

ASSESSMENT AND FORECASTING OF DROUGHT FLOW CONDITIONS IN IRISH RIVERS

MICHEAL MAC CARTHAIGH BE C.ENG MIEI
SENIOR RESEARCH OFFICER
WATER RESOURCES SECTION
ENVIRONMENTAL RESEARCH UNIT

PAPER TO BE PRESENTED TO THE WATER AND ENVIRONMENTAL
ENGINEERING SECTION OF THE INSTITUTION OF ENGINEERS OF IRELAND ON
MONDAY 16 NOVEMBER 1992 AT 8.00 PM.

SUMMARY

THE MOST SEVERE DROUGHT FLOWS RECORDED OCCURRED IN 1975 AND 1976. THE CLIMATIC CONDITIONS THAT CAUSED THOSE DROUGHTS ARE EXAMINED. THE DROUGHT FLOWS OF 1989, 1990 AND 1991 ARE COMPARED WITH 1975 AND 1976 AND THE CLIMATIC CONDITIONS ARE ALSO COMPARED.

BASED ON THESE COMPARISONS IT WOULD BE POSSIBLE TO ESTIMATE THE SEVERITY OF LOW FLOW CONDITIONS WHICH WOULD RESULT FROM LONG PERIODS OF INSIGNIFICANT RAINFALL IN THE SUMMER MONTHS.



Assessment and Forecasting of drought flow conditions in Irish Rivers

Introduction

This paper is based on research carried out by the author on the low river flows measured in the period 1989-1991 and a report on this work is expected to be published by the Environmental Research Unit in December 1992.

The report was prepared with four objectives:

1. To examine the rainfall and river flows that occurred in the years 1989-1991;
2. To compare the rainfall and low flows in 1989-1991 with rainfall and low flows in previous years;
3. To see if the experiences in these droughts could be used to predict the relative severity of droughts.
4. To evaluate the implications of the low flows which occurred in the years 1989-1991 for water supply sources and the concern that was expressed that water supplies would be affected if these trends continued.

The paper deals with river catchments i.e. catchments that have negligible lake storage and are not regulated. It does not seek to deal with the particular problem of reservoir storage.

Methodology

An examination was undertaken of the rainfall at a selection of stations in the period April-October in the years 1975, 1976, 1989-1991. The low flow in the same years was also identified. The absolute drought periods, partial droughts and dry spells were identified. Examining both sets of data, the effect of small amounts of rainfall at the end of the drought in each year was identified in order to identify when the river flow started to rise. Rainfall data for 1934, 1935, 1949, 1955 and 1959 was also examined and compared to the limited runoff data for these years.

River Flows

River flow is comprised of a) surface runoff from rainfall and b) baseflow from groundwater storage. During a period of drought, when flows decrease, the proportion of flow arising from surface runoff decreases. In the absence of rainfall, the magnitude of the baseflow component also continues to decrease with time, but at a diminishing rate. At the end of a long period of drought, the river flow may be attributed totally to baseflow with no effective contribution from surface runoff.

Drought Flows

Drought river flows occur when a prolonged dry spell coincides with a time of year when groundwater levels are at their lowest due to reduced inflow to groundwater storage from rainfall while at the same time there is a reduced outflow from groundwater storage to support baseflow and any uptake of moisture by evapotranspiration.

In small catchments with relatively little groundwater reserves a lack of rainfall, even for very short periods, can cause very low flows. In large catchments short periods with little or no rainfall will reduce the surface runoff component of river flow but may have only a negligible effect on baseflow, depending on the time of year when the lack of rainfall occurs.

The main determinants of the low flow at a particular location on natural streams (without lakes or impoundments) are:

- 1) Lack of rainfall;
- 2) the catchment area contributing to the flow at the location;
- 3) the variability in the geology and surface cover which can vary both within catchments as well as from catchment to catchment.

Severity of Drought

The severity of a drought on river flows depends on a number of factors:

- . the distribution, duration and time of year when the lack of rainfall occurs;
- . the size, topography, surface cover and geology of catchments;
- . antecedent groundwater conditions prior to the drought;
- . antecedent river flow conditions prior to the drought;
- . any lag in the response time to rainfall events;
- . soil moisture deficit.

Water Balance Studies

In 1981 the author was involved in water balance studies (1) of river flows in the period December 1975 - November 1977 at hydrometric stations in the Glyde, Dee, Finn and Blackwater (Monaghan) Rivers. This study showed that in this area groundwater inflow occurred in the months October - March and that there was no infiltration in the months April - September. Hence if groundwater levels are at their lowest in Autumn each year, groundwater outflow will be at its minimum. Consequently a

drought that continues into Autumn will be more severe than one ending in earlier months of the year.

Definition of a Drought

There is no standard definition of a drought in regard to river flows. In the preparation of water quality management plans use has been made of the dry weather flow which has been defined as a flow which has a 50 year return period and the 95 percentile flow, the flowrate which is equalled or exceeded 95 percent of the time.

Meteorological Classification of Droughts

The following definitions of a drought have been used by the World Meteorological Organisation(WMO):

(1) Prolonged absence or poor distribution of precipitation;

and

(2) Period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance.

The following definitions have been used by the Meteorological Service to describe absolute droughts, partial droughts and dry spells:

Absolute drought: Period of 15 or more consecutive days, on none of which 0.2 mm or more of rain fell.

Partial drought: Period of at least 29 consecutive days, the mean daily rainfall of which does not exceed 0.2 mm.

Dry spell: period of 15 or more consecutive days, on none of which 1.0 mm or more of rain fell.

In practical terms the Meteorological Service definition is more useful and quantifiable for the conditions pertaining in Ireland than the WMO definition and is used in this paper.

The difficulty which arises for a hydrologists in the use of the Meteorological Service classifications of a drought is that it does not have regard to river flows or the effect of evapotranspiration.

From a meteorological perspective the order of absolute drought/partial drought/dry spell may be in the order of increasing severity. However, from a river flow point of view, the reverse order may be more significant. Small amounts of rainfall in a drought period may be lost in evapotranspiration or satisfying a soil moisture deficit rather than causing runoff.

A small amount of rainfall, falling at the end of a drought, may break the formal definition of an absolute drought/partial drought/dry spell but may not be sufficient to cause surface runoff or may cause such a small amount of surface runoff that the river levels will return very quickly to the pattern which pertained prior to the rainfall.

For this reason we have developed a term called "periods of insignificant rainfall", which will have regard to the runoff effects of small rainfall amounts in drought periods.

The application of this definition is subjective. A definition would be:

1. Any period of consecutive days commencing with a period of no rainfall;
2. The rainfall falling towards the end of the drought, when averaged over the full period of the drought, is about an average of 0.3 mm per day;
3. Individual rainfall amounts, of up to 6 mm, or other small amounts over a number of days, have been disregarded for the purpose of identifying these periods of insignificant rainfall;
4. Use in conjunction with the hydrographs of daily mean flows in identifying the response of individual catchments to particular rainfall amounts in drought periods.

Rainfall Stations:

Data have been received from the Meteorological Service for the following Rainfall Stations used in this report:

Clones, Mullingar, Dublin Airport, Casement Aerodrome, Kilkenny, Moorepark(Fermoy), Killarney(BVM Park), Shannon Airport, Birr, Claremorris, Glencolmcille and Malin Head. The rainfall stations at Moorepark(Fermoy), Killarney(BVM Park) and Glencolmcille are not Synoptic Stations. The locations of these selected rainfall stations are shown in Figure 1.

Rainfall data for both Glencolmcille and Killarney(BVM Park) was not available for 1975 and data for Glenties Hatchery and Muckross House was used as alternative for these stations for this year.

In the case of the rainfall for 1934 and 1935 data for Phoenix Park, Markree Castle (County Sligo), Birr Castle and Valentia were used.

The stations used were selected in order to give a good geographic spread over the whole country.

KEY

● LOCATION OF RAINFALL STATIONS

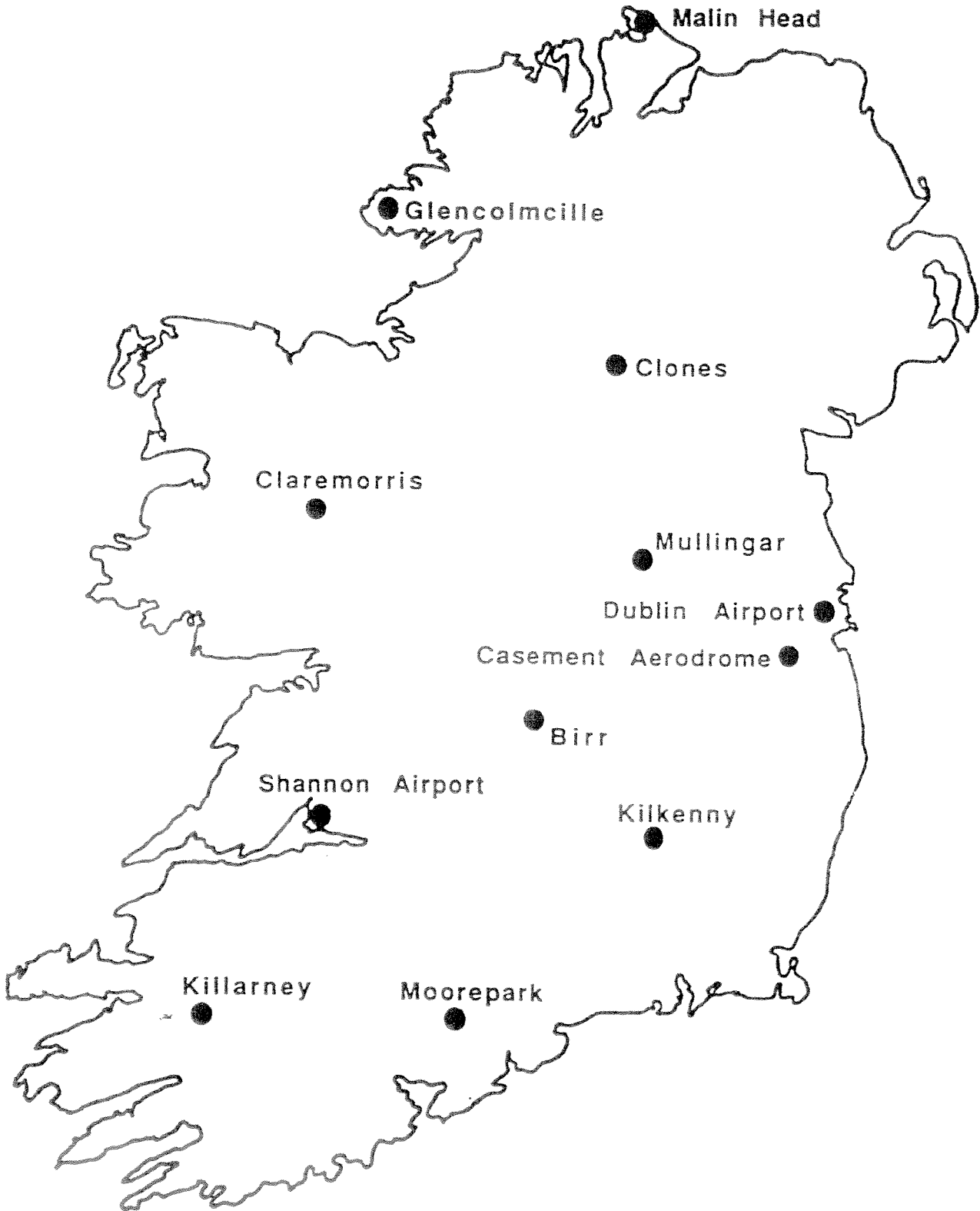


Fig. 1 SELECTED RAINFALL STATIONS

TABLE 1

Periods of absolute drought, partial drought, dry spells and periods of insignificant rainfall in the period May-October (inclusive) in 1975, 1976, 1989, 1990 and 1991 at Clones, Mullingar, Dublin Airport, Casement Aerodrome, Kilkenny, Moorepark, Killarney, Shannon Airport, Birr, Claremorris, Glencolmcille, Malin Head Rainfall Stations

Rainfall Station year	Period of Absolute Drought	Period of Partial Drought	Dry Spell	Period of Insignificant Rainfall(days)
Clones				
1975	15 May-29 May	none	15 May-29 May	
1975		none	20 Jun- 7 Jul	14May- 9Jul(57)
1976	13 Aug-28 Aug	none	13 Aug- 7 Sep	16Jul- 9Sep(56)
1989	none	none	none	2Jul-24Jul(23)
1990	none	none	none	10Jul-28Jul(19)
1991	19 May-4 Jun,	9 May-7 Jun	none	30Apr- 7Jun(39)
1991	27 Aug-12 Sep			10Aug-13Sep(35)
Mullingar				
1975	13 May-31 May	none	13 May-31 May	
1975		none	20 Jun- 8 Jul	11May- 9Jul(59)
1976	13 Aug-30 Aug	21 Jul-7 Sep	13 Aug- 7 Sep	16Jul- 9Sep(56)
1989	none	none	2 Jul-24 Jul	2Jul-24Jul(23)
1990	none	none	none	7Jul-13Aug(38)
1990	none	none	none	1Sep-17Sep(17)
1991	none	30 Apr- 4 Jun	4 May- 4 Jun	30Apr- 7Jun(39)
1991	28 Aug-11 Sep	none	none	28Aug-14Sep(18)
Dublin Airport				
1975	15May- 1 Jun	15 May-15 Jun	14 May- 1 Jun	
1975			17 Jun- 8 Jul	11May- 8Jul(59)
1975				22Aug- 7Sep(17)
1976	13Aug-28 Aug	21 Jul-28 Aug	21 Jul-11 Aug	
1976			13 Aug-28 Aug	16Jul- 9Sep(56)
1989	none	none	none	1Jul- 4Aug(35)
1990	none	16 Jul-13 Aug		7Jul-13Aug(38)
1990			30 Aug-15 Sep	30Aug-15Sep(17)
1991	10 May- 1Jun	30 Apr- 4 Jun	none	30Apr- 4Jun(36)
1991	28 Aug-13Sep			24Aug-14Sep(22)

Table 1 Continued

Rainfall Station year	Period of Absolute Drought	Period of Partial Drought	Dry Spell	Period of Insignificant Rainfall(days)
Casement Aerodrome				
1975 1975	15 May-31 May	13 May-8 Jul	13May-14 Jun, 17Jun- 8 Jul	11May- 8Jul(59)
1976 1976	13 Aug-28 Aug	16 Jul-9 Sep	16Jul- 6 Aug, 8Aug-28 Aug	16Jul- 9Sep(56)
1989	none	none	none	1Jul- 4Aug(35)
1990 1990	none	7Jul-11 Aug	16Jul-11 Aug	7Jul-11Aug(36) 30Aug-15Sep(16)
1991 1991	none	30Apr- 1 Jun	10May- 4 Jun, 24Aug-13 Sep	30Apr- 4Jun(36) 24Aug-13Sep(21)
Kilkenny				
1975 1975 1975	15May-29 May, 20Jun- 6 Jul	13 May-14 Jun	13May-29 May, 17Jun- 8 Jul	13May- 8Jul(57) 26Aug- 5Sep(11)
1976 1976 1976	13Aug-7 Sep	16 Jul- 9 Sep	16Jul-11 Aug 13Aug- 7 Sep 13Aug- 7 Sep	16Jul- 9Sep(56) 11Sep-18Sep(8)
1989	none	1 Jul-30 Jul	1Jul-30 Jul	1Jul- 4Aug(35)
1990 1990	none none	none none	none none	7Jul-26Jul(20) 30Aug-15Sep(17)
1991 1991 1991	10May- 2 Jun 24Aug-11 Sep	30 Apr- 4 Jun	7May- 4 Jun, 6Aug-21 Aug, 24Aug-13 Sep	30Apr- 4Jun(36) 7Aug-14Sep(38)
Moorepark				
1975 1975 1975	15May-29 May, 18Jun- 6 Jul	15 May-14 Jun	15May- 3 Jun 18Jun- 6 Jul	15May- 6Jul(53) 23Aug- 3Sep(13)
1976	none	19 Jul-21 Aug	19Jul-10 Aug	15Jul-18Sep(66)
1989	1Jul-19 Jul	none	1Jul-20 Jul	1Jul- 7Aug(38)
1990 1990	none none	none none	none none	30Jul-11Aug(13) 1Sep-20Sep(20)
1991 1991 1991	10May- 3 Jun 25Aug- 9 Sep	none	6Aug-21 Aug 24Aug-11 Sep	1May- 3Jun(34) 24Aug-13Sep(21)

Table 1 continued

Rainfall Station year	Period of Absolute Drought	Period of Partial Drought	Dry Spell	Period of Insignificant Rainfall(days)
Killarney				
1975	15May-29 May		15May-29 May	15May- 5Jun(22)
1975	19Jun- 6 Jul		19Jun- 6 Jul	19Jun- 6Jul(18)
1976	none	none	24Aug- 7-Sep	21Jul- 9Sep(51)
1989	none	none	1Jul-19 Jul	30Jun-27Jul(28)
1990	9Jul-25 Jul	none	9Jul-25 Jul	7Jul-25Jul(19)
1991		30 Apr- 3 Jun	9May- 3 Jun	30Apr- 3Jun(35)
1991	24Aug- 8 Sep		23Aug- 9 Sep	23Aug-12Sep(21)
Shannon Airport				
1975	15May-29 May,	none	14May-29 may	
1975	19Jun- 4 Jul		17Jun- 4 Jul	14May- 6Jul(54)
1975			22Aug- 5 Sep	22Aug- 7Sep(17)
1976	none	none	24Aug- 7 Sep	16Jul- 9Sep(56)
1989	none	none	19May- 7 Jun	19May- 7Jun(20)
1989	none			1Jul-24Jul(24)
1990			1Jul-24 Jul	8Jul-26Jul(19)
1990	none	none	none	1Sep-17Sep(17)
1991	19May- 2 Jun	none		30Apr- 4Jun(36)
1991	26Aug-11 Sep		24Aug-13 Sep	24Aug-14Sep(22)
Birr				
1975	14May-29 May,	13 May- 8 Jul	13May- 3 Jun	
1975	22Jun- 8 Jul		17Jun- 8 Jul	10May- 9Jul(61)
1975				26Aug- 5Sep(11)
1976	13Aug-28 Aug	21 Jul-28 Aug	13Aug-28 Aug	16Jul- 9Sep(56)
1989	none	none	1Jul-20 Jul	1Jul- 4Aug(35)
1990	none	none	none	7Jul-26Jul(20)
1991		1May- 2 Jun	14May- 4 Jun	30Apr- 4Jun(36)
1991	22Aug-11 Sep			11Aug-14Sep(35)

Table 1 continued

Rainfall Station year	Period of Absolute Drought	Period of Partial Drought	Dry Spell	Period of Insignificant Rainfall (days)
Claremorris				
1975	14May-31 May,	none	14May- 3 Jun	
1975	20Jun- 7 Jul		20Jun- 7 Jul	13May- 8Jul(67)
1976	13Aug-29 Aug	16 Jul- 7 Sep	19Jul- 2 Aug,	16Jul- 9Sep(56)
1976			8Aug- 7 Sep	
1989	none	none	1Jul-20 Jul	1Jul-27Jul(27)
1990	none	none	none	7Jul-26Jul(20)
1991	none	none	none	30Apr- 7Jun(39)
1991	24Aug-11 Sep	none	none	10Aug-12Sep(34)
Glencol'clle				
1975	14May-30 May	none	14May-30 May	14May- 3Jun(21)
1975	none	none	19Jun- 7 Jul	20Jun- 9Jul(20)
1976	12Aug-29 Aug	none	12Aug-29 Aug	12Aug- 7Sep(27)
1989	none	none	none	1Jul-27Jul(27)
1990	none	none	none	16Jul-27Jul(12)
1991	none	none	19May- 2 Jun	13May- 2Jun(21)
1991	28Aug-12 Sep	none	none	19Aug-12Sep(25)
Malin Head				
1975	none	none	14May-31 May	1May- 3Jun(34)
1975				20Jun-12Jul(23)
1976		none	15Apr-30 Apr	15Apr-30Apr(16)
1976	13Aug-29 Aug		13Aug- 7 Sep	13Aug- 9Sep(28)
1989	none	none	none	6Jun-24Jun(19)
1990	none	none	none	10Jul- 2Aug(24)
1991	none	none	19May- 7 Jun	30Apr- 7Jun(39)
1991	28Aug-12 Sep	none	none	19Aug-12Sep(25)

1975

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

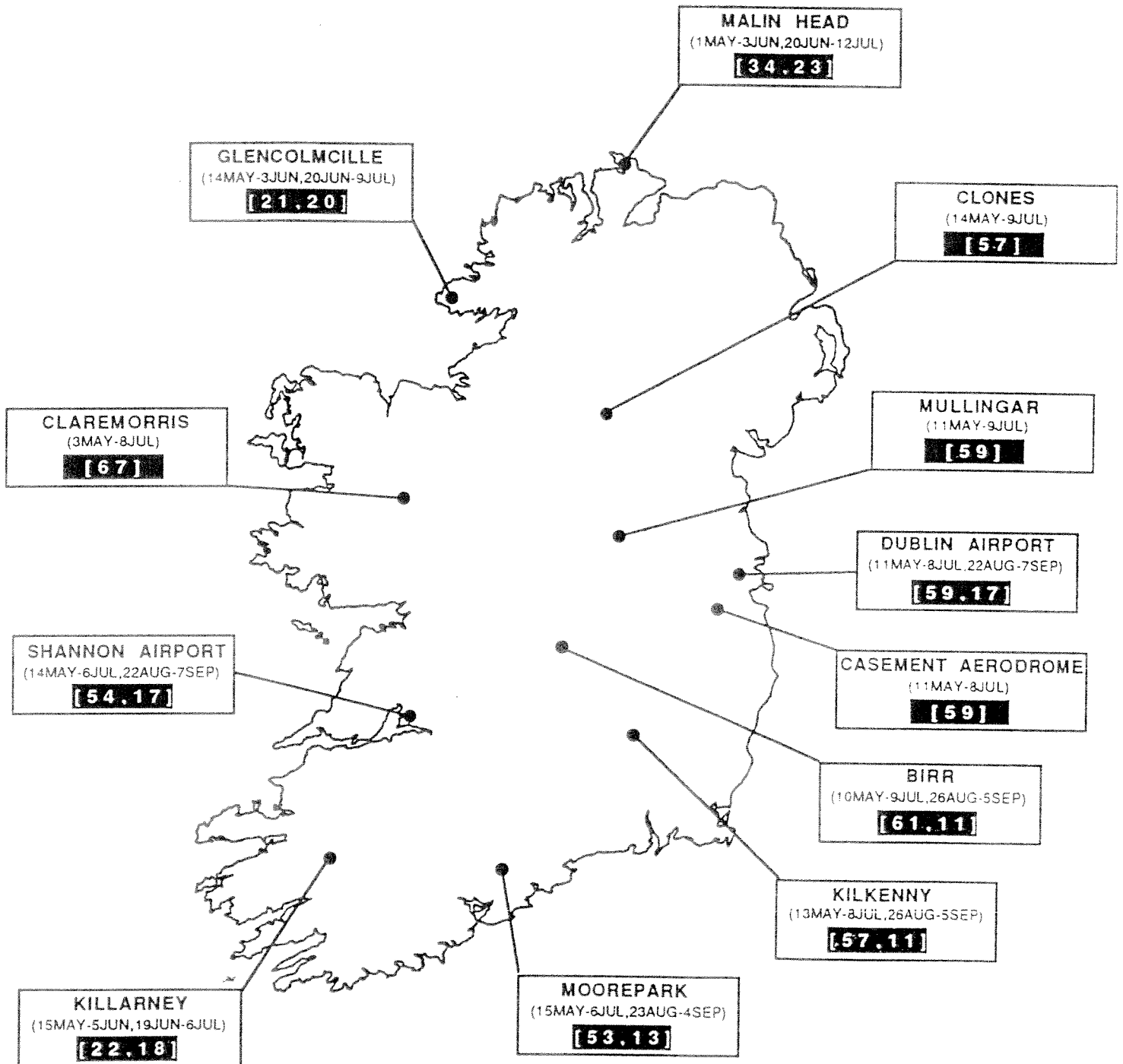


Fig. 2 PERIODS OF INSIGNIFICANT RAINFALL

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

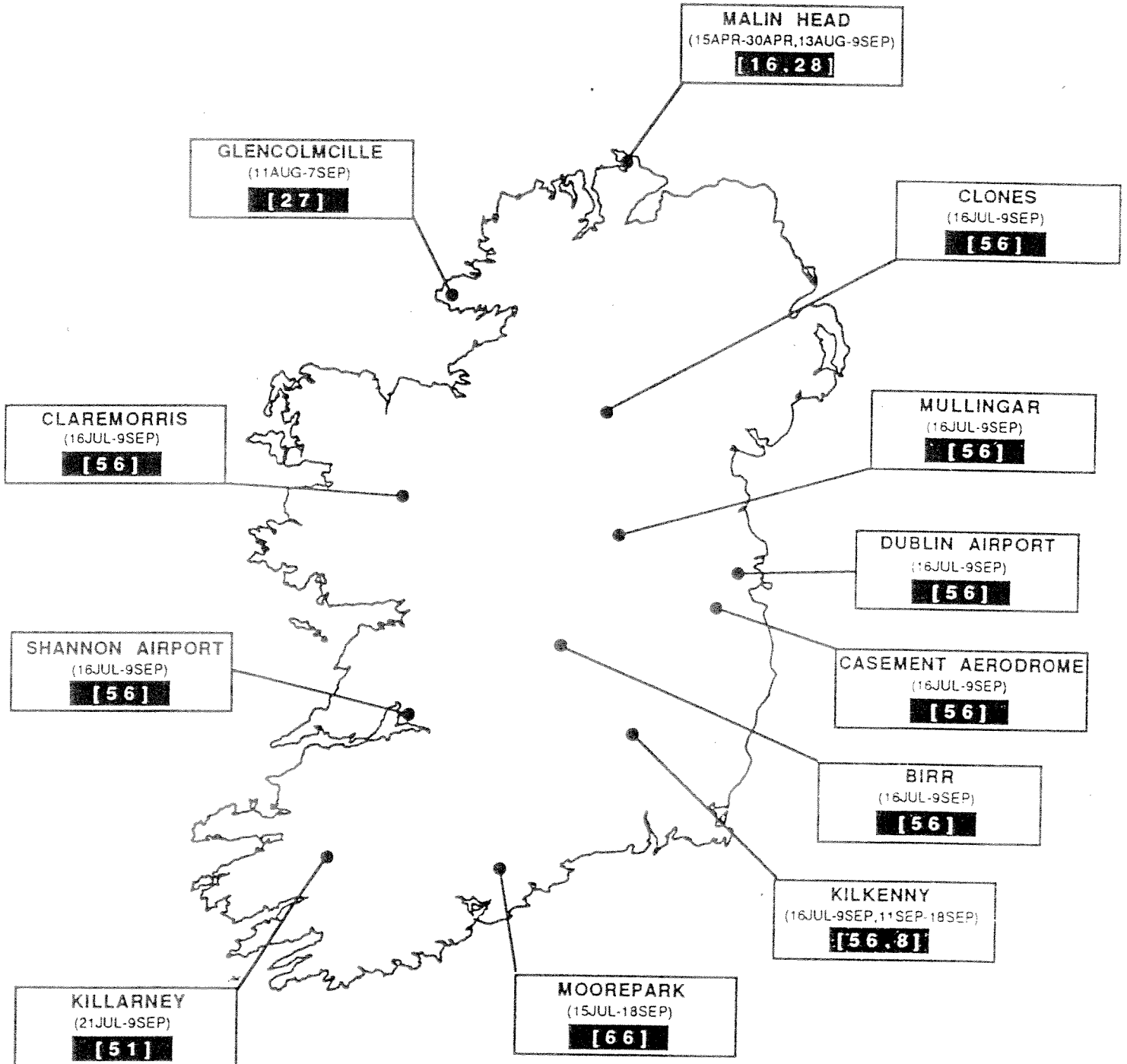


Fig. 3 PERIODS OF INSIGNIFICANT RAINFALL

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

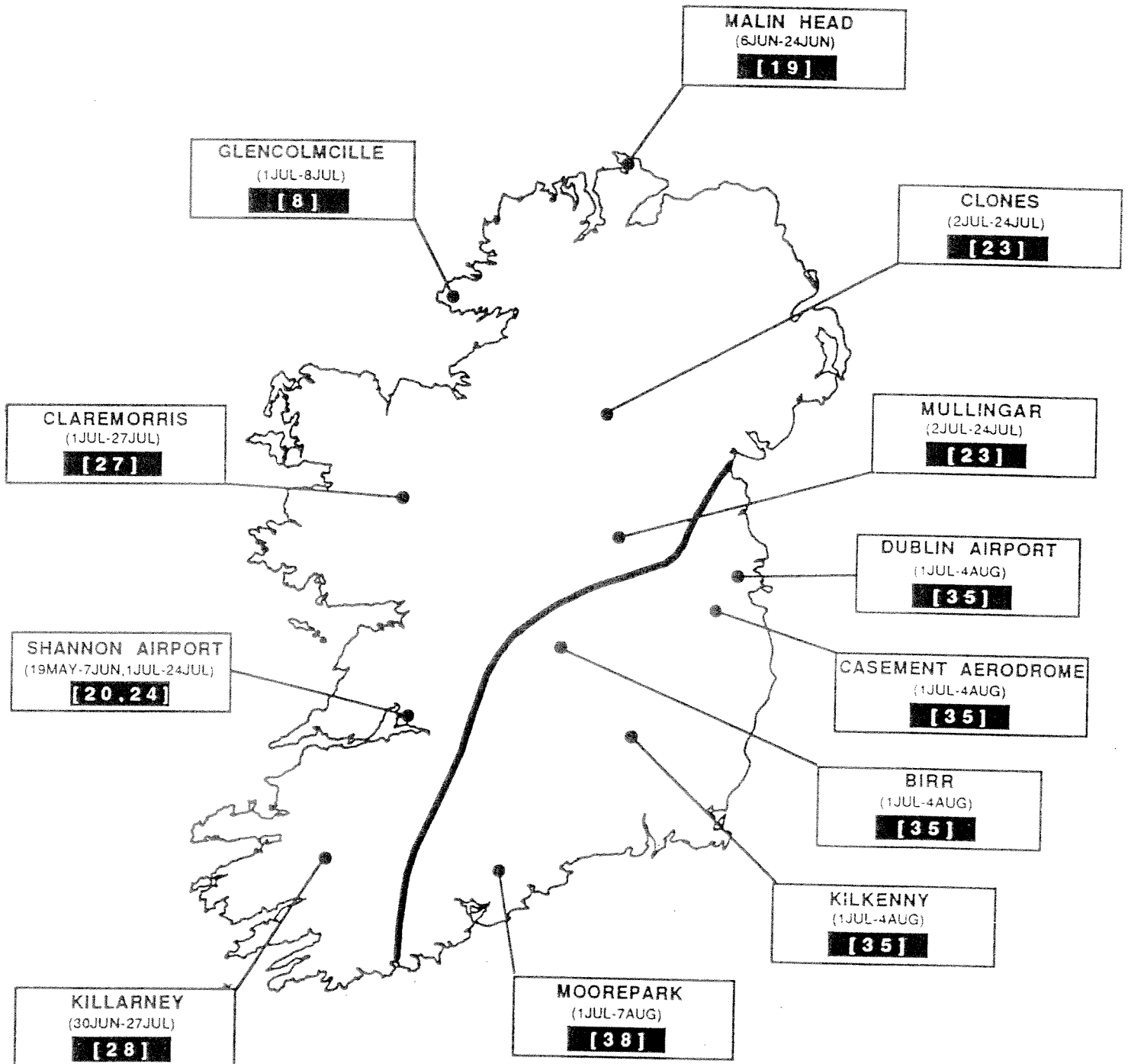


Fig. 4 PERIODS OF INSIGNIFICANT RAINFALL

1990

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

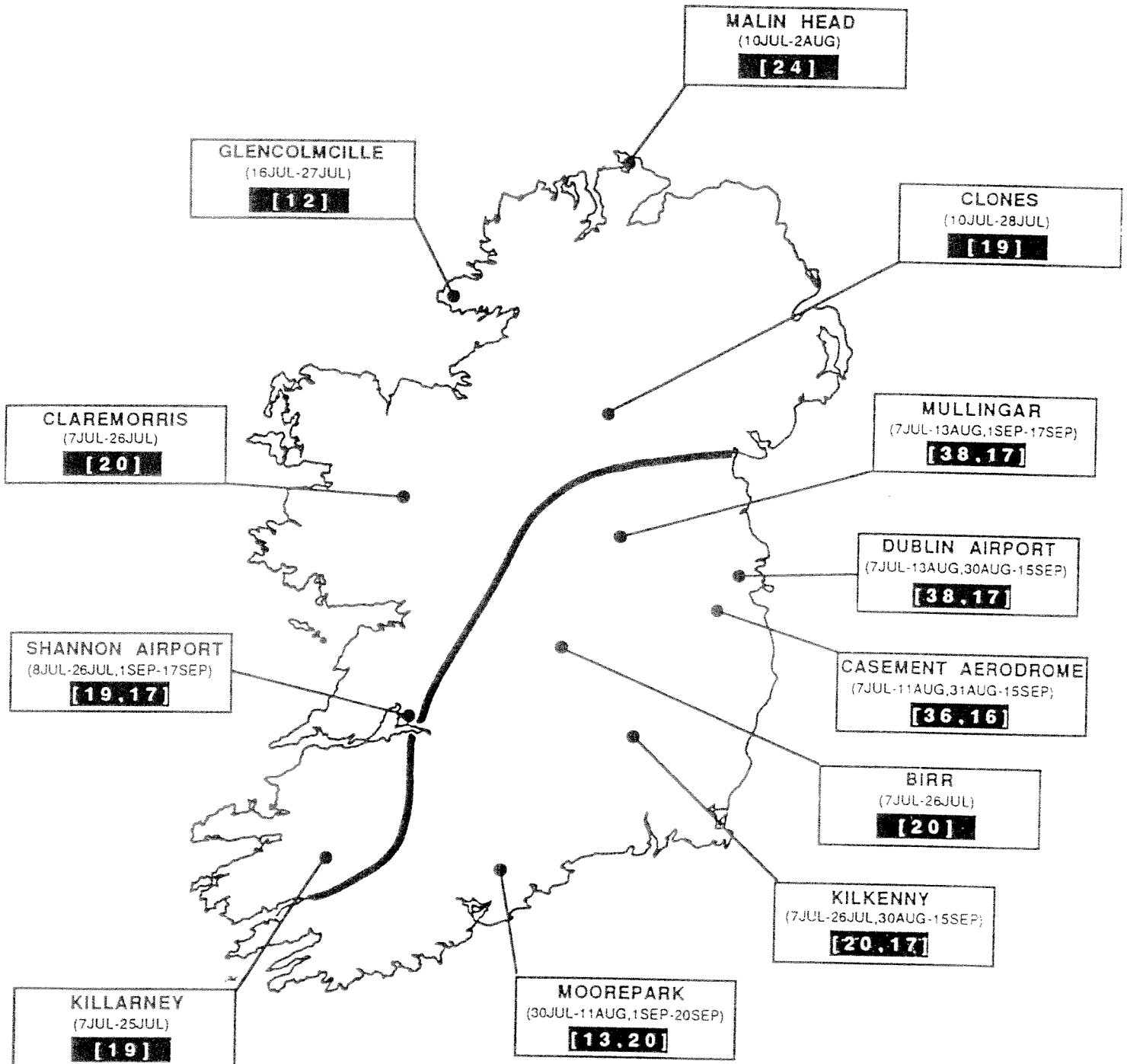


Fig. 5 PERIODS OF INSIGNIFICANT RAINFALL

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

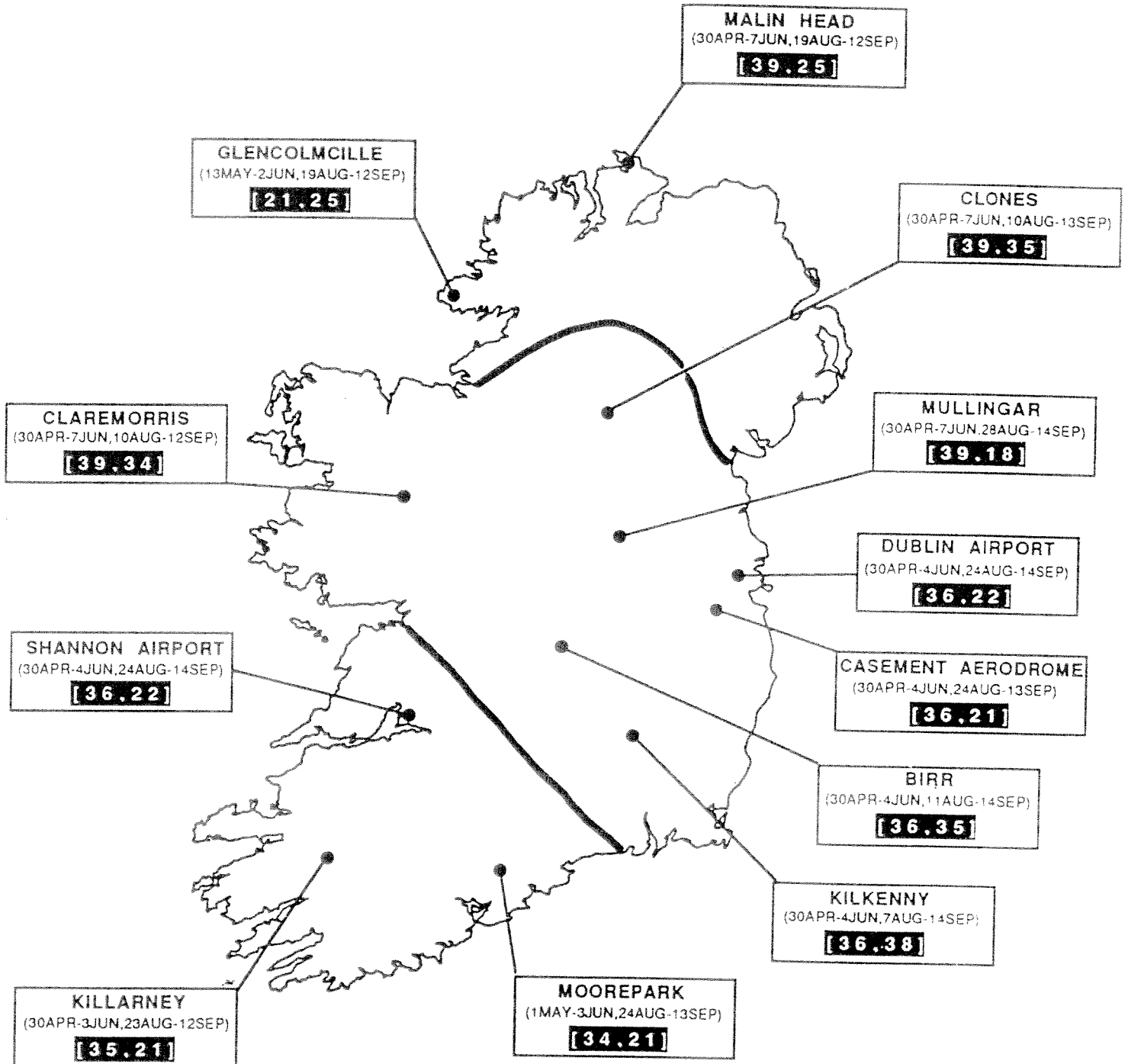


Fig. 6 PERIODS OF INSIGNIFICANT RAINFALL

Use of Rainfall data

Rainfall data have been used in this report as indicators of the drought periods and to identify the areas affected by drought.

Examination of Rainfall in the period April-October 1975 and 1976

In Table 1 the periods of absolute drought/partial drought/dry spell and periods of insignificant rainfall in the years 1975 and 1976 are listed for the selected stations. The periods of insignificant rainfall are also shown in Figures 2 and 3 for the years 1975 and 1976 respectively.

An examination of this table indicates that the duration of the drought in 1975 ranged from 23 days at Malin Head (ending on 12 July) to 67 days at Claremorris (ending on 8 July). In most areas it ended in the first week in July; South of a line from Dublin-Shannon-Moorepark there was a recurrence of drought conditions ending around 5-7 September.

In 1976 the duration of the drought ranged from 27 days at Glencolmcille (ending on 7 September) to 66 days at Moorepark (ending on 18 September). At most stations the drought ended on 9 September.

Comparison with rainfall in 1989, 1990 and 1991

The periods of absolute drought/partial drought/dry spell and periods of insignificant rainfall in 1989, 1990 and 1991 are also included in Table 1 and the periods of insignificant rainfall for these years are shown in Figure 4, 5 and 6 respectively.

In 1989 the duration of the dry period ranged from 8 days at Glencolmcille (ending on 8 July) to 38 days at Moorepark (ending on 7 August);

In 1990 the duration of the drought ranged from 12 days at Glencolmcille (ending on 27 July) to 38 days at Dublin Airport and Mullingar (ending on 13 August). On the east and south-east coast the dry period recurred for about 20 days, ending around 15 September.

In 1991 the duration of the first dry period ranged from 21 days at Glencolmcille (ending on 2 June) to 39 days at Mullingar (ending on 7 June). There was a second dry period ending between 12-14 September with the period of insignificant rainfall ranging from 18 days at Mullingar to 45 days at Kilkenny.

Comment on Rainfall data for 1975-1976 and 1989-1991:

From the above, we can conclude that the rainfall data would indicate that the 1975 and 1976 droughts were virtually nationwide and of approximate equal severity.

The 1989 drought was most severe east of a line from drawn from Dublin-Birr-Moorepark (Figure 4).

The 1990 drought was most severe east of a line from drawn from Louth-Shannon-West Cork (Figure 5).

The 1991 drought was most severe in a corridor drawn from Sligo to Kilkenny (Figure 6).

The 1989, 1990 and 1991 droughts were not as severe or as extensive as the 1975 or 1976 drought.

Examination of Rainfall for 1934, 1935, 1949, 1955 and 1959

The periods of absolute drought/partial drought/dry spell and insignificant rainfall in the period April- October in the years 1934, 1935, 1949, 1955 and 1959 are shown in Table 1A (Appendix) and the periods of insignificant rainfall for these years are shown in Figures 7, 8, 9, 10 and 11 respectively (Appendix). The periods of insignificant rainfall in these years are based on the a comparison of the rainfall data with the hydrographs for a small number of hydrometric gauging stations and should be used with caution.

The rainfall in 1934 and 1935 was examined asd a result of a comment in a paper to this Institution (2) which stated that the river flows recoreded in the River Liffey in July 1934 and August 1935 were the lowest in the period 1923-1938. An examination of the rainfall in these years shows that these were not significant droughts (Figure 7, 8).

In 1949 the worst area of drought was east of a line from Shannon to Malin Head (Figure 9).

In 1955 the area most affected by drought was east of a line from Kilkenny- Claremorris-Malin Head. The drought included almost the full months of July and August 1955 (Figure 10).

In 1959 the area most affected was east of a line from Killarney to Malin Head. Although there was a large amount of rain, falling almost nation wide, around 20 September and which was reflected for a short period in higher runoff, river flows subsequently fell and did not finally rise until 8 October 1959 (Figure 11).

Hydrometric Data

Introduction

Hydrometric data, on a systematic and extensive basis, has only been collected for low flow conditions since about 1970. Prior to that the data collected related to particular projects(3,4). In the 1920's the RDS/UCD erected a gauge on the River Liffey at Burgage Bridge(2). Dublin Corporation erected gauges at

Pollaphouca and at New Bridge (near Celbridge) on the same river also in the 1920's (2).

In the 1930's the ESB erected recorders on rivers with a view to their use for power generation. From the late 1940's, subsequent to the passage of the Arterial Drainage Act 1945, the OPW have erected gauges mainly for the purposes of the design of arterial drainage schemes.

The droughts in 1975 and 1976 generated a tremendous interest in data on low river flows.

With the passage of the Water Pollution Act 1977, the needs of Local Authorities for data for the assessment and issuing of licences gave rise to the need for more hydrometric stations. An Foras Forbartha and latterly the Environmental Research Unit, assessed the requirements of the individual Local Authorities and advised them on the appropriate gauging to fulfill their needs and processed the data into tables of daily mean flows, flow duration curves and sustained low flows.

It should be noted that in the ranking of low river flows there may be years where the difference in the low flow from one year to the next is marginal or within experimental error and that in absolute terms there is no significant difference in flows.

Table 2

Selected hydrometric gauging stations

Station No. and Name	River	Catchment Area km ²
0613 Charleville	Dee	307.0
0709 Navan	Boyne	1610.0
1002 Rathdrum	Avonmore	233.0
1028 Knocknamohill	Aughrim	204.0
1506 Brownsbarn	Nore	2388.0
1611 Clonmel	Suir	2173.0
1806 CSET Mallow	Blackwater	1058.0
2102 Coomhola	Coomhola	65.0
2103 Ballylickey	Inchiclough	75.0
2104 Inchiclough	Mealagh	46.0
2317 Trienearagh	Smearlagh	119.0
2511 M ^o ystown	Brosna	1227.0
2522 Syngesfield	Camcor	160.0
2527 Gourdeen	Ollatrim	118.0
2629 Dowra	Yellow	109.0
3021 Christina's Bridge	Robe	138.0
3212 Newport Weir	Newport	
3301 Glenamoy	Glenamoy	73.0
3401 Rahans	Moy	1911.0
3424 Kiltimagh	Pollagh	128.0
3430 Tully Mills	Palmerstown	
3631 Lisdarn	Cavan	52.0

TABLE 3

LOW FLOW RECORDED AT SELECTED GAUGING STATIONS FOR THE YEARS INDICATED

STATION NO. AND NAME	1975		1976		1989		1990		1991	
	FLOW	DATE	FLOW	DATE	FLOW	DATE	FLOW	DATE	FLOW	DATE
0613 Charleville	0.1**	5/9/75	0.17	10/9/76	0.34	16/9/89	0.25	8/8/90	0.20	15/9/91
0709 Navan	N.A.		1.94*	8/9/76	2.38	27/7/89	2.82	10/8/90	2.57*	9/9/91
1002 Rathdrum	0.4*	6/9/75	0.50*	23/8/76	N.A.		0.79	18/9/90	0.73	13/9/91
1028 Knocknamohill	N.A.		N.A.		0.55	5/8/89	0.54	16/9/90	0.66	14/9/91
1506 Brownsbarn	3.1	4/9/75	3.38	15/8/76	3.62	19/9/89	4.3	20/9/90	4.7	9/9/91
1611 Clonmel	6.7	5/9/75	6.5 E		8.80	29/7/89	10.3	19/9/90	10.4	27/9/91
1806 CSET Mallow	N.A.		1.7 E		3.0	9/8/89	3.1	19/9/90	2.4	10/9/91
2002 Curranure	N.A.		0.55	14/9/76	N.A.		0.65	28/9/90	0.96	8/9/91
2102 Coomhola	<0.01	6/7/75	<0.01	8/9/76	0.07	22/7/89	0.23	16/9/90	0.07	8/9/91
2103 Ballylickey	N.A.		0.04	8/9/76	0.07	21/7/89	0.22	20/9/90	0.1	10/9/91
2104 Inchiclough	<0.01	7/7/75	<0.01	9/9/76	0.02	21/7/89	0.09	27/9/90	0.07	10/9/91
2317 Trienearagh	N.A.		N.A.		0.06	24/7/89	0.11	9/8/90	0.15	8/9/91
2511 Moystown	2.1	1/9/75	1.99	27/8/76	3.1	28/7/89	3.1	30/9/90	3.5	7/9/91
2522 Syngesfield	N.A.		0.34	2/9/76	0.48	24/8/89	0.33	12/8/90	0.37	13/9/91
2527 Gourdeen	0.11	7/9/75	0.14	10/9/76	0.23	10/9/89	0.21	29/9/90	0.22	29/9/91
2629 Dowra	0.09	8/7/75	0.12	4/9/76	0.12	27/7/89	0.27	26/7/90	0.21	13/9/91
3021 Christina's Bridge	0.11*	8/7/75	0.12*	7/9/76	0.14	28/7/89	0.15	15/9/90	0.22*	14/9/91
3212 Newport Weir	N.A.		N.A.		0.54	15/7/89	0.49	4/6/90	0.64	13/9/91
3301 Glenamoy	N.A.		N.A.		0.24	20/7/89	0.26	27/7/90	0.19*	12/9/91
3401 Rahans	4.0*	7/7/75	3.6	20/9/76	5.43	25/7/89	6.9	15/8/90	7.85	13/9/91
3424 Kiltimagh	0.16*	10/7/75	0.20	21/8/76	0.2	28/7/89	0.27	26/7/90	0.32	12/9/91
3631 Lisdarn	0.03	30/8/75	0.03	5/9/76	0.03*	26/7/89	0.04	1/10/90	0.03*	2/9/91

* Flow measurement

** 0623 DRUMGOOLESTOWN

N.A. Not available

E Estimated

The river flows in 1975, 1976, 1989, 1990 and 1991 were examined at the stations listed in Table 2. These stations were chosen because they give a good geographical spread of stations throughout the country and low flow data was available for 1975 and/or 1976. In some cases, stations were included in order to show the relative position, from a flow point of view, of the low flow in 1989, 1990 and 1991.

Examination of runoff in 1975 and 1976

The years 1975 and 1976 were chosen as they were very severe droughts covering a large area of the country. In this way we can use them as benchmark years against which one can compare the droughts occurring in other years. The low flow at selected hydrometric stations in the years 1975, 1976, 1989, 1990 and 1991 are shown in Table 3.

1975

In 1975 the drought ended in the first week of July. Where there was a recurrence of drought conditions, generally in the area bounded by Dublin-Shannon-Wexford, low flow conditions recurred in the first week in September and these were the lowest flows of the year and among the lowest flows ever measured.

1976

In 1976 the drought ended on 9 September although low flows continued to occur up to 18 September in the south and south east. The flows measured at the end of this drought are among the lowest flows ever recorded and is a good indicator of the dry weather flow.

Comment on 1975 -1976 Low Flows

The flows measured in July 1975, September 1975 and September 1976 are the lowest ever measured in this country. In general terms, in the Glyde, Barrow, Nore, Suir, Lower Shannon Catchments, the low flow in September 1975 was about the same as that measured in September 1976. In the same catchments the flow in July 1975 was greater than that measured in September 1975.

In the Boyne Catchment the low flow in September 1976 was lower than that measured in September 1975.

In West Cork the low flow in 1975 occurred in July 1975.

In tributaries of the Upper River Shannon (hydrometric area 26) the low flow in September 1976 was in most cases lower than that measured in July 1975 or September 1975.

In parts of hydrometric area 30 (Corrib) the flows measured in September 1976 were equal or lower than those measured in July or September 1975.

In parts of hydrometric area 34 (Moy) and 35 (Sligo Bay) the flows measured in July 1975 were lower than those measured in this area in September 1976

Examination of runoff in 1989, 1990 and 1991

1989

In general, the low flow in 1989 occurred about the end of July/beginning of August. This ties in with the rainfall pattern. The lowest flows occurred in the region east of a line from Moorepark to Louth (Figure 4).

1990

North of a curve line from Louth to Shannon to West Cork (Figure 5) the low flow occurred around the end of July. In this region the flows were higher than the flows that occurred in 1989. South of this line there was a recurrence of low flows and the lowest flows of the year occurred in September. These flows were lower than the flows that occurred in 1989.

1991

Lowest flows occurred in a corridor from Wexford to Mayo (Figure 6) and the lowest flows of the year occurred around the middle of September. In most cases the low flows were higher than the flows which occurred at these stations in 1990.

Comment on Low Flow Data in 1975/76 and 1989-1991

The low flows which occurred in Irish Rivers in 1989, 1990 and 1991 were not as severe as those which occurred in the same rivers in 1975 and 1976.

While there are regional variations, in all three years the low flows were of the same order of magnitude and considerably in excess of those recorded in 1975 or 1976.

The flowrates in 1989-1991 and 1975/76 are comparable with the periods of insignificant rainfall in those years.

In some areas flow rates measured at the end of the drought in 1989, 1990 and 1991 approximate to the 95 percentile flow.

In general a period of say 60 days of insignificant rainfall and ending in September/October will produce lower flows than the same period of insignificant rainfall occurring at any other time of the year.

Groundwater Levels and Flow

Ground water levels are not recorded on a systematic and on-going basis nationwide. However the evidence from the low flow runoff during drought periods to date appears to indicate that groundwater levels recover quickly and respond fairly rapidly to rainfall. The evidence for this is that the low flows, which represent groundwater runoff, are not getting lower.

Conclusions

1. The flow rates measured in the 1975/1976 drought are the lowest flows on record and can be used as a benchmark drought against which other droughts can be compared.
2. All droughts examined were independent of the previous years low flows and were due to the lack of rainfall in these years.
3. Drought flow conditions can be predicted using rainfall records and corresponding flow rates.
4. The low flows recorded at the end of the 1976 drought can be used as good indicators of the dry weather flow.
5. To predict the severity of a particular drought, one can assess the periods of insignificant rainfall, the time of year at which it occurs and estimate the corresponding flow rates.
6. From a river flow point of view, the period of insignificant rainfall is more relevant to extreme river conditions than the use of absolute drought, partial drought and dry spell.
7. There is an on-going need for reliable data on low flows and the conditions that relate to them.

Acknowledgements

The author would like to thank all those involved in the supply of data for the report upon which this paper is based. In particular the contribution of the following should be acknowledged:

His colleagues in the Water Resources Section of the Environmental Research Unit;

The Regional Hydrometric Teams operated by the Local Authorities;

County Engineers in each Local Authority;

Hydrometric Section of the Office of Public Works;

Hydrometric Section of the Electricity Supply Board/ESBI;

Meteorological Service;

Minerex Limited.

He would like to thank J. Sheedy, acting Director, ERU, for permission to present the paper.

References

1. An Foras Forbartha & Geological Survey Office " Groundwater Resources in the N.E.(R.D.O.) Region, March 1981
2. O'Riordan, J. A. "Run-off of the River Liffey and the Lower River Erne", ICEI, February 1949.
3. Chaloner Smith, J. "Notes upon the average volume of flow from large catchment areas in Ireland; the probable duration of stated rates of flow, deduced from gaugings on the River Shannon at Killaloe", ICEI, January 1919.
4. Dooge, J.C.I. "The flow of Irish Rivers", Seminar Proceedings, RIA, February 1989.

APPENDIX

TABLE 1A

Periods of absolute drought, partial drought, dry spells and periods of insignificant rainfall in 1934, 1935, 1949, 1955 and 1959 at Clones, Mullingar, Phoenix Park, Dublin Airport, Casement Aerodrome, Kilkenny, Moorepark, Killarney, Valentia, Shannon Airport, Birr, Claremorris, Markree Castle, Glencolmcille, Malin Head Rainfall Stations (where available).

Rainfall Station	Period of Absolute Drought	Period of Partial Drought	Dry Spell	Period of Insignificant Rainfall (Days)
Clones 1955 1955 1959 1959	15 Jul-1 Aug 12 Nov-26 Nov None	4 Jul-12Aug None	4Jul -1 Aug None	4Jul-31Aug(59) 16Aug-19Sep(35) 26Sep- 8Oct(13)
Mullingar 1949 1949 1955 1955 1955 1955 1959 1959	None 3 Jul-1 Aug 12 Nov-27 Nov None	None 3 Jul-1 Aug None	11Jun-26 Jun 2Mar-21 Mar 3Jul- 1 Aug 29Jul-12 Aug	13Jun-12Jul(30) 12Sep-50Oct(24) 3Jul-15Aug(44) 19Aug-31Aug(13) 16Aug-19Sep(35) 26Sep-80Oct(13)
Phoenix Park 1934 1934 1935 1935	None None	None None	1Feb-23 Feb 23Apr-14 May	1Feb-28Feb(28) 30Jun-10Jul(11) 23Apr-14May(22) 20Jul-7Aug(19)
Dublin Airport 1949 1949 1949 1949 1955 1955 1955 1959 1959	None 4 Jul-1 Aug 12 Nov-27 Nov None	None 4Jul-15Aug None	15 Mar-1 Apr 27 Apr-15May 13 Jun-27Jun 6 Sep-20Sep 4 Jul-1 Aug 12 Nov-7 Dec 23 Aug-19Sep	8Jun-13Jul(36) 6Sep-20Sep(15) 3Jul-15Aug(44) 23Sep- 2Aug (9) 21Aug-19Sep(30) 26Sep- 5Oct(10)

Cont/d Table 1A

Casement Aerodrome				
1955	4 Jul-1 Aug	3Jul-1 Aug	4 Jul-1 Aug	4Jul- 1Aug(39)
1955				3Aug-15Aug(13)
1955	12 Nov-30 Nov		11 Nov-1 Dec	
1959	None	30Jul-19Sep	23 Aug-19Sep	30Jul-19Sep(52)
1959				22Sep-80Oct (17)
Kilkenny				
1949	13 Jun- 3 Jul	8Jun-13Jul	13Jun-3 Jul	8Jun-13Jul(36)
1949				11Aug-29Aug(19)
1955	10 Apr-24 Apr		10Apr-24Apr	
1955	5 Jul- 1 Aug	3Jul-12Aug	3Jul-1 Aug	3Jul-12Aug(41)
1955	12 Nov-27 Nov		12Nov-27Nov	22Sep- 50Oct(14)
1955				
1959	16 Aug- 4 Sep	16Aug-20Sep	16Aug-4 Sep	14Aug-23Sep(41)
				26Sep- 80Oct(13)
MOOREPARK				
1949	None		15Mar-31Mar	
1949		8 Jun-13Jul	8 Jun-13Jul	8 Jun-13Jul(36)
1949				22Sep-5 Oct(14)
1955	3 Mar-17 Mar		2 Mar-21Mar	
1955	10Apr-24 Apr		1 Apr-24Apr	
1955	6 Jul- 1 Aug	28Jun-1Aug	6 Jul-1 Aug	24Jun-1Aug(39)
1955			11Nov-27Nov	24Sep-30Oct(10)
1959	None	None	14Aug-4 Sep	14Aug-23Sep(41)
1959			6 Sep-20Sep	
KILLARNEY				
1949	None	None	14Mar-31Mar	6 Jun-12Jul(37)
1949				25Sep-40Oct(10)
1955		None	2 Mar-16Mar	
1955			10Apr-24Apr	
1955	12Jul-1 Aug		12Jul-1 Aug	12Jul-7 Aug(27)
1955	12Nov-26Nov		12Nov-27Nov	19Aug-31Aug(13)
1959	None	None	None	15Aug-23Sep(40)
VALENTIA				
1934		26Jan-23Feb		28Jan-23Feb(27)
1934	26May-12Jun		24May-12Jun	
1934	27Jun-11Jul		27Jun-11Jul	27Jun-14Jul(18)
1935	None	None	None	5 May-18May(14)
1935				22Jul-3 Aug(13)

Cont/d Table 1A

SHANNON AIRPORT	1949 1949	None	8 Jun-13Jul	8 Jun-3 Jul	8 Jun-13Jul(36) 25Sep-5 Oct(11)
	1955 1955 1955 1955	2 Mar-17Mar 5 Jul-29Jul	3 Jul-1 Aug	2 Mar-21Mar 5 Jul-1 Aug 12Nov-27Nov	3 Jul-1 Aug(30) 19Aug-31Aug(13)
	1959 1959	None	None	None	20Aug-4 Sep(16) 6 Sep-19Sep(14)
BIRR	1934 1934 1934	None	None	1 Feb-28Feb 28Jun-12Jul 14Nov-29Nov	1 Feb-28Feb(28) 29Jun-12Jul(13)
	1935 1935	None	None	None	23Apr-14May(22) 21Jul-10Aug(21)
	1955 1955 1955 1955 1955	5 Jul-1 Aug 12Nov-27Nov	3 Jul-1 Aug	2 Mar-21Mar 10Apr-24Apr 5 Jul-1 Aug 11Nov-27Nov	3 Jul-1 Aug(30) 19Aug-31Aug(13)
	1959 1959	None	14Aug-19Sep	15Aug-19Sep	15Aug-19Sep(36) 26Sep-8 Oct(13)
CLAREMORRIS	1949 1949	None	None	None	9 Jun-26Jun(18) 10Sep-30Sep(21)
	1955 1955 1955	5 Jul-29Jul	3 Jul-14Aug	2 Mar-19Mar 5 Jul-1 Aug	5 Jul-14Aug(41) 19Aug-31Aug(13)
	1959 1959	None	None	None	25Aug-4 Sep(11) 26Sep-7 Oct(12)
MARKREE CASTLE	1934 1934	25May-8 Jun	None	25May-8 Jun	22May-12Jun(22) 30Jun-14Jul(15)
	1935 1935	None	None	None	23Apr-15May(23) 21Jul-6 Aug(17)
GLENCOLM- CILLE	1955 1955	None	None	None	3 Jul-29Jul(27) 17Aug-30Aug(14)
	1959 1959	None	None	None	26Aug-4 Sep(10) 26Sep-6 Oct(11)

Cont/d Table 1A

MALIN HEAD				
1949	None	None	None	14Jun-18Jul(35)
1949				10Sep-7 Oct(28)
1955	None	3 Jul-31Jul	3 Jul-21Jul	3 Jul-14Aug(42)
1959	None	None	None	15Aug-19Sep(36)
1959				25Sep-5 Oct(11)

1934

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

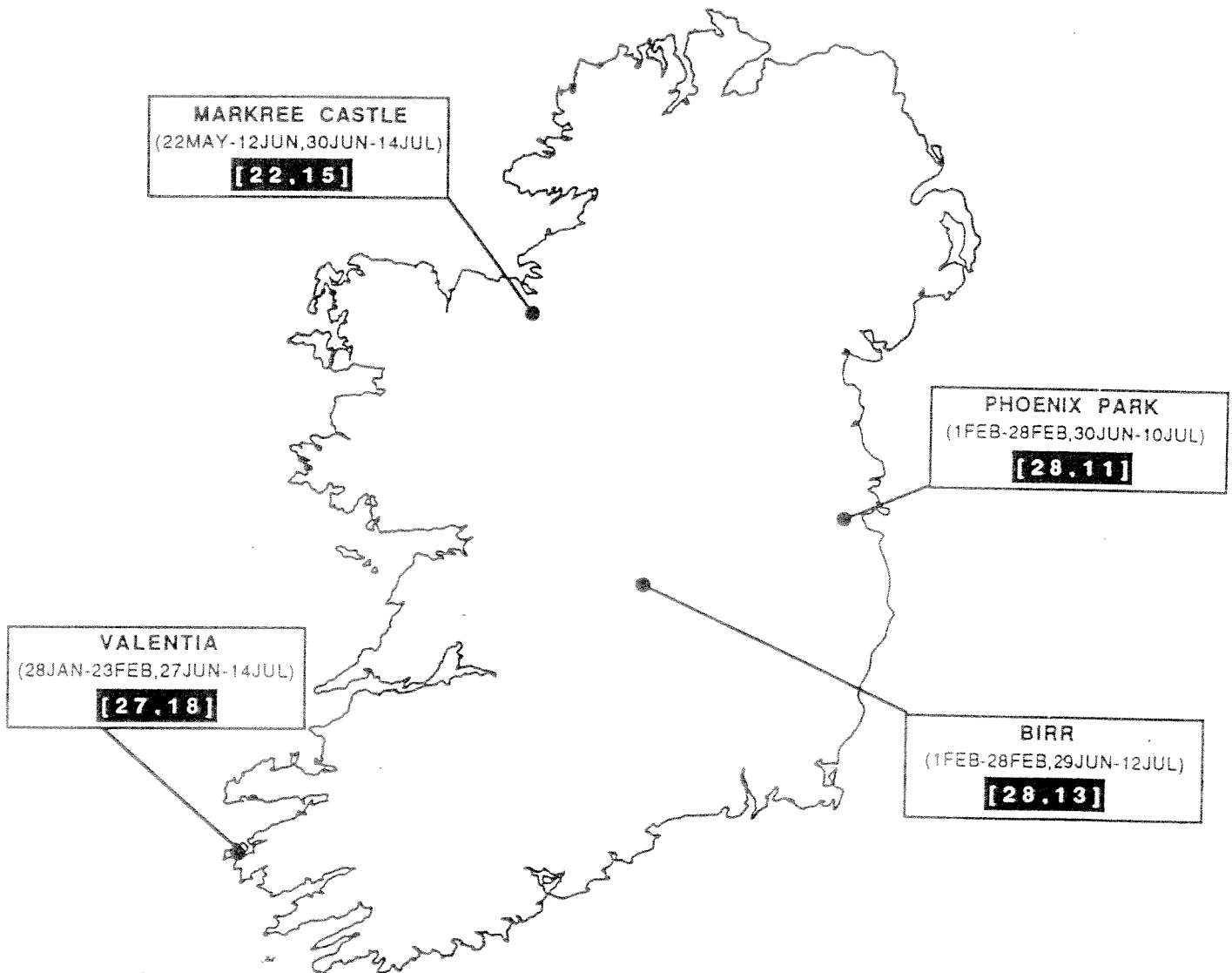


Fig. 7 PERIODS OF INSIGNIFICANT RAINFALL

1935

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

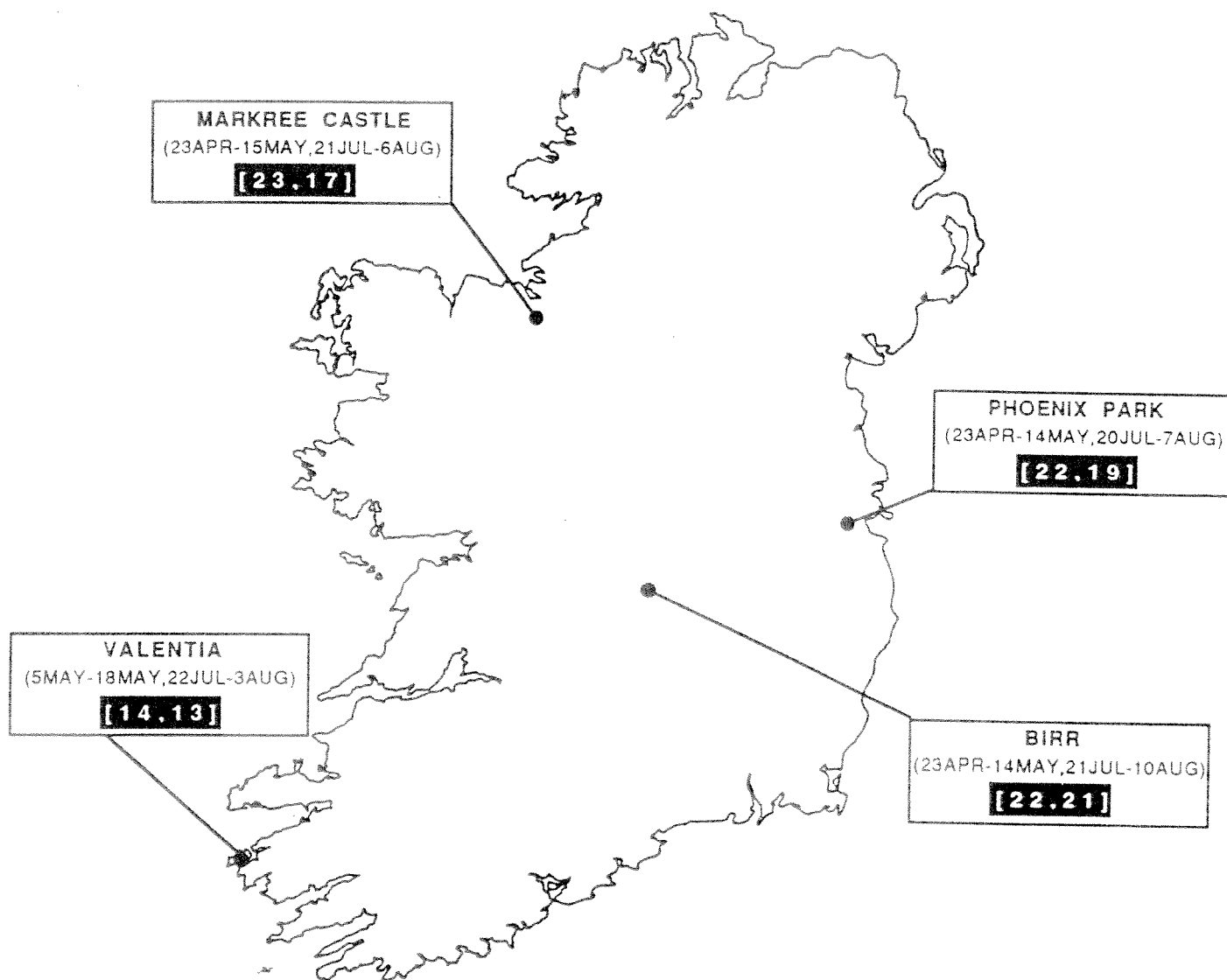


Fig. 8 PERIODS OF INSIGNIFICANT RAINFALL

1949

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

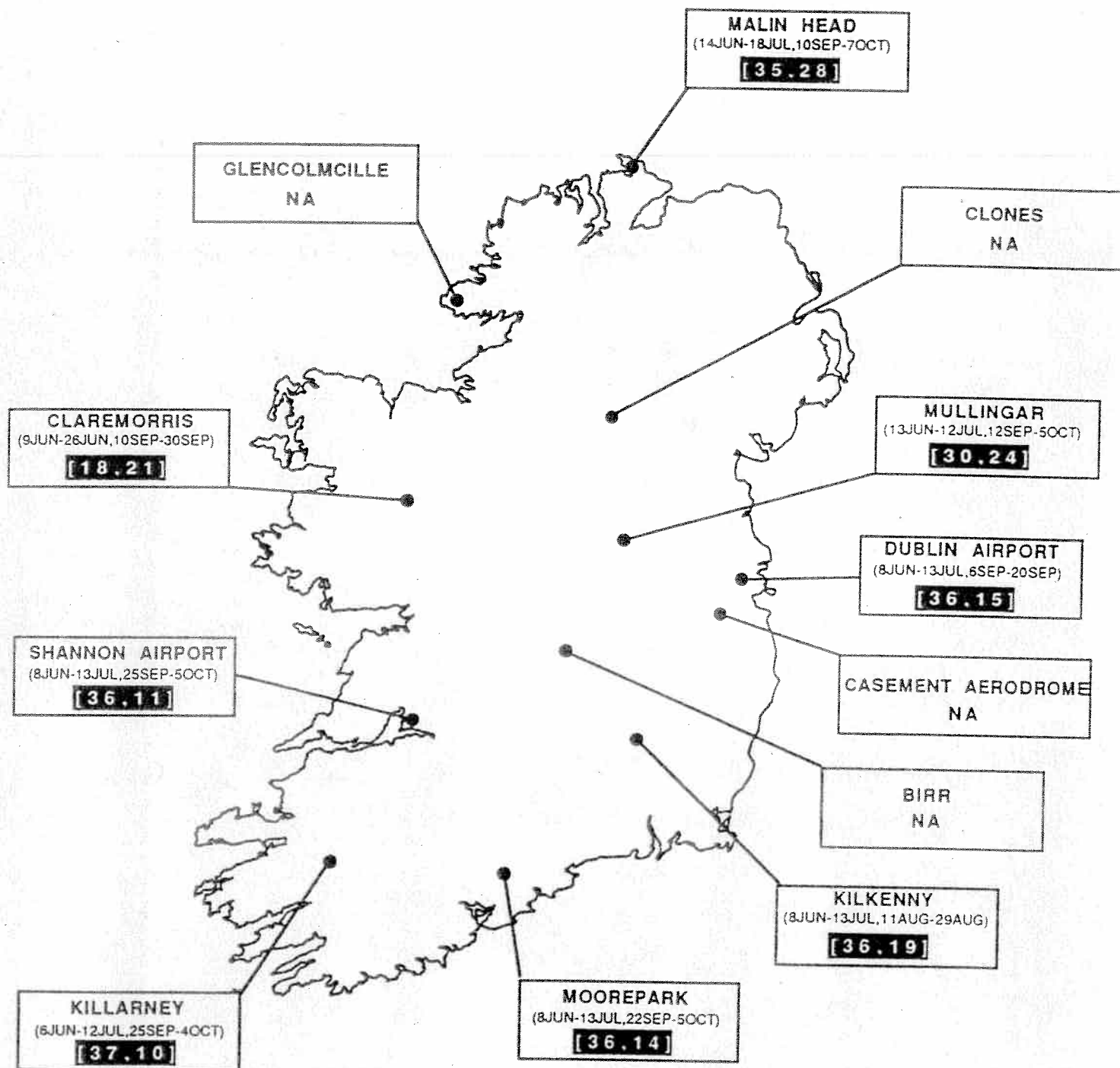


Fig. 9 PERIODS OF INSIGNIFICANT RAINFALL

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

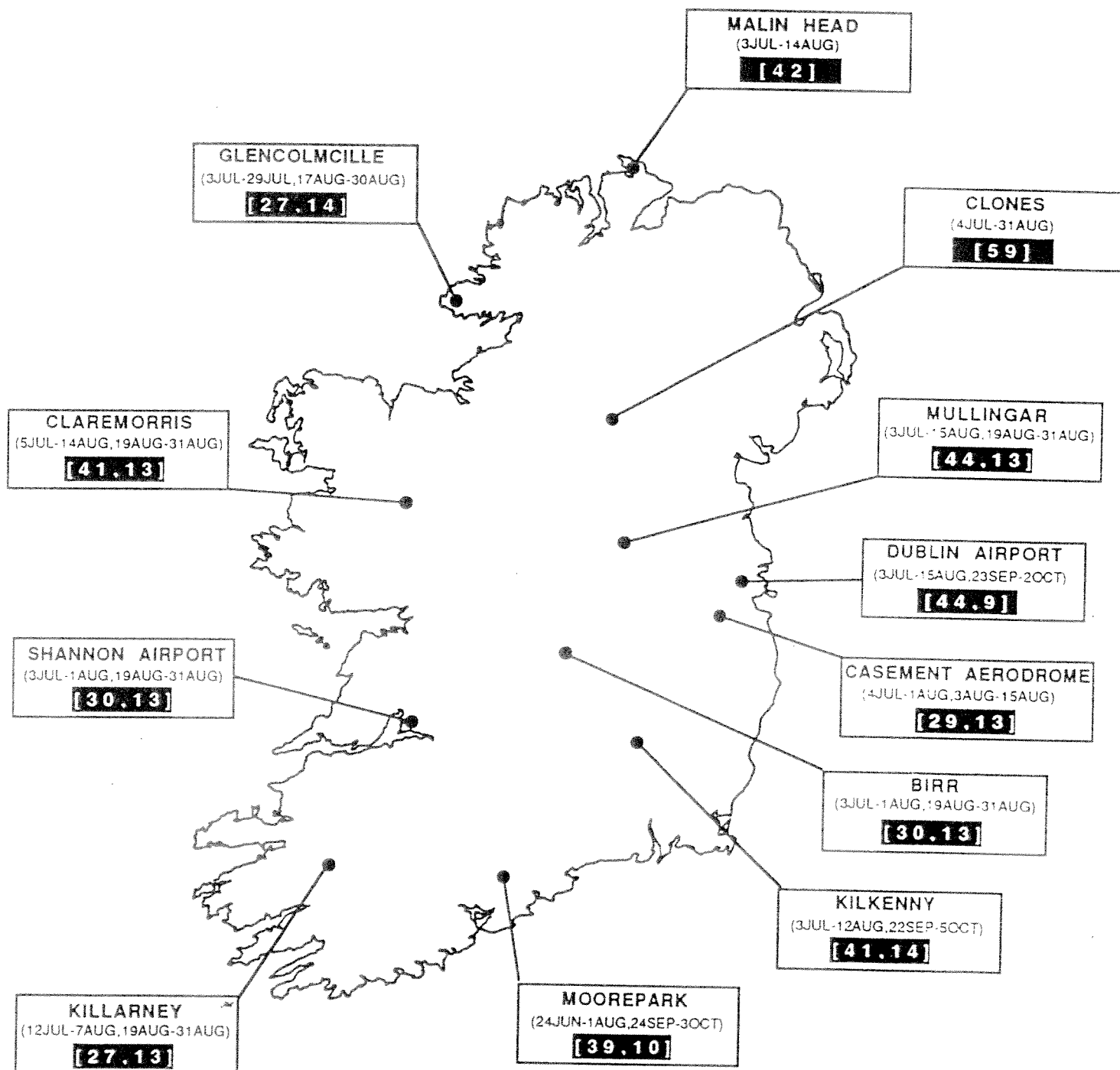


Fig. 10 PERIODS OF INSIGNIFICANT RAINFALL

KEY

- LOCATION OF RAINFALL STATIONS
- () PERIODS OF INSIGNIFICANT RAINFALL
- [] LENGTH IN DAYS OF PERIODS OF INSIGNIFICANT RAINFALL

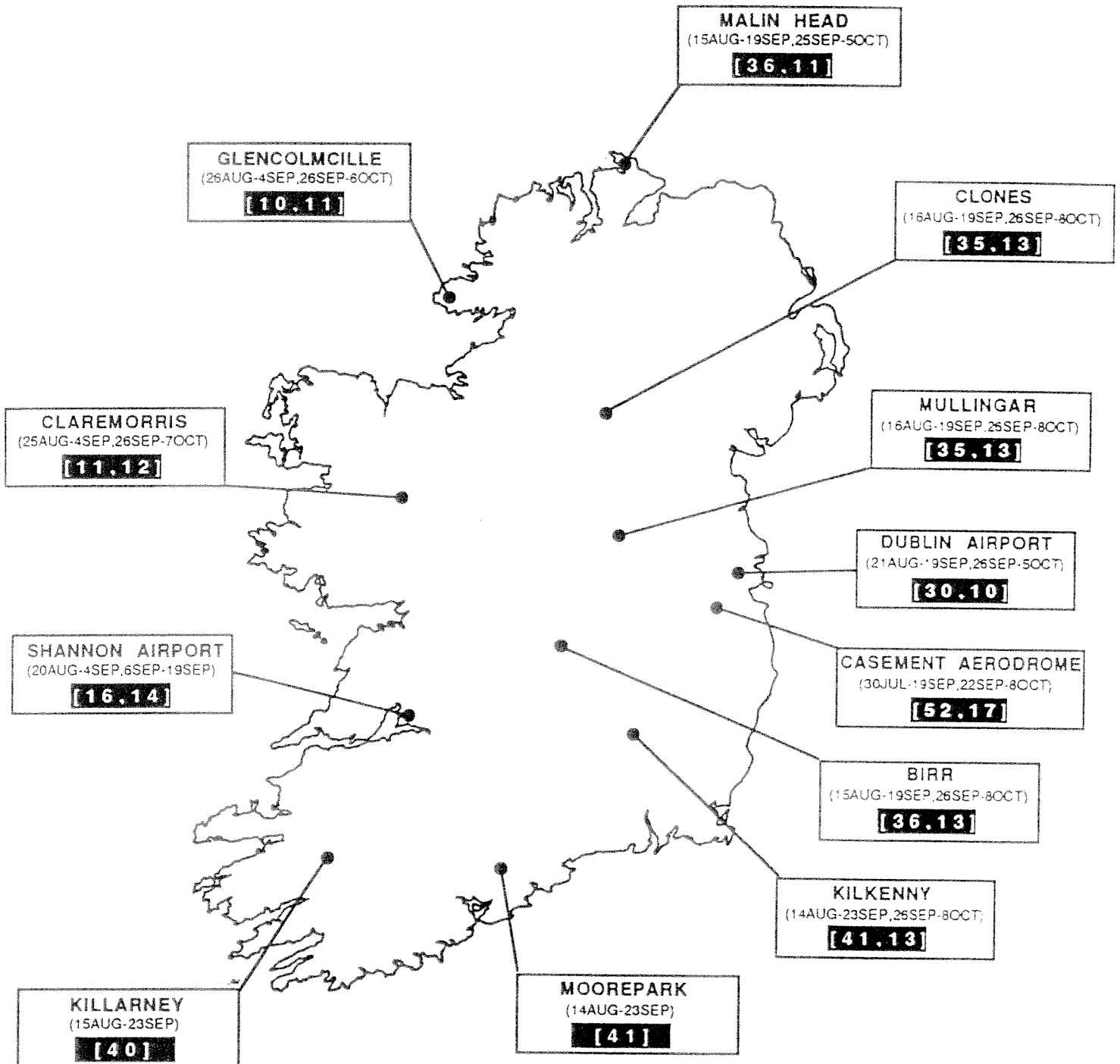


Fig. 11 PERIODS OF INSIGNIFICANT RAINFALL

