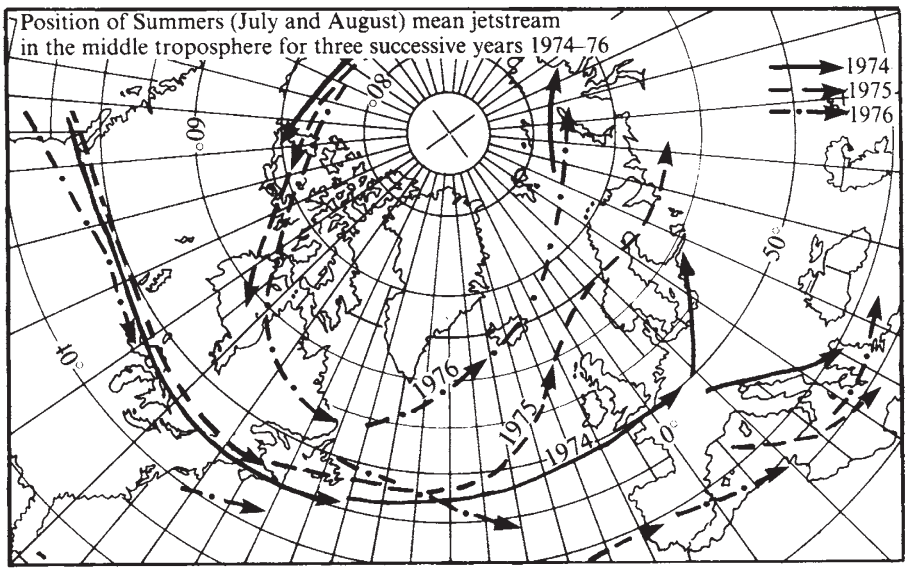
to develop a new jetstream from the eastern USA across the Atlantic towards western Europe, thereby fundamentally changing the situation. Indeed this has already occurred and has been responsible for the recent heavy rain over much of the area worst affected by the drought.

The movement of the mean jetstream flow well to the north of the British Isles was the major cause of the marked reduction in rainfall, and the excesses of rain further north were clearly associated with an increase of jetstream activity not normally present in those latitudes. At the same time the influence of a jetstream upon rainfall anomalies is of limited geographical extent and such is the nature of the circulation that the predominance of cyclonic or anticyclonic regions in a particular region usually leads to the development of anomalous regimes in an adjacent region. The excess rainfall over the eastern and southern fringes of Europe is probably associated with this kind of circulation compensation.

The overall trend during the 1970s has been one of increased cyclonic activity in the Arctic basin, especially across the extreme north Atlantic and Norwegian Sea, and increased anticyclonic conditions over western Europe. Such a circulation implies more frequent and stronger westerly winds than usual north of about 55° N in our sector. The increased westerly winds and cyclonic activity in the north have been associated with a marked recession northwards of the Arctic ice. Up to 1969 Arctic ice to the north of Britain was extending southwards and reached its extreme southern position in March 1969 (see map). By March 1976 the area of open water in the Greenland–Spitzbergen area had increased by about 1.4 million square kilometres compared with March 1969. □



Europe's drought (2)

Water everywhere?

Haydon Richards of the Central Water Planning Unit assesses Europe's water resources

WATER is one of the natural resources with which Europe is better endowed than many other large areas of the world. This generalisation does, however, mask variations in geographical distribution of resources as compared with demands. The summer of 1976 has emphasised an extreme of variation. The driest 16-month period on record, from May 1975 to August 1976, has severely tested resources designed to provide a continuous water supply, but on the whole demands have been met and criteria used for design have proved to be sound. If living conditions are to be maintained or improved then demands have to be met for the four main sectors of public water supply, industry, agriculture and thermal power station cooling. The unusual conditions of 1976 have at least emphasised those areas where additional storage of water in some form needs to be made available in order to satisfy these demands and not impose severe restrictions on water use.

Estimating demand

Reasonably accurate estimates of demand need to be made in order to plan development of suitable resources. Traditionally, trends over a number of years have determined the level of demand to be met at a particular time in the future, but more recent estimates have attempted to break down the components of the total demand. A good deal still remains to be done in this field. Publicity this summer has led to marked lowering of demand for public water supplies and for industry, amounting to at least 20% of normal demand in some areas. However, the knowledge that water is again abundant after a time may well reduce the attitude of care and thus increase demands to "normal" levels.

Apart from the demands to be met from the four major sectors the needs of ecology and amenity have to be borne in mind. Sufficient water must be left in rivers and lakes for aquatic life to continue, effluents to be suitably diluted, navigation to be possible and for fishermen and picnickers to enjoy their leisure. There must therefore be some idea of the quantity to be left in a natural watercourse to prevent unacceptable damage to the environment. This quantity can be determined only by agreement between all users of a particular river catchment and the criteria used may differ from one to the other, general amenity perhaps being over-riding in an upland or rural setting and effluent dilution in an industrial area.

Future projections in demand for water until the end of the century suggest high growth rates in excess of 200% in the Netherlands and at least 150% in Luxembourg, whereas in France demands may increase by little more than a quarter. Recent estimates indicate that Germany and the United Kingdom will need to increase use by 60 or 70%. Those countries with a high proportion of agricultural water demands locally, such as France and Italy, may have developed methods of meeting those demands locally, whereas the increased industrial demands in other countries have to be met by providing major new resources at some distance from the centres of demand.

Increasingly, demands for cooling water are being met from saline waters. Italy and Denmark benefit from long coastlines and use only a small proportion of freshwater for cooling in thermal power stations, although thermal pollution then becomes a problem. Some 30% of cooling tower water is evaporated, and this forms a consumptive use of water because it is lost as a resource. In the same way

water used for irrigation is almost totally lost as a water resource. Groundwater is important for meeting demands for potable water because it is usually of good quality, but only in France is it used to supply water for power station cooling. In Denmark, where there are no rivers of any size, nearly all water for public supplies, agriculture and industry is derived from groundwater storage, and in Belgium about three-quarters is so derived; in Ireland very little is used.

Water resources

Water resources are renewed annually from precipitation on the land surface, the effective rainfall being that which remains for surface runoff or infiltration to groundwater storage after evaporation and replenishment of soil moisture deficits.

Calculating average annual renewal of water resources provides an idea of the potential resource available in different countries. Ireland with its moist equable climate has approximately 32,000 litres a day available for each person from effective rainfall, whereas Belgium has about 3,000 litres a day; figures for other countries in north-west Europe lie between these.

The daily per capita consumption for all purposes in 1969 in Belgium was 119 litres and other countries range up to 280 litres. Even allowing for minimum flows to be maintained in rivers, therefore, nature still provides a substantial surplus of water which can be exploited to meet changing or increasing demands. Belgium's fresh water resources are found in three rivers and in extensive aquifers, and from the latter is obtained almost three-quarters of the public water supply. Regarding other European countries:

- On the low-lying Danish peninsula the small streams are fed by natural groundwater discharge. Some surface water is used to supplement the Copenhagen supply, but groundwater supplies nearly all the country's needs apart from thermal power plant cooling.
- Rainfall in France varies from about 850 mm per annum in the west to less than 500 mm near the Mediterranean. Below average snowfall in the Alps last winter slightly reduced some streamflows during the summer of 1976. There are extensive aquifers in north east France and alluvial aquifers in the major river valleys.
- In West Germany there are also several rainfall zones, from the alpine south with high rain and snowfall, through the central highlands where the average annual rainfall is at least 1,000 mm, to the central lowland with an annual average of 730 mm. The flows of all the main rivers are fairly uniformly distributed throughout the year. Groundwater occurs mainly in the flat alluvial tracts of the river valleys and beneath the northern plains, and provides well over half the public water supplies.
- Ireland is better endowed with water resources than most other countries in Europe, having a low population density and high rainfall which varies from 2,000 mm per annum on the west coast to little over 600 mm on parts of the east coast. There are several rivers and numerous lakes. Groundwater is widely used to supply farms but this source accounts for only about 7% of the total demand for potable water.

The Rhine is of first importance to water management in the Netherlands and it provides over 60% of the total, including power station cooling; groundwater provides more than a quarter of this total and the remainder is derived from the Meuse and small rivers. Navigation requirements also exercise control over water use because minimum levels have to be maintained to meet international agreements. Any open connection with the sea creates the possibility of an inflow of salt water and so substantial outflows are required in the areas below sea-level in the west of the country. Such control is linked to the general care taken to control salt water seepage into the polder areas. Potential resources from the Rhine are very large, but because of variations in the quality of the water management problems in the Netherlands are complex and involve storage in lakes, artificial recharge of sand dunes and the linking of existing sources.

There are marked geographical variations in rainfall in the United Kingdom; annual variations have been highlighted recently with rainfall in the year to August 1976 only 63% of the long term average over England and Wales. Groundwater provides 35% of public water supplies in England and Wales. Natural groundwater discharge provides 80% or more of the total annual flow of many rivers flowing from or over the major aquifer, the Chalk. Lesser percentages are contributed to streams from other aquifers.

Traditionally in the United Kingdom demands have been met in most areas by direct pipeline supply from upland reservoirs; reservoirs in the lower Thames valley are filled by pumping from the river. Along several rivers in England, water is used, returned as treated effluent and re-used lower down stream, and advances in the technology of water treatment in the last few decades has increased the possibility of using upland storage to regulate the flows of such rivers.

Water management

Both Ireland and Denmark tend to use a water resource and then ensure that the effluent is discharged after suitable treatment to the sea. Countries with large inland industrial and urban areas such as France, Germany and the United Kingdom are faced with the problems of costly effluent treatment if the environment is to be protected, and particularly if water is to be re-used for further public, industrial or agricultural supply or amenity. In France, as in Italy, there are large numbers of small reservoirs in the hilly areas providing storage for farm irrigation, but this is not common elsewhere. Systems of control over agencies supplying water, managing rivers and dealing with effluent and sewage treatment vary greatly, but most countries have some form of statutory or voluntary means of tackling aspects of water development and use in defined catchments.

Direct supply of water from source to demand area will continue, but study of the relative costs of providing additional resources will probably produce different methods of using some existing sources. Schemes for the combined use of a number of sources can exploit their contrasting temporal characteristics, as for example when a supply from a river during winter is stopped during summer at times of low river flow, the summer supply being obtained by abstraction from groundwater storage which in turn is normally refilled by winter infiltration from rainfall. Such complex operations require suitable systems of data collection relating to quantity and quality of water in storage above and below ground, and the ability to forecast resources in store, changes in demand, operational problems and the likely results of any decision to use resources differently.

In spite of the uneven distribution of rainfall and of resources in rivers, lakes and aquifers there is sufficient water in the countries of north west Europe to satisfy foreseeable demands well into the next century. Care will be needed to ensure correct treatment of effluents, protection of the quality of surface water and groundwater and the maintenance of river flows for navigation and amenity. Additional storage is needed to meet shortages in certain areas, and by and large these have been emphasised during the dry period of the summer of 1976. This year has also shown that many of the major reservoirs have been designed so as to provide a large part of the required supply even through these unusual conditions. Groundwater storage has also helped by allowing abstraction at rates in excess of the long-term average renewal of storage, and the potential for even greater use during another severe dry period should be determined in necessary detail. No doubt methods of influencing demand patterns and modifying demands will be explored and developed. □