (with any start month) in the general rainfall series since 1785. Beyond the six-month timeframe a very clear amelioration in the drought severity may be recognised - a consequence of the wettest winter (December to February) since 1914/15. In some eastern, central and southern areas the winter rainfall was not especially abundant and the recent intense drought is overlain on a long term rainfall deficiency. It is in such districts that the hydrological and water resources situations are most fragile.

There is no modern parallel to the transformation in hydrological conditions since February. Widespread spate conditions have given way to notably low discharge rates entering the autumn. Runoff in August was low, but not exceptionally so, in northern and western regions of Britain. Away from the more maritime areas, however, river flows were among the lowest on record - commonly the lowest since the 1976 drought in eastern England. In a few eastern catchments the minima established in August 1976 were eclipsed. Elsewhere the August runoff was well above the corresponding runoff in 1976 - typically twice as great.

Broadly speaking, the drought has achieved its greatest severity in those regions most dependant on groundwater resources. The long term paucity of recharge in the east and other parts of the English lowlands has produced very depressed groundwater levels for the second successive year. In parts of Humberside and Lincolnshire the August levels were unprecedented; some areas in Kent and Sussex may be approaching historical minima. Away from such districts water-tables are substantially below average but generally considerably above those recorded in the late summer of 1976.

Soil moisture deficits remain very high, albeit somewhat less than in 1976, throughout southern and eastern Britain. They will certainly considerably delay the seasonal upturn in runoff and recharge rates as evaporative losses decline through the autumn. This will maintain pressure on water resources, especially in lowland England and parts of Yorkshire. In these areas above average rainfall through the winter period (without a repetition of the very early onset of the seasonal decline in runoff and recharge rates which occurred this year) will be essential to allay concern regarding the water resources outlook for 1991.

Rainfall

The first half of August was generally dry; the initial anticyclonic conditions gave rise to the highest temperature ever officially recorded, on the 3rd. Isolated thunderstorms and weak frontal features brought light rain to the north and west. The middle of the month was more unsettled with one or two days of widespread rain; some areas in the south recording their first significant rainfall for 38 days on the 14th. The later part of the month saw frontal activity bringing variable rainfall to the west and depressions centred over northern France triggered thunderstorms over central and southern England. Although locally heavy, rainfall amounts were generally low.

Rainfall was below average in all areas away from the extreme north and west of Scotland. Throughout England and Wales the particularly dry sequence beginning in March was extended further with August rainfall registering 54% of average (Table 1). On the basis of provisional data, the March-August accumulation of 240 mm (Table 2) represents the second driest such sequence in the full England and Wales rainfall series (from 1766) - only 1976 was drier. Considering ***any*** six-month sequence this century, only in 1921 (188mm), 1929 (234mm) and 1976 (two overlapping sequences of 203 and 218mm) have lower accumulated totals been recorded. The large rainfall deficiencies in lowland England constitute severe meteorological drought conditions over a wide area. The Severn-Trent, Anglia, Thames, Southern, Wessex and Welsh NRA regions, each have associated return periods around the 100 year mark or more. Figure 2(a) provides a comparison between March to August rainfall in 1990 with that in 1976 based on the major administrative units in Great Britain. 1976 may be seen as only a little drier than the current drought throughout England and Wales. At the catchment scale some lowland districts - the Nene Valley being an example - recorded lower rainfall totals this year.

Abundant rainfall early in the year provided a substantial counterbalance to the subsequent drought and with the notable exception of East Anglia, 1990 rainfall totals - and those for the last 12 months - are not greatly below average. Figure 2(b) emphasises the different perspective provided by a comparison with the 75/76 drought within a 12-month timeframe. Over the longer term, many of the rainfall deficiencies in lowland England and along the north-eastern seaboard, which began to build in the spring of 1988, were not fully satisfied even in the 1989/90 winter. The regional picture obscures localities which are experiencing more extreme conditions; parts of north-east Yorkshire, the lower Trent valley, parts of East Anglia and Kent, for example.

The situation in Scotland is somewhat different; the August rainfall was below average in all River Purification Board areas, but not to the same extent as in England and Wales. Some eastern regions were, once again, disproportionally drier than the west and north and, in these areas, deficits accumulated over the last six months are modest, with the exception of the Tweed RPB area. Over the medium to long term the pattern of north, west and south-west Scotland with remarkable surpluses is continued, if a little moderated, whilst the Tweed and North East RPB areas maintain significant deficits particularly around the lower reaches of their major river systems.

Evaporation and Soil Moisture Deficits (SMDs)

The warm sunny weather which has prevailed throughout much of 1990 continued in August and extended the sequence of months for which potential evaporation (PE) losses have been exceptional. In Kent, for example, computed MORECS PE values over the January-August period eclipsed the record established only last year for a thirty year period. Considering the last 12 months, PE values have been remarkably high in all regions. However, as a consequence of sustained high SMDs, actual evaporation (AE) anomalies display a far less uniform pattern. Broadly speaking, record, or near record, 12-monthly accumulations of AE (for grass) characterise western and northern areas of Britain with below average totals typifying the South-East. Nonetheless, AE losses in the English lowlands are substantially greater than those computed for 1975/76.

Soils were at, or close to, field capacity in western Scotland towards the end of August. Elsewhere, end-of-month SMDs were substantially above average. Positive anomalies (ie. drier conditions) in the range 30-50 mm were widespread in England and Wales with maximum deficits (125 mm using the MORECS model) obtaining throughout much of lowland Britain and along the eastern seaboard. In eastern, central and southern areas the existing deficits are the equivalent of about 2 months average autumn rainfall. This will serve to limit the hydrological effectiveness of the rainfall over the next few months and delay the seasonal upturn in river flows and aquifer replenishment.

Runoff

With the exception of the north-west of England decreases in runoff from July to August were more moderate than in other recent droughts. Nonetheless, August flows were well below average throughout Great Britain. Broadly speaking, runoff totals in western catchments in England and Wales were similar to those of 1989 and, commonly, significantly greater than in August 1984. In the lowlands a more complex picture emerges. In relatively impermeable catchments flows responded to the limited surface runoff as a consequence of the sporadic, but locally heavy, rainfall; in some catchments flows exceeded those of last year. More typically, runoff rates were lower than 1989 and similar to those registered during the hot summers of 1983 and 1984. Hydrologically, the situation becomes more fragile towards the east. Close to the eastern seaboard a number of catchments, including the Kent Stour and the Yorkshire Derwent, registered August runoff totals comparable with those in 1976; runoff for the River Welland (at Ashley) fell marginally below the 1976 figure.

Expressed as a percentage of the average, August runoff generally appeared healthiest in rivers supported largely from groundwater. When account is taken of their subdued annual range of flows, the hydrological drought may be seen to be substantial in such rivers, especially in the east. This reflects the paucity of recharge since late February (and in some areas over a very much longer timescale). Commonly, flows in the Chalk and other limestone rivers of lowland England are at their lowest since 1976.

Comparison with the 'Great Drought' of 1976/76 are complicated by the artificial augmentation currently practised in many lowland catchments. The region where flows are lower than in 1976 is very restricted. Generally, flows were one and a half to two times greater than in August 1976, with higher multiples appropriate away from the South-East, East Anglia and parts of Yorkshire. On the Thames, the naturalised flow for August was the lowest for 40 years with the exception of 1976 but was significantly above the corresponding flows recorded during earlier droughts - particularly those of 1898, 1906, 1921, 1934, 1944 and 1949. Return periods associated with the August runoff are mostly in the 10-50 year range for those catchments where the drought is most severe; the rivers featured in Table 4 are drawn principally from such areas. The relatively modest return periods compared to some of the extreme values assessed during 1976 (when return periods of hundreds of years were common) is partly a reflection of the incorporation of the Great Drought flows (and, to a lesser degree, those of 1984 and 1989) in the analyses. Accumulated runoff totals over periods of 3 and 6 months are very low, exceptionally so for the Trent, Lud, Medway and Tone, for instance (see Table 3). These also fall short of accumulations recorded during corresponding periods in 1976; the Yorkshire Derwent excepted.

In most cases the severity of the hydrological drought decreases rapidly as the timeframe is extended back into the winter. Twelve-month accumulations for most rivers in England and Wales, whilst low, are within the normal ranges - yearly totals exceeded 75% of the long term average in all regions away from Humberside and the north east, where the Lud and the Derwent were about or below 50% of average. In Scotland historically ***high*** 12-month runoff totals are associated with rivers draining from the Highlands - the runoff for the Tay being exceeded only once in a 38-year record but in the Berwickshire region in the south east, the Whiteadder accumulation was below 50% of average. Over longer durations in parts of eastern and southern England and south east Scotland, the heavy winter runoff was but a short interlude in a sustained period of runoff deficiency.

For monthly accumulations in the 20-28 month range up till August 1990, runoff is the lowest, or close to the lowest, for the Whiteadder, Trent, Lud, Medway, Itchen and Brue. The accumulated runoff deficiency on the Yorkshire Derwent is remarkable - August is the 23rd successive month with below average runoff and the shortfall relative to the mean is unprecedented. But for a marginal breach of the average flow threshold in July this record is closely matched by the

Whiteadder (a responsive tributary of the Tweed) where monthly flows have been below average since September 1988 and the long-term accumulations are substantially lower than any since the 1972/73 drought.

Groundwater

With the continued low rainfall during August, there has been little, if any recharge even to fissure type aquifers such as the Jurassic oolite or the Magnesium Limestone which generally react rapidly to rainfall even during the summer months. Some very moderate localised recoveries were reported following intense rainfall on the 19th but generally the recessions which commenced, in most areas, in February continued unabated.

Groundwater levels, especially in the deeper boreholes, can reflect not only the infiltration over the previous winter but also that occurring in preceding years. The well hydrographs (Figure 4) for eastern aquifer units show clear evidence of the impact of limited recharge since early in 1988. Consequently, whilst water-tables are below average in almost all unconfined major aquifers, there is a distinct regional dimension to the current groundwater drought. The intensity of the drought close to the eastern seaboard is illustrated by the Dalton Holme (Humberside) hydrograph - for the second successive year groundwater levels are entering the autumn close to their lowest level (for September) in a 101-year record; only 1905, 1976 and 1989 registered comparable levels. The pattern of meagre recharge over the last two years - for which there is no recorded precedent - is confirmed by the Little Brocklesby trace. Very depressed levels also characterise parts of East Anglia, Kent and Sussex; typically, though, groundwater depletion is not as severe as in 1976. The hydrograph for The Holt (in Hertfordshire) reveals a continuing benefit from the record levels reached in early 1988 and provides evidence of the considerable spatial variation in groundwater depletion. In the Cotswolds, levels in the Ampney Crucis borehole are exceptionally low but generally a clear improvement may be recognised in a westerly direction with groundwater levels well above those recorded in August 1976. In the Triassic sandstones of Wales and the South-West, levels, as evidenced by the Llanfair and Bussels boreholes, are within the normal range. A similar picture emerges from the most westerly of the Chalk outcrops (see the Limekiln hydrograph).

In general terms, water-tables are most depressed in those regions where even in a normal year the surplus of rainfall over evaporative losses is small - typically less than 150 mm. Aquifer storage is therefore particularly sensitive to relatively small differences in rainfall amounts over the winter period. Dramatic recoveries in groundwater levels were recorded following the end of the 1976 drought; winter rainfall totals were commonly 50 per cent above average over the outcrop areas. Average, or higher, spring levels have been attained with rather more modest rainfall amounts. In 1965/66 and 1972/73 for instance, winter rainfall was above average but not greatly so. However, as last winter so clearly demonstrated, the temporal distribution of the rainfall can be as influential as its magnitude in determining the water resources impact.

Institute of Hydrology / British Geological Survey

14 September 1990

TABLE 1 1989/90 RAINFALL AS A PERCENTAGE OF THE 1941-70 AVERAGE

		Jul 1989	Aug	Sep	Oct	Nov	Dec	Jan 1990	Feb	Mar	Apr	May	Jun	Jul	Aug
England and	mm	38	58	41	98	61	134	133	142	20	38	25	70	35	49
Wales	%	52	65	49	118	63	149	154	219	34	66	37	115	47	54
NRA REGIONS															
North West	mm	33	116	29	145	84	100	196	187	47	52	49	97	55	70
	%	32	93	24	123	69	83	175	231	65	68	60	117	53	55
Northumbria	mm	19	77	20	71	35	75	111	133	33	28	51	68	40	57
	%	25	76	25	95	37	100	139	202	63	51	80	111	52	56
Severn Trent	mm	40	44	38	82	52	135	107	110	21	30	19	62	29	39
	%	62	54	57	126	66	193	155	208	40	58	30	111	44	48
Yorkshire	mm	43	41	20	77	45	98	118	112	24	24	29	83	34	61
	%	61	46	28	112	51	132	153	175	45	43	48	143	48	68
Anglia	mm	41	35	30	41	36	98	52	74	15	36	16	45	22	30
	%	72	55	58	79	58	185	101	177	38	90	34	92	39	47
Thames	mm	37	44	28	65	37	141	91	114	12	35	7	46	15	34
	%	62	63	45	102	51	214	147	242	26	76	13	88	25	49
Southern	mm	28	29	37	79	50	142	121	135	6	43	11	59	12	32
	%	54	40	52	101	53	175	159	238	12	90	20	118	21	45
Wessex	mm	37	43	49	101	58	165	124	157	15	35	13	63	30	42
	%	60	52	62	123	60	183	147	265	26	65	19	117	49	51
South West	mm	31	62	107	148	100	196	195	238	25	47	24	98	58	61
	%	37	61	103	131	75	145	151	264	30	66	29	151	69	60
Welsh	mm	48	91	62	180	109	199	240	214	37	45	33	94	48	62
	%	51	76	50	140	76	137	176	223	43	52	36	115	50	52
Scotland	mm	49	184	96	187	60	96	248	291	183	97	55	124	67	86
	%	44	143	70	126	42	62	181	280	199	108	60	135	60	67
RIVER PURIFICATION BOARDS															
Highland	mm	65	222	118	252	79	109	293	364	395	148	57	137	94	138
	%	51	150	75	135	47	56	179	274	346	130	55	125	74	93
North-East	mm	25	84	57	87	29	54	103	145	87	51	48	108	47	66
	%	27	79	66	90	28	53	114	195	140	84	62	154	51	62
Tay	mm	30	140	83	136	51	86	236	249	186	62	43	122	40	71
	%	29	119	72	111	43	64	200	270	227	83	45	147	39	60
Forth	mm	27	144	69	112	39	79	220	221	134	50	39	119	50	56
	%	28	124	64	106	36	72	222	287	194	74	46	159	51	48
Tweed	mm	23	113	47	68	30	78	166	180	53	47	46	101	54	66
	%	27	99	51	77	29	87	179	260	91	77	61	149	61	58
Solway	mm	42	176	77	145	59	119	250	282	97	50	77	120	76	83
	%	38	135	51	101	41	79	179	303	107	57	84	133	69	64
Clyde	mm	63	252	120	244	73	107	316	343	290	144	58	134	96	114
	%	48	177	69	133	44	58	196	304	276	140	60	130	74	80

Note: August figures for England and Wales for 1990 are based upon MORECS figures supplied by the Meteorological Office

Scottish RPB data for August 1990 are estimated from the isohyetal map of August rainfall in the MORECS bulletin. The Scottish national value was provided by the London Weather Centre.

TABLE 2 RAINFALL RETURN PERIOD ESTIMATES

		JUN - AUG 90		MAR - AUG 90		JAN - AUG 90		SEP 89 - AUG 90		NOV 88 - AUG 90	
			Est Return Period, years		Est Return Period, years		Est Return Period, years		Est Return Period, years		Est Return Period, years
England and	mm	153		240		515		848		1425	
Wales	% LTA	68	10	59	80-120	92	2-5	93	2-5	86	5-10
NRA REGIONS											
North West	mm	221		369		752		1109		2012	
	% LTA	71	5-10	68	20-30	102	<2	91	2-5	92	2-5
Northumbria	mm	165		277		521		722		1255	
	% LTA	69	5-10	68	20-30	94	2-5	82	10	78	10-20
Severn Trent	mm	130		200		417		724		1215	
	% LTA	64	10	54	80-120	85	5	94	2-5	86	10
Yorkshire	mm	178		255		485		725		1252	
	% LTA	82	2-5	66	20-50	92	2-5	87	5	82	20-30
Anglia	mm	98		165		291		496		889	
	% LTA	57	10-20	55	80-120	74	10-20	81	10	80	20-50
Thames	mm	95		149		354		625		1043	
	% LTA	52	20	45	>200	81	5-10	89	2-5	81	20
Southern	mm	104		164		420		728		1138	
	% LTA	57	10-20	49	100-200	89	2-5	92	2-5	79	20-50
Wessex	mm	135		198		479		852		1344	
	% LTA	68	5	52	80-120	92	2-5	98	2-5	85	10
South West	mm	217		313		746		1297		1981	
	% LTA	87	2-5	64	20-50	105	2-5	109	2-5	91	5
Welsh	mm	204		319		772		1322		2196	
	% LTA	69	5-10	57	80-120	98	2-5	99	<2	91	5
Scotland	mm	293		681		1222		1661		2967	
	% LTA	88	2-5	112	5	144	>>200	116	10-20	115	20-50
RIVER PURIFICATION BOARDS											
Highland	mm	369		957		1615		2173		3930	
	% LTA	96	2-5	134	50	159	>>200	126	50-100	127	>>200
North-East	mm	221		400		648		875		1519	
	% LTA	82	2-5	85	5	102	2-5	86	5-10	82	50
Tay	mm	233		522		1006		1362		2381	
	% LTA	77	5-10	94	2-5	132	20-50	109	2-5	105	2-5
Forth	mm	225		453		893		1192		2107	
	% LTA	78	5-10	89	2-5	130	20-50	107	2-5	104	2-5
Tweed	mm	221		351		697		920		1597	
	% LTA	82	2-5	75	10-20	111	2-5	92	2-5	88	10
Solway	mm	279		524		1056		1456		2580	
	% LTA	85	2-5	87	2-5	127	20	102	2-5	101	<2
Clyde	mm	344		819		1478		2022		3584	
	% LTA	92	2-5	120	5-10	155	>>200	121	20-50	121	80-120

Return period assessments are based on tables provided by the Meteorological Office*. These assume a start in a specified month; return periods for a start in any month may be expected to be an order of magnitude less. "Wet" return periods underlined.
The tables reflect rainfall totals over the period 1911-70 only and the estimate assumes a sensibly stable climate.
The August 1990 RPB values are estimated from the isopleth map within the August summary published in the Met. Office's MORECS bulletin.

* Tabony, R C, 1977, The Variability of long duration rainfall over Great Britain, Scientific Paper No. 37, Meteorological Office (HMSO).

FIGURE 1. MONTHLY RAINFALL FOR 1989 – 1990 AS A PERCENTAGE OF THE 1941 – 1970 AVERAGE FOR ENGLAND AND WALES, SCOTLAND, AND THE NRA REGIONS

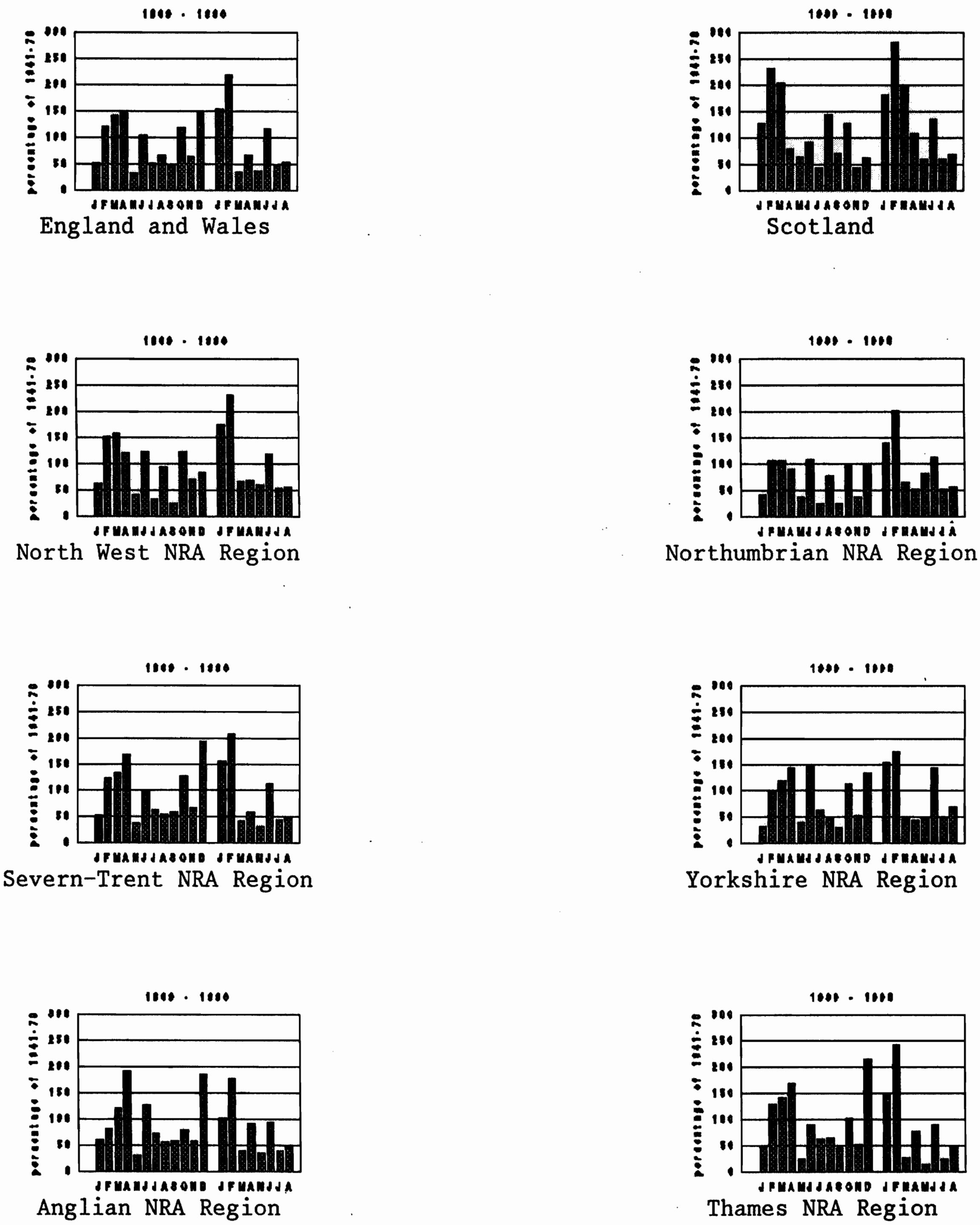
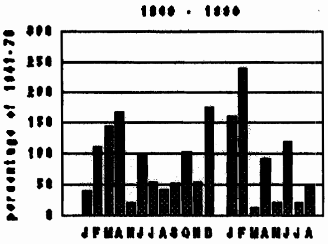
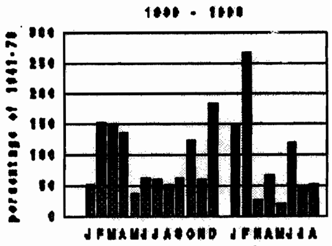


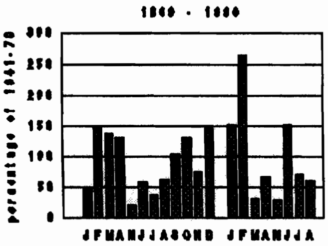
FIGURE 1 (continued)



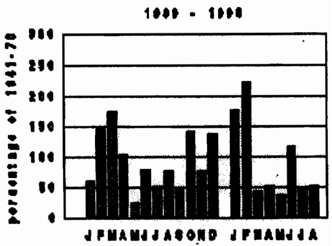
Southern NRA Region



Wessex NRA Region

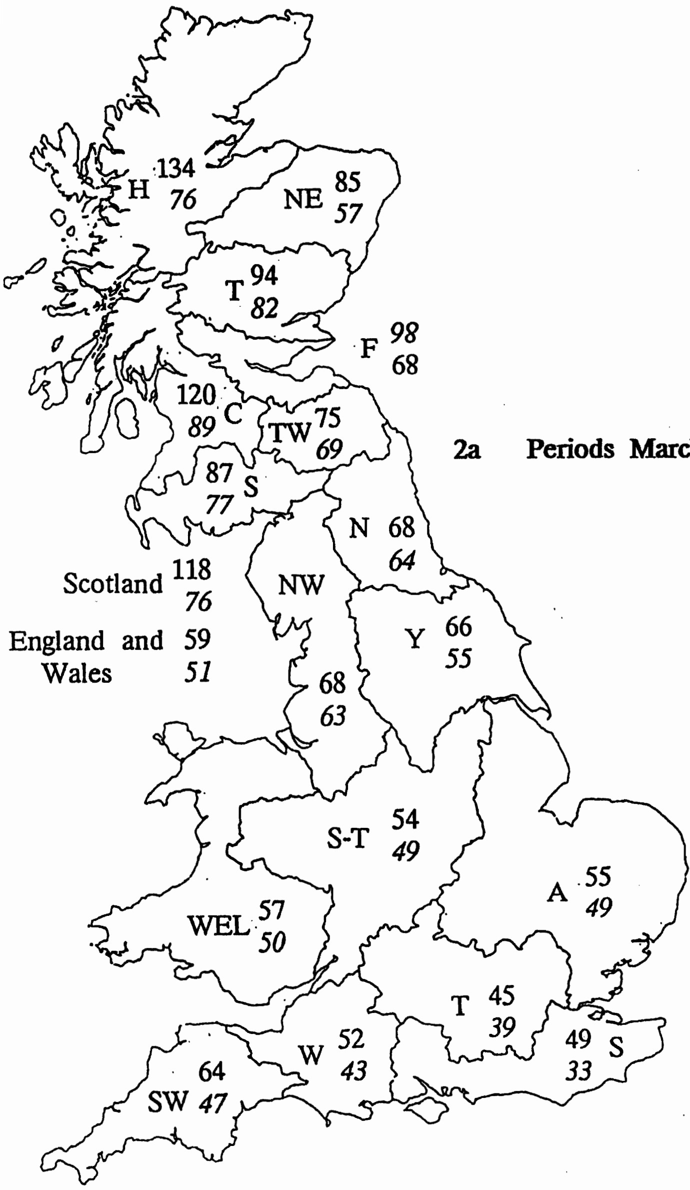


South West NRA Region

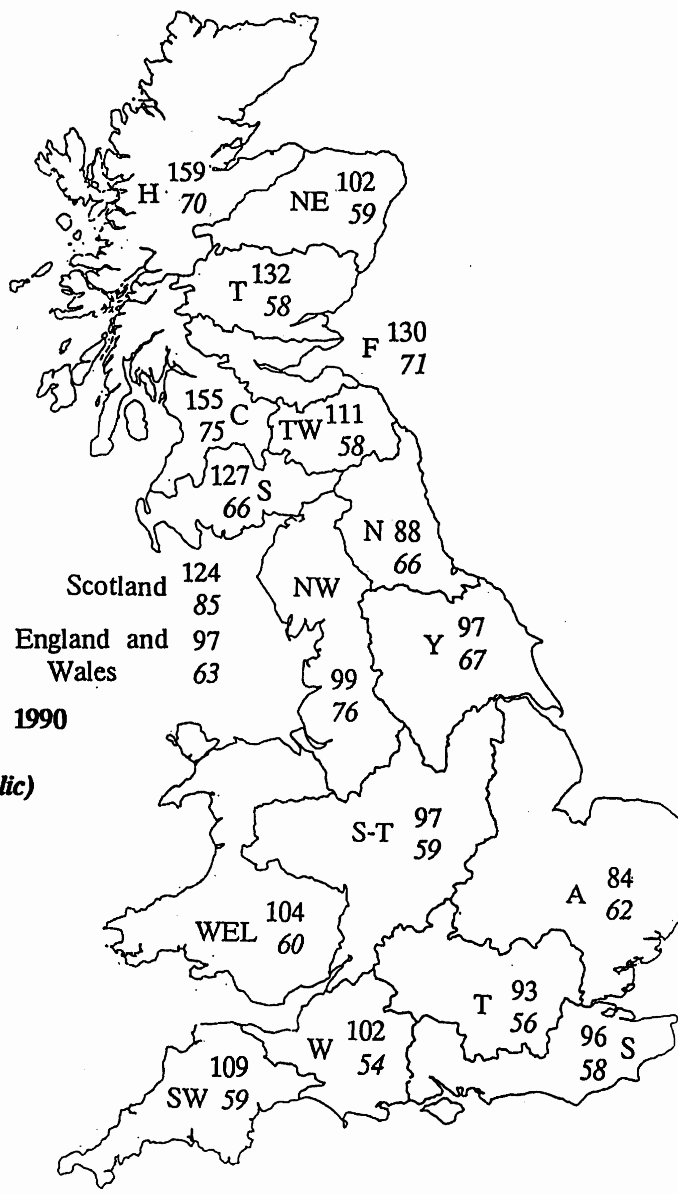


Welsh NRA Region

FIGURE 2 COMPARISON OF RAINFALL ACCUMULATIONS BETWEEN SELECTED PERIODS FROM 1975/76 AND 1989/90



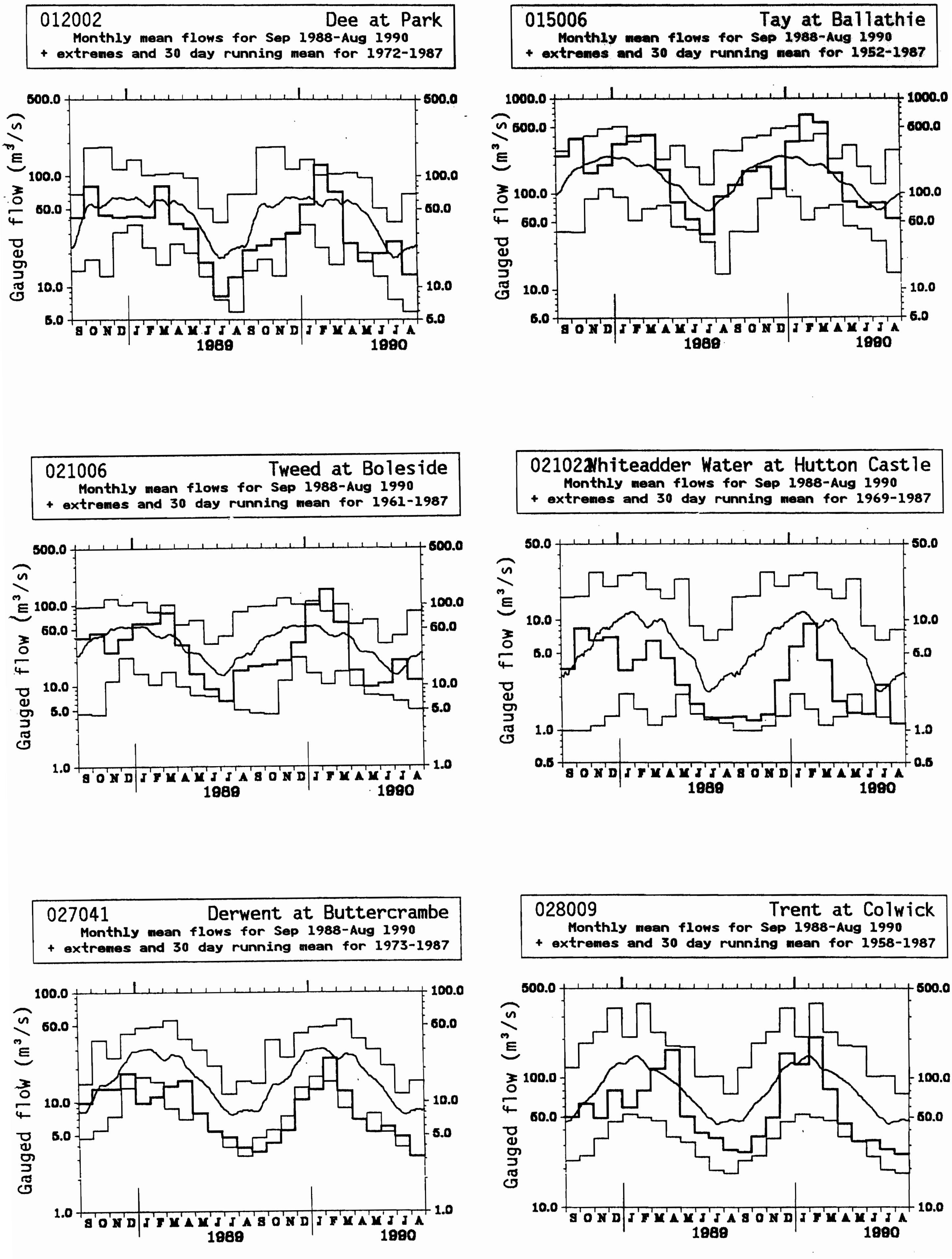
2a Periods March to August 1990 and March to August 1976 ***(italic)***



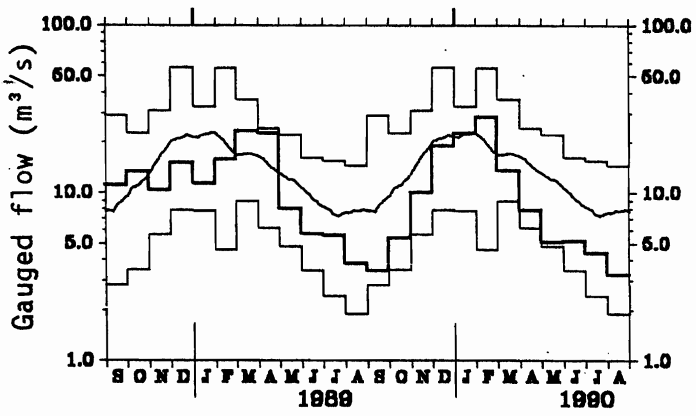
2b Periods September 1989 to August 1990

and September 1975 to August 1976 ***(italic)***

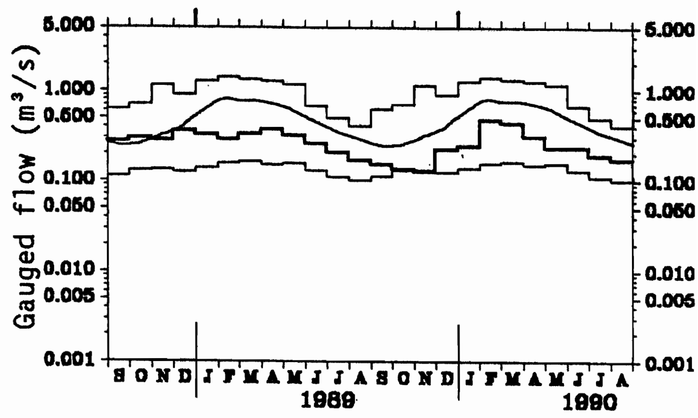
FIGURE 3 MONTHLY RIVER FLOW HYDROGRAPHS



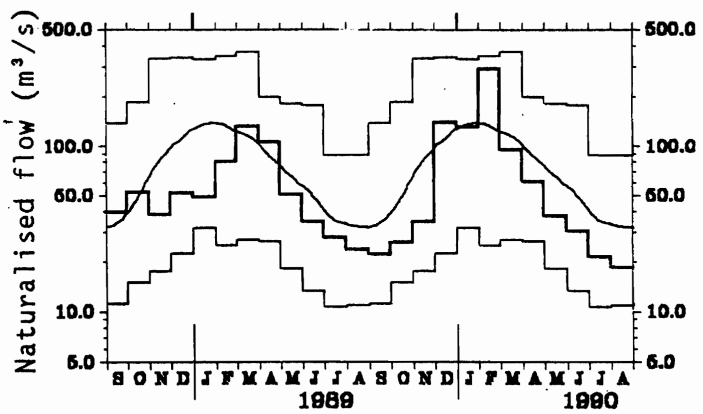
028018 Dove at Marston on Dove
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1961-1987



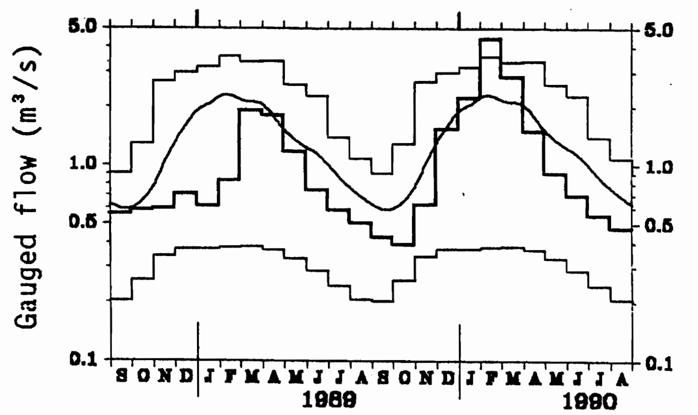
029003 Lud at Louth
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1968-1987



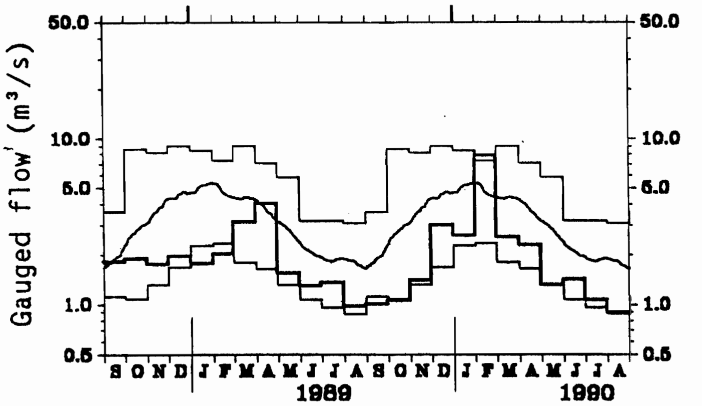
039001 Thames at Kingston
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1883-1987



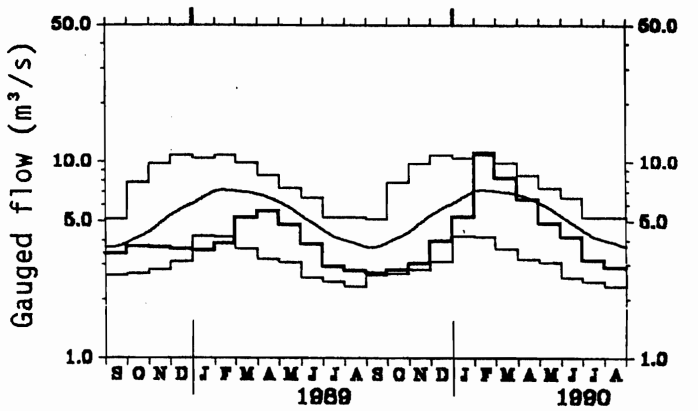
039020 Coln at Bibury
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1963-1987



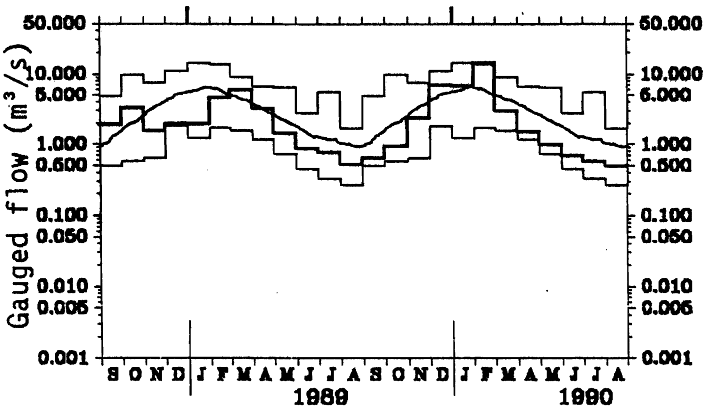
040011 Great Stour at Horton
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1964-1987



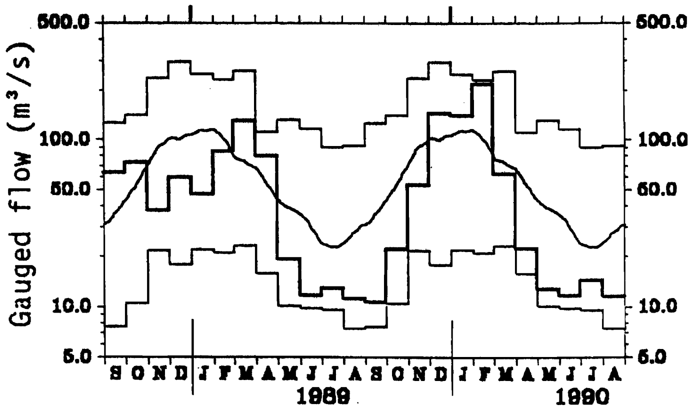
042010 Itchen at Highbridge+Allbrook
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1958-1987



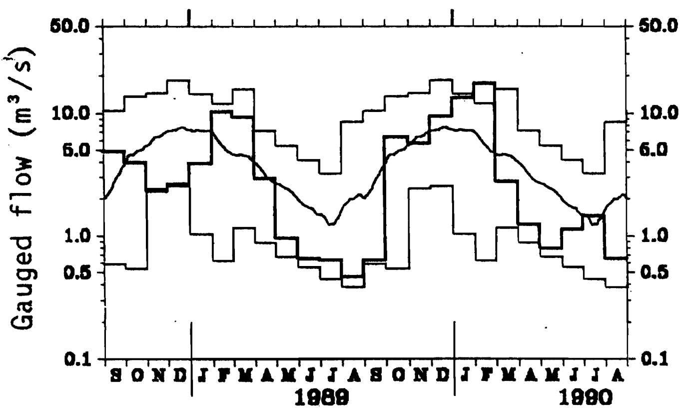
052005 Tone at Bishops Hull
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1961-1987



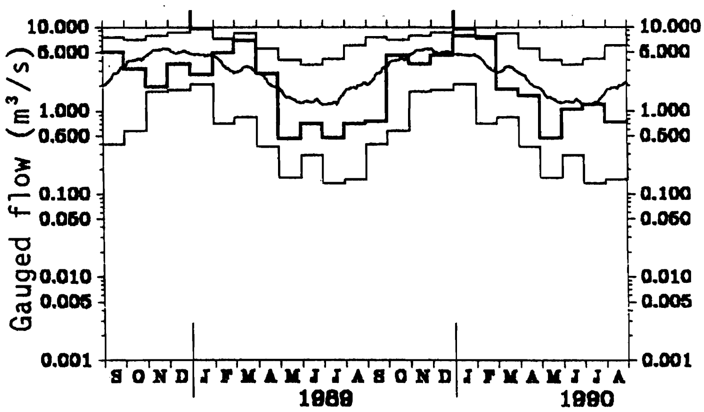
054001 Severn at Bewdley
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1921-1987



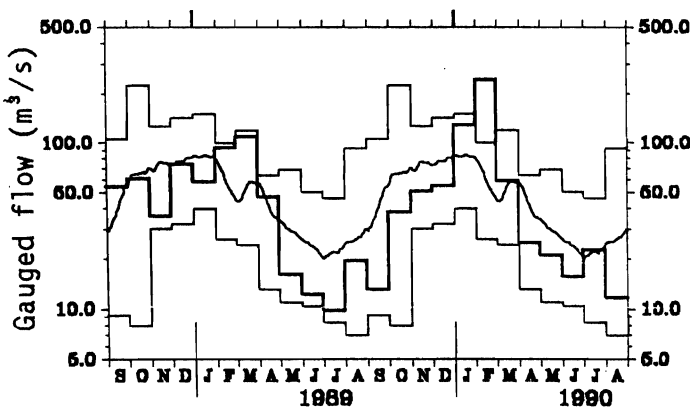
057004 Cynon at Abercynon
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1957-1987



067018 Dee at New Inn
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1969-1987



076007 Eden at Sheepmount
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1967-1987



084013 Clyde at Daldowie
Monthly mean flows for Sep 1988-Aug 1990
+ extremes and 30 day running mean for 1963-1987

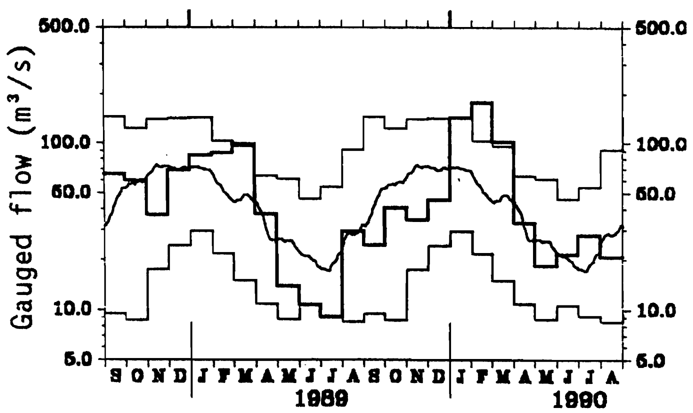


TABLE 3 RUNOFF AS MM. AND AS A PERCENTAGE OF THE PERIOD OF RECORD AVERAGE WITH SELECTED PERIODS RANKED IN THE RECORD

River/ Station name	Apr 1990	May	Jun	Jul	Aug 1990		6/90 to 8/90		3/90 to 8/90		9/89 to 8/90		11/88 to 8/90	
	mm %LT	mm %LT	mm %LT	mm %LT	mm %LT	rank /yrs	mm %LT	rank /yrs	mm %LT	rank /yrs	mm %LT	rank /yrs	mm %LT	rank /yrs
Dee at	34	24	28	37	18	9	83	10	244	5	632	2	1141	2
Park	43	37	75	134	55	/18	85	/18	74	/18	79	/17	78	/17
Tay at	91	47	40	46	31	10	117	15	581	36	1474	36	2579	37
Ballathie	110	67	89	116	60	/38	86	/38	140	/38	131	/37	126	/37
Tweed at	26	17	18	36	20	12	75	13	222	9	798	17	1381	12
Boleside	51	39	64	134	51	/29	80	/29	83	/29	107	/28	101	/28
Whiteadder Water at	20	17	11	34	6	1	27	5	66	2	176	2	379	1
Hutton Castle	36	44	44	127	37	/21	58	/21	42	/21	44	/20	48	/18
Derwent at	11	9	10	8	5	1	23	1	64	1	162	1	331	1
Buttercrambe	33	35	59	60	36	/17	53	/17	44	/17	48	/16	51	/16
Trent at	15	11	11	10	9	2	31	2	87	2	292	6	537	2
Colwick	45	43	57	62	53	/32	59	/32	58	/32	81	/31	79	/31
Dove at	23	15	15	13	10	2	38	4	118	3	377	3	738	3
Marston on Dove	53	42	57	57	43	/29	53	/29	58	/29	76	/27	78	/27
Lud at	15	11	11	9	8	4	28	3	75	4	138	3	275	2
Louth	45	39	53	54	58	/23	56	/22	51	/22	51	/22	54	/21
Bedford Ouse at	10	6	5	4	3	18	12	19	45	16	223	31	405	26
Bedford	49	45	61	67	58	/58	61	/58	53	/58	102	/57	96	/56
Colne at	7	4	4	2	2	3	8	4	29	5	100	5	208	6
Lexden	52	45	73	47	49	/31	58	/31	53	/31	72	/30	78	/30
Mimram at	12	10	8	7	6	5	21	6	57	8	110	10	205	7
Panshanger Park	94	81	73	72	67	/38	71	/38	84	/38	87	/37	87	/36
Thames at	16	10	8	6	5	21	19	20	71	28	237	47	393	29
Kingston (natr.)	71	57	63	63	57	/108	63	/108	70	/108	96	/107	84	/106
Coln at	36	23	17	14	12	2	42	4	173	7	403	9	636	6
Bibury	83	69	63	66	71	/27	66	/27	88	/27	101	/26	84	/26
Mole at	22	14	18	18	12	9	48	10	105	2	444	9	749	1
Kinnersley Manor	63	52	100	141	79	/17	104	/17	65	/16	97	/15	86	/13
Medway at	10	5	4	3	3	3	11	2	36	2	231	8	358	1
Teston	44	34	41	47	42	/34	46	/32	40	/29	82	/27	68	/24
Ouse at	20	10	9	9	8	12	27	11	80	4	335	11	528	3
Gold Bridge	58	40	58	89	72	/31	73	/30	58	/30	85	/29	71	/27
Itchen at	46	36	30	23	21	3	75	4	218	7	423	7	712	2
Highbridge+Allbrook	98	84	86	75	74	/32	80	/32	93	/32	91	/31	81	/31
Stour at	22	15	10	6	5	2	21	2	106	5	432	11	664	4
Throop Mill	63	63	63	53	47	/18	57	/18	72	/18	109	/17	87	/16
Tone at	19	13	9	8	6	2	23	2	93	2	492	15	782	5
Bishops Hull	48	46	50	51	48	/30	50	/30	55	/30	103	/29	86	/28
Brue at	12	8	7	5	5	2	17	2	63	2	391	7	672	2
Lovington	39	34	46	30	32	/26	37	/26	42	/26	89	/25	81	/25
Severn at	13	8	7	9	7	10	23	5	83	5	432	33	729	14
Bewdley	41	33	40	63	40	/70	47	/70	55	/69	96	/69	86	/68
Teme at	16	12	10	9	7	10	26	7	89	4	422	17	624	5
Knightsford Bridge	45	56	70	109	80	/21	83	/21	65	/20	112	/20	87	/19
Cynon at	30	20	28	37	16	7	81	8	200	5	1476	26	2301	14
Abercynon	39	33	69	109	32	/32	65	/32	53	/32	117	/30	100	/30
Lune at	43	28	15	68	12	3	95	7	243	5	1127	13	1979	11
Caton	58	56	37	132	17	/28	60	/28	64	/28	99	/26	96	/24
Eden at	28	24	17	26	14	4	57	7	178	6	761	13	1301	10
Sheepmount	60	73	66	95	45	/20	69	/20	78	/20	111	/18	104	/17
Clyde at	45	26	29	39	29	12	97	16	311	24	935	24	1587	24
Daldowie	109	74	110	146	71	/27	103	/27	127	/27	123	/26	116	/26

Notes (i) Values based on gauged flow data unless flagged (natr.), when naturalised data have been used.
(ii) Values are ranked so that lowest runoff as rank 1;
(iii) %LT means percentage of long term average from the start of the record to 1989. For the long periods (at the right of this table), the end date for the long term is 1990.

TABLE 4 RIVER FLOW RETURN PERIODS

River	Station Name	First Year of Rec.	Mean August Flow	1990 August Flow	Return Period (in years)	Base Flow Index [b]
Whiteadder	Hutton Castle	1969	2.20	1.14	10-25	0.52
Derwent	Buttercrambe (Yorks)	1973	8.23	3.14	25-50	0.68
Wharfe	Flint Mill Weir	1937	11.62	3.09	10	0.39
Trent	Colwick	1959	47.0	25.7	10-25	0.64
Dove	Marston on Dove	1961	7.73	3.26	10	0.60
Lud	Louth	1968	0.286	0.170	10	0.90
Welland	Ashley	1970	0.530	0.110	25-50	0.41
Colne	Lexden (Essex)	1959	0.348	0.174	10	0.53
Mimram	Panshanger Park	1952	0.449	0.292	10	0.94
Kennet	Theale	1961	5.733	3.78	10-25	0.87
Coln	Bibury	1963	0.676	0.471	10-25	0.94
Great Stour	Horton	1964	1.77	0.891	10	0.69
Itchen	Highbridge	1958	3.82	2.89	10-25	0.97
Stour	Throop Mill	1973	4.24	1.90	25	0.66
Piddle	Baggs Mill	1963	1.08	0.637	25	0.89
Tone	Bishops Hull	1961	0.948	0.489	25	0.58
Brue	Lovington	1964	0.782	0.233	25	0.47

Note (i) The stations featured are drawn from those areas where the hydrological drought is currently most severe

Note (ii) The precision of low flow measurement may be affected by gauge sensitivity and, further, by uncertainties in summer stage discharge relations which are generally addressed retrospectively. The pattern of water utilisation in certain catchments, particularly regulation and/or augmentation at low flows, plus the the influence of abstractions and the discharge of sewage effluent, means some return periods need to be treated with especial care.

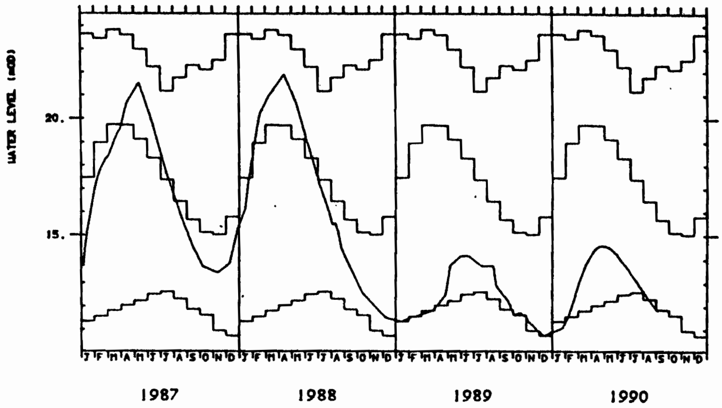
b The base flow index is an indicator of what proportion of the the hydrograph is represented by base flow following a hydrograph separation exercise on the whole record. The lower the index, the lower the base flow contribution and the more responsive the catchment is to rainfall.
See: Low Flow Studies, 1980 NERC

FIGURE 4 GROUNDWATER HYDROGRAPHS

Site name: DALTON HOLME

National grid reference: SE 9651 4530 — Well number: SE94/5

Aquifer: CHALK AND UPPER GREENSAND — Measuring level: 33.50



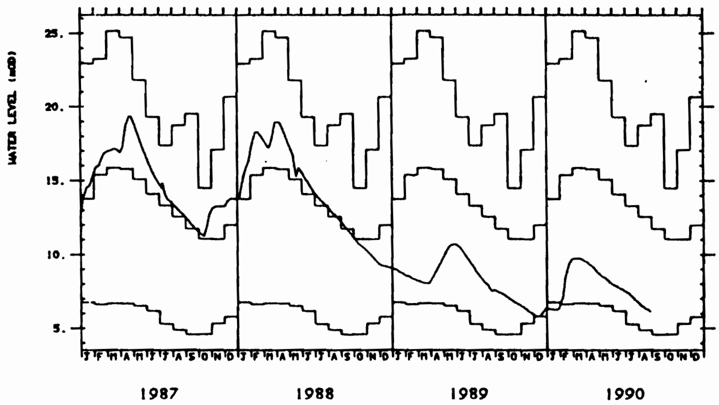
Max, Min and Mean values calculated from years 1889 TO 1989

A break in the data line indicates a recording interval of greater than 8 weeks

Site name: LITTLE BROCKLESBY

National grid reference: TA 1371 0888 — Well number: TA10/40

Aquifer: CHALK AND UPPER GREENSAND — Measuring level: 44.33

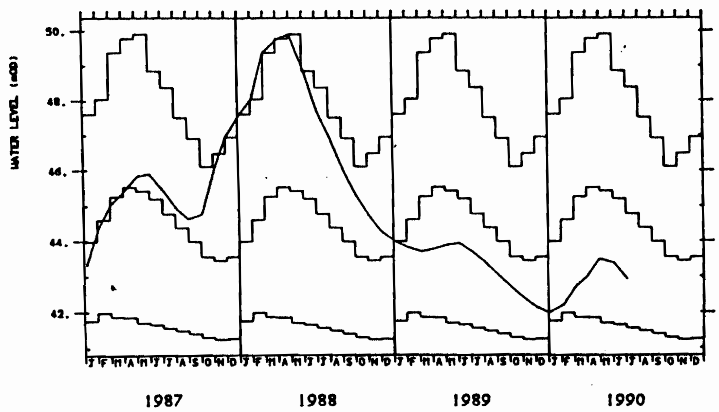


Max, Min and Mean values calculated from years 1926 TO 1989

Site name: WASHPIT FARM

National grid reference: TF 8138 1960 — Well number: TF81/2

Aquifer: CHALK AND UPPER GREENSAND — Measuring level: 80.20

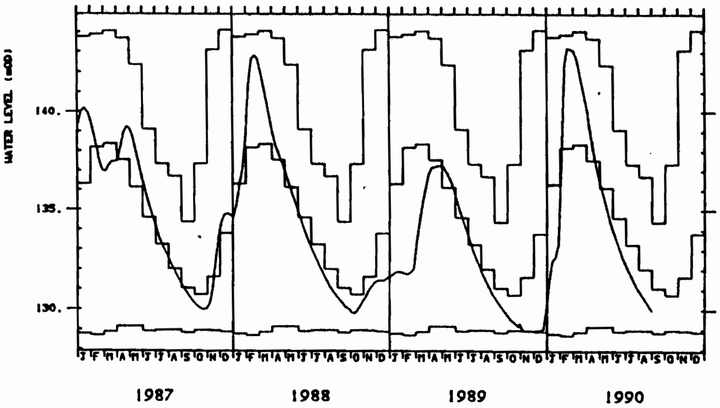


Max, Min and Mean values calculated from years 1950 TO 1989

Site name: ROCKLEY

National grid reference: SU 1655 7174 Well number: SU17/57

Aquifer: CHALK AND UPPER GREENSAND Measuring level: 146.39

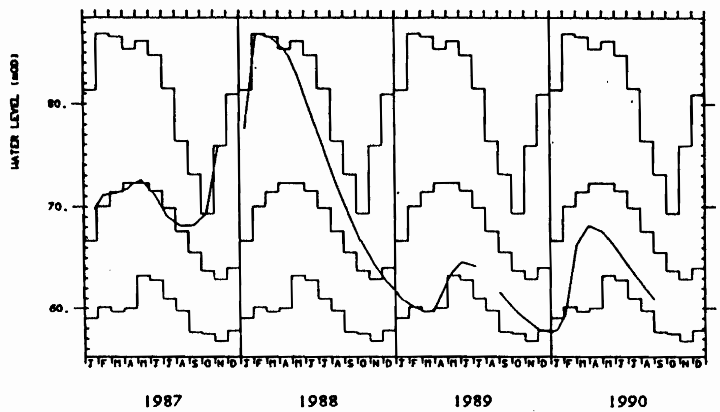


Max, Min and Mean values calculated from years 1933 TO 1989

Site name: LITTLE BUCKET FARM,WALTHAM

National grid reference: TR 1225 4690 Well number: TR14/9

Aquifer: CHALK AND UPPER GREENSAND Measuring level: 87.33



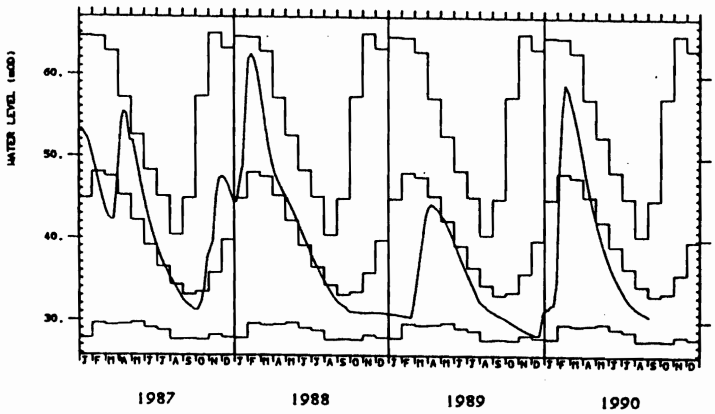
Max, Min and Mean values calculated from years 1971 TO 1989

A break in the data line indicates a recording interval of greater than 8 weeks

Site name: COMPTON HOUSE

National grid reference: SU 7755 1490 Well number: SU71/23

Aquifer: CHALK AND UPPER GREENSAND Measuring level: 81.37

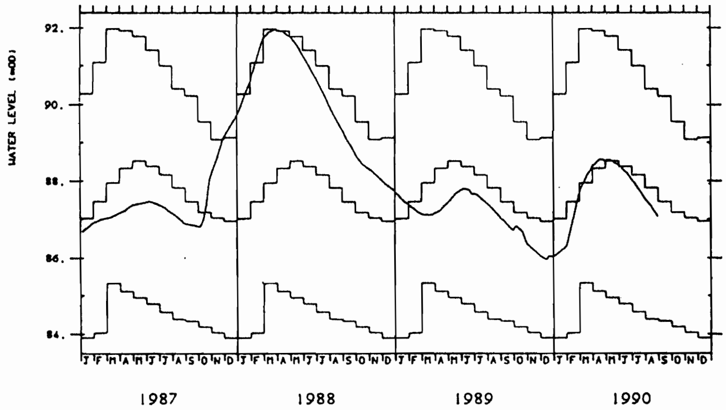


Max, Min and Mean values calculated from years 1894 TO 1989

Site name: THE HOLT

National grid reference: TL 1692 1965 — Well number: TL11/9

Aquifer: CHALK AND UPPER GREENSAND — Measuring level: 140.21

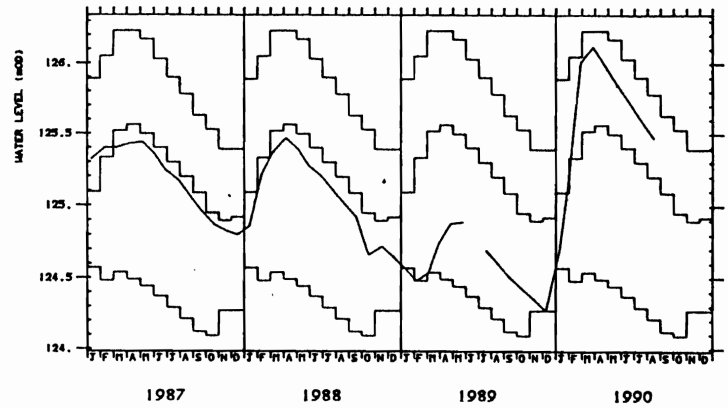


Max, Min and Mean values calculated from years 1964 TO 1989

Site name: LIME KILN WAY

National grid reference: ST 3763 0667 — Well number: ST30/7

Aquifer: CHALK AND UPPER GREENSAND — Measuring level: 130.19

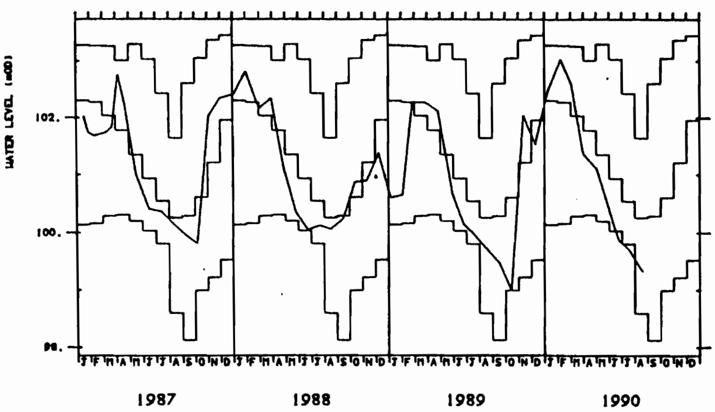


Max, Min and Mean values calculated from years 1969 TO 1989

Site name: AMPNEY CRUCIS

National grid reference: SP 0595 0190 — Well number: SP00/62

Aquifer: MIDDLE JURASSIC — Measuring level: 109.70



Max, Min and Mean values calculated from years 1958 TO 1989

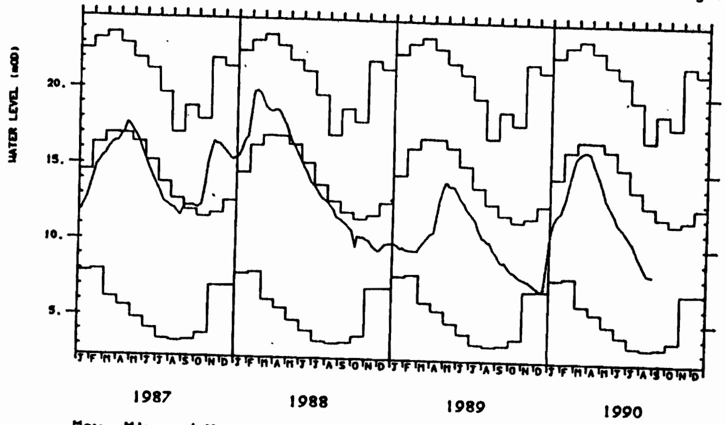
Site name: NEW RED LION

National grid reference: TF 0885 3034

Well number: TF03/37

Aquifer: LINCOLNSHIRE LIMESTONE

Measuring level: 33.82



Max, Min and Mean values calculated from years 1964 TO 1989

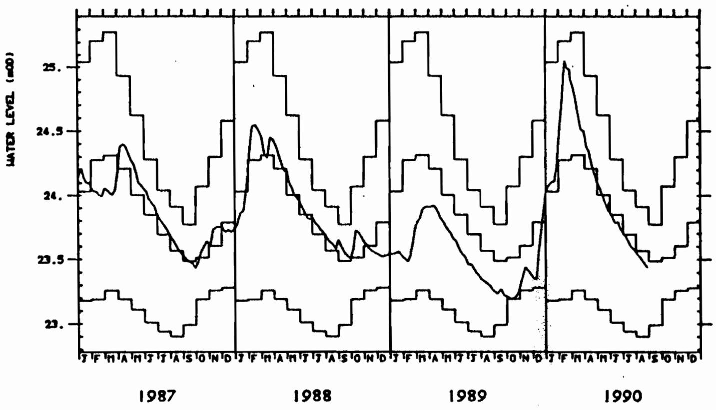
Site name: BUSSELS NO.7A

National grid reference: SX 9528 9872

Well number: SX99/37B

Aquifer: PERMO-TRIASSIC SANDSTONE

Measuring level: 26.07



Max, Min and Mean values calculated from years 1972 TO 1989

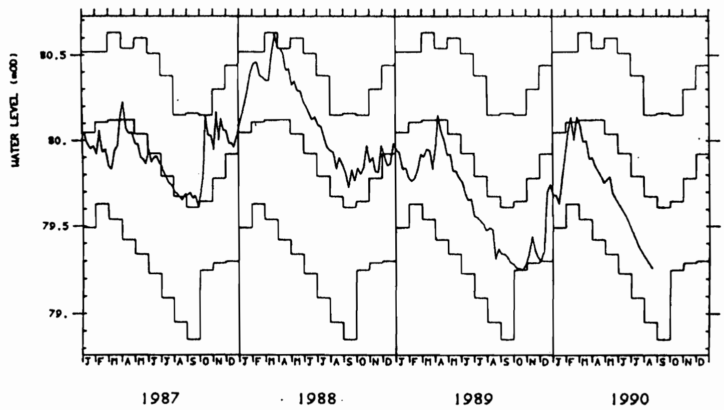
Site name: LLANFAIR DC

National grid reference: SJ 1374 5556

Well number: SJ15/15

Aquifer: PERMO-TRIASSIC SANDSTONE

Measuring level: 82.00



Max, Min and Mean values calculated from years 1972 TO 1989

TABLE 5 A COMPARISON OF JUNE GROUNDWATER LEVELS: 1990 AND 1976

Borehole	Aquifer	First year of record	Av. Aug. level	Aug 1976		Aug 1990		No. of years of record with Aug. levels <1990
				Day	level	Day	level	
Dalton Holme	C & U.G.	1889	16.46	28	12.32	28	12.00	none
L. Brocklesby	"	1926	12.55	27	4.87	29	6.13	1
Washpit Farm	"	1950	44.38	1	41.70	1	42.56	4
Rockley	"	1933	132.02	29	128.97	1	130.98	18
Compton House	"	1894	33.11	23	27.65	28	30.81	4
L. Bucket Farm	"	1971	67.58	9	69.75	15	61.92	1
Limekiln Way	"	1969	125.20	15	27.65	17	125.47	4
Therfield Rectory	"	1883	80.75	3	74.22	2	81.01	43
New Red Lion	L.L.	1964	12.77	24	3.29	28	8.25	1
Llanfawr D. C.	PTS	1972	79.67	1	78.95	21	79.26	1
Bussels 7A	"	1972	23.57	31	22.90	29	23.44	5
Ampney Crucis	M.J.	1958	100.26	29	98.59	20	99.52	1

C & U.G. Chalk and Upper Greensand;
L.L Lincolnshire Limestone
PTS Permo-Triassic Sandstones
M.J. Middle Jurassic Limestone

FIGURE 5 LOCATION MAP OF GAUGING STATIONS AND GROUNDWATER INDEX WELLS