SECTION FIVE

FUTURE DEMAND

103 Our aim in this Section is to build up an estimate of the agricultural industry's likely demand for water in the year 2000. The probable changes in the economic and structural environment of agriculture are briefly considered. Special attention is paid to developments in irrigation practices for each of the main irrigated crops; but projections for water consumption for livestock purposes, vegetable washing and processing, and domestic consumption are also made, culminating in a forecast of aggregate demand.

104 To give greater meaning to our figures we have provided a regional breakdown and, in the case of irrigation, an estimate of peak daily water demand. We think it essential, however, to first outline the economic and structural assumptions which provide the external setting for our estimates.

Economic and structural background

105 We have assumed that by 2000 AD there will be a modest increase in the total volume of food moving into human consumption in the UK; that the efficiency of agriculture will continue to improve through the adoption of new technologies, better management practices and improving farm structure; and that there will be an expansion of domestic agricultural production to meet the increased home demand for temperate foodstuffs, to exploit the scope for import substitution, and to provide for increased export potential.

106 We expect the trend towards the concentration of crops into those areas best suited to their production to continue, whilst some areas will revert to less intensive use. There will be pressures from other land-using interests, principally afforestation and recreation. Neither is likely to impinge significantly upon the highly intensive sector but could impose pressures on water demand and availability in other areas. Social pressures generally could have an increasing influence on farmers' freedom of choice as to land use and their farming operations, but the impact of these is difficult to assess.

107 A trend for land prices to rise at a faster real rate than other inputs could have a dual effect. On the one hand, it is likely to lead to a more intensive use of the better quality land including that suitable to highly mechanised production; on the other hand, there could be a reversion to more extensive farming practices in the less tractable areas. A net reduction in the total land area available for farming would be a further contributing factor.

108 We expect the number of those working on the land, both farmers and workers, to continue to fall, although not at the rate of recent years. Workers themselves will continue to develop higher skills, and wage rates can be expected to increase accordingly. Pressures for improvements in working conditions are likely also to be maintained.

109 The industry's appetite for capital will inevitably grow in all systems of production and it is likely to become increasingly dependent on new sources of finance, including institutional landowners. The costs of servicing capital provided by those outside farming will become a larger element in farmers' outlays, and investment decisions will be of critical importance.

110 Recent MAFF estimates of fuel costs are that they can be expected to double in real terms by the year 2000. A reduction in the availability of fuel could affect the use of fertilisers and enhance the attractiveness of water as an input. But this, in turn, will partly depend upon the extent to which the fuel component in the cost of irrigation can itself be contained.

111 There is every reason to believe that the pressure of economic forces will result in a continuing squeeze on margins and that the majority of farmers will respond, as they have done historically, by intensifying production. This increases the vulnerability of farmers to unforeseeable fluctuations in performance, and farming systems and production methods which provide a safeguard against natural and economic uncertainties will become increasingly attractive. All these influences affect demand for water.

112 Market requirements will exercise a growing influence over methods of agricultural production. Higher standards of quality, consistency and uniformity, and a tighter regulation of the timing of production to meet market demands will feature more prominently. Pressure will come from all parts of the marketing structure and affect a much wider range of produce.

113 At the same time, agricultural and horticultural producers form part of an international trading community. Just as we expect greater specialisation within UK agriculture, we also see a trend towards specialisation both within the EEC and internationally on the strength of comparative advantage. This will affect UK production of many commodities - their location, quality requirements, production methods and seasonality. All these trends in the market environment will bear on future water requirements.

Irrigation practice

114 Apart from the pressures for change described above, we have been obliged to make the following assumptions in estimating likely future irrigation demand:

a. that the profitability and demand for individual commodities in relation to each other will not change substantially over the next 20 years;

b. that the cost of the water applied will represent broadly the same proportion of total costs as at present;

c. that there will be no *fundamental* technological changes affecting the demand for water;

d. that there will be an increasing awareness on the part of the farmer of the benefits of irrigation;

e. that there will be no major climatic changes; and

f. that the water will be available.

115 No doubt some of these assumptions will not hold good in the event, but we think they provide a reasonable working basis for our calculations. We next consider the likely course of development in each of the main irrigated crops.

116 *Potatoes.* The latest MAFF Census shows a renewed interest amongst growers, whether of earlies or maincrop, since 1976. We do not share the

view that this surge of interest is only a short-lived reaction to an abnormally dry year and, in common with many who gave evidence to us, we think that irrigation will increasingly be used in all sectors of *potato* production. A continuing shift of the growing area to the lighter textured soils, more suitable to highly mechanised cultivation, is anticipated. Steadily growing pressures on producers to deliver consistent quantities of produce of higher standard will be a further major influence. These factors lead us to project that 15,000 ha of *early potatoes* will be irrigated by 1985, increasing to 16,000 ha by the year 2000, compared with 13,000 ha in 1977. Our projections for *maincrop potatoes* are for 44,000 ha irrigated in 1985 and 64,000 ha in 2000 compared with 22,000 ha in 1977.

117 *Sugar Beet.* The experiments at Brooms Barn Experimental Station showing the benefits of earlier irrigation have important implications for this crop which, under the pressure of full-scale mechanisation, is being grown more and more on the lighter and drier soils. Furthermore, if the home industry is to continue to produce at least half the national requirements for sugar, there will be increasing pressure to raise yields and to smooth out their fluctuations from year to year. We think that the industry will seize the opportunity and that there will be a significant increase in irrigation of this crop. We project an increase to 28,000 ha under irrigation in 1985, and to 50,000 ha by the year 2000, compared with 18,000 ha in 1977.

118 *Soft Fruit.* Rising costs of labour, packing and transport, as well as the greater leisure time of the consumer, are all expected to stimulate "self-pick" developments. These are already widespread, especially in areas within easy access of major conurbations. Continuity of harvest is essential to their success and should they continue to develop we think there will be increasing recourse to irrigation so as to ensure maximum and steady supplies and thus improve viability. We accordingly foresee the irrigated area of *soft fruit* rising from the 1977 figure of 3,800 ha to over 5,000 ha during the period.

119 *Top Fruit.* We think that the only area in which there will be a significant increase in irrigation is that of *dessert apples.* Our projections are for an increase for *all* top fruit from the 1977 level of 5,400 ha to 8,000 ha by 1985, and to 11,000 ha in the year 2000.

120 *Vegetables.* An increase in the production of *vegetables* of about 10 per cent over the period, to meet domestic demand and to substitute for some imports, is expected; this could be somewhat higher if export markets were to be developed. The increasing disciplines of the market, both domestic and overseas, will impose a need for higher standards upon growers and so provide a stronger incentive to irrigate as an aid to quality, as well as to continuity and consistency of supply. Most affected will be those crops – such as *cauliflower, lettuce, celery, turnips, onions* and *beans* – showing the greatest response to water application. *Peas* similarly show a high rate of response to irrigation and we foresee a significant expansion in this sector. Given a higher utilisation for animal feed of *peas* for harvesting dry we estimate an irrigated area for this crop of perhaps 17,000 ha by the year 2000. In the case of *vining peas,* and assuming that any increase in the size of the market will need to be met by improved production per hectare, it is thought that about 30 per cent (18,000 ha) of the area could be irrigated in the longer term. Taking *vegetables* as a whole, we project an increase in the total area irrigated from 25,000 ha at present to 30,000 ha by 1985, and to 55,000 ha over the full period.

121 *Cereals.* Although some farmers will continue to make profitable use of their irrigation equipment for cereals when suitable occasions arise, we expect the practice to spread only marginally.

122 *Grassland.* Most of the grassland that is irrigated is utilised for dairy cattle. Economic pressures will, we believe, increasingly force dairy farmers to irrigate their grassland as a means of containing the relative cost of feed and to ensure a sufficient and continuous supply of grass of the right quality. Given the necessary change in dairy farmers' attitudes to irrigation, some 82,000 ha of grass for the dairy herd might be irrigated by the year 2000. Local variations would be wide, from only a small proportion of the area in the North and West to perhaps 50 per cent or above in the East. It should be remembered that the actual water requirement per hectare is much greater than for arable crops since grass grows over a long period in the year and shows a high response to irrigation which may frequently be appropriate during this time.

123 *Other Crops.* Of all the crops grown in the drier parts of the country, *forage maize* is the one likely to expand significantly in area. We anticipate that this will double by the year 2000, of which 20,000 ha will be irrigated.

Estimated overall demand – irrigation

124 *Outdoor Crops.* On the basis of this analysis, we set out below our estimates of the potential for irrigation in the years 1985 and 2000 AD, broken down by crop. The areas referred to are those that farmers would irrigate in a dry year, the 1977 figures being derived from the MAFF Census. The forecasts are, of course, dependent upon the assumptions elaborated in paragraph 114 above and should any of them not be fulfilled, farmers' expectations and plans for subsequent dry years would need to be revised. We think it prudent that these forecasts be regarded as the upper limit of irrigation demand up to the end of the Century.

TABLE 15: OUTSIDE CROPS – FORECAST OF POTENTIAL IRRIGATED AREA AND WATER DEMAND IN ENGLAND AND WALES IN 1985 AND 2000 AD

	AREA – '000 hectares			ANNUAL WATER DEMAND – Mm^3		
	1977	1985	2000	1977	1985	2000
Early potatoes	13	15	16	6	10	13
Maincrop potatoes	22	44	64	17	42	77
Sugar Beet	18	28	50	11	23	50
Soft fruit	4	4	5	3	4	6
Top fruit	5	8	11	2	4	5
Vegetables	25	30	55	16	23	51
Cereals	6	6	6	1	2	2
Grassland	30	35	82	30	47	134
Forage maize	-	5	20	-	2	12
TOTALS	123	175	309	86	157	350

Notes: The water demand estimates assume the needs during the 5th driest year in 20 which is generally accepted as the year against which to plan equipment and storage capacity. It is further assumed that water is applied at 50 per cent of the theoretical optimum rate in 1977, at 65 per cent in 1985 and at 80 per cent in 2000. The total 1977 figure differs from that of the Water Data Unit since the basis of calculation is not the same – see paragraph 42.

125 It will be seen that we envisage the possibility of a fourfold increase in overall water demand by the industry up to the year 2000. As a comparison, the Anglian Water Authority, in the recent survey of demand in its area for irrigation water, postulated a lower limit of increase of 200 per cent, and an upper limit of 750 per cent.

Regional demand

126 The rate of increase we forecast nationally is to a large extent reflected in the figures for individual MAFF regions. The largest absolute increases, as the Table below shows, are likely to be in the Eastern, South Eastern, West Midland and East Midland Regions, in that order, and we expect these areas to show a slightly larger percentage increase than the rest of England and Wales.

TABLE 16: OUTSIDE CROPS – ESTIMATED POTENTIAL ANNUAL IRRIGATION REQUIREMENTS BY MAFF REGION (Mm_3)

Region	1977	1985	2000
Eastern	33	64	136
South Eastern	15	25	57
East Midland	9	19	41
West Midland	13	23	53
South Western	8	11	32
Northern	2	4	7
Yorks and Lancs	4	8	17
Wales	2	3	7
TOTAL	86	157	350

Peak demand

127 It is important for those who supply and utilise water to have a measure of daily peak water consumption by spray irrigators. These figures, on a regional basis, are set out below, and have been derived from the estimated areas of crops requiring June irrigation and the peak daily transpiration rate of each.

TABLE 17: OUTSIDE CROPS – ESTIMATED DAILY IRRIGATION PEAK DEMAND RATE (JUNE) BY MAFF REGION (Mm_3)

Region	1977	1985	2000
Eastern	1.7	2.4	4.1
South Eastern	0.7	1.0	1.7
East Midland	0.4	0.6	1.1
West Midland	0.6	0.8	1.4
South Western	0.3	0.4	0.8
Northern	0.2	0.2	0.2
Yorks and Lancs	0.1	0.3	0.5
Wales	0.1	0.1	0.2
TOTAL	4.1	5.8	10.0

128 *Protected Crops.* No significant change in the relative areas devoted to the various protected crops is anticipated and we see no more than a marginal increase in the overall area. No allowance has therefore been made for any increase in the water requirement over and above the present

12 Mm^3 per year which will, we consider, continue to be met without problem, primarily by the public supply. We would also expect the regional pattern of demand to remain largely unchanged.

Water for livestock production

129 In contrast to our forecasts of a significant expansion of irrigation, we do not think it likely that there will be any large increase in the amount of water used for livestock purposes. Greater intensification might be expected to lead to increased water consumption per capita but this effect will be relatively small.

130 *Milk Production.* From the evidence we have received it would seem likely that, taking into account population growth, changed eating habits and patterns of *liquid milk* delivery, the consumption of dairy produce will decline modestly to the year 2000. A change in the relationship between imports and exports may allow some expansion of output, principally achieved by the raising of milk yields. Water consumption can be expected to increase with higher yields, and we anticipate as a result a rise in overall demand from 57 Mm^3 per year to 60 Mm^3 per year by 1985, with no further change to the year 2000. There is likely to be a decrease in the amount of water used for cleaning, as a result of the introduction of more modern parlours, from 10 Mm^3 per year at present to around 9 Mm^3 per year in 1985 and subsequently.

131 *Beef cattle.* We think it unlikely that there will be any change in beef husbandry practices that will materially affect water consumption. This sector is expected to become more self-sufficient, rising to 88 per cent by 1985 and to 92 per cent by 2000, even with static levels of demand, and we think it unlikely that there will be any significant increase in exports. We project that water consumption will rise slightly, to perhaps 64 Mm^3 in 1985, and remain constant thereafter.

132 *Sheep.* We anticipate no significant change in water consumption per capita, and even a considerable expansion in sheep numbers is likely to make little difference to water demand. We have concluded that it could rise to perhaps 16 Mm^3 per year by 1985 and to 17 Mm^3 by the year 2000.

133 *Pigs.* On the assumption that the share of pork in the market for meat is likely to increase substantially up to the end of the Century, there could be an increase in the pig population of as much as 20 per cent. The greater use of pipe-line feeding could increase water usage per pig by about 10 per cent: in 1977, 23 per cent of herds used pipe line feeding and this is expected to increase to 30 per cent in 1985 and to 40 per cent in 2000. As a result water consumption could rise to 24 Mm^3 per year by 1985 and to 28 Mm^3 by the year 2000.

134 *Poultry.* It appears unlikely that there will be much change in the egg production sector. However, some growth is anticipated for both *broilers* and *turkeys,* and we have assumed that the broiler sector will increase by perhaps 50 per cent over the next 20 years and that turkey production might treble. Total water consumption might thus rise from about 7 Mm^3 at present to 8 Mm^3 by 1985, and to 9 Mm^3 by the year 2000.

135 Our projections for overall water consumption by livestock to the year 2000 are therefore:-

TABLE 18: ESTIMATED ANNUAL LIVESTOCK WATER CONSUMPTION

(Mm^3)

	1977	1985	2000
Dairy cattle	67	69	69
Other cattle	61	64	64
Sheep	15	16	17
Pigs	20	24	28
Poultry	7	8	9
TOTAL	170	181	187

Vegetable washing and processing

136 All the indications are that the demand for pre-washed vegetables will increase. Chain stores and supermarkets require a high standard of cleanliness, and their share of the market increases year by year. Furthermore, small grower co-operatives and groups are turning their attention to prepacking and processing on the farm, while farm-gate sales are expanding. Both trends are likely to increase the use of water on the holding.

137 Vegetable washing and processing are good examples of demands that should not be overlooked merely because they are small in the aggregate. National demand could well increase by up to four or five times by the end of the period, even allowing for improvements in re-cycling methods, and whilst the amount of water involved would still be small overall, local problems could well increase.

Domestic consumption

138 We see no reason why the rate of increase in domestic consumption per capita on the farm should vary significantly from that of the population as a whole. Using the rate of increase projected by the Central Water Planning Unit for consumption from unmetered supplies, the annual domestic demand we have estimated as 36 Mm^3 per annum at present may be expected to rise to 41 Mm^3 by 1985, and to 52 Mm^3 by the year 2000.

Agricultural water demand to the year 2000

139 Our aggregate forecasts for water demand by agriculture in 1985 and 2000 are summarised below. Because of the nature of the assumptions made, the forecasts should perhaps be regarded as an "upper limit" but nonetheless borne in mind by Water Authorities and other responsible bodies as a guide to the load which may well be placed by agriculture on available water supplies.

TABLE 19: AGRICULTURAL WATER DEMAND TO THE YEAR 2000

Mm^3

	1977	1985	2000
Outdoor irrigation*	86	157	350
Livestock	170	181	187
Domestic	36	41	52
Protected crops	12	12	12
Washing and processing	1	3	7
TOTAL	305	394	608

* Assuming the 5th driest year in 20.

140 Although these figures are capable of refinement, we believe that they provide the best national estimates available and *we recommend* that:

a. Government Departments and Water Authorities should use them as a basis for long-term planning;

b. they should be periodically up-dated, say every 5 years, to take account of emerging new features and of the operation of supply constraints;

c. that some central agency, either NWC, DOE or MAFF, or all three in concert, should take on this task, at the same time developing improved methodology for long-term projections of water demand.

Summary

141 The economic and structural environment that farmers are likely to face over the next two decades will encourage an expansion of water use, notably in spray irrigation. Analysis of the prospects for the major irrigated outdoor crops, taking account of both technical and locational change, suggests that demand may increase as much as fourfold by the year 2000, with a slight tendency for a greater proportionate increase in the East and South of England. Peak daily demand for irrigation may rise some two and a half times overall, a figure which broadly applies to each of the major irrigating regions.

142 For *protected crops* no significant change in water requirement is foreseen and only a modest increase in water use in *livestock production. Vegetable washing and processing* needs are likely to expand sevenfold, but this is a small element in total demand and presents a problem only in isolated instances. For *domestic use* on farms a consumption trend in line with that predicted for home consumers generally has been assumed. In total, the demand for water for agricultural purposes could double by the year 2000.

143 The estimates can only represent broad orders of magnitude, and on today's judgement probably represent the upper limit of the range of likely outcomes. Nevertheless they provide a frame of reference for those responsible for programmes and policies for water supply and utilisation.

SECTION SIX:

WATER QUALITY

144 Although we have primarily concerned ourselves with the quantities of water that the industry is likely to use, we must not overlook the question of its quality and suitability for different agricultural uses. This Section examines the various kinds of contamination liable to affect water for farming purposes and the possible implications for the industry of current anti-pollution legislation, both domestic and within the EEC framework.

145 We have been conscious throughout our study of the need for farmers to recognise their duty to the community to prevent possible pollution, and for the community in turn to have regard to its responsibilities to provide the agricultural and horticultural industries with water of suitable quality.

146 We have not, however, concerned ourselves with the possible effects that farming practices have on water quality for other uses. This has recently been considered by the Royal Commission on Environmental Pollution whose report makes a number of recommendations for future research which we hope will be carefully considered by the responsible Departments.

147 The chief concern to farmers is to have water available of the right quality, and in sufficient quantity, for the particular purpose required. Whilst mains water is adequate, or more than adequate, for most agricultural and horticultural purposes, cost will restrict its use in many sectors: for spray irrigation, in particular, privately abstracted water is much more economic. Of the other sources available to farmers, particularly surface waters, contamination with urban or industrial effluents will sometimes make them unsuitable for agricultural use. However, the quality of most water used in agriculture does not normally give rise to problems although there are some potential areas of difficulty.

148 In assessing the factors that can affect the acceptability of water from both public and private supplies for farm use, account has to be taken of certain parameters relating to human and animal diseases, crop yields, and the actual process of abstraction. These fall into three broad categories:-

A. CHEMICAL CONTAMINANTS

B. MICRO-BIOLOGICAL CONTAMINANTS

C. PHYSICAL CONTAMINANTS

CHEMICAL CONTAMINANTS

149 *Salinity* High saline levels in water may adversely affect the health and productivity of livestock as well as limit irrigated crop yields. A high proportion of sodium in relation to the calcium and magnesium contents of irrigation water may also lead to an eventual breakdown of soil structure.

150 High salinity in water supplies is caused in a number of ways. In some coastal and estuarial areas incursions of sea water may be a considerable problem in both surface and ground water. Particularly in parts of Eastern England, the leaching of salts from the soil into slow-moving watercourses,

coupled with high evaporation rates of surface water, may in some seasons lead to excessive saline levels. Such high levels were reached in many marsh channels during the drought of 1976 that cattle in East Anglia died from salt water poisoning. Mainly affected were the traditional marsh grazing areas where animals drink from the dykes. Saline discharges from mine workings may also adversely affect some surface waters.

151 Some vegetables are especially sensitive to high salinity and to chloride in particular: these include *peas, beans, lettuce* and *celery* and to a lesser extent *brassicas* and *carrots.* A number of fruits, such as *strawberries,* are also sensitive although they are not generally grown in areas of high saline risk. *Potatoes* are moderately salt tolerant, and *sugar beet,* except at germination stage, is one of the most tolerant of crops. It is difficult, however, to assign absolute tolerance limits for irrigation water because of the interactive effects of such factors as the quantity of water applied, weather conditions, depth of rooting, soil-type and individual crop tolerance. Advice is available from a number of sources, including ADAS, on the general limits to the use of saline water and on procedures for treating affected soils.

152 Abstractors taking water for irrigation from estuaries, or from watercourses or boreholes near the coast, are generally aware of the risks of high salinity and of the need to monitor the quality of the water in the light of ADAS guidelines. But drought conditions can extend the problem areas and catch some farmers unawares, making it necessary to have advice promptly available.

153 *Fluoridation* A number of local authorities now add fluoride to public water supplies, up to 1 part per million (1 ppm) being generally recommended. Levels of this magnitude can also occur naturally, although most natural water sources contain less. It has been suggested that irrigation using water from either source containing amounts of 1 ppm of fluoride might be injurious to crops, although such water is unlikely to be harmful to livestock.

154 At concentrations of 1 ppm of fluoride and above, flowers grown from corms – notably *freesias* and *gladioli* – show marginal leaf scorch and this can affect marketability. There is also some evidence that the vase life of a number of cut flowers may be reduced. However, research into the effects of fluoride in irrigation water on glasshouse crops has shown that in general *tomatoes, cucumbers,* and *lettuce,* as well as *carnations* and *chrysanthemums,* are not adversely affected. Nevertheless, ADAS and others continue to do work on the possible effects of fluoride added to water supplies, including studies of the uptake of fluoride by crops grown hydroponically, and of possible phytotoxicity to container-grown plants in acid compost. This work is largely precautionary in view of the public concern about the subject: in fact no problems beyond those already known and mentioned above have so far been identified.

155 *Boron* Detergents in rivers may give rise to high levels of boron which may be phytotoxic if the water is used for irrigation. Only one or two cases are known of visible damage to crops, although the situation needs continuous monitoring. Glasshouse growers are potentially most at risk because they use proportionately more water per hectare, especially since boron, as with other dissolved materials, can become concentrated if not

leached out. Raw river water is, however, used only exceptionally in glasshouses.

156 *Spillages of Toxic Substances* Accidental contamination due to spillage from factories and leaching from industrial waste tips has caused occasional problems with growing crops. Although the effects can be serious for the farmers or growers immediately involved, very few cases of widespread consequence to the industry have so far been reported.

157 We feel that Water Authorities should play a more positive role in warning farmers of changes in water quality which might be harmful to agriculture and we understand they already have regular programmes for monitoring the quality of the major watercourses, especially where they themselves are major abstractors for public supplies. Because of the growing risk of pollution, therefore, we *recommend* that MAFF, and the Water Authorities, examine the need for extending the present monitoring arrangements to lesser watercourses. We think the Authorities are particularly well placed to know of changes in water quality, and we therefore also *recommend* that they should have a duty to give advance warning to farmers when pollution is known to be approaching harmful concentrations. We appreciate however, that the Water Authorities cannot be expected to provide a monitoring service on anything like a comprehensive scale and we further *recommend* that farmers in known risk areas should be encouraged to arrange for regular analysis of water used for irrigation and stock purposes.

158 To assist in the warning function suggested above, and as an aid to farmers, we also *recommend* that MAFF makes available an advisory leaflet containing detailed guidance on the levels at which the various substances mentioned are likely to become harmful. We appreciate the concern expressed by horticulturalists about the potential hazards from fluoride and *recommend* that ADAS continue to study the effects of fluoride on horticultural crops – taking account of appropriate evidence from other countries.

MICRO-BIOLOGICAL CONTAMINANTS

159 *Algae in irrigation water* An assessment by the Institute of Water Engineers (IWE) in 1946 classified an area of England approximately south of a line joining Grimsby and Lands End as one of frequent and severe algal growth. This area includes the whole of the Anglian, Southern, Wessex, Thames and South Western Water Authority regions, presently accounting for some 75 per cent of the irrigation in England and Wales.

160 Such growths may cause blockages in pump intakes and other irrigation equipment. Most difficulty is caused by the filamentous type of algae although this is not widespread: nevertheless, the more commonly occurring single-celled planktonic algae may also block equipment utilising small jets. Most susceptible to algae formation are waters from surface sources rich in nutrients, especially when stored for long periods in open reservoirs; this can become a very troublesome problem during the summer months. Algal growth is not confined, however, to water from surface sources: water from deep boreholes or the public mains can similarly become infested when stored for long periods in open reservoirs. Some degree of filtration is usually required before water containing algal growth can be pumped and applied by the usual spray equipment, and fine straining is necessary for trickle and glasshouse irrigation systems using the smaller diameter tubes and jets.

161 In the case of public water supplies, contamination in open reservoirs is usually controlled by chemical treatment and/or removed by micro-straining or sand filtration. This treatment can also be used for irrigation water, for which a number of suitable algicides are available. The control of algal growth by roofing over the reservoirs to exclude light is not a practical proposition for large farm installations but floating covers are being developed and are already in use on smaller reservoirs.

162 With the expected trend towards finer-bore trickle methods of irrigation and the use of more on-farm storage, it is likely that algal contamination will continue to pose problems to farmers. However, since effective methods both of physical and chemical prevention are now available we do not consider it necessary to call for any further action. We think that the assistance readily available from MAFF, in particular the information on aquatic herbicides in the list of approved products for farmers and growers under its Agricultural Chemicals Approval Scheme, should be enough to enable farmers to cope with most problems.

163 *Pathogens* On quite a number of farms, streams and rivers still provide the principal supply of drinking water for livestock, especially when grazing. Such watercourses may receive effluent from farms, domestic dwellings, sewage plants, and factories, and become polluted by pathogenic micro-organisms. A national micro-biological survey by MAFF during 1975/76 disclosed frequent contamination of streams and rivers by salmonellae. Recognising the dangers. MAFF emphasises in its advisory leaflets the importance of clean drinking water for livestock and that a piped mains supply – or a borehole, well or spring – are preferable to ponds, streams and rivers.

164 *Salmonellae* discharged into watercourses from sewage works and meat processing plants can be a particular disease risk to both humans and livestock. Outbreaks of clinical salmonellosis in cattle have also originated on occasions from discharges from human dwellings, and the spread of salmonella dublin infection in South Wales is thought to have been largely due to contamination of watercourses by grazing animals and effluent from farms.

165 Cattle have sometimes been affected with *Johne's disease* through drinking, as calves, from ponds heavily contaminated with dung from infected mature cattle. However, the risk of dissemination of Johne's disease by infection entering watercourses is thought now to be small. There is also some evidence to suggest that *brucellosis* may have been spread by infected water supplies, perhaps from aborted calves deposited in streams and rivers. With the imminent completion of the Brucellosis Eradication Scheme the risks from this disease will be much reduced.

166 There is also a potential hazard from such pathogens to humans eating irrigated and/or washed crops if these are not subsequently cooked. Various methods of water treatment are available and storage for a period may give an adequate reduction in pathogen numbers. Where directly-abstracted water is used for irrigation, a safety period between the cessation of irrigation and harvesting will provide protection to consumers of most crops, but poor quality water should not be used on crops which tend to hold water, such as *lettuce* under glass. It should be noted too that the use of poor quality water for *crop washing* is not acceptable to the main retail food outlets.

167 Recognising the potential risk from pathogenic micro-organisms in watercourses to both livestock and humans, MAFF advocates the use of piped drinking water supplies wherever possible. We would endorse this but realise nevertheless that in many cases it may be difficult, if not impossible, for farmers to have access to public supplies and that they therefore may have to rely upon watercourses. We also acknowledge that most growers are conscious of the potential hazards to humans in irrigating salad crops with directly-abstracted surface water and do take the necessary precautions.

168 We feel nevertheless that more needs to be done to guard against the risk of pathogenic infection and we therefore *recommend* that MAFF consider with the National Water Council and the industry the advisability of guide lines for farmers covering the watering of livestock, as well as a Code of Practice covering the irrigation of crops eaten uncooked.

169 *Watercress* The health risks associated with pathogens are particularly relevant to watercress growing. Some 110 hectares are grown in this country, mainly in Hampshire and Dorset, the majority of the enterprises drawing water from the chalk aquifers. Fairly large quantities of water are used, most of it being afterwards discharged into the river systems. As watercress is easten uncooked, and was at one time viewed with some suspicion by the Public Health Medical Authorities, it is of the utmost importance that the clean underground water is not contaminated by any surface run-off or effluent before entering the beds. A recently introduced voluntary NFU "Code of Practice", drawn up with the help of ADAS, specifies ways to maintain a high degree of water purity and also sets standards for the quality of the water discharged after use. It is estimated that 25 per cent of watercress production already meets these requirements.

170 The evidence shows, however, that for many years there has been no case of commercially grown watercress causing risk to health. We have been told by MAFF that the initial response to the voluntary code of practice has been generally favourable and in these circumstances we see no need for change.

171 *Re-cycled water* We have tried to discover the extent to which recycled waste water is currently being used in agriculture and whether there are likely to be health risks as a result, especially with regard to *crop washing.* We have not found any evidence that waste water is being used significantly for this purpose, since the problems and costs of filtration and sterilisation to bring the water to a suitable standard are such that mains or high quality water from private sources are both simpler and cheaper. The same applies generally to *livestock,* although waste water may be used for such jobs as washing down cowsheds and yards.

172 In horticulture the introduction of new growing methods such as cropping in modules and hydroponics has increased the importance of high quality water. For these purposes growers find it increasingly worthwhile to collect and store rainwater and condensation moisture from the glasshouse itself, so avoiding over-reliance on the mains supply as well as helping to ensure quality standards. The practice is already widespread in the horticultural industry in the Netherlands because of the generally poor quality of other sources of water available there. We believe there is considerable scope along these lines for water conservation within the glasshouse sector, and we

recommend that MAFF should draw growers' attention to the advantages of the practice when advice and grant aid are being sought.

PHYSICAL CONTAMINANTS

173 *Fine Sands in Borehole Water* Supplies from boreholes in water-bearing sands may cause seizing of rotating sprinkler nozzles and eventually block fine trickle tubes and orifices. This is particularly the case if other dissolved matter such as certain iron salts are present which can help to create larger obstructions. In glasshouse practice, where trickle tubes of very small bore are often used, the problem is more acute. All solid particles will produce a high rate of wear on the borehole pump elements: usually, however, all but the smallest ones can be excluded when boreholes are sited in sandy formations, and in the majority of cases the problem be reduced to an acceptable level.

174 Iron rich water can also cause blocking of small bore irrigation trickle equipment. It can also give rise to unacceptable staining of fruit and salad crops. Necessary reductions in iron content can usually be obtained with comparatively simple treatment such as aeration. Iron can also be almost completely removed by chemical treatment and subsequent pressure filtration, but the cost is high and only worthwhile with valuable crops such as tomatoes.

175 Both these kinds of physical contamination may well become more troublesome should the trend towards finer tubes in irrigation continue. However, they are not of widespread occurrence and the techniques to overcome the difficulties are well known. We therefore see no cause for special action.

LEGISLATION

176 Apart from being a hazard generally, water polluted by agriculture can cause problems for other farmers if it is required for further agricultural use. It is plainly in their own interests for farmers to do what they can to avoid this. Part II of the Control of Pollution Act 1974 (when finally implemented), the EEC Directives and draft Directives on Water Pollution, and the report on pollution and agriculture by the Royal Commission on Environmental Pollution are all likely to have implications for the industry.

177 When *Part II of the Control of Pollution Act 1974* is implemented the consent of the water authority will be necessary for the discharge of sewage or trade effluent into inland and coastal waters, including specified groundwater. Temporary exemption orders may be granted for particular activities. Discharges from agricultural premises onto land are covered because they can find their way into water. The Act also makes it an offence to cause a polluting entry. Crop spraying and a number of agricultural activities will be affected, although the Act does establish the defence of "good agricultural practice".

178 The implementation of Part II is linked with a current review by Water Authorities, aimed at defining quality objectives for rivers and the setting of consent conditions at levels needed to achieve them. The objectives will have regard to the existing quality of a river and, where this is not adequate, a target objective will be set. Existing consents for discharges will be reviewed and in the great majority of cases the effect will be a relaxation of conditions to match the actual quality of the discharge. There is apparently no intention of allowing any deterioration in discharges or in the actual quality of the rivers. We questioned whether the review would result in the amount of

water available for abstraction being reduced in order to preserve adequate river flow and water quality, but we have been advised by MAFF that this is not likely to happen.

179 Unacceptable deterioration of the quality of water abstracted from a watercourse may nevertheless occur on occasions, often as a result of changes in the balance between effluent and natural water. For example, the natural flow may become insufficient to dilute polluted material carried by the watercourse, or the degree of pollution itself may increase beyond the cleansing capacity of the natural flow. Should there be such changes, which may be quite unexpected, and the farmer not be warned by the Water Authority, the use of the water for irrigation may have harmful effects upon his crops. Similar changes in drinking water supplies might cause health problems to livestock. We have already made recommendations (paragraph 157) about the wider role that might be played by Water Authorities in monitoring the quality of watercourses and in warning farmers of any deterioration.

180 Water Authorities already have the legislative power to prosecute polluters of water supplies although private individuals can at present only take limited action. The Control of Pollution Act 1974, when fully implemented, will alter this situation. All aggrieved parties will then be able to proceed against Water Authorities or individual polluters if they consider they have justifiable cause. In these circumstances, it will be in the interests of Water Authorities to ensure that the water supplies for which they are responsible are of the required quality.

181 However, our general conclusion is that the implementation of Part II of the Control of Pollution Act is unlikely to cause any serious problems in the way of the future availability of water for agriculture: indeed, we think it could well lead to progressive improvement in the quality of water generally, to the benefit of the industry.

EEC Legislation

182 The Community shows much interest in water pollution and this is likely to continue. A large number of Directives are already operative or projected in this area and we have examined those we think could have direct implications for the availability or quality of water for agriculture. These concern:-

a. the Directive on the quality of water for human consumption;

b. the Directive on the quality of surface water intended for abstraction as drinking water;

c. the proposed Directive on the quality of water for agricultural purposes; and

d. the Directive on the protection of ground water against pollution caused by certain dangerous substances.

183 *The Directive on the quality of water for human consumption* was adopted by the Community after protracted negotiation. Under this Directive it will be necessary to give a final "rinse" to vegetables in water of "drinking" quality. The Commission has however still to submit the proposal for a Directive on *the quality of water for agricultural purposes,* under which it

might propose quality parameters for water used for crop irrigation as well as for stock watering. *The Directive on the protection of ground water against pollution caused by certain dangerous substances* has recently been adopted. This covers agricultural activities but unless certain specified substances are expected naturally to find their way into groundwater as a result, there will be no requirement upon farmers to seek prior authorisation for those activities.

184 The only aspect of this legislation which is likely in our view to have any significant implications for agriculture concerns the *draft Directive on the quality of water for agricultural purposes.* Should this Directive set values which are too strict it could reduce unnecessarily the supply of water available to agriculture: there have in fact been some pressures, because of particular pollution problems in some Member States, to set such standards. Clearly, also, standards for stock watering and irrigation will be based on different considerations. We hope that the Ministry will continue to use its best endeavours to ensure that the standards eventually agreed upon allow for flexibility, leaving the UK to adapt the more detailed aspects to its own needs. In this connection, we have already referred in paragraph 168 to the possible introduction of Codes of Practice to cover *irrigation* and *livestock watering.*

Summary

185 UK agriculture is fortunate in the quality of water which is available to it. There are some problems associated with chemical, microbiological and physical contamination of supplies, but it is evident that agricultural productivity in the UK is not being harmed to any significant extent because of deficient water quality. The existing and proposed legislation, both UK and EEC, seems to hold few dangers for agriculture provided that its application is characterised by the same flexibility of approach and regard for good agricultural practice as has been traditional in the UK. Quality is not likely therefore to be a major inhibiting factor in securing future water requirements.

SECTION SEVEN

SUPPLY

186 In our forecasts of agricultural demand for water in the previous Section we made the critical assumption that water in sufficient quantity and of suitable quality would continue to be available. In this Section, we examine the sources of supply; their adequacy in each of the Water Authority areas; licensing and charging policies; and Government grant-aid particularly towards on-farm storage of water.

Sources of supply

187 The 1963 Water Resources Act and the 1973 Water Act place on ten Water Authorities in England and Wales the responsibility, with certain minor exceptions, for the supply of water from all sources and for all purposes. The Authorities are public utility undertakings operating as autonomous bodies and, together with their 29 agent Water Companies, they supply water to a wide variety of consumers. But they are not obliged to provide piped supplies where the costs are unreasonable, nor are they required to guarantee the quantity or quality of private abstractions.

188 As the following Table indicates, abstractions for public water supplies (which include supplies taken by agriculture through the mains) were increasing steadily until the drought of 1976. Most noticeable, however, has been the decrease over recent years in abstractions by industry.

TABLE 20: WATER ABSTRACTION IN ENGLAND AND WALES (Mm^3)

Year	Public Supplies	Power Stations	Other Industry	Agriculture
1971	5,236	6,897	3,363	87
1972	5,401	6,613	3,344	85
1973	5,567	6,485	3,160	78
1974	5,630	5,470	2,964	84
1975	5,610	5,006	2,924	98
1976	5,479	4,822	2,430	121
1977	5,368	4,868	2,610	112

Source: Water Data 1977 – Department of the Environment Water Data Unit

189 As well as having to provide for the uses mentioned above, Water Authorities are faced with increasing demands from fisheries, recreation, conservation and navigation interests. The maintenance of minimum acceptable flows in watercourses to meet these requirements might in some circumstances be possible only by restricting supplies to agriculture. Whilst regrettable, we think it will have to be accepted by farmers in the wider public interest.

190 Water for agricultural purposes may come either from the public mains or by private abstraction.

a. *Public mains* About 5 per cent of the volume supplied through the public mains is estimated to be taken by agricultural and horticultural holdings, some 80 per cent of the total. Overall, about two-thirds of agricultural consumption is accounted for by domestic and livestock (including dairying) use within the farm buildings, the remainder being taken for livestock watering elsewhere on the farm and for irrigating

protected crops or high-value outside crops. In practice the cost of mains water generally restricts its use to those sectors where guaranteed quality and reliability are of crucial importance or where in the absence of any other cheaper source the use of high quality water is the only choice.

b. *Private abstraction* Water supplies developed by private initiative come from two sources: by direct abstraction from rivers and streams (surface water) or from wells and boreholes (groundwater). Water from either sources for *general agricultural use* is not charged for by the Water Authority, nor need it be licensed when taken from a surface source for use on adjacent land. For *spray* irrigation purposes, however, water from either source is both licensed and charged, although for other types of irrigation it is generally treated as if for general agricultural use.

Grant aid

191 Grant aid is available from MAFF towards the cost of all permanent works for supplying and storing water for the purposes of an agricultural or horticultural business. The supply, whether from a public system or private source, may be used for a range of activities including stock watering, dairying, irrigation, frost protection, vegetable washing, and crop spraying. Grant is payable either for the initial provision of a supply or in connection with its replacement or improvement. The Table below indicates the Schemes concerned and current rates of grant.

TABLE 21: MAFF WATER SUPPLY GRANT SCHEMES AND GRANT RATES

Scheme	Normal Rate	Less Favoured Area Rate
	%	%
FHDS (Agriculture)	25	50
FHDS (Horticulture)	30	30
FCGS	20	50
HCGS	25	25

192 Following the drought of 1976, higher rates of grant were allowed exceptionally during the following year for water storage schemes. The FCGS rate went up to 40 per cent; that of FHDS (Agriculture), to 45 per cent; the FHDS (Horticulture), to 50 per cent; and the Less Favoured Area rate to 70 per cent. Something like 2000 schemes were approved under these higher grant provisions at a total scheme cost of about £8.5 million.

193 Exchequer aid under the Rural Water Supplies Grants Scheme is also available to assist towards the cost of first time provision of mains water supplies to properties in rural areas. To qualify for such grant, the supply must be requisitioned under the Water Act 1945 and the requisioner has to guarantee the payments required by the Act. Where the supply will result in benefit to agriculture, the Water Authority can apply to MAFF for a supplementary grant.

Adequacy of supply

194 We have tried to obtain precise and reliable information to help us gauge the adequacy or otherwise of present water supplies to meet the various demands of the agricultural industry. We have been assisted in this by evidence from the National Water Council, Water Authorities, the farming organisations, MAFF and other interested bodies. We set out below the broad picture of supply, as described to us, in each of the Water Authority areas.

Anglian

195 About half the irrigation in England and Wales is concentrated in this Authority's area. Potential transpiration exceeds summer rainfall 9 years in 10, and irrigation is increasingly important, accounting for some 5 per cent of the average annual quantity of water abstracted for all purposes in the region and for nearly 40 per cent of the total abstracted during the week of peak demand in a very dry summer. Supplies of raw water are generally adequate for present needs and though some reductions in direct abstractions for agricultural purposes were necessary during the 1976 drought, these were achieved through voluntary restrictions and by agreement and it was not found necessary to impose restrictions statutorily. There were only isolated instances of complete failure of supply, mainly related to shallow wells.

196 Since the drought there has been a sharp rise in irrigation demands, and whereas the enhanced rates of grant during 1977 to farmers towards the cost of water storage facilities have helped to provide greater reliability of supplies on some holdings and thus contributed towards meeting this increased demand, there will still be an increasing need for regional conservation works. Fortunately, recent water resource developments have provided some temporary 'spare' capacity and an enhanced capability to transfer it around the region. Further measures to augment and transfer water resources for irrigation are feasible if the size and the strength of demand is sufficient: the transfer options include the increased use of existing surface channels to convey water to abstraction points for spray irrigation.

Northumbrian

197 There is little demand for irrigation and the Authority has not yet needed to impose any restrictions specific to agricultural use since its formation in 1973. There would seem no reason to think that this situation will change in the future. Most farms are well provided for from both urban and rural mains systems although some individual holdings have inadequate storage facilities. However, the hill farms in the more isolated or elevated locations often have to rely upon private supplies from springs or, in fewer cases, boreholes. The Kielder Reservoir, at present under construction, will impound water in the upper reaches of the North Tyne and will regulate the flows in the Tyne, Wear and Tees. Water will be transferred from the Tyne to the two more southerly rivers and will enable further abstractions to be made from each of the three rivers. There is unlikely to be much in the way of direct benefit to consumers in the more remote situations however.

North West

198 Compared with other Authorities, agricultural consumption makes up an insignificant proportion of total abstraction, due primarily to the large amount of industry in the region. Although there may be occasional local difficulties, supplies are likely to be adequate for all forecast requirements for agriculture for many years to come.

Severn Trent

199 Agriculture accounts for about 2 per cent of total annual abstraction in the region. Some private groundwater sources ran short during the drought but this has been remedied as the aquifiers have recharged. Applications for grant-aid on water supply schemes have fallen to some extent since 1970, which suggests there is no widespread dissatisfaction over supply. A number of rivers are supported by treated sewage effluents from STWA reclamation works which can be a valuable source of irrigation water subject to its quality being suitable for the particular crop irrigated. Small schemes for the extension of public water mains are carried out from time to time and the provision of mains water to hill areas is improving slowly but steadily. The net result is a modest improvement in supplies over recent years.

200 New abstraction licences for irrigation continue to be issued, but there are still areas where the available water is insufficient to permit this. Abstractions from the Severn are already supported with water stored during the winter months. With the objective of relieving summer pressures on supplies and satisfying summer demand, the Authority actively encourages farmers themselves to store water by advantageous winter pricing (currently one-tenth of the summer rate). The 1976 drought, combined with the 40 per cent grant, evoked much interest in reservoir storage, but since the grant rate was reduced applications have decreased.

201 No cases are known where problems with water supplies are such as to adversely affect production to any appreciable extent. Little change in the situation is expected in the future, although a number of measures, already in force or projected, may help to augment summer supplies. The most important of these are the regulation of river flow through the exploitation of groundwater reserves, as is being proposed along the Severn, and the pilot scheme for the recharging of aquifers with excess winter water.

Southern

202 Good quality farmland is well distributed throughout the region, the driest part being East Kent, with residual rainfall increasing westwards. Only about one-fifth of spray irrigation abstraction comes from groundwater, most being taken from surface sources. Metered mains water is used for irrigation by a number of farmers and glasshouse growers.

203 Most licences embody conditions limiting times and volumes of permitted abstraction so as to protect both the environment and the rights of existing licence holders. These conditions often relate permitted abstraction from surface sources to minimum stream flows, and may restrict or prohibit abstraction during the summer thus requiring the provision of farm reservoir storage. During the 1976 drought the flow in many streams was insufficient to meet the abstraction quantities or conditions specified in the licences, the streams fed from chalk groundwater being least seriously affected. Farmers dependent on boreholes for water supply generally fared better than those dependent on surface sources. The latter are not numerous, as most abstraction for general agricultural purposes, other than for spray irrigation, is from groundwater sources.

204 Applications for spray irrigation licences are expected to continue at about the same rate as during the last 10/15 years. In the areas of most intensive use in Kent, this could mean a doubling of existing licensed abstraction by the turn of the century. In these areas, demands could only be met by increased water resource conservation works, undertaken either by the farmer or the appropriate Authority. In Sussex and Hampshire the situation is less critical, although both surface and groundwater abstractions will be subject to detailed conditions. There are generally no serious limitations imposed on current agricultural productivity by lack of water supplies.

South West

205 The general picture is of a gradual increase in water requirements as enterprises, particularly in agriculture, become more efficient and intensified. There is very little irrigation practised. The effects of the 1976 drought were widespread and often severe although agriculture was regarded as an essential user and not subject to any really onerous restrictions. However, some areas were affected by reduced mains pressure, and a number of farmers on private supplies suffered severely through either a reduction in yield or a complete drying up of their sources. Several hundred requests were made to the

Authority during this period either to provide emergency supplies or to re-open disused wells. In general it was possible to accommodate all demands though in some instances farmers were forced to import water by road tanker. Whilst there is no general shortage of water for irrigation, farmers are now required to build reservoirs to store winter water as a condition of their licences.

Thames

206 Irrigation is a significant component of agricultural demand in this region. However, even in the 1976 drought there were no formal restrictions placed on private abstractions although an appeal had to be made to abstractors from the upper Thames, during the later period of the drought, voluntarily to reduce demand; and in the Lea Valley a system of "staggered" abstraction periods was introduced. There have so far been few serious abstraction problems, although restrictions have sometimes had to be imposed on levels of abstractions. In Oxfordshire one reported result of such restrictions has been the holding back of investment in irrigation machinery. No significant change in this situation is expected by the Authority over either the short, or longer, term; but much will depend upon the timing and the degree of severity of any future drought, together with the circumstances of individual catchments and regional resources.

Welsh

207 High rainfall, the topography, the soil and the rock structure generally ensure that there is no problem over water supplies for agriculture in Wales. However, the lower rainfall and more freely draining strata in the southern section of the Wye catchment and in south Pembroke lead to greater reliance there on spray irrigation for certain crops. Following the 1976 drought the Authority was compelled to cut off mains supplies for limited periods in a small number of cases. There were also some failures of private sources, in particular those based on wells into shallow aquifers, but in most cases alternative supplies were available, such as water carting by the Authority, although it was under no obligation to provide these at short notice. Most of the shallow wells quickly filled again after rain and the remainder have, for the most part, also now recovered. There is some concern that in time of drought, abstractors for spray irrigation depending entirely on surface water may be subject to restrictions, although such restrictions were not imposed during the 1976 drought.

208 Concern has also been expressed that river regulation projects have resulted in streams at certain times having less water in their upper reaches than formerly, but in general such projects increase flow in dry periods. These considerations apart, there has been no cause to impose restrictions upon private abstractors nor is there any reason to think that this situation will change in any way even over the longer term. Generally the supply situation has had no adverse effect on agricultural production, though there are farms where improvements to supplies are desirable.

Wessex

209 The capacity of the public water supply is at present more than sufficient to meet the commitment. Further developments are planned or in progress and steps are being taken to strengthen both source and distribution systems to meet future demands and to maintain appropriate standards. Moreover, the Authority has just commissioned a new supply from the Wimbleball Reservoir project which will meet forecast demands over the greater part of the Somerset supply area for many years to come.

210 Water resources were fully tested during the 1976 drought. Whilst in Somerset it proved necessary in the late period of that year to curtail direct abstraction from rivers, no restrictions were imposed in the Bristol Avon, and Avon and Dorset, areas. Immediately following the drought the Authority in consultation with representatives of the industry reviewed its policies and procedures particularly with regard to the licensing of agricultural abstractions from surface water. The Authority's analysis of records of actual abstractions for agricultural purposes has revealed no meaningful trend of demand. Whilst difficulties are sometimes encountered in meeting requirements of applicants for licences to abstract from local river reaches, water resources are generally found to be sufficient for their needs. The Authority emphasises the benefit of farmers providing their own storage and its licensing policy takes account of such provision.

Yorkshire

211 Agriculture accounts for less than 1 per cent of surface abstractions in the region, and for only 3 per cent of direct abstractions from groundwater. Although the 1976 drought created problems, there were only a few isolated cases of complete failure and through co-operation between neighbours and some ingenuity the producers involved coped with the situation without too much difficulty. There is no real shortage of water for agricultural purposes. Where, on occasion, several farmers have sought to use the same small stream, or where an aquifer has become oversubscribed, it has been necessary to insist on conditions of prescribed flow or groundwater level by licence; but no application has ever been refused outright. Demands to date for spray irrigation have been met without any insistence upon winter storage. A review of spray irrigation by the Authority after the drought suggested that the balance between demand and availability was unlikely to be upset in the foreseeable future.

212 *Public Supplies* As far as public supplies are concerned, the picture set out above points firmly to the conclusion that most farmers requiring water from the mains have been able to obtain sufficient supplies. Nonetheless, we were told of a number of problems, associated for the most part with farms in the more remote locations, where the cost of installing mains can be uneconomic. Difficulties were also reported of farmers already connected to the public supply who were at the end of a mains extension or where the line was overstretched or obsolescent. The cost of extending or replacing the mains supply in such cases is generally high relative to the financial return to be expected from the comparatively small number of farmers/consumers standing to benefit. Water Authorities are therefore on occasion reluctant to undertake such schemes.

213 We understand that variations in the conditions determining eligibility for grant under the Rural Water Supplies Scheme have in the past led to fluctuations in investment by Water Authorities in this type of installation. There is little doubt, however, that the Scheme has played a valuable part in encouraging the extension of mains in rural areas and providing farmers with guaranteed supplies of good quality water. For this reason we think that it is important not only that the Scheme should continue but that the payment of grants for this purpose should be based on criteria which enable Water Authorities to plan well ahead. In view of the possibility that more stringent conditions concerning water for livestock may in future become mandatory, we *recommend* that the administrative arrangements, under which both eligibility for grant aid and the rate of grant are determined, should be

revised by the Departments concerned so as to provide Water Authorities with a more stable basis on which to plan their rural mains extension works.

214 *Private Supplies* The general situation regarding private abstractions is much less reassuring. There are many comparatively small streams where the licensed quantities of water for spray irrigation already exceed the dry weather flow. The problems are naturally worse for those farmers wishing to irrigate who are situated some distance away from watercourses or groundwater supplies. Indeed, they may have no chance of access at all to water for irrigation purposes. In certain areas, there is also a fear that large-scale abstractions of groundwater by Water Authorities could have a cumulative effect in lowering water tables.

215 In Section Five we predicted that the potential demand for irrigation water would rise to 350 Mm^3 by the turn of the century. There is little prospect of groundwater sources supplying a larger proportion of total irrigation demand than at present. Cost and limitations in rate of supply lead to the same conclusions on the use of mains water on outdoor crops. It follows that the increased demand will need to be met mostly from surface sources, the total licensed quantity of which in 1977 was only 103 Mm^3. It seems unlikely, however, that direct abstractions in the summer can be much increased, and the extra demand for surface water will depend on the provision of additional storage on the farm and elsewhere.

Licensing

216 Under the Water Resources Act 1963, a farmer has to obtain a licence from the appropriate Water Authority should he wish to abstract water for spray irrigation from a local source of supply. A licence is also required should he wish to abstract water for general agricultural purposes from an underground source such as a well or borehole. If he wishes to increase the amount of water specified in his licence he must apply to the Water Authority for permission.

217 A licence will normally specify the point of abstraction; the land on which the water is to be used; the purpose (eg spray irrigation); the maximum quantity which can be abstracted during any period (hourly, daily or annually); the means of abstraction, eg pump; and the basis to be used for measuring or assessing the amount actually abstracted. It also indicates whether it will remain in force only until a specified date, or until revoked. The possessor of a licence acquires a "protected right" to the water specified in his licence, which may not be derogated by the excessive granting of licences to other abstractors. However, the Secretary of State for the Environment may initiate action to revoke or vary a licence whether or not he has received representations that he should do so. Water Authorities also have these powers but in such cases the Secretary of State is only involved where the licence-holder objects. Where loss or damage is incurred by the licensee as a result of such action compensation may be paid, but not in cases where no water has been abstracted during the 7 years preceding the date of the revocation or variation of the licence.

218 Abstractors operating during the 5 years preceding the Act were entitled to claim "licences-of-right". Although they are licences in the sense of the 1963 Act, they do not specify an expiry date. As with all licences, they are hereditable and this, together with their indefinite duration, makes them a most valuable attribute to a holding. Their most significant feature, however, in the context of our inquiry, is the privilege they confer compared

with licences granted subsequent to the passage of the Act – for example, a licensee of right is free from any requirement to install storage in conjunction with his abstraction. Nevertheless, any licence, whatever its nature, may be suspended by an Authority in times of shortage if it has been granted for the purposes of spray irrigation, although growers of protected crops are normally exempt from this proviso.

219 A licence is also necessary should a farmer wish to impound a surface flow of water for storage. When combined with an application to abstract, this can take the form of a licence covering both purposes. Should the water not be impounded, ie if the storage consists of a reservoir constructed away from the watercourse, abstraction from the reservoir is not subject to control and the water can be used freely as and when needed although a licence may be required for any abstraction to fill the reservoir.

220 Concern was expressed to us about the operation of the licensing system and it is obviously a cause of some dissension and dissatisfaction within the industry. In some areas the overall quantity of water specified in the licences is close to the total amount available, as a result of which "new entrants" are unable to obtain licences to abstract where they might intrude upon the protected rights of existing abstractors. But it is known that the quantities of water actually taken, even in drought years, seldom approach the quantities specified in the licence, around 40 per cent in a dry year being typical of agricultural abstractors. This is a characteristic by no means confined to the agricultural industry. There are other licensed abstractors, many also with licences-of-right, and the average quantity abstracted nationally is in fact no more than 50 per cent of the total licensed even in a dry year. There has undoubtedly been a tendency in the past for abstractors, including farmers, to apply for higher quantities than are really required, which led some of those who gave evidence to us to suggest that Water Authorities could allow much more water to be abstracted, for whatever purpose, if the licences were more rationally allocated.

221 The policies of "protected right" and "first come, first served" are undoubtedly a cause of resentment to would-be irrigators; and with the passage of time the restrictions on the amount and timing imposed upon new applicants for licences will no doubt become more onerous. The peak demands for irrigation tend to coincide with periods of insufficient rainfall and of low surface and groundwater levels. At such periods – although the most critical for the farmer and precisely the times when he should be able to derive the maximum benefit from a plentiful supply of water – Water Authorities may be forced to invoke their powers to limit abstraction. The evidence we received indicates that licensing cannot be avoided; nor can the need to impose restrictions in times of emergency.

222 Our principal concerns are to see licences more closely related to needs, fewer barriers put in the way of newcomers seeking licences to abstract, and a greater incentive given for those not fully utilising their licences to reduce the quantities specified therein. The proposals which follow are designed to achieve these objectives. They do not call into question the "first come, first served" principle.

223 We believe that farmers could co-operate voluntarily to stagger direct abstractions. Arrangements of this kind were made during the 1976 drought and were found to be satisfactory. Although by no means a complete

solution to water scarcity, we *recommend* nevertheless that where the conditions are suitable, farmers should enter into such voluntary agreements with one another to stagger direct abstractions.

224 But, more important, we are anxious to encourage the transfer of licences, whether they be licences of right or post-1963 conditional licences. Where, therefore, the allocation of the available water supplies has reached a point where Water Authorities are no longer able to entertain further applications for licences, we think they should permit farmers to buy and sell licensed entitlements – in whole or in part – amongst themselves. This practice could only of course cover exchanges between parties abstracting from the same source. Water Authorities, for their part, need do no more than ensure that the interests of other users were safeguarded, and that water resources were not lost to agriculture. We accordingly *recommend* that Water Authorities should allow the buying and selling of licensed entitlements to water between farmers, with the Authorities merely giving their formal endorsement. We understand that such arrangements could be implemented with a minimum of administrative complication.

225 In some areas, however, a complete solution is unlikely without a fundamental review of licensing policy. We *recommend*, therefore, that where Water Authorities are compelled to refuse applications for new licences, while other existing licences in the area are clearly being underused, they should be prepared to use their powers to vary the licences concerned (whether licences-of-right or those issued since 1963) with compensation as appropriate, and to re-allocate the quantities to those with demonstrable need for extra water. Knowledge of the existence of the intention to use this sanction, where appropriate, would provide those underusing their licensed entitlement with a greater incentive to sell to willing buyers.

Charges

226 The 1973 Water Act requires Authorities to have regard to the costs of their services when fixing charges and, with effect from 1981, "not to discriminate unduly against any class of persons". In practice therefore the price of the water used in agriculture must henceforth reflect the true economic cost of that water to the community as a whole. One class of user cannot subsidise another.

227 *Public supply* Water taken from the public mains is charged at the same unit rate throughout the whole of an Authority's area, irrespective of the purpose for which it is used. Extending the principle to agriculture, there is thus no distinction in unit cost within a particular Authority between mains water used for livestock, irrigation, glasshouse cultivation, or any other sector although a "minimum consumption" agreement may be required by the Authority. Since under this system no one imposes an identifiably greater cost on the community than another, we regard it as a generally acceptable and satisfactory arrangement.

228 *Private abstraction* Charges for authorised abstractions from rivers, streams and underground water are much lower than those for mains water, varying according to the purpose for which the water is used. Abstractions for domestic and agricultural purposes (except spray irrigation) are exempt from charge save, where appropriate, for the licence fee. Charges for other purposes (including spray irrigation) are differentiated in order to reflect broadly the costs involved. Such charges are levied by an Authority on the

basis of the quantities licensed and at rates laid down in its particular charging scheme. They may vary according to the locality and source of the water and, most important, the period of the year when it is required.

229 Charging practices vary within Authorities, but a typical method is first to fix a token standard rate (usually expressed in pence per 1,000 gallons) and then to use this as a basis for calculating actual rates eg a winter charge expressed as a reduced percentage of the annual rate, and for summer a "surcharged" rate. Typical rates currently applied by Water Authorities range from 0.1 to 0.7 pence per m^3 for winter abstraction to 0.3 to 1.9 pence in the summer. A farmer abstracting 7 million gallons a year from a medium quality watercourse in winter might thus pay less than £20, compared with a cost of £330 for the same amount of water from a better quality source in the summer.

230 These arrangements appear to us generally satisfactory but, recognising the importance of encouraging farmers to store winter water, we *recommend* that Water Authorities should arrange their charging systems so that it pays farmers to store water abstracted in the winter, rather than to abstract directly in the dry season. Whilst not suggesting the arbitrary adoption of any particular ratio of summer to winter charges, we note that in certain areas a proportion of 10 : 1 has been established and has operated successfully, the winter rate being set so as to cover only the Authority's administrative costs. We regard this as a minimum differential.

231 Farmers should also take more advantage of opportunities to "top up" their reservoirs outside the winter season when sudden surpluses of water become available. Large quantities of potential irrigation water in the form of 'summer flushes' following storms are at present being needlessly lost. We *recommend* that the same criteria should be applied by Authorities in fixing the charge for 'summer flush' water as we have already suggested for winter abstraction. Administrative difficulties should not be insuperable: meters capable of recording the date of abstraction as well as its quantity are now available.

232 In some years a farmer may not find it necessary to abstract the full quantity licensed for his spray irrigation, and additional arrangements are usually made by the Authority for a two-part tariff system whereby a proportion of the charge rate, often 25 per cent, is related to the licensed annual quantity and the remainder to the quantity abstracted over the year. This arrangement can combine the advantages of both flat-rate and pro-rata systems but only experience will show in what proportions the two are best combined, and this may well vary from district to district. We *recommend* that Authorities should continue to investigate and experiment with this dual arrangement.

233 Complaints were received from the farming organisations that whilst water for agricultural purposes could once be considered to be relatively cheap, there had been dramatic cost rises during the last few years. Some misgivings were expressed about future cost trends. We realise that to an extent this concern arises from sharp increases in a few selected areas resulting from the equalisation policies of Water Authorities. Nevertheless we attach considerable importance to the principle that farmers should be able to plan against a background of predictable water charges. We think that

Water Authorities should avoid sudden shifts in charging policy where this might have a significant impact on farming costs.

234 *Equalisation of charges* Whilst it has been Government policy to reduce the disparities between regional charges for domestic water consumption, we were assured by the Water Authorities that for other purposes equalisation applied only within regions and was strictly related to each particular category of usage concerned. There was no question of their aiming to achieve equalisation of charges nationally or, within an Authority area, between forms of use. For private abstraction charges for irrigation, they intend to maintain their present structure differentials, according to the purpose of the abstraction, and which aim broadly to reflect the costs involved. Spray irrigation, for example, is usually charged at a higher rate than other uses because of the small amount of water returned and of the high proportion of the abstraction which takes place in the summer.

Storage

235 A number of farmers have installed their own storage systems, ranging from small-scale arrangements aimed at making better use of poor mains supplies to the much larger irrigation reservoirs. Considerable stimulus was given to such storage when, following the 1976 drought, the FCGS rate of grant was temporarily increased. For mains systems, a straightforward scheme for short-term storage of a few thousand gallons of water in a tank may be all that is needed – for example, by a livestock farmer as an emergency reserve supply. At the other extreme, an earth reservoir holding perhaps tens of millions of gallons may be required for watering crops.

236 The more fortunate farmer may already have a ready-made reservoir on his land in the form of a gravel, clay or marl pit. Others may be able to build an off-stream reservoir, or impound the necessary water by a dam across a watercourse. Whatever the type of reservoir chosen, the Reservoirs (Safety Provisions) Act, 1930, requires that if it is capable of holding more than 5 million gallons of water above the natural level of any part of the adjoining land, it must be designed, constructed under the supervision of, and periodically inspected by, a qualified civil engineer of one of the panels set up under the Act. In practice, reservoirs of any significant size are seldom built without the services of a qualified and experienced civil engineer. The implementation in 1980 of the provisions of the Reservoir Act 1975 will bring about an even more rigorous system of supervision and inspection.

237 Storage in reservoirs serving a single farm has for the individual farmer the merit of flexibility. Water is available when and where it is needed, low value land can sometimes be used as the site, and the financial outlay easily be covered by the likely benefits. An important advantage is the lower rate of charge generally applied by Water Authorities when the water is abstracted in the winter.

238 However, there are three reservations to be made about individual farm storage schemes. First, the construction of numerous, often small, reservoirs can together represent an unnecessarily wasteful use of valuable land. Secondly, they can only be undertaken by farmers who have access to a source with, in the winter at least, an adequate supply of water of reasonable quality. Thirdly, the smaller the reservoir, the larger is the surface area in relation to volume, which tends to give rise to relatively greater losses through seepage and evaporation.

239 All three objections can be met in suitable conditions by co-operative schemes. These can provide for the use of the least fertile land in a chosen area as a large-scale collective reservoir, from which water can be distributed to individual member farmers in agreed proportions, to their mutual benefit and at the cheapest cost. We think there is also a case for Water Authorities themselves initiating this type of scheme, perhaps over a larger "district". In fact a number have expressed interest in doing so, and this approach could lead to a still more effective utilisation of land and capital.

240 We believe that the expansion of irrigation in the future will increasingly be linked with the winter storage of water and that this is essential to achieve the most effective conservation, utilisation and overall planning of our natural water resources. Accordingly, we *recommend* that rates of grant should be set so as to encourage the development of storage facilities.

241 While in our opinion the public mains system is adequate for most purposes, there are isolated deficiencies which can be extremely serious for the users concerned, especially if they are livestock farmers. We feel that all such farmers should be alert to the consequences of a complete failure in their supply and should install overnight storage as a partial insurance. The use of such facilities, which can be filled at a low but consistent rate, is also advantageous to Water Authorities since it helps to even out fluctuations in demand and promote the best use of the existing distribution system. We therefore *recommend* that installation of mains storage should continue to be encouraged by grant-aid under the Ministry's Capital Grants Schemes.

242 We have said that farmers and Water Authorities should be encouraged to make greater use of the opportunities available to them to initiate storage schemes on a larger scale. But where Water Authorities promote developments designed primarily to benefit agriculture it does not seem to us appropriate that the cost should be met, as is required by the Act, by charges on all abstractors. This problem can be more effectively resolved by adopting a policy of seeking capital contributions from the beneficiaries. Where farmers are prepared to provide the necessary contribution, we think that Water Authorities should respond favourably to plans for large-scale agricultural storage projects. We therefore *recommend* that greater use should be made of capital contribution arrangements from the direct beneficiaries in providing district supply facilities for farmers. Participants should understand that in the case both of private co-operatives and of Water Authority schemes financed by capital contributions, the arrangements for Ministry grant aid are essentially similar to those applying to a private scheme for on-farm storage.

Summary

243 We have identified the main sources of water used in agriculture and horticulture and briefly surveyed the supply situation in each Water Authority region. Supplies are at present sufficient for most agricultural purposes, but undoubtedly there remain farmers who do not have enough water for what they would like to achieve. Two issues stand out. First, it is of absolute necessity to extend storage facilities on farms, both for security purposes and to ensure that water is available at the right time. Secondly, the licensing system appears not to be effective in obtaining the best use of water for irrigation. Our recommendations should go some way towards easing these problems.

SECTION EIGHT

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

244 Water is vital to all forms of farming. Fortunately for most farmers and growers there should be enough of it and of the right quality to sustain current production levels for the foreseeable future. This is ensured either by adequate rainfall or else from public supplies and ground or surface water. Nevertheless, there are important parts of the farming industry where demand is not satisfied and where, in dry seasons, present supplies fall well short of potential consumption. To a large extent the problems are sub-regional – affecting certain areas served by the Anglian, Severn-Trent, Thames, Wessex and Southern Water Authorities – and principally concerned with abstractions for irrigation. Elsewhere, attention centres on deficiency of supply for other purposes, notably dairy farming and other livestock production. There are also certain problems of quality, but they are more closely associated with specific types of enterprise than with particular regions. We foresee a large increase in agricultural demand for water over the next two decades which will not be satisfied unless the major interests take suitable measures. Water being a key resource, all these issues have an important bearing on the industry's future prosperity.

PRESENT DEMAND

245 We have estimated that the current annual intake of water by agriculture is about 300 Mm^3 (65,000 million gallons), 60 per cent derived from public mains and the remainder from private abstractions. Livestock husbandry is, perhaps surprisingly, the largest single consumer, accounting for some 160 Mm^3 (35,000 million gallons), followed by irrigation using 90 Mm^3 (20,000 million gallons) in a dry year.

246 However, irrigation is outstandingly the area with the greatest growth potential, and our examination of current practices and recent trends confirms that there are very few years in which crops grown in most lowland areas of England and Wales could not benefit from additional water, whether in the interest of higher yields, reliability and continuity of supply, or quality of product. We attach particular importance to the part that irrigation can play in the reduction of year-to-year variations in crop yields. There is evidence of much more interest in it in recent years and its use has been increasing on the major crops not hitherto irrigated widely, for example *sugar beet* and *grass.* Even *cereals* are now receiving more water. Those crops recognised as offering a high return from irrigating – *potatoes,* certain *soft fruits, top fruits* and *field vegetables* – are still under-irrigated in the country generally. The potential gains are substantial.

247 With livestock production, on the other hand, there is no evidence of potential demand being unsatisfied to any material extent, although contemporary husbandry does tend to lead to the use of more water largely for washing and cleaning purposes. The on-farm washing and processing of vegetables is increasing but any problems will be of only local significance.

TECHNICAL RESEARCH AND DEVELOPMENT

248 The improved methods of crop and grass production in prospect are likely on balance to lead to increased water demand. Recent experimental work into the basic physiology of the plant, coupled with the lengthening of the growing season as the result of new seed treatments and transplanting techniques, indicates that in many situations the inability of the soil to provide sufficient moisture is inhibiting the full realisation of the production

potential now attainable. Should this be confirmed, higher and more stable yields will require the use of irrigation over a wider range of crops, climate and soil conditions than is currently recognised.

249 In the grassland sector, the availability of cheap nitrogen fertiliser has resulted in the preponderant use of ryegrass mixtures. Likely increases in the relative cost of nitrogen fertiliser point to the need for a re-assessment of the contribution that clovers may be able to make to the productivity of the sward. Any return to clover based mixtures will give an impetus to irrigation.

250 The development of more highly automated systems will reduce labour inputs and so encourage more farmers and growers to practice irrigation. Such systems will also be more intensively used. Although new techniques such as spot watering and trickle and mist irrigation will allow more accurate, and less wasteful, application of water, they will also serve to stimulate the use of irrigation and its extension to a wider range of crops. It seems unlikely on the other hand that plant breeders will be able to produce crop varieties with reduced water needs that will give yields comparable with those receiving adequate moisture and so help to offset the overall demand for water. More refined weather forecasting techniques, when available, should help the farmer to make more economical use of water, but much more meteorological research needs to be done.

251 There already exists a broad based R & D input concerned with water use in agriculture and we do not think any considerable increase is needed in the total amount being done, nor any fundamental change in present work programmes. In general, our review of the present state of knowledge within the industry leads us to conclude that whilst much is already known about the operation of irrigation systems it is rarely included as a standard husbandry treatment in experimental work. Before the new technical developments can be implemented, knowledge of, and confidence in, their commercial potential are required. We therefore envisage a role for agricultural education and advisory services such as ADAS in stimulating the practical use of irrigation as a standard component in the husbandry systems that are the subject of research. We accordingly *recommend* that the sponsors of state-aided R & D, notably MAFF, should give a high priority to (a) soil hydraulics; (b) low pressure irrigation systems; (c) fertilisers and pesticides in irrigation water; (d) response of grass/legume swards, and of new crop varieties, to irrigation; (e) new and more reliable techniques of weather forecasting; and (f) lower cost methods of waterproofing surface reservoirs.

ECONOMICS OF IRRIGATION

252 For the individual farmer, the long term benefits of irrigation for a wide range of crops are readily recognisable. Increased yields are the most readily measurable benefit, but better quality, assured continuity of production and marketing, and the ironing-out of year-to-year fluctuations in yield also bring significant economic advantages. Confining the measurement of benefits to those arising only from increased yields, a wide range of economic responses between crops emerges; indeed, for some, irrigation is only a viable economic proposition when complementing the irrigation of other crops yielding a high return. Costs likewise vary widely according to circumstances, showing about a fourfold difference between the extremes of a sprinkler system with direct summer abstraction on the one hand and, on the other, a large mobile spray irrigator drawing on supplies from a lined reservoir. The provision of storage facilities, which is inevitable with most new installations,

is a major item of cost, and where lined reservoirs are necessary storage costs are so high as to rule out their installation except for a few high-return crops.

253 The decision to invest in irrigation is complicated. Data on yield increases resulting from irrigation and estimates of costs of possible systems are readily available, but uncertainties about the weather mean uncertainties about the need for water, and therefore about the overall economic benefit, in particular years ahead. A dry year early in the life of the investment offers a prize of great value. Taxation, notably optimising the use of capital allowances, is another factor influencing the timing of investment decisions. So also is the level of profit from the farm as a whole and therefore the amount of funds available for investment. In the short term, installing irrigation is one of the less certain forms of agricultural investment, even if in the long term its advantages are beyond dispute. We believe the pressures on farmers to achieve higher yields, better and more consistent quality, and a more assured return, will lead to a much more widespread recognition of the value of irrigation to the individual farm business.

254 In the aggregate, the economic benefits from irrigation are considerable. We estimate them to be of the order of £16 million in a year of average weather, given the irrigation intentions that farmers stated in their replies to the 1977 MAFF Census inquiry, and using crop responses based on experimental data and field experience with well-managed crops in areas of established irrigation need. In so doing, we assumed that farmers generally, for a variety of reasons, applied water at 50 per cent of the optimum needs of the crop irrigated. Looking forward to the year 2000 we forecast an annual net benefit of £50 million at constant prices. This threefold increase in benefit would be the result of an expansion in the area irrigated and of rates of applications of water increased to nearer the optimum plant needs. Potatoes and field vegetables together will probably provide more than half the total benefit in the year 2000, but we expect sugar beet and grass to make a noticeably bigger contribution than at present.

255 £200 million or so of new capital investment, over and above that required to replace existing facilities, will be needed if our irrigation projections for the year 2000 are to be achieved. These forecasts are, however, realistic, provided farmers take a long-term view and that Government is prepared to support and encourage the development of irrigation as a matter of national policy in ways described in other parts of our Report.

FUTURE DEMAND

256 All the evidence points to a substantial increase in the demand for water by agriculture over the next 20 years, notably as a result of a greatly extended use of irrigation. We estimate that the period will see a doubling in the demand for water by the industry as a whole, and a quadrupling in the demand for irrigation. Whilst the increases are likely to be spread fairly evenly over all regions, there will perhaps be a rather greater increase proportionately in the East and South East of England.

257 The compilation of these forecasts has been a major objective of our inquiry, requiring a complex set of assumptions and judgments from a diversity of expert sources. As far as irrigation is concerned, they should perhaps be regarded as the upper limit of the range of likely outcomes – reflecting the growth which we think is economically justifiable, if not necessarily attainable. Nevertheless although they are no doubt capable of

refinement, we believe that they provide the best national estimates available and we *recommend* that:

a. Government Departments and Water Authorities should use them as a basis for long-term planning;

b. they should be periodically up-dated, say every 5 years, to take account of emerging new features and of the operation of supply constraints;

c. that some central agency, either NWC or DOE or MAFF, or all three in concert, should take on this task, at the same time developing improved methodology for long-term projections of water demand.

QUALITY

258 In considering water quality we have been at pains to avoid duplicating parts of the ground covered in the RCEP's examination of agricultural and environmental pollution. We have looked at water quality from the standpoint of chemical, microbiological and physical contamination, and of the legislation affecting the use of water for various agricultural purposes. Except in drought years, few farmers and growers encounter problems of inadequate water quality. Nor should existing legislation pose difficulties for agriculture generally, although it is important that it should continue to have due regard to sound agricultural practice.

259 Salinity, in particular high chloride concentrations, is the main problem of chemical contamination. There can be dangers too from boron and possibly fluoride although there are efficient methods of physical and chemical treatment to deal with most microbiological contamination. Physical contamination is not a significant problem. We have however made a number of minor *recommendations*, as follows:

a. Water Authorities should, for both major and minor watercourses, accept a duty to give advance warning to farmers when pollution is approaching harmful concentrations;

b. the study of the effect of fluoridated water on sensitive crops should be continued; and

c. MAFF, in consultation with the farming and water industries, should draw up guidelines or Codes of Practice, similar to those for watercress, covering the watering of livestock and the irrigation of other crops eaten uncooked.

SUPPLY

260 Supply constraints present the biggest obstacles to the desirable expansion of water use in agriculture. Already there is evidence that a significant number of farmers are unable to gain access to supplies of sufficient quantity, notably for spray irrigation purposes. Some, whose farming could benefit considerably from off-farm sources of supply, have no access at all to abstraction sources. Others are unable to avail themselves of satisfactory public supplies because of inadequate or outworn distribution networks. The lack of water in suitable volume and quality (notably the former) is a hindrance to agricultural productivity. It is not widespread, showing itself mostly in the drier, and highly productive, parts of eastern, central and southern England. Nevertheless it is an issue of substance for the national economy.

261 We appreciate that Water Authorities and Central Government have responsibilities to all water users. We also acknowledge that Water Authorities are laying plans to improve water supplies generally – by augmenting storage facilities, and by initiating water transfer schemes and river regulation operations – and that this is a continuing process. Naturally we have confined our attention to agricultural supplies, and explored the possibilities in three main problem areas. First, we have examined the operation of the licensing system and how it could be adapted to encourage a more equitable allocation of supplies and thus put them to more profitable use. Second, we have looked at charging policies and ways of revising them so that charges reflect more closely the availability of supplies during the year. Third, we have considered means of encouraging more storage facilities for agricultural use, supplementing the general-purpose provision being made by Water Authorities. Although the problems of mains supplies have not been overlooked, we have concentrated on the regulation of private abstractions as the area where most problems are likely to arise.

Licensing

262 The licensing system is the main regulatory instrument used by Water Authorities for achieving some equilibrium between demand and supply. The 'first come first served' principle in dealing with applications for licences over the years, and the fact that licence holders have certain protected rights, has placed existing licence holders in a somewhat privileged position. The situation is exacerbated in some areas by over-licensing in relation to need.

263 In order to make the licensing system better attuned to allocating supplies in accordance with need, and the ability to put water to most productive use, we *recommend* that:

a. although the potential will be limited by topography and farming practices, farmers and Water Authorities should, where the conditions are suitable, enter into voluntary arrangements for the staggering of direct abstractions from surface sources. Modern irrigation equipment makes this easier to achieve than formerly;

b. Water Authorities should, from particular supply points and subject to certain safeguards, allow the sale of "licensed quantities" of water for spray irrigation between willing buyers and sellers in the agricultural sector. This would aid economic resource allocation through normal market forces, without requiring Water Authorities to sit in judgment and without prejudice to the perfectly defensible 'first come first served' principle; and

c. where the licensed quantity is in excess of need, Water Authorities should make greater use of their powers to vary those licences (whether 'licences of right' or those issued post–1963), with compensation where appropriate.

Charging – spray irrigation

264 Although not the most powerful weapon at their disposal, Water Authorities should make more use of charging policies as a means of bringing about a better balance seasonally between supply and demand. To this end we *recommend* that:

a. to encourage surface abstraction in winter into storage reservoirs, the winter charges should represent only the cost of administering

a differential winter price; and we regard the 1:10 ratio of winter and summer prices as a useful yardstick in present circumstances;

b. "summer flush" water be charged at the winter rate for farmers prepared to install suitable metering systems.

Storage

265 It would be neither realistic nor responsible to expect water for agriculture to be freely available on demand from the primary source, particularly for those uses with a marked seasonal incidence. Storage provision must be a major factor in supply strategies, and the expansion of irrigation will become increasingly dependent on water stored from winter flows and summer flushes. In a similar general vein we see the extension of provision of short-term water storage on livestock farms and in glasshouse production as an important insurance against unreliable mains supplies.

266 Accepting that Water Authorities will be developing larger-scale storage schemes, we still foresee the need for "agricultural" storage facilities to be expanded as a complement to the normal Water Authority activity. We have already noted that on-farm storage provision is expensive in certain circumstances and suggested that Water Authorities and Central Government should provide encouragement and support. We therefore *recommend* that:

a. MAFF should continue to grant aid on-farm storage schemes – both reservoirs and storage tanks – at rates which will provide a stimulus to greatly increasing these facilities;

b. farmer co-operative storage schemes should continue to be eligible for MAFF grant aid, also at attractive rates of grant; and

c. Water Authorities should in response to needs specified by farmers, be prepared to provide storage facilities or river regulation schemes for the primary benefit of agriculture. The possibility of seeking a capital contribution from the beneficiaries, to fund all or a major part of the outlay, should also be examined.

267 These measures would encourage the creation of the storage facilities that the industry will require if its future water demands are to be satisfied.

CURRENT RESEARCH AND DEVELOPMENT

This Appendix presents a selection of Research and Development at present being carried out at official research stations and within ADAS. We have not attempted to list work being carried out at Universities or other such establishments because of the practical difficulties of compiling a complete list. None of this work is directed at irrigation itself, but much of it has an impact on the efficiency and scale of water use. Much research into irrigation is carried out abroad but this, too, cannot be covered here. The organisations carrying out the work are listed – a key to the abbreviations is also provided.

Meteorology

Refinement of the calculation of weekly evaporative demand. Use of radar rainfall records to provide 6 or 12 hour synoptic forecasts of rainfall. Development of computational procedures for the production of local quantitative rainfall forecasts for 6-18 hours. (MO)

Supply and storage

Prediction of future water resources – measurements of water yield from upland catchments and the reductions associated with afforestation; models of hydrological behaviour of catchments. Further exploitation of water resources by river flow regulations. (IH, WA, WRC)

The use for irrigation of the liquid fraction mechanically separated from livestock slurries. Disposal to grassland of effluents from vegetable processing plants (European work). (ADAS, NIAE)

Water quality

Biological contamination – nutrition and development of algae and the processes of eutrophication particularly in reservoirs; use of algicides in irrigation lines and possible phytotoxic effects; testing water supplies for the presence of fungal plant pathogens, chemical and radiation methods of control and possible adverse effects of the chemical treatments on crops; incidence and origin of veterinary pathogens in water; inactivation of viruses by chlorination. (ADAS, GCRI, WA, WRC)

Chemical pollutants – monitoring saline incursion into rivers; analysis for a range of specific pollutants; improved sewage and effluent treatment, including removal techniques for specific pollutants. (WA, WRC)

Soil factors and crop water relations: strategic work

Soil water relations – soil properties affecting wetting; water movement in unsaturated and in heterogeneous soils; water availability in seedbeds of varying tilth; effects of soil moisture content on impedance to seedling emergence; classification of soil types in terms of available water content for a range of crops. (LL, NVRS, RES, SHRI, SS)

Water uptake by plant roots – root growth pattern, activity and competition in a number of crops in relation to their drought resistance and to the distribution of soil moisture; estimation of resistance of water transfer in the root and from the soil; modelling of field crop water uptake. (EMRS, LL, NVRS, RES)

Plant water relations – the effect of growth conditions on plant water potentials and the prediction of these in a model of crop growth; physiological factors in water use by crops both in the field and in controlled environments, with or without irrigation; growth analysis combined with micrometeorological and physiological measurements to give an understanding of the dynamics of plant response to water stress; hormonal factors in stress response. (GCRI, LARS, LL, PBI, RES)

Deep cultivation either by improved subsoilers or double digging, combined with deep fertiliser placement, leading to greater root exploration of subsoil reserves and nutrients; the effects of this on crop yield and water use. (NVRS, RES)

Crop establishment

Seedbed preparation by direct drilling or minimal cultivation – suitability of soil types for repeated use; effects on soil organic matter, aggregate stability and fissuring; distribution and depth of soil moisture and available nutrients; extent, time and distribution of root growth (especially cereals); usefulness of the techniques for a range of field vegetables. (ADAS, LL)

Fluid drilling – methods and equipment for pre-germinating and drilling chitted seed; establishment of a range of crops and effects on emergence, yield and time of maturity. (ADAS, NVRS)

Development of an automatic block transplanter. (NIAE)

Changes in growing techniques

Intensive orchard systems – root growth, interplant competition and soil moisture depletion; applied work on growth and yield responses to nutrition and irrigation; herbicide management programmes. Application of fertilisers in water by trickle irrigation. Sugar beet – irrigation requirements on different soil types. Grassland – cumulative effect of irrigation on soil characteristics and on herbage production, comparing grazed or mown swards of grass/white clover with heavily fertilised grass. (ADAS, BB, EMRS, GRI)

Continuing factorial experiments on yield determinants in potatoes; analysis of historical yield and weather data for cereals. (ADAS, RES)

Plant breeding

Selection of grasses and cereals for increased growth under developing water stress and higher summer yields. (PBI, WPBS)

Developments in irrigation equipment

Effectiveness of trickle irrigation in terms of soil area wetted and yield returns in top and bush fruit. (ADAS)

Use of mist irrigation to reduce water stress at peak transpiration periods in fruit trees; design problems on a field scale. (EMRS)

Glasshouses and nursery stock

Nutrient film technique – optimum nutrient levels in solution; effects of root temperature and water quality; possible disease problems. (ADAS, GCRI)

Capillary watering using matting or sand beds for growing pot plants both under protection and outdoors. (ADAS)

Key

ADAS	Agricultural Development and Advisory Service
BB	Brooms Barn Experimental Station
EMRS	East Malling Research Station
GCRI	Glasshouse Crops Research Institute
GRI	Grassland Research Institute
IH	Institute of Hydrology (NERC)
LARS	Long Ashton Research Station
LL	Letcombe Laboratory
MO	Meteorological Office
NIAE	National Institute of Agricultural Engineering
NVRS	National Vegetable Research Station
PBI	Plant Breeding Institute
RES	Rothamsted Experimental Station
SHRI	Scottish Horticultural Research Institute
SS	Soil Survey for England and Wales (at RES)
WA	Water Authorities
WPBS	Welsh Plant Breeding Station
WRC	Water Research Centre

EVIDENCE RECEIVED

Agricultural Research Council

* Anglian Water Authority

Association of Drainage Authorities

Mr A J Brereton

* British Sugar Corporation

* Country Landowners' Association

Department of the Environment

Farmers' Union of Wales

* Farrow Irrigation Ltd

Food Manufacturers Federation

Institute of Hydrology

Institution of Water Engineers and Scientists

JCO For Research and Development in Agriculture and Food

* Meat and Livestock Commission

Meteorological Office

Mr R H Miers MICE MIWE

* Milk Marketing Board

Ministry of Agriculture, Fisheries and Food

National Anglers' Council

National Association of Agricultural Contractors

National College of Agricultural Engineering

* National Farmers' Union

National Union of Agricultural and Allied Workers

* National Water Council

Nature Conservancy Council

Northumbrian Water Authority

North-West Water Authority

* Potato Marketing Board

Rothamsted Experimental Station

* Royal Institution of Chartered Surveyors

* Severn-Trent Water Authority

* Southern Water Authority

* Indicates that both oral and written evidence were received

South-West Water Authority

Thames Water Authority

Water Research Centre

Welsh Water Authority

Wessex Water Authority

Yorkshire Water Authority

GLOSSARY

ADAS	–	Agricultural Development and Advisory Service
ARC	–	Agricultural Research Council
CWPU	–	Central Water Planning Unit
DOE	–	Department of the Environment
EEC	–	European Economic Community
FCGS	–	Farm Capital Grants Scheme
FHDS	–	Farm and Horticulture Development Scheme
GM	–	Gross margin
Ha	–	Hectares
IWE	–	Institute of Water Engineers
Kg	–	Kilograms
Mm^3	–	Million cubic metres
MAFF	–	Ministry of Agriculture, Fisheries and Food
NFT	–	Nutrient Film Technique
NWA	–	National Water Authority
NWC	–	National Water Council
ppm	–	part(s) per million
R & D	–	Research and Development
RCEP	–	Royal Commission on Environmental Pollution
SMD	–	Soil Moisture Deficit
WDU	–	Water Data Unit