Advancing hydrological data collection in the xixth and xxth Centuries.

Progrès de la collecte des données hydrologiques aux xixème et xxème siècles.

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Abstract
The publication of yearbooks and similar productions played a significant part in the development of hydrology in the xixth and xxth Centuries. This paper examines how British Rainfall helped the growth of the rain gauge network in the United Kingdom and discusses the results of rain gauge experiments it reported.

Key words: hydrological yearbooks, raingauges, United Kingdom

Résumé
La publication d’annuaires et les autres publications de ce type ont joué un rôle important dans le développement de l’hydrologie aux xixème et xxème siècles. Cet article examine comment « La Pluie Britannique » a aidé à l’agrandissement du réseau pluviométrique et discute des résultats des expérimentations sur pluviomètres qu’ils ont favorisés.

Mots clés: annuaires hydrologiques, pluviomètres, Royaume-Uni.

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1. Introduction

While the volume of hydrological literature appearing in recent years has been rising, it is noticeable that there has been a sharp decline in the production of hydrological yearbooks and allied publications. Yet it could be argued that that, at a time when a global water crisis seems to be approaching, the effective dissemination of information about river flows, groundwater levels, precipitation and other hydrological variables is assuming much greater importance, especially dissemination in the printed form. Print on paper is, after all, the most readily accessible of all the media. It is readily accessible to politicians, decision makers...
and the general public — probably the most important audiences, certainly as important as the professionals who use the data.

Prior to the 1970s, the production of hydrological yearbooks was taken as a tangible sign that hydrological data acquisition and dissemination had come of age (Marsh, 1995). The state of the nation’s water resources was published annually in tables of average daily and monthly discharges and the extreme flows, lake levels, water levels in aquifers, precipitation and the values of other variables, including, in some cases, data on water use. Then the yearbook was an important index of how effective and efficient was the national hydrological or hydrometeorological service. Now yearbooks seem to be part of the losses suffered by many of these services, as they attempt to survive the financial and administrative rigours of the XXIst Century.

Of course, in a number of countries these changes have been brought about, in whole or in part by the advent of the computer and its use in hydrological data management. Suites of retrieval packages are available to meet the needs of customers, on-line access to archives is possible and data and hydrological maps are presented on the web. However there are a number of questions about access to these services and their costs, while there are the problems of exchange of data and products and certain other sensitive issues, which make the situation more difficult now than when virtually every task was performed by hand. Conditions were very different some forty years ago and even more different 100 or so years ago!

2. Developments in the XVIIIth and XIXth Centuries

During the Eighteenth and Nineteenth Centuries, fostered by its extensive applications, hydrology seems to have gradually emerged as a distinct part of the natural sciences. These times included the period of “Modernisation” (Ven Te Chow, 1964) from 1800 to 1900, when a range of discoveries and innovations were occurring that are basic to today’s hydrology. The individual scientists and dedicated amateurs who had previously led the way were forming into interest groups and societies and a number of government institutions were being established dealing with water. Some of these institutions became, wholly or partly, the national hydrological or hydrometeorological services, for example the US Geological Survey which was founded in 1879. It is also interesting to note that this was the time which saw the start of the longest hydrological time series existing to day: daily rainfall at the Radcliffe Observatory, Oxford from 1815; discharge of the Rhine at Basle from 1808 and groundwater levels at Chilgrove, Sussex, from 1836.

Part of the process to improve the organisation of hydrology involved moves to standardise methods of observation, including rules for observer
practice and the adoption of a single type of instrument for countrywide use. These instruments came to be designated the national standard, particularly instruments for recording water level and for observing rainfall and evaporation. The collection of the records by a national centre, their collation, archiving and publication reinforced this process. The appearance annually in print of the records collected at the various points of observation across the nation, helped to consolidate the hydrological network. Indeed WMO (WMO, 1994) stresses that such publications provide in a convenient form to most users of the data; tabulations, maps, graphs, and summaries of observations, as well as the results of the secondary processing of the observations. To emphasize this point Marsh (1998) lists the present objectives and advantages of yearbook publication (Table 1).

1. to catalogue available water resources and flood and roughs information.
2. to provide representative snapshots of water resources and benchmarks for climate change impact studies.
3. to serve as a national archive and a safeguard against loss and destruction of data.
4. to act as a gateway of the national hydrological information system.
5. to motivate field and office staff and foster their attention to accuracy and discipline.
6. to provide products which indicate the value of the return of the investment in the hydrological network.
7. to provide an incentive to keep archives up to date.
8. to raise awareness of issues involving hydrology and water resources and encourage the use of hydrological data.
9. to promote hydrological research through the ready provision of data.

Table 1: Principle aims and objectives of the publication of National Yearbooks (after Marsh T.J., 1998)

The second half of the Nineteenth Century saw the launch of a number of national yearbooks, many by the government hydrological service, some by learned societies and some by private individuals. For example, in Norway, Vandstandsobservationer i norske vasdrag 1890 (water level observations in Norwegian rivers in 1890) was published in 1891 by the Canal Director, using the presses of Dagbladet, Kristiana (a daily newspaper) (Tollan, 2001). In Austria in 1895, the Hydrographischen Central-Bureau started to publish precipitation and water level observations in the Jahrbuch des Hydographischen Dienstes in
Osterreich (Nobilis, 2001). In the United Kingdom a private body, the British Rainfall Organisation, was established in 1860 on the initiative of G.J. Symons, who published “English Rainfall 1860” from the records collected from some 150 observers (Symons, 1861). It is interesting to note that there was a delay in the publication of British river flow data until the xxth Century. Although gauging stations had been set up in the 1920s on a number of Scottish rivers by Captain W.N. McClean, it was not until 1935 that the Surface Water Year Book of Great Britain was published with records from 21 stations (Rodda, Downing and Law, 1976).

3. British rainfall

When it first appeared in 1860, “English Rainfall” was simply a four-page pamphlet (Fig. 1), but it was soon followed by the first volume of British Rainfall in 1862. This was a combined volume for 1860 and 1861 (British Rainfall, 1862) containing records from nearly 500 sites. From that time until 1939, British Rainfall appeared as a separate volume for each year (HMSO, 1963). A number of single year and several combined volumes were produced between 1939 and 1968 (HMSO, 1974), when the 108th and final volume of British Rainfall was published. From 1969 the Meteorological Office published annually in paperback form: “Monthly and annual totals of rainfall for the United Kingdom", until “Rainfall 1991” appeared in 1993 (Meteorological Office, 1993).

Between 1860 and 1919 the British Rainfall Organisation and the publication of British Rainfall were maintained very largely by the volunteer observers, who made the rainfall observations and by many of the same people and the bodies that employed them, who presented gifts of money and made purchases of British Rainfall (10 shillings a copy from 1881 to 1918). British Rainfall 1919 (HMSO, 1920) records that His Majesty King George V gave two guineas to support the Organisation, amongst a total income for that year of about £300. It also noted that the British Rainfall Organisation had been transferred to the Meteorological Office on 24 July 1919 and that Dr H.R. Mill, who had led the work since the death of G.J. Symons in 1900, had retired. In his Introduction to the volume, Napier Shaw, the Director, stressed that the Meteorological Office would continue to rely on the work of the voluntary observers. The number of observers grew from about 500 in 1862, to some 4800 in 1919 and to nearly 6000 in 1960 when the 100th anniversary volume appeared. In 1971 the total number of observers was 6831 (Met Office, 1972), probably the highest figure reached. Since that date there has been a decline in the number of rainfall stations to about 4000 in 2001 and this figure includes a range of automatic and telemetering gauges. That the United Kingdom is covered by a network of weather radars and by satellite imagery is very important to the determination of rainfall.
ENGLISH RAINFALL, 1860.

The Compiler having commenced an extensive investigation into the Rainfall of the British Isles, has experienced much difficulty in collecting the earlier observations from the numerous works in which they are scattered; wishing to prevent others suffering like inconvenience in future, he offers this summary, hoping that year by year the number of stations will increase, and these papers become more valuable in themselves and more worthy the acceptance of the contributors.

The height of the gauges above the ground and above sea level (when known) will be stated, so that the differences due to these causes may be allowed for, if desired.

In order that the correction for altitude above the ground may be better known, similar gauges should be placed at different heights, wherever the position is advantageous, such observations being at present very scarce.

The order of the Stations is nearly that adopted by the Register General, but the ordinary county boundaries are maintained, and the stations in each county are arranged in the order of their latitude.

The Rainfall in 1860 was considered above the mean at most stations, the average excess over the mean of previous years being about 25 per cent. It was nearly 50 per cent in excess in Herefordshire, and some parts of the Lake District, while at Manchester it was only 3 per cent, and at Retford 4 per cent, above it. There does not appear to be any station which has less than the usual fall.

G. J. S.

### DIVISION I – MIDDLESEX.

<table>
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<th>STATIONS</th>
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* Gauge out of order 3 days in October.
The table of contents of British Rainfall remained remarkably similar between the early volumes and those appearing up to Volume 100 in 1960, although the volumes before 1919 provide more details of gifts and donations and more information about the observers. All volumes to 1960 contain records of the deaths of observers, with obituaries of those who had maintained lengthy observations and who had contributed to science in various ways. These facts were usually listed in the section on the work of the Organisation, latterly within the Meteorological Office. They were followed by a discussion of the rainfall for the year in question. In this section heavy falls in rainfall days, monthly and seasonal rainfall, the distribution of rainfall in space and time and the relationship to the average were analysed. Records of evaporation and percolation were also included in this section, together with commentaries on droughts, dry spells and exceptional events. The section that followed, known as the general tables, contained the complete list of rainfall stations. For each station there was a description of the site and the gauge, the annual total rainfall and the number of days with rain. Stations were listed by river basin and later indexed by national grid reference. A snow survey was also included in later volumes. Special articles were usually featured as the last section of the volume. A change was made from British Rainfall 1961 (HMSO, 1967) with the general tables appearing as Part 1, summary table and maps as Part 2 and Part 3 containing special articles and additional material.

Through the first volumes of British Rainfall, Symons advocated the standardisation of both the rain gauge and the practice of observation. A description of the standard rain gauge was given in British Rainfall 1866 and from that time onwards the proportion of gauges with a height of 355mm (1 ft.), an orifice of diameter 127 mm (5 in.) and other characteristics in common increased rapidly. “Suggestions for securing uniformity of practice among rainfall observers” (Fig. 2) were published in British Rainfall 1881 (British Rainfall, 1882), with twenty specific requirements. These requirements later became rules and “Rules for Rainfall Observers” incorporating them is still published today. Another article in British Rainfall 1881 commented on the nine gauges used to study the annual variation in rainfall over England since 1830 and pointed to an error of 20 % in the gauge at Exeter due to the growth of a holly bush. In the same volume there are expressions of regret that few inspections of rain gauge stations had taken place that year and comments on the time and costs of visiting all 2500 stations. However the number of sites inspected grew as time went on, with the height of the gauge, whether it was level and the nature of obstructions around the site receiving particular attention. From 1919 the Meteorological Office employed a number of Rain Gauge Inspectors, but currently these inspections are conducted by staff who have the task of looking at all types of field instruments. The Environment Agency now assists in this process of quality maintenance.
IX. – DATE OF ENTRY. – The amount measured at 9 a.m. on any day is to be net against the previous one; because the amount registered at 9 a.m. of, say, the 17th contains the fall during 15 hours of the 16th, and only 9 hours of the 17th. (This rule has been approved by the Meteorological Societies of England and Scotland, would be altered, and is particularly commended to the notice of observers).

X. – MODE OF ENTRY. – If less than one-tenth (°10) has fallen, the cypher must always be prefixed; thus, if the measure is fall up to the seventh line, it must be entered as 07, that is, no inches, no tenths, and seven hundredths. For the sake of clearness, it has been found necessary to lay down an invariable rule that there shall always be two figures to the right of the decimal point. If there be only one figure, as in the case of one-tenth of an inch (usually written °1) a cypher must be added, making it °10. Neglect of this rule causes much inconvenience. All columns should be cast twice — once up and once down, so as to avoid the same error being made twice. When there is no rain, a line should be drawn rather than cyphers inserted.

XI. – CAUTION. – The amount should always be written down before the water is thrown away.

XII. – SMALL QUANTITIES. – The unit of measurement being °01, observers whose gauges are sufficiently delicate to show less than that, are, if the measure is °005 or °005 to °010 inclusive, they are to enter it as °01.

XIII. – ABSENCE. – Every observer should train some one as an assistant; but when this is not possible, instructions should be given that the gauge should be emptied at 9 a.m. on the 1st of the month, and the water bottled, labelled, and tightly corked, to await the observer’s return.

XIV. – HEAVY RAINS. – When very heavy rains occur, it is desirable to measure immediately on their termination, and it will be found a safe plan after measuring to return the water to the gauge, so that the morning registration will not be interfered with. Of course there is the slightest doubt as to the gauge holding all that falls, it must be emptied, the amount being previously written down.

XV. – SNOW. – In snow three methods may be adopted – it is well to try them all. (1) Melt what is caught in the funnel by adding to the snow a previously ascertained quantity of warm water, and

Figure 2: Early rules for rain gauge observers

4. Rain gauge experiments

The rain gauge has a long history; some authorities claim it extends over 2000 years and more (WMO, 1973). Countless of types of gauge have been
devised and deployed over the centuries, especially during the last 250 years. It is something of a puzzle that so many of these studies have been conducted in Britain, perhaps because rain is such an obvious feature of the British climate. Some of these studies took place in the XVIIIth Century, for example, Heberden (1769) experimented with three rain gauges, one in a garden (30.5 cm), one on a roof top (14.17 m) and the third on the top of a tower of Westminster Abbey (71.33 m), to show that the volume caught decreased with height in the ratio of 100:80:54. However many more studies and experiments are recorded in the volumes of British Rainfall. This may be a paradox: having advocated gauge standardisation more or less from the outset, Symons and his successors were very willing to publish in British Rainfall the results from many different types of gauge exposed in very different ways.

There are accounts of experiments with gauges with a large diameter orifice as opposed to ones with small orifices, on inclined gauges, on gauges with shields, on different exposures, using gauges made out of various materials, with gauges of different shapes, on recording gauges, comparisons of the British standard gauge with those used by other nations, and many other tests of gauge performance. The question of the decrease in catch with the height of the gauge above ground level seemed to attract a considerable amount of attention. For example, a series of experiments were performed at Rotherham from 1872 to 1890 with gauges exposed at six different heights above ground level from 30.5 cm to 11.81 m. Some of the results were published in the volume for 1881 (British Rainfall, 1882) and they showed that the highest gauge caught 93% of the catch of the lowest.

Mill (British Rainfall, 1901) summarised many of the results of the early studies in his article: “The development of rainfall measurement in the last forty years”, principally to allow observers to understand the past work on which the rules for observing rainfall were based. Among the different subjects discussed, he showed that it was the increase in wind speed with height above ground that determined the catch of the gauge rather than condensation in the boundary layer, static electricity or some of the other effects that had been held responsible previously. Accounts of various experiments feature in many of the volumes up to the 1930s. For example, the conclusions from the five years of studies on shielding a gauge by surrounding it with a concentric wall of turf were reported by Huddlestone in the 1930 volume (HMSO, 1931). Indeed the turf wall gauge became advised practice for rain gauge stations in exposed locations as a result of these studies. The 1937 volume (HMSO, 1938) reports a study of wind speed measurement at the rim of the gauge within a turf wall, which confirmed its value.

The volumes of British Rainfall published in the 1950s and 60s contain articles on evaporation measurements by lysimeters and snow surveying, rather than on rain gauge experiments. The results of studies of rain gauge
performance seems to have been published elsewhere, perhaps because of the delays in the publication of British Rainfall that were occurring.

5. Conclusions

While there may be some question about the value of hydrological yearbooks in the XXI\textsuperscript{st} Century, there can be little doubt that they played an important part in the development of hydrology in the XIX\textsuperscript{th} and XX\textsuperscript{th} Centuries. Although the particular aim of publishing a yearbook may have varied from one nation to another, they provided a timely national catalogue of water resources information and a means of publicising the importance of activities in hydrology. Perhaps the potential of such publications has yet to be fully exploited in the progress of hydrology today.

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