DRAINAGE AND SOIL

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PART

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Design of Piped Subsoil Drainage

IN the costs of soft landscape works that of under-drainage can often be the most expensive single element; it must be desirable in these circumstances to be able to design within small limits and to be able to justify the costs with reference to some critical method and recognised criteria. Alas in this scientific age this is one area in which empiricism has not yet fully given way to scientific method. The design of field drainage systems is still considered more as an art than as an exact science, although there have been many attempts to give mathematical exactitude to it.

In 1934 J. L. Russell[8] was saying " it must be concluded that the mathematical formulation of the movement of ground water to drains is of doubtful validity and that while it may have some practical application in homogeneous light soils it has none in heterogeneous or heavy soils."

In 1942 Nicholson[4] confirmed this " because of the uncontrollable and erratic variables which influence the final result ". As he said " given flat ground, a level water table, a soil uniformly permeable from surface to depth and rain falling at a steady rate it is possible to work out depth and distance apart, which will keep the water table from rising above a certain height midway between the drains ".

And of course this was only a discussion of water table problems—in clay lands water tables do not exist and there is an entirely different set of variables to consider.

In more recent, 1959,[9] American textbooks, the statement is made that " no method has been developed which is satisfactory for all areas ". However, there are solutions for some specific conditions and a study of these textbooks[3 9 11 15] and also in the few Russian translations some answers are given to enable mathematical solutions.

If you are seeking economic and/or optimum design the new textbook *Techniques of Landscape Architecture*,[7] 1967, will not help very much. Tables of depth and distance are given there with ranges over very few soil types; for instance, " in clay—4 yards to 7 yards apart " that is 1,210 linear yards to 691 linear yards per acre, which costed at 10s. equals £605 to £345, a difference of £260 per acre. In " sand " the variation is 403 linear yards to 220 linear yards or £202 to £110 per acre, a difference of £92 per acre. Which then do you choose, and upon what basis —the upper or lower limits? Is there a landscape designer in the country who has dared to face his client with a bill for £605 per acre for lateral land drains, plus mains and outlet costs? It is clear to me that recommendations of this nature are not helpful in design as they are only based upon the roughest and vaguest classification of soil in terms of clay, sand and loam and can only lead to excessive and wasteful work.

The table in *Soil and Water Conservation*,[9] page 324, is more helpful because it adds another dimension, namely " relative permeability " which is a much more realistic measurement than a bald description of soil type.

In this connection I would draw attention to the table in *Code of Practice* 2001 which lists the " Classification and Characteristics of Soils for Roads and Airfields ",[2] not because the classification is of much use to us as it treats soil as an engineering material, but because it shows a column of " Drainage Characteristics " of some soils under divisions of " excellent, good, fair, poor and practically impervious ", and I would particularly remark on the following list:

" *Practically Impervious*

—Well-graded gravel with small clay content.

—Gravel sand mixtures with excess of fines.

—Well-graded sand with small clay content.
—Sands with excess of fines.
—Clayey silts (inorganic).
—Organic clays of medium plasticity.
—Highly compressible micaceous or diatomaceous soils.
—Organic clay of high plasticity."

Consider the "range"—from "well-graded gravels, etc., gravel-sands, sands with clay, sands with fines, clayey silts, organic clays, etc." and compare these "practically impervious" soils with the bald classifications laid down in agricultural and landscape textbooks which recommend the spacings of drains under three or four headings based upon such impossible terms as clay, loam and sand with consequential expenditure varying from £100 to £600 per acre. By far the most difficult soils to drain are the "silts" and these are not distinguished sufficiently in *Techniques of Landscape Architecture*.

Such empirical tables are no substitute in drainage design for carrying through a series of in situ investigations before making decisions as to depth and spacing —firstly with the geological and soil maps available; secondly looking at a profile of the soil to identify its general drainage characteristics by cracks, colours and depth of roots; thirdly assessing permeability if necessary by laboratory tests; fourthly comparing the soil profile with some other known soil which has been drained (the Ministry of Agriculture's drainage officers can often assist here); fifthly by finding out if the land has been previously drained and what has happened to them; sixthly finding out what is actually causing the condition of impeded or unsatisfactory drainage.

I must quote a remark made by R. A. Walpole (Drainage Officer for Yorkshire) who in a discussion at Askham Bryan Agricultural College in 1966 said: "For many years we have been aware of the main problem confronting us in the

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design of land drainage schemes; this is basically the lack of comprehensive investigations into design of schemes, their relation to results, and the degree of control of water obtained. There is a dire need for some standard pattern based upon statistical results."

I can see some light being shed on this subject in the not too distant future. Many soil researchers have been looking critically at what is called "the permeability" of the soil—using the term qualitatively "to represent the quality or state of a porous medium related to the readiness with which it conducts or transmits fluids". This can be measured by what is called "hydraulic conductivity" which is usually stated in cm./sec., in./hr. or ft./24hr. and which is abbreviated to "k" in much the same way as acidity or alkalinity can be indicated by "*p*H".

My studies of the literature of this has led me to the tentative conclusion that there is some hope in this direction. In 1954 Visser in the Nederlands proposed mathematical solutions for homogeneous soils using "hydraulic conductivity" as the basic measurement, and he produced some formulae for it. Others, notably O'Neal, Smith and Browning,[10] have produced tables. And Luthin[11] in the latest American textbook 1965, *Drainage Engineering*, says "It is now possible to design drainage systems based upon measurable soil properties".

Mains and Outlets

It will not be necessary to spend so much time on the references to the design of mains and outfalls because the practices are well documented and mathematical solutions are well tried. *CP* 301 and 303[12] give formulae for rainfall and run-off and guides as to the factors to be taken into account in "areas of buildings, roads, paths and parks, gardens, lawns and wooded areas". Refinements can be found in Road Research Technical Paper No. 55[13] which also lists many references.

For areas entirely soft landscape a good guide to sizes of outfalls and mains can be obtained from the table in "Land Drainage Notes No. 3"[14] of the Ministry of Agriculture. Although here you will have to make decision as to the selection of the "Coefficient" or the amount of water to be removed in 24 hours. In doubtful cases in Kent we use 1 in. in 24/hr., but ½ in. for low rainfall areas of North Kent is probably adequate bearing in mind the large graduation in sizes of standard pipes from 3 in. to 60 in. in steps of 3 in.; usually it is easy enough to allow for safety margins in areas which include hardened urban development or where flooding cannot be tolerated.

For some information as to the design of soakaways and boreholes there are some notes in "An outline of Field Drainage with special reference to the Drainage of Sports Fields",[19] which I wrote for the N.A.G. in 1960.

Some Notes on Soil Types

I have mentioned above some of the pitfalls in designing inherent in the crude classifications of soils—which it would be well for landscape designers to be aware of. No study of this aspect would be complete without some reference to the sources of information on soil physical features. One of the simplest and in my opinion best books is *Good Soil* by

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Brade-Birks. He reminds us that classification can be made in soil series (general) soil types (species) and soil phases (varieties) and also that for the general purpose of recognition of texture he lists 18 classes. We need now a further classification of these phases into permeability classes with figures for hydraulic conductivity. As I mentioned above, engineers have already attempted this, but their general classification is not altogether helpful for those who deal with soil as a living material.

" It may be objected that such a multiplicity would be confusing, but in other sciences no one attempts to reduce complexity by calling two substances by the same name to reduce the complexity of the diversity. In entomology, for instance, there are 3,000 species of beetle but not one would suggest that in order to avoid confusion in speaking of them, three or four species should be combined and called by the same name."[15]

Proper Description

One of the most important hurdles yet to be overcome in the sphere of field drainage design is the inability of those who talk about their soil, to properly describe it so that accurate comparisons can be made of the effects of various techniques. There is, for example, a general impression that permeability progresses from good to bad as one goes from coarse sand, to fine sand, to very fine sand, to loamy sandy loam, sandy loam, loam, to silty loam, silt loam, silty clay loam, clay loam, clay; this is just not so and I showed above how engineers have shown that the characteristic known as " practically impervious " relates sometimes to " well-graded sand with small clay content ", " sands with excess of fines ", " clayey silts ", " organic clays ", etc. In my experience the worst soils in Kent to drain for sportsground purposes are not the clays at all, but the silts. Indeed one of the most intractable of all is miscalled by the geologists " Tunbridge Wells Sand " (part of the Divisions of the Hastings Beds), in which the silt fraction is of the order of 65 per cent., and clay 20 per cent.—it is by Brade-Birks' scale a silty clay loam, with a permeability of 10^{-7} cm./sec., which borders on the " practically impervious " range.

A further factor also intervenes to confuse the issue in drainage design criteria for such a soil. It is well known that certain clays, which Nicholson[4] lists, some of the Boulder, London, Gault, Kimeridge, Ampthill, Oxford, Weald, etc., can be successfully mole drained especially where the textures lie in the regions of 45 per cent. clay and less than 20 per cent. sand (and even some success is likely where the fractions are between 35-45 per cent. clay and 20-45 per cent. sand). Now where such clays can be mole drained the cost of the operations is very low, but the silts cannot be so mole drained at all and the costs of tile draining them are highest of all because piped drains are most often essential and what is worse, silts are easily transported by running water and the life of the piped system is often short.

I am supported in my thesis here by a comment by E. Crompton of Kings College, Newcastle on Tyne. He says,[17] " In the matter of soil physical properties clays are not the most difficult. Soils with a high proportion of silt can be much worse; the small hard particles, often platy in character, can pack closely together leaving only very small spaces. A small amount of clay may be sufficient to bind the particles very tightly when dry and may effectively prevent aeration when wet. The most striking example of this problem can be seen in the Dombes region of France where a soil with almost 70 per cent. silt and only 13 per cent. clay appears to have defeated all attempts at orthodox management—it is cropped for a year or two and then flooded for use as a fish pond, after which another year or two of cropping is possible in the residues on the lake floor."

The point I am making I hope is that in the present state of our knowledge some silts cannot be successfully drained and we should not pretend to do so.

In this connection see pages 355-356 of Russel's *Soil Conditions and Plant Growth* for a description of silty soils which cannot be said to possess a " field capacity ".

Materials and Mechanisation

If we have sufficient time I will conclude my talk by a reference to the strides which have been taken in new material and machines recently. Here the developments are tangible. In the last five to seven years we have seen a number of new pipes made of p.v.c. plastics, pitch and bituminous fibre, and so on. Early hopes that these might drastically reduce prices of finished work have not been realised, but they have helped to stabilise. Prices for drainage work have not risen very much in recent years.

The new pipes have many advantages mainly on account of their light weight and ease of handling and laying; additionally they are useful in difficult ground conditions such as running sand and peat, because they are made in long lengths of between 20 ft. and 660 ft.; they are as little as 1/30th of the weight of clay tiles.

Some of these pipes are:

(i) 2 in. and 4 in. " Lamflex " of p.v.c.; 660 ft. of 2 in. weighs 84 lb., and can be laid by a modified mole plough and D7 tractor.

(ii) 2 in. " Carag " of polythene in 20 ft. lengths—less than 4 lb. weight per length; also in $3\frac{1}{2}$ in. size. Can be laid like tile.

(iii) 2 in. " Landcoil " of polythene in 660 ft. lengths weighing $1\frac{1}{2}$ cwt. per coil. Needs special machinery to lay it. Also available in $2\frac{1}{4}$ in. size.

In considering design of schemes with these pipes, reference should be made to the *Notes and Codes of Practice* issued by the Ministry of Agriculture Land Drainage Division,[20] which lists permissible lengths of laterals, methods of laying, materials for gravel envelopes and so on. In my opinion the days of the clay tile are numbered.

In the sphere of mechanisation the development of such new machines as the latest Allen heavy Drainer costing £6,000 reaching a speed of 40 ft./min. (half a mile an hour) with automatic placing and laying drains down to 54 in. Such machines are specialist contractors' tools, and when used with hopper feeding for gravel backfill and envelopes, new light pipes and trained men, costs will be kept level for some time to come.

In the lighter machines for small schemes and for maintenance such implements as the " Ditch Witch ", " Trench Devil " and less exotic-named Davis T66, cutting about 10 ft./min. are most economic. The great advantage of these machines is their ability to cut narrow trenches for the new narrower pipes and so show considerable savings on labour and more particularly when gravel backfill is used, trenches of 3 in. to 4 in. give substantial economies.

The introduction of the McConnel-Thornton-Garnett pipe feeding mole-plough may revolutionise under-drainage of new and established sports fields in the future, when the principles can be properly evaluated and ancillary gravel feeding equipment can be brought into use.

Reference to Textbooks and Papers referred to in the Text:

The second and concluding part of a talk given to the Architectural Association for Advanced Studies in Environment, May, 1968.

[10] " Relation between Soil and Water, " ed. T. J. Marshall, *Technical Communication No.* 50, Commonwealth Bureau of Soils.

[11] *Drainage Engineering*, ed. J. N. Luthin—American Society of Agronomy.

[12] *British Standard Codes of Practice Nos.* 301 and 303.

[13] " The Design of Urban Sewer Systems, " Road Research Technical Paper No. 55, H.M.S.O.

[14] " Monograph of Discharge Curves for Drain Tile ", Ministry of Agriculture, Fisheries and Food.

[15] *Principles of Underdrainage Design in the Belorussian SSR*, pub. American Natural Science Foundation.

[16] *Good Soil*, S. Graham Brade-Birks, Hodder & Stoughton.

[17] " Problems of Assessing Soil Structure ", E. Crompton, Kings College, Newcastle on Tyne: paper read by British Grassland Society, Dec. 1960.

[18] " Recent Developments in the Techniques of Land Drainage ", Paper by R. A. Walpole to 7th Askham Bryan Horticultural Technical Conference, E.F.P.P.

[19] *An Outline of Field Drainage with special reference to the Drainage of Sports Fields*, A. L. Turner, pub. by National Association of Grounds men, 1960.

[20] " Ministry of Agriculture—Technical Paper No. 209 " and " Notes for the guidance of applicants for grants for Field Drainage, " etc.

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