ISSN 0309-023X

soil and water

JOURNAL OF THE SOIL AND WATER MANAGEMENT ASSOCIATION LIMITED

NATIONAL AGRICULTURAL CENTRE • STONELEIGH • WARWICKSHIRE CV8 2LZ

1980 VOL 8 NO 1 25p

SAWMA VIEWPOINT

In the previous issue current and future activities of the Association were outlined. The changes of Officers were indicated, but it must be placed on record our thanks to the retiring officers for their foresight and contribution during the formative years of the Association. We extend our best wishes to them.

Dick Dotteridge and Dr. Harry Allen have both put in a tremendous amount, and we owe them much. Our gratitude can best be expressed by moulding SAWMA into an organisation with the capacity to implement the Aims and Objectives upon which it was formed.

It is time to consolidate, and expand. With the experience gained, we should better utilise the wealth of expertise available to the benefit of membership and UK Agriculture. The Minister has urged British Agriculture to improve its Marketing. This goes for SAWMA too. There are the sceptics who question that this can be done, or even if it should be a part of our make-up.

MARKETING

Let us consider some of the implications of the term 'Marketing' alongside our possibly forgotten Aims. These are:—

- To embrace all areas of Soil & Water Management
- To provide a core of knowledge and expertise on these subjects
- To promote and study techniques of good Soil husbandry
- To co-ordinate Science and Practice by communication

To succeed we have to 'sell' the idea, we have to generate the resources to enable our programme to meet the needs of membership — we have to promote — We have a vast wealth of expertise at our disposal which is not at present appreciated or fully applied in our organisation. This means MARKETING to our membership and progressively to UK and World Agriculture.

PROVEN RECORD

It is necessary to stress the proven record of SAWMA. It has presented Conferences on Soil Compaction, Tillage techniques, Irrigation, and Drainage. It has organised field Study visits to Farms, Research Stations, and Water Authorities, and initiated the Irrigation and Drainage Courses. The latter are established to the point of being over-subscribed, and have proved to be of great success.

The interest expressed in the field visits indicates that there is a real need to many members. Of particular importance have been those relating to the study of Soil Structures, which determine growth potential of crops and the effective use of fertilizer, sprays, and seed. Attendance includes specialists who are able to explain the problems found, and help to determine the courses of action to improve matters.

WHAT CAN SAWMA DO FOR ME?

A fair question requiring an answer. Basically, it depends upon your need and interest, and what you are able to contribute.

First, whether you are in Research, Farming, Manufacture, Drainage Contracting or Advisory and Consultancy, you have much to gain by personal contact with a wide variation of experience and have the opportunity to see what others are doing and apply it to your special circumstances. Secondly, discussion and study of your field work and techniques, present methods which others may adopt and extend. Your in-put is vital to get the right machines for the job, to direct future research, and better to understand the factors that influence developments.

MEMBERS VIEWPOINTS

The Farmer:— "When I saw the soil structure improvement by Muirhead, I dug a hole on my farm, and was for the first time aware of the causes of some of my moderate crop performances."

The Manufacturer:— "We learn a lot from our SAWMA field contact, and hearing farmers and Contractors in discussion. The personal contact in areas in which we do not normally participate is of great value."

The Research Scientist:— "SAWMA provides us with the opportunity to pin point areas in which further research should be initiated to solve current field problems. We welcome the practical contact so afforded."

The Drainage Contractor:— "The introduction of the practical Drainage and Irrigation Courses is most constructive. Those attending help to improve our standards and efficiency in field operations. SAWMA can help to stress the importance of Drainage in achieving good soil structure."

The Consultant/Advisor:— "To see and hear how Farmers apply equipment, recommendations, and the latest techniques, enables us to get experience on the practical aspects related. This assists in the quality of, our consultancy work."

These are some of the reactions to the Services offered by SAWMA membership. For all the enthusiasts, there are the critics. The main criticism is that we have been too academic, and more practical policy should be adopted. Further, it is said, that there are many other Associations and Organisations which cover the various topics within SAWMA, — so why SAWMA?

SAWMA, was initiated to provide a body comprising expertise in a wide field of the most important aspect of Agriculture, Soil and Water Manage-

In this issue

ment. A topic of prime interest to any Farmer, Horticulturist, or Land Owner. It offers an independent organisation within which personal contact, and discussion can take place, to link, communicate and weld together the wealth of knowledge available. Further, Farmers have the opportunity to influence new research and equipment to meet their needs.

To do this requires a good basic programme, and Journal to communicate events, and views from all categories of the interests of SAWMA membership. SAWMA is now to extend the range of interest to include Soil, Water, and Plant Management. This will embrace the fields of Horticulture, Forestry, and Land Reclamation.

REPUTATION

The Aim will be to generate an Association with a National reputation capable to act as a catalyst for technical development, and to initiate practical participation. The Association will become a source of reference to membership on related topics. It will be able to publicise activity in specialist sectors to those who do not normally have such contact. An exchange of view will also come from similar organisations overseas.

To the commercially minded the possibilities are immense. Personal contact in Marketing is a valued Asset. SAWMA with your participation can offer this and your comments are always welcomed by our Office.

Mike Darbishire
Chairman
SAWMA Technical Committte

V8-1

Basic Resource

THE BASIC RESOURCE — WATER AND ITS AVAILABILITY

K. F. Clarke, **M.Sc.,** M.I.C.E., F.I.W.E.S. Assistant Director Resource Planning, Anglian Water Authority.

Introduction

The 1975 White Paper 'Food from our own Resources' (Ref. 1) advocated that the United Kingdom should develop more food from its own resources. And in 1977 the 'Little Neddy' for Agriculture stresses in its report 'Agriculture into the 1980s', (Ref. 2) that inadequate water supplies from either rainfall or irrigation impose limitations on food output, particularly in the eastern counties, even in an average rainfall year. The Government's concern about this subject was emphasised in March 1978 when John Silkin gave the Advisory Council for Agriculture and Horticulture in England and Wales, a new remit to study the future water needs of the agricultural and horticultural industries, and the measures necessary to promote its efficient use.

The Advisory Council has just published its report entitled 'Water for Agriculture: Future Needs', (Ref. 3) in which it is concluded:

a) *that the long-term benefits of irrigation for a wide range of crops are readily recognisable. Increased yields are the most 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;*

b) *that there may be a quadrupling in the demand for water for irrigation in the next 20 years;*

c) *that the net benefit of irrigation is £16m in a year of average weather, and by the year 2000, the net benefit will be £50m (at 1977 prices); and*

d) *that supply constraints present the biggest obstacle to the desirable expansion of wafer use in agriculture.*

The Advisory Council's main recommendations are:

a) *that Water Authorities should use the Council's forecasts of future demand for irrigation water as a basis for their long-term planning;*

b) *that there should be voluntary schemes for taking water on different days to reduce peak demands on water resources;*

c) *that the sale of 'licensed water' should be allowed;*

d) *that Water Authorities should vary licences where the licensed quantity is very much greater than need;*

e) *that surface abstraction in winter into storage reservoirs should be encouraged;*

f) *that 'summer flush' water should be charged at the winter rate;*

g) *that MAFF should continue to grant-aid on-farm water storage;*

h) *that farmer co-operative schemes should continue to be eligible for MAFF grant aid; and that*

i) *Water Authorities should be prepared to provide storage and/ or river regulation schemes for the primary benefit of agriculture.*

These conclusions and recommendations are a major step forward in presenting the agricultural industry's views on the future needs for water; however, the Water Authorities will have to decide which can he implemented.

Regional Water Authorities

The Water Act 1973 set up ten Regional Water Authorities and gave them the following functions:

a) *water resource conservation and development;*

b) *abstraction, treatment, supply and distribution of water;*

c) *sewerage, treatment and disposal of waste water;*

d) *river management, land drainage and flood protection; and*

e) *the recreational use of water space.*

More specifically their water resource function is:

a) *to conserve, redistribute or otherwise augment water resources in their areas and to secure the proper use of those water resources; and*

b) *to assess the water resources of their areas in terms of quantity and quality, prepare estimates of future demand over a period of 20 years, and to prepare a plan of action.*

The planning process adopted by the Water Authorities involves:

a) *the development of a long-term plan which includes scenarios of the future demands on their services, the analysis of the ways of meeting these demands, and the review of potential policies for meeting them; and*

b) *the translation of the longer-tern1 plan into a five year rolling capital development programme, and the selection of short-term operating strategies.*

The Water Authorities' planning takes into account the water supply needs of agriculture and therefore it is within their planning framework that the water industry and the agricultural industry can explore their interrelationship and make arrangements for mutual co-operation.

The advantages of co-operation will accrue to both; farmers getting the water supply they require and the water industry being better able to manage the effect of agricultural abstraction upon the river system.

Demand for Water for Irrigation

In England and Wales there are about 32,000 agricultural and horticultural licensed abstractors; 72 per cent of the total number of licensed abstractors. However, they only account for about 1 per cent of the total licensed volume. About 30 per cent of the volume of water ahstracted for agriculture and horticulture is used for spray irrigation but in the region of the Anglian Water Authority, irrigation accounts for about 51 per cent. Table I gives a comparison of agricultural demand between England and Wales, and the Anglian Region, though it must be stressed that it is based on poor quality and fragmented data.

The potential growth in demand for irrigation water varies throughout the country, for very little is carried out north of a line from the Humber to the Mersey. About 50 per cent of the water used for spray irrigation is used in the dry eastern part of the country within the region of the Anglian Water Authority. This amount accounts for about 5 per cent of that Authority's average daily demand, however the average daily agricultural demand in a peak week can be as high as 40 per cent of the total daily demand for all purposes.

Most crops have a theoretical irrigation need 9 years in 10 equivalent of up to about 300 mm of rain a year. To provide this over the relevant part of the Anglian Region would require 3,000 million cubic metres of water. In 1976, however, the volume abstracted by about 3,000 irrigators was less than 2 per cent of the theoretical volume. This is probably due to many reasons. One would be the fact that the farmer is unconvinced that there is a long-term benefit to be obtained from irrigation. Another could be the assumption that there is a eeneral lack of water to meet irrigation needs.

When considering future irrigation

demand the Water Authorities will have to take into account the following factors:

Table 1. Comparison of Agricultural Water Demand (1977)

Type of Use	England & Wales		Anglian Water Authority	
	Million m^3	%	Million m^3	%
Outdoor irrigation	86	28	37	51
Livestock	170	56	21	29
Domestic	36	12	10	14
Protected crops	12	4	4	5
Washing & processing	1		1	1
Total	305	100	73	100

a) The Advisory Council for Agriculture and Horticulture recommendations in 'Water for Agriculture: Future Needs';
b) before **1965** the irrigated acreage was increasing annually. In that year licensing was introduced and the acreage then decreased until **1976,** when the drought resulted in a many-fold increase in the number of applications for abstraction licences for spray irrigation purposes;
c) there have been significant technical advances in the application of water;
d) farm management has become more scientific and therefore more able to handle spray irrigation;
e) irrigation equipment will be installed to increase production in most years as an insurance against a drought;
f) there could be a balance point of market forces which when reached makes it uneconomic for farmers not to irrigate;
g) demand for water for spray irrigation may have been suppressed due to uncertainty by the Water Authorities, and their predecessors, on the magnitude of water resources or their ability to augment these resources;
h) the income generated by additional licences will have to cover the cost of the augmentation of water resources in the long-term; and
i) water accounts for only about 5 per cent of the total cost of irrigation.

To help answer these questions, the Anglian Water Authority has carried out a survey of **3,300** farmers, because it is the individual farmer who makes the decision whether or not to irrigate. The survey suggests:

*a) the Anglian Region is dominated by cereals (**59** per cent) and grass (**17** per cent). Areas devoted to these crops are expected to drop marginally due to growth in acreages **of fruit and vegetables;***

*b) **12** per cent of the Region's farmers irrigate and a further **20** per cent **say that they** intend **to irrigate** within **5** years. (Which in **round** figures would mean irrigated area would increase from 84,000 **to 250,000** hectares);*

c) irrigation is most likely to be practised on very small farms or very large farms, and by younger and college-trained farmers;

d) the following proportions of total crop areas are said to be irrigated in a dry year:

	%
All crops	*3*
*All **crops excluding** cereals and grass*	*12*
Soft fruit	*33*
Orchards	*27*
Sugar beet, beans, brassicas and other vegetables	*10*
Grass	*3*
Cereals	*0.3*

*e) expected growth rates are similar for most crops, **though** somewhat higher for grass, soft fruit, brassicas and cereals;*

*f) the survey suggests that between **70** and **140** mm are **applied** in a dry year depending **on** crop. It also suggests **that** farmers consider it would be profitable **to** use up to **44%** more water per hectare (a maximum **of 80** to **200** mm depending on crop) if the water was available. These **quantities** are considerably more than those used in practice, **but** considerably less than the theoretical **quantities** of up to **300** mm;*

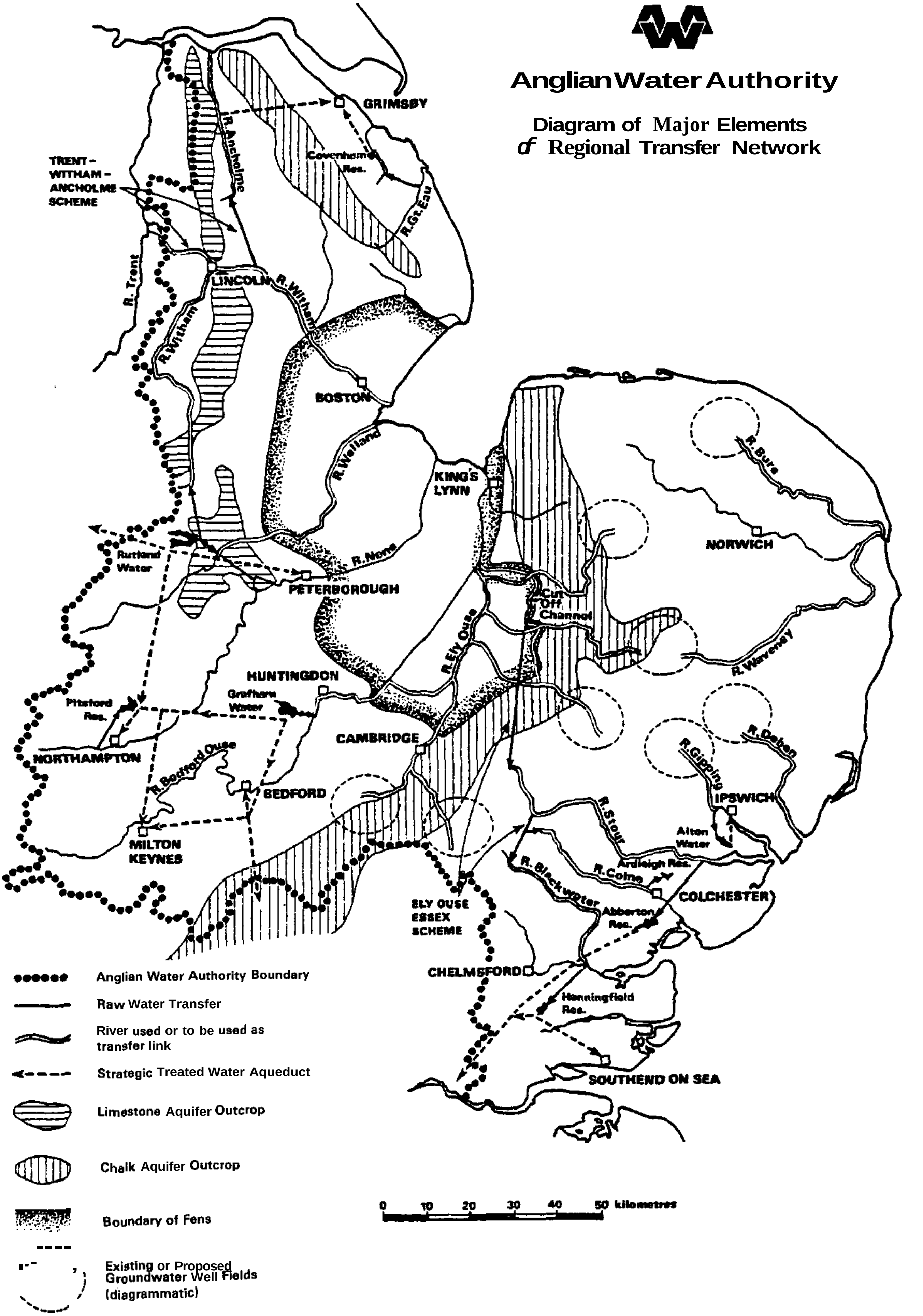
*g) the farmers suggested **that** they, as a group would use **87** million cubic metres of water if **this** year was a drought, **but** using the maximum depths suggested **they** would **use** about **333** million cubic metres of water in **1982;***

*h) farmers are strongly of **the** opinion that irrigation pays for itself, and that more farmers will irrigate over the next few years. However, it appears **that** it is the availability of money which restricts irrigation growlh; and*

*i) finally, it is reassuring **that** only a minority resent the Water Authority while a large **majority** consider the Authority essential to conserve water supplies.*

V8-1

Basic Resource



The survey suggests, therefore, that farmers foresee up to a 280 per cent growth of irrigation by 1982. However, for several reasons this does not appear to be realistic and therefore the survey results will only be one of a number of inputs to demand forecasts. It has shown. however. that farmers are generally aware of the advantages of irrigation and with Government encouragement the amount of irrigation could increase significantly in the next decade.

However. future demands are heavily dependent upon decisions made by the agricultural industry, and therefore. even though the water industry must have the ultimate responsibiitv for selecting the demand forecast on-which its operations and capital development programmes are based, it can only successfully make forecasts in co-operation with the agricultural industry.

The Basic Resources — Water Resources

Nearly half of the rain falling over England and Wales is returned to the atmosphere in evaporation, either directly or through plants. The remainder, known as residual rainfall, replenishes the rivers and reservoirs or percolates into the ground water storage of water-bearing strata. The average residual rainfall over England and Wales is equivalent to about 190 million cubic metres per day. BY comparison, the present consumption of public water supplies is some 15 million cubic metres per day, only about 8 per cent of the residual rainfall. Total abstractions, including direct supplies to power stations, industry and agriculture as well as public water supplies, amount to some 36 thousandmegalitres per day, about 19 per cent of the residual rainfall, but about two-thirds of this water is passed back to the rivers enabling re-use in its passage downstream. The country as a whole is therefore well endowed with water resources.

The rain, however, does not fall evenly within a year, or from one year to another. Nor does it fall evenly across the country and the residual rainfall in the drier parts of the Anglian Region is some twenty times less than in the mountainous areas of the North West and Wales. This fact is shown by Table 2. Furthermore, the concentrations of population in urban areas produce demands in excess of localresources. The problem is to provide an economic level of storage and distribution of water resources in order to make reasonable provision against droughts while also maintaining flows in the rivers to a satisfactory environmental standard.

Table 2. Residual Rainfall: Comparison Between the Anglian Region and the Rest of England and Wales

	Rest of England and Wales			Anglian Region		
	Average year	1 year in 10	1 in 10 year as percentage of average	Average Year	1 year in 10	1 in 10 year as percentage of average
Rainfall	967	793	82	613	503	82
Actual evaporation	430	415	97	445	430	97
Residual rainfall	537	378	70	168	73	43

As a result of the hydrometric works (devices measuring rainfall, evaporation, river flow and ground water levels) and investigations made possible by the Water Resources Act 1963, the Water Authorities now have a fairly good idea of the quantity of water available for abstraction from water resources — rivers, lakes and aquifers. Additionally, in recent years, a significant number of works necessary to conserve or augment these resources have been constructed. The main types of development are:

a) construction of a dam in an upland valley toform a reservoir;
b) construction of a 'circular' reservoir alongside the lower reaches of a river, which is then filled by pumpingfrom the river;
c) construction of a number of boreholes for comprehensive development of an aquifer;
d) the *release* of water from reservoirs or by pumping from aquifers into rivers so that their low flows are increased (this is known as river regulation);
e) transfers from one river, which has surplus water, to another, the resources of which have been depleted; and
f) combinations of these developments.

A good example of the use of a combination of water resource developments is in East Anglia. Figure 1 shows the major elements of the Anglian Water Authority's regional transfer network. In times of drought, boreholes in the Cambridgeshire chalk aquifer can be used to pump water into tributaries of the River Ely Ouse. At the lower end of this river, water can be diverted into a channel, used to carry flood water in winter, to flow South, where it is diverted into a 2500 mm tunnel. At the end of the tunnel, water is pumped along an 1800 mm pipeline to the River Stour. It flows down the River Stour and is then pumped into a reservoir operated by the Essex Water Company. The distance travelled by the water is about 200 kms. Some of the water is abstracted en route to be used for irrigation.

The abstraction of water from water resources is regulated by the Regional Water Authorities under duties laid down by the Water Resources Act 1963; it is a management device for obtaining equilibrium between demand and supply. With certain exceptions such as very small abstractions and those for domestic purposes, each abstraction from a river, aquifer or body of water has to be licensed under the terms set out by that Act. The Water Authorities have the duty to refuse an application for an abstraction licence if in their opinion (and, of course, subject to the right of appeal by the applicant to the Minister) such an abstraction would derogate from existing licences. Under their general duties, however, as an alternative the authorities could choose to augment water resources so that the abstraction could be licensed. The cost of augmentation, however, can by high and it is axiomatic that the Water Authorities need to establish that a demand for water is not speculative and that the agricultural industry will meet the cost.

The maximum charge by the Water Authorities for spray irrigation water without conditions ranges from about 0.4 to 4.0 pence per cubic metre. If water is taken to fill farm storage in the winter only, the cost is reduced by about 90 percent. This compares with a total irrigation cost of from 15 to 60 pence per cubic metre, predominantly made up of the cost of labour, equipment and where necessary of farm storage. The cost of water, therefore, does not appear to be a dominant factor in the decision to irrigate.

Storage of water on the farm is necessary where the farm has access neither to a river having reliable summer resources nor to surplus ground water resources. Where possible, it appears cheaper to abstract water in the summer, paying the higher rate, than to build storage; even though in due course it might be necessary for the Water Authority to construct conservation works to support (or compensate for) such abstractions. Such a decision would, of course, depend heavily on many local factors, the most important probably being whether the ground in which the reservoir is built necessitates lining —

a lined reservoir costs about five times as much as an unlined reservoir.

Conclusion

There is no doubt that water resources are, or can be, made available to meet the demands of water for irrigation. The Water Authorities, however, will need to be sure that if they invest public funds to augment water resources for the benefit of farmers, the demand will materialize and the farmers will meet the cost. At present, an agriculturalist may revoke a licence after a year, even though significant expenditure may have been incurred on his behalf. It may be that an equitable arrangement would be for the agriculturalist to pay a contribution towards the capital costs incurred on his behalf in the same way as a property developer; this idea has been adopted by the Advisory Council for Agriculture and Horticulture in its report 'Water for Agriculture: Future Needs'.

Acknowledgement

The Author wishes to thank Mr. P. H. Bray, Chief Executive of the Anglian Water Authority, for permission to publish this paper.

References

(i) *Food From Our Own Resources.* HMSO (cmnd 6020) 1975.

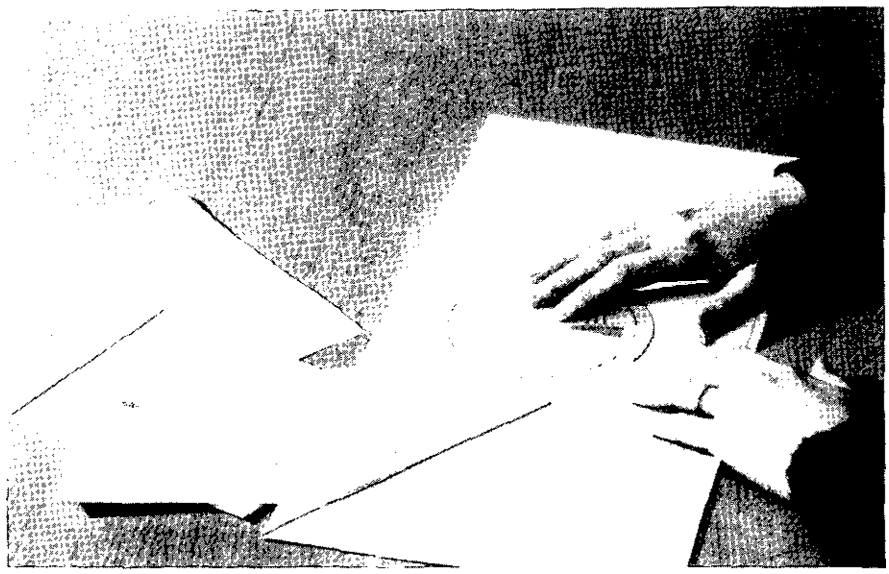
(ii) *Agriculture into The 1980s.* Agriculture Economic Development Committee. 1977.

(iii) *Water For Agriculture: Future Needs.* Advisory Council for Agriculture and Horticulture in England and Wales. February 1980.

NEW! ...

TWO NEW AIDS TO FERTILISER ECONOMY

Two new publications from the National Vegetable Research Station are designed to improve the efficiency of fertiliser usage. The nitrogen calculator is a completely new publication which enables farmers and growers to make corrections for losses of nitrogen by leaching, while the new NPK predictor is an improved version of the NPK predictor first published in 1975.



The N Calculator

Of the three major plant nutrients N, P, and K, nitrogen is the only one which is easily washed (leached) by rain to a depth where it becomes unavailable to the plant. The amount of leaching taking place will depend upon a number of factors, for example not only will the amount of rainfall and the plant's rooting depth be important but also the soil type, because this affects the soil water holding capacity. The essential figure is drainage, but this is easily found from information provided in the calculator and rainfall measurements which may even be obtained from a local meteorological office.

The nitrogen calculator, developed by Dr. Ian Burns, informs farmers and growers of how much nitrogen is lost by leaching and thus how fertiliser applications can be adjusted to compensate. Two types of calculations can be performed. The first deduces the amount of nitrogen lost due to winter rainfall and how to calculate adjustment of spring base dressings, while the second enables losses of nitrogen spring base dressing, by spring rainfall, to be estimated and thus the amount of top dressing needed to compensate.

The calculator is simple to operate. With only slight differences in procedure, depending upon the type of calculation, the water holding capacity of the soil and the amount of drainage are dialled into a rotating disc and the percentage of nitrate leached is read off from a window. Using this figure it is simple to calculate adjustments to fertilizer applications. Good examples of all stages of calculations are provided.

The calculator will be important not only to vegetable growers but also to our farmers. Although in some years, of more than average rainfall, it will be necessary to apply extra nitrogen, calculations show that had cereal farmers been using the calculator over the last ten years they would have used less nitrogen in the long term. On average this would have amounted to some 8.7 kg of nitrogen per ha less per year giving an annual saving of £6.7m to cereal farmers over the whole country. In addition there are further advantages in that by extra application of nitrogen yield losses in wet years can be avoided.

New NPK Predictor

Commercial considerations often make it essential for growers to apply levels of nutrients that are different from those recommended. The new NPK Predictor, like its predecessor, which has become the basis for fertilizer recommendations, will enable growers to make the most efficient use of fertilizers available to them. It gives predicted presponses of different vegetable crops to applications of nitrogen, phosphate and potassium fertilizer on soils containing different amounts of these nutrients as measured by standard methods. Growers can thus make proper informed choices about quantities of fertilizer applications.

With potassium and phosphorus it has been found that the most advantageous long term policy is to maintain soil fertility levels at about 150–200 parts per million from year, to year. There are new tables in the Predictor which show the amounts of P and K removed from the soil by harvest of various parts of the crop, so that these quantities can be applied to replace the amounts removed.

Both publications, N calculator price f1.50 and NPK Predictor price f1.00 post paid, are available from the Liason Officer, National Vegetable Research Station, Wellesbourne, Warwick, CV35 9EF.

CALCULATING WHEN TO APPLY WATER

Frank Cope, Fisons Limited — Fertilizer Division, Levington Research Station.

Introduction

Farmers accept that cost beneficial responses can be obtained when irrigation is applied to some crops in the east and south of England though experimental difficulties restrict the supporting data. Capacity installed is usually insufficient to meet high demands, e.g., in drought years (though returns are then good) and efficient use of the resource is essential. Excessive applications waste resource and may harm the soil and crop. Poor aeration may result and reduce growth or encourage disease. Slaking may occur and damage soil structure, or drainage leach nutrients away from the roots. Accurate scheduling of the time and amount of irrigation can:

i) Use water and equipment to best advantage.
ii) Allow well informed choice between conflicting demands on resources.
iii) Reduce ill effects of excess water on soils and crops.
iv) Control some diseases such as potato scab.
v) Promote germination, fruiting etc of some crops.

Scheduling systems range from simple observations of the wilting of the crop or the feel of the soil, through measurements of available water, and bookkeeping and computing methods. Some work well for the areas in which they were developed — for example, systems based on temperature work well for maize growers in the midwest of USA, but less well here. Most systems will work for the dedicated enthusiast but may be less appropriate for others. This paper is concerned primarily with calculation methods, some alternative methods are mentioned briefly.

Physical Methods of Prediction

Observation of the soil and crop. Whilst simple observations will not give the best results, they are part of good husbandry and should be carried out in conjunction with another method. Examine the soil in the root zone, not simply on top, and note the leaf cover and its turgidity. Penetrometers (ref. 1) are pushed into or rotated in the soil; they fall midway between simple observation and measurement. Some have torque meters to measure soil resistance, torque being related to water content by experiment.

Measurement of soil or crop water. Crop water may not be a reliable indicator until too late and most methods in use measure soil water. A standard method, used to calibrate other techniques, is weighing samples of soil before and after oven drying. Many samples from various depths are needed to characterise an area of

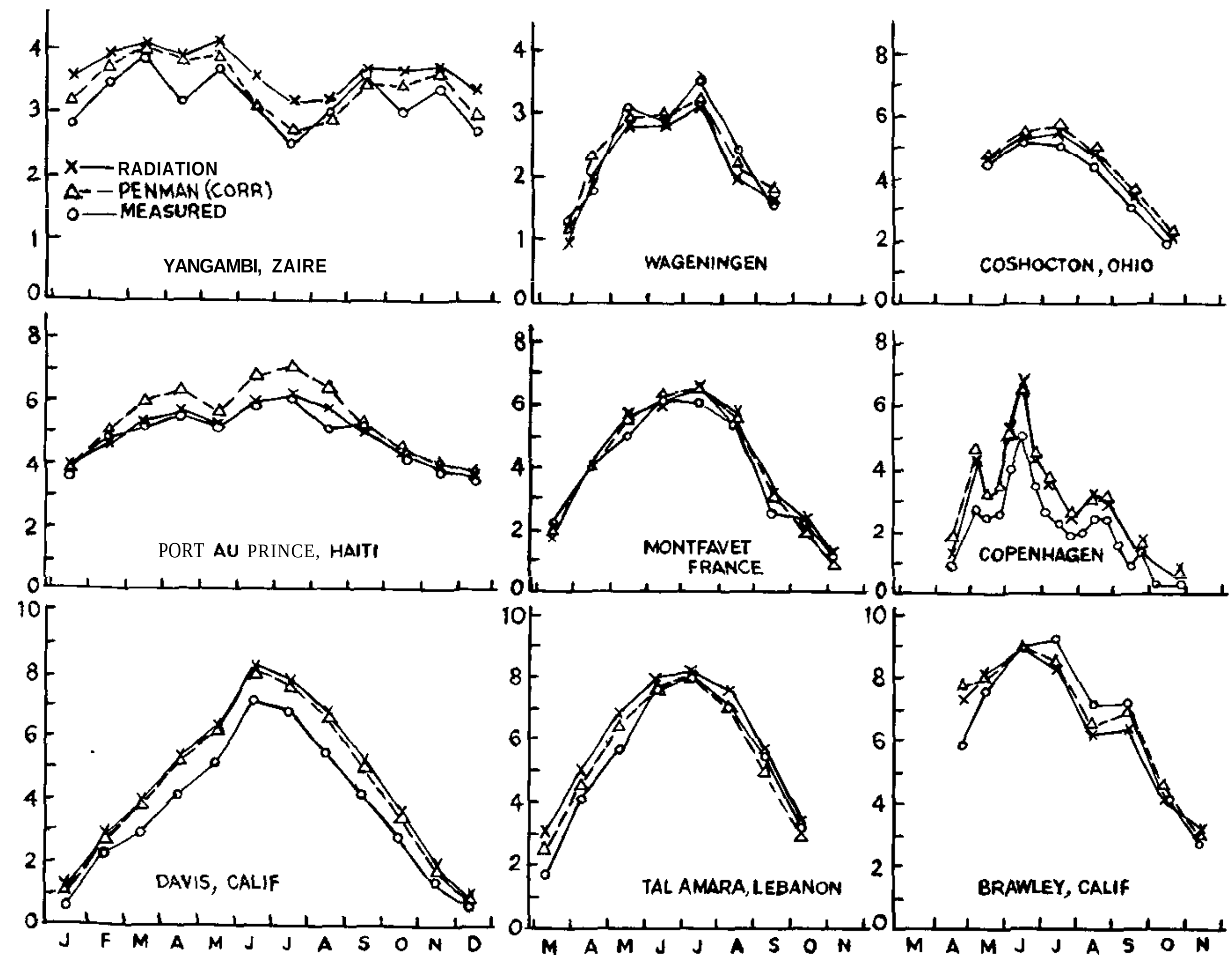


Fig. 1 Measured and Calculated ETo using Presented Methods (ref. 2).

Calculating

soil adequately, making it too laborious for farm use.

Various rapid chemical and physical methods of moisture measurement on samples have been proposed (ref. 1) but have found little favour with farmers.

For irrigation scheduling in situ measurements are preferred to sampling methods. The most important are tensiometers, gypsum blocks, Lysimeters and neutron probes. All have some virtues but none are well suited for scheduling irrigation on farms in the UK for reasons summarised below.

a) Tensiometer — comprises a water-filled porous cup set in the soil at the required depth and connected to a manometer or gauge. This measures the tension created as water in the cup is drawn out in response to suction outside as soil water becomes depleted. When soil suction exceeds 0.8 bar for several hours, so much water is extracted that air enters and the tensiometer breaks down. This may occur earlier if contact between soil and cup is poor. Tensiometers indicate tension at one point only in the soil. Irrigation requirement is calculated from a graph though accurate calibration is tricky. 0 – .8 bars is a limited range but one which covers at least 50% of the available water in most soils. To adequately characterise an area, several tensiometers located at more than one depth are needed. Location in the most demanding soil only will lead to overwatering elsewhere. Faulty readings due to entry of air may not be obvious so some duplication is needed. Temperature fluctuations can also affect readings and to obtain reliable results a fair amount of trouble and expense is involved which makes tensiometers less attractive to farmers than they might otherwise seem.

b) Gypsum blocks placed in the soil absorb water which affects their electrical resistance and changes are read on a meter connected to wires which lead from electrodes in the block to the soil surface. Blocks have little sensitivity in the wet range i.e., their limitation is at the opposite end to that of tensiometers. Well made, properly calibrated, blocks plus a meter are not cheap and again many are needed to adequately characterise an area. Fertilizer and other salts in soil affect accuracy as does the solution of the gypsum. Blocks are somewhat temperature sensitive. Because of these problems and the limited range the method is little favoured by irrigationists in the UK.

c) Neutron probes (ref. 1) are lowered into boreboles to rapidly log water content down the soil profile. They are expensive and being radio active need careful handling. TMs limits their use to research projects.

d) Lysimeters — tanks containing soil and growing a crop are much used in irrigation research but are also too expensive and demanding to suit farmers' needs.

Calculation Methods

At first sight direct measurement would seem preferable to calculation. Unfortunately unless a large amount of time, effort and perhaps expense is put into the measurement this tends not to be the case in practice. Calculation and bookkeeping methods though tedious in the past are now better suited to the needs of farmers. The tedious part is taken over by a computerised system and the famer can concentrate on his main job of managing the farm.

Calculation methods are based in some degree on meteorological measurements. Some involve other measurements on soil and some on the crop also. The FAO Group on Crop Water Requirements (ref. 2) chose four methods from the field, i.e., Blaney Criddle, radiation, pan evaporation and modified Penman. Of these the FAO report that concerning accuracy...'the modified Penman method would offer best results with minimum possible error of ± 10% in summer'. The efficiency of prediction of the four compared with lysimeter measurements is shown in Fig. I. These methods each calculate the reference crop evapotranspiration ETo which the FAO define as the rate of evapotranspiration from an extensive suface of 8 – 15 cm tall green grass cover of uniform height, actively growing, completely shading the ground and not short of water. They use a crop coefficient to convert ETo to the ET for the actual crop. The variations between crops shown in Figure 2 are due to differences in stomatal action, crop height and roughness, reflection and ground cover. FAO suggest that special effects of local conditions, irrigation methods etc, be taken into account in the calculations.

The Penman method of calculating ETO

Evaporation from wet surfaces (leaves or soil etc) uses solar energy. The energy reaching the outer atmosphere Rs is well defined (2 cals/cm^2/min) but scattering, reflection

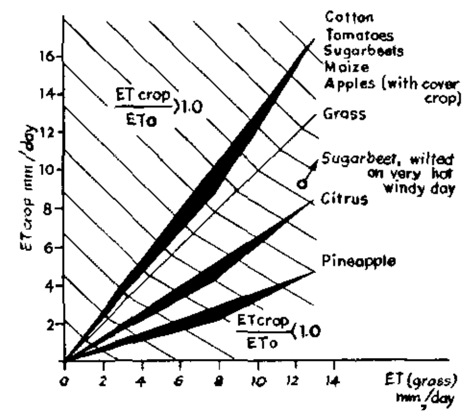


Fig. 2 ETcrop as compared to ETo (ref. 2).

and absorption reduce the radiation arriving at the earth's surface (R_I). (Fig. 3).

The equation for calculation is

$$R_I = rR_S + R_B + H + E$$

where r = albedo (reflectance fraction), R_B = back radiation mosphereande in heat of the atmosphere

E = energy available for evaporation.

As water evaporates from a surface its vapour saturates the air layer close to that surface checking further evaporation until movement of air removes the vapour. The evaporation rate (E) can be calculated from Dalton's equation.

$$E = f(u)\,(e's - e)$$

where f(u) is a function of wind speed in m/s, e's is the saturated vapour pressure at the evaporating surface in mb, and e the vapour pressure in the atmosphere above in mb.

Penman (ref. 3) combined these two approaches, the radiation term and the aerodynamic (wind and humidity) term into one equation which, variously modified, forms the basis for calculation of potential evapotranspiration by hand (ref. 4) and computer (ref. 5) methods. It is the most complex of the calculation methods generally available and is best solved by computer. The method was developed in the UK and generally gives the best results of any calculation method in this country.

Meteorological office/ADAS system

Various methods for calculating ETo and hence irrigation requirement have been offered by ADAS in the past using information supplied by the Meteorological Office. Early versions suggest hand computation of Penman equations, using look-up tables or graphs. Understandably these found little favour with irrigationists. Others used historical average ET data to simplify the calculation of deficits. However, these comments on the Meteorological Office service relate to the latest MORECS (2) computer model and subscribers to the service (option 2) receive a weekly Hydro meteorological Bulletin with rainfall, etc, on grid maps of the UK and tables (11/16a)

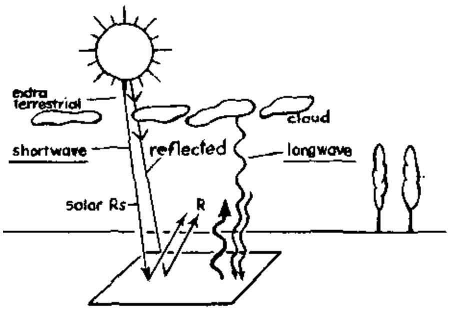


Fig. 3 Illustration of the radiation balance (ref.

of computed soil moisture deficits. The tables have one line entry for each of 190 40 km² areas on the grid. Each line shows computed moisture deficit averaged over the square (based on landsat measures of the average albedo) and for a number of crops — permanent, temporary and rough grassland, cereals, maincrop potatoes, orchards and woodlands. Crop deficits are derived from ETo using simple empirical models and derived values for the albedo of the crop area at the time in question. For a while in 1978 the service issued tables of soil moisture deficit of grass, cereals and potatoes for soils of 'high', 'medium' and 'low' water retaining capacities.

The MORECS model takes data from met stations throughout the country and uses interpolation procedures, altitude corrections, etc to obtain values for every grid square. ETo is computed by a modified Penman method on a daily basis but reported in weekly summaries. The system represents a considerable improvement on earlier Met office/ ADAS systems. A few difficulties remain some of which are inherent in a service without access to data on site, soil and crop. Problems are:

a) No account is taken of soil effects and available water capacity of the soil is not measured. ADAS suggests that users allow for this by irrigating light soils at lower deficits than heavy soils.
The water retention characteristics of soils affect the rate of actual ET. As the soil dries, light and heavy soils will differ in the restriction placed on water loss particularly when ETo is high.
The service does not compute differences in its present form. Even if it did only topping up due to rain could be allowed for and not that due to irrigation.

b) is fairly flat and **most of the met factors important in the calculation of Pe an ETo** (e.g., sunshine, humidity, wind, temperature) will not vary greatly over a 40 km² area of flat land. Summer rainfall however does vary quite markedly and a general service cannot presently take account of this. Of course the farmer can use ETo data in the Hydrometeorological Bulletin and his own measure of rainfall to calculate actual crop ET but this work reduces the attraction of a service. Accurate daily rainfall is needed to compute evaporation from bare soil.

c) A general system cannot take account of the leaf cover, which varies with sowing date, season, variety, disease, soil type, etc, nor of rooting depth and the mass of soil exploited by that crop. The farmer may make empirical corrections for these factors in his own budgeting system.

d) In fenland sites particularly a crop may have access to water from a water table. The contribution from shallow ground water can be appreciable as figure 4 shows.

Fisons Irrigation Advisory Service

What the Service offers

This service aims to provide the best possible advice on scheduling irrigation with the least worry to the farmer. It is a personal service and thus avoids some of the drawbacks of general service. Since its conception nine years ago the models used had 5 years of field tests and comparison with neutron meter measurements of crop water use.

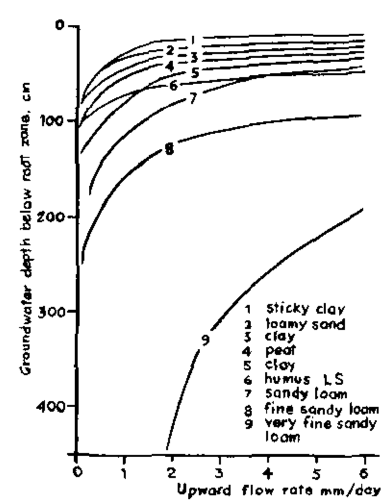


Fig. 4 Contribution of groundwater to moist root zone in mm/day.

The service is based on a set of computer models. One such calculates ETo by a modified Penman method. Others model evaporation from bare soil and features of crop growth. It depends upon three factors, the availability of computers, the close association between Fisons representatives and their farmer customers, and modern communications.

The system is a complex one which requires information from three sources (Fig. 5) though this complexity is not apparent to the user who receives simple and direct reports.

The three information (or data) sets are set-up data from the site at the beginning of the year, daily values of meteorological measurements received weekly, and crop and irrigation data weekly from each irrigation site.

Annual set-up data

Data collection starts early in the year when a Fisons representative visits the site to collect samples of soil and complete a computerised set-up form with the help of the irrigator. Samples are sent to Levington Research Station for laboratory testing to establish water characteristics (available water, field capacity, release pattern). Set up data on the farm includes:

Site: grid reference, height, aspect, slope and variability.
Crop: variety, likely root depth, sowing date and harvest area, special uses (e.g., potato for crisping).
Soil: type, description, sub-soil features, stability.
Drainage: depth and spacing of tiles, water table.
Irrigation: method and amount, allowed deficit, preferred schedule.
Special features: e.g., scab control regime.

Details on the form are checked by an agronomist and queried with the representative if necessary. They are then entered in a computer file with the name and address and phone number of the irrigator.

Weekly meteorological data

The computer model calculates ETo by a modified Penman method using data supplied by the Met Office from a range of stations supple-

V8-1

mented by a further 10 stations with which Fisons have special arrangements.

The selection of a Met site to represent a farm is based on agrometeorological considerations, not on a grid square. Computations of ETo are made by the Met Office computer on a daily basis and telexed directly to Levington each week where they are read into a Fisons computer. The data used for the Penman computations are:

- Temperature: Max. and min. to give mean in "C.
- Sunshine: hours per day of bright sunshine.
- Wind: run of wind in kilometres per day corrected to 2m height.
- Humidity: wet and dry bulb temperatures or R.H.
- Hours of daylight: computed from site latitude.

Site data on crop and irrigations

The third set of data is supplied weekly by phone or telex by the irrigator from his site. The starting date for this data varies with the season and for special crops but is usually around 1st April. It comprises:

- Rainfall: daily in mm.
- Irrigation: amount and date.
- Crop cover: as a percentage estimate.

Plus in special cases only:

- Number and date of cultivations
- Water table depth.
- Incidence of crop disease.
- Weed control measures.

This data is used by special models in the computer to correct the potential ET to the actual ET for the site at that time. A crucial model is one which predicts ET from soil not covered by the crop. Combinations of linear and experimental models are used to predict the restriction of ET as the soil dries, depending upon laboratory assessment of the soil.

Model outputs and the Irrigation Report

The Fisons model attempts to make as many worthwhile corrections as possible when computing crop ET without imposing impossible demands on the farmer for additional data. Modern techniques to improve the service such as the use of Landsat data for crop cover and cloudiness are being continually evaluated. Throughout the irrigation season each user site receives a report (Fig 6) by post.

If action is suggested within 7 days of the report date, a phone or telex report is also sent. The report is short and contains, in addition to the basic data on crop cover, etc, the weekly entry in the budget account of gains and losses in water available to the crop. From left to right in fig 6 the 'old' deficit is that of the end of the previous week, next appear gains from rain and irrigation. Losses of water from the root zone are then shown, first the loss by evaporation from soil and transpiration from crop and the drainage from the zone (not necessarily from tile drains).

The report is a weekly one but the model computes on a more accurate daily basis. Thus drainage of water might occur early in a week though a deficit was built up later. The new deficit appears on the right hand side

Fig. 6. **FISONS IRRIGATION ADVISORY SERVICE**

DATE: 21. AUG 78
SITE NO: 6997R
PERIOD: 14. AUG 78 TO 20. AUG 78
CROP: POTATO
CROP COVER: 100%

OLD DEFICIT (MM) ON 14th	PERIOD GAINS (MM) RAIN	IRRIGATION	POTENTIAL PERIOD LOSSES (MM) EVAPOTRANSP	DRAINAGE	NEW DEFICIT (MM) ON 20th
31.6	03	0.0	261	0.0	50.0

1" IRRIGATION SUGGESTED IMMEDIATELY PLUS FURTHER
1" LATER THIS WEEK IF NO EFFECTIVE RAIN AFTER 20th

 AW50/SO/MA13/D30/125.4

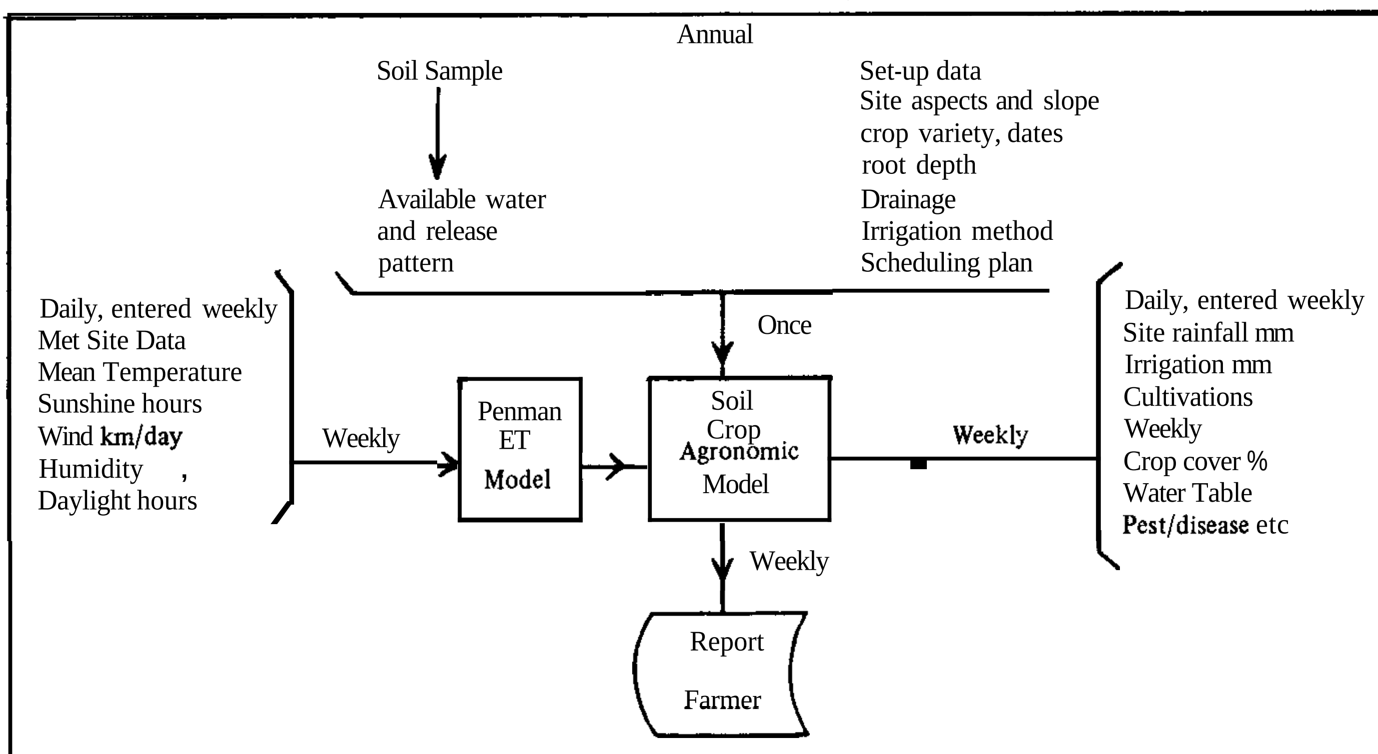


Fig. 5 Data and operation of Fisons Irrigation Scheduling Model.

and is the most important item of information. From this the irrigator can judge how urgent the need for water is and see how much to apply to satisfy that need. He may if he wishes use computed tables of likely ET for his crop over the following seven days to up-date the budget daily then correct his budget when the next report arrives, but few find this necessary. A final section of the report contains an interpretation placed on the state of the water budget by the model. This is agreed by an irrigation agronomist and modified if necessary before the report is sent out.

The interpretation usually takes the form of a note suggesting the amount and timing of irrigation. The amount to be applied will be based on the irrigation practice of the farm and on the scheduling system. Fisons are prepared to give advice on these and the assumptions can be varied during the season if required.

The note may also refer to agronomic and management considerations which should over-ride the need-to correct a soil deficit. Examples are that the crop may be near harvest when a high deficit is likely to be preferable, or irrigation of seedling plants by raingun could dislodge them, so this is pointed out.

Validating and checking the Fisons model

No calculation method is perfect and there are dangers of getting out of phase, or of faulty data being submitted. Error checks are applied to meteorological data and to ETo computations on a common sense basis of comparison across the range of sites. Ground cover estimates may be checked by crop growth models which are season dependent. Errors detected in visual and computer checks on data are referred back to the irrigator by phone. Essential data is reported back on the form sent to the farmer so that errors can be noted.

Fisons agronomists visit selected sites each season to check conditions and to sample the soil for comparison of predicted and actual water contents. A neutron moisture probe is used at Levington to continuously log water loss on a 24 hour basis from an irrigated potato plot as a check on system reliability. Irrigated experiments at Levington and other East Anglian sites are included on the service and are monitored carefully as regards predictions and crop yields. Finally meetings are held with users of the service and useful comments and criticisms are acted upon wherever possible.

REFERENCES

1. Cope F and Trickett E S, 1965. Measuring Soil Moisture. Soils and Fertilizers 18, 201 – 208.
2. Food and Agriculture Organisation of the United Nations. 1977. Crop Water Requirements. FAO Irrigation and Drainage Paper NO. 26. Rome.
3. Penman H L, 1963. Vegetation and Hydrology. Commonwealth Agricultural Bureau of Soils. England.
4. Withers B and Vipand S, 1974. Irrigation design and practice. B T Batsford Ltd, London.
5. Berry G, 1964. The evaluation of Penmans natural evaporation formula by electronic computer. Aust. J. Appl. Sci. 15, 61 – 64.

V8-1

NEW! ...FROM WRIGHT RAIN LTD.

IRRIGATION...A GROWING INTEREST

Although many laymen find it strange that the UK suffers a moisture shortage, it is [illegible] a fact that, in certain a[illegible] crop irrigation is essential nine years out of ten.

A recent report by the Advisory Council for Agriculture and Horticulture in England and Wales says "There are very few years in which crops grown in most lowland areas in England and Wales, would not gain from additional water at some time during the growing season". The report goes on to list increased crop yields, better quality, timeliness of harvest and the assured reliability and continuity of supplies to the market.

All this of course will give little reassurance to holiday makers experiencing continuous rain during the summer vacation, but even they enjoy these benefits when their greengrocer's shelves remain full and prices are stabilised throughout the year.

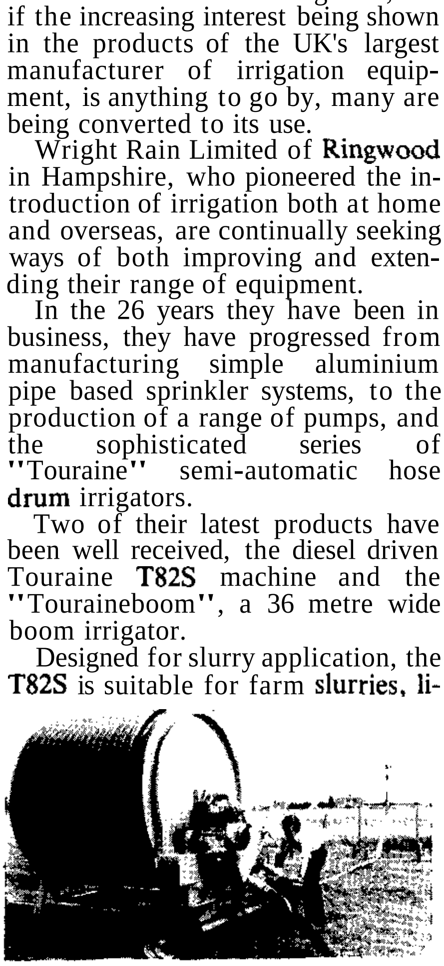
Some farmers have also been sceptical about the value of irrigation, but if the increasing interest being shown in the products of the UK's largest manufacturer of irrigation equipment, is anything to go by, many are being converted to its use.

Wright Rain Limited of Ringwood in Hampshire, who pioneered the introduction of irrigation both at home and overseas, are continually seeking ways of both improving and extending their range of equipment.

In the 26 years they have been in business, they have progressed from manufacturing simple aluminium pipe based sprinkler systems, to the production of a range of pumps, and the sophisticated series of "Touraine" semi-automatic hose drum irrigators.

Two of their latest products have been well received, the diesel driven Touraine T82S machine and the "Touraineboom", a 36 metre wide boom irrigator.

Designed for slurry application, the T82S is suitable for farm slurries, liquid separates and municipal effluents, the unit is operated by a Petter AB1 S bhp diesel engine, in place of the usual turbine.



This photograph of the new Wright Rain T82S slurry application machine, clearly shows the Petter diesel engine drive.

This drive, being independent of the flow through the machine, allows for the distribution of slurry containing a high solid content with no restriction to cause blockage. If the effluent being distributed is capable of being pumped along a pipeline, then it can be handled by the T82S.

Having the same simple automatic operation features common to the Touraine series, the T82S has full engine throttle control plus a variable speed drive, which combine to give a wide range of application rates, varying from 4 to 40mm per pass. It is possible for one man to apply 4mm to up to 20 acres in one day. The Wright Rain Manurain sprinkler gives even distribution up to 25 metres from the wind-in carriage, allowing lane spacing of 42 to 45 metres.

The T82S is even more versatile in operation, when fitted with the Nelson P100 Big Gun, the machine can also be used for irrigation purposes. As no pressure is required from the water supply to drive the machine, it can operate at extremely low water pressures and give light water applications not possible with a turbine or bellows driven unit. This makes the T82S ideal for the control of dust and light soil "blows" and for seed bed applications.

Fully guarded to UK and EEC requirements, the unit [illegible] end of run, automatic shut-down and engine stop safety features.

Used in conjunction with Wright Rain's H3LM range of open vane impeller pumps, the T82S can be used for industrial and municipal applications in addition to the normal agricultural use.

The "Touraineboom" is designed for use with the small medium size Touraine hose drum irrigation machines.

Replacing the normal raingun trolley, the boom is fitted with up to seven Wright Rain sprinklers, thus giving the small droplet, low pressure, even distribution irrigation

The 36 metre spread of the Wright Rain boom irrigator is demonstrated by this "worm's eye view".

normally associated with conventional pipe based systems, while at the same time enjoying the labour saving benefits of the hose drum machine.

This new concept widens the scope of the Touraine series, it may be purchased as a separate unit or can be provided as an option with new machines, it can also be used with most other makes of hose drum irrigators.

Construction of the boom is simple, based on an adjustable width, four wheeled trolley, the unit has a central column each side of which is connected a three section, telescopic, aluminium pipe. When extended the sections are twisted and locked into position using a special coupler, each section is supported by cables. These cables return to spring operated pulleys mounted on the central column, which automatically reel in when the boom is dismantled.

For towing purposes, the telescoped boom is stowed on racks built on to the column, the unit is equipped with fittings for mounting on a tractor three point linkage for transportation.

Flow rates required to operate the boom effectively are between 70 and 205 gpm depending on machine type, the recommended lane spacing is 63 metres (maximum wetted width 75 metres).

Application rates also vary; they range from a very light application for seed bed irrigation of below ½", to a maximum of approximately 1½".

The Touraineboom was recently shown at the SIMA exhibition in Paris where it aroused much interest.

Further Wright Rain developments are well advanced, a "Super Touraine" series has been built and tested and will be introduced to the UK market shortly. Other ideas, currently with Wright Rain's Research and Development department, will ensure the company's position as the UK's number one.

THE MANAGEMENT OF IRRIGATION PROGRAMMES ON THE FARM

L. J. Walton is a former partner of Greens of Soham

Personal Experience

My own irrigation experience has been in the area of Fenland outdoor vegetable growing, different circumstances to many of you, but many of the basic principles will still apply.

For the last 10 years I have been involved in the management of **2,000** acres in the Cambridgeshire Fens, growing approximately **450** acres of celery, **120** acres of leeks, **280** acres of potatoes (mainly for the crisping trade), **500** acres of beetroot (mainly for processing), **250** acres of onions (150 of which are over-wintered), **450** acres of wheat and small acreages of outdoor lettuce and salad onions.

Why do we irrigate?

The aim of our business is to establish accurately the market requirements in terms of volume, timing and quality in the crops well suited to our circumstances and to make a profit out of servicing these requirements, whether to processors, supermarkets or the wholesale market.

The keys to success in this endeavour are consistency of quality and continuity of supply. The main causes of variability in crop yields from year to year on the same site are:—

1. Solar radiation
2. Soil fertility
3. Moisture status

Solar radiation is beyond our control, we are all used to spending a lot of effort and money to maintain soil fertility, but how many of us put as much effort into correct moisture status?

Note the use of the term 'moisture status' because we cannot consider irrigation in isolation, it is inevitably tied up with drainage. There is little point in using expensive irrigation equipment on poorly drained and badly structured soils, it is likely to cause more problems than are solved, so do the drainage first.

Provision of Water Supply

The first thing to be considered when thinking about irrigation is the water supply and in many cases this will be a major part of the capital cost for an irrigation scheme. Exactly where the water will come from will depend on the Regional Water Authority; establish a good working relationship with them. They are, in my experience, keen to find out farmers' problems and respond to a proven need if it is possible so to do. Again consider irrigation alongside drainage, the ditches which carry water away from the field in winter may well be useful for carrying water to the field in summer, if correctly sited and designed. For example, an irrigation ditch may need to be slightly deeper than would be required purely for drainage, in order to have enough flow for the pump to continuously operate. We are fortunate in the Fens in that although our summer rainfall is very low, our rivers receive large amounts of water on their way to the sea. All we require then is the organisation to utilise the resource.

In the Fens this organisation consists firstly of the Anglian Water Authority, controlling the river and overall water use. Secondly, the District Internal Drainage Board, acting on behalf of all the farmers within the district boundary and liaising with the Water Authority and neighbouring Drainage Boards, to maintain a water level in the district appropriate to its needs. This involves pumping water out in the winter and bringing water back into the system from the rivers in summer.

We then have quite a complex system of farm ditches, supplied by an electric pump from the Internal Drainage Board system to give a water supply to every field on the farm. The level of water is maintained in the ditches by dams with varying sizes of boards to give a fine degree of control over the water level to different parts of the farm. This system requires an accurate survey of surface levels on the farm to ensure that the lower areas are not flooded. In the Fens this needs to be reviewed from time to time as surface levels drop with the wastage of peat.

The release of water at the end of the season into the Internal Drainage Board system needs to be done with the knowledge of the Internal Drainage Board to prevent sudden inundation of some lower lying land.

Another problem to be aware of is the slumping of clay or silt subsoil by continuously high water levels. Effective drainage through clay to a tile drain depends on natural cracks in the clay formed when it is very dry. If it is never allowed to be dry, the cracks are lost and drainage problems may well ensue. The level of dams in our case is in the control of one man to whom all of the irrigation teams refer when they require water for a particular area.

Selection of Equipment

This is a very broad subject and could easily occupy a book of its own, let alone a half hour paper. I will, therefore, confine myself to what we use and why we made the choice.

As a broad policy, though, I would recommend that before a choice is made the subject should be carefully studied in considerable technical detail. A lot of 'experts' have come into the irrigation sales and consultancy field since the dry years of **1975** and **1976.** Some are very good but many are not and considerable knowledge is required to judge the advice given. A lot of information is published and available. If you take the time to study it you may well know more than the 'expert'.

We have two basic kinds of equipment. Sprinkler systems and hose reel type rain gun irrigators. The first of the sprinkler systems I shall talk about is the Wright Rain conventional system. This consists of lines of three inch bore aluminium pipes 35 ft long with a sprinkler on each pipe, fed from a five inch main line. This system will apply one inch of water in three hours. We use it mainly for watering in of planted crops. It has the advantage of low capital cost, but rather a high labour input. It is very flexible for watering in windy conditions, where the line spacings may have to be varied to suit wind speed and direction. This is also a useful back-up for peak irrigation demands over small areas not covered by the larger equipment.

A typical set would comprise one pump (usually a small tractor driven pump), a length of **5"** main-line (aluminium) and about **48** 3" sprinkler lines. This is practically capable of applying 1 M" of water to **2.3** acres at a setting or **7** acres per day, therefore, might serve up to 60 acres, allowing for field changes etc. The work involved in moving the system is very hard and unpopular and can be quite damaging to crops which are sensitive to being trodden on. It is very difficult to place your feet carefully when carrying **35'** of **3"** pipe. The capital cost of this system would be approximately **£7,500** or **£125** per acre.

The second sprinkler system we use is the Wright Rain portagrid. This consists of lines of 1¼" bore aluminium pipes laid into the crop after planting at 60 ft. intervals with riser stands down the lines again at 60 ft. intervals. Once laid into the crop they will remain there until harvest. The sprinkler pipes plug into the stands, each 1¼ pipe being capable of supplying water for two sprinklers at any one time. The system is capable of applying 1" of water in 4½ hours and we can achieve 3 moves a day with the system. The capital cost of the equipment is very high, in the order of £560 per acre and this may be prohibitive in the present environment, but the majority of our portagrid is now 10 years old.

Labour input is much lower than 2 men able to service 150 acres of installation providing for themselves weekend cover. Also, the work is easier and sustainable over long periods than the conventional system. It is vital with this system to adopt a careful discipline of pipe removal at harvest as the 1¼" pipes are very fragile and easily damaged.

The hose reel type rain gun irrigators combine a relatively low capital cost with low labour input. A typical 'set' consists of two rain guns, one pump and about 300 metres of steel main line. The total capital cost of this set is about £26,000 to service 150 acres, i.e. about £175 per acre.

A team of two men can comfortably keep two such sets running continuously including providing weekend relief. Since the drought years there have been many machines of this type to choose from. Here are some practical points which may influence the type chosen.

1. Does the pipe length fit your field length?
   Too short a pipe length will require considerable reorganisation of the field layout and increase the ratio of moving time to working time. Too long a pipe length will be difficult to pull out on crops which offer a lot of friction resistance, for example peas and onions. Larger pipe lengths also increase pumping costs.
2. Reel irrigators have a natural tendency to speed up as they get closer to the main line because:
   a) The effective diameter of the reel increases as the coils of pipe are added to it.
   b) The pipe drag reduces with the length in contact with the ground.

   On piston drive machines with no compensating device fitted the difference in speed between the start and finish of the run can be in the order of 50%. Turbine drives are, to some extent, self compensating and many machines now offer a compensating device in addition.
3. Piston drives are likely to be prone to mechanical problems where fine sand is present in the water.
4. Where permanent underground main lines already exist on the farm, they may not be strong enough to withstand the high water pressures required for reel irrigators. In this case a booster pump may have to be fitted to the irrigator.

Pumps

Pump size and type will obviously depend on the type of system and water output required, for example sprinkler systems require only relatively low pressure pumpmg, whereas the high pressure required by rain guns will require a multi-stage type of pump. In general though, it is worth purchasing a pump and power unit which is well on top of its job. The right pump well maintained will last for many years. One which is running to its absolute maximum all the time is likely to cost money and fail when the sun is at its hottest and there is no rain in sight.

We are more and more turning to the purpose built direct coupled diesel engined pump unit. These are more efficient in power transmission than the tractor p.t.o. driven pumps and can more easily be fitted with safety engine cut out devices. The pumps are fitted with time clocks to shut off the last run on sprinkler irrigation or no flow switches when used with rain guns. They also have engine cut outs for loss of pump pressure. high engine temperature and low oil oressure. There are units available to kit to tractors for irrigation pumping but because they are temporary they tend to be less reliable than those on purpose built pumps.

Main Lines

Aluminium main is perfectly satisfactory for the low pressures of sprinkler irrigation. It is lighter and length for length cheaper than steel. It can also be used with a single reel type machine, but if there is a possibility that another machine will be added at a later stage, steel main should be the choice from the outset. Again, possible future expansion of the system should be considered when deciding on the diameter of the mains, slight over capacity may pay dividends in the future.

Establishing water requirements

The local ADAS can be very useful in the planning stages by providing information on local rainfall and evapo-transpiration rates. Coupled with this we need a view of the soil type and rooting depth of the watering target. For example, potatoes grown on a deep soil with good moisture holding capacity can perhaps tolerate a moisture deficiency of up to 3" whereas with a light sandy soil this figure may be in the order of 1 – 1½". If capacity is limited it is better to maintain the right growing conditions on fewer acres than to make a poor job of all the acres.

There are a number of formulae and devices to assess the moisture deficit during the irrigation season. However, there is nothing to beat taking a spade and digging a hole both before and during watering. It is vital with irrigation to get out and look at the soil in detail. For instance there may well be areas of the field which require less water than others.

There may be a root restriction for some reason which will require less water more frequently applied. No formulae or figures can tell you this, you must get out and look. Also to be borne in mind is when to stop watering. With celery, for instance, there is no choice, as soon as it becomes dry it will rapidly mature and need harvesting almost regardless of growth stage. With potatoes and beetroot, however, the decision has to be made perhaps to sacrifice the last bit of potential yield to ensure a good harvest condition on some difficult land.

Organisation of the work

Before going into how the work is organised, it will be useful to note just how much equipment we are dealing with. At Hasse we have two sets of conventional equipment, 300 acres of portagrid equipment, 6 Bauer Rain Star hose reel tupe irrigators and one Farrow Dolpin travelling irrigator.

The lead irrigation man, or men, in the well managed system is a very important figure in the whole growing operation. During the winter planning period our lead irrigation man is given a set of maps of the fields to be watered during the next season. With these he can doodle away and suggest the best field layout of rows and headlands from an irrigation viewpoint. These may require some modification for other reasons, but consultation at this stage can save a lot of work later on.

Also during the planning period, I like to set out a bar chart showing the acreages of crops to be watered, the periods they will require water and the amounts required in a dry year. Totalled across week by week are the total amounts of water required. The equipment and labour required to fill the need can then be calculated and the resources planned in from the outset. If this calculation is done for a dry year it is far easier to reduce inputs in the event of extra rainfall than to find extra resources in the heat of the season.

The total amount of work is split down into 2-man teams. each with a defined area of crop to look after with the defined amount of equipment. We aim to work a 5 day week with the men because the hours tend to be unsociable and the season is long. A 2-man team can be organised so that each man works 5 days on and 2 off, staggered so that the weekends are covered. The days they are together can be used to get ahead with laying out main lines etc., in preparation for when one man is on his own.

At the end of each week I do a plan for the next fortnight, indicating the fields to be watered and the approximate amounts required. This plan of course, has to be altered in the event of rainfall or when more water needs to be applied than was planned for, but a rough plan is better than no plan at all. A copy to the team enables them to be one step ahead with preparation and provision of water supply. It can also highlight potential problems, such as two teams trying to draw from the same water source at the time where flow is restrictive.

Generally speaking with rain guns we aim to apply 1M" of water at any one time. This may be altered slightly in the planning stages to get the most out of the equipment, i.e. reduced very slightly if this enables an extra run to be accommodated or increased slightly where the field can take it and where the alternative is to lose machine running time. With very sandy soils the amount applied is reduced to 1″ of water at shorter intervals. With portagrid in celery we are in a position to apply 1" of water twice every 7 days which is a requirement in peak growing conditions.

Recording

Each week the irrigation team fills in a sheet showing the fields irrigated with the date and the amount of water applied, this is then used to keep the farm crop diary up to date and also to calculate the water usage for the Water Authority charges. We are currently investigating and testing a number of metering devices for the latter purpose as this will very shortly become a requirement.

V8-1

Application Equipment

APPLICATION EQUIPMENT - PRESENT AND FUTURE

This article by **G.G.Curtis** who is Projects Manager for FARROW IRRIGATION takes a look at current trends and future developments

Irrigation has been practised for thousands **of** years and yet the application methods that we use today have chiefly **been** developed during the last 50 years. Possibly the greatest advance in the industry has taken place over the last 15 years during which mechanical irrigation methods have been introduced to keep pace with the trend toward increased mechsnisation in agriculture.

This article is confined to irrigation in **Europe** with emphasis on the U.K.

Present Application Methods

Currently there is a wide choice in the systems available. An irrigation scheme must be tailored to suit the needs of the user and the crop requirements. It is, therefore, important to understand what is available and what benefits are to be gained from a particular irrigation system. It is impossible to he specific, the following is intended only as a guide to help get things in perspective.

The following systems are currently in use:—

- Surface *Irrigation*
- ***Handmove Sprinklers***
- ***Solid/Permanent Set***
- Stationary Guns
- Travelling Irrigators
- Side-Roll
- Rotating Booms
- Centre Pivot
- Drip Irrigation

From these nine systems new users would most **probably** select either **Travellers, Handmove or Solid Set. The other systems being discounted for the following reasons.**

Surface Irrigation:

Totally unsuited to U.K. farming. Land preparation and farming practices must be strictly followed each year whether or not irrigation is ultimately used.

Stationary Guns:

This relatively inexpensive system has fallen, from popularity because it usually gives poor distribution and the larger droplets constantly fall in the same area. The **crop** response is uneven and maximum yields are not achieved.

Side Roll:

Although an extremely popular tool in some foreign markets, the system is rather inflexible when presented with the different shaped fields commonly found in the **U.K.**

Rotating Boom

The machine size and the inconvenience of frequent moves have probably been the chief reasons for this method's decline in popularity.

Centre Pivot:

Many farms are unsuitable because of the existing field shapes, or there may be obstructions such as trees or powerlines preventing full circle operation. There is possibly a natural resistance to new technology. Typically the U.K. farm would require relatively small diameter machines which would mean that initial capital investment will be high. Larger diameter pivots can be very competitive with other systems.

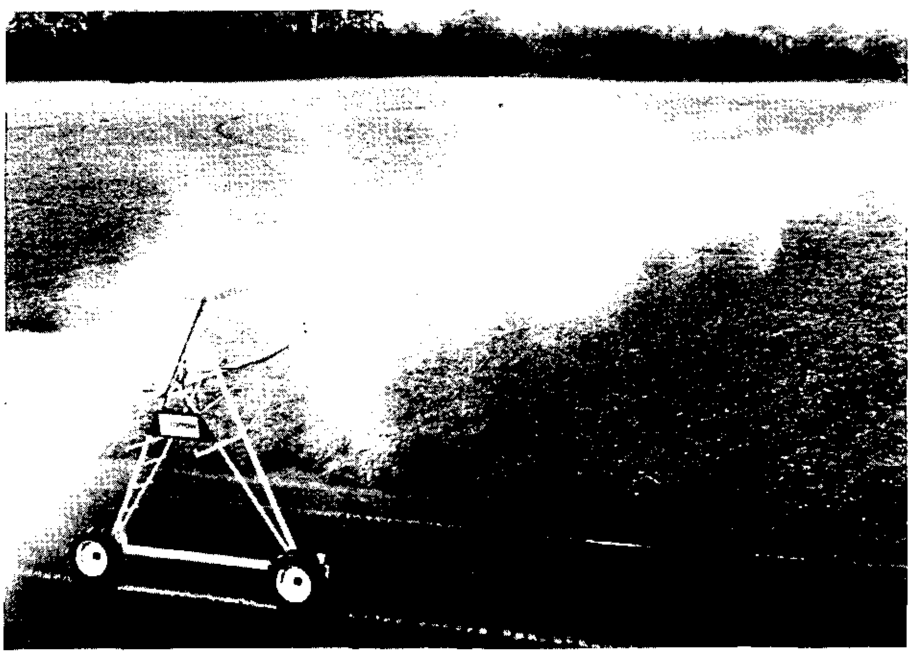
Drip Irrigation

Better suited to horticulture or for the irrigation of trees, bushes etc. where the application of water can be localised.

Present Trends

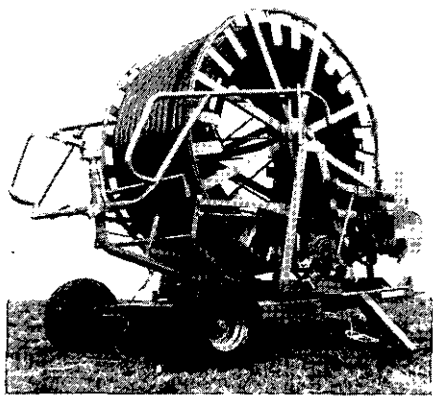
Since the introduction of **self**-travelling irrigation systems in the late **60's,** we have seen a steady increase in popularity. Today the traveller commands more than 50% of the total irrigation market, its growth having singularly outstripped all other methods.

(Note:— The word "traveller" encompasses **both** drag-hose and coiled hose machines, with or without booms)



Why has the traveller **been** so **suc**cesful?

If we assume adequate water and energy. Then consider the effects of LAND, LABOUR and CAPITAL as



limiting resources. It is possible by the following diagram to illustrate the type of irrigation most suited to a limiting resource. It can be seen that travellers have a wide application whatever the limiting factor. Of the three factors the traveller is biased toward low labour which today has become a very significant point in selecting an irrigation system.

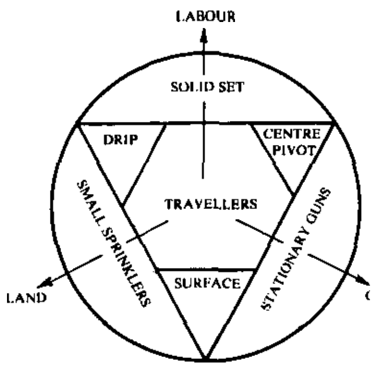


Fig. 1. EFFECT OF LIMITED RESOURCES (Assuming adequate water and energy)

Equipment Costs

It is almost impossible to generalise on the cost of any particular installation because of the number of variable factors involved.

The following table is intended only as a guide so that the reader may have a perspective view of the various systems available.

Future Trends

When looking at the future trend in irrigation, we must look worldwide. The developments will be strongly influenced by a shortage of one or more of the basic resources. An expanding population will demand that the farming community produces high yields of high quality each and every year.

The following five points will most certainly be factors governing future developments.

1) Limited Labour

This speaks for itself. The ultimate being total automation. Future methods must lend themselves to partial or full automation.

2) Limited Water Resources

This means that the industry must move toward systems that give high irrigation efficiencies. It would also be extremely advantageous if the systems were capable of light frequent applications allowing a greater degree of control in balancing the water in the soil profile.

3) Limited Land

This means that the systems must maximise land utilisation. They must be able to fit any field shape and provide the full irrigation requirement, not only over the whole field, but ideally to the extreme edge of the field boundaries.

4) Limited Energy

Low energy requirement must become an important, ingredient, ignoring the high cost, it will be essential for the agricultural industry to make its contribution to energy conservation.

5) *Population*

Increasing population will mean continual efforts to increase productivity. Developments such as the ability to apply fertilisers, herbicides and insecticides through the irrigation water, aerial monitoring of systems and crops, infra-red photography and automatic irrigation scheduling will be required to achieve the necessary high levels of efficiency.

Future Systems

From the above we can extract a number of points that must play an important role in the desing of future systems. They can be summarised as follows: —

1. Automatic capability.
2. Uniform distribution (High application efficiency).
3. Flexibility (Application, area and topography).
4. Low energy.
5. Chemical application ability.

Referring back to the original list of current systems and trying to fit their potential to the above five points. The following systems can be adapted to meet most, if not all, of the important features.

1. Surface Irrigation.
2. Solid/Permanent Set.
3. Boom Travellers.
4. Centre Pivots — low/medium pressure.
5. Drip Irrigation.
6. Linear Move.

Linear moves have been added to this list. The Centre Pivot technology is now being developed into machines that travel in a straight line, irrigating rectangular areas rather than circles.

For the U.K. market this list can be further reduced. Surface Irrigation will not be used, Solid Set and Drip will be less popular because intensive labour will be required to install and remove equipment each year. This leaves the mechanical systems as the probable popular choice.

In the U.K. farming practices have been changed to suit new technology. The trend in irrigation may depend to some extent on the adaption of farms to irrigation equipment rather than the reverse.

A common misconception about mechanised irrigation is that the land must be flat. These systems can be used on sloping terrain. As a generalisation a Centre Pivot can be used on any terrain that can be mechanically cultivated and harvested.

Fig. 2. TABLE OF RELATIVE COST, LABOUR & ENERGY

	Cost index	Labour index	Energy index
Handmove Sprinkler Lines	100	100	100
Surface Irrigation (manual)	90	120	20
Hopping System (Risermatic)	140	75	100
Solid Set	400	20	100
Side-Roll	200	40	110
Rotating Booms	160	M	180
Traveller — Drag Hose	130	30	150
— Coiled Hose	170	20	190
Centre Pivot — Sprinklers	250	15	130
— Spray Nozzles	250	15	75
Drip	400	15	35

Summary

For the immediate future the popularity of travellers will continue, they will probably be front runners for some years to come unless some external pressure, like energy costs, replaces the 'convenience at a reasonable price' factor.

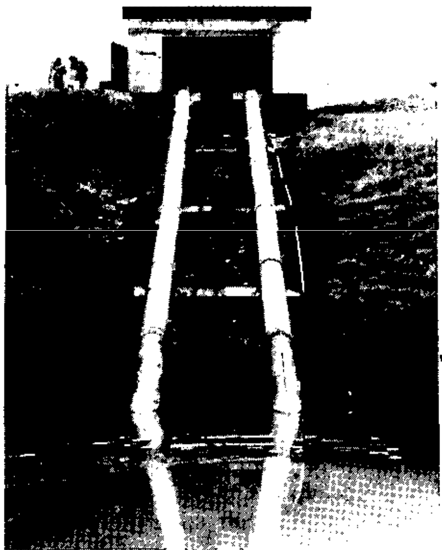
In the long term it would seem probable that mechanised equipment, with low energy requirements, could dominate the market. In the larger farming organisations automation will become essential. Irrigation scheduling and management methods will be of prime importance to ensure that the high levels of efficiency attainable are achieved.

Rapid technological advances have been made in recent years and this trend is likely to continue. Every encouragement should be given for users to increase their own knowledge through technical publications and training programmes. System evaluation must play an increasingly important role in the selection of an irrigation scheme, especially when automation is being considered and .capital investment could be high.

The total irrigation. market will never be satisfied with a single concept. All of the various systems have their place. The panacea may be control of the weather, but until that time man must use his machines. Irrigation will never be an exact science, but it can be an excellent compromise.

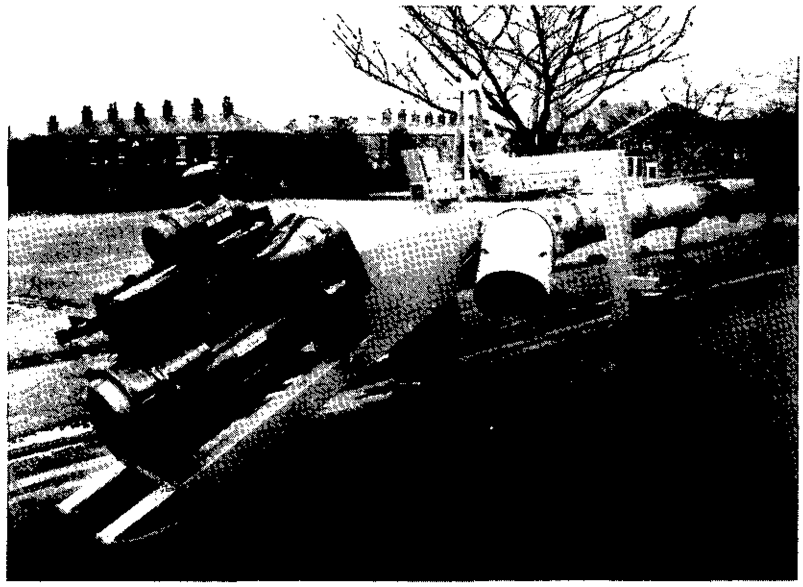
V8-1

NEW! ... FROM MONO PUMPS LTD.



MONAX AXIAL FLOW TURBINE PUMPS

The Monax Axial Flow Turbine Pump for high volume/medium lift pumping, is manufactured by the Water Pump Division of Mono Pumps Ltd, with nearly 50 years international pumping experience. It is ideal for all irrigation, water supply and drainage needs. Designed for vertical or inclined sites, it has low installation costs. Monax has a variety of drives available, with excellent fuel economy, and is highly efficient at all speeds. The range of 4 models will pump up to 8,200m^3/hr per pump, and lift to 50 metres. For further information contact Mono Pumps Ltd, 1 Sekforde Street, London ECI. 01-253 8911.



MONAX MOBILE PUMP

The Monax Mobile Pump for completely portable high volume low lift pumping, is manufactured by the Water Pump Division of Mono Pumps Ltd, with nearly 50 years of international pumping experience. It can be towed behind a car or tractor and can go wherever a tractor can go for all irrigation, water supply drainage, or emergency use at many different locations. It has an integral petrol or diesel engine, or can be fitted for tractor offtake. The 4 models which will pump up to 160m^3/minute for lifts up to 15 metres, with excellent fuel economy and high efficiency. For further information contact Mono Pumps Ltd, 1 Sekforde Street, London EC1. 01-253 8911.

'THE PADI PUMP'

The Padi Pump is an unique portable solution for low cost irrigation and drainage needs in rice and winter wheat growing areas. It is manufactured by the Water Pump Division of Mono Pumps Ltd, with nearly 50 years of international pumping experience. The Padi Pump can be moved easily along muddy banks, it can be used as an outboard on small boats where only water transport is available. Diesel or petrol engines are available, with excellent fuel economy, pumping up to 100 litres/sec with lifts of up to 14m. For further information contact Mono Pumps Ltd, 1 Sekforde Street, London ECI. 01-253 8911.

SCHOOL OF AGRICULTURE, ABERDEEN

THE NORTH OF SCOTLAND COLLEGE OF AGRICULTURE
SPECIALIST DRAINAGE ADVISER

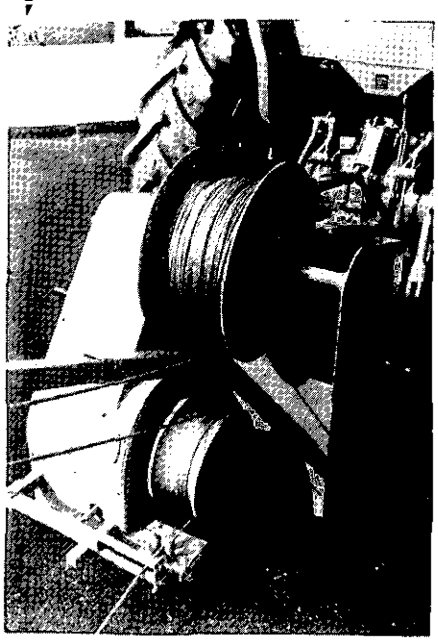
Applications are invited from suitably qualified persons for a new post of Specialist Drainage Adviser within the Agricultural Engineering Division, Craibstone, Bucksburn, Aberdeen. Duties will be in all aspects of Agricultural Drainage with a particular remit to co-ordinate the multi-disciplinary efforts of the College particularly in the advisory context but also in appropriate Research and Development.

Appointment will be to the following salary scale:—

Grade II — £8,029 to £10,095.
with entry according to qualifications and experience.
Superannuation Scheme.

Further particulars and forms of application (reference number 28/80) may be obtained from the Secretary, School of Agriculture, 581 King Street, Aberdeen AB9 1UD with whom applications should be lodged not later than *31st* October 1980.

★NEW!... FROM T. H. WHITE ENGINEERS LTD.

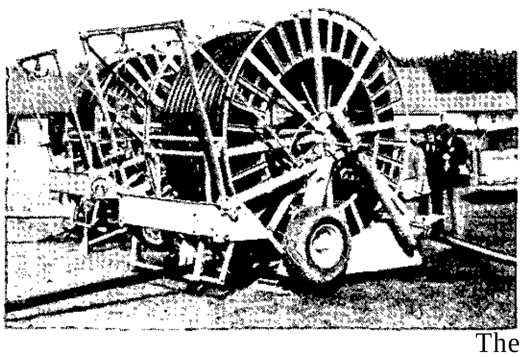


'IRRIGATION WINCH'

To meet the needs of the smaller or occasional user of irrigation equipment, unable to justify the considerable cost of a full scale irrigation system, T. H. White, Engineers, Ltd. have developed a low speed winch for linkage mounting on any tractor. Driven from the tractor P.T.O., the winch is capable of hauling in and storing up to 400 metres of 8mm wire rope, and can be operated to give a constant rope speed in the range of 2 – 14 feet per minute on an average tractor.

The winch will handle loads of up to 30 cwt. and is designed for use with a conventional rain gun and sledge to which water or liquid manure is pumped through a flexible flat hose from a pressure tanker or pump. Priced at £1,300.00, complete with 400 metres of wire rope, the winch forms the basis of a cheap alternative system (particularly where a suitable tanker or hydrant system is already available) and eliminates the possibility of blockage or damage to self propelled irrigators when organic irrigation is required. Further details from the manufacturer, T. H. White, Engineers, Ltd., Vallis Road, Frome, Somerset.

★NEW!... FROM BRITISH & GENERAL TUBE CO. LTD.



'BAUER RAINSTAR IRRIGATORS'

The Bauer range of mobile irrigators is now the most comprehensive available, consisting of 16 machines with piston or turbine drive. An extended sprinkler boom for use with the mobile irrigator is also available for horticultural and other light precipitation requirements. The DHT model illustrated can be lowered on to its base frame using the tractor hydraulics. With the low centre of gravity and held by harrow teeth the unit is stable during operation. The machine can then easily be turned to any desired working position on the rotating frame — a one man operation.

V8-1

Irrigation Programmes

IRRIGATION PROGRAMMES FOR FIELD VEGETABLES

P. C. Rickard is the Assistant Regional Vegetable Specialist, ADAS Cambridge.

We are often posed the question, "What response will I get from irrigating my vegetable crops?" Before we can answer such questions, we need to have a clear understanding of the effects of soil moisture stress on the particular crops under consideration. It will cause less confusion if it is realised that crops do not respond to irrigation; they only respond to drought. In other words, adequate soil moisture can be considered the norm. If there is no possibility of drought affecting the crops, then it is most unlikely that there will be any crop loss and hence it is unlikely that there will be any advantage in applying water. Numerous irrigation trials have suffered misleading interpretation, because it was assumed that the lack of reponse to irrigation indicated that the crop itself was 'not responsive' to irrigation, when in fact the irrigation was applied to a soil that was not short of water.

Before we can decide on the worthwhileness of an irrigation plan in any particular situation we need to know the answers to two questions.

1. Are we in an area of potential drought (i.e. an area of irrigation need)?
2. What is the effect of drought on the crop?

1. Areas of potential drought

Long term studies of meteorological data, including both rainfall and the factors affecting the rate of evapo-transpiration have enabled predictions to be made of the probability of any degree of drought being experienced in any particular part of the country during any period of time. These predictions are assembled in 'The Atlas of Long Term Irrigation Need for England and Wales'. The use of this and other techniques for estimating soil moisture deficits will be discussed later, but in the meantime we can use it as an example by which we may estimate the probability of the crop experiencing drought, and to what degree.

2. Effects of drought on crops

Modern vegetable production is becoming a very precise practice. The primary or secondary consumers damand supplies to a very tight specification. Not only do the individuals need to conform to the required size and shape, but quality must be guaranteed. and most of all the crop must be programmed so that it is available at exactly the right time. Meanwhile the producer must strive to maintain high yields and in particular to be able to secure as much of the crop as possible to remain profitable.

The soil/plant water relations can have important effects on seedling emergence, growth rate, plant development and maturity. It follows that the best economic use of irrigation will be obtained by ensuring that the crop is not suffering from drought during the stage of growth when the ultimate yield is most affected. It will be obvious that seedling establishment is critical; no plants = no yield! Research has also established the most critical phases of crop development, during which the effects of drought have the greatest effect on economic yield andconversely that the use of irrigation would be most worthwhile.

For the purpose of this paper we can divide the whole range of vegetable crops into three broad categories, namely:

(a) leaf and stem crops
(b) root crops
(c) flower crops

(a) *Leaf and stem crops*

In this group we can include the cabbages, lettuce, celery and brussels sprouts. These crops do not have really critical periods. They respond well to irrigation throughout their life, although it is especially essential to avoid drought during the period before harvest, to ensure that high yield of fresh, crisp produce is obtained. Celery needs adequate water throughout the growing period to prevent stringiness and the blackheart disorder. The earlier crops of brussels sprouts need to maintain a good growing schedule, and a good stem length is important to allow sensible button development with easy picking.

(b) Root crops

Root crops, with the exception of potatoes (which are really-a stem crop, after all), have a reputation for being unresponsive to irrigation. Perhaps this is because, given sufficient time they will ultimately all produce their potential yield. It is when crops, such as carrots are being programmed to meet a specified size/ harvest date combination that a period of drought can upset the plan. Similarly, a moist soil at drilling is essential if haphazard emergence is to be avoided. aeain with serious consequences to control of root size. Onions have hitherto suffered neglect in the experimental programme,–and consequently we arr only just beginning to realise the full value of irrigation to this crop. Drought not only lowers the yield, but perhaps of more importance is the effect on maturity. Adequate soil moisture will allow the crop to mature uniformly. This allows harvesting to be advanced, thus leading to improvements in quality.

(c) ***Flower crops***

This group includes peas and beans and is perhaps the most interesting from the point of view of irrigation, because these crops do have such a precise critical response period. Early irrigation will produce agood growth of haulm, without increasing the economic yield. However, irrigation at the beginning of pod swelling can produce large increases in vield without producing much extra haulm. It is difficult to harvest dwarf french beans if the plants are too short, and so it may be advantageous to provide sufficient irrigation to allow plant development for this purpose alone.

During this paper, we have considered the factors which lead to crop losses, and we have discussed the ways in which different crops may respond to irrigation. It is clear that no general recommendations can be made, but that each individual crop needs to be considered in its own situation.

The following extract from the ADAS Booklet ***2067 Irrigation*** suggests specific schedules for each of the vegetable crops.

REFERENCES

Hogg W. H. Atlas of Long Term Irrigation Needs for England and Wales MAFF 1967.
Bulletin 138 'Irrigation'. Fourth Edition MAFF 1974. (Under revision).
Salter P. J. & Goode J. E. Crop Responses to Water at Different Stages of Growth CAB 1967.
Williams J. B. Progress in Biometeorology. Vol. I Swets & Zeitlinger 1975 Booklet 2067 Irrigation MAFF 1979.

Irrigation Schedule for Outdoor Vegetable Crops

Crop	Months in which irrigation pre-sowing planting may be needed	Response Periods: Growth stager at which to water	and rime when they occur	Irrigation plan for 3 soil types* (mm of water at mm SMD): A low AWC	B medium AWC	C high AWC	Remarks
Asparagus							No experimental evidence. Tradition holds that watering is not beneficial
Beans, Broad		a. at early flowering b and pod swelling	Mid-May to early early July	25 at 25+ plus 25 at 25	25 at 25+ plus 25 at 25	25 at 25+	
Beans. French, Dwarf or Stringless	April/May	Early flowering	June to July	25 at 25+	25 at 25+	25 at 25+	
Beans, Runner Pinched or Climbing	April to May	Early flowering onwards	June to Augurt	25 at 25+	50 at 50+	50 at 75	(EX)
Beetroot	April to June	Throughout life	May to Augurt	25 at 25+	25 at 50+	25 at 25+	(OBS)
Brussels Sprouts	May to June (To establish transplanted crop)	When lower buttons are 15–18 mm diameter	Augurt to October	40 at 40	40 at 40	40 at 40	(EX)
Cabbage. Spring hearted	July to August when following another crop e.g. potatoes	20 days before cutting	April to May	25 at 25	25 at 25	25 at 25	One application only at pre-harvest stage (OBS)
Cabbage, Greens	July to Augurt						Watering in fertiliser may be beneficial in a dry spring (OBS)
Cabbage, Summer and Autumn	April to June	Throughout life	May to September	25 at 25	25 at 25	40 at 50	Where water is limited satisfy the SMD up to 50 mm about 20 days before cutting. (EX)
Cabbage. Winter and Savoy	June to July	From direct drilling or planting to early September	July to September	25 at 25	25 at 25	25 at 25	
Carrots	May to June	Throughout life	June to September	25 at 25	40 at 50		Do not irrigate between sowing and 4 rough leaf stage. If large deficit builds up later irrigation may increase splitting. (EX)
Cauliflowers, Earlv Summer		Throughout life	April to June	25 at 25	25 at 25		Where water is limited satisfy the SMD up to 50 mm about 20 days before culling; if more than 50 mm SMD apply 50 mm on all soils. (EX)
Cauliflowers, Summer and Autumn		Throughout life	May to September	25 at 25	25 at 25	50 mm 20 days before cutting starts	As for early summer cauliflowers harvested before mid-September (EX)
Cauliflowers, Winter	May to June	After planting for establishment	July	25 at 40	25 at 40	25 at 40	
Celery. self blanching	June	Throughout life	June to August	25 at 25	25 at 25	25 at 25	(EX)
Leeks	April to July	Throughout life	May to August	25 at 25	25 at 50	50 at 75	
Lettuce, Summer	April to July	Throughout life	April to Augurt	25 at 25	25 at 25	25 at 50	Irrigation before the 4 true leaf stage may reduce plant stand. Irrigation of block raised and transplanted lettuce immediately after transplanting is very important.
Lettuce. Winter		14–21 days before cutting	April to May	25 at 25	25 at 25	25 at 25	One application only at pre-harvest stage.
Marrows	April to May	Throughout life	May to August	25 at 25	25 at 25	25 at 25	
Onions, Bulb Spring sown		Throughout life	May to July	25 at 25			Do not irrigate after July or the ripening of the bulbs may be delayed.
Onions. Bulb Autumn Sown	August	To aid rapid germination		25 at 25+	25 at 25+		
Onions. Salad	April to August	Throughout life	April to Augurt	25 at 25	25 at 25	25 at 25	

V8-1

Irrigation Programmes

Irrigation Schedule for Outdoor Vegetable Crops — *Continued*

Crop	Months in which irrigation pre-rowing planting may be needed	Response Periods: Growth stager at which to water and time when they occur		Irrigation plan for 3 soil types* (mm of water at mm SMD): A low AWC	B medium AWC	C high AWC	Remarks
Other Bulbs and Corms		During season of bulb expansion		25 at 25	25 at 25		
Parsnips	April to May						No experimental evidence but at present irrigation is not advised except for drilling late crops.
Peas, Green. Vining and Harvesting Dry	April to May	a. at early flowering b. at pod swelling	June June to July	25 at 25+ 25 at 25+	25 at 25+ 25 at 25+	25 at 25+ 25 at 25+	(EX)
Potatoes, Early and Canning		After tuberisation reaches 10 mm diameter. For canning from emergence to lifting.	May to July	25 at 25–35	25 at 25–35	25 at 25–35	(EX)
Radish	April to August	Throughout life	April to August	25 at 25	25 at 25	25 at 25	(EX)
Rhubarb		When pulling has stopped	May to September	40 at 50+	40 at 50+	50 at 75+	
Spinach	April to July	Throughout life to August	May to August	25 at 25	25 at 25	25 at 25	
Swedes for Market	May to June						
Sweet Corn	June	Throughout life	June to August	25 at 50	25 at 50	50 at 75	
Turnips	April to May	Beginning of root swelling onwards	June to July	25 at 25	25 at 25	50 at 75	(EX)

* SOIL CLASSIFICATION FOR IRRIGATION

The reserve of soil water available for use by crops varies with texture, stoniness, organic matter content, structure (particularly the degree of compaction), and the depth to rock or other impediments to rooting. It also varies with the rooting habit of the crop, which in turn is influenced by seasonal weather and soil structural conditions. In some localities, the ground-water table remains within or near rooting depth during the summer and contributes an additional reserve.

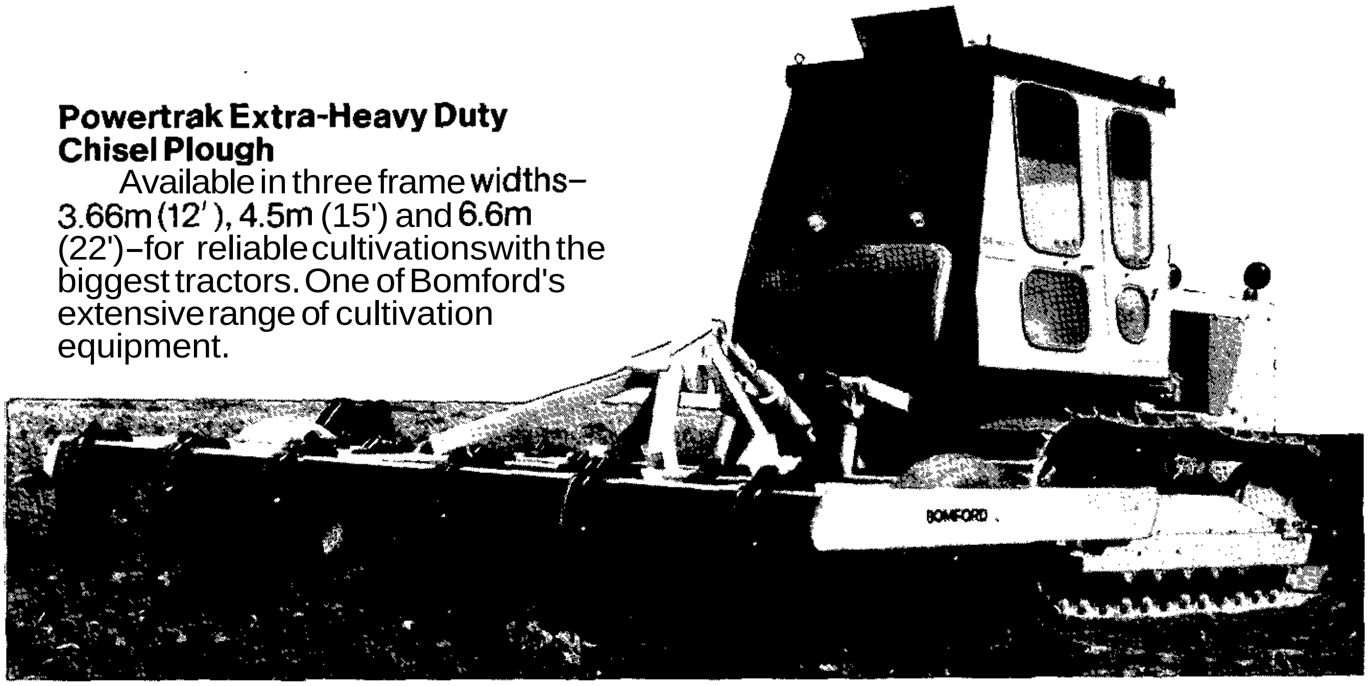
Confronted with these complex field relationships and rather little experimental work, only a broad classification is possible. It is based an the amount of available water within 500 mm depth and is applicable to field and horticultural craps excluding fruit and hops.

Not all the available water is easily accessible, particularly for young plants still establishing their root system. Therefore, varying with crop and its critical growth stages, irrigation mav be recommended when as little as 25 mm of the available water within 500 mm is used up.

Soil Classes of Available Water within 500 mm depth.

Class A Low	Less than 60 mm (in volume terms 12 per cent)
Class B Medium	60 to 100 mm (in volume terms 12 to 20 per cent).
Class C High	Greater than 100 mm (in volume terms 20 per cent)

BOMFORD



Powertrak Extra-Heavy Duty Chisel Plough

Available in three frame widths–3.66m (12'), 4.5m (15') and 6.6m (22')–for reliable cultivations with the biggest tractors. One of Bomford's extensive range of cultivation equipment.

Highwayman Flail Cutter

Available with interchangeable heads for fast and economical grass/hedge control and brush/scrub clearance.

From the World's largest manufacturer of tractor mounted flail mowers.

For land or water management choose **Bomford.**

BOMFORD Bomford & Evershed Ltd.. Evesham, Worcestershire, WR11 5SW.
Tel: Bidford-on-Avon (0789-88) 3383. Telex: 311081.

Published by the Soil Et Water Management Association Ltd.., Editor: P. A. Watkins and printed by Avon Litho Ltd.. Stratford-upon-Avon, Warks.