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SAWMA VIEWPOINT

It was very encouraging to see such a good turnout of members to the Fourth Annual General Meeting which was held on the 27th January, 1978 at Rothamsted Experimental Station.

Members, I am sure, will be interested to learn of the appointment of Sir Emrys Jones as President of the Association. The retiring President, Lord de Ramsey, has, during the last five years, done a tremendous amount of work on behalf of SAWMA which has greatly contributed to the Association's successful establishment.

Other changes took place during the Council Meeting. Mr. R. W. Ward, O.B.E. duly retired as Chairman of Council after a three year period of total support to the aims of SAWMA. Mr. C. V. Dadd, O.B.E., the recently retired Agricultural Director of the Royal Agricultural Society of England was elected. Having worked with Christopher Dadd for some time, I can assure members of a lively and interesting time ahead, not only in SAWMA's programme of events but also in the subject area that is covered.

Mr. Dick Dottridge, for many years the Association's unofficial Vice-Chairman, was, after an agreed amendment to the constitution, elected to this post. A fitting tribute to the enormous amount of work he does in chairing working parties for courses, publicity and many other activities.

Dr. Harry Allen recently retired from I.C.I. Plant Protection Division takes over from Stephen Bond as Chairman of the Technical Committee which plans many of the visits, conferences and events. Thank you Stephen for all your good, conscientious work.

So SAWMA is now under 'New Management', which I am sure has your full support.

Mr. John Day (right) of the Alne Brick Company, examines the clayware tile with Mr. Jimmy Beal in the field where it was unearthed.

The picture above is of interest to all associated with land drainage. The clayware drainage tiles were unearthed on a Yorkshire farm some years ago in near perfect conditions, and are certainly more than 100 years old and possibly of Roman origin. The tiles were discovered when Mr. Jimmy Beal was laying a hard standing around a drinking trough on his Sutton on Derwent farm, York.

Has anyone seen them before, how old are they and who made them?

Irrigation Course

All irrigation users will be interested to know that SAWMA is to hold a course on irrigation practice at the National College of Agricultural Engineering, Silsoe Bedfordshire on the 3rd, 4th and 5th April, 1978.

The course has been designed to fill the need of the people already using irrigation equipment in this country so that they are able, after the course, to use their resources more efficiently and effectively. The course has been made as practical as possible with the second day made up of visits to look at existing irrigation systems, The lectures are being given by college staff and guest speakers, all of whom are used' to talking in the most practical terms possible to maximise the benefit to you.

There are only 28 places available and some of these are already taken. If you are interested will you contact Peter Watkins, S.A.W.M.A., National Agricultural Centre, Stoneleigh, Kenilworth, Warks. CV8 2LZ.

In this issue

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In the last edition of Soil and Water the references for the article 'Why Burn Straw' were omitted. With apologies to the A.R.C. and Letcombe Laboratory they are printed on the left.

Drainage Course News

The second SAWMA Drainage Course was a great success or so the course assessment forms told me after three days of interesting lectures and field work. Besides being very pleased with the way things went, it was also good to see a mixture of people attending from all sides of the industry. The only area which is difficult to give facts about is the cost/benefit of underdrainage – an area where most people know it makes sense, but one where it is difficult to give hard facts. I know that some of the A.D.A.S. Land Drainage Divisions have done work on this but are there any farmers who can come up with some before and after figures on cropping changes and yields?

There has been a decision taken to hold the course again next year. If you are interested, there is already a waiting list to which your name can be added. Contact Peter Watkins, S.A.W.M.A., National Agricultural Centre, Stoneleigh, Kenilworth, Warks. CV8 2LZ.

Spring Drainage Conference

The Farmers Weekly International Drainage Event is on the 11th May at Layer-de-la-Haye, near Colchester, Essex.

The SAWMA Conference will be held at Writtle Agricultural College, Chelmsford, Essex on the afternoon of May 10th, followed by a dinner in the evening. We are now planning the Conference and intend to make the proceedings as practical as possible, by having a gathering for farmers where they can discuss the reasons for, the costs, the Farmers Weekly scheme and after cropping and soil care in practical terms.

If you want to come, places can be booked just by writing or telephoning Peter Watkins.

"HOSTILES AT 12 O'CLOCK– DIVE! DIVE! DIVE!"

SUBSCRIPTIONS

Remember these became due on 1st January, 1978.

To renew your Membership or enrol use the coupon provided on the back page.

Groundwater in Soil

STUDIES IN GROUNDWATER IN SOILS

Dr. **Norman Pizer,** who many of you know is acting as **Soil** Management Consultant to some of the most eminent landowners in East Anglia takes, in the following article, a practical look at some of the ground water problems which have confronted him over the years. As the undoubted authority on this subject I have no hesitation in devoting this journal to Dr. **Pizer's** work.

Water in soils

The properties of soils vary from soil to soil in degree but not in kind. Water is largely responsible for this. It is an active material influencing all properties and processes in soils.

The physical properties of soils are caused and controlled by water, small amounts binding or holding soils together, large amounts loosening or separating them, the water acting like a glue or lubricant according to the amount present and the nature of the soil.

The physical states of a soil are a consequence of its physical properties, its content of water and forces acting on the soil. Among these are the consistency states of hard, harsh; friable, soft; plastic, sticky; and viscous, fluid; so important in soil and crop management.

Water can create order or disorder in the arrangement of soil particles and influence the sizes and shapes of soil structures, fissures and pores. By occupying the spaces in soils, water directly influences aif content and diffusion and so determines whether the biological state is aerobic or anaerobic. Evaporation of water from soil lowers its temperature and condensation raises it.

Because of these considerable effects and because the amount and distribution of water in soils is variable over a field, it is as important to know and understand the water profile of soils as it is the mineral profile.

Some of these effects are well known; others are not. When a farmer walks over his land, among the things he notices are the amount and distribution of water and the effects it is having on the state and behaviour of soils, in low areas, on slopes, and on higher ground. These effects are seldom the same in all parts of the field. His assessment of them determines his choice and timing of operations.

Timing is important, more so for some crops than others and more in some seasons than in others. It tests the skill of the cultivator and can have big effects on yield.

Assessment of water in soils in the field should take into account how it is held and how it moves, its rate of movement and its distribution within the soil and over the field.

How water is held in soils and how it moves through them is well understood. Briefly it is held by forces of tension between the water and the soil and air surfaces with which it is in contact. The structure, porosity and texture of a soil broadly determine the area of contact with the soil. The numbers, widths and continuity of pores and fissures determine the proportion of water that is held or restrained by surface tensions and the proportion that can move freely down pressure or gravity gradients.

The water that can move freely is known as ground water. It is at zero tension or less (under pressure).

The water that is held at tensions up to 15 bars is called available water i.e. available to plants. By this definition it includes ground water. Availability begins to fall off at tensions above 0.5 bars and wilting of many plants occurs above 15 bars.

The consistency states of soils change with water tension roughly as follows:—

Consistency	Hard, harsh	Friable, soft	Plastic, sticky,	Viscous, fluid
Tension in bars	Above 32	32 to 0.6	0.6 to 0.0	zero and below
Moisture state	Dry	Nearly dry to nearly wet	Wet to very wet	saturated

Table I

The tensions favourable to cultivations and bearing strength are on the drier si of the friable state of consistency. Those favourable to water availability are on the wetter side of the soft state and extend into the plastic and sticky states.

Groundwater is a source of water at low tensions to the surrounding soil, above and to the side of it, creating there a range of wetness that is very favourable for water uptake by plant roots but quite unsuitable for cultivation or carrying machinery. In this contrast lies the problem with grc water which is whether to control it so that it does not interfere with cultivations and crop management while remaining a useful source of water to plants or, to lessen its effects much more. The situation, the variability of seasons, and the requirements of management usually decide which it should be.

The rate of movement of water through soils is variable. It is dependent on the widths and continuity of pores and fissures; the slopes or vertical to horizontal directions of fissures; pressure and gravity gradients; temperature and atmospheric pressure; and so varies from place to place in a field and season by season.

In fields that are underdrained, the rate of flow of water from pipe outlets provides information on the rate of removal of water from the area the pipe serves. Usually the rate and duration of flow from outlets varies along a collecting ditch, and neighbouring pipes may contrast markedly.

Rapid discharge of water from pipe drains is not always an indication of sound porosity and fissuring in the soil body i.e. porosity and fissuring that allows high retention of available water and easy, extensive access to it and the soil surfaces by plant roots. Rapid discharge from pipe drains can occur down wide cracks or mole slits, when a dry soil is being re-wetted by rain, with little entry of water into the soil body either because entry and movement of water remain slow until the soil surfaces have been thoroughly wetted or, because fissuring is poor and pores are largely fine and not continous and entry of water is checked by opposing air pressures.

In a fully wetted soil, the latter structural conditions are associated with waterlogging, anaerobic conditions, water held at high tensions, poor access of roots and less available water.

For assessing rate of water movement, pipe outlets with rapid flow indicate that the main drainage channels are open for drainage and further, if the flow is prolonged or nearly continuous, the main areas of water in soils and where much ground water is to be found. Pipes with little or no flow may indicate little or no movement of water in the area they serve, which could arise, in a wet area, from defects in structuring and fissuring and, in a dry area, from good natural drainage.

In fields that are not underdrained or only partly underdrained, the wetness of areas may be judged from where water lies after rain and how long it takes to disappear and for the soil to become workable.

Much more certainty on wetness in soils and its causes, follows from knowledge of the effects of water on soils and through the use of a soil auger and spade in selected areas of a field, to examine these effects.

So valuable and useful is this knowledge, that farmers should have it. It should not be difficult to impart for the limited range of soils found on one farm. It is being successfully imparted, for soils in general, to members of Young Farmers Clubs by the B.P. Soil Assessment Competition.

The farmer has the great advantage of knowing and seeing his land season after season and, if he is able to examine the soils on it effectively, he will know their conditions and how they are changing; he will be able to assess the effects of season and mangement; and to relate soil conditions to crop performance.

While this is not the place to outline how to examine soils in the field, it should be said that soil colours, their relative intensities, uniformity and variability, provide valuable evidence on soil wetness and the movement or stagnation of water in soils. Of great value also is the fact that pores and fissures that can be seen by the unaided eye and are open-ended are ones through which water can move freely and which rootlets can enter.

Groundwater creates characteristic colour patterns where it lies, fluctuates or moves. The kind of wetness that extends from ground water into the surrounding soil or fringe also has characteristic colour patterns, soil porosity and fissuring.

Groundwater in soils

As with other things about soils, there is variability in groundwater and its effects. The more obvious variables are in the area of land affected, the position and depth of the groundwater, the s [illegible] of it, its rate of movement and [illegible]on, fluctuation, pressure and temperature. Less obvious are salinity, iron salts in solution, acidity, alkalinity, hardness from calcium (and sometimes magnesium). bicarbonates and sulphates and seasonal variation.

Groundwater affects a larger area of land than it occupies. Its influence extends outwards and upwards into fringe areas. If a high proportion of the pores and fissures in the fringe areas are connected and are wide enough to drain freely (wider than 0.6mm), the fringe will absorb water from the ground water, the parts nearer to the ground water becoming wettest but not saturated. Such fringes will lose water by drainage where there is a gravity gradient.

It there are few pores and fissures wider than 0.6mm and most are much smaller, the fringe will take in water, hold it strongly and become saturated. Fringes of this kind are not uncommon. Their state may be little changed from that when they were laid down, or the materials in them may have settled as a result of continued wetness or they may have slaked and settled as can happen to materials that are unstable to water.

Impervious fringes can also be produced by the filling of pores and 'fissures with products from salts carried in solution. The most common products are iron oxides and hydroxides from iron salts and calcium carbonate from calcium bicarbonate. These fringes can prevent water passing through, and separate the groundwater from the surrounding soil. They can form on slopes where springs seep through and divert spring outlets, and they can form in the soil next to drainage ditches and prevent water seeping through to the ditch.

Where such fringes lie above the ground water, they can make the soil above them shallow and subject to drought and waterlogging. Improvement should aim to control the groundwater and break up the sealed layer so that crops can benefit from improved drainage, deeper rooting and access to ground water.

Vertical pipes of about 2in. internal diameter are inserted into soils for measuring the depth from ground level of the top of the ground water. Such pipes are known-as dip wells. The water in a dip well reaches pressure equilibrium with water in the soil immediately around the dip well. The pressure at the water surface is the local atmospheric pressure and since this is taken as zero pressure for soil water, the pressure of water in the soil at the same level is zero. Above this level, soil water pressures decrease.

Water at zero pressure or greater is by definition ground water. The level of water in the dip well therefore marks the boundary between ground water and fringe water. This boundary is called the water *table*. It is sometimes more useful to keep in mind that it is, by definition, the place where pore water pressure is zero.

Although in a dip well the boundary between water and air is distinct, the boundary in the soil is diffuse, and water at lower pressures extends into the fringe area. Here the wetness of the soil can vary from saturated and not drainable to unsaturated and drainable, according to the continuity and widths of pores and fissures as has been described. The nature and thickness of the fringe area are therefore important factors influencing the effectiveness of underdrainage. The fringe may need to be opened up to obtain the benefits expected from underdrainage, particularly the benefits of more favourable and uniform soil/water conditions, more soil accessible to roots, an earlier soil for crops and management, and more latitude in timing.

The examples of groundwater in soils that I shall describe are from farmlands in the eastern counties but they are common elsewhere. The landforms range in elevation from a few feet below sea level to under 400 feet. They are variable as elsewhere but are smoother and less steep. Covering them is a range of materials brought in by three or four glaciations and worn down and part redistributed by water and wind in milder periods. Alluvium and peat of more recent origin occur in valleys, coastal areas, the Fenlands and the Broads. All are variable. On farms and within fields they give rise to soil patterns related to the local topography. The area is relatively dry and parts are arid. Wetness in soils must be dealt with but available water retained as much as possible for use by crops.

The studies were carried out to understand and deal with patterns of wetness and dryness which were affecting crop growth, crop and soil management, and the use of machinery, the machinery sinking in or being unable to function properly.

The alternation of wetness and dryness in land affected by groundwater has been [illegible]plained [illegible]d attributed to conditions in the fringe areas. Both wet and dry seasons are made more difficult, the wet years for using machinery, the dry years for crops finding water. Timing for the field may depend on the state of the wetter areas or these may be sacrificed or avoided. Timing for the crop according to its state and needs, as it should be, may result in more soil damage in the weaker areas. Damage has to be put right, at a cost, and severe damage may take two or more seasons to put right. The uneven soil conditions result in uneven crop growth and high yields are not possible. It is therefore most important to understand the causes of wetness and ground water in soils and to deal with them effectively.

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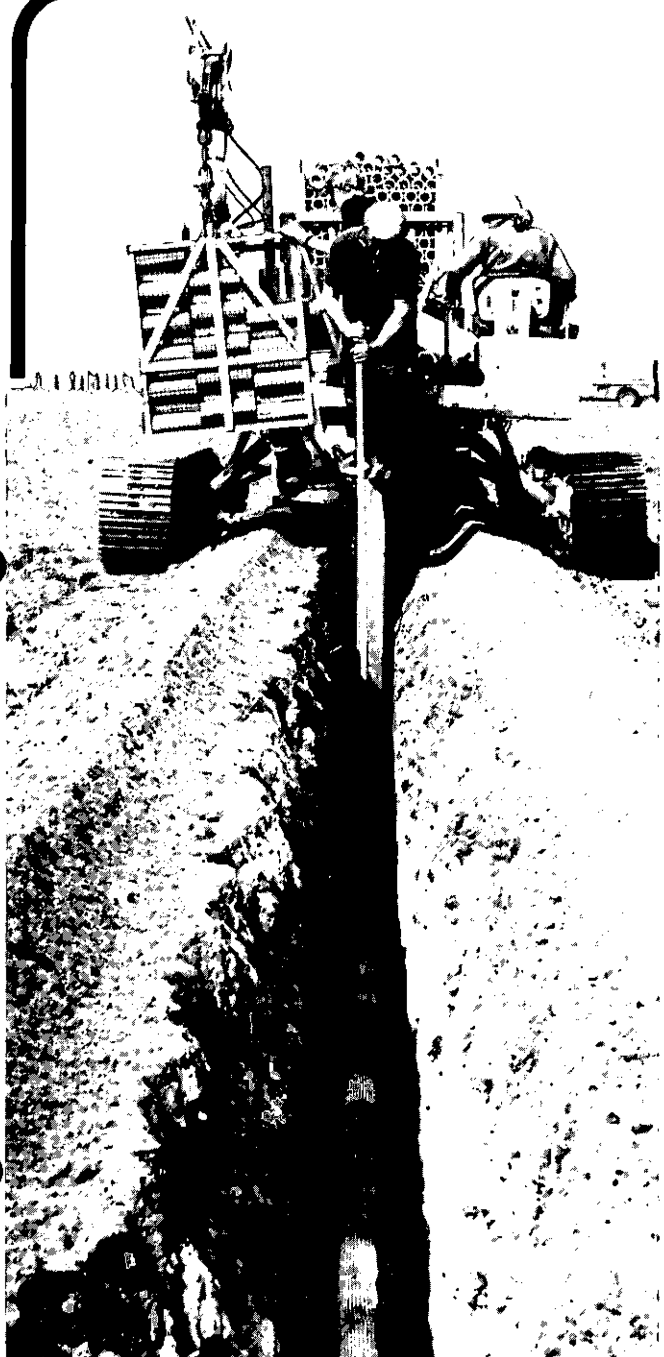

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Groundwater in Soil

Groundwater in soils in upland areas

Bedrock clays, such as the Oxford and London Clays, are impervious to water throughout most of their depth, because of the fineness of their pores and fissures. In the upper few feet, however, just below the overburden the fissures can be wide enough to carry groundwater.

In the summer of 1977, when a new reservoir was being made in a sloping field alongside the Abbots Ripton Brook in Huntingdonshire, the excavation passed through 3 to 5 ft of overburden into Oxford Clay. This was a dark, blue-grey silty clay, moist enough to be just plastic. The surface of the clay was divided by cracks into polygonal shapes 1 to 3 ft across. The cracks were 1 to 2% ins wide but in places widened to 7 in. They extended at least 4 ft down into the Oxford Clay and were filled with moist to wet coarse sand. In some the sand was brown, in others white, and in others heavily rusted. Within the polygons, the clay was in thin layers with a sprinkling of sand between them and sometimes with a collection of narrow white crystals which were thought to be gypsum.

It is fair to assume that this structure of cracks, polygons and horizontal fissures was formed by ground-ice when the ground was exposed to conditions of permafrost, that is long, very cold winters with little precipitation and snow cover, and short, cool summers. During summer thaw, they preserved their form, and coarse sand entered and filled the cracks and fissures. Conditions probably remained dry and ice and snow were mostly removed by evaporation and the sand was blown in.

Groundwater causes bleaching of the soil colours where it moves through the soil and rusting in the fringe areas. These effects, as seen in the coarse sand, imply that water had moved through the areas of white sand for a long time and that the white areas were the channels which the water mainly followed and the rusted areas were its margins.

A different kind of channel for water was exposed along the west boundary of the field. This was a channel in the Oxford Clay about 6 ft deep and more wide, infilled with wet, bleached sand, gravel and some clay. It extended into the higher land and collected local water which ran strongly after the winter rains, and after periods of wetness in summer and autumn.

The overburden also had ground water moving through it. The soil over the mid and upper slopes was a sandy clay loam to sandy clay with angular flints. Soil conditions in it were very variable. There was variation in drainage due to a settled or packed layer, 4 to 6 in thick, which varied in depth, 16 to 20 in. from the surface. Water collected on this layer and seeped down the slope causing increasing wetness.

Alongside the brook the overburden was built up in layers with sand, clay and flints in varying proportions and showing the bleaching and rusting effects of groundwater. The brook had cut down into the Oxford Clay and could only affect the overburden in flood times.

Alongside the channel in the Oxford Clay were similar deposits but more tightly packed particularly from 10 to 32 in. — a very marked fringe effect.

The mid and lower parts of the field were therefore receiving areas for much groundwater coming from a large area of higher land through cracks and channels in the Oxford Clay and, also, for much less seepage water coming entirely from within the field.

The latter and its causes are not difficult to deal with by underdrainage and moling or subsoiling. The large volume of deeper groundwater is another matter. Its effect is to make the soil in and around it fluid. Lowering it to 4 ft by pipes spaced at ½ chain intervals might deal with it except at the times when the brook was in flood. It was probably a wise decision not to try but to use these parts of the field for storing water.

Having found one large infilled drainage channel in the Oxford Clay it is advisable to look for others, for such channels would have drained the surface of the Oxford Clay before it became covered with overburden. An indication of their possible position is given by the red 25 ft contour lines on the 1:25,000 (2½in to lml) maps of the Ordnance Survey. Sharp incurving of these lines towards the higher ground may mark their course.

In February 1975, a section of another infilled channel further east was found on higher ground and its probable course to the Abbots Ripton Brook was followed on the O.S. map. It was carrying water down the slopes and saturating a wide area of land on either side of it. The texture of the soil was a sandy clay loam with variable clay content and as often happens where soils have this texture, large areas in the subsoil had slaked and settled. Further east a similar smaller channel was found. It was not known whether the top of the Oxford Clay was extensively and deeply cracked but this was suspected, for fairly level high ground remained firm while land on the slopes was soft and wet. Deep cracks under the higher ground would aid drainage there but discharge water on the slopes.

One way of dealing with such wetness had been to cut ditches across the slope to collect ground water coming through the soil. Another had been to pipe the obvious wet areas. These could be in the fringe areas and it would be better to locate the actual channel and pipe it. Pipes were added to what had been done, at 2 chain intervals across the slope. It remains to be seen whether they will adequately tap all water channels. In addition compacted subsoil in the fringes and elsewhere was lifted and broken up by close subsoiling.

Similar cracks, polygons and channels in bedrock clay have been seen in the top of the London Clay in Essex. The channels are likely to be common in such clay lands, but the frost polygons if they were formed could have been removed in places by subsequent erosion.

In the hilly areas over the London Clay in Essex, around and south of Braintree, there seems to be more groundwater under and within the overburden than around Abbots Ripton. Some of the ground water appears to be collected from large areas and to move through extensive layers of gravel. These layers of gravel need not be very thick, a few inches can carry a lot of water. They are probably debris from erosion of boulder clay.

This part of Essex is where glacial ice reached its southern limit and it would be much affected by seasonal or longer advances and retreats of the ice. The deposits from an advance would be eroded during the following retreat, leaving a residue of gravel to be covered by the next advance, and this in turn would be eroded and its gravel layer covered over, so forming a succession of gravel layers in the overburden as is found today. The gravel layers may cover a limited area of land or connect with the more extensive and thicker deposits of gravel in the river valleys. On the slopes above rivers, brooks and streams, and in the banks above roads, water carried through gravel layers may break out as a spring or spring line, seasonally or continuously.

Similar gravel layers and springs have been found in the boulder clay country in Suffolk, around Thorpe Morieux and Monks Eleigh and where it borders the Breckland around Livermere. In these areas the bedrock is Chalk.

The ***seasonal flows*** may only occur in some years as happened in 1975 when flows began early in the year and continued into October and November, causing large, soft, wet

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Groundwater in Soil

areas in the fields and awkward problems for management. Their previous activity is recorded in the names of some of the fields, e.g. Rush field lying 50 to 75 ft above the River Brett at Monks Eleigh and the Bog which slopes up 60 ft above the River Brain at Faulkbourne, Essex.

In the years when they do not flow, their possible activity is indicated by a fan shaped hollow in the land just below the outlet and by bleached stones, sand and soil on the surface and to a depth. The fringe area may be considerable and the soil in it compacted through slaking and settling to depths of 24 in. and showing the grey and rust colours of wetness and the pale and bleached colours of seepage. They are wet areas in winter, poor for crops to root in, and in most years, very dry in the summer.

In fields where seasonal flows occur, the rest of the field should be examined for wetness, bleaching and settling and also the land at a lower level, for the outlet simply marks where water is at the surface and it may well be moving through the soil elsewhere. Usually evidence of seepage over a settled layer and groundwater below it, is to be found in the surrounding land. The treatment needed is direct piping of the outlet, systematic piping of the [illegible] g land [illegible] d thorough l [illegible] and breaking up of settled and compacted soil. Direct piping is important because porosity, and fissuring that are favourable to drainage, are destroyed by water in the fringe areas making it impossible for a pipe placed there to be reached by water from the spring. Breaking up compact soil is also important for roots to enter it thoroughly and its available water to be increased. How this should be done is often decided from experience or trial and error. Where the texture of the soil is a sandy clay loam or sandy clay, gradual breaking from the top downwards is the best, with tines working as close as 12 to 24 in.

The soil evidence on Rush field was that much of the field had both seepage and groundwater moving through it after wet periods, which would usually be the winter months, and in some years the groundwater rose high enough to spill out in places over the surface. When the field was in grass, rushes probably grew there and gave the field its name.

In the Bog, the source of. water seemed much larger and the water moved through at least two thin gravelly layers in a loam of brickearth type. The effects of groundwater had gone further than in Rush field, producing in one area a bleached, compact subsoil, which was strongly cemented by deposits of calcium carbonate and the rust and black bydroxides and oxides of iron and manganese to a variable depth in a layer between 6 and 18 in from the surface. The topsoil was black from a residue of peaty organic matter indicating a former state of wetness. In May 1974, grass growing in this area was stunted and withering, the topsoil was powdery dry and the subsoil dry and hard as concrete. A short distance away groundwater was found at 30 in. In September 1975, the dry area was moist and the nearby area discharging water over the surface. It seemed that water formerly coming out in the dry area had been diverted. Water also came out strongly lower down the slope. As in Rush field, the main water flows needed piping and the slopes piped and subsoiled, but a much harder cemented area had also to be broken up.

In some areas where groundwater is carried in underlying gravel, there is useful purpose in having underdrains at two levels, a deep system to control the water in the groundwater and another at 3 to 4 ft to drain the soil. A field near Livermere, Suffolk, has this. The deep pipes were laid over a century ago and in some years discharge water continuously.

Groundwater. with much calcium bicarbonate dissolved in it, has a so been found in land north of Hatfield Peverel, not far from the Bog. In ditch bottoms, a hard smooth deposit of calcium carbonate can form under drain outfalls and silt in the pipes can be firmly bound together by it. This probably happens in the summer months when the rate of water flow is low and the higher soil temperature causes the groundwater to lose carbon dioxide. It seems to happen in and just behind outlets mostly, which is where soil temperatures around the pipe would be higher. Eventually the outlet becomes nearly closed, water builds up behind it and saturates the surrounding soil and the less wet, firmer soil around the outlet then falls away towards the ditch, taking the outlet with it. There seems to be no solution to this problem, other than increasing the gradient of the pipe to check silting and increase the rate of flow when water in the pipes is low. Where this is not possible, regular rodding of the outlets before deposits harden is needed.

Where a slope on boulder clay is bounded by a stream, there is usually an area of alluvium and wind-borne materials alongside the stream with fine sandy loam to silt loam' textures which lie on a stony or gravelly bed through which ground water flows. The area also receives run-off and seepage from the slope which varies in amount and rate of arrival according to rainfall, the state of the slope and the crop growing on it. With potato ridges up and down the slope the rate of run-off can be fast.

The groundwater causes the bleaching and fringe effects already described. The seepage creates another fringe where it enters the area, in which the soil can be slaked and settled. The run-off can cause slaking

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of the topsoil. The soils have some of the properties of brick-earths. They drain well unlesscompacted, but hold much available water at low tensions and their bearing strength can then be much lower than the clay soils on the slopes.

The width of this alluvial strip is important. The wider it is the more it is able to accept water from the slopes and dispose of it without settling or slaking. Where it is wide, the fringe at the bottom of the slope forms a distinct area in which the soil will hold much water and machinery will sink in, when other areas are sufficiently firm. Where it is narrow, the seepage and groundwater fringes can be continuous and check drainage, and water may saturate the soil and lie on tap.

Added to these problems are those resulting from use of the strip as a headland. It may not be possible to master the but they can be lessened by control of vater and seepage and opening up the fringe areas. Seepage can be checked by improved underdrainage and opening up of the soils on the slopes. Groundwater can be lowered by lowering the ditch or stream bed, if this is possible, and it can be diverted to the stream by pipes laid across the strip. I have found pipes-spaced at ½ chain intervals to achieve this which were put there a long time ago. They did not remove run-off very well because of slow drainage through the overlying soil. They would have done so better by being covered with gravel to the bottom of the topsoil and keeping the latter open — difficult to do in some seasons.

When an alluvial strip alongside a brook also receives groundwater from sand ınd gravel sheets or channels under the slopes, the problems of control and management become much more difficult and extend over the sloping areas of the field.

All these problems, in many forms, are to be found in land between Livermere and Ampton, Suffolk. Here a brook, which drains Ampton Water and flows on to join the River Lark, separates the Boulder Clay upland from the Sands of the Breckland. The slopes on either side have sandy and silty deposits on them which are very unstable to water. In the fringe areas around springs they can become fluid, particularly on the sandier Breckland side. When the flow of water lessens they can settle into a massive state through which water drains very slowly. Drain pipes placed in the fringe areas can be ineffective. They must tap the channels and areas where water flows. Alongside the brook are deposits of gravel, sand and silt in irregular layers or spreads and in the lowest part, which may formerly have been a lake, is a cover of several feet of peat. At the base of the peat, flint gravel is to be found shattered as though by intense cold.

Until 1973, the iower ground was under water and the slopes very wet and the whole area was covered with trees and scrub. Reclamation began in 1973. The story is one of mastering groundwater, beginning with straightening and deepening the brook, dividing the land into areas, and dealing with wetness in them stage by stage. I will describe only one difficult problem, which has not already been mentioned.

In 1975, the year the groundwater flowed strongly, some areas became very wet. Underdrains in the peat area and cut-off drains in the sandy and silty areas bordering the peat seemed unable to collect and take the water away. In the peat area, you walked carefully for it was easy to sink in. Below 10 to 12 in. the peat was fluid and in places quick. The latter condition indicated that strong vertical springs. were coming up with sufficient pressure to separate the silt and peat and allow them to float.

In 1976, a deep trench was dragged out where the peat had been quick and the bottom filled with stone and large rubble and the peat returned on top. Th: has given firmness and bearing strength to the peat above. As an afterthought, its action was to spread out the area of the head of the spring and so lessen the upward pressure of water in the overlying peat, as well as providing a channel for water to drain to the brook.

Groundwater in soils alongside estuaries & in coastal marshes.

The land in these areas is never quite flat. It rises and falls by a few feet and has hills, valleys and hollows that were shaped by flood waters from the upland and from the sea. It has received water from these sources for a very long time. Water would be its main element without banks to contain rivers and streams, walls to keep back the sea, internal drains to collect and carry water away, and means to control water levels.

The land was built up in layers from materials deposited by wind, by rivers and by the sea. The deposits may be gravels, sands, loams, silts or clays. The pattern of their distribution was determined by the relief of the land and the flow of water at the time, and changed as these changed. Deposits may change from coarser to finer and conversely. Some or all of them may be permeable to water. Evidence of the-influence and action of groundwater is common.

Former surfaces of the land may be marked by a peaty layer and the buried drainage channels of these surfaces may still carry land water to estuary or sea, or saline water in the reverse direction. Buried also, may be isolated sections of these channels and former pools in which water still ponds.

The changes in the land surface and variations in the nature of the deposits and in the distribution of groundwater at different levels, produce a diverse pattern of soils and soil conditions. Each field or enclosure needs individual study and treatment to lessen differences for crops and management. Fortunately, with good underdrainageand deep cultivation or subsoiling to open up compacted layers, the problems and effects of groundwater are greatly diminished and arable crops can be grown an high yields obtained.

Many of the problems with groundwater are similar to those on upland soils but on a larger scale Of importance to crops and management are differences in fissuring in apparently similar materials deposited side by side. They can result in parts of a field being well-drained and other parts slow draining and holding water strongly. Sometimes the contrasts are between neighbouring fields.

The silty clay loams and silty clays provide marked contrasts of this kind. In one part of a field, the subsoil can be in stable polygonal shaped columns which are well-fissured and separated one from the other by fissures that remain drainable when the soil is fully wetted. In other parts of the field, the structure and fissuring can appear to be basically similar, but the fissures are generally much finer and few are drainable. When the soil shrinks on drying, wide cracks appear around large blocks of soil in which the soil is tightly held together.

It is possible that the poorly fissured soil is a deteriorated form of the good, — for the latter is the one seen forming in outmarshes, — and deterioration is a result of a wetter state and gradual settling of the soil into a compact condition. It could be that settling began in a fringe area above ground water, and above the fringe wetness developed from impeded drainage and was followed by slow settling. This situation has been found.

From the idea of deterioration follows the idea of reversal of the process by lifting up the soil and giving it sufficient volume for fissures to become wider and drainable, but having first provided good underdrainage. Lifting and breaking is best

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done in stages from the top downwards as already described and may be necessary because of the strength of the soil. Subsequently, lifting and breaking may be done by a machine working at 3 depths. It should be done as deeply as possible. Up to 3 ft. seems possible with suitable power and equipment and for this pipe drains need to be at depths between 3 and 4 ft.

In some of the clays in marshland areas, the fissures around and within the polygons are found to be partly filled with a deposit of yellow ochre containing sulphates and oxides of iron. The ochre and the soil around it can be intensely acid and some of the acidity can be acquired by the groundwater. An example of this was recently found in the bottom of a deep ditch newly dug in the marshes around Coleward, east of Burnham-on-Crouch, Essex, but there have been others.

The acidity is due to oxidation of iron sulphides in the clay to sulphuric acid which moves into the groundwater unless there is sufficient calcium carbonate in the soil to neutralize it. In the 1950's groundwater, with pH between 1 and 2 due to sulphuric acid, was found bordering a marshland area near Dersingham, Norfolk. The groundwater made the overlying soil extremely acid and neutralized applications of lime. Where it broke out as springs it left reddish brown deposits of iron hydroxides over the ground.

The problem of soil acidity can only be dealt with by preventing rise of acid groundwater into the soil. This was not possible at Dersingham. At Coleward, soil acidity was not a problem. The source of acidity was 6 to 8 ft down and deposits of brown ochre had filled and sealed at least 12 in. of the overlying material, thus containing the acidity below this level. It is possible that this happened a long time ago and much of the overlying material has been deposited since. The groundwater and the underdrains were above the brown ochre layer and isolated by it from the underlying acid clay. This is a situation where ochre deposition is beneficial and where the ochre filled layer should be preserved unbroken.

Iron sulphides are formed in marine clays deposited along a shoreline. Very acid marine clays, contributing sulphuric acid to the groundwater, underlie many parts of the Fenland, according to where shore line conditions existed when the clays were deposited. Two of the bedrock clays, the Oxford and Kimmeridge clays, may also contain iron sulphides and generate acid areas. The materials over these clays, may he sand and gravel, silts, clays or peats. Ochre layers and ochre cemented layers have been found at the base of them and high acidity in the material above the layer. In sand and gravel, the cemented layers can be very hard and difficult to break. In peats, deposition of ochre makes the peat brown and drummy (meaning dry and difficult to wet):

The rate of production of sulphuric acid depends on the amount and distribution of iron sulphides in the clay and whether, through lowering of the groundwater, air reaches them. Examples were found in 1974, where only the top 7 to 12 in. of clay was highly acid and the sources of acidity apparently exhausted. It is probable that oxidation of sulphides began when the marine clays emerged as marshland and remained active until they were again submerged, and the process was re-started when the fens were drained.

The process and its effects become of importance in farming when they affect the top 3 to 4 ft of soil. In the 1950's, examples were found when examining areas where soil acidity was high and returned soon after liming because the groundwater was acid. In these instances, the high costs of controlling the groundwater and of liming, and uncertainty on the extent and activity of the sources of acid production, prevented reclamation being attempted.

Other instances have been found where acid water discharged from underdrains, but only the soil below 33 in. was highly acid and normal liming could be expected to keep the top 33 in. safe, even for sugar beet, though confining the roots of crops within this depth.

In the peat areas, examples will certainly be found where wastage of the peat brings marine clay near to the surface and acid soil comes within ploughing depth. In one found recently, 12 in. of peaty loam, rested on 6 in. of very drummy peat and this on 7 to 12 in. very acid clay underneath which was a chalky clay. Here the treatment proposed was to use a soil mixer at a depth of about 3 ft and mix chalky clay, acid clay and very drummy peat together and so deal with acidity and create a more favourable subsoil in one operation.

Not all ochre filled layers that are found restricting root development in Fenland soils and causing uneven growth and drought in crops are associated with acid groundwater, though they may have been when they were formed. In many areas, the groundwater is calcareous and most useful to crops if their roots can reach it or the fringe above it. Here again the action of a soil mixer is needed to break through sealed layers and mix useless and useful soil together and provide a mixture that is favourable for roots to grow in. Where this has been done, crops have grown evenly and finished well. In a peat in Soham Fen, two crops in one year were made possible by the improved water profile.

Sometimes the groundwater is

saline. In a boring recently made near Benwick, saline water with a pressure head of 10 ft was reached at 23 ft under 8 ft of drummy peat and 15 ft of silt and clay over the peat. Here the drummy peat was an effective seal against water and salt rising into the overlying silt. The site is 24 mls from the sea and its elevation is either just above or just below O.D. One wonders how extensive the saline water is and where it comes from. It may come in from the sea along a buried former channel of the River Nene. In the silt areas of Holland, Lincs, much nearer the sea, saline groundwater has been found in ditches and affecting growth of crops in glasshouses.

With wastage of the peat areas, the flatness of the land gradually changes to the relief of the mineral deposits under the peat. This is seldom flat but has slopes, hollows, hills and valleys through which drainage is no longer fairly uniform and simple. Water levels in ditches and drains must be lowered to control groundwater generally but within fields new problems with water arise which are similar to those on upland mineral soils. On slopes there are problems of run-off, impeded drainage and seepage. In hollows, there are problems of impeded drainage and ponding. In addition are the problems arising from a pattern of mineral soils of different- textures and behaviour to water, a pattern that roughly follows changes in the relief.

New systems of underdrainage must be introduced to cope with these problems and ways considered for maintaining high yields and lessening management difficulties.

In favourable situations, it is possible to restore the advantages of level land, nearly uniform soil and water profile by the operation of levelling. In studying land for this purpose, water retention, drainage and movement in the different areas of the field must be judged and the prospect for and the method of obtaining near uniformitv in these water properties assessed.

One favourable situation is where the higher ground is a stable light to medium silt which carries groundwater and the lower ground is a well-fissured silty clay loam or silty clay; over the field the effects of groundwater are-little or no benefit on the ıighe 1; crop benefit aı c some nana problems on the slopes; and wetness from run-off and seepage on the lower ground.

The objective is to extend the favourable water properties of the light to medium silts and the favourable groundwater effects over the whole field and to leave a level surface.

This is done by stripping off the topsoil, levelling with the light to medium silt and restoring the topsoil. If there are structural defects in the top of the heavy soil in the hollows these should be remedied before it is covered over and also any compression of the levelled surface before the topsoil is put back.

It is a job to be started early in autumn when the land is dry and completed before it becomes wet. If, as in 1976, September is very wet, completion should be left to the following spring. The skill and experience of the man doing the job are most important. He can be helped by having levels marked, but choice of the part of the field to work in day by day and the amounts to move rests with him, as also does the evenness of spreading of the topsoil.

Ideally underdrainage should follow with pipes laid so that they could be used for sub-surface irrigation.

The land should carry a crop with a good root system during its first winter; winter wheat and winter barley are both suitable. Decision on the crop to follow and on cultivations can be left until the first crop has been harvested and the problems, if any, are known.

In these notes I have describe many situations where water and groundwater in soils need to be studied and understood and have indicated ways of dealing with problems. I hope that I have also shown, what is too often forgotten or ignored, that fields are variable but also individual pieces of land and need individual study to meet the requirements of management and get the best from them.

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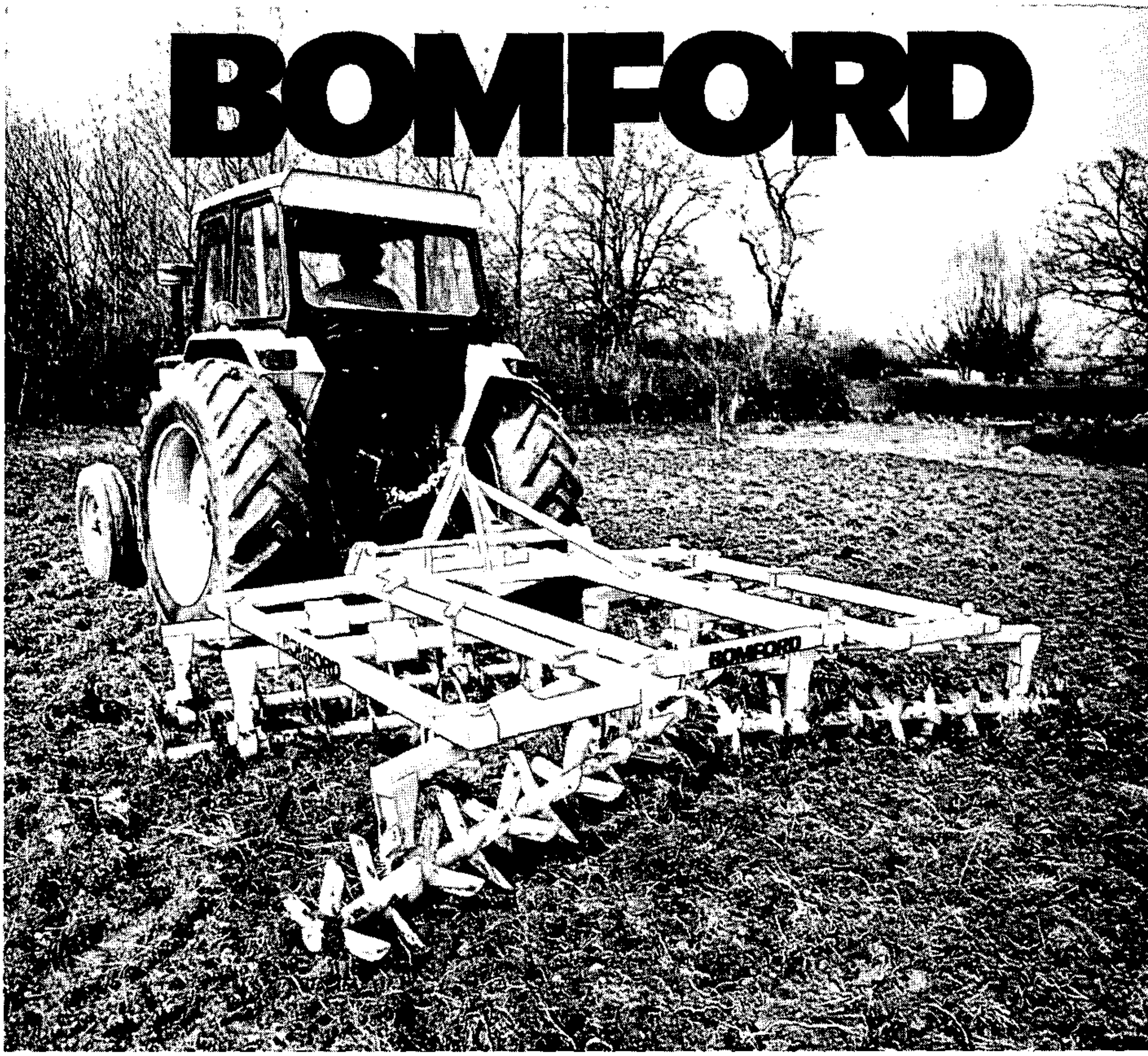

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