Acknowledgements

The writer is indebted to many colleagues for their help and for providing information and criticism. Amongst these are Drs. Hugh M. French, R. Van Everdingen, R.J.E. Brown, M. Seppala, S. C. Zoltai, O. J. Ferrians, Jr., J. L. Sollid, H. Svensson, A. Rapp, R. Åhman, A. L. Washburn, and A. Pissart. Their help is gratefully acknowledged.

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SOME GEOGRAPHICAL ASPECTS OF WATER SUPPLY IN SOUTHWEST ENGLAND DURING THE 1975–6 DROUGHT

With 4 figures and 1 table

V. GARDINER

Zusammenfassung: Einige geographische Aspekte der Wasserversorgung von Südwest-England während der Dürre 1975–76

Sogar in Jahren mit hinreichenden Niederschlägen ist die Wasserbeschaffung in Südwest-England nicht problemlos. Diese Probleme traten insbesondere im Jahr 1976 in verschärfter Form auf, zum einen wegen der extremen Klimabedingungen, zum anderen wegen der unzureichenden Zeit, welche der frischgegründeten South West Water Authority zur Verfügung stand, um eine regionale Wasserbewirtschaftungs-Strategie wirksam werden zu lassen. Die Strenge der Dürre verstärkte sich im allgemeinen ostwärts und dieser Gradient der Dürre-Abstufung entspricht insgesamt den Engpässen der Wasserversorgung. Der tatsächliche Wasserverbrauch für 1976 wird als Anteil des vorausgesagten Bedarfes kartographisch dargestellt und einige der zugrundeliegenden Abhängigkeiten des sich ergebenden Verteilungsmusters werden erörtert. Die Reaktion der Administration auf die Dürre wird skizziert. Es ergibt sich, daß das räumliche Muster der Wasserversorgung sowohl von menschlichen wie von naturräumlichen Faktoren abhängt und daß eine regionale Wasserbewirtschaftungs-Politik in Südwest-England notwendig wäre.

The drought which occurred in England Wales during 1975–6 was an event unique in its severity during the period of instrumental meteorological observations, and probably within the period of non-instrumental records. Although there have been many studies examining various aspects of the drought (e.g. COX, 1978; DOORNKAMP et al., 1980) water supply has normally been discussed (excluding limited-circulation reports of individual Water Authorities), at only the national scale (e. g. NATIONAL WATER COUNCIL, 1977; GARDINER, 1980a). The time elapsed since the event has allowed sufficient data to have been made available to enable a more detailed examination, and this may furthermore now be made with greater objectivity than has hitherto been possible, because of increased detachment from the event. This paper, therefore, focusses attention on the impact of the 1975–6 drought on water supplies at the regional scale, where geographical factors are of considerable importance. These concern both the way in which the physical environment governs water availability and the way in which the human environment influences consumption; the topic is, therefore, one which combines consideration of both physical and social factors within a spatial framework, and which documents one form of human adjustment to a particular climatic hazard. This is achieved by detailed consideration of one area within England, the Southwest peninsula.

Water supply in the Southwest is in general terms attended by several problems. First, the upland supply areas of high rainfall (Fig. 1) are separated from the areas of high population and, therefore, demand for water, because the major urban areas are in coastal locations. Second, the largely rural nature of the peninsula has not stimulated capital investment for the development of large-scale water storage, supply and re-distribution facilities. Finally, summer increases in population in parts of the Southwest because of tourism create the highest demand for water (Fig. 1) when supplies are at their lowest, the majority of rainfall being during the winter months (Fig. 1, insets).

The management of water supplies in England and Wales is the responsibility of ten Water Authorities, and water supply in Devon and Cornwall is provided by the South West Water Authority. For administrative purposes this is divided into three Divisions, each of which is further divided into two Areas (Fig. 2). Re-organization in the water industry in 1974 meant that in 1976 plans for a regional water management strategy by which water resources could be moved throughout the region were not as yet implemented.

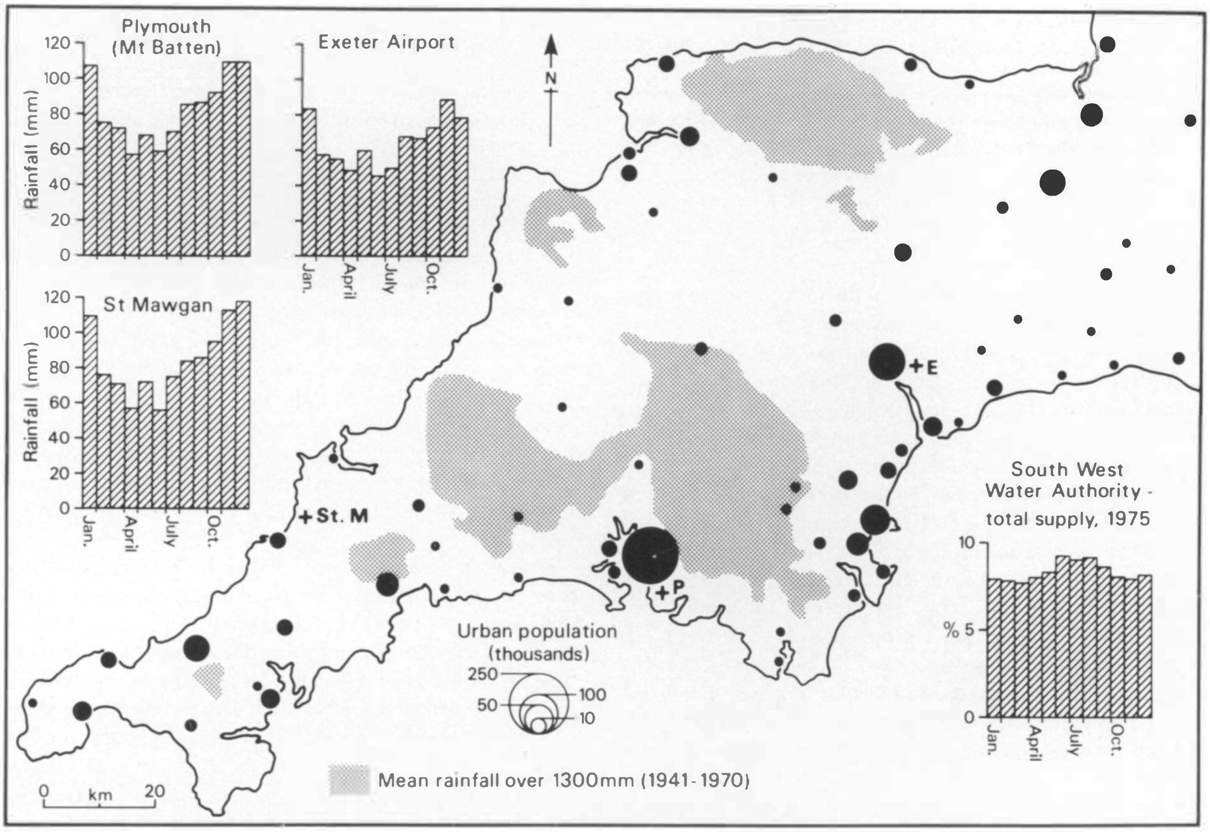

Figure 1: The distribution of population in relation to areas of highest rainfall. Insets show monthly total water consumption in 1975 as a percentage of the year's consumption and mean monthly rainfalls for three representative stations, for the period 1941–1970.

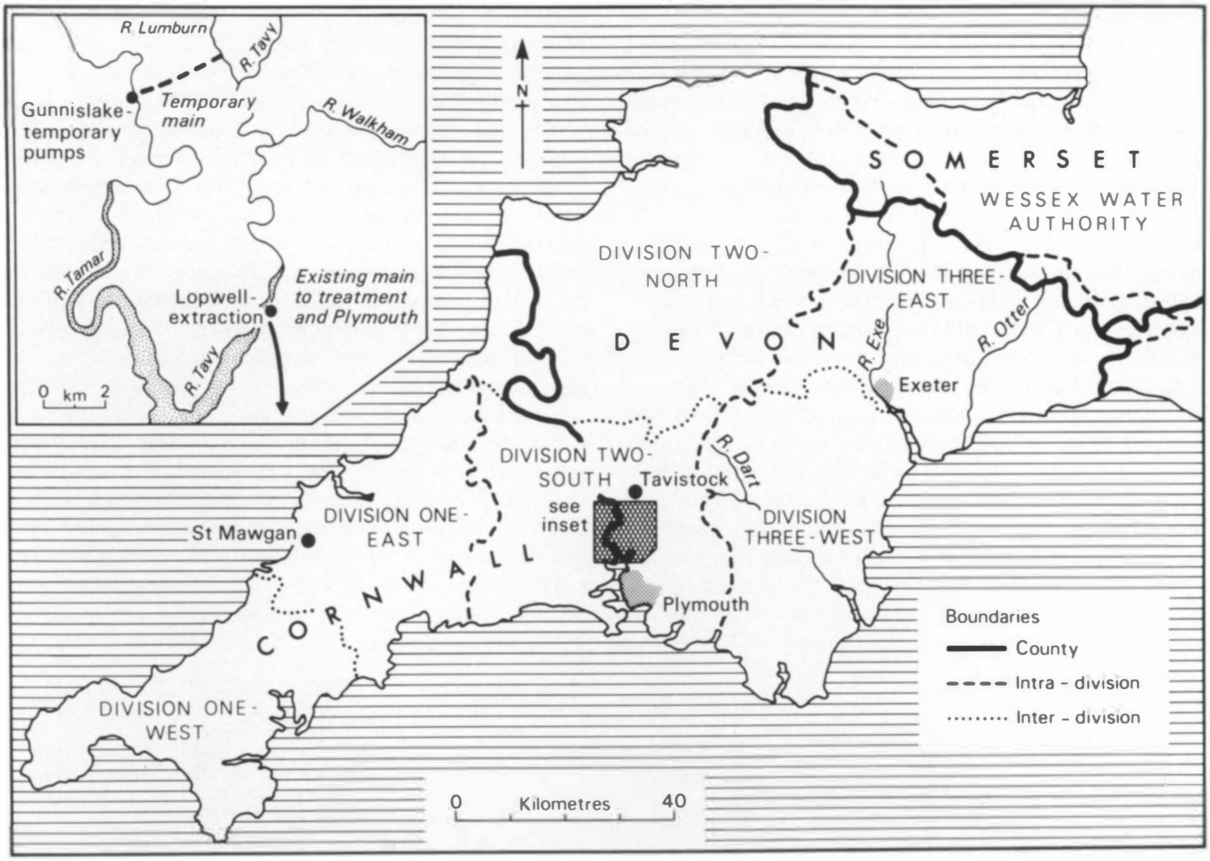

Figure 2: The administrative structure of water supply in Southwest England and location of towns and rivers mentioned in the text. The inset is explained in the text.

The drought

Rainfalls in England and Wales for the sixteen month period from May 1975 to August 1976 were only 62% of the 1916–50 average (Speight, 1977) and rainfall totals as low as those recorded for this period have not been recorded for an equivalent period since 1750. The generalised spatial pattern of rainfall during this sixteen month period in Southwest England, as a percentage of the long-term average, is depicted by Fig. 3 D, which shows that the deficit of rainfall was far from uniform even within this relatively small area. There was a general increase in the shortfall of rainfall in an easterly direction, with parts of East Devon receiving less than half of their average rainfall. Rainfall in Cornwall was much less below normal than that in Devon. Associated with the low rainfall were high temperatures and low humidities, particularly during the summer months of 1976 (Fig. 3 A–C). Water losses from reservoirs by evaporation were, therefore, increased greatly, thereby exacerbating the shortage of rainfall.

Water demand in 1976

Under normal conditions water supply is adequate to meet demand and the two terms are often used interchangeably by the water industry (Park, 1980). However, under drought conditions the amount of water supplied is reduced because of enforced reductions associated with such measures as bans on the use of hosepipes, and because the consumers exercise economies in water use as a response both to administrative and media pleas for economy, and to their own consciences. The amount of water supplied during a drought, therefore, falls short of that which would theoretically have been supplied under normal conditions; this predicted consumption may be identified as a theoretical demand for water.

Prediction of water demand may be performed in two ways. First, the amounts of water consumed during preceding years of more normal conditions may be extrapolated by regarding the year as an independent variable and water consumption as the dependent variable. Regression affords a suitable statistical procedure, and the relationship between the two variables may be either linear or of a more complex form. This method implies a regular, or at least simple, growth in consumption during the time period considered, and subsumes changes in industrial composition and output, and in population size and socio-economic status, within the temporal incremental growth.

The second method recognises that population size is likely to be the most important determinant of water consumption and this is, therefore, used as the independent variable, in the same way as year in the first method. The use of population is limited by the inability to allow for changing patterns of water consumption associated with changing economic status of the population, where for example the acquisition of an automatic washing machine may greatly increase a family's demand for water (RUMP, 1978). In the area studied this method also suffers from the great disadvantage that it takes no account of the way in which population within the area changes seasonally due to tourism. It was, therefore, felt inappropriate in the present case.

Both of the methods described above may be enhanced by the incorporation of further independent variables, such as those indicative of personal economic status, industrial output or climatic conditions, and many studies on the micro-scale have suggested the value of such variables as indicators of water demand. For example, DANIELSON (1979) demonstrated how both income levels and climatic variables explained some of the variation in individual household consumption of water in Raleigh, North Carolina, where water was charged by amount consumed. However, the impact of such variables is likely to be much less where, as in England, domestic consumers are not charged according to consumption. In addition, such data are not readily available for the time periods and areas of concern.

Accordingly the method first described above was employed in this study. This method is that which is most commonly employed, and is widely accepted as the most appropriate for short to medium term predictions (e. g. CENTRAL WATER PLANNING UNIT, 1977). For the South West Water Authority data on water consumption from 1961 to 1975 are available for each of the six sections making up the Authority, although data for the years before 1973 are synthetic data derived from statistics related to the former Water Board areas. By simple linear regression of water consumption on year estimates of demand for water in 1976 were derived from these figures. The use of curvilinear regression was also investigated, but in no case was the additional complexity warranted by a statistically significant ($p < 0.05$) increase in the validity of the relationships.

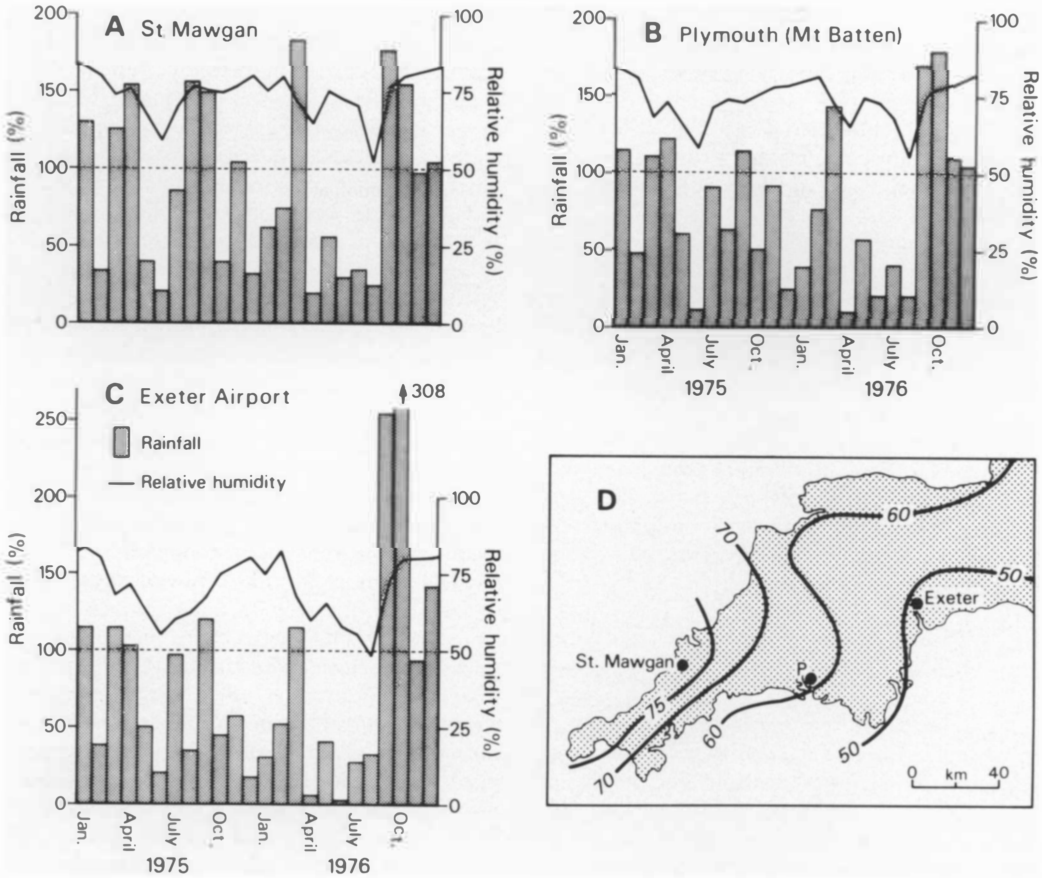

Figure 3: Climatic conditions in 1975–6 in Southwest England. A–C show mean monthly rainfall and humidity values at 15.00 for three representative stations. Rainfall is expressed as a percentage of the 1941–1970 average. D shows the distribution of rainfall in the sixteen month period May 1975 to August 1976 as a percentage of the mean rainfall for this period from 1916 to 1950.

Estimates were prepared for total water supply and for its metered and unmetered components separately. Metered supplies are largely those to industry and other large users such as recreational activities and agriculture. Unmetered water is supplied largely to domestic consumers. This distinction is not, however, a rigid one as it depends upon the metering policies of both the existing Water Authorities and the previously-existing organisations.

Total consumption of water is controlled by many factors, including changes in population, industrial composition, economic situation and social habits. However, for all six regions in the South West there is a definite and consistent rise in annual total water consumption over the time period considered. Correlation coefficients between the amounts of water supplied and the year are all greater than 0.92, and are all statistically significant ($p < 0.01$). The average rates of increase vary from 8100 cubic metres per day per year in Division One East to 1800 cubic metres per day per year in Division One West.

The estimates of metered consumption are almost all as statistically significant as those for total consumption, the correlation coefficients being, with one exception, greater than 0.92. The exception is Division Two South. When individual yearly figures are examined for this region the reason for this becomes apparent. This area, which contains Plymouth, is the South West's most industrial region and metered consumption during the 1970s fluctuated erratically, possibly in sympathy with the changing economic situation of the area. Prediction of metered demand in 1976 for this area is, therefore, slightly less reliable than for the other areas, although the correlation coefficient is still statistically significant ($p < 0.01$).

Unmetered consumption has been examined in terms of the consumption per head of the population, in order to minimise the effects of changing population sizes. This category of water supply is less easy to predict since it depends not only on changing residential and tourist population but also upon changing social and economic patterns in domestic water usage. Four of the six regions yield correlation coefficients which are statistically significant ($p < 0.01$). For Division One East and Division Three East the temporal pattern of water use is much more irregular and no statistically sound estimates could be derived. Unmetered consumption for these two areas has, therefore, not been examined further except as a component of total water supply.

Water supply in 1976

Fig. 4 depicts the spatial distribution of total water supplied in 1976 and that of its metered and unmetered components, as a percentage of the predicted demand. The shortfall of total water supply shows a systematic increase in an easterly direction. Water supply in Cornwall was much less affected by the drought than in Devon, possibly because of the higher rainfall (Fig. 3), better provision of reservoirs in relation to the area's population, and the existence of a partly-completed spine main water distribution system. Division One West had in fact a total water consumption slightly in excess of that predicted and Division One East's consumption was only 1.1% less than the predicted demand. During drought conditions water consumption in areas not most severely affected will often stay at high levels in this manner, because the increased consumption of water occasioned by the higher temperatures more than counter-balances any economies made by the users when the supply is still fairly readily available. For example, Danielson (1979) reported that in North Carolina a 7 °C increase in temperature resulted in an increase of 5% in water consumption, occasioned by an increased frequency of garden irrigation and lawn sprinkling. That this may have been the case in Cornwall is suggested by examination of the components of water supplied to Division One West. Although metered supplies were reduced to less than 87% of that predicted, unmetered supplies were nearly 6% greater than predicted.

For Devon total water supplies were much less than predicted for the year, the figure for each section being less than 90%. The greatest reduction was in Division Three West where only 79.4% of the predicted total demand was supplied. The general easterly increase in severity of the drought-imposed shortfall is broken by Division Three East, where as much as 88.5% of the predicted demand was supplied.

The spatial pattern of reduction in supply, therefore, closely mirrors that of the severity of the drought in terms of rainfall. The mechanisms bringing about this interaction between supply availability and actual consumption are not, however, clear, since publicity to reduce demand (see below) was applied fairly uniformly across the whole Authority area, and a consumer would not know of the shortage of supply in his own area, relative to that of the rest of the Authority. Similarly, it is tempting to suggest that the higher percentage amounts of water supplied to Division Three East may have in part arisen because East Devon is the only part of the Authority's area to obtain any substantial part of its supply from ground water supply, which was less severely affected by the extreme climatic conditions than the surface water from which the majority of the rest of the country's supply is extracted. Again, however, there can be no simple mechanism responsible for this, as the ordinary consumer would have had no indication that ground water supplies were more plentiful than surface water supplies and, therefore, no lessened incentive for restraint in water use. Indeed, he is unlikely in many cases to know that his supply is from ground water. Elucidation of the information sources and processes responsible for individual levels of restraint necessitates micro-scale data gathered at the time of or shortly after the event; these are lacking in the present case, but there is at least some indication from the aggregated data that a fairly complex set of perceptual and decision-making processes may be involved.

Discussion of the spatial pattern of water supply may be supplemented by examination of its temporal pattern, since the annual figures necessarily give a very generalised impression. The more normal monthly total consumption figures for 1975 (Water Data Unit, 1978) shown in Fig. 1 may be compared with those for 1976 in Fig. 4. The 30% increase in population (GREGORY, 1980) because of the influx of tourists in summer normally results in a marked summer peak of water consumption. Division One is the most affected by this influx, being subject to a 73% increase in summer population, but for reasons already outlined Division One was not as badly affected by the drought as elsewhere in the region. Division Two does not have a large increase in summer population but Division Three has an average increase of 32%. The 1976 monthly figures for the whole Authority show a slightrise of water use in June and July but this trend reversed in August and September as the ‚Save It' campaign and the publicity associated with the drought began to be effective.

Administrative reactions to the drought

The South West Water Authority, like most of the others in England and Wales, was placed in a very difficult position in 1976. A limited resource was fast running out and there was no means by which this could be replenished except by natural rainfall, and no indication of when this might occur. All that the Authority could do was to exercise considerable ingenuity in ensuring that the water available lasted as long as possible and was equally distributed. The Authority started a low-gear campaign to conserve water as early as January 1976 and this was progressively intensified as the year proceeded. In March advice was given as to how water consumption could be reduced, and existing hosepipe bans were widened. In July and August 1976 the national crisis resulted in the emergency passage through Parliament of the Drought Act 1976, which gave the Water Authorities more effective powers in order to eke out existing reserves. (BLACKSELL, 1980).

Inevitably some difficulties were encountered with public relations, which it is felt (KAVANAGH, 1977) stemmed from a dormant discontent with the Authority occasioned by increased water charges, lack of direct representation and resentment at the exemption policy. Priority was given to supplying industry, agriculture and tourism, for economic reasons, and this inevitably caused resentment amongst domestic users. Despite the crisis environmental lobbies were still active, and proposals to repair some of the abandoned leats on Dartmoor to allow their original purpose of water transfer were described by some objectors as desecration. As soon as drastic rationing measures became inevitable the Authority attempted a liaison and public relations exercise by arranging meetings with county emergency officers, social services staff and voluntary organisations, to arrange assistance and exemptions where necessary.

Some attempts were made to develop further ground water resources in parts of the area, for example in the Dart Valley (Fig. 2), where existing water extraction from superficial gravels was increased by new boreholes. Such attempts were however of only local significance. Even in East Devon it was found necessary to increase the amount of ground water extractation, for example nine planned boreholes in the Otter Valley (Fig. 2) were expedited before their scheduled time in order to help meet the crisis.

Despite the reduction in water use as a response to pleas for economy the Authority had also to undertake many projects to redistribute the rapidly-dwindling supply in order to maintain satisfactory river levels and to allow all areas to have some supply. Rivers fell in some cases to unprecedented levels. For example WARD (1980) shows how for 1975–6 rivers in the peninsula discharged less than 60% of their mean annual runoff volumes; the Exe fell to a flow of about 35,500 cubic metres per day, and Exeter's daily demand, which is extracted from the Exe, is about 26,400 cubic metres per day. Had the Exe fallen much lower environmental damage to for example fishing would have resulted below Exeter, and below the critical level immediate water rationing would have been introduced in the city. In total 42 separate schemes to augment existing supplies were studied by the Authority and 29 were implemented, by the exercising of great ingenuity. These consisted largely of the installation of temporary mains and pumping capacity to use resources which would not otherwise have been exploited. For example a disused and flooded quarry at Wilminstone near Tavistock (Fig. 2) was used as a source of water by installing a temporary main linking it with á treatment works and hence Tavistock, thereby providing the town with about 1500 cubic metres per day. This large river is not normally used to supply water and consequently has no abstraction points or treatment works. A series of temporary pumps installed at Gunnislake (Fig. 2, inset) pumped about 13,600 cubic metres of water per day through a two kilometre long temporary main over the watershed into the River Lumburn, a tributary of the Tavy. Water was then abstracted at Lopwell on the Tavy and pumped to Plymouth via the Crownhill treatment works. In association with this scheme sanction was obtained to reduce the flow in the Tavy, to nil if necessary, and more flexible pumping arrangements were improvised at Lopwell extraction point to deal with quantities of water below 13,600 cubic metres per day. This and other schemes devised in 1976 have been detailed elsewhere (ANDREWS, 1976).

However despite these schemes, and the public response to appeals for economy, rationing eventually became necessary in September 1976. The South West Water Authority was the only one to use stand-pipes as a method of rationing although the Welsh Authority used cut-off rationing and other Authorities had installed some stand-pipes but had not yet implemented their use when the drought ended. The use of some form of rationing in parts of NorthDevon and South-Central Devon was necessary in order to ensure continuance of some domestic supply to all users. Cutt-off rationing was examined as an alternative to the use of stand-pipes, but rejected for several reasons, including the less flexible management of exemptions and the hilly nature of the area, which would have meant that the mains in higher areas would not have been able to recharge during the limited periods of water availability. Reduction in consumption was therefore dependent upon the personal inconvenience caused by having to carry all water from the nearest standpipe. The guidelines adopted for standpipe provision were that one standpipe should serve 20–25 properties, and that no property should be more than 100 m from its nearest standpipe.

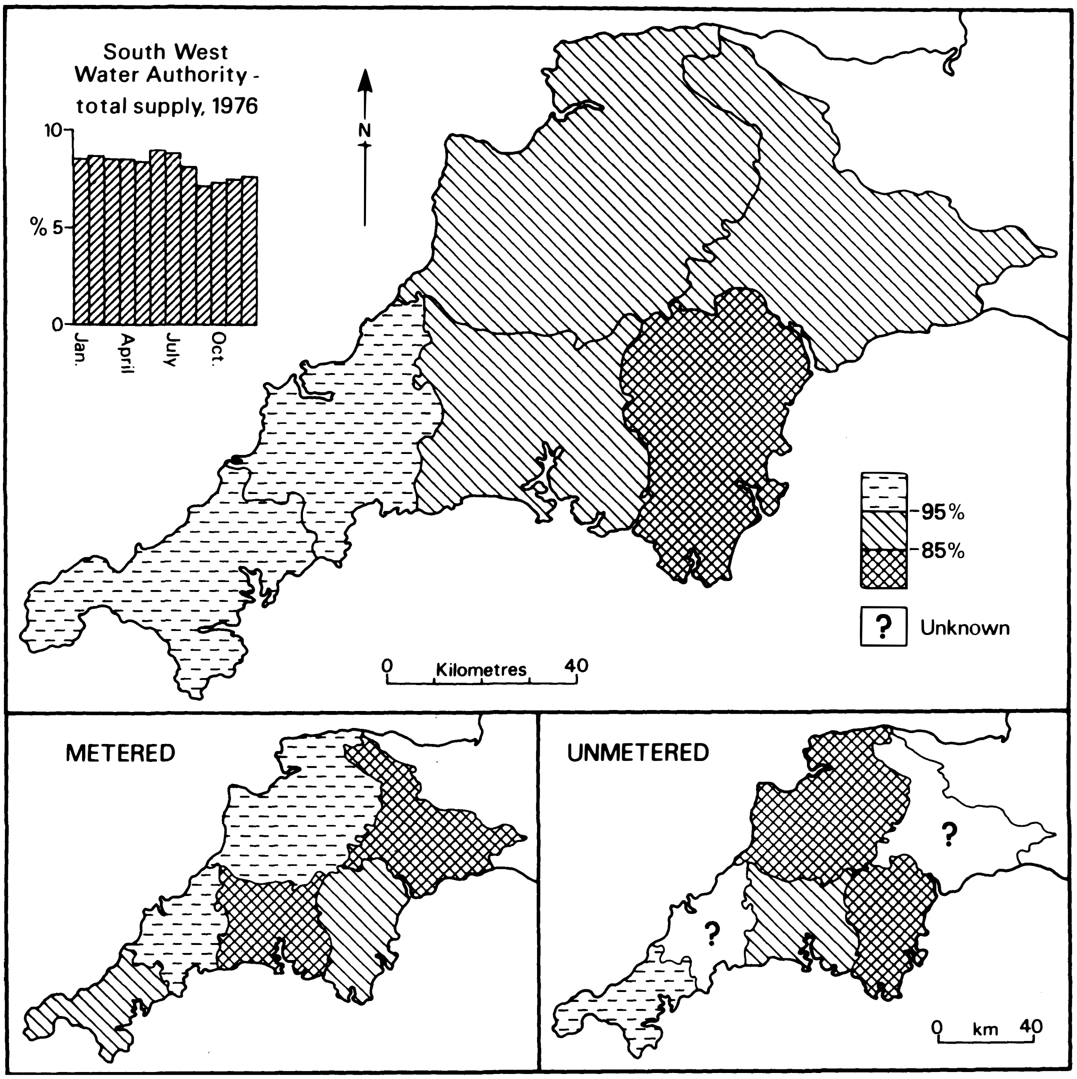

Figure 4: Water supply in the South West Water Authority in 1976 as a percentage of the predicted consumption. The inset shows monthly total consumption on the same basis as in Figure 1.

However, the largely rural nature of the area and the dispersed population distribution resulted in an average of only about 10 properties per standpipe, in order to satisfy the second guideline. Because water supplies to individual properties were turned off immediately outside each property a flexible and fairly generous exemption policy was possible, with supplies being continued to businesses, horticulture and agriculture, tourist accommodation with more than six rooms, and individual cases of hardship such as those requiring water for kidney dialysis machines. In all 4,500 properties were exempted out of the 21,200 within the rationed area. By the end of September 2,410 standpipes were actually used, serving about 65,000 consumers; this resulted in a reduction of water consumption in the rationed areas of about 45% below the alteady low consumption, as shown by Table 1. Here it can be seen that in the entire Division Two North section savings of over 30% were made by comparison with equivalent periods of 1975, about one-third of the division being subject to rationing from 15th September 1976.

Table 1: Reduction of weekly supply for 1976 compared with equivalent weeks in 1975, Division Two North.

Week beginning	Reduction (%)
August 16	28
August 23	25
August 30	22
September 6	23
September 13	30
September 20	32
September 27	32

The drought eventually ended in a dramatic fashion with heavy rains at the end of September and in October (Fig. 3). By October 6th reservoirs in the area were half re-charged and water supply was restored to all consumers. This came just in time to avoid the introduction of standpipe rationing in the major urban areas of Plymouth, Torbay and Exeter, which would have otherwise occurred progressively from 1st to 15th October. The change in conditions was so great that flooding occurred in some areas and Water Authority staff had to be transferred from standpipe erection to flood damage clearance.

Conclusions

Two overall conclusions may be reached from this brief examination of the 1976 drought in South West England. First, the spatial pattern of water supply which occurred during the drought resulted from an amalgam of many human and physical factors, operating within a spatial framework. Study of such phenomena therefore provides one way in which disparate threads of geographical enquiry may be linked together (CHORLEY, 1969). Secondly, because the peninsula was badly affected by the drought, and according to some criteria was the worst affected area in the country (DOORNKAMP and GREGORY, 1980) the maintenance of a water supply was inevitably very difficult. The recently instituted South West Water Authority, despite some public criticism, therefore did an excellent job under trying and extreme conditions. In this they were eventually aided greatly by the response of the public to pleas for economy, and by the very fact that being one body responsible for all aspects of water management throughout the hydrological cycle within a large area meant that labour and materials could be more flexibly and efficiently used. The next drought may however pose entirely different problems to the Authority and the only effective long-term answer may be an ambitious but inevitably expensive water re-distribution network such as that being developed by the Yorkshire Water Authority (GARDINER, 1980b).

Acknowledgements

I would like to acknowledge the generous assistance given by the South West Water Authority, who provided much of the data on which the paper is based. I am also indebted to Mrs. G. Gardiner and Dr. C. C. Park for help and comments on the manuscript.

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