Extended Flow Records at Key Locations in England and Wales (Phase 2)

Climatic Research Unit
University of East Anglia

R&D Technical Report W25

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Research contractor:
Climatic Research Unit
University of East Anglia

Environment Agency
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS12 4UD

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Commissioning Organisation
Environment Agency
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol BS12 4UD

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This report is not for immediate implementation but for information only. It provides the results of the second phase of a project to reconstruct flow records at five key locations which can be used to assess surface water yield.

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This document was produced under Environment Agency R&D Project i678 by:
Climatic Research Unit
University of East Anglia
Norwich
NR4 7TJ

Tel: 01603 456161
Fax: 01603 507784

Environment Agency Project Leader
The Environment Agency's Project Leader for R&D Project i678 was:
Dr John Mawdsley - North East Region

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EXECUTIVE SUMMARY

Monthly-mean riverflows are reconstructed from rainfall data for five catchments in England and Wales, for the period from about 1850 to 1994. The work reported here improves the spatial availability of reconstructed riverflow records from ten to fifteen locations across England and Wales. The reconstruction accuracy, for the five catchments (Medway, Itchen, Teifi, Dee and Derwent) is as good as that achieved earlier, and it enables longer-period drought assessment to be made on a regional basis.

Rainfall data were collected from the Rainfall Archive at the Meteorological Office for years up to 1960, and from the NRA regional offices for the 1961-95 period. Monthly catchment rainfall estimates were produced from about 1850 to 1995 by constructing six or seven long homogeneous rainfall records for each catchment. All catchments, except the Teifi, have major alterations to the measured flows due to abstraction and/or river regulation thus 'naturalised' flow series were used for calibration and validation of the catchment model. Such 'naturalised' records were of short duration on the Derwent, and have not been produced since the late 1980s on the Itchen and the Dee. The reconstructions produced here are probably of sufficient accuracy to assist in future and continued 'naturalisation' of monthly riverflow records.

Apart from the validation exercises, with riverflow data held back from the calibration exercises on the five catchments, longer riverflow records from three sites were also used to assess further the quality of the reconstructions. (For the Itchen, the record from Bedhampton Springs, for the Dee, the 'naturalised' outflow from Lake Vyrnwy and for the Derwent, the observed and 'naturalised' flows at Yorkshire Bridge). On all catchments the reconstructions are best for low flows, with the largest errors occurring in winter. No correction for snowfall has been applied and during cooler winters, particularly on the Dee, Teifi and Derwent, runoff will be delayed when significant snowpacks develop.

KEYWORDS: Rainfall/runoff modelling Precipitaton series homogeneity
Catchment model validation Flow reconstruction Flow naturalisation
Rainfall archive Historic low flows

1. INTRODUCTION

The purpose of the project is to extend the riverflow reconstructions, recently updated by Jones and Lister (1995) on ten catchments in England and Wales, to five new catchments. Details of the five new catchments are given in Table 3.1. The five were chosen to supplement the original ten in order to provide a better coverage of catchments across England and Wales (see Figure A1 which outlines all 15 catchments).

The reconstructions were made using a statistical catchment model developed by Wright (1978). This model is discussed in the second Chapter and in more detail by Jones (1984), and Jones and Lister (1995). Chapter 3 of the report gives details of catchment characteristics for the five catchments. The success of any riverflow reconstruction is principally dependent on good estimates of catchment rainfall being produced, for as far back in time as possible. In Chapter 4, the rainfall data sources are listed, along with the methods and necessary corrections, to produce between six and seven long homogeneous rainfall series for each catchment. Areal catchment series are produced by averaging the homogeneous records and producing series which extend from about 1850 to 1995.

The other important aspect to enable good riverflow reconstructions to be produced, is the accurate measurement of river discharge. Chapter 5 discusses the quality of the riverflow data on each catchment and lists the periods of 'naturalised' flow availability on four of them. Only the River Teifi is considered to have an unmodified flow record. The final Chapter (6) brings the rainfall and riverflow data together with the catchment model. The model fitting, over the calibration period and, more importantly, the assessment of this over an independent verification period is discussed for each catchment. The results of this exercise are given in Table 6.1. On three of the catchments, longer riverflow records from either less reliable sources on the same catchment or from neighbouring catchments with longer records, have been used to assess the worth of the reconstructed riverflow data (see tables B2-B4).

2. CATCHMENT MODELLING

Modified from Jones *et al.*, 1984. Few catchment models have been specifically developed for riverflow reconstruction. Exceptions are the conceptual models of Porter and McMahon (1971) and Manley (1978), and the empirical model developed by Wright (1978), at the Central Water Planning Unit (CWPU), used in this study. Two versions of Wright's model are available, depending on the time base, monthly or daily. In the version used here, values of the logarithms of mean monthly riverflow are related to linear combinations of data on soil moisture and effective precipitation (precipitation minus actual evaporation) by regression techniques. The monthly model is described in detail in Jones (1983). Both the latter paper and Jones (1984) are included as Appendix C in the earlier Jones and Lister (1995) report.

This model is very simple and easy to calibrate, the relationships between rainfall and riverflow being determined by regression techniques. The only inputs required by the model are monthly time series of catchment areal precipitation estimates. The model uses constant monthly values of actual evaporation based on long term averages, rather than variable values of potential evaporation estimates calculated, for example, using Penman's (1948) method. Wright (1978) argues that the use of these seasonally constant values leads to more accurate modelling of riverflow than estimating actual evaporation by methods such as described by Thom and Ledger (1976). The modelling accuracy achieved by Jones (1984), Jones and Lister (1995), and in this study - particularly in independent verifications, is further justification of the use of seasonally constant values.

The empirical 'black box' nature of the relationship between precipitation and riverflow may not please catchment model 'purists'. It is therefore necessary to test or verify the catchment model reconstructions for this period over an independent period by comparing the reconstructions with measured riverflow values that were not used in model calibration. The CPWU model was fitted to data from ten catchments (Jones *et al.*, 1984, Table 1) using as much data as then (early 1980s) possible, while still retaining some data for model verification. This was possible on all the catchments except four, where only 12-14 years of measured riverflow data were available for model development. The regression equations developed during the early 1980s were used in Jones and Lister (1995) to extend the riverflow reconstructions from the late 1970s to 1993. The accuracy of those reconstructions for this period, is testament to the usefulness of a model just requiring monthly areal precipitation estimates, for this type of work.

3. BASIC CATCHMENT CHARACTERISTICS

This chapter identifies primary catchment characteristics with regard to geology, relief, and rainfall, and how these shape the natural flow regime. Outline catchment maps are given in Figures A2.1-A2.5, and these include the main river system and principal settlements. Table 3.1 lists catchment size and a number of flow related statistics, including the baseflow index (BFI, Institute of Hydrology, 1980), and the flow exceeded 10% (Q10) and 95% (Q95) of the time, for each catchment.

Table 3.1 Catchment areal and flow statistics

River	Gauging Station	Area km^2	Period	BFI	Flows Mean	cumecs.* Q10	Q95
1. Medway	Teston	1256	1956-85	.41	11.1	24.7	1.4
2. Itchen	Highbridge+All'brk	360	1958-85	.96	5.3	7.8	3.1
3. Teifi	Glan Teifi	894	1959-85	.54	28.2	63.1	3.0
4. Dee	Manley Hall/Erbist'k	1019/					
		1040	1937-85	.52	30.9	70.5	4.9
5. Derwent	Derby/Longbr. Weir	1054	1935-85	.62	17.7	36.3	5.1

* -All flows 'observed' not 'naturalised'
All data from Institute of Hydrology (1993)

3.1 Medway to Teston

The catchment is of mixed geology with impervious formations accounting for up to half of its area; baseflow index is 0.41. A mosaic of clays and sands from the (Weald) higher elevations in the south, changes to Weald Clay at the lower elevations of the river valley. The geology of the northern catchment is dominated by an outcrop of Lower Greensand.

The greatest elevations, with values in excess of 200 m, are to be found at both the northern and southern divides of the catchment. Set in the drier south east of England, rainfall is highest in the higher parts of the catchment which lie to the south and west of Tunbridge Wells. Here average annual values generally exceed 825 mm and may be as high as 950 mm. The lower Medway valley and much of the valley of a tributary, the Beult, receives less than 700 mm of rain. (Ministry of Housing and Local Government, 1964).

The relatively high proportion of impervious formations, give rise to a rather 'flashy' flow regime, and a wide range of flows. For the period 1956-85, the 10 percentile and 95 percentile flows are 24.7 and 1.43 cumecs respectively. Mean flow for the same period is 11.1 cumecs.

3.2 Itchen to Highbridge and Allbrook

The catchment is very permeable with a 90% chalk geology, and a baseflow index of 0.96. Upper Chalk dominates, with a small area of Middle and Lower Chalk in the Winchester area. The groundwater catchment area is larger than the topographical catchment (Institute of Hydrology, 1993 and Hampshire River Authority c.a. 1972).

Annual rainfall varies between 750 mm towards the coastal strip, and around 900 mm in the highest parts of the upper catchment. (Hampshire River Authority, c.a. 1972). Maximum elevation, at around 180 m, occurs to the north east of Winchester.

The range of flows is, as would be expected from such a permeable catchment, very narrow. The 10 Percentile flow is 7.8 cumecs and the 95 Percentile flow is 3.10 cumecs The mean observed flow for the period 1958-85 is 5.37 cumecs.

3.3 Teifi to Glan Teifi

Catchment geology, in the upper reaches, is dominated by Silurian deposits. There is a significant area of more recent alluvium to the north of Tregaron, and this poorly drained area is known as the Tregaron Bog. Ordovician deposits predominate in the lower reaches, that is, from a point which is approximately 30 km downstream of Tregaron (South West Wales River Authority, 1970). Base flow index is 0.54.

The Teifi rises to the north of Strata Florida, at an elevation of approximately 455 m. This is a hilly area, with a number of natural lakes which have been utilised for water resource purposes. The river gradient is very steep upstream of Tregaron Bog. Below Lampeter, the river valley slowly widens and gradients are less steep.

Situated on the western side of Britain, and with high elevations, the catchment has areas which receive high rainfall. The areas of highest rainfall are situated to the north east and east of Tregaron. Here annual average rainfalls exceed 1800 mm, and may be as high as 2000 mm (South West Wales River Authority, 1970). Average annual rainfall for the catchment to Glan Teifi, for the period 1959-1985, is 1344 mm (Institute of Hydrology, 1993).

A combination of high rainfall, steep slopes, and moderate natural storage within the catchment, produces a flow regime with a very wide range. The 10 Percentile flow at Glan Teifi is 63.1 cumecs and the 95 Percentile flow is 3.04 cumecs; mean flow is 28.2 cumecs.

3.4 Dee to Manley Hall/Erbistiock

Catchment geology is described as: 75% shales, slates, mudstones and palaeozoic grits; 25% extrusive igneous and Carboniferous rocks (Institute of Hydrology, 1993). Baseflow index is calculated at 0.52.

With the Dee and its upper tributaries rising at altitudes approaching 900 m, and situated on the western side of Britain, annual rainfall can be very high. The range of average annual rainfall is large, with values in excess of 2500 mm to the west of Llyn Celyn. Lower down the catchment, in the region of Manley Hall, annual rainfall values below 800 mm prevail. (Dee and Clwyd River Authority, 1971).

The combination of high rainfall and thin soils covering impervious rocks, often on steep slopes, produces a flow regime which is very responsive to rainfall, and has a wide range. Natural storage within the catchment is quite low, and flows fall off quickly in dry weather. For example, looking at the sub-catchment to Bala (area 261.6 square kilometres, NGR SH 942357), for the period 1957-1985, the 10 Percentile and mean flows are 29.4 and 12.54 cumecs respectively. The 95 Percentile flow is 2.10 cumecs (Institute of Hydrology, 1993).

3.5 Derwent to Derby St. Marys/Longbridge Weir

Catchment geology, in the upper reaches of this large upland catchment, is mainly Millstone Grit and Carboniferous Limestone. The lower catchment geology is, in the main, Coal Measures on the 1b and Triassic sandstones, and further Millstone Grits - baseflow index is 0.62 (Institute of Hydrology, 1993, and Trent River Authority, 1971).

The Derwent rises near Howden Moor, in the north of the catchment, where elevations can exceed 600 m. With much gentler relief towards the gauging station at Derby, elevations are generally below 150 m. Average annual rainfall, for the 'high' sub-catchment above Yorkshire Bridge (NGR SK 198851), for the period 1933-85, is 1377 mm (Institute of Hydrology, 1993). Annual rainfall values in the order of 700 mm or less, are common in the Derby area.

The presence of Carboniferous Limestone and Millstone Grit offers the potential for reasonable groundwater storage within the catchment. Nevertheless, the upland peats and steep slopes encourage a quick response to rainfall. Therefore the resulting flow regime displays quite a high range. The 10 Percentile flow at Derby for the period 1935-85 is 36.3 cumecs, with the 95 Percentile flow being 5.07 cumecs; mean flow is 17.7 cumecs.

4. DEVELOPMENT OF AREAL RAINFALL SERIES

4.1 The General Method Used

The general methods used to derive catchment areal-rainfall series, for the purposes of riverflow reconstruction, are described by Jones (1983). Jones (1984) and Wigley *et al.* (1984) have estimated that about five to six homogeneous records are needed in catchments of up to 1500 km^2 to give a specified level of accuracy. The absolute accuracy of the areal catchment series depends on the rainfall variability across the catchment. With this level of rain gaugess, the areal average catchment series will correlate to 0.97 or better with the hypothetical 'infinity-sampled' catchment (Wigley *et al.*, 1984). (The largest catchment within the present study is that of the Medway to Teston, which has an area of 1256 km^2).

Rainfall records, for the period pre-1961, were photocopied from the archives held at the United Kingdom Meteorological Office (UKMO), Bracknell. Attempts were made to achieve a good spatial coverage of each catchment, with particular attention to the presence of any upland parts of the catchment. Post-1960 records, which followed on from those copied from UKMO, were obtained (on computer disk) from regional National Rivers Authority (NRA) archives. All rainfall data were collected and analysed as monthly totals.

The need to have good spatial coverage of the catchments, along with good continuity of (homogeneous) site specific data series is, as always, tempered by the quantity and quality of the records held. Inevitably older records, for various reasons, suffer from problems of insufficient quality control. In addition, very long-run site-specific records are rare. Thus the need to be able to make preliminary assessments of quality control, before the amalgamation of records from a wider area, is vital.

Homogeneity testing, described by Craddock (1977) and Jones (1980, 1981), requires at least one long, and relatively local record which is known to be homogeneous. The need for such 'homogeneity standards' may require the use of records from outside the catchment area. For example, the areal-rainfall determination for the Derwent involved the use of the Redmires record which lies to the east of the catchment (see Table A2.5, Appendix A).

Tables A1.1-A1.5 give full details of all rainfall records collected during the production of the six or seven catchment specific homogeneous series. Tables A2.1-A2.5 give a breakdown of the individual components of all compiled records, along with the correction factors (based on total rainfall within an overlap period or, alternatively, on UKMO long term averages for a standard period) necessary to adjust the record from one location to another. Figures A2.1-A2.5 show the location of the long homogeneous gauge records and the location of the most recent gauge used in localised compilations.

The correction factors do not always correspond to the transition between component gauge records within a particular compilation. In many instances, correction factors have been applied within records and across transition boundaries. If an inhomogeneity was detected within specific gauge records when they were compared with the standards, then a correction factor was applied, regardless of whether the cause could be ascertained.

Inter-record inhomogeneity can occur for a whole host of reasons. The most common cause is from changed exposure of the gauge. This may be due to slight changes of gauge location, or growth around the gauge location by trees or shrubs. Indeed, codes of practice for observers have changed with time and such changes can produce record inhomogeneity.

Once the six or seven homogeneous rainfall series had been finalised for each catchment, they were combined to produce a catchment-areal series for the period c.a. 1850-1995.

The monthly combined series were produced by the following equation:

$$\mathrm{ACC} = \sum_{i=1}^{N} \frac{\mathrm{AAAR}}{\mathrm{AAR}_i} g_i$$

where g_i is the monthly total at gauge i of N gauges
AAR_i is the 1961-90 annual average rainfall at gauge i*
AAAR is the 1961-90 areal annual average rainfall for a catchment**
and ACC will be the monthly average catchment rainfall

*if 1961-90 standard-period values not available, 1941-70 values used
**1961-90 standard-period values not commonly available, see Table 4.1 below

Figure A3 shows the sequence of the number of rainfall records on which the catchment estimate is based. It should be noted that numbers reduce rapidly during the 1850-1880 period. The reliability of catchment rainfall, for this early period, should be judged by the number of gauge records available.

Winters with appreciable snowfall can, of course, significantly affect the timing of the appearance of precipitation as a component of riverflow. However, to correct for this, it is necessary to have a daily temperature as well as rainfall series for each catchment. The acquisition of such data can prove very expensive and the occurrence of such winters is not common. Snowfall correction has been omitted from this work. Without snowfall correction, it would be the winter and spring periods when resultant errors would be seen in reconstructed flow series. The (predominantly upland) catchments of the Derwent, Dee and Teifi would normally be the most affected, and the potential for error from this source should be borne in mind when reconstructed flow data are used. The monthly timescale implies that reconstructed flows are best for low flow studies.

4.2 The Method Applied to the Five Catchments

The following sub-sections detail the application of areal-rainfall determination to the individual catchments. Table 4.1 gives catchment area, details of the number of rain gauge series used in areal-rainfall calculation, average catchment rainfall, and the period over which average catchment rainfall was calculated (see Section 4.1 above).

Table: 4.1 Catchment area, number of rain gauge series used and catchment-average rainfall (for the period c.a. 1961-90)

River	Gauging Station	Area (km^2)	No of rainfall series used	Period of catch. ave.	Catch. av. (mm)
1. Medway	Teston	1256	6	1956-90	752
2. Itchen	Highbridge & Allbrook	360	6	1958-90	846
3. Teifi	Glan Teifi	894	6	1959-90	1349
4. Dee	Manley Hall/Erbistock	1019/ 1040	6	1937-90	1402
5. Derwent	Derby/Longbridge Weir	1054	7	1941-70	1001

4.2.1 Medway to Teston

The catchment of the Medway does show a relationship between elevation and rainfall received (Chapter 3.1). However, the localised variation in relief is insufficient to produce high spatial variability of annual rainfall between rain gauges within a localised region.

With the Medway area having a history of good continuity of site-specific rainfall records, it was not a difficult operation to produce six homogeneous rainfall series. (The long record at Falconhurst (Tables A1.1 and A2.1) proved a good 'homogeneity standard'). A relatively good spatial coverage of the catchment was obtained, with a slight bias to the west and south (Figure A2.1). This bias coincides with the wetter parts of the catchment, thus helping somewhat towards an accurate areal-rainfall series.

4.2.2 Itchen to Highbridge and Allbrook

As with the Medway, there is a relationship between elevation and rainfall and, again, the geography of the catchment is such that high variability of rainfall catch is not present within localised areas. The production of apparently good compilations was not a difficult task. Continuity of site specific records is quite good within this catchment.

There were a few problems with the choice and use of the 'homogeneity standard'. The use of the Chilgrove record, (whilst some 25 km. to the east), with its site specific continuity, as the 'homogeneity standard', did not prove to be straightforward. On comparison with the other five rainfall series, there were common discontinuities with the annual catch ratios. This suggested the possibility of inhomogeneity within the Chilgrove record.

After experiments with the use of the Southampton record as the 'homogeneity standard' and comparison of Southampton and Chilgrove records, Southampton became the 'homogeneity standard', but only after a degree of modification itself (Table A2.2). Figure A2.2 shows a good spatial coverage by the catchment rainfall measurement-series network, the basis for *the* catchment monthly series.

4.2.3 Teifi to Glan Teifi

The availability of rainfall records for rural west Wales, for the 19th and early 20th Centuries, is poor compared to many other parts of Britain. This is doubly unfortunate from the perspective of catchment areal rainfall determination. In areas of high relief, close to Atlantic shores, a high variability of catch, both between and within specific localities may be expected. It is therefore difficult to compile local rainfall series from sparsely distributed and often (temporally) discontinuous records.

This lack of coverage is, to some degree, mitigated by the historic interest in Welsh and other UK upland catchments for water resource purposes. Rainfall measurement networks, often in relatively confined but high-rainfall areas, have been maintained for resource assessment purposes since well back into the 19th Century. For example, several gauges have been run in the adjacent Claerwen (upper Wye) catchment for these reasons. The rainfall measuring station at Bwlchyrhendre (Table A1.3) is one such gauge and was run by, or for Birmingham Water Works from 1892 to 1983.

At first sight, the spatial distribution of rainfall series (Figure A2.3) for the Teifi catchment is not ideal, with quite a strong bias towards the north east of the catchment, and many of the stations are outside the catchment altogether. This is a true reflection of the availability of historic rainfall data, and also reflects the points made earlier.

However, the area to the north east of Tregaron has the highest elevations and annual rainfall in the Teifi catchment (Chapter 3.3). This is the area where much of the flow in the Teifi originates. High density (rain gauge) coverage of this area is probably advantageous to the generation of an accurate catchment-rainfall series. A compiled rainfall series based on the area around Rhayader (Tables A1.3 and A2.3), in the upper Wye catchment, provided the 'homogeneity standard'.

4.2.4 Dee to Manley Hall/Erbistock

Historically, the Dee catchment has been reasonably well covered by rainfall measurement stations, not least, due to its intensive use for water resource purposes over many decades. It is also adjacent to other areas of long standing water resource interest. Alwen Reservoir, in the north of the catchment was constructed during the 1920s to supply Birkenhead. Lake Vyrnwy which lies just to the south of the Dee catchment (upper Severn), has been used by Liverpool Corporation since about 1880.

Lying close to Atlantic shores and with pronounced differences in relief, rainfall varies greatly within the catchment (Chapter 3.4). The resource interests have greatly improved rainfall-measurement by their concentration on what would otherwise be a sparsely populated upland area with little or no observation. A compilation of rainfall records from the Bala area served as the 'homogeneity standard' (Tables A1.4 and A2.4).

4.2.5 Derwent to Derby St. Marys/Longbridge Weir

Once again, a long standing interest, from a water resource perspective, has encouraged rainfall measurement in the high rainfall/runoff parts of the catchment. Water resource development, as initiated by the Derwent Valley Water Act (1899), led to a network of rain gauge sites in the northern part of the catchment around 1900 (Thompson and Saxton, 1963).

This interest in the more remote parts of the catchment has combined well with a relatively good record of observation in the lower catchment and adjacent areas. Seven homogeneous rainfall series provide a good coverage of the catchment (Figure A2.5). The long record from Redmires (Table A1.5 and Figure A2.5) made a good 'homogeneity standard'.

5. OBSERVED FLOWS FOR THE CATCHMENTS

5.1 The General Availability of Relevant Flow Data

Four out of the five catchments in the study, experience moderate to extensive artificial modification of flows. The Teifi stands alone in having an essentially natural flow regime. Hence, it is important that the observed flow series be 'naturalised' before calibration (and validation) of the reconstruction model.

The more complex the catchment water use strategy, the more complex the 'naturalisation' process. Flow 'naturalisation' is made even more difficult where abstraction is predominantly from groundwater (eg the Itchen); the problem here being one of timing the effect of abstraction on flow. The complexity involved, and thus the investment required to produce realistic 'naturalisation' of observed flows, means that long series are not always available. Table 5.1 shows the availability of all flow series for the five catchments.

Table: 5.1 Flow Data Availability (Complete years)

Catchment	Observed flow (period)	Naturalised flow (period)
1. Medway to Teston	1957-95	1957-93
2. Itchen to Highbr.+ Allbrook	1959-95	1959-88
3. Teifi to Glan Teifi	1960-95	-
4. Dee to Manley Hall/Erbist'k	1937-95*	1937-89*
5. Derwent to Derby St. Marys/ Longbridge Weir	1935-95**	1977-93

* -the data in these series are regarded as being of variable quality (Chapter 5.2.4).
** -the data in this series, are regarded as being of variable quality (Chapter 5.2.5).

In addition to the catchment flow data, a further three flow series have been located which were of potential use for validation purposes. These have been used to evaluate further, the accuracy of reconstructed flow series for the Dee, Itchen and Derwent. All of these additional series are long, and relate to nearby catchments with similar (catchment) characteristics.

These are:

1. 'Naturalised' flows for the Vyrnwy (Vyrnwy Reservoir, Stn. No. 54003), for the period 1879-1989.*

2. Observed flows at Bedhampton Springs (location near Portsmouth), for the period 1909-92.*

3. Observed and naturalised flows for Yorkshire Bridge (Upper Derwent sub-catchment, Stn. No 28001), for the period 1936-74 (Thompson and Saxton, 1963 and Marsh, T., personal communication)

*Marsh, T., personal communication.

5.2 Specific Flow Series and their Use

5.2.1 Medway to Teston

Flow gauging at Teston began in 1956 and a 'naturalised' flow series has been produced by Southern Region NRA, for the period January 1957 to October 1994. The mean monthly observed flow for this period is 10.9 cumecs. The mean monthly 'natural' flow for the same period is 11.1 cumecs. However, when compared on a month by month basis, the observed and 'natural' monthly flows can differ quite markedly. This shows the maximum augmentation of flow to be 8.4 cumecs. and maximum loss to flow (by abstraction) to be 11.0 cumecs. Significant flow modification is therefore possible.

Water use is complex. The presence of the artificial reservoirs in the upper reaches permits the primary resource use strategy, which is one of direct abstraction in the lower reaches with flow augmentation in the upper reaches when necessary. Bewl Water, which is south east of Tunbridge Wells, is the most important regulating reservoir (Oakes, S., Area Catchment Management Officer, personal communication). Hence the need to 'naturalise' the observed flow record, for the purposes of relating rainfall and runoff.

5.2.2 Itchen to Highbridge and Allbrook

Gauging began at this 'split-channel' site in 1958. Abstractions are predominantly from groundwater and flows can be augmented from groundwater in dry periods. Other than some problems due to weed growth prior to 1971, when the rated river section was superseded by a Crump weir (Institute of Hydrology, 1993), there is reasonable confidence in the accuracy of measured flows.

Observed flows have been 'naturalised' by personnel from the Worthing office of the National Rivers Authority (NRA). The 'naturalised' series runs from October 1958 to July 1989 and the data have been provided by the Hampshire Area Office of the NRA. Comparison between observed and 'naturalised' monthly flow series shows that the mean loss to flow to the gauging point, due to net abstraction, amounts to 1.037 cumecs. However the following points must be made about the methods used for the 'naturalisation' process:

1. Abstractions from groundwater were treated as having an instantaneous effect on flows. Catchment storage processes were not considered.

2. A significant groundwater abstraction, that at Easton (NGR SU 500321, licensed quantity 27Mld), was not included due to lack of data.

3. There is the potential for significant re-routing of groundwater by the extensive cress farming operations in the river valley. If natural spring flow becomes insufficient, pumping is resorted to. The combined flow of groundwater 'through' cress farms is more than 1 cumec.

(Pearce, J., Water Resources Officer, NRA, Winchester, personal communication.)

With an apparent loss to flow (to the gauging point) of more than 1 cumec, there is an unquestionable need to 'naturalise' observed flows for the purposes of rainfall/runoff modelling. However, the information above leaves some doubt as to the likely accuracy of any 'naturalised' flow series produced.

5.2.3 Teifi to Glan Teifi

The catchment is very rural with little in the way of urban or industrial development. It has escaped water resource development by external interests, because of its geographical location. The natural lakes in the upper catchment are, however, used as impounding reservoirs, and some water is lost to direct abstraction. Flows are essentially natural, and no attempts have been made to adjust observed values.

There is a flow record for the station at Glan Teifi for the period 1959-1995. The gauging point uses a natural river control which is rated. Except for a number of missing (monthly) values in 1970 (which have been substituted for by their reconstructed counterparts where necessary), there are no known problems with the record. The flow series has been supplied by the Welsh Region of the National Rivers Authority.

5.2.4 Dee to Manley Hall/Erbistock

Manley Hall superseded Erbistock as the principal flow gauging station on this part of the Dee in 1970. Erbistock has a relatively stable river section which was used for flow gauging. Stage was related to flow by the use of current meters but their use was difficult in this particular location. This, and further problems due to seasonal weed growth, have cast doubt on the stage/discharge relationships obtained (Mayall, S., NRA Area Hydrologist, personal communication). Extensive examination and re-working of the Erbistock record by successive river authorities (including the use of correlations with flow records from higher in the catchment), suggests that the record is flawed, particularly in the period 1956-64.

A combination of naturally occurring lakes (eg. Lake Bala), and natural valleys, which facilitate the construction of artificial storage, along with high rainfall/runoff, has promoted large scale human intervention in order to utilise the water resources of this catchment. The relative proximity of the area to industrialized, and thus heavily populated, parts of north west England has led to heavy modification of flows on the Dee since the latter half of the 19th Century.

A mixture of direct export of water from the upper catchment via aqueducts, and, more recently, the augmentation of flows by controlled release from upland water bodies to facilitate abstraction in lower reaches, makes the Dee a highly managed river. Particularly since the Lake Bala Scheme in the late 1950s, which provides massive storage in the upper catchment, flood flows have been reduced, and low flows significantly augmented in the lower reaches.

Gauged or observed flows must be adjusted to reflect what the natural situation would be, for the purposes of relating rainfall and runoff. A 'naturalised' flow series for Manley Hall has been supplied by the Welsh Region of the National Rivers Authority. The series of monthly-mean flows covers the period 1937-1989. There is good confidence in the accuracy of the post-1969 part of this record.

5.2.5 Derwent to Derby St. Marys/Longbridge Weir

Derby St. Marys (ultrasonic mechanism) superseded Longbridge Weir as the principal flow gauging station, on this part of the Derwent, in the early 1980s. Flow gauging began at Longbridge Weir in 1935. The weir was not constructed as a gauging structure and, primarily because of its length (92 m), and variable (seasonal) algal formation, there were inherent problems of insensitivity. The weir was shortened in 1971, to increase the sensitivity of flow measurement. (Trent River Authority, unpublished material, 1974).

The proximity of this wet upland area, with its steep natural valleys, to centres of heavy industrial activity, invited its exploitation for water resources. The Derwent Valley Water Act, 1899, set up the Derwent Valley Water Board which impounded the upper Derwent and its tributary, the Ashop. Water was subsequently supplied to the Corporations of Derby, Leicester, Nottingham and Sheffield, and to local authorities in Derbyshire (Thompson and Saxton, 1963).

The main export of water from the catchment, via direct abstraction, takes place at the Lady Bower Reservoirs. There is also direct abstraction for Derby, which takes place above the gauging point. Since 1993, river regulation has been possible, with the construction of a pipe line to Carsington Reservoir (NRA, 1995).

Gauged or observed flows must, therefore, be adjusted for the above interventions, which have the potential to produce significant modification of natural flows. A lack of relevant data has only permitted the production of a 'naturalised' flow series for the period 1977-1993 This data series of mean monthly flows has been supplied by the Severn Trent Region of the National Rivers Authority.

An extended source of partially 'naturalised' flows for this catchment has been obtained by the use of flow records for Yorkshire Bridge (Section 5.1). By subtracting observed from naturalised flows at this location, for the period 1936-74, it has been possible to quantify the monthly loss (export from Lady Bower Reservoir). This was a major source of flow modification for the period in question, and it has been possible to add the 'lost' flow to the observed values from the Longbridge weir record, thus producing a partial 'naturalisation'.

6. RIVERFLOW RECONSTRUCTION

6.1 Model Calibration and Testing

During the last 25 years, the UK has experienced notable oscillation between dry and wetter periods, with perhaps the most notable events being those of prolonged, below-average-rainfall. For this reason, it was felt that model calibration would, ideally, be centred on the last 20 or so years. However, the choice of calibration period was, to a degree, constrained by the availability of appropriate 'naturalised' flow data (Table 5.1). Where choice of period was available, the latter parts were used for calibration and earlier parts of data sets were set aside for validation purposes (Table 6.1).

Basic regression equations for all five catchments, and the optimisation methods for regression parameters, are described by Wright (1978). Model calibration was undertaken on a catchment by catchment basis. Comparison of observed and reconstructed flows for the calibration, and where possible, validation periods, took various forms. It should be remembered here that 'observed' flows are gauged-flows, adjusted for net abstractions (naturalised) where appropriate (see Chapter 5.1). Table 6.1 lists calibration and validation periods and summarises various comparison statistics. Table 6.2 is similar in that the tools of comparison are the same, however, the period of comparison is set at 1970-93. This table has been produced to compliment a similar analysis undertaken by Jones and Lister (1995), for earlier work with ten catchments in England and Wales. Due to the shortcomings of flow data series, there are several instances where complete 1970-93 comparisons have not been possible.

An approximate determination for Q90, a measure of the modelling performance for low flows, is included in the above tables. It was calculated by listing (in ascending order) the observed and reconstructed flow series for the given period. The value approximating the 10% position in the series is the value quoted. This approximation to Q90 is not a true flow duration statistic and its approximate nature is exacerbated by the use of relatively short monthly flow series.

The production of 'seasonal' statistics, extends further the comparison of observed and reconstructed flows. (The period for this analysis is 1970-93, and matches the tables produced by Jones and Lister, 1995. The additional 1988-92 seasonal analysis is designed to concentrate on that notably prolonged dry period). Observed and reconstructed values of mean-monthly flows for a succession of consecutive months, and over specific periods, can be compared to evaluate model performance on a seasonal basis. For example, are summer (April-September) flows modelled better than, say, whole year (January-December) values? Tables B1.1-B1.5 list the seasonal comparisons by catchment. Similar seasonal statistics have been produced as part of the additional validation exercises (Section 6.2).

To allow a visual assessment of model performance, across the range of flows for each catchment, flow duration curves have been produced which compare reconstructed and observed flows for identical time periods. (Further comparison is facilitated by the addition of the curve which represents the 1860-1995 reconstructed flows.) Here, 'observed' flows are those which have been used in calibration and validation exercises. In several of the study catchments, (for a variety of reasons) the validation and calibration observed-flow series are not concurrent (see Tables 5.1 and 6.1). However, meaningful flow duration statistics rely upon relatively long data series. It was felt, therefore, that calibration and validation periods could not be treated separately.

Graphical representation of all time-series analysis given in Appendix B. Figures B1.1-B1.5 show the observed and reconstructed monthly flows for each catchment. Figures B2.1-B2.5 show the reconstruction errors (observed minus reconstructed monthly-flows) for each catchment, for the period 1956-95. (The period 1956-95, whilst not universally complete, was used for all catchments as an aid to visual comparison). Figures B3.1-B3.5 show the flow duration comparisons.

Table 6.1: Comparison of Reconstructed and Observed Monthly Flows - 1. Calibraton Periods 2. Validation Periods

Catchment	Gauge	Period	Calibration R^2%	Means Obs.	Means Rec.	R R_u	R R_T	Durbin-Watson D_u	Durbin-Watson D_T	Appx. $Q90_O$	Q_{90} $Q90_R$
1 Medway	Teston	1970-93	91.7	10.42	10.08	0.94	0.96	2.05	1.62	1.47	1.62
2 "		1957-69	-	12.25	10.88	0.95	0.96	1.68	1.74	1.91	1.81
1 Itchen	Highbridge + Allbrook	1969-88	94.1	6.37	6.37	0.96	0.97	0.96	1.03	4.48	4.46
2 "	+	1959-68	-	6.47	6.68	0.91	0.93	0.41	0.50	4.51	4.68
1 Teifi	Glan Teifi	1971-94	90.0	28.24	27.61	0.94	0.95	1.98	1.57	4.91	5.76
2 "		1960-69	-	28.45	27.86	0.94	0.91	1.94	1.71	7.09	7.96
1 Dee	Manley Hall/Erbistock	1970-89	91.5	31.71	32.83	0.93	0.94	2.34	1.85	5.50	7.69
2 "	*+	-	-	-	-	-	-	-	-	-	-
1 Derwent	Longbridge/Derby St. Marys	1977-93	93.0	21.07	20.88	0.95	0.96	2.26	1.88	7.26	7.95
2 "	*	-	-	-	-	-	-	-	-	-	-

R_u - Correlation of the monthly 'observed' and reconstructed series [Untransformed]
R_T - Correlation of the monthly 'observed' and reconstructed series [Transformed (log_{10})]
D_U - Durbin-Watson D statistic calculated from the monthly 'observed' and reconstructed series [Untransformed]
D_T - Durbin-Watson D statistic calculated from the monthly 'observed' and reconstructed series [Transformed (log_{10})]
$Q90_O$ - Observed
$Q90_R$ - Reconstructed

+ - Additional verification exercises have been undertaken using historic flow data from a nearby catchment - see Chapter 5, Chapter 6 and Tables B2 and B3.

* - Verification exercises have been undertaken using historic flow data from the same catchment, but the observed data are inherently less reliable - see Section 5, Section 6 and Tables B2 and B4.

Table 6.2: Comparison of Reconstructed and Observed Monthly Flows - 1970-93

		Means		R		Durbin-Watson		Appx.	Q90
Catchment	Gauge	Obs.	Rec.	R_u	R_T	D_u	D_T	$Q90_O$	$Q90_R$
Medway	Teston	10.42	10.08	0.94	0.96	2.05	1.62	1.47	1.62
Itchen	Highbridge + Allbrook	-	6.23	-	-	-	-	-	4.44
Teifi*	Glan Teifi	28.22	27.48	0.94	0.95	1.93	1.53	4.91	5.76
Dee	Manley Hall/Erbistock	-	33.02	-	-	-	-	-	7.77
Derwent	Longbridge/Derby St. Marys	-	19.61	-	-	-	-	-	7.79

R_u - Correlation of the monthly 'observed' and reconstructed series [Untransformed]
R_T - Correlation of the monthly 'observed' and reconstructed series [Transformed (log_{10})]
D_U - Durbin-Watson D statistic calculated from the monthly 'observed and reconstructed series [Untransformed]
D_T - Durbin-Watson D statistic calculated from the monthly 'observed and reconstructed series [Transformed (log_{10})]
$Q90_O$ - Observed
$Q90_R$ - Reconstructed

*Missing values (March, April, August) in the Glan Teifi record for 1970 have been substituted by the reconstructed ones.

6.2 Full Reconstructions and Further Testing

Monthly flow reconstructions were produced for the period c.a. 1850-1995. Given good calibration performance, the reliability of catchment rainfall series poses the most obvious constraint to the production of realistic flow reconstructions. Calibration requires that input flows reflect the characteristics of a natural catchment, and the likelihood of this is discussed in Chapter 5. The possibility of a change in flow characteristics, with time, through changes in catchment-land or resource use cannot be discounted. However, such changes are notoriously difficult to quantify or even detect. For example, after extensive analysis of flow data for three lowland rivers in East Anglia, there was little evidence of changed flow behaviour, at a catchment level and over several decades, despite known changes in land and resource use (Boar *et al.*, 1994). The variability of flows due to the fluctuation of weather patterns over years or even decades, serves to mask all but the most extreme catchment-management induced changes in flow behaviour.

Early flow reconstructions should be judged by the strength of early rainfall determinations and Figure A.3 is the guide to this. Figures B4.1-B4.5 show the monthly reconstructions for all catchments, for the period 1850-95. Figures B5.1-B5.5 show the reconstructed annual-mean flows, with observed values when available, for the same period.

Following the full reconstruction exercise, it was possible to undertake further validation exercises. These were additional comparisons of observed (or proxy observed) flows and their reconstructed counterparts. (A listing and details of the observed series used is given in Chapter 5.1.) The Vyrnwy flows were scaled-up according to the ratio of the mean-flow for the Dee to that of the Vyrnwy. This allowed further comparison for the period 1879-1989. Figures B6.1-B6.6 show the monthly comparison for the whole period. Statistics of comparison are given in Table B2

Additionally for the Dee, a comparison of Erbistock observed flows, with those reconstructed, was possible in the knowledge that the Erbistock record for the period 1938-1955 was flawed, but reasonable (Chapter 5.4.2). Figure B7 shows the monthly comparison of observed ('naturalised') and reconstructed flows for this period, and statistics are given in Table B2

In a similar exercise (to that described above for Vyrnwy flows), a scaling-up of the Bedhampton Springs series, to the levels of the Itchen, has allowed a comparison of 'observed' and reconstructed flows for the period 1909-1992. Figures B8.1-B8.3 show the complete comparison, and statistics are given in Table B3.

The partially 'naturalised' series for the Derwent at Longbridge Weir, has also been compared with reconstructed flows for the period 1936-1974. Figures B9.1 and B9.2 show this comparison. Statistics are given in Table B4.

6.3 Evaluating the Catchment Reconstructions

This section assesses the reconstructions with reference to comparison statistics (Tables 6.1, B1.1-B1.5 and B2-B4), and the graphical presentations which are shown as time-series Figures in Appendix B.

6.3.1 Medway to Teston

The calibration period analysis (Table 6.1) suggests that the model performance is good. There is strong correlation between observed and reconstructed monthly-flows, with a small shortfall in the reconstructed mean-monthly flow. The Durbin-Watson statistic shows that autocorrelation of the residuals (observed minus reconstructed) flow is minimal.

For the validation period, autocorrelation increases slightly and there is a larger shortfall in the reconstructed mean-monthly flow. Given the confidence in the catchment areal-rainfall series (Chapter 4.2.1), it seems more likely that there are some problems with the naturalised flow series (Chapter 5.2.1), which have led to the underestimation flows during the validation period. This shortfall in flows is shown by the plots of annual mean flow (Fig. B5.1).

The seasonal comparison statistics (Table B1.1) show a good model performance for all seasons, and this is illustrated by the observed versus reconstructed monthly-flow plots (Figs. B1.1a/b). The flow duration comparison for this catchment suggest a good agreement between observed and reconstructed series across the full range of flows (Fig. B3.1).

6.3.2 Itchen to Highbridge and Allbrook

A lack of up-to-date 'naturalised' flow data, beyond 1988, has not allowed the 1988-1992 dry period to be included in any calibration or validation exercises. With respect to mean-monthly flow prediction, and correlation between observed and reconstructed flows on a monthly basis, the calibration looks impressive (Table 6.1). However, this is to some degree a function of the natural predictability of the 'textbook chalk stream', where virtually all precipitation is routed, via the chalk aquifer, to the river channel.

The Durbin-Watson statistic and the plot of (observed minus reconstructed) flows (Fig. B2.2), reveals quite a high degree of autocorrelation. This applies to calibration and validation periods, and may well be due to an expansion and contraction of the groundwater catchment area during wetter or drier periods. Wright (1978), urges caution with this type of catchment modelling, that is, for catchments not having the same topographical and groundwater divides. The simplified naturalisation techniques used for this catchment (Chapter 5.2.2), may also be partly responsible for the autocorrelation in the residuals.

There is a notable period in late 1960/early 1961 (Fig. B1.2a),when the model markedly over estimates the flow. (This follows a period of high catchment rainfall for the second half of 1960). The annual-flow time series (Fig. B5.2) shows the same anomaly, but does not show any reverse trend in the next year or so. Either the catchment rainfall has been exaggerated or, more likely, there is some problem with the observed flow series. The gauging weir at Highbridge can drown, that is, flows can exceed the measuring capacity of this gauging structure (Institute of Hydrology, 1993). At other times, seasonally or otherwise, observed and predicted flows show good agreement.

The comparison (plots) of reconstructed flows with those from Bedhampton springs (Figs. B8.1-B8.3), show excellent synchronisation. For much of the comparison period (1909-1992), the reconstructed flow shows greater amplitude, with over-estimation of winter flows and under-estimation of summer flows. The difference here could be down to that small component of Itchen flows which does not follow the groundwater route to the river. Table B3 gives comparison statistics for the series.

Flow duration comparison techniques (Fig. B3.2), when applied to this catchment, neither add to, nor detract from the above summary relating to model performance.

6.3.3 Teifi to Glan Teifi

Both calibration and validation period analyses, using observed and reconstructed monthly flows, show close agreement by almost all measures used (Table 6.1). The most notable differences are, at 17% for calibration and 12% for validation, between observed and reconstructed Q90 flows. This apparent divergence between observed and reconstructed series, at lower flows, is also shown in the flow duration comparison (Fig. B3.3). However, caution is required here with the use of a log scale which distorts the vertical scale through the range of flows.

The Durbin-Watson statistic indicates minimal autocorrelation in the residuals, and this is illustrated by the 'error' plot (Fig. B2.3) for the period 1959 to 1995. The monthly comparison plots (Figs. B1.3a/b) show good agreement between observed and reconstructed summer low flows. The 'seasonal' comparison, for the period 1970-93, indicates good all-round model performance, with only the 'July-September' seasonal analysis showing any degree of difference (Table B1.3).

Despite the lowest (at 90%) calibration coefficient of multiple-correlation for all the catchments in the present study, flow reconstruction appears very good (Table 6.1). The poorer calibration 'fit' is probably due to the difficulties in producing the catchment precipitation series (Chapter 4.2.3). However, this has probably been mitigated by the quality of the observed flow series (Chapter 5.2.3).

6.3.4 Dee to Manley Hall/Erbistock

As with the Itchen, it was not possible to include the 1988-92 dry period in any calibration or validation exercise, due to a lack of recent 'naturalised' flow data. In this case, the reliable observed flow series begins in 1970 and ends in 1989. In addition to the lack of coverage of the latter period, it was felt that there were insufficient data to allow meaningful validation and calibration exercises. However, older flow series (see later in this Section) have allowed a degree of model testing.

The comparison of observed and reconstructed monthly flows for the calibration period shows that model performance is good (Table 6.1). This is generally borne out by the time-series comparison, however, there is a recurring tendency to both over-estimate, and under-estimate, higher winter flows (Figs. B1.4a/b). Mean flow is very close and correlation is good. The Durbin-Watson statistic does suggest a degree of autocorrelation and this can be seen in the residuals (Table 6.1). Seasonal statistics do not single out any particular season as being poorer than others (Table B1.4). The close agreement for the winter indicates that the model over-estimations are evened out by those of an opposite nature, suggesting that it is probably related to snowpack development. At lower flows, the flow duration comparison shows that observed and reconstructed flows are very close over the observed-flow-availability period. However, the 1860-1995 curve shows lower values and suggests that, in the longer term, drier summers were more common (Fig. B3.4).

The comparison of reconstructed flows with those of the Vyrnwy catchment (Chapters 5.1 and 6.2), allows a very long check on model performance. (However, assumptions are being made as to the common nature of flow response for the two catchments). Good synchronisation is evident from the time-series comparison (Figs. B6.1-B6.6). The comparison statistics (Table B2) show remarkably good agreement, on an annual mean flow and 'summer seasonal' basis. Good estimation of low flows is evident throughout the whole period, with the possible exception of the period 1970-1990.

The comparison with the Erbistock series (1938-55, Chapters 5.1 and 6.2) also shows very close agreement, particularly during summer periods, between observed and reconstructed flows (Fig. B7). This impression is corroborated by the statistics shown in Table B2.

Whilst there is good confidence in the rainfall series derived for this catchment, there is little information regarding the 'naturalisation' technique or the likely quality of adjusted flows. However, there is no evidence from the analysis undertaken which suggests problems with the 'naturalised' flow series.

6.3.5 Derwent to Derby St. Marys/Longbridge Weir

A lack of suitable flow data has meant that calibration has missed the early to mid 1970s, when dry periods were notable. However, the 1988-1992 dry period was included. As with the Dee, there were insufficient data to include a validation period such as that used on the Medway, for example.

Model performance, from a monthly perspective, and for the calibration period, is good. Mean flows are very closely reconstructed and correlation is very strong. Low summer flows are well estimated, and Durbin-Watson statistics suggest only slight autocorrelation in the residuals (Table 6.1). Reference to the 'seasonal' analysis (Table B1.5) shows very close agreement between observed and reconstructed flows.

Fortunately, it is possible to have a degree of validation outside of the calibration period. This has been achieved by the use of the 'partially naturalised' series for Longbridge Weir, for the period 1936-74 (see Chapters 5.1 and 6.2). Both the synchronisation, and magnitude of monthly reconstructed flows, for this whole period, look good (Figs. B9.1/2). The comparison statistics (Table B4) strengthen the evidence of a good model performance. The flow duration comparison (Fig. B3.5), which includes the Longbridge Weir flow series, serves to emphasise the close agreement between observed and reconstructed flows described above.

The high confidence in the quality of rainfall determination for this catchment; and a similar confidence in the 'naturalised' flow series (following NRA details of derivation etc.), appear to be justified by the results of the modelling exercise on this catchment.

6.4 General Conclusions

The previous sub-sections emphasise the general good fit of reconstructed flows and their observed (natural) counterparts through the calibration and verification periods, and thus by inference, through the whole of the period of reconstruction. The type of model used with monthly time increments, is aimed at giving a simple but effective way of extending flow series, with the emphasis on the accuracy of flow levels during abnormally dry periods (Wright, 1978). The general performance through calibration and verification periods has been in line with these aims.

The largest errors (Figs. B2.1-B2.5) occur at the higher flows (Figs. B1.1-B1.5). One potential source of large error during the winter months is the absence of any mechanism within the model used which allows for the build-up, and subsequent thawing of snowpacks during particularly cold winters. Indeed, the model does not have a complex approach to the possibility of normal catchment storage mechanisms being overcome by, for example, prolonged rainfall of high intensity.

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REFERENCES

Boar, R.R., Lister, D.H., Hiscock, K.M. and Green, F.M.L., 1994: The Effects of Water Resource Management on the Rivers Bure, Wensum and Nar, North Norfolk. Final Report to the National Rivers Authority (Anglian Region).

Craddock, J.M., 1977: A homogeneous record of monthly rainfall totals for Norwich for the years 1836-1976. *Meteorol. Mag., 106,* 267.

Dee and Clwyd River Authority, 1971: First Periodical Survey of Water Demands and Resources, 1963 Section 14. Mason, Chester.

Hampshire River Authority, c.a. 1972: First Periodical Survey.

Institute of Hydrology, 1980: Low Flow Studies Report. NERC, Wallingford.

Institute of Hydrology, 1993: Hydrological data UK *Hydrometric Register and Statistics 1986-90.* NERC, Wallingford.

Jones, P.D., 1980: An homogeneous rainfall record for the Cirencester area 1844-1977. *Meteorol. Mag. 109,* 249.

Jones, P.D., 1981: A survey of rainfall recording in two regions of the northern Pennines. *Meteorol. Mag. 110,* 239.

Jones, P.D., 1983: Riverflow reconstructions and their use, Pt. I and II. *Water Services 87,* 485-486, 528-531.

Jones, P.D., Ogilvie, A.E.J. and Wigley, T.M.L., 1984: Riverflow data for the United Kingdom: Reconstructed data back to 1844 and historical data back to 1556. *Climatic Research Unit Publication 8,* Norwich.

Jones, P.D. 1984: Riverflow reconstruction from precipitation data. *J. Climatology 4,* 171-186.

Jones, P.D. and Lister, D.H., 1995: Extended flow records at key locations in England and Wales. Phase I, *Project Report for 515/2/N & Y,* National Rivers Authority, Bristol.

Manley, R.E., 1978: The use of a hydrological model in water resource planning. *Proc. Inst. Civil Eng., Part 2, 63,* 223-235.

Ministry of Housing and Local Government, 1964: Hydrological Survey, *Kent Rivers.* HMSO, London.

National Rivers Authority, Severn Trent Region c.a.1995: A Guide to Flow Naturalisation in the Severn Trent Region.

Penman, H.L., 1948: Natural evaporation from open water, bare soil and grass. *Proc. Roy. Soc., Ser. A, 193,* 120-145.

Porter, J.W. and McMahon, T.A., 1971: A model for the simulation of streamflow from climatic records. *J. Hydrol. 13*, 297-324.

South West Wales River Authority, 1970: First Water resources Survey Report. S.W. Wales River Authority, Llanelli.

Thom, A.S. and Ledger, D.C. 1976: Rainfall, runoff and climate change. *Proc. Inst. Civil Eng., Part 2, 61*, 633-652 and *63*, 721-731.

Thompson, R.W.S. and Saxton, K.J.H., 1963: Rainfall and runoff in the Derwent Valley to Yorkshire Bridge, Derbyshire. *Proc. Inst. Civil Eng., 26,* 147-164.

Trent River Authorty, 1971: Water Resources- A First Development. Trent River Authority, Nottingham.

Wigley, T.M.L., Briffa, K.R. and Jones, P.D. 1984: On the average value of correlated time series, with applications in Dendrochronology and Hydrometeorology. *Journal of Climate and Applied Meteorology 23*, 201-213.

Wright, C.E. 1978: Synthesis of riverflows from weather data, *Tecnhical Note No 26,* Central Water Planning Unit, Reading, U.K.

APPENDIX A

Rain gauge details

Tables A1.1 - A1.5

Table A.1.1 Catchment: Medway to Teston

Location	UKMO No.	Grid Ref.	Obs. Period	Alt.(m)
Sevenoaks (River Hill)	294519	5543 1521	1861-1930	160
Sevenoaks (River Hill)	294520	5541 1520	1929-1954	152
Bayley's Hill Res.	294470	5519 1521	1952-1995	212
Pembury Water Wks.	295038	5627 1425	1876-1995	60
Falconhurst	293375	5470 1426	1850-1995	110
Tonbridge	******	558- 139-	1860-1870	38
Tonbridge (St. Steph.)	******	558- 139-	1868-1899	29
Penshurst Park	******	553- 144-	1889-1930	81
Penshurst Place	294415	5528 1440	1886-1995	40
Goudhurst Vicarage	******	573- 137-	1867-1906	128
Scotney Castle	295563	5685 1354	1873-1995	64
Goudhurst Pump Stn.	295668	5711 1367	1956-1995	37
Linton Park	******	577- 150-	1855-1876	90
Linton Park	******	577- 150-	1887-1909	90
Hunton Court	******	572- 149-	1858-1897	24
Langley, Rumwood Ct.	297390	5799 1523	1900-1976	108
Barming Water Wks.	297347	5735 1549	1899-1995	75

Sites for which data were obtained but not used in record compilations:

Bedgebury Park Gdns.	295609	5719 1341	1922-1975	79
Bedgebury Pinetum	295604	5722 1333	1934-1995	85
Goudhurst Maypole	******	573- 137-	1901-1919	126
Goughurst, Gore Court	295725	5723 1395	1904-1950	60
Tunbridge (Bredbury)	******	55-- 13--	1888-1909	127
Tunbridge (Courtlands)	******	55-- 13--	1900-1919	143
Tunbridge, Calv. Park	293198	5588 1392	1914-1964	107
Maidstone	******	57-- 15--	1848-1857	15
Detling (The Croft)	297701	5795 1582	1884-1942	101
Maidstone (Brn. Gdns.)	297727	5759 1561	1904-1995	15
Maidstone (Mill St.)	297722	5761 1555	1899-1968	11

******	-no UKMO reference number
-	-exact value unknown
?	-uncertainty
+	-record may extend further

Table A1.2 Catchment: Itchen to Highbridge and Allbrook

Location	UKMO No.	Grid Ref.		Obs. Period	Alt.(m)
Eling Ho, Southampton	******	436-	112-	1848-1869	5
Otterbourne	******	446-	123-	1864-1879	35
Otterbourne Water Wks.	325736	4469	1233	1892-1975	34
Otterbourne Water Wks.	325738	4468	1233	1975-1995	34
Selborne (The 'Wakes')	******	474-	133-	1850-1879/89	122
Alton ('Ashdell')	******	472-	139-	1866-1909	125
Ellisfield Manor	324904	4643	1457	1906-1957	194
Bishop's Sutton	324738	4605	1320	1935-1995	78
Alresford (Cheriton)	******	458-	128-	1878-1891	73
Winchester (Harestock)	******	446-	131-	1879-1903	92
Twyford Pumping Stn.	325608	4493	1249	1901-1984	42
Winchester (Harestock)	325445	4469	1318	1953-1995	67
Swarraton Rectory	******	456-	137-	1870-1913	95
Ovington Rectory	325165	4562	1317	1876-1956	67
Chilland	325262	4526	1328	1909-1966	62
Martyr Worthy	325267	4517	1338	1956-19--	84
Martyr Worthy (No.2)	325268	4517	1338	1977-1995	84
Southampton (compil'n)	******	44--	11--	1856-1978	-
Southampton (Mfr. Pk.)	326216	4416	1113	1970-1995?	3
Testwood P. Station	330972	4355	1151	1976-1995	7
Chilgrove House	320994	4837	1144	1834-1995	91

Sites for which data were obtained but not used in record compilations:

Location	UKMO No.	Grid Ref.		Obs. Period	Alt.(m)
Southampton (Gas Wks.)	******	44--	11--	1848-1861	6
Abbot's Ann	******	432-	143-	1847-1862	54
Red Rice	******	4339	1418	1867-1885	84
Winchester (Gas Wks.)	******	447-	129-	1842-1847	48
Winchester (St. Cross)	******	447-	127-	1907-1925/49	41
Winchester (St. Giles)	******	449-	129-	1913-1925	66
Winchester (East Hill)	******	450-	128-	1913-1942	78
Winchester (Rec. Grnd)	325489	4484	1300	1946-1966	38
Winchester (Romy. Rd.)	325524	4475	1294	1952-1979	82
Itchen Abbas	******	453-	133-	1850-1862	-

****** -no UKMO reference number
- -exact value unknown
? -uncertainty
+ -record may extend further

Table A1.3 Catchment: Teifi to Glan Teifi

Location	UKMO No.	Grid Ref.	Obs. Period	Alt.(m)
Frongoch (Lisb. Mines)	******	272- 274-?	1860-1869	261
Goginan Mines	******	270- 282-?	1861-1883	88
Gogerddan (Abery'with)	******	263- 283-	1870-1928	25
Hafod	******	275- 273-	1890-1930	177
Claerddu	465050	2792 2686	1908-1983	434
Llanafan	519565	2671 2730	1924-1951	64
Claerwen	465044	2820 2673	1891-1995	381
Bwlchyrhendre	465098	2807 2664	1892-1983	483
Ciloerwynt	465259	2882 2629	1944-1995	319
Rhayader compilation	464991	2909 2639	1858-1983	256?
Rhayader S. Wks.	464675	2978 2674	1975-1995	197
Castle Malgwyn	******	2224 2429	1865-1915	15?
Fishguard, Castle Hill	******	195- 237-	1877-1888	61
Goodwick Stn.	******	1945 2390	1903-1919	17
Cardigan (County Sch.)	******	217- 246-	1919-1937	22
Cardigan, Cedrwydd Gl.	517222	2190 2459	1929-1972	12
Aberporth Met. Office	517546	2242 2521	1941-19---	133
Rhydlewis	516375	2339 2471	19--- 1995	94
Carmarthen Gaol	******	241- 220-	1863-1882	28
Dynevor Castle	502950	2612 2224	1872-1955	62
Brechfa	504383	2523 2299	1933-1963	88
Golden Gro. Fm. Inst.	503057	2596 2203	1952-1995	30
Lampeter St. Dav. Col.	******	257- 248-	1855-1883	128
Carmarthen Asylum	******	241- 220-	1869-1893	58
Carmarthen, The Friary	******	241- 220-	1899-1936	19
Troedyraur Rectory	******	232- 245-	1886-1895	43?
Abergwesyn	******	285- 252-?	1894-1947	305?
Llanllyr	******	2543 2559	1905-1919	69
Lampeter (Falcondale)	514695	2565 2490	1906-1951	152
Llandyssul (S. Horeb)	515656	2406 2428	1947-1965	104
Gorsgoch Res.	515406	2460 2501	1962-1968	323
Llanybyther (H.M.Sch.)	515035	2501 2432	1967-1995	130

Sites for which data were obtained but not used in record compilations:

Aberystwyth, N. Parade	520623	2585 2818	1895-1938	5
Aberystwyth, Corp. Yd.	520631	2584 2814	1930-1979	4
Fishguard (Langton)	******	193- 236-	1920-1933	98
Trenewydd (Goodwick)	512533	1913 2396	1898-1967	91
Carmarthen (M&P Sch.)	******	241- 220-	1931-1940	20
Cwmoernant Res.	505200	2419 2212	1934-1972	41
Abergorlech	504116	2585 2336	1927-1962	76
Maes-y-bettws	******	275- 255-?	1884-1943	277
Str. Florida (SE of ?)	******	28-- 26--?	1910-1922	405
Swyddffynnon, Crug-Las	513865	2696 2655	1955-1974	179
Tregaron Vicarage	******	267- 259-	1892-1897	159
Llandyssul (Prengwyn)	515705	2426 2440	1935-1946	191
Llandyssul (J. Gard)	515669	2414 2406	1952-1962	119

****** -no UKMO reference number
- -exact value unknown
? -uncertainty
+ -record may extend further

Table A1.4 Catchment: Dee to Manley Hall/Erbistock

Location	UKMO No.	Grid Ref.	Obs. Period	Alt.(m)
Vyrnwy (B. Cynon Isaf)	425002	3019 3191	1879-1909	229
Vyrnwy (Bryn Vyrnwy)	425004	3018 3189	1889-1963	235
Bryn Gwyn	424961	2999 3196	1879-1995	400
Llanfihangel	425345	3098 3168	1975-1995	274
Oswestry (Hengoed)	******	329- 332-	1858-1894	143
Ellesmere	******	339- 334-	1892-1899	100?
Oswestry, Mount Res.	427865	3275 3304	1898-1983	213
Llanforda Res.	427859	3268 3296	1897-1995	213
Oswestry School	427863	3285 3293	1985-1995	139
Bala (Henblas ?)	******	295- 336-	1865-1886	166
Bala (Eryl Aran)	******	293- 337-	1887-1938	183
Bala Grammar School	542717	2927 3364	1934-1965	164
Bala Sluices	542719	2935 3356	1960-1995	163
Wrexham (Brymbo)	******	329- 353-	1863-1883	193
Pack Saddle Res.	546042	3305 3479	1878-1983	113
Cae Llwyd Res.	546023	3270 3480	1879-1995	280
Corwen (Rhug Gdns.)	******	307- 343-	1875-1889	152
Llangollen (Vivod)	544636	3191 3424	1886-1995	195
Pant-y-Maen	543564	2977 3587	1892-1974	402
Nant Heilyn	543462	2925 3554	1906-1973	373
Alwen Res.	543510	2957 3529	1928-1995	335

Sites for which data were obtained but not used in record compilations:

Pwll Brwyn, Fawnog	424988	3014 3219	1879-1983	413
L. Vyrnwy, Carreg Goch	424797	2974 3237	1879-1983	543
L. Vyrnwy	425001	3017 3188	1944-1985	303
Wynnstay (Ruabon)	******	33-- 34--	1869-1896	148
Ruabon (Bryn Oerog)	******	33-- 34--	1901-1920	-
Wrexham, Plas Power	******	33-- 35--	1870-1885	144
Rossett, Trevalyn Hall	******	337- 357-	1870-1903	18
Chirk Castle	545430	3269 3380	1914-1953	192
Chirk (Old Vicarage)	545460	3293 3376	1946-1970	107
Ruabon (Cefn Mawr)	544876	3273 3425	1956-1969	95
Llyn Bran	543535	2960 3593	1899-1960+	435
Ruthin (Tymawr)	******	31-- 35--	1908-1919	122
Conway Mussel Tanks	534494	2785 3773	1924-1994	8

****** -no UKMO reference number
- -exact value unknown
? -uncertainty
+ -record may extend further

Table A1.5 Catchment: Derwent to St. Mary's Bridge/ Longbridge Weir

Location	UKMO No.	Grid Ref.	Obs. Period	Alt.(m)
Matlock Bath (Chdwck.)	******	429- 358-	1866-1939	152
Whatstandwell W. Wks.	108956	4326 3554	1904-1995	75
Chatsworth Gdns.	107389	4262 3701	1860-1995	133
Buxton (Devon. Hosp.)	107520	4056 3737	1865-1879	306
Buxton (Devon. Hosp.)	107521	4057 3736	1880-1925	301
Buxton (Terrace Slope)	107494	4058 3734	1925-1995	307
Woodhead Station	******	4112 3999	1851-1919	268
Fairholmes	106297	4173 3893	1906-1978	209
Howden Dam	106238	4168 3924	1906-1983	258
Derwent Dam	106295	4175 3899	1960-1995	249
Derby (Corn Market)	******	435- 335-	1844-1874	55
Derby (Duffield)	******	434- 343-	1866-1889	76?
Derby (Ry. Rifle Rng.)	110486	4365 3349	1880-1960	48
Derby (Markeaton Pk.)	110371	4333 3377	1935-1960+	58
Derby (Brayfield Rd.)	105608	4335 3338	1958-1991	69
Derby (Spondon)	110525	4395 3345	1983-1995	40
Combs Res.	******	404- 379-	1857-1919	216
Hayfield, Oaken Clough	558446	4064 3860	1902-1995	381
Redmires Res.	082512	4262 3857	1840-1971	338
Redmires Filters	082511	4267 3856	1972-1995	305

Sites for which data were obtained but not used in record compilations:

Wirksworth (Biggin)	******	424- 346-	1878-1884	146
Wirksworth (Manor Ho.)	******	4287 3540	1897-1930	152
Wirksworth (Budge Ho.)	******	428- 354-	1895-1915	152
Alderwasley (Crich)	******	434- 353-	1885-1901	165
Alderwasley Hall	******	434- 353-	1900-1911	163
Darley Dale, Ww. Inst.	******	428- 362-	1893-1939	110
Bakewell (Ashford Rd.)	108125	4206 3691	1938-1953	152
Stretton Lindway Res.	******	435- 358-	1890-1910	136?
Lindway Res.	109392	4356 3582	1910-1981	181
Clay Cross, Press. Res.	109149	4354 3659	1912-1983	232
Bamford	106869	4202 3829	1903-1983	155
Killhill (Hope)	106734	4171 3838	1915-1976	171
Yorkshire Bridge	106584	4198 3853	1926-1995	168
Derby (Mickleover Mo.)	******	429- 334-	1870-1919	85
Derby (Park Grove)	110380	4345 3374	1892-1960	60
Derby, The Arboretum	110430	4356 3350	1894-1954	59

******	-no UKMO reference number
-	-exact value unknown
?	-uncertainty
+	-record may extend further

Tables A2.1 - A2.5

A2.1 Catchment: Medway to Teston

Medway1 1861-1995 Bayley's Hill

Period	Gauge location	Comments
1861-1954	River Hill	Two gauges used here
1955-1995	Bayley's Hill	

	Adjustment factors (ratios)
1861-1929	1.1246
1930-1954	1.0156
1955-1995	1.0000

Medway2 1876-1995 Pembury W. Wks.

Period	Gauge location	Comments
1876-1995	Pembury W. Wks.	Part-record adjustment required

	Adjustment factors (ratios)
1876-1960	1.0156
1961-1995	1.0000

Medway3 1850-1995 Falconhurst

Period	Gauge location	Comments
1850-1995	Falconhurst	'Homogeneity standard'

	Adjustment factors (ratios)
1850-1995	1.0000

Medway4 1860-1995 Penshurst Place

Period	Gauge location	Comments
1860-1867	Tonbridge	(Dr Fielding)
1868-1885	Tonbridge	(St. Stephens)
1886-1995	Penshurst Place	Patched with P'hurst Pk.

	Adjustment factors (ratios)
1860-1867	1.0000
1868-1885	0.9726
1886-1906	1.0000
1907-1936	0.9200
1937-1995	1.0000

Medway5 1867-1995 Scotney Castle

Period	Gauge location	Comments
1867-1872	Goudhurst Vicarage	
1873-1995	Scotney Castle	Patched with Goudhurst Pumping Station

	Adjustment factors (ratios)
1867-1872	1.1519
1873-1960	1.0754
1961-1995	1.0000

Medway6 1855-1995 Barming water Wks.

Period	Gauge location	Comments
1855-1876	Linton Park	
1877-1886	Hunton Court	
1887-1899	Linton Park	Slight difference to above
1900-1960	Rumwood Court	
1961-1995	Barming Water Wks.	

	Adjustment factors (ratios)
1855-1876	0.9685
1877-1886	1.0002
1887-1899	0.9685
1900-1960	0.9410
1961-1995	1.0000

A.2.2 Catchment: Itchen to Highbridge and Allbrook

Itchen1 1856-1995 Testwood P. Stn.

Period	Gauge location	Comments
1856-1978	Southampton	'Homogeneity-standard-compilation' having compared with Chilgrove and made necessary adjustments
1979-1995	Testwood P. Stn.	

	Adjustment factors (ratios)
1856-1970	0.9921
1971-1978	1.0446
1979-1995	1.0000

Itchen2 1850-1995 Otterbourne W.W.

Period	Gauge location	Comments
1850-1863	Southampton	(Eling Ho. record)
1864-1879	Otterbourne	
1880-1891	Winchester	(Harestock)
1892-1995	Otterbourne W.W.	Two gauge records here

	Adjustment factors (ratios)
1850-1879	1.1410
1880-1891	1.0060
1892-1914	1.1410
1915-1931	1.0521
1932-1995	1.0000

Itchen3 1870-1995 Martyr Worthy

Period	Gauge location	Comments
1870-1876	Swarraton Rectory	
1877-1955	Ovington Rectory	
1956-1966	Chilland	
1967-1995	Martyr Worthy	

	Adjustment factors (ratios)
1870-1876	0.9266
1877-1908	0.8988
1909-1950	0.8229
1951-1955	0.8988
1956-1995	1.0000

Itchen4 1879-1995 Winchester

Period	Gauge location	Comments
1879-1891	Alresford	(Cheriton Rectory)
1892-1900	Winchester	(Harestock)
1901-1976	Twyford P. Stn.	
1977-1995	Winchester	(Harestock-UKMO 325445)

	Adjustment factors (ratios)
1879-1891	0.9880
1892-1900	1.0131
1901-1919	1.0807
1920-1976	1.0131
1977-1995	1.0000

Itchen5 1850-1995 Bishop's Sutton

Period	Gauge location	Comments
1850-1865	Selborne, Wakes	
1866-1905	Alton, Ashdell	
1906-1934	Ellisfield Manor	
1935-1995	Bishop's Sutton	

	Adjustment factors (ratios)
1850-1865	0.9194
1866-1934	0.9569
1935-1995	1.0000

Itchen6 1834-1995 Chilgrove

Period	Gauge location	Comments
1834-1995	Chilgrove House	Part-record adjustment made after comparison with Southampton compilation

	Adjustment factors (ratios)
1834-1868	1.2236
1869-1937	1.0574
1938-1995	1.0000

A2.3 Catchment: Teifi to Glan Teifi

Teifi1 1860-1995 Claerwen

Period	Gauge location	Comments
1860-1891	Goginan Mines	Frongoch data for 1860
1892-1924	Hafod (S. Florida)	
1925-1940	Llanofan	
1941-1960	Claerddu	
1961-1995	Claerwen	Patched with Elan Village (UKMO 465396)

	Adjustment factors (ratios)
1860-1871	1.6647
1872-1885	1.6923
1886-1891	1.5139
1892-1924	1.2780
1925-1940	1.5998
1941-1960	1.0187
1961-1972	1.0792
1973-1995	1.0000

Teifi2 1892-1995 Ciloerwynt

Period	Gauge location	Comments
1892-1960	Bwlchyrhendre	
1961-1995	Ciloerwynt	

	Adjustment factors (ratios)
1892-1915	1.0841
1916-1960	0.9626
1961-1974	1.0693
1975-1995	1.0000

Teifi3 1858-1995 Rhayader

Period	Gauge location	Comments
1858-1980	Rhayader	'Homogeneity-standard-compilation'
1981-1995	Rhayader S. Works	

	Adjustment factors (ratios)
1858-1980	0.7808
1981-1995	1.0000

Teifi4 1865-1995 Aberporth

Period	Gauge location	Comments
1865-1915	Castle Malgwyn	
1916-1918	Goodwick Station	
1919-1928	Cardigan Co. Sch.	
1929-1940	Cardigan	(Cedrwydd Glas)
1941-1995	Aberporth M. Off.	Patched by Cedrwydd Glas 1960-70, and Rhydlewis, 1992-95

	Adjustment factors (ratios)
1865-1917	0.7996
1918-1940	0.8440
1941-1960	0.8642
1961-1995	1.0000

Teifi5 1863-1995 Golden Gr. Fm. Inst.

Period	Gauge location	Comments
1863-1872	Carmarthen Gaol	
1873-1940	Dynevor castle	
1941-1960	Brechfa	
1961-1995	Golden G. Fm. Ins.	Patched with Abergorlech (UKMO 504116)

	Adjustment factors (ratios)
1863-1872	1.0563
1873-1891	1.0783
1892-1940	1.0184
1941-1960	0.8188
1961-1995	1.0000

Teifi6 1855-1995 Llanybyther

Period	Gauge location	Comments
1855-1883	Lampeter	(St David's College) Patched with Carmarthen Gaol/Assylum
1884-1885	Carmarthen	(Assylum)
1886-1904	Troedrraur R'ory	Patched with Abergwesyn 1896-1904
1905	Llanllyr	
1906-1947	Lampeter	(Falcondale)
1948-1960	Llandyssul	(Sychpant Horeb)
1961-1967	Gorsgoch Res.	(Patched with Llandyssul)
1968-1995	Llanybyther	

	Adjustment factors (ratios)
1855-1905	1.2166
1906-1960	1.0368
1961-1967	0.8386
1968-1995	1.0000

A2.4 Catchment: Dee to Manley Hall/Erbistock

Dee1 1880-1995 Bryn Gwyn

Period	Gauge location	Comments
1880-1889	Vyrnwy	(Bank Cynon Isaf)
1890-1960	Vyrnwy	(Bryn Vyrnwy)
1961-1983	Vyrnwy	(Bank Cynon Isaf)
1984-1995	Bryn Gwyn	Patched with Llanfihangel

	Adjustment factors (ratios)
1880-1910	1.2368
1911-1915	1.6079
1916-1983	1.2368
1984-1995	1.0000

Dee2 1858-1995 Llanforda Res.

Period	Gauge location	Comments
1858-1891	Oswestry (Hengoed)	
1892-1897	Ellesmere	
1898-1983	The Mount Res.	
1984-1995	Llanforda Res.	(Patched with Oswestry School)

	Adjustment factors (ratios)
1858-1891	1.0183
1892-1897	1.1245
1898-1995	1.0000

Dee3 1865-1995 Bala

Period	Gauge location	Comments
1865-1886	Bala (Henblas)	
1887-1934	Bala (Eryl Aran)	'Homogeneity-standard-compilation'
1935-1960	Bala Grammar Sch.	
1961-1995	Bala Sluices	

	Adjustment factors (ratios)
1865-1886	0.9590
1887-1934	0.7977
1935-1960	0.9590
1961-1995	1.0000

Dee4 1863-1995 Cae Llwyd Res.

Period	Gauge location	Comments
1863-1878	Wrexham (Brymbo)	
1879-1960	Pack Saddle Res.	
1961-1995	Cae Llwyd Res.	

	Adjustment factors (ratios)
1863-1885	1.1414
1886-1903	1.0325
1904-1960	1.1414
1961-1995	1.0000

Dee5 1876-1995 Llangollen

Period	Gauge location	Comments
1876-1885	Corwen (Rhug Gdn.)	
1886-1995	Llangollen (Vivod)	

	Adjustment factors (ratios)
1876-1885	0.9436
1886-1902	0.8339
1903-1935	1.1063
1936-1995	1.0000

Dee6 1892-1995 Alwen Reservoir

Period	Gauge location	Comments
1892-1907	Pant-y-Maen	
1908-1960	Nant Heilyn	
1961-1995	Alwen Reservoir	

	Adjustment factors (ratios)
1892-1909	0.8607
1910-1953	0.9690
1954-1960	0.9104
1961-1995	1.0000

A2.5 Catchment: Derwent to Derby St. Marys/ Longbridge Weir

Derwent1 1867-1995 Whatstandwell W.Wks.

Period	Gauge location	Comments
1867-1918	Matlock Bath	
1919-1995	Whatstandwell W.W.	

	Adjustment factors (ratios)
1867-1887	0.9412
1888-1898	1.0973
1899-1918	0.9412
1919-1936	0.9527
1937-1949	1.1067
1950-1960	0.9527
1961-1995	1.0000

Derwent2 1860-1995 Chatsworth

Period	Gauge location	Comments
1860-1995	Chatsworth Gdns.	Some part-record adjustment necessary

	Adjustment factors (ratios)
1860-1909	0.9442
1910-1995	1.0000

Derwent3 1865-1995 Buxton (Terrace Slope)

Period	Gauge location	Comments
1865-1925	Buxton	(Devonshire Hospital)
1926-1969	Buxton (as above)	Slight gauge variation
1970-1995	Buxton Tce. Slope	

	Adjustment factors (ratios)
1865-1902	0.9167
1903-1995	1.0000

Derwent4 1857-1995 Derwent Dam

Period	Gauge location	Comments
1857-1905	Woodhead Station	
1906-1983	Howden Dam	
1984-1995	Derwent Dam	

	Adjustment factors (ratios)
1857-1905	0.9513
1906-1983	0.9876
1984-1995	1.0000

Derwent5 1844-1995 Derby

Period	Gauge location	Comments
1844-1866	Derby (Corn Mkt.)	
1867-1880	Derby (Duffield)	
1881-1934	Derby	(Railway Rifle Rnge.)
1935-1960	Derby	(Markeaton Park)
1961-1991	Derby	(Brayfield Rd.)
1992-1995	Derby (Spondon)	

	Adjustment factors (ratios)
1844-1866	0.9690
1867-1880	0.9039
1881-1934	0.9792
1935-1960	0.8776
1961-1991	0.9556
1992-1995	1.0000

Derwent6 1857-1995 Hayfield (Oaken Clough)

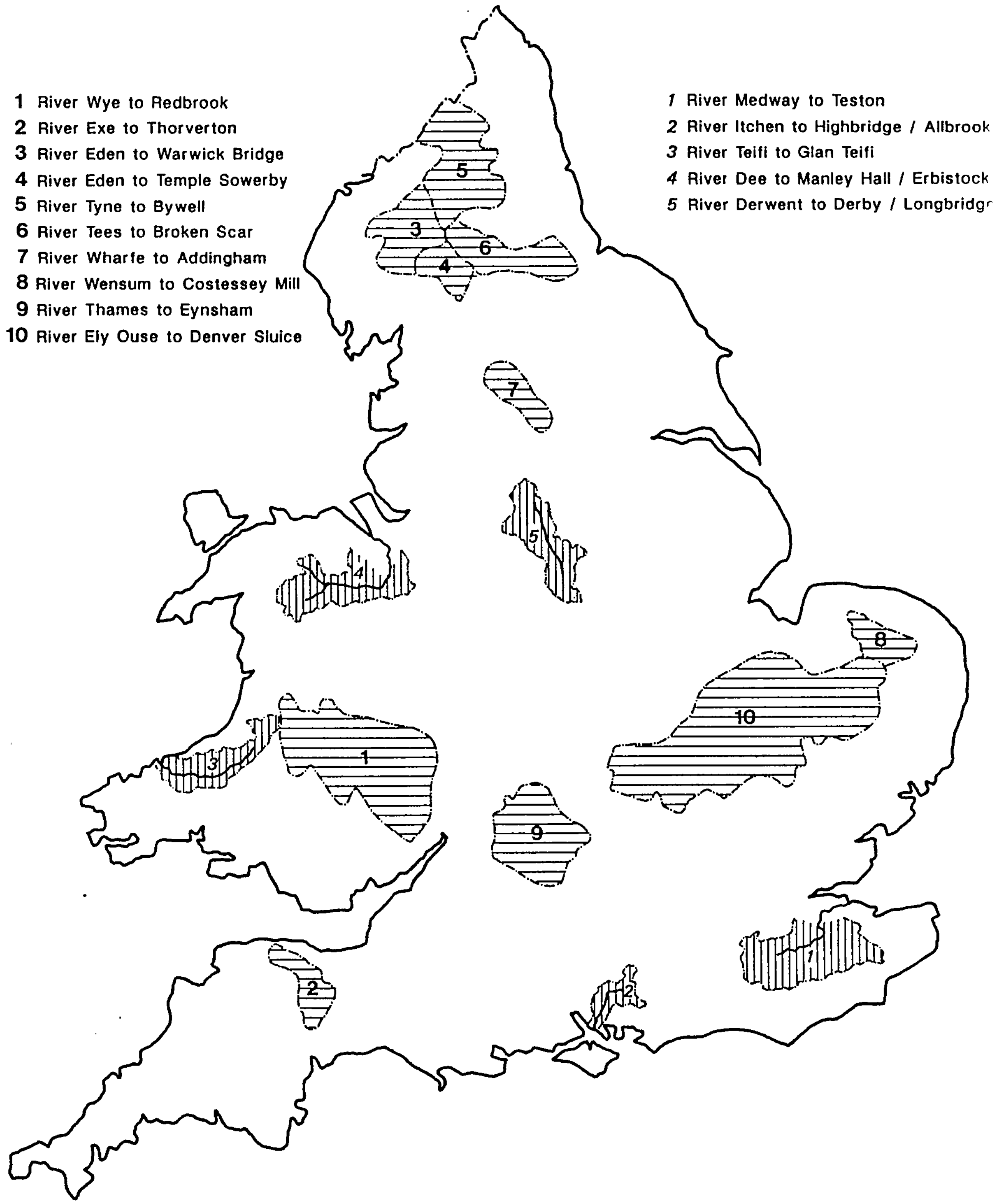
Period	Gauge location	Comments
1857-1901	Combs Reservoir	
1902-1995	Hayfield Oaken Cl.	

	Adjustment factors (ratios)
1857-1874	0.9017
1875-1923	1.1831
1924-1995	1.0000

Derwent7 1840-1995 Redmires

Period	Gauge location	Comments
1840-1971	Redmires Res.	'Homogeneity-standard-
1972-1995	Redmires Filters	compilation'
	Adjustment factors (ratios)	
1840-1995	1.0000	

Figure A1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2 River Exe to Thorverton
3 River Eden to Warwick Bridge
4 River Eden to Temple Sowerby
5 River Tyne to Bywell
6 River Tees to Broken Scar
7 River Wharfe to Addingham
8 River Wensum to Costessey Mill
9 River Thames to Eynsham
10 River Ely Ouse to Denver Sluice
1 River Medway to Teston
2 River Itchen to Highbridge / Allbrook
3 River Teifi to Glan Teifi
4 River Dee to Manley Hall / Erbistock
5 River Derwent to Derby / Longbridge

Figure A2.1

Medway

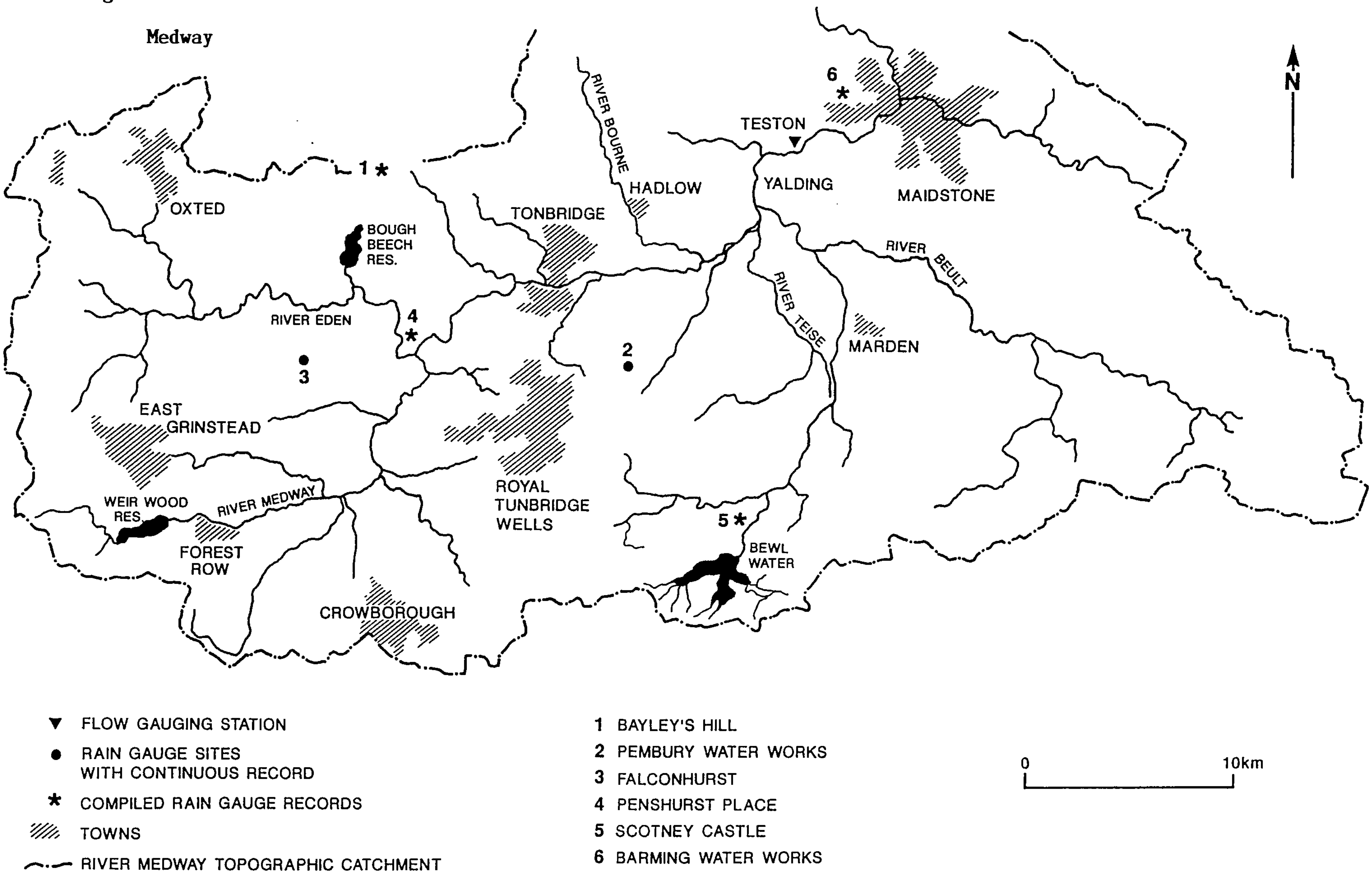


Figure A2.2

Itchen

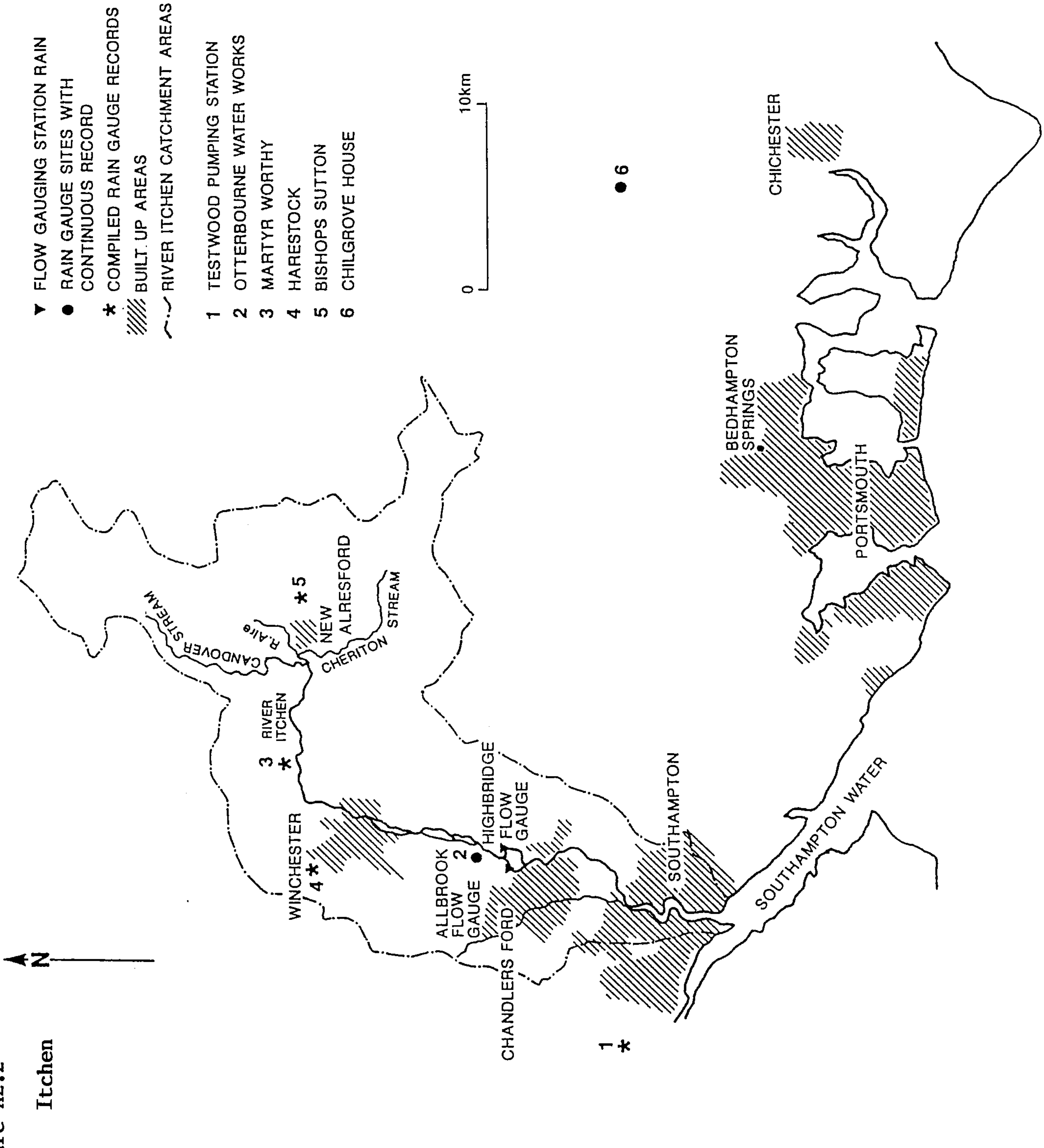


Figure A2.3

Teifi

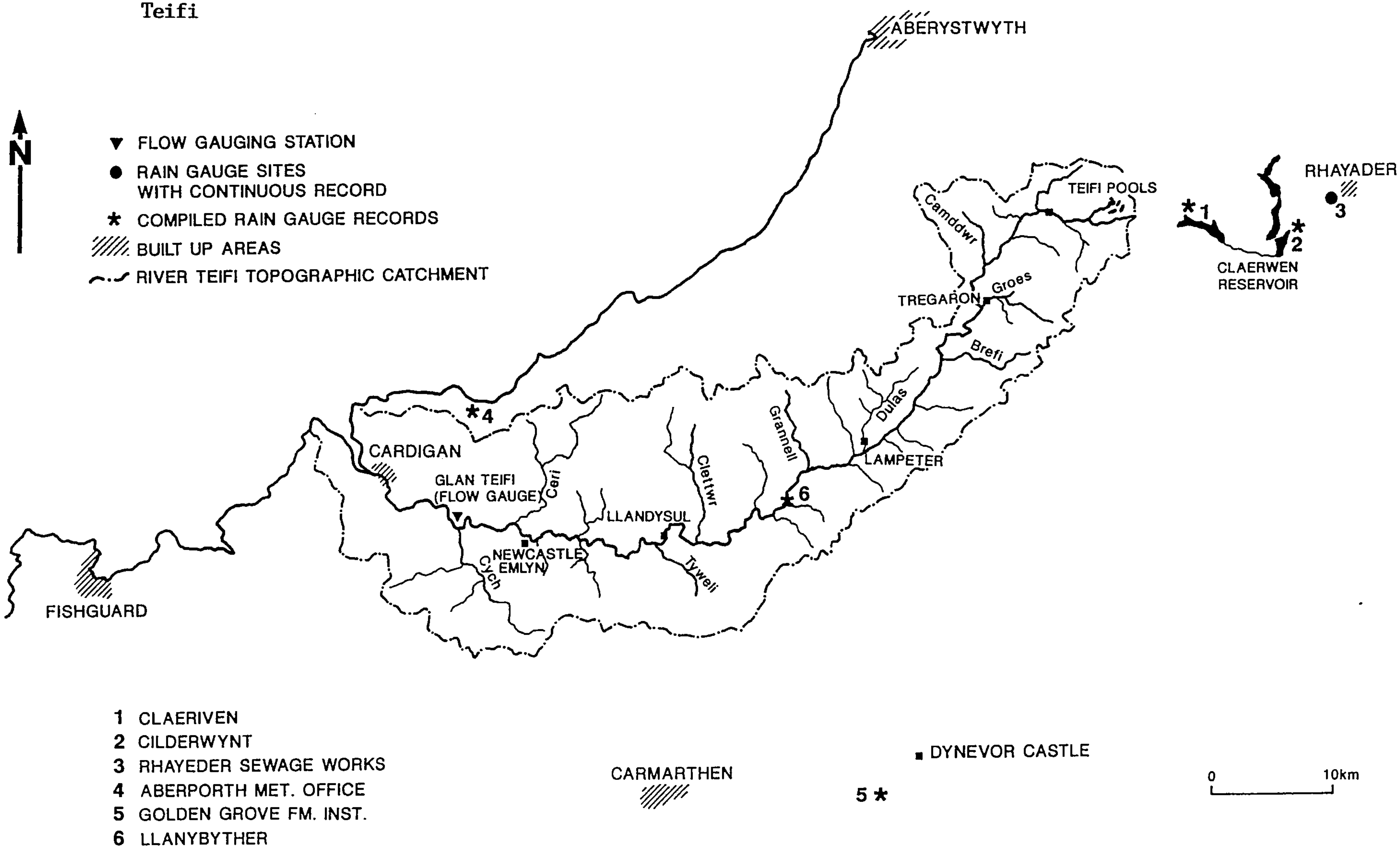


Figure A2.4

Dee

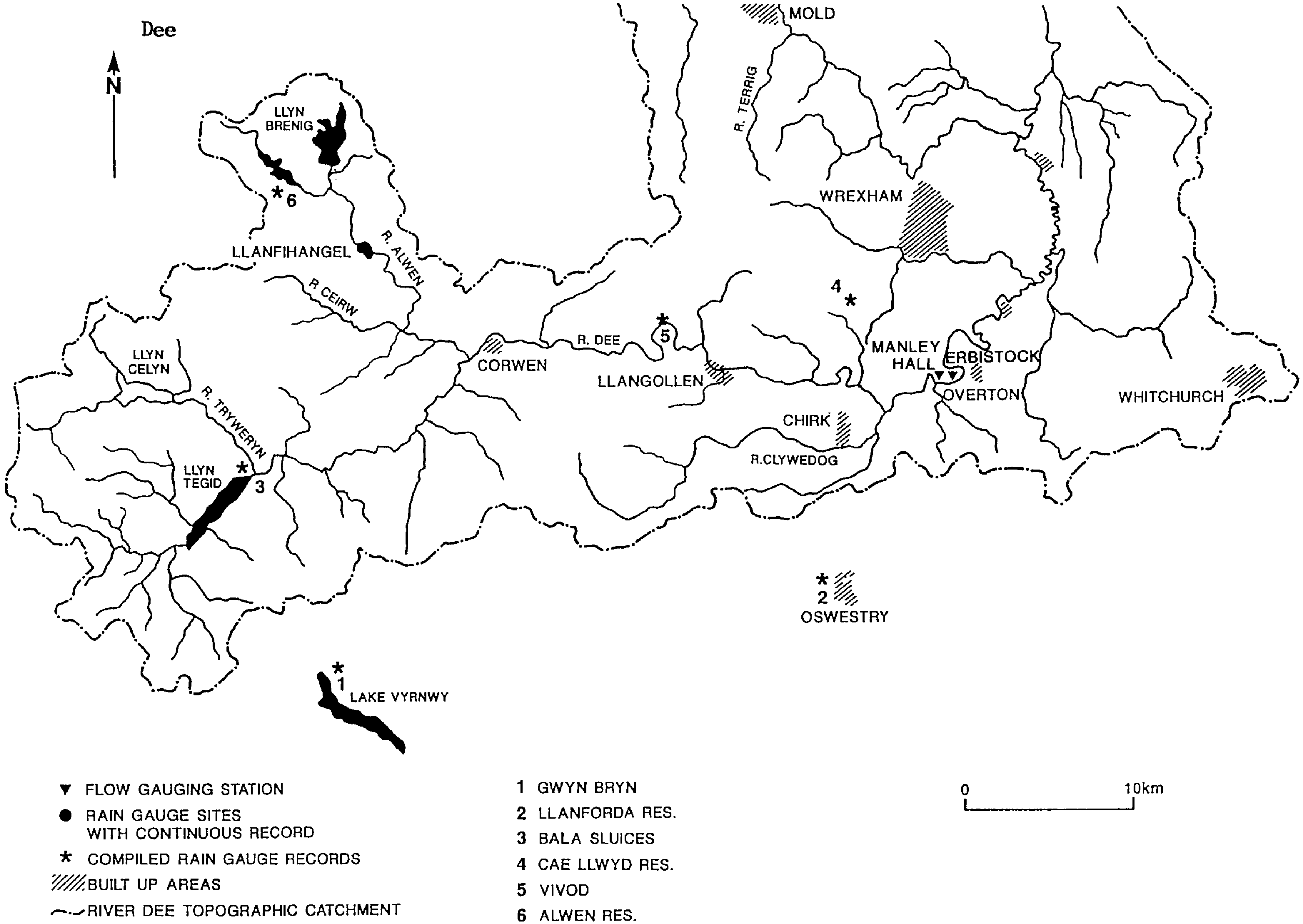


Figure A2.5

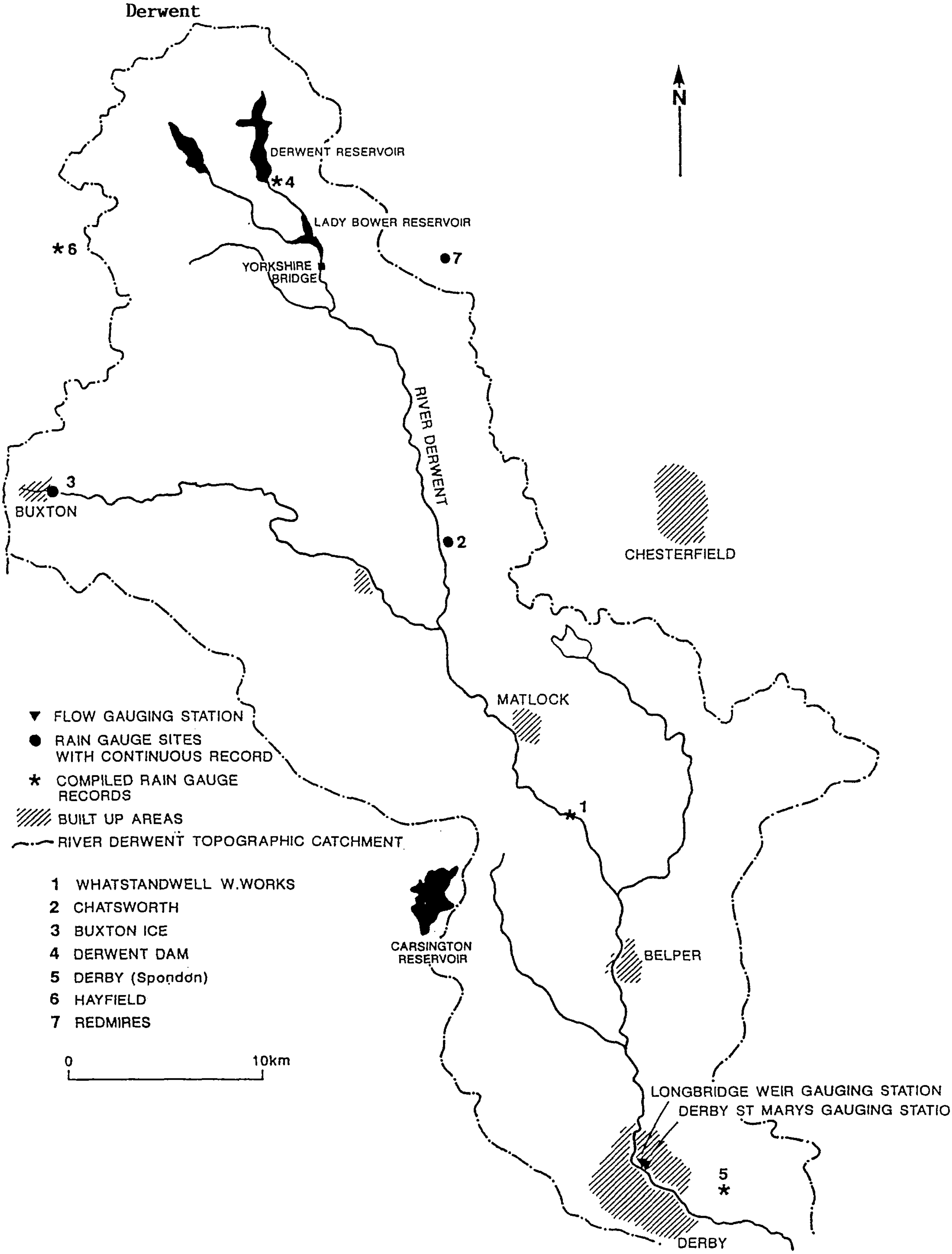
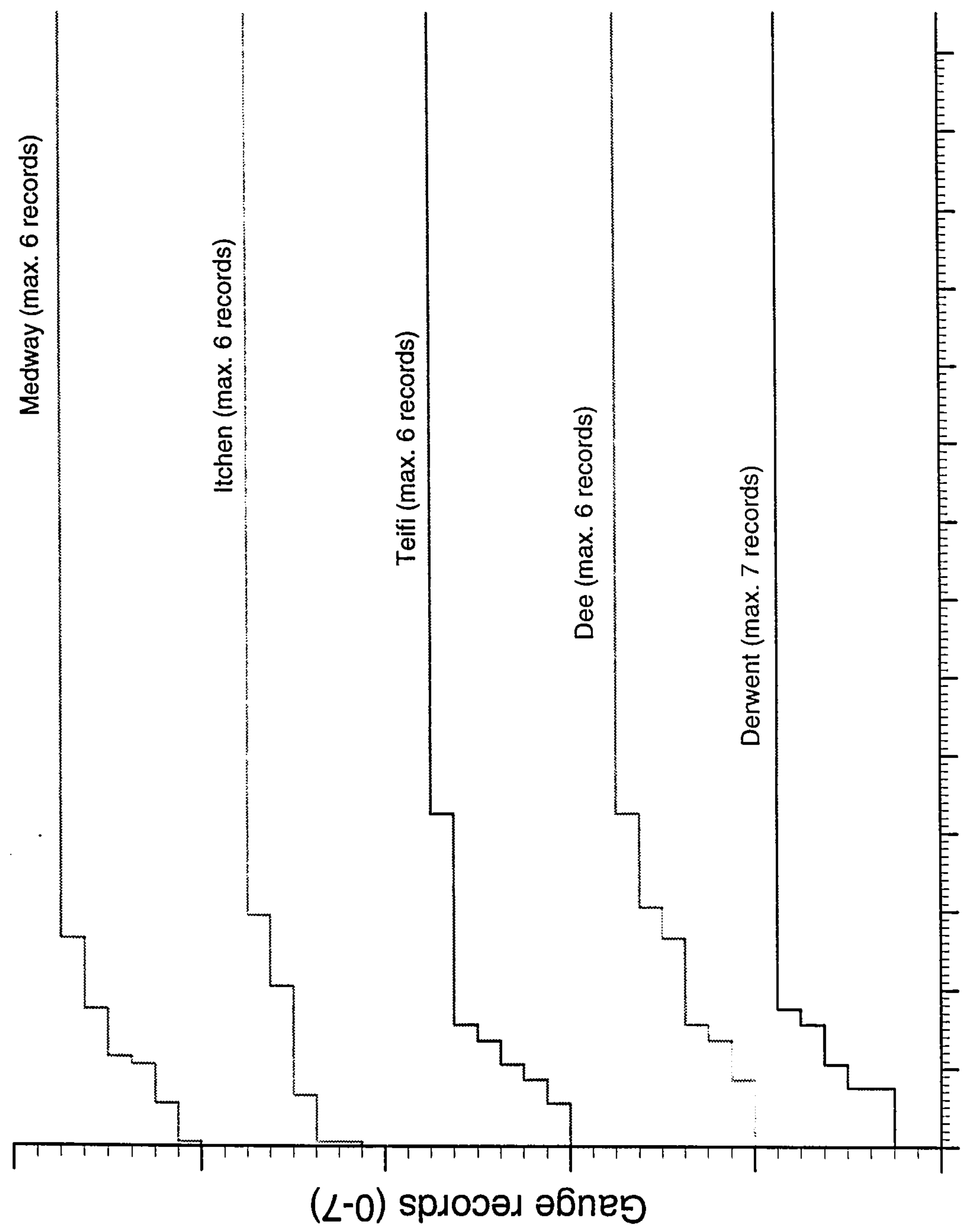

Derwent
N
DERWENT RESERVOIR
*4
LADY BOWER RESERVOIR
*6
•7
YORKSHIRE BRIDGE
RIVER DERWENT
3
BUXTON
•2
CHESTERFIELD
MATLOCK
1
CARSINGTON RESERVOIR
BELPER
LONGBRIDGE WEIR GAUGING STATION
DERBY ST MARYS GAUGING STATION
5
DERBY
▼ FLOW GAUGING STATION
● RAIN GAUGE SITES WITH CONTINUOUS RECORD
* COMPILED RAIN GAUGE RECORDS
BUILT UP AREAS
RIVER DERWENT TOPOGRAPHIC CATCHMENT
1 WHATSTANDWELL W.WORKS
2 CHATSWORTH
3 BUXTON ICE
4 DERWENT DAM
5 DERBY (Spondon)
6 HAYFIELD
7 REDMIRES
0
10km

Figure A3

Number of gauge records included in areal rainfall estimations-all catchments



APPENDIX B

Comparison of reconstructed and observed flows

Table B1.1-B1.5 Seasonal Statistics (6 seasons for 1970-1993 or nearest alternative, and 2 seasons for 1988-1992) - Means and standard deviations of the flows in cumecs

Table B1.1 Medway to Teston

'Season'	Observed		Reconstructed		R
(1970-93)	$\bar{x}$	σ	$\bar{x}$	σ	
Jan - March	18.47	8.15	18.30	8.29	0.94
April - June	7.33	3.51	6.85	2.78	0.88
July - Sept	2.59	1.53	2.38	1.37	0.91
Oct - Dec	13.30	9.29	12.79	8.22	0.96
April - Sept	4.96	1.91	4.62	1.40	0.84
Jan - Dec	10.42	2.59	10.08	2.28	0.88
April - Sept (1988-92)	3.87	1.38	4.41	1.11	0.78
Jan - Dec (1988-92)	8.60	1.84	9.05	1.93	0.79

Table B1.2 Itchen to Highbridge +Allbrook

'Season'	Observed		Reconstructed		R
(1970-88)	$\bar{x}$	σ	$\bar{x}$	σ	
Jan - March	7.98	1.29	8.03	1.40	0.95
April - June	6.74	0.97	6.73	0.97	0.93
July - Sept	4.88	0.55	4.89	0.51	0.92
Oct - Dec	5.67	1.04	5.74	1.04	0.96
April - Sept	5.81	0.74	5.81	0.71	0.95
Jan - Dec	6.32	0.66	6.35	0.66	0.93
April - Sept (1988-92)	-	-	5.38	0.56	-
Jan - Dec (1988-92)	-	-	5.68	0.70	-

Table B1.3 Teifi to Glan Teifi

'Season' (1970-93*)	Observed $\bar{x}$	Observed σ	Reconstructed $\bar{x}$	Reconstructed σ	R
Jan - March	41.43	12.10	42.40	12.65	0.97
April - June	16.11	7.88	16.69	7.15	0.94
July - Sept	11.17	6.25	9.76	4.56	0.89
Oct - Dec	44.17	11.98	41.06	10.22	0.90
April - Sept	13.64	5.57	13.23	4.30	0.93
Jan - Dec	28.22	5.07	27.48	4.31	0.90
April - Sept (1988-92)	12.37	6.49	13.32	5.11	0.98
Jan - Dec (1988-92)	27.79	2.02	26.95	1.55	0.62

*Missing values (March, April, August) in the Glan Teifi record for 1970 have been substituted by the reconstructed ones.

Table B1.4 Dee to Manley Hall/Erbistock

'Season' (1970-89)	Observed $\bar{x}$	Observed σ	Reconstructed $\bar{x}$	Reconstructed σ	R
Jan - March	45.69	11.14	46.39	14.12	0.90
April - June	18.34	8 03	19.70	7.01	0.96
July - Sept	15.64	6.46	15.19	5.04	0.81
Oct - Dec	47.18	10.44	50.05	11.96	0.92
April - Sept	16.99	4.89	17.45	3.72	0.89
Jan - Dec	31.71	4.85	32.83	5.04	0.90
April - Sept (1988-92)	-	-	15.73	5.02	-
Jan - Dec (1988-92)	-	-	32.07	3.87	-

Table B1.5 Derwent to Derby St. Marys/Longbridge

'Season' (1977-93)	Observed $\bar{x}$	Observed σ	Reconstructed $\bar{x}$	Reconstructed σ	R
Jan - March	32.60	9.53	32.87	10.51	0.95
April - June	16.94	6.20	16.81	5.72	0.96
July - Sept	9.31	2.79	9.36	2.59	0.91
Oct - Dec	25.44	5.51	24.46	5.53	0.96
April - Sept	13.13	3.49	13.09	2.96	0.94
Jan - Dec	21 07	3.54	20.88	3.80	0.94
April - Sept (1988-92)	10.12	2.82	11.27	2.51	0.98
Jan - Dec (1988-92)	17.65	2.59	18.21	2.73	0.95

Table B2: **Dee to Manley Hall/Erbistock - Additional validation exercises comparing reconstructed flows with**
1. Observed flows (with proportional adjustment) at Lake Vyrnwy for the period 1879-1989
2. Observed flows at Erbistock for the period 1938-55

'Season'	Observed		Reconstructed		R
	$\overline{x}$	σ	$\overline{x}$	σ	
1 Monthly	29.57	20.58	30.80	22.90	0.88
2 "	30.87	22.74	31.83	25.03	0.90
1 April - Sept	18.57	5.74	18.19	5.12	0.84
2 "	17.97	5.26	18.16	3.56	0.92
1 Jan - Dec	29.57	4.93	30.80	5.87	0.85
2 "	30.87	5.86	31.83	5.80	0.91

Table B3: **Itchen to Highbridge + Allbrook - Additional validation exercise comparing reconstructed flows with those observed at Bedhampton Springs (after proportional adjustment*), for the period 1909-92**

'Season'	Observed		Reconstructed		R
	$\overline{x}$	σ	$\overline{x}$	σ	
Monthly	6.61	1.45	6.50	1.89	0.87
April - Sept	6.49	0.69	5.89	0.85	0.83
Jan - Dec	6.62	0.76	6.50	0.95	0.86

*and the removal of two apparently incorrect values for observed flow at Bedhampton

Table B4: **Derwent to Derby St. Marys/Longbridge - Additional validation exercise comparing reconstructed flows with a partially naturalised series at Longbridge Weir for the period 1936-74**

'Season'	Observed		Reconstructed		R
	$\overline{x}$	σ	$\overline{x}$	σ	
Monthly	19.74	12.39	19.58	12.15	0.93
April - Sept	13.36	2.85	12.92	2.47	0.84
Jan - Dec	19.74	3.83	19.58	3.93	0.92

APPENDIX C

Reconstruction program

Appendix C1.1 and C1.2: Fortran programs for the reconstruction of flows

C1.1: Residpp (This program calculates the 'effective' rainfall for each month using catcment rainfall and monthly evaporation data)

```
program residpp
    dimension x(12,200)
    dimension e(12)
    read(1,*)iy1,iy2
    read(1,*)e
    iyf1=iy1-1
    do 21 jj=iy1,iy2
    j=jj-iyf1
  21 read(2,*)jk,(x(i,j),i=1,12)
    nmon=(iy2-iy1+1)*12
    m1=1
    m2=iy1
    write(6,78)nmon,m1,m2
  78 format(3i6)
    sm1=0.0
    write(6,79)sm1
    do 23 jj=iy1,iy2
    j=jj-iyf1
    do 24 i=1,12
    f=x(i,j)*0.1-e(i)
    write(6,79)f
  79 format(f8.1)
  24 continue
  23 continue
    stop
    end
```

C1.2: CATCHMENT (This program reconstructs the riverflows from 'effective' rainfall and the optimised calibration parameters)

```
      program CATCHMENT
      INTEGER YR0,RMAXLG
      REAL RC(20),M00,LF,RX(20),ML,GC(20),R(20),G(20),M(21)
      COMMON /BLOCK/A,B,C
      READ(1,*)NLAG
      MM=NLAG+1
      READ(1,*)RMAX,RMAXLG,(RC(N),N=1,MM),ML,(GC(N),N=1,MM),FRFR,
     1FR1,FRFG,FG1,M00,RP,CON,EB,EBC,ESMD,ESMDC,EC,ECC,A,B,C
      IF(RMAXLG)9,9,8
8     DO 7 N=1,RMAXLG
7     RX(N)=1000
      IF(RMAXLG-NLAG)9,9,18
9     DO 19 N=RMAXLG+1,MM
19    RX(N)=RMAX
18    WRITE(3,35)CON
      CALL OUT2(RC,MM,'RAINFALL','R')
      CALL OUT2(GC,MM,'MOD RAIN','G')
      CALL OUT2(RX,MM,'RAIN MAX','X')
      IF(M00.NE.0.)WRITE(3,34)M00
      IF(RP.NE.0)WRITE(3,36)RP
      IF(ML.NE.0)WRITE(3,37)ML
      CALL OUTPUT(FRFR,FR1,'FRFR    ')
      CALL OUTPUT(FRFG,FG1,'FRFG    ')
      CALL OUTPUT(EC,ECC,'EC      ')
      CALL OUTPUT(EB,EBC,'  X     ')
      CALL OUTPUT(ESMD,ESMDC,'   Y     ')
      WRITE(3,38)A,B,C
      READ(2,*)NMON,MR0,YR0
      M1=MM+1
      B=B*.01
      READ(2,*)M(M1),(R(M1-J),J=1,NLAG)
      DO 1 K=1,NLAG
      MR0=MR0+1
      IF(MR0-13)5,6,6
6     YR0=YR0+1
      MR0=1
5     K1=M1-K
1     M(K1)=AMAX1(M(K1+1)-R(K1),0.)
      DO 4 K=2,MM-1
      CALL GCALC(R(K),R(K+1),M(K+2),G(K))
4     CONTINUE
      DO 2 K=1,NMON-NLAG
      READ(2,*)R(1)
      FLOW=CON
      M(1)=AMAX1(M(2)-R(1),0.)
      CALL GCALC(R(1),R(2),M(3),G(1))
      DO 3 K1=1,MM
3     FLOW=FLOW+AMIN1(R(K1),RX(K1))*RC(K1)+G(K1)*GC(K1)
      IF(FRFR)14,15,14
14    FLOW=FLOW+FRFR*AMAX1(AMIN1(R(1)+R(2)-FR1,R(1)),0.)
15    IF(FRFG)16,17,16
16    FLOW=FLOW+FRFG*AMAX1(AMIN1(G(1)+G(2)-FG1,G(1)),0.)
17    FLOW=FLOW+EB*AMAX1(G(1)-EBC,0.)-ESMD*AMAX1(M(1)-ESMDC,0.)
     1+EC*AMAX1(R(1)+G(1)-ECC,0.)
      LF=FLOW-ML*M(NLAG+2)+RP*AMAX1(R(1),0.)-M00*M(1)
      FLOW=10.**LF
```

```
      FLOW=FLOW*0.001
      WRITE(3,30)MR0,YR0,R(1),M(1),G(1),LF,FLOW
30    FORMAT(1H ,I3,I5,2F7.0,F9.2,F10.5,F10.4)
34    FORMAT(' SMD IN YEAR 0',E13.5)
35    FORMAT(1H ,'PARAMETERS'//' CONSTANT' ,E12.5)
36    FORMAT(' POSITIVE RAINFALL',E13.5)
37    FORMAT(' LAGGED SMD',E13.5)
38    FORMAT(' G FACTORS'/' A ',F5.0,'  B ',F5.0,'  C ',F5.0//10X,'RIVER
     1 FLOWS'/' MON YEAR   RAIN    SMD   M RAIN  LOG FLOW  FLOW(M/S)')
      M(NLAG+2)=M(NLAG+1)
      DO 21 K2=1,NLAG
      K3=NLAG-K2+2
      K4=NLAG-K2+1
      R(K3)=R(K4)
      M(K3)=M(K4)
21    G(K3)=G(K4)
      MR0=MR0+1
      IF(MR0-13)2,20,20
20    YR0=YR0+1
      MR0=1
2     CONTINUE
      STOP
      END
C
      SUBROUTINE GCALC(R0,R1,S,G)
      COMMON /BLOCK/A,B,C
      G=0.
      IF(R0)1,2,2
2     G=R0*AMAX1((R1-S+B*R0+A)/C,.1)
      G=AMIN1(G,R0)
1     RETURN
      END
      SUBROUTINE OUTPUT(X,Y,H)
      IF(X)1,2,1
1     WRITE(3,3)H,X,Y
2     RETURN
3     FORMAT(' PARAMETER',A4,2H =,E13.5,10X,'CONSTRAINT',F5.0/)
      END
      SUBROUTINE OUT2(X,M,H,H1)
      REAL X(M)
      WRITE(3,4)H
      DO 1 N=1,M
      IF(X(N).EQ.0..OR.X(N).GE.500.)GOTO 1
      N1=N-1
      WRITE(3,5)H1,N1,X(N)
1     CONTINUE
4     FORMAT(10X,A8)
5     FORMAT(1H ,A1,I2,E13.5)
      RETURN
      END
```

Tables C2.1-C2.5: Optimized calibration parameter values for use in flow reconstruction
(Note each is the channel 1input file to pogram CATCHMENT in C1.2)

C2.1: Medway to Teston

5
130 1
0 21974E-7 5810E-7 5810E-7 4434E-7 4434E-7
0
82698E-7 0 0 0 0 0
0 0 0 0
56620E-7 0 3.57110
-41861E-7 70
-41710E-7 30
0 70
300 70 300

C2.2: Itchen to Highbridge/Allbrook

15
200 1
6192E-7 4325E-7 6109E-7 5125E-7 4410E-7 4410E-7 3659E-7 3659E-7
2187E-7 2187E-7 2187E-7 824E-7 824E-7 824E-7 824E-7 824E-7 0
0 7479E-7 2437E-7 2437E-7 2437E-7 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 3.58003
0 50
0 30
0 50
210 80 300

C2.3: Teifi to Glan Teifi

3
100 1
-41830E-7 31159E-7 3025E-7 3025E-7 0
95060E-7 0 0 0
0 0 0 0
61160E-7 0 3.72413
-32109E-7 100
0 30
0 50
270 70 300

C2.4: Dee to Manley Hall/Erbistock

4
110 1
0 20066E-7 1349E-7 1349E-7 1349E-7 0
131380E-7 0 0 0 0
0 0 0 0
0 0 3.73332
-102020E-7 30
45054E-7 45
0 15
230 60 300

C2.5: Derwent to Derby/ Longbridge Weir

9
160 3
0 15784E-7 6816E-7 6816E-7 2274E-7 2274E-7 1812E-7 1812E-7 1812E-7 1812E-7
0
48167E-7 0 0 0 0 0 0 0 0 0
0 0 0 0
17839E-7 0 3.84556
-17708E-7 70
0 30
0 50
200 70 300

Tables C3.1-C3.5: Monthly evaporation values [Note the required form for the *eg* 1850-1995 reconstructions.......(evaporation in mm) for the 12 calendar months. These files are used as input (channel 1) to program Residpp in C1.1]

Table C3.1: Monthly evaporation, Medway to Teston

1850 1995
6 9 16 30 55 80 86 75 65 30 15 9

Table C3.2: Monthly evaporation, Itchen to Highbridge/Allbrook

1850 1995
7 6 22 45 66 80 75 64 52 26 14 8

Table C3.3: Monthly evaporation, Teifi to Glan Teifi

1855 1995
12 10 14 26 38 68 66 66 65 24 18 12

Table C3.4: Monthly evaporation, Dee to Manley Hall/Erbistock

1858 1995
10 10 15 28 41 88 76 60 50 26 18 7

Table C3.5: Monthly evaporation, Derwent to Derby/Longbridge Weir

1850 1995
10 10 18 32 52 73 72 72 56 30 18 11

APPENDIX D

Reconstructed and observed river flows

Table D1.1a: Reconstructed flows, Medway to Teston, 1851-1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1851	27.18	10.54	23.45	11.97	3.58	2.12	1.80	1.78	1.13	2.46	2.40	1.99	7.53
1852	23.02	11.78	5.13	3.34	3.80	20.19	3.44	9.31	25.33	70.09	68.28	50.70	24.53
1853	52.65	13.09	10.89	12.77	4.65	2.55	2.40	2.53	2.57	28.08	8.32	5.19	12.14
1854	11.42	5.89	3.94	2.49	6.98	3.22	2.01	1.64	1.37	4.91	7.27	11.10	5.19
1855	5.47	6.56	12.04	4.10	3.56	2.52	2.02	1.88	1.16	6.82	10.77	10.85	5.65
1856	13.76	9.61	7.87	20.61	20.70	4.09	2.36	2.19	7.34	6.88	5.96	16.45	9.82
1857	24.74	6.87	8.23	7.97	3.77	2.56	2.01	1.85	10.29	18.23	14.23	6.58	8.94
1858	7.12	6.25	5.57	6.59	4.42	2.38	1.60	1.72	1.30	1.48	1.90	4.21	3.71
1859	7.47	9.58	9.00	8.18	4.38	2.61	1.87	1.56	2.48	15.19	28.02	37.13	10.62
1860	33.58	13.62	18.99	15.51	11.60	14.86	4.46	8.36	7.24	7.43	13.59	16.73	13.83
1861	6.31	10.36	12.98	4.81	2.77	2.18	2.04	1.75	1.35	1.70	26.13	13.85	7.18
1862	12.59	7.46	22.98	10.87	6.46	3.94	2.43	1.96	1.98	19.72	7.85	11.84	9.17
1863	20.91	9.02	5.82	3.71	3.03	8.03	2.69	1.56	3.11	6.30	9.16	10.54	6.99
1864	7.00	7.23	18.86	5.54	3.73	2.53	1.51	1.09	1.25	1.60	9.36	6.39	5.51
1865	23.94	18.47	11.72	4.69	8.21	3.43	3.46	10.01	2.81	36.05	22.06	11.99	13.07
1866	38.01	52.98	21.27	10.95	4.35	3.73	2.96	2.24	16.07	6.84	9.40	10.65	14.95
1867	22.25	13.72	18.04	8.39	5.04	2.96	4.33	2.82	1.97	6.05	5.75	12.06	8.62
1868	25.70	10.35	8.15	7.75	3.73	2.14	1.31	1.61	1.85	3.05	4.14	37.81	8.97
1869	31.49	24.66	18.13	7.51	15.26	3.77	1.65	1.09	1.96	3.49	5.67	23.70	11.53
1870	14.45	10.75	11.36	4.61	2.83	1.89	1.27	1.35	1.27	6.62	6.26	22.43	7.09
1871	30.06	13.14	9.82	15.93	4.50	2.75	2.69	2.26	5.02	3.85	3.42	7.84	8.44
1872	31.43	14.53	12.80	6.45	11.46	5.55	2.83	2.20	1.89	17.09	41.44	49.75	16.45
1873	38.45	20.79	14.71	5.97	3.41	3.26	2.47	1.88	2.11	13.46	12.23	5.48	10.35
1874	7.91	8.53	6.14	7.64	3.10	2.21	2.11	1.75	2.15	13.79	12.44	16.35	7.01
1875	26.47	9.89	6.07	4.97	3.36	2.67	9.81	3.22	2.11	14.66	28.01	12.35	10.30
1876	8.00	18.30	22.62	11.64	3.86	2.35	1.54	1.19	2.45	1.94	4.97	49.51	10.70
1877	74.96	23.50	20.76	18.60	7.46	3.20	1.90	2.16	1.83	2.92	35.36	22.51	17.93
1878	10.08	10.33	10.25	25.41	17.46	4.17	2.38	3.55	2.62	4.73	21.05	12.11	10.35
1879	18.74	29.95	9.30	15.34	10.53	6.15	4.88	8.26	5.60	3.81	5.42	5.44	10.29
1880	4.32	12.36	5.66	5.91	2.83	1.91	2.16	1.79	2.59	36.21	24.31	24.95	10.42
1881	14.37	20.18	15.01	4.86	2.88	2.26	1.74	1.96	2.11	5.21	20.51	23.31	9.53
1882	11.24	10.30	7.17	12.82	3.92	2.40	2.46	2.17	2.22	25.95	27.85	20.18	10.72
1883	16.61	31.47	10.68	6.51	4.88	2.84	2.08	1.65	1.70	3.73	19.32	8.81	9.19
1884	18.17	12.71	10.70	6.36	2.99	1.98	1.54	1.23	1.73	1.92	2.04	7.41	5.73
1885	15.75	23.14	10.98	8.74	11.08	3.42	1.61	1.01	1.82	5.79	15.72	8.03	8.92
1886	24.55	8.95	8.32	6.68	7.56	2.96	1.56	1.59	1.47	2.73	12.27	35.31	9.50
1887	19.42	7.26	9.48	7.74	4.76	2.48	1.43	1.18	1.51	1.93	13.39	14.30	7.07
1888	6.89	8.25	21.38	9.02	3.42	2.71	9.48	4.36	2.39	3.01	21.21	13.14	8.77
1889	7.16	13.09	12.40	12.97	5.04	2.73	2.07	1.95	1.70	16.52	8.29	9.06	7.75
1890	19.82	9.58	14.75	11.12	4.73	2.99	3.60	3.57	2.46	2.07	14.00	6.63	7.94
1891	13.44	4.96	9.56	4.21	5.70	3.09	2.95	6.21	2.70	26.98	17.60	24.84	10.19
1892	8.92	9.38	9.86	5.54	3.01	2.28	2.23	2.38	2.21	17.37	19.66	12.71	7.96
1893	15.09	27.66	7.47	3.27	2.34	1.66	1.34	1.26	1.00	3.20	5.24	12.61	6.85
1894	27.39	14.54	8.98	8.03	4.55	2.91	5.44	2.87	4.03	16.75	30.57	14.95	11.75
1895	14.85	6.89	9.44	7.99	2.95	1.57	1.29	1.53	1.11	1.53	14.19	28.31	7.64
1896	9.11	5.53	15.67	5.56	2.62	4.62	2.49	1.52	14.59	23.79	9.48	23.20	9.85
1897	19.96	20.82	32.31	11.31	4.70	2.86	1.92	1.42	1.93	1.66	1.98	10.40	9.27
1898	5.53	6.97	9.00	4.84	8.78	3.16	1.73	1.22	1.05	1.64	4.45	7.06	4.62
1899	21.40	20.62	7.76	12.23	5.05	2.68	1.72	1.28	1.25	2.19	12.72	11.41	8.36
1900	21.45	49.09	12.43	5.89	3.42	2.77	2.32	1.46	1.44	1.96	6.89	19.28	10.70
1901	8.12	8.96	13.08	9.77	3.59	2.17	1.64	1.41	1.19	1.66	1.94	11.47	5.42
1902	7.85	8.31	8.60	4.31	5.76	4.09	2.54	2.63	2.32	4.52	8.30	9.98	5.77
1903	14.07	10.26	15.09	9.97	6.38	12.76	16.04	8.41	5.07	32.27	18.82	13.59	13.56
1904	32.33	34.23	13.74	5.78	5.30	3.08	1.86	1.38	1.18	1.80	2.66	10.14	9.46
1905	9.08	6.34	19.60	12.46	4.14	7.66	3.00	1.85	2.02	2.28	19.30	7.16	7.91
1906	20.85	23.41	14.09	6.50	4.46	3.33	2.11	1.32	1.17	6.51	36.31	20.43	11.71
1907	11.18	11.06	7.41	12.98	6.36	3.01	2.04	1.61	1.50	5.67	9.20	16.65	7.39
1908	13.14	8.45	15.45	11.09	4.89	2.78	2.40	8.59	3.75	5.03	5.45	16.19	8.10
1909	9.07	5.26	20.05	8.43	4.05	3.06	2.95	2.64	4.73	28.78	9.38	25.45	10.32
1910	28.94	35.86	14.56	9.19	8.10	3.88	2.64	2.30	1.89	3.07	19.04	26.47	13.00
1911	12.47	9.80	15.30	10.98	3.99	2.52	1.85	1.11	0.99	4.90	39.03	58.94	13.49
1912	31.33	20.06	40.92	6.71	3.03	2.51	2.11	9.37	7.28	15.10	14.20	23.35	14.66
1913	39.40	11.24	18.62	17.34	4.92	2.43	1.54	1.57	1.21	6.32	23.83	10.07	11.54
1914	6.56	23.87	49.46	10.49	3.94	2.45	1.59	1.24	0.92	1.15	4.80	61.71	14.01
1915	33.65	41.07	10.15	7.10	14.46	3.58	2.68	2.45	2.24	4.07	15.47	57.53	16.20
1916	14.77	36.49	43.74	11.13	7.03	5.33	3.00	1.98	1.90	12.11	29.99	30.12	16.47
1917	13.48	7.87	10.15	9.58	5.64	3.64	5.27	17.98	4.29	15.01	10.71	14.62	9.85
1918	24.23	9.62	6.54	12.83	5.14	2.54	4.11	2.63	13.06	9.69	11.17	15.23	9.73
1919	33.70	21.16	27.74	21.48	4.37	2.16	1.58	1.66	1.51	1.22	3.05	18.42	11.50
1920	27.49	7.55	7.62	13.27	4.13	2.28	2.97	2.32	3.01	2.95	4.15	14.19	7.66
1921	17.14	8.25	8.84	6.12	3.94	2.18	1.12	0.94	0.94	0.88	1.48	2.52	4.53
1922	9.68	14.98	13.44	15.70	5.02	2.76	2.09	2.16	2.22	2.74	4.87	20.93	8.05
1923	11.57	25.68	17.25	11.87	10.50	3.29	1.77	1.45	1.33	17.64	15.07	18.14	11.30
1924	19.92	9.13	9.81	14.86	12.67	4.56	4.10	3.66	5.60	16.05	22.24	31.03	12.80
1925	26.53	33.98	10.80	11.71	7.76	2.90	2.15	2.07	1.67	7.13	16.16	23.54	12.20
1926	25.81	21.87	6.77	21.09	5.83	4.04	2.76	1.81	1.52	2.27	33.56	8.23	11.30
1927	14.95	33.48	38.28	11.47	4.20	6.75	7.61	13.57	14.40	7.87	15.59	36.45	17.05
1928	39.46	15.41	11.87	10.93	5.65	4.19	2.57	2.13	1.96	16.03	25.73	27.37	13.61
1929	12.15	6.81	4.63	3.42	2.94	2.12	1.40	1.29	1.32	2.81	48.50	73.87	13.44
1930	41.63	14.89	9.77	7.69	7.69	2.96	1.68	2.11	4.05	3.41	26.34	22.33	12.05
1931	15.90	18.29	6.06	19.69	7.60	3.05	2.08	3.96	2.89	2.23	17.39	6.81	8.83
1932	16.96	6.94	7.90	9.60	8.79	3.21	1.91	1.69	1.29	20.96	8.44	4.98	7.72

1933	10.21	13.28	20.48	5.37	4.88	3.00	2.02	1.57	1.77	2.78	2.85	2.77	5.91
1934	13.63	5.44	14.32	10.97	3.45	2.24	1.64	1.33	1.19	1.69	5.39	46.04	8.94
1935	12.64	30.16	8.11	15.04	6.15	3.23	2.28	3.17	8.60	17.04	46.56	37.95	15.91
1936	52.35	24.29	10.43	9.70	3.58	2.40	3.06	2.23	1.71	3.21	22.21	23.94	13.26
1937	49.47	53.09	44.63	21.24	8.85	4.61	2.61	1.88	1.95	4.58	5.69	21.48	18.34
1938	29.47	9.47	5.47	3.82	5.24	2.59	1.47	1.48	1.67	5.39	17.63	23.74	8.95
1939	45.87	15.99	10.28	11.59	4.95	2.67	1.71	1.62	1.41	24.71	42.80	14.08	14.81
1940	17.01	17.26	23.42	9.84	4.32	2.43	1.94	1.71	0.97	3.01	47.27	15.13	12.02
1941	21.56	24.28	20.86	9.57	5.14	3.09	2.30	5.76	2.57	1.93	13.84	12.21	10.26
1942	17.46	7.62	14.88	7.32	9.71	3.08	1.53	1.68	1.66	4.45	4.76	16.96	7.59
1943	40.22	17.64	5.83	5.25	7.38	3.24	1.95	1.65	1.46	3.50	4.52	11.39	8.67
1944	11.90	8.06	4.22	4.46	2.76	1.73	1.39	1.56	1.84	11.95	30.78	19.96	8.39
1945	17.03	13.40	10.67	5.68	5.92	2.87	2.48	2.34	1.75	4.59	2.83	18.10	7.30
1946	16.67	20.67	10.78	11.10	7.87	3.97	2.51	12.22	7.13	5.22	26.61	25.34	12.51
1947	22.50	16.40	42.95	14.30	5.08	3.69	2.67	1.72	1.09	1.14	1.47	3.92	9.74
1948	22.99	14.97	6.71	5.99	5.23	5.01	2.57	3.43	2.64	3.22	6.64	19.91	8.28
1949	10.46	8.10	6.18	5.31	3.70	2.11	1.22	0.88	0.85	8.57	22.51	9.15	6.59
1950	8.87	36.62	12.76	12.07	4.67	2.60	1.95	1.68	2.01	1.75	22.59	16.73	10.36
1951	22.40	63.80	39.47	15.80	6.67	3.62	2.53	8.72	8.54	4.76	25.90	28.90	19.26
1952	21.92	9.23	21.48	9.87	3.83	2.34	1.44	1.62	2.36	4.19	21.70	23.56	10.29
1953	10.39	9.14	4.98	8.45	3.75	2.27	2.00	1.92	3.28	10.42	8.16	6.02	5.90
1954	8.61	12.16	17.88	4.57	4.40	4.92	3.56	3.51	2.96	6.92	30.91	16.20	9.72
1955	27.89	18.69	10.55	4.46	12.39	4.43	2.41	1.82	1.63	17.67	7.43	13.70	10.26
1956	35.01	10.95	6.68	5.58	3.06	2.16	2.55	2.36	2.61	2.84	3.57	19.85	8.10
1957	16.59	29.48	10.14	3.96	2.93	2.25	2.39	2.15	2.41	2.52	14.85	14.95	8.72
1958	21.96	18.38	10.43	6.71	4.56	9.34	3.28	5.98	10.31	14.20	9.56	24.18	11.58
1959	24.99	6.16	9.76	10.29	3.81	2.14	1.45	1.23	0.87	1.24	5.71	42.54	9.18
1960	30.92	19.82	13.72	5.56	3.97	2.72	2.27	7.02	5.99	39.12	59.47	41.87	19.37
1961	42.36	25.65	6.75	8.38	3.83	2.23	1.48	1.09	1.03	4.00	6.71	20.99	10.38
1962	26.79	8.15	9.49	8.04	5.76	2.61	1.47	1.54	1.81	2.10	6.45	18.63	7.74
1963	6.88	5.51	19.11	15.19	5.72	3.52	2.31	2.45	2.41	3.43	30.90	8.86	8.86
1964	7.11	8.25	21.23	16.40	6.93	10.80	3.35	1.75	1.38	1.70	3.81	10.10	7.74
1965	19.09	6.68	9.40	7.52	3.98	2.55	1.94	1.79	14.12	4.32	12.75	33.99	9.84
1966	15.12	33.77	8.01	20.17	6.16	3.60	6.15	4.08	2.65	20.17	19.14	24.59	13.63
1967	21.40	22.10	14.97	13.82	17.76	5.26	2.54	1.70	2.31	15.09	16.65	14.05	12.31
1968	18.19	16.92	8.67	11.82	6.01	3.56	2.39	2.66	29.27	19.79	10.19	18.98	12.37
1969	28.46	15.97	15.47	5.74	5.95	3.11	2.56	2.60	2.03	1.52	15.46	18.56	9.78
1970	22.58	16.27	12.26	14.34	3.98	2.14	1.45	1.36	1.84	1.64	22.90	17.96	9.89
1971	23.41	9.72	14.74	8.75	5.30	12.44	3.21	2.21	2.09	3.20	6.42	6.88	8.20
1972	18.95	14.91	13.21	9.40	4.82	2.81	1.86	1.44	1.09	1.12	2.21	11.35	6.93
1973	7.30	7.45	5.60	8.32	7.02	3.90	2.41	1.63	3.19	2.77	3.45	7.26	5.03
1974	20.42	40.90	12.04	5.20	3.14	2.33	2.06	2.01	19.05	18.88	38.67	20.60	15.44
1975	44.62	15.08	28.01	13.19	9.51	3.43	1.53	1.17	4.04	3.67	9.55	9.56	11.95
1976	6.70	7.56	4.97	3.47	2.34	1.61	1.09	0.91	1.65	11.52	39.19	31.37	9.36
1977	36.71	40.65	28.60	9.02	5.10	3.38	2.18	1.74	1.68	1.48	8.56	21.09	13.35
1978	33.98	25.41	16.37	13.45	8.37	3.58	2.36	1.97	1.40	1.18	1.23	10.05	9.95
1979	23.16	15.26	30.45	12.76	11.48	4.43	2.46	1.82	1.55	1.95	5.30	30.31	11.75
1980	19.86	15.26	20.45	6.17	3.26	4.01	5.14	3.51	2.37	13.07	11.67	11.74	9.71
1981	8.34	5.78	23.55	7.30	9.53	3.45	1.98	1.70	5.96	18.83	9.52	21.74	9.81
1982	15.09	10.62	17.04	5.15	3.05	2.62	2.12	1.55	1.62	25.37	31.18	30.17	12.13
1983	23.10	12.06	11.13	22.52	21.29	4.22	2.13	1.38	1.26	2.20	2.89	15.04	9.93
1984	38.40	13.94	16.86	4.95	5.78	3.12	1.72	1.31	1.17	4.89	19.20	22.02	11.11
1985	19.64	9.65	12.14	10.52	5.29	3.85	2.50	4.23	2.45	1.64	6.33	25.92	8.68
1986	40.13	9.65	13.66	13.59	5.78	2.76	1.56	1.62	1.64	3.88	23.59	25.12	11.92
1987	11.40	9.03	12.54	7.13	4.26	3.51	5.27	3.86	2.46	30.38	18.60	7.13	9.63
1988	52.80	17.74	19.75	7.99	4.60	2.67	1.79	1.83	1.27	2.64	2.80	2.53	9.87
1989	3.35	9.49	16.60	22.06	3.99	2.01	1.58	1.08	0.93	1.25	1.97	11.05	6.28
1990	40.17	53.54	8.91	9.11	4.00	2.30	1.71	0.92	0.92	2.25	4.00	5.93	11.15
1991	23.97	12.06	8.92	10.87	3.71	10.15	4.66	2.40	1.75	2.04	8.80	5.85	7.93
1992	4.64	6.44	11.69	13.60	4.65	2.42	1.70	3.10	2.62	12.46	31.48	25.29	10.01
1993	27.03	7.47	6.34	16.06	7.96	3.19	2.12	1.79	4.35	21.91	11.85	33.21	11.94
1994	50.10	20.27	13.90	16.70	15.78	4.37	2.32	3.77	8.91	19.66	9.79	27.73	16.11
1995	72.78	44.70	21.44	5.67	3.25	2.09	1.26	0.85	1.68	1.82	1.75	*	*

Table D1.1b: Naturalised flows, Medway to Teston, 1957-1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1957	14.17	49.24	9.81	3.81	2.82	1.70	2.19	1.82	2.50	2.08	13.67	12.50	9.69
1958	25.12	23.24	11.23	11.95	3.72	9.88	3.45	7.94	15.52	23.69	15.58	31.17	15.21
1959	29.27	6.79	8.48	9.31	4.10	2.35	1.55	1.41	0.94	1.55	4.03	36.68	8.87
1960	28.61	18.71	13.44	7.37	3.85	2.34	2.59	7.18	6.27	38.68	67.00	37.22	19.44
1961	39.95	22.40	9.17	6.79	5.70	2.48	1.86	1.36	1.50	4.40	6.58	17.86	*10.00*
1962	34.11	9.54	6.52	11.22	5.09	2.35	1.83	1.75	1.84	2.36	8.98	6.51	7.68
1963	5.54	11.93	29.00	17.72	7.49	3.63	2.96	2.41	4.98	4.30	45.91	10.33	*12.18*
1964	9.11	9.47	31.71	17.21	7.00	21.87	3.18	1.91	1.31	2.13	2.87	10.00	9.82
1965	19.97	5.63	11.85	5.73	5.57	2.77	2.13	2.43	10.70	3.71	13.06	38.26	10.15
1966	18.55	45.65	8.82	21.52	7.04	4.30	4.26	7.91	2.68	26.18	18.37	28.91	16.18
1967	25.15	21.51	18.95	14.45	17.29	9.01	3.10	3.06	3.49	10.12	25.84	14.62	13.88
1968	26.16	25.53	6.57	7.67	12.09	4.53	3.11	5.87	30.69	14.37	14.33	28.01	14.91
1969	30.87	22.61	22.74	7.15	6.20	3.55	4.08	3.65	1.72	1.62	12.04	18.83	11.26
1970	28.58	20.58	15.21	15.84	4.33	1.49	2.34	2.20	3.40	1.72	19.64	11.59	10.58
1971	32.85	11.02	16.61	7.82	5.08	17.60	3.07	3.86	1.55	3.33	4.71	4.31	9.32
1972	20.32	21.67	14.69	7.18	4.01	3.75	2.35	1.57	1.48	1.17	2.63	15.34	8.01
1973	5.14	8.28	3.69	5.21	9.28	3.84	2.07	1.18	4.38	2.50	2.28	5.77	4.47
1974	21.73	46.21	12.91	3.77	2.50	2.13	2.23	2.13	17.81	22.27	50.71	15.66	16.67
1975	45.81	19.44	31.92	19.39	16.74	4.53	1.80	1.33	4.73	4.28	9.19	12.61	14.31
1976	6.03	6.52	3.25	2.13	1.53	0.90	0.83	0.36	2.23	10.82	33.97	40.79	9.12
1977	38.77	32.85	18.75	8.44	7.45	4.28	1.47	2.86	1.92	2.50	8.68	19.05	12.25
1978	23.53	22.03	15.66	11.67	20.29	3.36	2.49	2.41	1.06	1.27	1.21	7.60	9.38
1979	17.91	22.10	24.55	13.36	11.12	6.29	2.17	2.23	1.08	2.25	5.86	30.56	11.62
1980	16.95	20.05	17.09	9.44	2.79	3.01	7.12	3.31	1.84	9.99	10.07	14.93	9.72
1981	8.03	5.01	28.30	9.17	12.86	4.60	2.15	2.90	8.18	16.65	10.81	27.82	11.37
1982	20.31	13.95	17.21	5.48	2.88	2.30	1.14	1.32	1.75	23.34	25.88	35.91	12.62
1983	15.81	16.42	9.21	23.46	16.53	9.37	2.94	1.92	1.80	3.73	4.68	17.20	10.26
1984	36.01	13.81	16.52	7.20	4.84	3.00	1.24	0.93	1.53	6.74	19.22	23.85	11.24
1985	27.78	13.62	11.65	15.97	6.52	4.77	2.11	10.33	2.27	2.40	3.36	14.62	9.62
1986	38.25	11.28	12.93	17.25	5.69	2.97	1.66	1.85	1.49	3.50	23.65	18.17	11.56
1987	16.93	10.50	14.54	12.24	3.61	5.19	6.28	4.68	2.56	53.78	24.28	7.55	13.51
1988	50.24	31.89	17.49	9.20	6.03	2.55	3.85	1.47	1.79	3.58	2.67	3.42	11.18
1989	3.46	9.59	15.59	21.19	3.14	1.89	1.17	0.82	1.11	1.31	1.83	14.77	6.32
1990	20.07	63.35	5.64	4.08	1.41	1.58	0.87	0.73	0.90	2.83	4.20	6.15	9.32
1991	24.56	11.74	9.09	6.21	5.30	8.57	6.78	2.04	1.26	1.57	8.86	4.08	7.50
1992	3.05	5.60	6.57	9.51	6.50	1.22	1.41	1.46	2.02	6.94	29.83	30.13	8.69
1993	21.41	6.39	3.27	14.32	5.77	3.03	1.63	0.96	2.46	26.85	9.96	42.24	11.52
1994	53.81	18.53	7.75	22.75	11.01	4.98	2.06	1.90	6.20	7.65	*	*	13.66

Table D1.2a: Reconstructed flows, Itchen to Highbridge/Allbrook, 1852-1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1852	5.56	6.84	6.16	5.50	5.27	5.17	5.18	5.53	6.12	7.82	11.30	14.69	7.09
1853	16.31	15.52	12.97	11.06	9.12	7.61	7.23	7.31	6.68	7.26	8.39	7.15	9.72
1854	7.16	7.34	6.07	5.23	5.33	4.63	4.31	4.05	3.67	3.97	4.20	4.53	5.04
1855	4.55	4.57	5.01	4.85	4.65	4.14	4.34	4.08	4.14	5.07	6.06	6.09	4.80
1856	6.80	7.43	6.68	6.84	7.24	5.88	5.13	5.10	4.75	5.15	5.38	5.74	6.01
1857	6.57	6.33	6.05	5.96	5.14	4.67	4.29	4.01	4.08	5.28	6.62	6.24	5.44
1858	6.15	6.07	5.65	5.51	5.36	4.53	4.39	4.09	3.97	4.15	4.42	5.04	4.94
1859	5.81	6.36	6.59	6.53	6.09	5.26	4.94	4.53	4.86	5.71	7.01	8.45	6.01
1860	9.87	10.10	9.01	8.09	7.20	7.43	7.99	7.52	8.00	8.28	8.12	9.29	8.41
1861	9.39	8.25	8.62	7.92	6.31	5.94	5.80	5.16	5.19	4.97	5.59	6.78	6.66
1862	7.00	7.15	7.50	7.70	7.06	6.42	5.66	5.12	4.78	5.44	6.03	6.18	6.34
1863	7.47	8.31	7.23	6.30	5.85	5.35	4.85	4.77	4.57	5.46	6.27	6.50	6.08
1864	7.14	6.97	7.26	7.28	6.06	5.29	4.56	4.10	4.01	4.01	4.59	5.05	5.53
1865	5.88	7.06	7.09	6.17	5.73	5.16	4.85	5.16	4.92	6.23	9.03	9.72	6.42
1866	11.17	14.13	13.68	11.40	9.60	7.61	6.19	5.99	6.52	7.45	7.11	7.30	9.01
1867	8.49	8.87	8.90	8.72	7.13	5.98	5.93	5.50	5.36	5.72	5.92	5.62	6.85
1868	6.33	7.32	6.87	6.98	6.40	5.05	4.47	4.58	4.67	5.32	5.66	7.40	5.92
1869	10.40	10.39	10.05	8.72	7.63	6.66	5.63	4.76	5.10	5.39	5.42	6.16	7.19
1870	6.97	7.31	7.70	6.58	5.58	4.70	4.19	3.86	3.70	4.21	4.47	5.14	5.37
1871	5.79	6.33	6.32	6.48	6.15	5.49	5.44	5.32	5.53	6.06	5.84	5.67	5.87
1872	7.51	9.29	8.65	8.40	7.29	6.29	5.97	5.27	4.97	5.84	7.85	9.75	7.26
1873	11.97	12.54	11.54	9.84	7.75	6.23	5.55	5.11	4.85	5.13	5.44	5.54	7.62
1874	5.69	6.15	6.11	5.69	5.15	4.72	4.05	4.12	4.13	4.82	6.04	6.67	5.28
1875	7.85	8.99	8.21	7.13	6.30	5.73	5.77	5.66	5.13	5.71	7.51	7.72	6.81
1876	7.13	7.52	8.12	7.74	6.42	5.53	4.60	4.57	4.72	4.85	5.48	7.76	6.20
1877	11.52	11.95	10.85	10.46	9.01	6.97	6.68	6.19	5.84	5.86	7.12	8.59	8.42
1878	7.98	8.31	8.08	6.93	6.80	6.09	5.10	5.35	5.27	5.30	6.04	6.54	6.48
1879	6.98	8.61	8.44	7.24	7.12	7.05	7.00	7.83	8.43	7.61	6.93	6.32	7.46
1880	5.79	6.12	6.55	5.93	5.04	4.76	4.66	4.47	5.07	6.05	7.22	7.76	5.78
1881	8.28	8.48	8.40	7.62	6.31	5.34	4.83	5.01	5.05	4.97	5.58	7.11	6.42
1882	7.18	7.09	6.99	6.47	6.14	5.70	5.10	4.87	4.82	5.76	7.77	7.91	6.32
1883	8.56	10.26	9.82	7.95	7.05	5.88	5.29	4.69	4.84	4.96	5.87	6.64	6.82
1884	6.64	7.42	7.64	7.11	5.92	5.18	4.63	4.24	4.15	3.95	4.09	4.60	5.46
1885	5.37	6.40	6.98	6.65	6.33	5.73	4.76	4.20	4.63	5.05	5.72	6.15	5.66
1886	6.57	7.07	6.73	6.41	6.18	5.33	5.04	4.47	4.22	4.71	5.63	7.42	5.82
1887	9.07	8.77	7.90	7.03	5.94	4.97	4.44	4.18	4.02	4.11	4.56	5.15	5.84
1888	5.48	5.45	5.90	5.99	5.40	5.19	5.49	5.60	5.08	5.00	5.71	6.78	5.59
1889	6.62	6.59	6.76	6.52	6.17	5.36	4.85	4.50	4.24	4.80	5.11	5.42	5.58
1890	6.30	6.90	6.20	5.98	5.75	5.14	4.95	5.05	4.58	4.56	4.70	4.81	5.41
1891	5.30	5.44	5.49	5.36	5.04	4.45	4.37	4.82	5.06	6.54	9.19	10.10	5.93
1892	10.39	9.22	7.91	6.57	5.68	4.89	4.45	4.51	4.54	5.23	6.08	6.52	6.33
1893	6.78	7.48	7.51	5.97	5.29	4.55	4.34	3.98	3.96	4.21	4.65	5.42	5.35
1894	6.47	7.45	7.22	6.91	6.24	5.26	5.47	5.50	5.10	5.69	7.44	8.57	6.44
1895	9.06	8.87	7.68	7.13	6.12	5.08	4.99	4.82	4.34	4.59	5.43	6.74	6.24
1896	6.88	6.48	6.55	6.25	5.23	4.83	4.09	4.00	4.70	5.39	5.41	6.20	5.50
1897	7.84	8.07	9.56	10.09	7.72	6.79	5.68	5.32	5.27	5.13	4.91	5.70	6.84
1898	6.31	5.81	5.86	5.36	5.14	4.89	4.18	3.81	3.70	4.20	5.03	6.31	5.05
1899	7.26	8.40	8.26	7.15	6.43	5.50	4.77	4.43	4.24	4.27	5.23	6.06	6.00
1900	6.70	8.79	9.46	7.74	6.72	6.10	4.96	4.96	4.56	4.52	5.08	6.17	6.31
1901	6.82	6.70	6.91	6.82	5.89	5.18	4.94	4.72	4.63	4.78	4.81	5.50	5.64
1902	6.57	6.33	6.34	6.17	5.59	5.37	4.99	4.89	4.65	4.83	5.16	5.95	5.57
1903	6.42	6.81	7.54	7.48	6.99	6.58	5.97	5.93	5.97	8.01	10.31	9.43	7.29
1904	11.38	13.27	11.58	9.56	8.78	6.95	5.86	5.54	4.97	4.97	4.98	5.47	7.77
1905	5.86	5.56	6.42	6.94	5.51	5.60	4.95	4.69	4.40	4.62	5.11	5.70	5.45
1906	7.12	9.15	8.96	7.46	6.69	5.65	4.56	4.33	3.91	4.52	5.65	6.43	6.20
1907	6.33	6.33	6.20	6.19	6.22	5.38	4.81	4.69	4.10	5.02	6.38	7.42	5.76
1908	8.48	8.07	7.80	7.75	6.89	5.59	5.26	5.05	4.80	4.85	4.77	5.28	6.22
1909	5.81	5.40	5.82	6.04	5.25	5.39	5.36	4.90	5.00	6.79	7.98	7.81	5.96
1910	9.52	10.16	9.64	8.65	7.53	6.43	5.66	5.30	4.50	5.04	5.83	7.54	7.15
1911	8.50	7.84	7.87	7.22	6.24	5.37	4.60	4.09	3.79	4.22	4.83	7.45	6.00
1912	10.49	10.16	11.15	9.97	7.58	7.00	6.34	6.64	7.10	7.20	7.34	8.32	8.27
1913	10.31	10.39	10.09	9.87	8.70	6.73	5.74	5.01	4.70	5.18	5.85	6.19	7.40
1914	6.15	6.98	8.94	8.44	6.96	5.88	5.29	4.66	4.41	4.47	4.88	7.44	6.21
1915	10.61	11.79	12.16	9.73	8.62	7.06	6.61	6.03	5.92	6.15	6.76	9.10	8.38
1916	10.82	11.15	12.53	10.55	8.13	6.60	5.59	5.11	4.89	5.70	6.91	8.71	8.06
1917	8.83	8.14	7.95	7.17	6.36	5.83	5.59	6.03	6.16	6.36	6.82	6.40	6.80
1918	6.78	7.33	6.67	6.19	5.89	4.90	5.02	4.95	5.36	5.99	6.15	6.67	5.99
1919	8.05	9.35	10.18	10.66	8.11	6.43	5.55	4.97	4.77	4.64	4.66	5.69	6.92
1920	7.56	7.59	7.21	7.43	6.55	5.66	5.86	5.62	5.18	5.44	5.72	5.95	6.31
1921	7.01	7.32	6.35	5.82	5.26	4.20	3.83	3.68	3.38	3.45	3.55	3.72	4.80
1922	4.58	5.54	6.26	6.59	6.29	5.50	5.30	5.23	4.91	4.74	4.96	5.65	5.46
1923	6.67	7.91	9.07	8.51	7.60	6.05	5.09	4.60	4.48	5.21	5.76	6.27	6.44
1924	7.15	7.31	6.56	6.45	6.68	5.89	5.84	5.80	6.03	7.49	8.27	9.55	6.92
1925	11.83	12.81	11.95	10.11	9.12	7.21	6.57	5.93	5.88	6.14	6.69	7.50	8.48
1926	8.88	10.33	8.91	7.94	7.32	6.10	5.32	4.88	4.27	4.43	5.62	6.61	6.72
1927	6.27	7.49	8.88	8.07	6.72	6.26	5.47	5.51	6.40	6.98	7.44	8.83	7.03
1928	10.91	11.82	10.91	10.21	8.08	6.79	5.68	5.16	4.67	5.71	7.04	7.41	7.86
1929	7.70	7.35	6.40	5.60	5.10	4.41	4.12	3.94	3.54	4.06	5.64	9.84	5.64
1930	12.49	12.20	10.72	8.92	7.61	6.04	5.44	5.30	5.21	5.23	6.00	7.63	7.73
1931	8.32	8.51	7.87	6.93	6.58	5.94	5.51	5.77	6.00	5.37	5.86	6.26	6.58
1932	6.24	6.58	6.04	5.83	6.43	6.13	5.62	5.20	5.19	5.95	7.16	6.68	6.09
1933	6.79	8.09	8.89	8.22	7.14	6.20	5.52	4.78	4.72	4.77	4.73	4.74	6.22

Table D1.2a: Reconstructed flows, Itchen to Highbridge/Allbrook, 1852-1995

1934	5.00	5.05	5.22	5.65	5.05	4.43	4.03	4.00	3.88	4.07	4.41	6.45	4.77
1935	8.52	7.78	8.33	7.96	6.70	6.49	5.57	5.20	5.49	6.45	8.91	11.47	7.40
1936	13.14	14.69	13.27	11.00	8.57	7.41	6.56	5.66	5.59	5.16	5.75	6.71	8.63
1937	8.80	12.01	12.95	12.20	10.08	7.86	6.41	5.49	5.04	5.11	5.33	6.14	8.12
1938	7.47	7.59	6.63	5.74	5.10	4.16	4.09	3.80	3.61	4.04	4.73	6.01	5.25
1939	7.85	8.99	8.20	7.28	6.29	5.39	5.23	5.07	4.60	5.24	7.08	8.17	6.61
1940	8.27	9.28	9.47	8.22	6.68	5.36	4.98	4.24	4.15	4.34	5.78	8.02	6.57
1941	7.97	8.79	9.41	8.80	7.65	6.28	5.50	5.46	5.07	4.80	4.98	5.71	6.70
1942	6.46	6.66	6.39	6.22	5.94	4.96	4.46	4.39	4.27	4.70	5.00	5.58	5.42
1943	7.60	8.81	7.62	6.53	6.21	5.18	4.82	4.40	4.07	4.56	4.92	5.12	5.82
1944	5.59	5.86	5.33	4.95	4.36	4.06	3.92	3.85	3.75	4.31	5.61	7.06	4.89
1945	7.41	7.65	7.39	6.28	5.73	5.24	4.80	4.57	4.43	4.59	4.74	5.34	5.68
1946	6.54	7.14	6.92	6.43	6.27	6.04	5.47	5.67	6.10	6.25	7.07	9.35	6.60
1947	9.68	9.36	11.08	11.39	8.53	7.33	6.16	4.95	4.64	4.34	4.24	4.59	7.19
1948	5.84	6.94	6.25	5.92	5.75	5.19	4.55	4.86	4.97	5.13	5.28	6.17	5.57
1949	7.11	6.68	6.71	6.22	5.49	4.79	4.31	3.81	3.78	4.83	6.16	6.77	5.55
1950	6.53	7.38	8.14	7.13	6.45	5.57	5.37	5.51	5.74	5.54	6.47	8.08	6.49
1951	8.22	10.19	12.40	11.61	10.17	8.20	6.72	6.50	7.01	6.52	8.15	11.03	8.89
1952	9.98	9.46	9.04	7.97	7.15	6.23	4.97	4.83	4.79	5.34	6.44	7.24	6.95
1953	7.26	7.10	6.54	5.86	5.54	5.13	4.95	4.79	4.80	5.49	6.27	5.98	5.81
1954	6.05	6.75	7.24	6.64	6.02	5.44	5.21	5.17	5.28	5.77	7.20	8.93	6.31
1955	9.21	9.18	8.58	7.03	6.82	6.29	5.14	4.70	4.44	4.68	5.31	6.27	6.47
1956	7.78	8.03	6.86	6.16	5.13	4.57	4.42	4.58	4.76	5.20	5.27	5.99	5.73
1957	7.68	8.39	9.01	7.71	6.32	5.37	5.30	4.99	5.14	5.34	5.60	6.33	6.43
1958	7.18	8.25	8.18	7.02	6.29	5.57	4.92	4.99	5.46	6.32	6.68	7.53	6.53
1959	8.74	8.19	7.90	8.09	6.56	5.44	4.91	4.49	3.93	4.30	4.58	6.07	6.10
1960	8.73	9.19	9.16	8.07	6.58	5.82	5.52	5.72	6.44	8.67	11.75	13.17	8.24
1961	14.99	15.72	12.49	10.77	9.26	6.94	5.74	5.08	4.82	5.02	5.50	5.98	8.53
1962	7.63	8.31	7.07	6.64	5.90	4.75	4.45	4.38	4.54	4.89	5.24	5.88	5.81
1963	6.05	5.79	6.56	7.41	6.52	6.03	5.24	4.94	4.88	5.10	6.17	7.33	6.00
1964	6.66	6.24	6.84	7.19	6.72	6.37	5.28	4.64	4.23	4.16	4.31	4.90	5.63
1965	5.81	5.98	5.90	6.02	5.44	4.93	4.83	4.68	4.85	4.97	5.29	6.75	5.45
1966	7.89	8.60	9.33	8.43	7.80	7.05	6.01	5.60	5.35	5.84	6.87	7.06	7.15
1967	7.84	9.22	9.02	8.01	7.83	6.81	5.69	5.24	5.08	6.10	7.45	7.43	7.14
1968	7.81	7.92	7.30	6.58	6.18	5.77	5.43	5.08	5.73	7.65	7.77	8.10	6.78
1969	9.94	9.98	9.24	8.50	7.33	6.04	5.62	5.05	4.64	4.40	4.92	5.86	6.79
1970	6.92	7.83	7.88	7.08	5.99	5.22	4.65	4.44	4.45	4.27	5.65	7.36	5.98
1971	7.66	8.78	8.51	7.85	6.75	6.53	5.61	5.30	4.63	4.70	4.94	5.04	6.36
1972	5.75	6.96	7.51	7.38	6.90	6.01	5.10	4.68	4.25	4.11	4.54	5.60	5.73
1973	6.67	6.26	5.90	5.59	5.15	4.66	4.44	4.11	4.07	4.06	4.06	4.47	4.95
1974	5.78	8.14	8.44	6.89	6.17	5.55	4.90	4.90	5.73	6.85	8.14	10.18	6.81
1975	10.93	11.31	10.77	9.90	7.72	6.15	5.31	4.62	5.06	5.04	5.29	5.47	7.30
1976	5.34	5.30	5.10	4.65	4.15	3.76	3.47	3.11	3.67	4.47	6.41	8.40	4.82
1977	9.04	10.90	11.80	10.12	8.41	6.99	5.70	5.52	4.90	4.93	5.37	6.71	7.53
1978	8.12	8.69	9.14	8.52	7.20	6.05	5.37	4.82	4.40	4.17	4.03	5.30	6.32
1979	7.41	7.66	8.42	8.63	7.80	7.21	6.32	5.76	5.34	5.45	5.38	6.57	6.83
1980	7.64	7.73	8.53	7.51	6.11	5.91	5.34	5.06	4.91	5.29	5.67	5.99	6.31
1981	6.30	6.14	7.22	8.01	7.05	6.20	5.67	4.69	5.35	6.07	6.26	7.00	6.33
1982	7.74	7.28	7.59	7.40	6.26	5.83	5.21	4.70	4.46	5.62	7.73	9.30	6.59
1983	10.31	9.91	8.76	8.10	7.78	6.69	5.55	5.04	4.76	4.74	4.90	5.44	6.83
1984	7.16	8.09	7.92	7.30	6.61	5.45	5.00	4.33	4.25	4.76	5.74	7.50	6.18
1985	8.45	8.50	8.43	7.61	6.36	5.82	5.30	5.44	5.18	4.92	4.88	5.99	6.41
1986	8.21	8.37	7.70	7.48	6.80	5.57	5.06	5.00	4.65	5.08	5.96	7.75	6.47
1987	8.08	7.54	7.99	7.60	6.51	6.03	5.26	4.62	4.38	5.35	6.77	6.96	6.42
1988	8.31	9.78	8.82	8.18	7.07	5.58	5.26	4.95	4.46	4.79	4.98	4.84	6.42
1989	4.94	5.45	6.38	6.61	5.69	4.97	4.24	3.87	3.66	3.95	4.10	5.34	4.93
1990	7.67	10.07	10.49	8.79	7.14	6.07	4.84	4.37	4.10	4.26	4.36	4.74	6.41
1991	5.53	6.41	6.88	6.92	5.73	5.56	5.47	4.86	4.61	4.61	4.90	4.94	5.54
1992	4.99	4.99	5.19	5.58	5.06	4.58	4.28	4.44	4.52	4.62	5.70	7.45	5.12
1993	8.57	8.65	7.62	7.40	7.17	6.11	5.39	4.88	5.11	6.19	7.53	8.40	6.92
1994	10.97	12.04	10.88	10.10	8.96	7.19	6.06	5.25	4.96	5.50	6.25	7.48	7.97
1995	9.82	12.55	12.57	9.93	7.91	6.15	5.10	4.28	4.64	4.52	5.36	6.27	7.42

Table D1.2b: Naturalised flows, Itchen to High bridge/Allbrook, 1959-1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1959	8.40	8.62	7.84	7.52	6.68	5.87	5.20	4.44	3.85	3.62	3.94	5.95	5.99
1960	7.48	9.14	8.57	7.31	5.73	5.27	5.02	5.06	5.55	8.78	10.77	11.76	7.54
1961	11.36	10.52	8.76	8.06	8.09	6.05	5.06	4.39	4.22	3.97	4.37	5.41	6.69
1962	7.12	7.57	7.09	6.67	5.94	5.26	4.58	4.65	4.19	4.72	5.11	5.06	5.66
1963	5.16	5.72	6.78	8.06	7.41	6.05	6.03	6.00	5.55	5.27	6.56	7.61	6.35
1964	6.22	5.13	6.17	7.09	7.17	6.35	5.07	4.96	4.23	4.31	4.60	4.94	5.52
1965	5.43	5.65	5.87	5.80	5.05	4.60	4.51	4.61	4.69	4.87	5.09	6.41	5.22
1966	8.04	9.09	9.70	8.05	8.43	7.53	6.28	5.57	5.27	5.58	6.26	6.23	7.17
1967	7.06	8.13	9.53	8.73	7.83	7.35	6.15	5.35	4.87	6.58	8.84	7.77	7.35
1968	8.51	9.13	7.64	6.47	6.33	6.30	5.67	5.09	6.09	8.00	8.56	8.39	7.18
1969	11.45	11.83	10.32	9.48	7.89	6.57	5.67	5.08	4.96	4.73	5.43	5.94	7.45
1970	7.11	8.47	8.40	7.53	6.30	5.15	4.80	4.65	4.67	4.48	6.00	6.68	6.19
1971	7.66	9.18	8.67	8.58	7.36	6.54	5.74	5.23	4.74	4.79	5.08	5.25	6.57
1972	5.49	7.15	8.39	7.67	6.74	5.70	4.95	4.55	4.23	4.10	4.35	6.74	5.84
1973	6.55	6.06	5.64	5.17	4.92	4.40	4.29	4.03	3.69	3.82	3.81	4.04	4.70
1974	5.73	8.51	7.93	6.74	5.61	4.94	4.62	4.25	5.45	5.44	8.48	9.65	6.45
1975	9.77	11.00	9.32	8.13	7.08	6.03	5.33	4.70	4.72	4.86	4.95	5.47	6.78
1976	5.15	5.06	4.70	4.24	4.09	3.72	3.56	3.30	3.77	5.03	6.07	7.84	4.71
1977	8.61	10.60	10.86	9.44	7.95	6.48	5.55	5.25	4.95	4.73	5.26	6.09	7.15
1978	7.25	8.51	8.62	7.93	7.33	6.41	5.30	4.71	4.46	4.26	4.12	5.70	6.22
1979	6.76	7.89	8.26	8.36	8.01	7.57	6.42	6.24	5.59	5.16	5.35	6.33	6.83
1980	7.23	7.90	7.92	7.65	6.44	5.67	4.94	4.67	4.57	4.57	4.90	5.50	6.00
1981	5.97	5.76	7.49	7.82	7.18	6.66	5.76	5.25	5.21	5.97	6.44	7.18	6.39
1982	8.51	8.23	8.76	8.01	6.77	5.80	5.18	4.61	4.41	5.95	7.50	10.65	7.03
1983	10.93	9.40	8.09	7.83	7.29	6.94	5.98	5.26	5.03	4.85	4.86	5.65	6.84
1984	7.29	8.70	8.29	7.76	6.83	5.95	5.08	4.71	4.52	4.91	5.82	7.46	6.44
1985	8.59	9.18	8.24	7.80	6.85	6.08	5.29	5.52	5.18	4.80	4.64	5.96	6.51
1986	8.94	8.62	7.73	7.28	7.01	6.11	5.52	5.23	4.81	4.63	5.86	7.58	6.61
1987	8.17	7.26	7.04	8.21	7.38	6.11	5.12	4.42	4.17	5.50	6.82	6.86	6.42
1988	7.72	10.64	9.17	8.01	6.80	5.58	5.15	4.54	4.51	4.78	4.74	4.66	6.36

Table D1.3a: Reconstructed flows, Teifi to Glan Teifi, 1856-1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1856	46.33	40.89	15.71	26.03	19.00	7.22	4.37	6.10	19.14	36.21	35.34	57.26	26.13
1857	50.53	40.29	49.67	46.14	16.46	7.78	9.79	9.34	13.86	28.67	17.74	17.22	25.62
1858	17.93	10.24	15.24	34.42	22.93	8.26	4.68	5.44	10.63	34.42	20.23	36.88	18.44
1859	37.66	30.15	49.58	42.08	11.49	4.74	8.98	15.65	34.43	41.50	61.14	56.86	32.86
1860	51.27	27.11	44.34	28.69	23.19	50.58	17.27	43.16	18.32	31.19	35.51	43.94	34.55
1861	19.66	30.62	42.55	12.31	8.30	9.71	21.75	23.85	27.18	29.36	50.81	47.72	26.99
1862	53.69	17.63	25.71	32.99	27.41	22.44	19.52	15.00	18.70	47.04	23.48	35.05	28.22
1863	52.22	23.76	16.52	12.76	10.27	15.20	8.60	10.10	34.45	56.43	50.01	28.65	26.58
1864	28.35	20.64	18.07	11.43	9.57	11.33	6.87	4.22	20.86	26.04	38.83	30.02	18.85
1865	43.28	39.25	25.58	10.03	22.90	10.32	6.85	24.51	8.63	18.94	50.91	33.76	24.58
1866	63.93	50.46	47.28	14.69	6.62	11.32	7.50	12.64	49.63	22.43	33.64	44.43	30.38
1867	52.77	34.43	28.59	39.86	26.80	7.81	7.35	7.83	7.46	36.02	14.04	24.29	23.94
1868	48.99	29.84	36.17	22.40	11.67	5.65	2.25	4.81	8.91	25.29	26.52	91.51	26.17
1869	62.86	52.21	22.89	17.97	23.41	8.17	1.94	1.57	25.12	30.78	41.75	60.16	29.07
1870	43.56	46.27	28.65	11.53	10.00	6.08	2.47	3.45	7.22	57.99	48.67	25.84	24.31
1871	35.39	36.17	23.93	32.77	11.34	7.11	24.26	12.03	15.18	46.79	17.91	28.40	24.27
1872	73.39	58.19	56.26	24.91	12.86	28.10	20.71	14.30	30.46	76.45	88.83	90.65	47.93
1873	70.46	19.83	24.70	12.67	9.76	6.78	8.98	23.43	15.28	27.43	25.84	15.25	21.70
1874	35.09	44.40	32.61	17.74	7.94	5.09	4.12	22.66	38.33	50.22	47.41	56.15	30.14
1875	69.75	21.14	11.70	11.52	12.34	12.18	19.51	29.51	35.39	56.01	63.10	30.19	31.03
1876	24.58	42.16	41.99	29.68	9.40	3.84	5.22	13.90	30.94	52.65	47.46	88.73	32.55
1877	79.30	51.72	36.38	29.71	28.90	15.97	27.15	47.08	15.35	29.34	67.00	41.54	39.12
1878	44.18	26.36	16.78	15.07	28.96	18.15	7.44	22.84	20.10	46.55	47.94	32.18	27.21
1879	25.82	39.16	28.27	13.12	13.42	31.84	33.54	51.18	30.50	17.30	10.20	15.34	25.81
1880	11.13	25.57	20.96	16.64	12.98	13.40	29.17	10.17	8.89	32.16	52.17	72.72	25.50
1881	16.08	29.46	42.29	17.81	15.63	15.19	8.33	16.25	10.11	15.55	55.38	49.84	24.33
1882	56.56	52.32	33.76	45.52	17.28	16.62	38.34	41.10	25.07	45.51	69.71	58.15	41.66
1883	58.06	78.57	27.65	12.29	8.81	11.79	17.97	10.29	21.73	49.37	57.58	37.38	32.63
1884	57.87	60.90	51.34	18.93	11.13	6.99	12.60	10.79	12.22	24.03	29.60	55.35	29.31
1885	46.51	68.80	27.11	23.15	19.30	10.64	6.07	5.93	24.73	50.33	49.25	22.75	29.55
1886	40.92	21.27	36.28	22.46	30.38	10.86	9.56	8.31	17.64	73.62	53.66	68.90	32.82
1887	46.09	18.59	16.26	12.06	9.16	5.34	2.58	3.94	9.18	18.06	29.50	42.82	17.80
1888	24.68	12.28	25.48	18.53	8.94	9.98	30.56	32.32	9.34	14.86	58.88	55.75	25.13
1889	24.55	26.43	31.10	29.35	22.37	7.36	4.75	13.99	9.78	28.61	25.56	29.96	21.15
1890	71.50	16.59	17.53	12.11	11.42	9.57	9.74	13.96	8.27	20.93	70.86	16.65	23.26
1891	25.22	12.03	8.99	15.34	17.49	13.34	9.78	24.97	25.25	75.25	47.17	84.22	29.92
1892	39.16	28.47	12.85	8.20	8.79	7.03	5.97	9.05	12.41	30.75	38.76	29.60	19.25
1893	25.53	43.37	14.86	6.28	6.50	6.50	7.27	9.79	10.72	29.97	38.94	55.51	21.27
1894	56.23	44.83	39.35	18.70	20.75	9.98	15.78	22.31	8.10	22.73	54.67	43.01	29.70
1895	51.22	12.34	22.97	23.95	7.89	3.17	9.53	17.69	6.71	18.21	51.91	39.94	22.13
1896	26.98	15.75	38.16	13.96	5.60	2.66	5.25	11.34	37.60	48.10	18.68	51.00	22.92
1897	23.54	30.00	54.80	37.69	12.98	6.46	6.29	17.61	34.43	21.08	33.00	80.27	29.85
1898	30.21	33.22	19.06	18.74	28.64	15.24	6.46	9.36	7.82	22.83	40.10	59.54	24.27
1899	78.04	48.86	22.84	31.49	24.05	7.85	4.32	4.44	7.40	25.53	38.76	40.05	27.80
1900	57.21	58.91	22.12	14.17	21.83	15.49	7.69	15.53	9.53	21.39	44.76	65.91	29.54
1901	42.93	22.95	33.51	36.90	11.10	8.52	6.98	12.62	13.59	24.20	28.55	53.65	24.63
1902	31.01	17.87	25.64	18.61	15.18	13.32	8.23	9.47	8.80	22.84	41.47	46.32	21.56
1903	61.08	44.72	80.43	21.40	16.71	8.57	8.52	28.76	40.27	139.52	47.15	46.70	45.32
1904	61.11	53.51	22.28	19.87	14.15	7.06	5.79	8.85	9.17	14.57	27.65	42.44	23.87
1905	31.75	25.62	47.68	44.65	11.83	5.11	4.64	20.11	10.79	16.25	38.62	17.36	22.87
1906	46.32	47.33	38.13	15.11	18.42	11.10	5.58	10.05	7.18	24.73	36.64	46.33	25.58
1907	35.74	23.56	17.42	23.24	28.44	29.34	16.64	15.55	7.48	25.91	37.32	49.57	25.85
1908	34.93	37.84	47.37	24.10	19.08	8.50	13.04	27.86	19.74	13.75	26.40	49.71	26.86
1909	33.34	14.56	24.68	37.82	14.35	6.79	12.29	9.60	11.92	48.22	18.32	38.20	22.51
1910	44.79	60.12	22.59	27.14	18.98	25.41	23.63	32.12	9.63	12.69	53.21	74.60	33.74
1911	24.06	22.93	22.06	17.17	11.21	12.09	6.40	4.77	13.08	28.29	55.21	106.70	27.00
1912	45.38	34.31	65.15	11.70	5.84	18.88	15.62	39.94	10.14	17.89	43.61	57.65	30.51
1913	64.21	25.31	44.72	56.24	25.56	13.52	6.63	3.77	8.73	26.40	54.30	31.36	30.06
1914	28.70	49.60	60.02	15.77	12.66	7.87	13.45	17.12	8.95	12.18	34.01	87.18	28.96
1915	56.21	78.38	17.14	12.65	11.74	6.71	11.15	12.30	6.21	10.03	27.19	89.23	28.25
1916	34.81	49.01	24.10	23.80	23.28	10.45	6.18	8.76	14.84	63.38	42.87	39.56	28.42
1917	22.42	13.38	16.94	18.89	16.51	9.96	7.04	37.28	13.15	34.92	43.27	18.21	21.00
1918	30.79	42.22	26.54	12.73	12.99	7.80	11.29	10.08	33.37	41.40	41.17	74.63	28.75
1919	53.15	31.14	49.56	28.49	9.52	7.54	6.25	6.57	7.64	10.10	18.72	60.43	24.09
1920	52.43	31.70	54.46	63.09	34.27	14.57	23.64	12.36	13.32	34.23	21.05	29.79	32.08
1921	55.75	12.61	25.58	15.32	8.86	5.33	1.83	19.87	9.78	8.90	23.45	38.18	18.79
1922	55.27	55.60	38.31	30.02	11.06	5.90	16.45	17.78	14.78	10.14	10.78	33.14	24.94
1923	43.99	97.22	22.92	18.45	22.05	8.43	7.06	14.74	21.11	61.80	49.56	52.79	35.01
1924	48.57	16.01	10.83	20.60	33.05	14.01	19.57	36.84	43.15	50.03	31.99	62.03	32.22
1925	46.71	79.18	19.93	18.14	28.72	8.16	2.90	11.50	15.24	40.56	35.48	42.53	29.09
1926	58.81	38.14	16.90	12.24	12.11	7.39	16.66	27.19	11.55	22.40	74.61	17.16	26.26
1927	35.90	42.02	47.71	22.92	10.64	16.90	26.14	46.87	41.94	37.82	42.40	29.22	33.38
1928	73.14	49.79	35.02	14.50	6.63	17.91	15.00	19.18	10.06	28.70	71.27	45.53	32.23
1929	19.07	10.96	7.54	5.88	11.96	10.54	8.95	8.34	5.81	28.38	107.52	105.11	27.51
1930	75.76	13.06	16.09	19.77	12.98	6.80	14.25	25.27	32.53	69.09	56.92	67.18	34.14
1931	52.99	47.99	16.56	20.27	23.47	12.67	14.56	19.61	12.67	11.19	54.56	31.50	26.50
1932	58.76	11.97	16.28	27.96	34.37	11.40	11.16	7.78	8.56	54.19	39.71	42.23	27.03
1933	51.74	48.67	37.47	12.01	7.16	9.28	8.59	5.71	3.12	21.85	13.93	9.80	19.11
1934	28.26	12.09	19.79	27.58	15.01	6.98	3.08	8.95	16.27	34.30	19.89	67.10	21.61
1935	22.51	37.69	17.56	29.02	15.23	17.39	8.48	2.68	26.05	53.82	62.71	43.94	28.09
1936	63.38	27.58	20.04	18.74	9.54	11.13	29.75	9.41	5.82	18.75	38.47	62.96	26.30
1937	73.53	67.78	33.76	29.04	12.10	5.93	5.74	5.11	5.95	22.07	14.72	24.14	24.99
1938	63.64	24.85	11.96	6.35	8.62	14.49	22.30	14.43	7.06	29.23	67.92	49.85	26.73
1939	64.50	54.67	34.94	22.02	8.55	6.05	30.79	20.77	7.18	7.75	66.28	37.60	30.09

Table D1.3a: Reconstructed flows, Teifi to Glan Teifi, 1856-1995

1940	35.34	38.54	34.91	19.27	9.26	5.17	14.57	9.05	3.40	25.98	91.49	44.33	27.61
1941	31.29	42.33	38.06	16.41	13.16	6.97	4.39	19.90	8.72	15.78	37.65	42.49	23.10
1942	56.41	16.03	20.32	20.67	33.30	9.40	7.05	17.19	16.95	37.58	12.97	37.42	23.77
1943	68.60	40.49	17.14	10.61	20.82	15.57	9.60	15.34	29.83	45.05	46.55	28.24	28.99
1944	41.20	24.95	9.93	8.95	9.22	6.95	7.86	7.92	14.52	48.39	67.12	46.56	24.47
1945	40.93	51.15	22.76	15.83	19.75	18.33	12.51	8.67	10.26	19.16	10.51	25.82	21.31
1946	53.24	54.68	17.53	9.30	9.90	12.26	8.97	25.12	41.48	17.53	46.84	48.40	28.77
1947	44.67	24.49	62.13	37.91	20.72	8.48	7.24	5.15	3.12	5.50	22.70	43.08	23.77
1948	86.35	31.68	21.97	15.34	11.43	14.81	12.87	18.23	25.27	32.94	31.57	67.98	30.87
1949	28.48	17.69	18.60	27.70	27.32	8.23	1.95	1.80	2.00	23.73	50.55	52.18	21.69
1950	23.35	48.54	27.09	28.48	14.01	6.27	7.85	28.67	63.53	28.90	53.09	48.66	31.54
1951	48.22	48.22	52.71	34.64	17.17	6.80	3.80	19.90	23.95	11.57	43.16	55.01	30.43
1952	50.70	27.51	21.43	20.34	20.67	12.40	6.36	13.55	16.80	31.58	34.12	42.90	24.86
1953	23.07	19.04	26.05	25.20	15.93	7.48	12.31	14.65	20.54	26.50	39.20	20.28	20.85
1954	26.50	45.19	40.34	14.50	14.21	17.66	16.87	21.03	25.05	59.18	81.16	52.85	34.55
1955	39.21	24.56	25.06	23.92	28.57	25.95	7.97	2.11	3.64	17.39	21.64	38.79	21.57
1956	51.94	14.67	14.21	11.09	6.44	5.97	8.76	24.74	27.66	22.10	20.36	37.97	20.49
1957	46.55	46.92	44.26	11.68	7.52	6.74	17.26	30.69	52.23	44.12	28.64	34.71	30.94
1958	47.43	57.14	16.34	8.39	14.67	15.57	16.67	16.38	37.14	42.87	27.93	35.27	27.98
1959	55.98	14.27	23.82	40.69	11.71	5.79	7.40	5.27	1.55	16.46	58.11	69.99	25.92
1960	69.01	58.43	22.23	25.42	13.91	6.51	14.11	23.58	26.90	45.74	84.47	56.91	37.27
1961	55.25	38.92	14.42	27.57	14.77	6.00	6.19	12.31	17.26	53.83	31.26	38.06	26.32
1962	64.80	29.52	16.25	27.87	26.00	8.42	3.97	19.05	41.65	18.05	21.67	37.91	26.26
1963	15.78	15.58	46.50	40.24	24.89	15.29	7.61	8.78	10.83	14.22	52.79	14.62	22.26
1964	9.91	11.45	17.43	17.07	13.35	8.55	7.54	7.96	6.29	18.77	38.68	68.23	18.77
1965	61.02	13.03	19.52	26.62	16.99	13.55	10.29	8.23	22.79	19.78	30.67	111.06	29.46
1966	31.82	56.48	24.35	32.46	27.95	14.82	11.47	10.11	8.68	30.40	42.50	86.43	31.46
1967	47.27	54.53	32.43	12.85	28.53	10.05	6.80	11.82	28.97	89.69	34.93	46.96	33.74
1968	61.26	19.66	28.41	38.10	25.47	16.09	11.74	8.33	17.19	40.17	28.46	38.26	27.76
1969	59.86	33.67	26.28	22.24	32.42	16.76	6.65	8.85	7.34	6.68	32.87	50.07	25.31
1970	67.66	53.40	44.78	44.61	12.03	4.98	7.66	10.64	9.97	25.50	80.95	27.17	32.45
1971	49.72	27.40	27.60	17.48	10.56	14.64	8.00	12.53	8.29	15.64	45.98	24.56	21.87
1972	46.48	47.92	43.67	45.93	34.47	26.10	10.18	6.41	5.54	8.86	35.85	63.27	31.22
1973	26.78	29.93	16.41	15.53	21.36	7.79	5.47	14.51	15.17	15.36	27.31	49.49	20.43
1974	126.47	68.85	24.76	8.67	8.86	8.94	10.18	10.48	30.10	40.04	50.33	66.92	37.88
1975	80.39	19.96	19.30	25.57	9.92	4.37	2.93	3.77	9.46	15.25	28.72	27.43	20.59
1976	31.76	30.63	23.30	9.66	9.52	5.92	1.64	1.07	4.10	54.81	38.76	44.13	21.28
1977	51.34	73.30	47.73	24.88	11.39	8.96	5.76	6.69	8.60	24.70	68.66	49.04	31.75
1978	54.96	47.41	45.86	23.20	8.43	4.70	9.49	7.41	7.16	7.28	20.42	59.53	24.65
1979	46.99	27.58	43.33	30.09	34.93	10.52	2.50	8.34	8.95	20.65	62.12	84.08	31.67
1980	38.21	45.46	50.24	12.09	5.31	12.84	8.63	9.03	9.97	27.24	43.13	50.61	26.06
1981	35.63	31.51	81.70	17.35	19.64	9.50	3.64	2.62	19.42	69.12	31.18	40.85	30.18
1982	46.77	40.17	49.09	13.38	6.28	12.77	7.91	8.42	23.30	42.41	66.85	55.36	31.06
1983	60.46	31.91	30.28	35.80	40.59	11.97	4.35	2.72	19.53	40.44	25.60	44.04	28.97
1984	72.79	40.59	20.65	7.64	5.73	5.11	2.60	2.65	21.85	47.89	67.81	54.14	29.12
1985	35.37	17.81	20.06	30.26	13.83	20.08	15.66	26.86	11.25	12.78	31.32	64.51	24.98
1986	62.39	12.15	21.27	30.46	25.06	9.64	5.64	18.27	8.17	15.63	71.89	87.64	30.69
1987	17.72	20.50	40.94	26.47	10.91	11.73	7.77	4.45	8.10	56.35	40.15	42.52	23.97
1988	84.15	39.60	53.26	17.67	19.06	9.61	17.78	24.05	17.43	30.24	21.07	16.96	29.24
1989	25.44	46.25	58.39	31.28	9.89	4.27	3.35	3.95	4.51	25.38	35.52	63.76	26.00
1990	80.38	70.05	17.29	9.95	6.82	6.66	5.94	4.13	5.02	24.26	36.01	52.09	26.55
1991	57.66	39.00	45.80	44.48	10.96	8.15	12.44	7.29	7.78	28.80	44.09	25.75	27.68
1992	19.03	22.23	38.54	28.33	16.56	7.21	5.82	32.98	16.25	17.59	46.63	52.41	25.30
1993	64.01	14.60	8.05	19.80	36.67	16.02	10.88	7.39	9.83	14.53	24.72	84.27	25.90
1994	63.78	47.76	60.05	42.15	15.89	6.40	3.58	6.24	12.45	31.01	42.25	96.02	35.63
1995	88.30	65.76	43.43	14.21	10.90	6.25	1.94	1.68	1.56	18.26	40.81	37.06	27.52

Table D1.3b: Observed flows, Teifi to Glan Teifi, 1959-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1959	*	*	*	*	*	*	3.06	2.07	1.07	14.22	77.63	79.60	*
1960	72.38	62.24	24.91	31.34	8.17	5.42	5.86	15.81	46.49	47.59	75.90	57.12	37.77
1961	45.17	42.33	10.04	32.09	23.64	4.02	5.03	7.62	16.49	69.18	29.67	39.56	27.07
1962	55.67	31.41	8.28	29.42	16.09	5.69	3.01	15.61	38.11	24.96	40.15	31.12	24.96
1963	7.09	18.07	58.65	30.67	19.78	9.59	14.94	5.84	7.14	15.75	61.19	17.82	22.21
1964	9.64	12.03	21.97	17.59	22.48	9.08	8.43	11.75	5.39	22.57	20.04	64.17	18.76
1965	54.55	11.14	22.57	20.08	17.29	15.00	11.07	9.06	41.95	21.25	35.07	93.96	29.42
1966	38.17	59.90	29.36	35.49	34.36	27.53	17.34	29.35	13.35	44.07	33.72	81.43	37.01
1967	41.11	47.68	30.19	14.55	29.23	12.60	8.31	25.04	38.09	83.98	46.55	45.29	35.22
1968	56.23	25.57	21.52	21.97	31.65	12.22	24.93	6.16	13.83	32.66	29.83	41.48	26.50
1969	59.23	38.82	15.71	16.80	29.17	21.73	7.04	11.68	7.10	6.49	35.23	58.36	25.61
1970	57.62	46.16	*	*	24.91	7.28	6.81	*	13.37	26.51	77.72	36.73	*
1971	46.39	26.46	33.21	15.21	8.60	19.20	6.55	22.40	6.12	17.23	33.51	35.47	22.53
1972	48.82	51.09	26.20	35.48	27.81	41.71	24.08	16.62	4.89	3.89	33.95	69.30	31.99
1973	20.14	28.45	19.75	14.31	15.20	5.94	4.91	14.03	8.67	19.15	28.48	50.22	19.10
1974	105.95	81.10	23.52	7.48	8.80	6.50	10.22	12.24	48.68	49.72	58.28	49.39	38.49
1975	71.85	29.20	16.76	28.74	13.55	3.81	3.43	2.46	6.65	12.04	31.08	34.50	21.17
1976	30.70	30.76	21.28	13.39	6.88	3.54	1.88	1.13	4.49	50.76	30.33	34.86	19.17
1977	48.11	81.03	36.29	17.91	19.20	5.35	3.69	3.75	6.16	25.96	78.08	43.63	30.76
1978	53.00	46.24	39.45	23.60	10.42	3.81	8.19	14.97	10.02	8.44	29.15	63.80	25.92
1979	37.29	36.30	51.94	31.48	36.78	18.02	3.31	13.28	8.34	44.42	74.05	87.57	36.90
1980	35.66	55.32	39.42	16.27	4.30	7.88	7.02	14.33	15.37	45.46	47.58	57.54	28.85
1981	30.02	24.87	96.73	13.78	19.46	15.07	5.82	3.46	23.69	102.01	38.99	50.62	35.38
1982	50.04	37.91	54.43	9.40	4.28	7.03	5.15	5.22	21.22	58.66	64.30	52.06	30.81
1983	53.67	23.30	23.82	21.39	34.81	11.92	5.25	5.56	24.01	35.77	16.06	51.11	25.56
1984	55.66	38.69	13.70	7.52	4.23	2.98	1.82	1.78	13.92	44.40	65.62	57.80	25.68
1985	32.05	24.64	19.26	41.81	10.14	16.36	12.52	39.21	15.48	23.67	23.91	63.75	26.90
1986	61.43	14.52	21.28	30.40	24.50	11.78	5.33	23.87	12.92	14.80	85.13	84.05	32.50
1987	29.86	22.12	37.49	31.92	6.25	11.40	8.32	8.17	13.00	75.96	45.90	36.43	27.24
1988	79.39	43.39	47.53	19.03	10.63	7.90	21.59	21.91	31.66	38.72	21.80	27.35	30.91
1989	31.33	42.77	64.11	25.06	7.42	3.55	2.35	2.17	3.72	24.93	50.35	54.87	26.05
1990	73.47	87.13	18.00	7.64	4.33	3.51	5.03	2.45	4.08	21.98	41.25	45.28	26.18
1991	64.31	34.49	44.17	31.87	10.87	7.03	8.32	10.54	5.89	30.06	62.65	16.71	27.24
1992	23.39	21.36	36.97	30.94	15.41	10.99	5.04	22.74	27.39	20.14	49.15	79.44	28.58
1993	59.26	16.84	9.35	21.93	20.24	36.88	11.50	9.77	13.67	22.59	29.73	63.52	26.27
1994	58.07	45.54	47.71	48.27	14.54	6.75	4.98	5.40	20.37	22.93	49.71	79.15	33.62
1995	72.29	71.08	38.13	10.37	6.55	5.93	2.90	1.51	3.27	12.84	*	*	*

Table D1.4a: Reconstructed flows, Dee to Manley Hall/Erbistock, 1859-1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1859	36.28	32.31	55.07	43.05	9.84	5.63	15.92	23.08	26.09	50.82	45.82	66.40	34.19
1860	57.19	24.99	30.09	20.85	24.31	46.53	9.76	52.72	25.43	36.86	31.86	43.46	33.67
1861	24.21	34.72	48.61	24.47	7.78	10.07	27.44	24.04	22.76	24.65	51.86	36.16	28.06
1862	38.22	20.28	37.81	33.98	45.03	13.71	13.38	18.96	25.38	45.21	27.29	36.34	29.63
1863	68.89	21.76	16.66	17.99	8.34	11.52	9.54	18.15	31.11	74.34	39.67	33.55	29.29
1864	27.83	22.32	38.45	26.81	22.82	7.79	5.67	7.66	16.93	25.83	38.31	27.85	22.36
1865	29.76	28.47	21.42	9.27	25.36	9.26	5.38	44.19	9.27	34.24	48.37	30.98	24.66
1866	56.61	54.43	33.30	11.11	14.05	24.63	8.48	22.65	81.42	26.97	40.13	45.50	34.94
1867	60.34	37.21	34.79	43.95	28.22	6.81	14.82	8.54	12.11	41.42	22.22	30.45	28.41
1868	55.20	38.06	45.07	28.02	11.84	4.58	1.73	4.95	15.27	23.73	35.15	212.64	39.69
1869	65.03	55.17	28.60	21.85	41.87	9.13	2.86	2.83	40.08	34.54	44.94	63.71	34.22
1870	43.67	34.77	30.26	22.22	12.24	5.87	2.53	3.15	10.16	83.62	43.01	42.58	27.84
1871	34.00	36.17	27.79	24.37	15.46	8.02	22.35	12.13	27.18	68.00	28.31	26.10	27.49
1872	64.42	50.92	39.68	34.94	25.84	33.45	45.34	29.89	68.00	129.42	105.73	80.35	59.00
1873	78.16	26.30	28.14	18.63	13.59	6.45	9.88	17.60	22.19	34.28	31.51	22.97	25.81
1874	30.78	33.88	28.50	21.96	20.64	6.03	4.40	17.30	26.89	39.09	65.31	56.23	29.25
1875	57.04	30.25	19.93	10.48	17.03	11.84	23.34	23.49	35.25	70.79	52.95	30.21	31.88
1876	21.94	41.10	45.09	39.90	9.59	5.06	5.50	17.47	38.13	40.59	61.09	96.72	35.18
1877	85.23	55.07	35.03	31.41	31.30	8.67	14.56	40.27	33.95	42.23	83.73	46.77	42.35
1878	44.58	27.95	23.87	19.91	32.93	18.48	6.40	22.57	27.74	46.94	49.02	40.32	30.06
1879	24.55	30.85	28.70	25.89	21.06	27.16	34.37	61.16	31.25	19.83	12.41	21.44	28.22
1880	14.97	26.23	33.68	23.21	18.82	18.53	46.55	16.46	17.52	48.42	60.79	72.67	33.15
1881	19.93	46.19	40.36	12.62	22.73	13.84	6.98	27.62	13.59	24.94	59.86	45.48	27.85
1882	47.65	35.89	33.34	38.28	22.07	19.39	27.45	26.87	19.65	31.50	79.83	61.04	36.91
1883	79.96	44.09	29.07	8.35	11.45	12.15	6.19	7.84	28.81	45.42	46.22	34.83	29.53
1884	65.14	52.23	37.30	21.43	14.22	6.58	13.66	7.16	10.07	17.03	25.32	50.01	26.68
1885	30.96	44.24	25.68	18.84	18.52	6.91	5.09	11.30	29.84	76.31	40.92	27.04	27.97
1886	40.48	24.35	32.51	28.15	51.40	9.56	10.81	6.54	17.00	51.42	36.48	71.33	31.67
1887	35.99	23.36	19.93	12.39	14.40	6.16	3.96	10.76	17.92	25.93	26.88	35.39	19.42
1888	25.15	12.84	19.89	19.38	7.51	9.21	32.02	28.92	7.65	15.23	64.49	38.83	23.43
1889	24.29	22.16	24.96	47.22	30.75	6.34	4.31	16.06	12.46	30.11	26.50	27.03	22.68
1890	87.41	18.81	18.32	12.98	17.23	6.99	6.12	20.79	8.70	15.74	64.45	23.96	25.12
1891	23.15	8.33	15.53	22.06	25.13	23.14	10.46	29.05	34.26	56.09	40.50	95.13	31.90
1892	39.22	27.83	19.22	9.54	18.24	8.12	9.48	18.52	22.92	65.50	30.02	25.91	24.54
1893	23.97	41.41	17.93	6.92	9.73	6.21	6.80	14.12	17.67	23.75	26.77	50.04	20.44
1894	47.47	52.90	33.52	22.22	21.99	7.80	9.81	18.63	7.36	26.56	43.12	40.95	27.69
1895	39.95	10.90	24.25	29.24	7.82	5.41	14.13	19.56	6.47	28.65	56.18	37.91	23.37
1896	23.61	13.49	37.02	21.92	6.48	5.02	6.69	7.57	30.79	47.58	22.27	39.58	21.83
1897	27.59	28.40	48.09	32.36	8.63	7.96	6.06	14.20	23.56	18.24	29.02	61.49	25.47
1898	32.76	33.60	21.13	19.72	33.35	9.53	4.86	17.99	11.04	33.45	29.51	45.05	24.33
1899	78.38	38.38	25.94	28.34	24.83	7.61	5.79	5.57	17.18	33.24	33.27	29.75	27.36
1900	40.95	54.42	20.89	17.07	15.60	6.50	5.27	32.15	8.98	31.81	43.51	54.09	27.60
1901	39.05	25.76	35.45	31.66	8.10	5.79	11.06	17.13	6.74	19.07	38.84	71.61	25.85
1902	34.16	24.74	22.63	20.74	24.57	8.28	5.53	14.12	10.10	25.53	29.93	40.73	21.76
1903	64.24	51.83	87.28	24.80	24.96	8.70	10.07	32.17	53.60	147.39	39.85	41.22	48.84
1904	54.30	55.34	29.29	22.16	19.54	6.90	4.84	19.55	9.05	11.13	19.43	33.21	23.73
1905	26.12	22.19	42.28	29.64	7.72	6.06	6.85	23.66	13.86	22.30	40.77	22.27	21.98
1906	47.02	46.07	36.42	11.77	20.82	8.29	3.33	13.02	7.79	37.03	36.93	43.49	26.00
1907	29.21	26.21	25.63	21.53	20.70	23.78	10.81	17.59	7.44	43.46	34.65	42.47	25.29
1908	37.47	36.84	46.00	34.75	26.59	12.76	18.98	24.86	29.58	24.43	27.67	39.01	29.91
1909	35.20	23.99	27.77	32.45	10.85	12.67	16.24	16.14	21.38	52.60	25.27	56.36	27.58
1910	48.74	56.46	25.41	26.47	23.32	13.24	16.10	27.00	8.91	19.70	66.28	82.26	34.49
1911	24.71	30.58	27.29	19.02	9.08	9.39	6.04	14.02	29.79	38.11	56.54	90.00	29.55
1912	45.32	33.42	54.91	9.86	11.90	21.91	23.47	44.32	9.46	27.60	41.19	61.41	32.06
1913	57.01	31.10	56.06	55.55	29.23	9.48	6.09	7.58	15.10	31.20	48.45	37.92	32.06
1914	40.57	52.48	52.45	17.24	17.93	9.40	20.21	19.91	15.72	16.72	41.05	141.89	37.13
1915	58.27	73.59	20.91	17.35	19.97	6.73	13.06	23.42	7.34	15.36	33.24	129.79	34.92
1916	37.53	52.85	36.27	27.21	29.51	8.96	5.62	8.30	17.76	67.42	43.10	34.33	30.74
1917	26.71	19.75	25.65	24.77	22.46	7.68	5.72	40.13	12.70	40.79	39.06	28.03	24.45
1918	30.75	49.22	24.01	17.09	23.62	8.20	13.89	12.50	64.48	32.90	28.51	64.81	30.83
1919	48.05	32.58	68.08	32.05	11.27	6.15	5.06	14.02	19.40	28.24	30.29	80.98	31.35
1920	65.91	46.59	67.41	63.51	42.82	25.14	35.34	19.16	17.73	24.52	24.45	36.06	39.05
1921	73.08	13.22	24.72	16.16	10.35	4.39	2.51	16.41	8.51	18.90	32.39	57.14	23.15
1922	60.75	62.21	39.30	32.04	8.48	5.59	14.59	19.00	19.84	10.40	17.22	57.39	28.90
1923	36.25	97.65	26.71	23.74	32.81	9.01	6.50	22.63	30.02	71.88	51.80	51.61	38.39
1924	42.17	16.57	17.14	23.68	45.65	9.67	25.14	35.30	39.59	54.20	33.36	59.13	33.47
1925	50.75	87.45	25.16	22.48	29.74	5.71	3.13	15.07	24.20	44.33	36.13	47.71	32.65
1926	55.58	37.03	17.75	16.65	21.49	7.66	16.00	25.59	23.13	31.00	82.16	24.43	29.87
1927	35.49	33.22	39.58	29.70	15.59	24.71	22.48	45.04	41.52	51.31	61.60	31.34	35.96
1928	88.21	58.58	34.53	21.17	8.70	21.13	8.27	16.51	13.19	43.85	84.35	41.23	36.64
1929	26.00	14.50	6.56	8.54	14.83	6.42	7.55	17.94	9.29	37.14	124.82	159.65	36.10
1930	87.02	18.09	26.34	38.84	21.98	6.60	13.44	28.44	38.05	71.44	66.35	82.50	41.59
1931	43.17	52.17	16.52	27.79	41.80	29.19	10.49	35.18	35.97	22.50	70.40	32.91	34.84
1932	56.20	9.64	19.61	45.40	36.31	8.84	19.75	12.19	20.94	66.63	36.22	30.07	30.15
1933	38.11	51.74	32.25	10.22	9.20	6.22	5.58	5.40	5.04	25.38	22.84	16.03	19.00
1934	31.92	9.79	21.10	29.36	24.02	7.35	4.05	13.76	20.20	37.94	26.11	69.57	24.60
1935	28.10	49.88	21.31	25.75	10.95	16.36	7.09	4.58	33.74	83.43	63.05	41.14	32.11
1936	73.70	37.48	35.32	25.72	19.17	24.11	33.67	9.16	19.04	30.08	44.07	78.33	35.82
1937	58.55	81.93	37.54	33.26	22.17	6.83	5.07	5.32	6.96	20.30	23.54	28.22	27.48
1938	77.43	26.26	16.41	6.68	15.27	21.23	21.09	24.23	10.55	50.06	65.08	50.87	32.10
1939	109.72	44.15	40.65	29.67	10.12	6.30	33.88	11.89	5.84	19.26	85.58	37.46	36.21
1940	36.17	37.33	34.85	32.00	24.85	7.37	12.14	7.03	12.30	41.13	121.80	36.30	33.61
1941	43.67	53.92	39.40	20.10	20.83	7.79	3.81	16.68	8.49	24.57	33.94	31.94	25.43
1942	52.07	27.68	26.61	25.48	31.11	6.86	8.54	20.83	22.97	25.82	14.31	39.72	25.17

Table D1.4a: Reconstructed flows, Dee to Manley Hall/Erbistock, 1859-1995

1943	80.80	37.14	21.72	17.19	28.17	23.02	10.11	18.77	34.74	44.79	36.75	29.39	31.88
1944	50.49	28.58	13.79	11.10	15.90	6.57	6.45	10.94	27.49	59.89	92.68	48.19	31.01
1945	44.36	54.22	25.38	21.61	28.82	21.79	6.86	10.53	15.11	40.41	9.16	31.44	25.81
1946	65.55	77.09	25.65	9.14	17.34	20.28	6.91	26.48	43.15	20.64	50.40	58.07	35.06
1947	52.18	32.60	106.83	45.29	34.14	10.05	15.14	6.78	7.97	6.12	33.98	38.31	32.45
1948	186.09	38.19	28.30	21.34	11.28	21.60	9.66	21.67	22.64	20.17	25.66	61.41	39.00
1949	36.59	28.97	23.99	34.48	30.30	6.42	4.34	8.13	5.57	39.38	58.92	68.46	28.80
1950	27.04	84.77	29.37	34.01	9.62	5.89	9.09	33.27	66.57	36.54	52.63	41.67	35.87
1951	42.77	55.36	70.20	31.76	26.94	8.23	4.10	18.51	30.08	18.13	83.07	90.94	40.01
1952	67.35	24.64	17.69	19.02	20.87	7.23	5.03	14.22	24.60	69.16	34.56	49.08	29.45
1953	24.76	21.89	23.78	27.29	22.26	6.93	14.78	21.19	32.14	25.05	35.20	27.38	23.56
1954	30.43	42.30	38.26	13.15	22.62	22.56	17.77	24.59	34.38	90.90	134.05	51.61	43.55
1955	42.60	36.12	29.53	17.42	31.40	27.18	6.54	3.42	5.33	15.94	24.09	48.48	24.01
1956	58.95	13.96	17.76	18.98	6.67	5.29	17.17	54.00	31.71	25.44	21.69	41.63	26.10
1957	50.62	45.13	35.33	8.92	12.70	6.73	20.35	53.55	76.14	38.58	30.08	31.61	34.14
1958	47.96	82.39	23.33	8.30	21.04	23.99	25.73	25.96	52.03	37.37	26.31	33.62	34.00
1959	69.97	11.62	18.16	40.99	23.99	6.65	14.05	6.84	4.37	21.14	53.56	121.56	32.74
1960	97.55	53.35	30.03	21.68	14.00	6.42	10.80	21.87	37.12	60.85	123.52	62.68	44.99
1961	64.81	42.11	14.30	25.33	23.80	6.83	9.59	19.34	20.71	44.68	37.81	50.41	29.98
1962	75.25	33.01	22.69	29.68	30.83	8.05	4.50	17.38	32.80	22.92	24.50	42.32	28.66
1963	24.24	12.39	36.18	34.39	16.99	16.86	7.01	11.95	17.48	19.89	74.34	23.45	24.60
1964	14.33	13.38	24.62	24.53	18.26	6.68	6.94	10.47	7.29	23.24	29.88	91.38	22.58
1965	74.06	17.07	25.59	29.94	27.83	21.58	17.76	10.01	31.51	26.26	38.28	135.01	37.91
1966	32.98	50.87	29.91	33.43	28.70	7.83	12.01	18.29	18.29	35.88	48.30	96.34	34.40
1967	33.41	54.97	32.91	16.15	43.32	9.59	6.67	13.69	35.42	126.97	39.97	61.92	39.58
1968	67.66	27.31	40.42	31.27	33.40	11.06	19.16	13.40	35.42	42.52	33.63	36.43	32.64
1969	45.76	50.06	33.96	27.56	49.90	9.74	5.69	12.99	7.36	7.50	68.02	53.03	30.96
1970	50.26	61.67	50.92	55.71	11.32	6.11	7.54	27.47	26.18	37.00	104.60	30.38	39.10
1971	42.83	31.67	26.39	23.00	8.10	15.99	10.86	26.33	9.19	28.29	61.30	26.60	25.88
1972	40.89	37.83	42.05	37.95	35.14	23.93	19.17	11.55	7.10	10.74	41.12	65.48	31.08
1973	28.24	26.23	22.21	25.05	31.03	7.69	14.05	29.73	31.72	42.48	45.00	44.29	28.98
1974	147.69	63.51	30.62	7.98	11.88	8.37	16.02	13.09	46.73	45.48	83.02	60.18	44.55
1975	92.93	25.53	25.39	28.55	15.70	5.24	7.46	11.76	21.97	23.01	27.56	40.77	27.16
1976	47.73	30.25	24.39	11.53	17.58	5.67	2.33	1.58	36.87	62.51	32.28	39.13	25.99
1977	52.94	103.74	44.53	31.83	19.40	23.33	8.27	9.34	12.64	26.52	80.53	48.75	38.48
1978	59.11	42.00	40.01	26.35	12.25	9.76	15.60	18.97	20.17	12.97	35.67	93.71	32.21
1979	39.01	29.46	65.12	31.19	32.87	8.51	2.51	10.98	8.62	18.41	44.66	154.65	37.17
1980	40.13	55.47	49.92	9.96	7.56	19.49	7.86	15.14	20.67	42.43	45.95	51.56	30.51
1981	40.63	42.62	84.96	24.23	23.65	8.42	5.43	5.40	25.49	67.30	45.13	47.73	35.08
1982	44.63	34.15	53.19	12.34	10.21	22.02	8.21	13.81	27.99	38.22	92.63	76.94	36.20
1983	80.42	25.69	28.68	44.92	45.47	9.72	5.01	5.83	29.38	44.70	25.50	51.21	33.04
1984	91.71	36.97	25.27	7.45	9.54	6.27	3.12	10.07	28.92	53.06	87.80	45.06	33.77
1985	30.98	21.65	24.20	31.15	25.98	21.06	7.27	21.78	8.96	15.80	42.88	61.56	26.11
1986	83.02	12.34	27.89	39.06	30.97	8.13	5.27	26.66	9.11	16.43	61.90	117.80	36.55
1987	25.01	23.37	44.19	28.67	15.08	17.79	10.40	16.58	22.96	81.80	39.23	37.74	30.24
1988	101.85	44.68	58.87	25.77	23.71	8.25	15.08	24.77	25.27	37.43	28.70	30.90	35.44
1989	28.72	42.14	55.19	40.63	9.65	5.89	5.56	7.14	6.54	29.55	36.58	82.42	29.17
1990	112.82	105.01	18.55	17.23	7.88	7.77	5.84	6.07	15.47	34.30	37.30	73.42	36.80
1991	51.11	40.01	42.88	40.63	9.67	9.78	9.65	6.04	8.70	28.24	52.90	36.95	28.05
1992	28.53	27.06	36.99	29.11	23.52	12.15	6.22	27.45	30.54	34.37	65.22	49.30	30.87
1993	64.30	13.05	8.95	25.85	53.82	24.77	16.16	16.80	23.55	23.68	24.66	185.82	40.12
1994	69.81	45.75	67.53	39.65	18.46	6.61	4.27	8.25	25.52	33.84	42.46	146.58	42.39
1995	105.12	88.59	34.15	9.44	16.88	5.61	4.17	3.12	11.60	*	*	*	*

Table D1.4b: Naturalised flows, Dee to Manley Hall/Erbistock, 1970-89

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1970	47.94	68.66	39.95	62.90	13.32	5.11	9.13	20.93	25.55	33.86	75.09	33.86	36.03
1971	44.13	43.81	25.87	14.94	7.23	13.37	7.23	26.25	9.44	42.23	42.07	22.45	24.82
1972	44.89	38.64	30.44	41.67	24.35	31.84	16.74	25.49	5.50	4.57	40.10	71.53	31.29
1973	19.02	34.54	23.21	22.02	20.16	6.68	12.17	27.77	24.37	40.33	34.99	39.19	25.33
1974	87.50	72.45	27.39	6.29	4.57	5.50	17.50	12.94	59.36	40.33	70.37	70.38	39.32
1975	71.14	25.27	20.93	26.73	16.74	3.54	9.51	4.19	17.69	18.64	25.55	31.96	22.68
1976	55.93	30.10	17.50	14.55	10.65	3.93	2.66	1.52	30.27	60.87	26.34	35.00	24.14
1977	50.22	87.61	37.28	29.49	19.78	15.33	6.85	5.33	13.76	28.91	82.56	46.80	34.90
1978	47.94	51.81	43.37	24.77	14.08	8.26	12.17	20.54	14.94	13.70	58.97	70.38	31.63
1979	31.96	30.33	87.12	38.13	30.44	12.19	3.42	14.08	14.15	21.69	53.47	96.25	36.22
1980	42.99	60.60	43.75	13.76	4.19	19.26	9.13	16.74	18.08	52.12	55.43	56.69	32.64
1981	45.65	40.86	82.56	14.55	22.83	19.66	8.37	4.19	25.16	68.48	49.93	35.00	34.80
1982	66.58	35.38	65.82	10.62	7.23	12.58	9.51	17.12	23.98	43.37	80.59	77.23	37.58
1983	78.37	31.59	30.82	36.56	41.09	13.37	5.33	3.42	36.17	51.36	15.73	58.59	33.64
1984	67.34	48.40	17.12	7.86	4.19	4.72	2.28	4.57	23.20	51.36	68.80	43.75	28.55
1985	25.11	24.43	25.49	42.46	14.46	22.02	13.32	39.57	16.51	23.59	33.02	63.16	28.63
1986	74.19	15.16	34.62	43.25	26.63	11.40	6.09	26.25	10.22	19.02	77.45	80.66	35.58
1987	35.76	31.17	41.85	31.06	7.99	20.05	11.03	9.89	24.37	75.71	39.71	38.43	30.60
1988	82.56	61.41	52.12	22.80	15.22	9.04	21.31	27.77	40.10	38.81	21.62	38.81	35.96
1989	28.15	44.65	70.00	40.49	7.23	5.11	4.19	4.19	5.11	29.68	43.25	67.34	29.05

Table D1.5a: Reconstructed flows, Derwent to Derby/Longbridge Weir, 1851-1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1851	26.01	17.51	26.82	16.63	12.22	15.11	17.55	10.14	7.45	10.84	10.50	11.52	15.19
1852	27.93	34.22	14.85	9.74	7.07	12.37	12.93	11.74	19.60	23.53	63.61	48.21	23.82
1853	40.07	19.91	14.87	13.70	9.76	18.57	15.48	12.65	12.91	22.12	20.89	12.64	17.80
1854	21.80	19.04	11.90	9.29	10.34	8.25	8.01	7.29	5.97	6.70	10.69	29.23	12.38
1855	13.62	13.60	16.80	10.20	9.09	10.46	17.98	9.65	6.39	16.40	10.55	10.44	12.10
1856	21.42	20.81	12.60	15.97	20.36	10.33	10.23	23.80	25.64	22.57	17.79	18.38	18.33
1857	22.91	14.19	15.79	14.73	9.54	7.65	7.15	15.12	13.58	11.10	10.68	9.49	12.66
1858	9.12	8.00	8.85	12.81	10.09	9.15	7.74	8.52	9.62	20.25	12.01	18.35	11.21
1859	16.43	16.93	26.85	30.02	11.56	7.84	6.70	12.65	18.86	19.65	24.35	25.87	18.14
1860	32.60	18.79	32.66	16.05	15.44	28.96	12.00	21.95	16.00	22.51	25.74	24.34	22.25
1861	13.09	25.54	47.24	18.96	11.42	9.10	12.19	8.75	10.05	9.68	18.92	18.53	16.96
1862	17.43	13.09	22.82	18.51	18.74	14.39	12.62	9.60	12.30	24.35	12.91	18.17	16.24
1863	37.10	17.47	12.09	10.95	8.68	12.93	8.93	10.23	15.08	27.34	25.92	25.92	17.72
1864	17.54	22.09	23.47	14.21	11.29	9.04	6.45	4.78	5.99	9.83	19.49	17.63	13.48
1865	22.48	21.12	13.29	11.17	10.98	7.80	6.51	10.15	6.85	20.17	26.46	14.46	14.28
1866	27.51	33.42	22.70	13.57	10.30	14.35	13.89	18.75	30.56	22.78	39.46	39.58	23.91
1867	37.43	39.04	28.15	38.46	16.13	10.55	12.01	10.82	10.32	18.62	13.46	20.63	21.30
1868	23.00	22.87	30.02	20.42	11.08	6.95	3.98	3.75	4.88	12.20	15.55	64.69	18.28
1869	49.08	38.50	21.59	15.54	22.37	10.45	5.99	4.56	11.59	12.97	20.98	37.40	20.92
1870	29.46	23.26	21.74	11.94	9.45	7.53	5.26	4.05	3.82	20.80	22.35	20.86	15.04
1871	16.50	20.80	14.48	17.43	11.88	12.99	14.01	8.66	18.33	25.21	14.95	15.94	15.93
1872	37.68	39.29	29.67	25.63	16.04	27.17	29.14	13.81	24.19	43.26	43.22	47.70	31.40
1873	39.33	19.18	23.28	12.32	11.95	10.58	8.95	10.08	9.43	15.78	20.89	11.60	16.11
1874	17.42	19.88	17.97	13.86	9.30	6.31	4.66	5.95	6.91	14.17	26.55	24.62	13.97
1875	30.36	18.25	11.63	9.85	8.96	9.30	16.54	14.89	16.89	39.52	42.35	22.66	20.10
1876	17.35	30.04	35.97	24.38	12.11	10.25	8.31	6.86	14.84	18.60	28.66	63.62	22.58
1877	65.86	52.02	34.59	23.90	25.79	13.64	14.85	27.99	16.77	21.10	37.40	33.41	30.61
1878	38.15	24.06	16.21	13.40	26.28	16.90	9.09	22.93	19.64	25.30	29.39	20.83	21.85
1879	17.19	28.61	18.23	17.24	15.82	27.63	19.69	28.63	19.35	12.76	13.77	16.83	19.65
1880	10.82	21.28	22.14	13.42	11.77	10.91	21.08	11.16	17.96	38.99	34.63	46.68	21.74
1881	17.93	44.33	47.45	17.06	15.38	11.01	8.24	16.72	10.97	20.93	34.11	32.30	23.03
1882	33.22	29.22	22.77	30.23	14.89	21.50	21.41	12.35	10.99	26.22	45.93	58.01	27.23
1883	60.15	47.53	20.04	17.10	11.27	12.30	11.68	9.13	23.00	28.57	28.97	23.19	24.41
1884	38.22	29.08	24.24	16.59	10.81	8.42	10.24	8.25	7.67	9.71	9.85	20.25	16.11
1885	21.83	24.25	18.32	13.40	11.32	10.97	7.75	5.91	9.79	38.40	31.37	18.02	17.61
1886	35.17	14.92	18.96	15.86	31.97	12.98	11.69	9.85	7.29	21.85	18.19	33.77	19.37
1887	27.53	13.34	13.38	10.23	9.28	6.95	4.61	4.01	4.88	6.69	9.85	14.58	10.44
1888	12.79	12.20	20.45	15.47	9.20	7.58	18.21	12.50	8.60	7.90	36.70	29.14	15.89
1889	18.87	19.10	27.09	26.35	19.47	9.26	7.31	11.15	10.40	21.57	14.52	16.79	16.82
1890	30.10	14.47	17.71	11.40	10.42	9.71	8.68	11.50	8.56	9.98	28.61	14.13	14.61
1891	18.13	11.38	12.28	15.13	15.22	13.90	9.84	15.30	11.00	24.79	29.37	48.83	18.76
1892	36.28	25.56	15.64	10.76	14.89	15.14	11.85	11.29	11.76	25.93	19.25	15.14	17.79
1893	16.35	30.21	13.78	9.61	11.08	7.91	8.52	7.53	7.29	10.03	12.25	24.52	13.26
1894	26.06	34.28	25.67	17.92	12.71	10.06	10.27	10.01	7.55	15.34	16.51	18.73	17.09
1895	31.29	12.80	17.16	15.27	8.70	6.38	11.30	9.54	7.16	11.24	21.47	26.90	14.93
1896	16.80	13.82	28.16	13.92	8.46	8.65	7.12	5.71	17.71	24.16	14.40	35.99	16.24
1897	27.08	29.27	36.70	22.22	12.46	12.91	8.54	7.60	11.75	9.45	18.29	28.44	18.72
1898	18.33	20.81	14.73	14.61	14.81	9.44	6.80	8.47	6.67	11.56	20.66	28.06	14.58
1899	37.16	21.94	15.32	20.79	15.72	10.26	8.33	6.05	10.86	16.02	13.01	19.70	16.26
1900	37.36	40.29	16.79	13.10	10.12	11.13	13.60	19.80	10.23	15.54	20.67	35.06	20.31
1901	29.47	19.44	25.03	17.49	10.35	7.49	9.12	7.45	5.61	8.16	18.85	44.92	16.95
1902	25.86	17.92	17.72	15.81	15.26	9.81	7.85	10.47	8.47	16.65	18.54	20.43	15.40
1903	26.11	23.25	33.12	18.95	15.47	9.75	8.56	16.77	20.38	51.96	36.73	23.01	23.67
1904	30.35	39.62	24.32	17.52	13.43	8.43	6.32	9.55	7.97	7.35	12.50	13.29	15.89
1905	13.46	13.87	23.18	18.50	9.35	7.36	6.60	9.37	8.51	10.71	25.33	13.17	13.28
1906	26.44	30.88	23.46	13.27	12.23	8.92	6.45	5.70	4.92	17.56	29.02	28.04	17.24
1907	18.48	18.14	20.55	15.03	19.24	25.00	13.68	12.81	8.60	20.61	25.81	25.07	18.58
1908	23.81	25.04	28.01	20.76	16.59	10.24	9.81	11.24	10.08	9.09	12.85	16.85	16.20
1909	14.96	13.82	23.05	14.90	10.63	10.30	11.99	9.32	9.59	22.03	12.73	43.57	16.41
1910	38.56	34.51	16.32	18.51	14.99	10.16	12.47	16.46	8.94	10.20	26.61	46.25	21.17
1911	22.59	25.51	19.58	14.55	9.96	7.76	6.02	4.25	4.73	6.83	15.75	39.55	14.76
1912	43.97	23.38	34.15	13.76	12.89	17.34	26.01	42.26	16.00	19.52	21.26	32.96	25.29
1913	39.18	20.89	38.04	34.76	16.49	10.52	6.94	5.27	5.15	11.78	19.82	18.55	18.95
1914	19.66	19.83	25.97	13.12	10.48	9.47	11.35	9.22	8.65	12.67	28.43	60.98	19.15
1915	60.04	57.67	24.97	14.48	10.76	8.06	16.68	13.00	8.42	9.06	15.62	45.92	23.72
1916	29.80	48.09	45.08	24.81	15.08	11.02	9.33	7.94	7.24	16.95	26.68	26.99	22.42
1917	26.68	13.73	15.81	12.93	9.66	8.89	7.22	15.58	9.74	19.36	24.38	16.93	15.07
1918	22.37	26.26	17.02	12.42	13.04	8.42	8.71	8.30	31.27	18.70	14.10	40.21	18.40
1919	39.97	25.38	39.55	19.40	11.36	8.48	7.31	8.83	9.55	13.90	17.70	40.38	20.15
1920	39.98	33.77	25.13	38.38	27.95	15.57	20.80	10.70	7.49	9.54	9.28	18.28	21.41
1921	32.09	13.16	14.84	11.59	8.37	6.13	3.82	5.99	5.57	7.13	10.42	21.68	11.73
1922	32.78	34.70	23.06	22.37	11.23	6.88	10.16	20.57	15.25	10.31	12.10	24.30	18.64
1923	25.18	42.40	23.97	19.05	19.70	9.15	9.45	11.52	14.05	18.37	29.29	33.24	21.28
1924	25.35	16.11	11.83	12.38	18.29	10.42	11.58	15.71	15.42	29.16	19.65	25.29	17.60
1925	31.96	42.19	21.42	18.49	25.86	9.34	5.44	6.42	9.90	20.88	23.22	25.00	20.01
1926	30.70	25.84	17.34	14.43	13.20	10.75	9.65	10.17	10.32	15.76	27.80	20.50	17.21
1927	22.82	18.82	27.94	25.47	11.68	16.86	12.19	13.67	26.33	23.47	31.39	24.35	21.25
1928	64.75	55.03	31.77	15.57	10.28	11.48	8.30	9.52	7.62	16.39	36.55	25.04	24.36
1929	19.16	12.35	9.30	8.47	9.13	7.31	6.29	7.12	6.04	13.58	41.65	64.86	17.10
1930	63.17	22.61	24.46	25.29	13.78	10.57	21.99	16.88	22.60	32.97	32.65	32.25	26.60
1931	38.59	42.75	15.53	25.87	17.70	17.61	19.37	29.08	23.06	12.54	27.40	18.32	23.98
1932	26.79	13.66	14.48	25.74	31.96	11.45	10.64	8.82	7.95	23.42	22.72	15.20	17.74
1933	18.35	31.99	24.85	13.11	10.38	8.80	7.83	5.90	4.37	13.84	14.10	9.49	13.58
1934	17.58	10.15	15.23	15.68	9.34	7.19	5.52	5.21	5.95	12.03	13.66	33.68	12.60

Table D1.5a: Reconstructed flows, Derwent to Derby/Longbridge Weir, 1851-1995

1935	22.18	32.80	17.62	18.74	10.47	9.79	8.13	5.60	12.53	33.71	49.66	46.46	22.31
1936	46.50	36.91	27.14	16.05	10.49	10.69	15.75	9.44	13.62	21.54	26.38	30.26	22.06
1937	43.68	63.80	42.09	27.16	17.49	10.25	8.84	6.95	4.95	7.74	10.02	21.02	22.00
1938	32.19	18.31	11.98	8.78	8.75	8.29	11.03	8.43	9.21	23.11	30.41	40.62	17.59
1939	65.04	36.92	25.79	19.13	11.29	9.04	19.58	11.40	8.29	16.92	34.29	24.54	23.52
1940	28.75	29.49	23.00	18.45	10.65	7.09	6.73	5.56	4.71	13.33	47.42	37.14	19.36
1941	37.14	39.70	40.94	22.25	16.12	10.17	10.07	14.98	8.40	14.62	24.74	17.56	21.39
1942	27.51	18.03	17.44	13.48	18.32	9.06	7.59	9.70	8.41	17.38	12.50	19.60	14.92
1943	38.42	25.10	14.28	13.18	14.32	9.84	7.48	8.62	12.52	12.50	19.06	15.65	15.91
1944	31.33	27.07	11.90	14.65	13.16	9.56	10.98	9.96	17.12	25.34	43.71	35.85	20.89
1945	34.16	39.42	17.04	15.01	14.82	12.91	9.66	8.47	7.75	21.55	11.55	15.14	17.29
1946	31.26	43.58	20.34	12.80	10.52	12.47	11.02	15.50	25.64	12.80	46.82	42.10	23.74
1947	33.22	30.16	52.39	34.14	18.32	12.23	8.94	6.71	4.84	4.93	11.31	24.18	20.11
1948	67.46	38.78	17.36	14.05	9.82	13.26	9.33	13.41	11.07	11.02	12.71	24.33	20.22
1949	19.73	15.64	14.35	17.78	12.10	7.64	6.81	6.59	5.75	12.71	28.56	38.50	15.51
1950	23.15	44.44	20.83	21.19	12.62	8.18	7.24	8.71	15.23	11.59	28.90	25.05	18.93
1951	27.91	35.74	42.53	23.13	17.30	10.49	6.73	11.33	9.72	8.44	45.14	44.68	23.59
1952	40.20	21.72	18.30	17.19	13.47	9.99	7.96	6.82	9.02	21.40	20.92	26.46	17.79
1953	17.52	17.82	17.01	17.39	11.96	10.67	12.05	10.95	8.98	10.22	13.39	12.62	13.38
1954	18.90	23.82	20.75	10.72	12.38	10.77	10.78	20.26	18.89	31.23	54.44	59.89	24.40
1955	41.18	32.22	33.34	15.63	18.58	14.73	8.90	5.56	4.12	5.56	9.67	20.72	17.52
1956	43.79	20.93	14.28	12.68	8.36	8.57	16.47	30.10	21.61	15.11	12.07	29.05	19.42
1957	24.59	26.09	26.81	11.56	7.94	6.02	7.84	15.81	32.65	22.34	19.01	29.51	19.18
1958	32.15	50.50	31.09	14.64	16.26	20.74	24.10	12.85	16.08	20.71	12.87	25.88	23.16
1959	30.89	13.04	13.74	19.20	9.60	6.51	5.55	4.46	3.05	4.00	13.06	35.90	13.25
1960	56.37	38.63	23.34	15.86	10.71	8.55	12.76	18.74	23.12	43.25	47.22	41.86	28.37
1961	48.00	34.94	17.18	24.97	13.20	8.74	8.14	10.95	9.16	17.94	18.20	22.76	19.52
1962	31.81	24.75	15.16	19.21	15.02	8.33	5.73	8.87	12.60	10.83	12.39	20.69	15.45
1963	14.53	11.06	17.04	17.26	11.00	14.01	9.09	9.98	14.04	13.14	31.00	15.27	14.78
1964	12.65	12.20	23.83	18.17	12.91	10.59	10.39	8.88	7.10	9.09	12.32	27.92	13.84
1965	36.38	17.70	22.48	18.65	14.89	11.53	13.10	10.50	33.69	15.23	26.67	101.43	26.85
1966	41.58	60.99	30.12	38.05	23.64	16.94	13.75	15.86	13.22	23.57	31.98	39.72	29.12
1967	27.90	29.97	23.55	13.89	29.86	11.41	6.64	6.50	7.97	26.13	25.82	26.29	19.66
1968	36.07	24.77	21.06	17.78	18.56	12.72	13.63	9.60	21.08	25.14	25.48	22.16	20.67
1969	28.05	32.41	28.20	24.67	30.54	14.55	10.11	8.63	7.40	6.97	26.48	30.42	20.70
1970	30.26	39.26	28.71	37.24	13.56	8.03	7.41	8.43	8.43	12.75	37.37	23.17	21.22
1971	26.41	17.87	17.08	18.32	10.90	11.05	9.06	13.26	8.56	11.46	23.03	14.90	15.16
1972	27.37	26.64	32.58	23.20	16.49	14.13	11.37	9.07	7.79	7.76	18.53	24.71	18.30
1973	19.19	21.19	12.49	18.35	14.20	9.23	20.43	12.18	11.06	14.43	13.21	22.06	15.67
1974	30.39	32.47	20.36	11.25	8.23	7.17	9.14	10.12	17.37	21.98	31.75	31.21	19.29
1975	35.63	17.81	19.85	19.38	11.88	8.09	5.81	5.43	5.04	5.83	8.65	14.27	13.14
1976	26.90	17.42	14.13	9.91	11.30	7.51	4.43	3.30	4.74	19.60	14.65	21.62	12.96
1977	36.43	84.81	41.82	23.23	13.20	11.29	8.30	6.07	6.31	9.34	26.60	29.14	24.71
1978	41.95	33.05	30.81	15.83	9.93	11.99	10.30	9.00	10.81	8.94	12.30	49.82	20.40
1979	37.35	27.95	42.94	32.80	34.41	13.93	7.71	8.76	7.33	8.89	22.75	44.29	24.09
1980	39.69	46.64	45.05	14.88	9.22	14.40	9.99	12.83	12.42	33.07	39.75	29.49	25.62
1981	34.37	33.50	56.77	42.51	24.53	12.78	8.76	7.51	15.78	31.70	31.75	34.77	27.89
1982	29.33	16.44	30.44	14.50	9.78	25.37	10.03	10.60	12.74	12.33	29.08	30.86	19.29
1983	42.91	25.54	27.06	36.58	32.47	11.65	6.55	4.85	7.41	14.83	14.27	41.09	22.10
1984	62.04	41.60	29.83	13.08	9.09	7.95	5.57	4.91	11.82	16.37	31.84	23.04	21.43
1985	24.45	12.96	13.51	19.48	13.86	12.20	9.43	10.68	8.20	9.34	16.31	26.30	14.73
1986	57.02	24.48	28.89	31.90	22.93	11.59	7.91	12.10	8.22	14.06	28.63	56.81	25.38
1987	29.43	19.73	31.62	20.05	12.01	23.56	12.23	8.79	10.54	23.49	23.04	19.15	19.47
1988	44.49	33.23	45.57	19.43	12.22	10.28	16.32	13.85	13.23	23.35	16.67	16.62	22.11
1989	14.07	23.91	29.86	33.89	13.30	9.87	7.94	5.34	4.53	9.27	12.63	33.05	16.47
1990	46.32	45.41	20.42	13.06	9.40	8.12	7.04	5.38	5.70	15.33	17.53	31.81	18.79
1991	30.54	22.35	19.39	16.94	9.52	9.25	8.68	6.09	5.06	8.09	16.72	26.08	14.89
1992	20.21	16.94	26.33	18.27	10.86	9.10	9.50	14.27	11.61	19.09	36.46	32.55	18.77
1993	32.08	14.54	10.38	17.91	13.02	10.04	13.16	9.05	16.01	15.83	15.37	57.63	18.75
1994	60.92	39.39	40.87	27.56	13.47	9.86	6.95	5.88	14.58	19.63	27.30	41.64	25.67
1995	73.19	56.82	35.73	15.41	12.03	8.46	5.45	4.14	4.67	*	*	*	*

Table D1.5b: Naturalised flows, Derwent to Derby/Longbridge Weir, 1977-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1977	41.08	79.93	31.89	20.87	18.15	10.74	7.35	6.41	6.44	8.97	29.38	27.28	23.66
1978	38.43	35.89	28.31	16.60	11.99	11.92	10.19	10.35	11.25	10.63	13.38	54.56	21.09
1979	25.85	26.82	62.88	39.45	24.89	17.49	7.63	10.67	7.25	8.05	26.52	42.90	25.05
1980	30.82	50.64	33.34	17.94	9.00	11.65	11.07	14.15	11.63	36.68	37.76	26.94	24.21
1981	39.45	29.68	57.13	31.08	28.23	15.95	10.67	8.40	13.45	32.72	30.54	28.22	27.15
1982	45.18	18.04	38.46	14.63	9.18	22.58	10.73	10.43	11.11	15.38	34.46	33.48	22.02
1983	40.55	30.97	23.64	33.32	29.01	16.64	7.85	5.44	10.42	16.62	11.86	42.10	22.35
1984	49.40	52.13	20.82	12.25	8.74	7.91	5.41	5.56	9.54	13.24	35.31	21.93	20.06
1985	22.88	17.60	13.09	28.07	14.23	14.29	9.10	13.90	12.42	11.54	16.87	31.67	17.13
1986	51.60	23.03	33.02	37.06	24.88	11.52	7.14	12.18	7.66	11.53	34.72	53.76	25.73
1987	40.88	20.21	30.74	29.58	10.88	25.94	12.14	9.24	10.47	29.76	23.39	18.51	21.82
1988	45.20	39.22	40.43	16.23	12.10	8.45	14.43	12.69	15.38	22.71	13.59	22.41	21.90
1989	14.08	19.99	36.43	38.95	11.28	7.45	7.26	4.65	4.34	9.51	13.09	30.46	16.43
1990	33.30	44.65	21.25	10.21	6.50	6.88	5.52	5.18	4.78	11.97	17.51	34.32	16.69
1991	35.39	19.38	23.04	14.87	8.14	8.61	7.20	5.08	4.62	5.72	18.70	30.29	15.09
1992	21.14	13.12	21.19	18.58	9.54	8.62	7.03	8.30	10.67	19.43	36.59	41.57	18.00
1993	28.24	14.22	8.17	17.69	10.19	13.27	10.90	9.91	19.12	21.67	15.98	61.05	19.27