Dränering av tomtmark, vägar, trädgårdar, kyrkogårdar, idrottsplatser, flygfält, m.m.

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Lantbrukshögskolan

D R Ä N E R I N G

av tomtmark, vägar, trädgårdar,
kyrkogårdar, idrottsplatser,
golfbanor, flygfält m.m.

Sammanställning
redigerad av

Gunnar Hallgren

Uppsala 1970

Förord

Den forsknings- och försöksverksamhet på dräneringsområdet som bedrives vid lantbrukshögskolan hänför sig av naturliga skäl i allt väsentligt till våra odlade jordar, den är huvudsakligen inriktad på frågor och problemställningar rörande åkerjordens dränering. Detsamma gäller undervisningen på området i ämnet lantbrukets hydroteknik för blivande agronomer. Detta har medfört den stora fördelen att undervisningen i väsentlig grad kunnat baseras på eget material, på undersökningar av svenska åkerjordar utförda under där rådande klimatförhållanden.

Sedan omorganisationen vid lantbrukshögskolan 1962 meddelas undervisning i lantbrukets hydroteknik även för blivande hortonomer. Det stod därvid redan från början klart att för dessa borde undervisningen i dränering ej begränsas till enbart jordbruket. Detta gällde särskilt hortonomie studerande med arkitektinriktning. Viss differentiering gjordes också på ett tidigt stadium i form av särskilda projekteringsövningar för dessa.

Föreliggande sammanställning rörande dränering av annan jord än jordbruksjord har tillkommit till tjänst för i första hand blivande arkitekter. Tiden har dock ej medgivit en tillräckligt ingående behandling av detta vidsträckta område utan det hela har såsom ett första steg till en mera genomarbetad framställning måst begränsas till i huvudsak en samling utdrag ur olika arbeten utan något större inbördes sammanhang.

Uppsala i februari 1970

Gunnar Hallgren

Innehåll

I. Inledning

Oavsett för vilket ändamål ett markområde skall användas, föreligger behov av avledning av vatten från detta så snart nederbörden är så riklig, att ett vattenöverskott uppstår. Dräneringsbehovet i det enskilda fallet blir sålunda beroende av dels nederbördens storlek och fördelning - icke minst intensiteten av kortvariga regn - och dels på beskaffenheten av den yta på vilken nederbörden faller. Ju större kapacitet marken har att ta emot och magasinera den fallna nederbörden, desto bättre blir utjämningen för dennas variationer ifråga om avrinningen. God kännedom om markens fysikaliska egenskaper, särskilt med avseende på vattenhushållningen, vilket undervisningen i agrohydrologi avser att meddela, är därför av stor betydelse när det överhuvud taget blir fråga om genomförande av dräneringsåtgärder. Härtill kommer emellertid, att kraven på en effektiv dränering kan sättas olika högt. Inom jordbruket är det sålunda av ekonomiska skäl icke möjligt att dimensionera en täckt ledning så att den under alla förhållanden klarar avrinningen; man måste här ta risken av kortvariga översvämningar vid enstaka tillfällen. När det gäller dränering för andra ändamål vill man vanligen gardera sig häremot, man vill vara på den säkra sidan, och man är som regel inte heller i lika hög grad beroende av kostnaderna för vattnets avledning.

Vidare måste beaktas att den yta från vilken avrinningen sker genom tekniska åtgärder kan ha fått en helt annan karaktär och helt andra egenskaper än som ursprungligen var fallet, ett förhållande som givetvis är av utslagsgivande betydelse och som i det följande skall närmare diskuteras. Ingreppet kan antingen ha gällt hela ytan från vilken avrinningen sker, eller delar därav. Någon gång kan kanske detta ha medfört att marken fått en bättre genomsläpplighet än förut, exempelvis genom djupluckring eller påfyllning av lös lucker jord - med minskat dräneringsbehov som följd - men vanligtvis är förhållandet det motsatta, ytan har gjorts mindre genomsläpplig för vatten. Härigenom försvåras nedsjunkningen och huvuddelen av avrinningen sker på ytan. Ju mer hårdgjord ytan är, desto starkare blir avrinningen vid en given nederbördsintensitet, detta särskilt om ytan är lutande. Här kan nämnas att i Taschenbuch für den Garten- und Landschaftsbau av R. Lehr (Berlin-Hamburg 1968) räknar man med följande avrinningsförhållanden från olika ytor relativt sett.

Ytans beskaffenhet	Relativ avrinning
Takytor	1,00
Gatubeläggning med täta fogar, betongytor	0,90
Gatubeläggning utan tätning av fogarna	0,85
Gångväg belagd med plattor	0,60
Icke hårdgjorda vägbanor	0,50
Lek- och idrottsplatser	0,25
Förträdgård (mellan husfasad och gata)	0,15
Större förstadsträdgårdar	0,10
Parkområden, koloniträdgårdar	0,05

I det följande skall frågan om dräneringsbehov och dräneringens utformning under olika betingelser närmare behandlas. För överskådlighetens skull har framställningen uppdelats i olika avsnitt, varje sådant med några inledande synpunkter och sedan utan närmare kommentarer utdrag ur vissa arbeten, som bedömts kunna vara av intresse i sammanhanget.

Innan vi går närmare in på de olika avsnitten kan det vara lämpligt att ta del av hur man från projekterande landskapsarkitekters sida ser på hithörande problem. Nedan följer därför ett utdrag rörande dränering ur Techniques of Landscape Architecture, edited för the Institute of Landscape Architects by A.E.Weddle (Heinemann: London 1967).

Drainage is concerned with the removal of surplus water from agricultural and urban land. All such water derives initially from precipitation. This may have been directly on the area considered or on an adjacent area from which it has then moved by surface flow or subsurface percolation.

4.9.1 The soil and drainage

The structure of the soil and its mineral composition are intimately concerned with the behaviour of ground water. The soil may have been produced *in situ* or deposited after glacial transport. However, as all soil is derived from the chemical breakdown of rock material the soil characteristics are related to the parent rock minerals. In transported soils mixing of different rock types has taken place and this has produced a wider variety of soils than parent rock material. Soils are not normally homogeneous. Soils may be generally classified according to the sizes of the particles of which they are made according to an internationally agreed scale.

A soil profile normally shows well-defined regions of topsoil and subsoil and, in some cases, of parent rock material in varying degrees of breakdown.

The soil itself consists of solid particles and a fluid

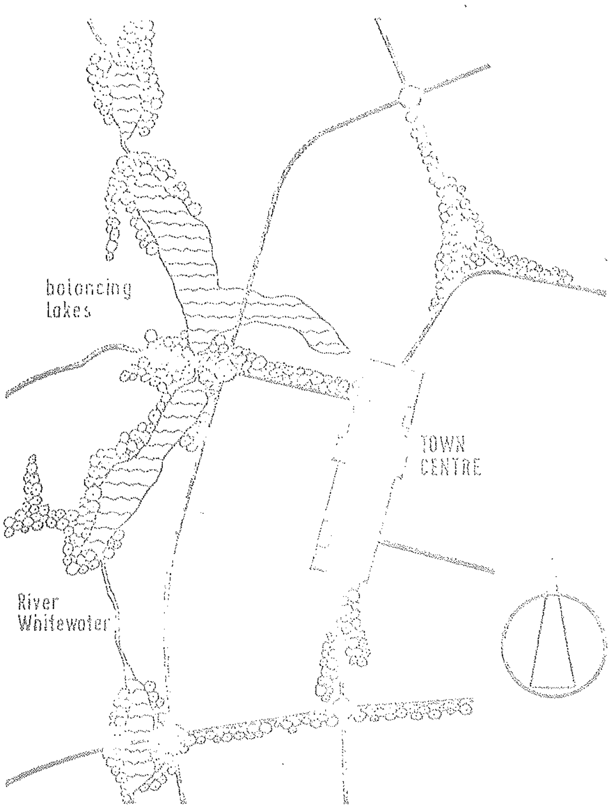

Fig. 4.10. THE HOOK PROJECT—balancing lakes used along the River Whitewater.

medium composed of gaseous air and liquid water. The soil porosity is a measure of the total soil volume not occupied by solid particles, and is usually expressed as a percentage pore space, i.e. the ratio of the volume of fluid to the total volume × 100. The value of soil porosity gives an indication of its water holding capacity. Generally the coarser the particles in a soil and the greater the mixture of different sizes the lower the porosity.

Type of Soil	*Average Percentage Pore Space*
Coarse sand	28
Sandy loam	37
Silt loam	45
Clay	55

More important than the pore space are the sizes of the interconnecting channels between the pores which will determine the rate of water movement. Water will flow through the soil in response to an applied force. This may be gravity, causing a downward percolation, or a hydraulic potential, causing a flow in the direction of decreasing hydraulic gradient. Those soils with the smaller channels will exhibit the lower rates of flow. Coarse sands have a low value of porosity but drain rapidly while clays have a greater pore space, but drain very slowly.

The water table in a soil is the upper limit of the pores which are completely filled with water. It thus separates the saturated region below from the unsaturated region above. In a waterlogged soil the water table is at or very near the soil surface. Water will drain from such a soil until that soil reaches field capacity. Further water can only be removed from the soil by evapo-transpiration. Most agricultural crops grow best in soils that have a water content slightly less than that at field capacity.

The rate of water movement through soil is measured by its permeability in units of in/hr. Some typical values are:

Soil Type	*Permeability* (in/hr)
Coarse sandy	18·7
Sandy loam	0·12
Silt loam	0·043
Clay	0·006

Actual soil profiles show varying permeability with depth. Three general cases exist:

(*a*) Increasing permeability with depth, e.g. loam soil overlying chalk—no drainage problem.
(*b*) Decreasing permeability with depth, e.g. a worked clay loam overlying a clay subsoil.
(*c*) Variable permeability with depth, e.g. boulder clays with perched beds of sand and gravel.

The maximum flow rate through a soil is fixed by the layer with the lowest permeability through which the water has to pass.

Rainfall rates in excess of the minimum permeability will cause water to accumulate in the soil or on the surface giving flood conditions on level ground and surface run-off on sloping ground. If the speed of surface run-off is excessive soil structure is destroyed and soil particles are transported giving rise to soil erosion.

Drainage is concerned with the removal of water in order to restore a soil to field capacity or to remove surface water which would accumulate on sites of low permeability.

4.9.2 Run-off and soil erosion

Rational formula. A rational calculation may be made of the amount of run-off from a site if it is assumed that all the precipitation leaves the site as surface water. A rainfall intensity of 1 inch per hour lasting for 1 hour would provide 1 acre inch or 3,622 ft^3 of water. If this water were to flow off the site at a uniform rate it would be at a rate of 1·008 ft^3/sec. By adding to the relationships so developed a factor C to account for the variation of peak run-off rates with intensities in different areas and under different surface conditions the rational formula for surface run-off becomes

$$Q = CiA \text{ ft}^3/\text{sec}$$

where Q is the peak run-off rate (ft^3/sec), i the intensity of rainfall (in/hr) lasting for the time of concentration of the water shed, A the area of catchment (acres) and C the run-off coefficient.

Criticisms of rational equation. The rational formula, while useful in giving some guidance, is now generally considered to be over-simplified and difficult to use. The main difficulty lies in choosing a suitable value for the expected intensity of rainfall. The British Standard Code of Practice 303:1952 suggests a modified form of the rational formula.

$$Q = 60{\cdot}5\ APR$$

where Q is the run-off in ft^3/min, A the watershed area in acres, P the permeability factor, and R the rainfall intensity in in/hr; with the following values of P for England:

Roofed buildings	$P = 0{\cdot}95$
Roads	$P = 0{\cdot}75/0{\cdot}90$
Paths	$P = 0{\cdot}50/0{\cdot}75$
Gardens, lawns and wooded areas	$P = 0{\cdot}10$

Design formulae for predicting peak run-off rates. The design of structures to deal with surface run-off is now generally based on information obtained from use of Bilhams formula for accepted recurrence intervals and duration of rain.

4.9.3 Ground modeling to control run-off

Reducing the peak intensity of run-off. The maximum peak rate of run-off from a site is directly proportional to the maximum intensity of rainfall expected for the time of concentration and within the recurrence interval selected.

An increase in the time of concentration enables a lower value of rainfall intensity to be selected in predicting the peak run-off rate. This can be achieved by delaying the discharge of surface water from an area being developed by constructing impounding or diversion dams or ponds. These smooth out the main fluctuating discharge from the watershed to a low safe rate of water release to the main channel.

Decreasing size of watershed. A decrease in the size of the collecting area will also reduce the peak intensity of run-off but will also lead to a greater number of structures to deal with the total run-off from an area although the dimensions of each structure may be reduced.

Grass lined waterways. The time of concentration may also be increased by impeding the surface flow of water as for instance by a grass sward in established waterways. This is an important method in controlling run-off from agricultural land because, in addition to the peak intensity, it also produces a more stable soil surface capable of withstanding higher water velocities.

4.9.4 Piped run-off of surface water

This may be achieved by structures offering less resistance to surface flow than that occurring naturally. In such cases open channels or, in extreme cases, underground pipes, of suitable dimensions to deal with the predicted run-off are used. Attention should be paid to the final discharge point. Such pipes rarely flow full and may be considered as special cases of open channels.

4.9.5 Piped drainage of underground water

Conditions requiring piped under drainage. In soils with a low inherent permeability or with small slopes or low lying land, natural drainage is a slow process because of the small size of pore interconnecting channels. Porous pipes laid with a grade in such a soil will receive water from the surrounding soil by virtue of the hydraulic gradient existing between the pipe (which is in connection with the atmosphere at its outlet) and the soil water adjacent to it. Such water can then be discharged from the pipe to an adjoining ditch easily and speedily.

The usual type of such underground drains is the 'clay tile drain' made in unglazed baked clay in 12 in lengths and various diameters between 1½ in and 8 in. The more usual diameters employed are 3 in for laterals and 4 in or 6 in for main lines. These tiles are laid end to end in a hand or machine dug trench with a specially formed base to locate the tile accurately and ensure accurate butting. Water enters these drains mainly through the small gaps between each 12 in length. Concrete land drainage pipes are also used but are more costly, partly by reason of their shortened life compared with clay tiles in soils having marked acidity or alkalinity and partly because of their material cost. Attempts have been made to lay such pipes automatically by injecting liquid or semi-liquid concrete behind a tine working to the required depth and then forming the concrete drain *in situ*. This requires a more expensive machine but economises in the cost of trenching.

New materials. Many new materials are now becoming available for land under-drainage in the form of plastic pipes produced from special grades of polyethylene. Water enters the pipe in the soil through specially cut slots 1¼ in long at 2 in intervals and the pipe is currently available in 20 ft lengths and 400 ft coils.

Slightly more expensive in initial cost, savings can be made in transport and laying cost because of its light weight and applicability to machine laying. A porous backfill is normally used with the pipe to increase the hydraulic gradient in the soil surrounding the pipe and to equalise vertical and horizontal pressures on the pipe during soil settlement after laying.

Some specialist machines are also available which form a circular cross-section drain pipe on a former pulled through the soil from a continuous sheet of plastic foil material. The flat sheet is passed down the leg of the implement, is turned through a right angle, formed into a tube and the slotted edges latched together. These drains do not require trenches to be cut.

Mole drains. In pure clay soils a drainage channel can be formed *in situ* by drawing a cylindrical plug through the soil. If done under moist conditions a water carrying channel is produced with an average life of about 3–5 years. The gradient of the mole drains should be between 1 in 300 and 1 in 100 in most cases, these extremes being dictated by the need to avoid silting up on the one hand and washing on the other. Decreases of grade should also be avoided.

4.9.6 Patterns of laying drainage pipes

(*a*) In 'thorough' drainage a herringbone or straight pattern of laterals is laid which lead into main drains which in turn discharge into ditches or watercourses. A 3 in lateral size is standard with a 4 in or 6 in main line.

(*b*) In 'natural' drainage a single line of drains is laid along the natural lines of water discharge. This is specially applicable to the drainage of isolated wet areas in an otherwise dry location.

(*c*) 'Interceptor' drainage is practised to control the lateral movement of subsurface water. Interceptor drains laid on a suitable grade to obtain effective discharge are laid across the land slope and just above the seepage line. In this way the water is trapped and discharged before reaching the surface at the spring line.

Depth and spacing of tile drains. Empirical methods are at present used to establish the spacing and depth of drain tiles.

Soil Type	*Spacing* (yd)	*Depth* (ft)
Clay	4–7	2–2½
Loam	8–12	2½–3
Sand	12–22	3–4

The greater the clay content of the soil the shallower and closer should be the drain tiles. Water will not reach deep drain tiles in an impermeable soil which, after heavy rain, may be observed to have a waterlogged surface without any discharge from the drain ends.

Laying of tile drains. The trench should only be excavated to the required depth. The depth and grade may be obtained by using boning rods and two sight rails previously levelled to the required grade. The base of the trench should be rounded to fit the tile surface. In a soil with a high silt fraction the surface sod and top soil should be placed in the drain before the rest of the backfill. In certain parts of the country a porous backfill is used. The gradient of the laterals should be greater than 1 in 250 or 3 in per chain and the gradient of the mains will suit the level of the discharge point and the designed carrying capacity. Junctions between mains and sub-mains and between sub-mains and laterals should be carefully made. Any junction at which a change in rate of flow is expected should have a silt trap with a removable inspection cover.

Protection of end of main. The point of discharge of the main line into a watercourse or ditch should be protected against the ingress of vermin and should be in glazed pipe to resist frost action. A hard surface to receive the discharge water is essential to prevent wash and the ditch side should be stone or brick faced around the discharging main. A main line should not pass within 6 yd of a hedgerow unless made of glazed pipe laid with sealed joints to prevent blockage by plant roots.

4.9.7 Ditches and French drains

Ditches. Important in controlling the level of the water table in the adjacent soil profile and in removing large volumes of water collected by tile drainage systems. They suffer from the disadvantage of restricting the movement of surface vehicles. The size and shape of a ditch will largely be governed by conditions at the site but as a general rule in a well-proportioned ditch the top width will be equal to the bottom width plus depth with the sides sloped at 45°. This may be varied according to the soil conditions. The gradient of a ditch will largely depend on the discharge level required, variations for different rates of discharge being taken into account in the cross-sectional dimensions of the ditch.

French drains. A ditch not full of water will control the water table in the adjacent soil. To improve the accessibility of areas interlaced by such channels, to ease maintenance and prevent land slip into the ditch a steeper sided trench may be used which is then filled with coarse stone or gravel to provide a French drain. These are always used in preference to open ditches on the sides of roads and railway cuttings to control the seepage which would otherwise occur on such slopes.

4.9.8 Machines for land drainage

Trenching machinery. A wide selection of machines for digging straight sided trenches are currently available. These fall into two main categories (*a*) the continuous rotary or endless-bucket trenchers, and (*b*) the single-bucket diggers. Group (*a*) tend to be more expensive, but achieve a higher rate of work in rock-free soils while group (*b*) are cheaper and with a slower rate of work can deal with soil with rock obstructions. They may also be fitted with special buckets for digging trenches of different widths and to a uniform depth. Both are used for trenching operations in conjunction with laying underground drains but the latter group may also be used for ditch construction although specialist side-arm dragline machines are preferred for this purpose.

Machinery for the automatic laying of drainage pipes. The rotary bucket trenching machines are particularly adaptable to the automatic laying of drainage pipes because of their steady continuous operation. For clay tiles a platform for storing tiles is required in addition to a chute on to which the pipes are placed end to end to travel down into the trench behind the machine. For plastic pipe a carrying rack for the 20 ft lengths is necessary and again a chute into which the pipe lengths are introduced by an operator on the machine. Special devices are required to maintain the true and correct grade so important in this work.

4.9.9 Disposal of run-off

Artificial drainage increases the volume of water which the rivers have to carry unless special provision is made to delay the flow of water to the rivers in times of heavy rainfall. An example of this is the provision of balancing ponds and lakes along the watercourse as in the L.C.C. New Town Project at Hook (Fig. 4.10). Without such provision artificial drainage tends to increase the risk of flooding from the overflow of rivers and streams.

Riverboard and internal drainage boards. The catchment areas of the principal rivers in England and Wales are covered by thirty-two river boards, together with the Thames and Lee Conservancies, and they are generally responsible for supervising land drainage within their catchment area, although only empowered to carry out maintenance or improvement work on the 'main river'. Internal drainage boards within the river board areas are responsible for the maintenance of streams feeding the main rivers in lowland areas.

Farm ditches and intermediate watercourses. Farm ditches are the responsibility of the farmer and in lowland areas will discharge directly into streams maintained by an internal drainage board. In upland areas there exist many miles of 'intermediate watercourses' linking the two which have recently received special attention by river boards.

Legislation. A considerable volume of legislation relates to the problems of the disposal of run-off, including the following:

H.M.S.O. *Land Drainage Act*, 1938, 20 and 21 Geo. 5, Ch. 94.

H.M.S.O. *River Boards Act*, 1948, 11 and 12 Geo. 6, Ch. 32.

H.M.S.O. *Land Drainage Act*, 1961, 9 and 10 Eliz. 2, Ch. 48.

see also

H.M.S.O. *Land Drainage in England and Wales*, Min. Ag. Fish. & Food, 1951.

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Ytterligare en fråga är det angeläget att här något beröra. Vid hydrologiska undersökningar i fält, i varje fall vid jordbrukshydrologiska sådana, studerar man marken i dess naturliga lagring, in situ, och även laboratoriemässiga undersökningar eftersträvar man att i görligaste mån utföra på prov i ostörd lagring, detta för att så långt möjligt kunna applicera därvid erhållna resultat på förhållandena i fält. Genom systematiskt utförda fält- och laboratoriestudier kan man efter hand få en god belysning av olika jordars fysikaliska egenskaper under olika yttre betingelser, hur pass motståndskraftiga de är mot påverkan av olika faktorer, m.a.o. en kartläggning av jordarna ur hydrologisk synpunkt.

Vid planeringsarbeten i fält, exempelvis anläggning av terasser, störes den ursprungliga lagringen med påföljd att man kan få en jord med helt andra fysikaliska egenskaper. De markfysikaliska data som man till äventyrs haft tillgängliga för jorden ifråga gäller då ej längre. Men hur förändras jorden, i vilken riktning med avseende på struktur, genomsläpplighet och dräneringsbehov? Detta är det ej möjligt att generellt svara på, det beror på ingreppets art. I vissa fall kan det månhända innebära att jorden luckrats upp och fått en bättre genomsläpplighet för luft och vatten - i gengäld torde man då få räkna med en betydande sättning. Men i många fall torde resultatet gå i motsatt riktning. Körning fram och åter med tunga moderna schaktningsmaskiner måste ofelbart leda till en betydande sammanpackning av jorden, detta särskilt om vattenhalten råkar vara väl hög. En tidigare väl strukturerad lerjord med goda fysikaliska egenskaper kan under sådana förhållanden helt förlora sin struktur och bli praktiskt taget ogenomsläpplig. Det kan nämnas att man vid invallningar på sådana vallsträckor där den underliggande alven har god genomsläpplighet brukar ta upp en ränna, ältgrav, på ungefär 1 x 1 m innan vallen bygges, fylla denna med lera och sedan medvetet förstöra fyllnadsmaterialets struktur genom att köra fram och åter i ältgraven med exempelvis en bandtraktor. Denna kärna bibehåller sedan sin täta konsistens genom att vallen hindrar tjälen att tränga ner i densamma.

Om en motsvarande hårdhänd behandling av en lerjord skett vid terassanläggning e.d., kan man visserligen räkna med att tjälen så småningom skall åstadkomma en viss strukturbildning i jorden. Men om man avser att få fram ett väl utvecklat vegetationstäcke, såsom en tät gräsmatta, är det otvivelaktigt nödvändigt att genomföra en minst lika intensiv dränering som skulle fordrats före planeringen.

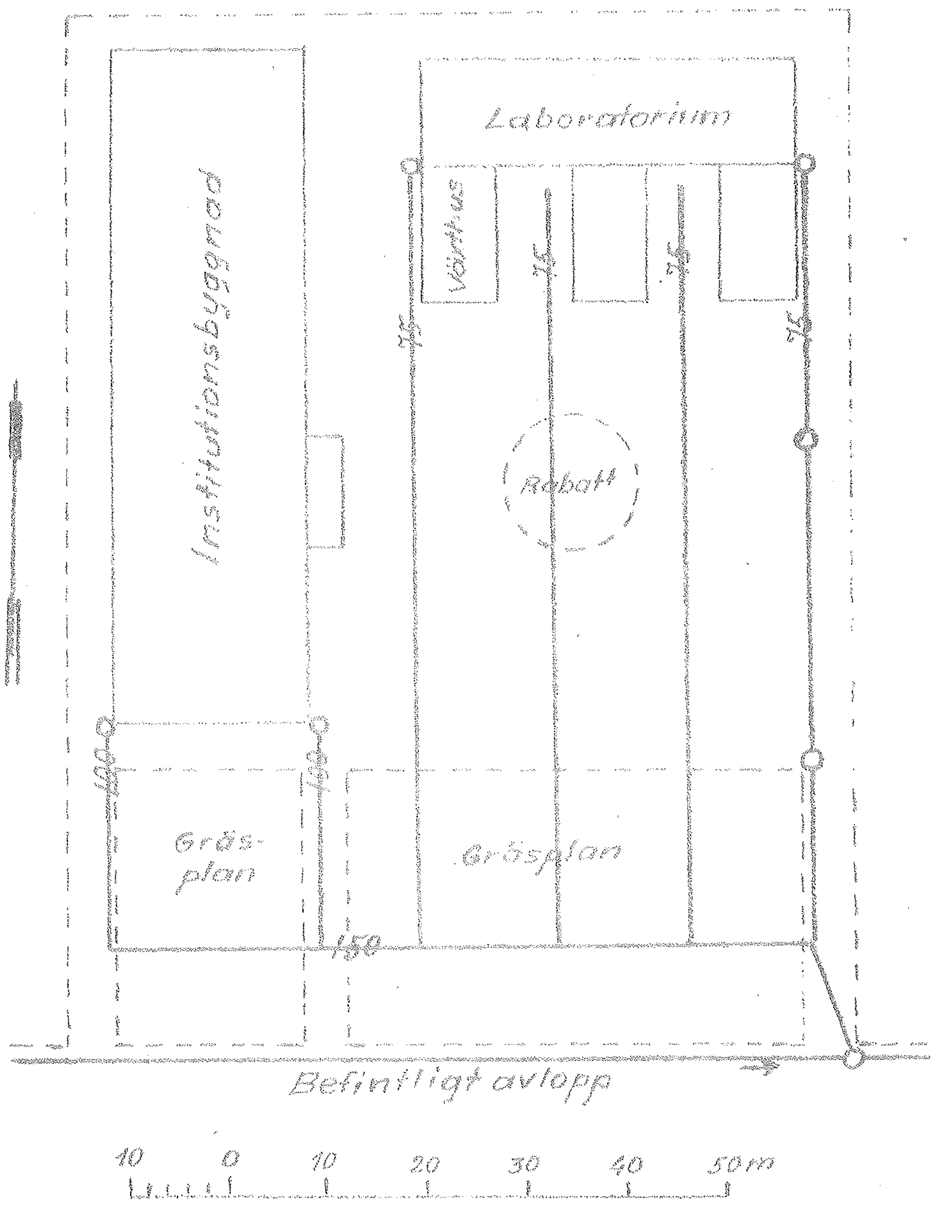
II. Dränering av tomtmark, byggnadsgrunder och vägar

En väl genomförd dränering av det till en byggnad eller grupp av byggnader hörande tomtområdet är vanligen en nödvändig förutsättning för att elementära krav ur arbetssynpunkt, trevnadssynpunkt och sanitär synpunkt skall kunna tillgodoses, detta såväl ifråga om landsbygdsfastigheter som industri- och bostadsområden. Allmänt gäller att ju svårgenomsläppligare tomtmarken är, antingen i sitt naturliga tillstånd eller till följd av sammanpackning genom tung trafik vid riklig nederbörd, desto angelägnare är det att dräneringsförhållandena ordnas. (Här bortses från sådan tätbebyggelse, där tomtområdet i likhet med gator o.d. helt eller till övervägande del hårdgöres och det är självklart att erforderliga nedtag för nederbördsvattnet till avledningssystemet måste anordnas.) Det tidigare på många håll tillämpade förfaringssättet att påföra grus löser inte problemet, man bara skjuter det tillfälligt ifrån sig. Man måste här bokstavligen gå till grunden.

Liksom vid dränering inom jordbruket har man att skilja på ytvattenavledning och grundvattenavledning och samma regel gäller, dvs. att man inte skall tvinga vattnet att ta den längre och långsammare vägen genom jorden ned till dräneringsledningarna om det med fördel kan tas ned i dessa via dagvattennedtag. Man har också att räkna med att ett tomtområde, även om marken i och för sig ej är särskilt svårgenomsläpplig, med tiden kan få en minskad genomsläpplighet, åtminstone inom de delar som trafikeras med fordon. Genom den kombinerade effekten av trafiken och tillförsel av material som avses ge bättre framkomstmöjligheter kan en successiv förtätning av ytlagret uppstå.

Härav följer att ytvattenavledningen vid tomtdränering måste ägnas särskild uppmärksamhet. Detta icke minst av den anledningen att så länge marken är tjälad - och tjälen kan gå betydligt djupare i mark som hålles fri från snö än i snötäckt sådan - så länge sker förekommande avrinning helt i form av ytvattenavrinning. Erforderliga nedtag för ytvattnet bör därför ordnas i första hand i befintliga svackor. Härvid kan användas dagvattenbrunnar av samma typ som vid åkerdränering. Om de inte skall vara till hinder för trafiken, får de självfallet ej sticka upp över markytan utan snarare vara något nedsänkta och i stället för betonglock ha ett gallerförsett lock av gjutjärn.

Det är ofta lämpligt att i dräneringssystemet för tomten även ta in vattnet från byggnadernas tak. Vid smärre byggnader kan det härvid vara tillräckligt att under stupröret placera en stensil med utlopp

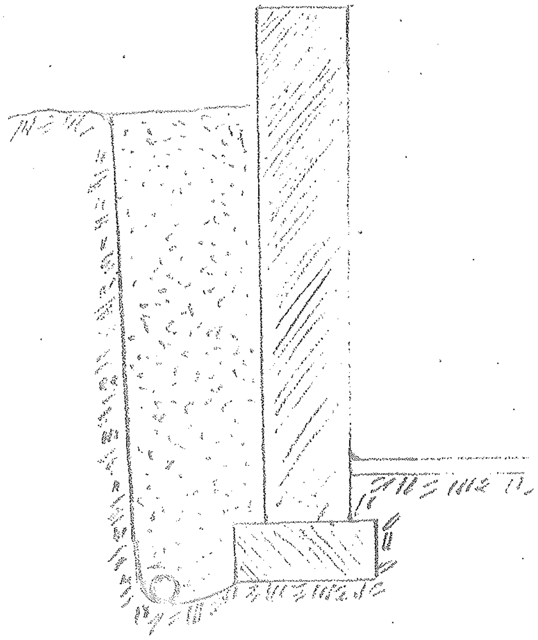


Dränering av gårdsplan

till dräneringssystemet, men vanligen kopplas stupröret till en brunn. Beträffande bostadshus och andra större byggnader är detta regel - en stensil har här inte tillräcklig kapacitet.

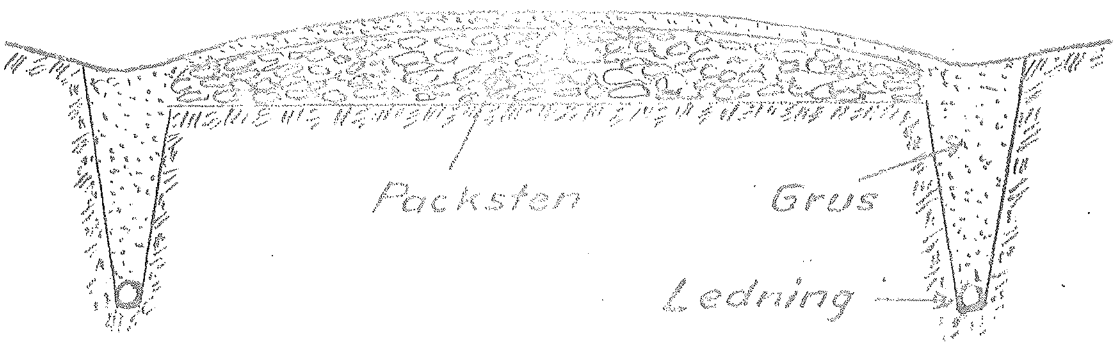
Beträffande dräneringsledningarna kan de vid tomtdränering inte läggas med jämna inbördes avstånd som vid åkerdränering utan får anpassas efter rådande förhållanden. Systemet blir därför sällan regelbundet. Dimensioneringen av rören för enbart grundvattenavledning behöver strängt taget inte vara annorlunda än vid åkerdränering, även om man av säkerhetsskäl i många fall inte använder mindre dimension än 75 mm. Återfyllningen bör ske med genomsläppligt material, helst grus. Därigenom ökas den vattenavledande förmågan avsevärt och mindre risk föreligger att vid intensiva och långvariga regn vattensamlingar skall uppstå.

Beträffande ytvattenavledningen blir det däremot fråga om helt andra intensiteter än vid dränering av åkerjord (jfr Lehrs relativa värden). För takytor och andra helt hårdgjorda ytor torde man få räkna med 40 à 50 l/sek/ha och för gårdsplaner och andra hårdgjorda jordytor ca 10 l/sek/ha. Då kostnaderna för en tomtdränering som regel är förhållandevis obetydliga kan det vara motiverat att som en säkerhetsåtgärd välja något större rördimensioner än som beräknas vara nödvändiga.



Dränering av byggnadsgrund

Den medtagna skissen över dränering av en gårdsplan ger ett exempel på hur dräneringen kan utformas. Här har takvattnet från byggnaderna intagits i systemet (endast antytt på skissen). Markytan har en svag lutning åt öster vilket motiverar placeringen av de båda dagvattenbrunnarna. Minimifallet i ledningarna är 5:1000.



Dränering av väg

Det är av stor vikt att även själva byggnadsgrunden är väl dränerad. Därigenom skyddas byggnaden från fuktskador och risken minskas för att grunden skall rubbas av frost. Dräneringen ordnas enkelt på så sätt att en ledning lägges kring grunden ett par dm utanför dennas sula och i jämnhöjd med eller något under sulans underkant (se skiss). Några större vattenmängder blir det här inte fråga om att avleda, men vanligen brukar härvid användas 75 mm rör. Att placera flera rör vid sidan av varandra är överflödigt. Ledningen täckes upp till markytan med grus eller annat genomsläppligt material. Detta motverkar effektivt grundvatteninfiltrationen.

Lika viktigt som att gårdsplaner och byggnadsgrunder är väl dränerade, lika viktigt är det självfallet att vägar och vägbanor är ordentligt torrlagda. Äldre tiders vägar torde utgöra ett övertygande belägg härför. Några åtgärder för vattnets bortledande från vägen vidtogs sällan; grusning var botemedlet. En dåligt dränerad väg kan dock inte bli fullgod genom enbart grusning, utan vattnet måste beredas avlopp från vägen. I första hand sker detta genom "bombering" av vägen (se skiss). Det från vägbanan avrinnande ytvattnet avledes sedan antingen genom grunda dagvattendiken på ömse sidor om vägen eller, om man vill ha möjlighet att var som helst från vägen kunna köra ut på exempelvis en angränsande gårdsplan, genom motsvarande rörledningar återfyllda med grus ända upp till ytan. Över dessa lämnas en svacka så att vattnet kan sjunka ned till ledningen eller, vid kraftiga regn, fortsätta efter denna svacka till de lägsta punkterna utefter vägens sträckning, där dagvattenned-tag (brunnar) anordnas.

En fråga som vid anläggning av större vägar kan aktualiseras bör här något beröras. En dylik väg som numera så gott som undantagslöst förses med en hårdgjord vägbana kan i väsentlig grad påverka avrinningsförhållandena. Om vägen går fram över åkerjord, måste givetvis de dräneringsledningar som därvid blir avskurna omläggas genom vägbyggarens försorg. På plant liggande områden, kan det då ligga nära till hands att leda in vägvattnet i en dylik avskuren täckt ledning för torrläggning av åkerjord, detta för att slippa lägga en egen kanske kilometerlång avloppsledning. Men risk kan då uppstå för att den befintliga ledningen blir överbelastad med översvämning på nedanliggande åkerjord som följd. Ett enkelt exempel kan belysa denna fråga.

Antag att vi har ett åkerområde som avvattnas genom ett täckt avlopp, dimensionerat för en maximalavrinning av 2 l/sek/ha. Antag vidare att 1/10 av nederbördsområdet (alltsammans åker) tages i anspråk för ett vägbygge och överföres till hårdgjord vägbana. Vi kan räkna med en maximiavrinning från denna på 40 l/sek/ha (vilken vid s.k. fortvarighetstillstånd motsvarar en nederbördsintensitet av 15 mm/timme). Under dessa premisser kommer avrinningen från området att öka från 2 till 6 l/sek/ha. Förebyggande åtgärder av något slag måste under sådana förhållanden vidtagas.

Nedanstående utgör ett utdrag ur Landwirtschaftlicher Wasserbau av Dipl.-Ing. Klaus Linemann (Deutscher Bauernverlag, Berlin 1959), avsnittet Entwässerungsmassnahmen.

3.31 Allgemeine Gesichtspunkte

Jede Wegebefestigung mit einer Steinschüttung, einer Stabilisation oder auch einer Betondecke kann noch so gut und dauerhaft hergestellt sein, ihre Lebensdauer ist, abgesehen von den Verkehrseinwirkungen, hauptsächlich davon abhängig, wie weitgehend das Wasser von der Deckenoberfläche und auch aus ihrem Untergrund ferngehalten werden kann. Dieses Fernhalten des Wassers ist nicht nur bei dem höherwertigen Netz der Land- und Stadtstraßen notwendig, sie ist es uneingeschränkt auch bei dem hier zu behandelnden Netz der landwirtschaftlichen Wege. Hier ist vielleicht dieses Fernhalten des Wassers von den Wegeanlagen noch notwendiger, da im Vergleich zum übergeordneten Netz der Land- und Stadtstraßen hier viel größere Schwierigkeiten in der Unterhaltung der fertigen Wege auftreten werden, worauf bereits des öfteren hingewiesen wurde. Es wird noch einmal in diesem Zusammenhang erwähnt, daß Schäden durch Wassereinwirkung die meisten Unterhaltungsmaßnahmen erfordern. Das Oberflächenwasser ist daher durch ein Quergefälle, das der vorhandenen Befestigung entspricht, von der Fahrbahn weg seitwärts abzuführen und in Gräben, Mulden oder in tiefere Geländeflächen abzuleiten. Die Gräben und Mulden sind, falls sie das Wasser nicht durch entsprechende Untergrundbeschaffenheit nach unten ableiten, mit einem Längsgefälle zu versehen, damit sie die Abflüsse irgendeinem geeigneten Vorfluter zuleiten können. Aber auch das Wasser aus dem Untergrund des Weges ist abzuleiten. Falls es sich um durchlässigen Untergrund handelt, sickert das Wasser von selbst nach unten ab. Falls bindiger Boden unter der Fahrbahnbefestigung ansteht, ist, wie bereits im Abschnitt 3.14 erwähnt wurde, eine wasserdurchlässige Schicht unter der Decke vorzusehen.

Falls Gräben oder Mulden, die einer Vorflut bedürfen, angelegt werden müssen, sind vor Baubeginn rechtzeitig entsprechende Untersuchungen zusammen mit den dafür zuständigen Verwaltungsstellen vorzunehmen, in welchen Vorfluter das Wasser aus diesen Anlagen abgeleitet werden kann.

Bei der Neuanlage von Hauptwirtschaftswegen, deren Entwässerung im allgemeinen größere Aufwendungen als die der Wirtschaftswege verursachen wird, ist daher in bezug auf ihre Linienführung sehr genau zu überlegen, in welcher Weise bestimmte Schwierigkeiten bei der Entwässerung gegebenenfalls durch Wahl einer anderen Linienführung vermieden werden können.

Abschließend ist zu dem gesamten Entwässerungsproblem zu sagen, daß bei der Neuanlage von landwirtschaftlichen Wegen sehr eng mit den zuständigen Wasserwirtschaftsdienststellen zusammengearbeitet werden muß.

3.32 Oberflächenentwässerung

Die notwendigen Werte für das Quergefälle der einzelnen Befestigungen sind jeweilig in den Abschnitten vermerkt, in denen die Befestigungen behandelt wurden. Die Werte sind durchweg um 1% höher angesetzt, als sie es sonst bei diesen Befestigungen im öffentlichen Straßennetz sind. Dies hat seinen Grund darin, daß bei der vermutlich nicht ausreichenden Unterhaltung der landwirtschaftlichen Wege auf jeden Fall durch ein sehr ausreichendes Quergefälle ein schnellerer Wasserabfluß mit einer besseren Säuberung der Wegoberfläche erreicht werden muß. Das seitlich von der Fahrbahn abfließende Wasser gelangt über den unbefestigten Seitenstreifen in den seitlichen Graben, die Mulde oder unmittelbar in tiefer liegendes Gelände.

3.33 Entwässerung durch Graben und Mulde

Man wird diese Gerinne vorsehen, wenn der Weg sich nicht aus dem umliegenden Gelände heraushebt oder sogar im Einschnitt liegt. Im Auftrag hingegen, wenn die seitliche Wegekante (Krone) mindestens 30 cm über dem umliegenden Gelände liegt, wird kein Gerinne ausgebildet. Das Wasser fließt über die Kronenkante hinweg auf das tiefer liegende Gelände und versickert hier mehr oder weniger schnell. Diese Art der höhenmäßigen Führung eines Weges ist stets die günstigste, da besondere Entwässerungseinrichtungen, abgesehen von der Entwässerung etwaiger Frostschutzschichten, nicht erforderlich sind.

Falls ein Gerinne angelegt werden muß, ist auf jeden Fall der muldenförmigen Ausbildung des Querschnittes vor der trapezförmigen der Vorzug zu geben. Die erstgenannte Form paßt sich besser der Landschaft an und ist auch verkehrssicherer, wenn irgendwelche Fahrzeuge von dem Wegrand abirren. Die Dimensionierung dieser Gerinne hat so zu erfolgen, daß das anfallende Niederschlagswasser voll abgeführt oder bei Versickerungsgerinnen voll zur Versickerung gebracht werden kann. Von der Fahrbahn muß es auf jeden Fall herunter. Bei Weiterleitung des Wassers zu einem Vorfluter oder zu Geländeflächen, wo es schadlos versickern kann, ist möglichst ein Mindestgefälle von 0,5% zu wählen. Mitunter sind zur Klärung, in welche Vorfluter oder in welches Gebiet Niederschlagwasser abzuleiten ist, wassertechnische Berechnungen von Fachleuten durchzuführen.

Für durchschnittliche Verhältnisse wird die Breite einer Mulde oder eines Grabens bei 1,3 bis 1,5 m liegen, wobei die Tiefe des Gerinnes, von der Kronenkante ab gerechnet, mindestens 30 cm betragen soll. Notwendige Ackerüberfahrten sind von Fall zu Fall anzulegen und mit geeignetem Baustoff, Pflaster oder Steinschüttung zu befestigen. Falls die Gerinne nur zur Versickerung dienen, sind keine Rohre unter diesen Überfahrten erforderlich. Ist das Gerinne jedoch an einen Vorfluter oder eine zur Versickerung geeignete Geländefläche angeschlossen, so müssen unter den Überfahrten Ton- oder Betonrohre verlegt werden. Ihr Durchmesser soll wegen der notwendigen Reinigungsmöglichkeit mindestens 30 cm betragen. Das bedeutet, daß dann die Tiefe des Gerinnes unter der Kronenkante größer als 30 cm sein muß, es werden sich hier Werte von 45 bis 55 cm als notwendig erweisen. Bei Gräben und Mulden genügt bei einem Längsgefälle bis zu 1% die Auskleidung der Seitenflächen mit fester Grasnarbe. Bei größeren Gefällen ist eine Befestigung der Sohle und der unteren Seitenflächen mit Pflaster von 10 bis 15 cm Dicke erforderlich, um Ausspülungen zu vermeiden. Gerinne, die nur der Versickerung dienen, sollen möglichst kein Längsgefälle aufweisen, damit das Wasser auf ganzer Länge versickern kann und sich nicht an einer oder mehreren Stellen sammelt. Eine Sohlenbefestigung ist hier nicht angebracht. Sollten in der Sohle dieser Gerinne bindige Schichten geringerer Mächtigkeit anstehen, so hilft man zur besseren Versickerung durch in bestimmten Abständen angebrachte senkrechte Sickerpackungen aus Kies oder Schotter, die bis zur durchlässigen Schicht geführt wird.

3.34 Untergrundentwässerung

Eine Untergrundentwässerung wird bei Frostschutzschichten immer erforderlich, um diese Schichten möglichst trocken zu halten. Damit das Wasser, das dieser Schicht zugelaufen ist, schnell abgeführt werden kann, ist das Planum mit einer starken seitlichen Neigung (5 bis 6%) zu versehen, und es müssen in bestimmten Abständen (10 bis 15 m) unter dem Seitenstreifen sogenannte Rigolen angelegt werden. Diese bestehen aus Kies- oder Schotterpackungen,

Abb. 30 Unterirdische Entwässerung einer Frostschutzschicht

die mit Splitt verfüllt sind. Sie wirken als Sickerleitung und entwässern bei tiefen Gerinnen unmittelbar in diese. Wenn die Sohle des Gerinnes zu hoch liegt, muß unter der Sohle des Gerinnes eine weitere Sickerleitung aus durchlässigem Material – wie oben erwähnt – oder aus porösen Rohren (Drainage) angelegt werden. An diese Längssicker wird dann die Rigole von Fall zu Fall angeschlossen. Diese Längssicker müssen unbedingt ein Mindestgefälle von 1‰ aufweisen und an geeigneten Stellen an eine Vorflut angeschlossen sein. Sie leiten auch gegebenenfalls das dem Untergrund unterirdisch von höher gelegenen Geländeflächen zufließende Wasser ab. In der Abbildung 26 ist der Regelfall der Entwässerung einer Frostschutzschicht dargestellt.

3.35 Besondere Maßnahmen bei hohem Grundwasserstand

Im Prinzip ist bei solchen Fällen genauso zu verfahren, wie es bei der Entwässerung von Frostschutzschichten angegeben wurde. Die hier notwendigen offenen und unterirdischen Entwässerungsleitungen müssen öfter als im Falle der Entwässerung von Frostschutzschichten an aufnahmefähige Vorfluter angeschlossen werden, damit die Entwässerungsleitungen nicht zu lang und damit auch nicht zu tief und zu teuer werden.
Wenn jedoch solche Entwässerungsmaßnahmen wegen zu hoher Kosten nicht zur Ausführung kommen können, muß mit einem dauernden Verbleiben eines hohen Grundwasserstandes zumindest in der feuchten Jahreszeit gerechnet werden. In diesem Fall darf jedoch keine Stabilisierung als Wegebefestigung vorgesehen werden, hier sind nur Steinschüttungen oder gegebenenfalls dünne Betondecken am Platze.

Det följande avsnittet rörande vägdiken och deras utformning ingår i Kortfattet Laerebog i Vejbygning og Kloakering af C.L.Feilberg, Sjette Udgave ved N.J.Dahl (København 1959), sid. 63 - 65. Från samma källa härrör de här medtagna profilerna, Plan 2.

4) *Skraaninger og Grøfter.* Udførelsen af disse er i det væsentlige allerede beskrevet under Jordarbejde. Sædvanlig har man Grøfter paa begge Sider af en Vej; kun undtagelsesvis kan man i Paafyldninger undvære Grøft, hvor Terrænet har rigeligt Sidefald bort fra Vejen. I Afgravninger, hvor Grøfterne tjener til Afvanding af Planum, bør Grøftedybden ikke være mindre end 0,7 m, ved Paafyldninger kan man nøjes med noget mindre, f. Eks. 0,5 m, i enkelte Højdepunkter *(Grøftehoveder)* endog 0,3 m. Bundbredden gøres sædvanlig 0,5 m, saa at Grøften bekvemt kan renses op med en Skovl.

Vejgrøfterne maa have rigeligt Fald efter Vejens Længderetning, f. Eks. 1 : 200—1 : 300. Paa fladt Terræn og paa Terræn med vanskelige Afløbsforhold kan det undertiden blive nødvendigt at skaffe Grøfterne Fald paa kunstig Maade ved paa sine Steder at grave dem dybere end ellers nødvendigt *(Fordybningsgrøfter)*, og under saadanne Forhold nøjes man gerne med svagere

Fald, f. Eks. 1 : 500, for ikke at faa for stort Jordarbejde. Navnlig i Afgravninger er dybe Grøfter kostbare, fordi hele Gennemskæringens Bredde bliver relativt stor (smlgn. Punkt 8, sidste Stykke).

Saa ofte man kan, leder man Grøfternes Vand bort fra Vejens Areal ved Hjælp af *Stikgrøfter* til Siden. Hvor der kun er Afløb til den ene Side, maa Grøftevandet fra den modsatte Side ledes under Vejen i et Rørgennemløb eller en Stenkiste. Hvor Grøfternes Fald er større end ca. 1 : 30, maa de brolægges i Bunden, hvis Jorden ikke er af særlig fast Beskaffenhed. Langs den udvendige Kant af Grøfter og Afgravninger for offentlige Veje er en Bredde af 1 Alen paa hver Side, den saakaldte *Vejalen*, udlagt som Vejens Ejendom til Sikkerhed for Skraaningernes Beverelse.

I den nyere Tid har man for at formindske Faren for Ulykkestilfælde ved Automobilkørsel undertiden erstattet Vejgrøfterne med lukkede Dræn*), f. Eks. af 8—10 cm brændte Lerrør, der nedlægges i godt 1 m Dybde og dækkes med groft Grus (Fig. 83). De kan passende have et Fald af 2—3 ‰, men bør i særlige Tilfælde gøres til Genstand for Beregning paa lignende Maade som almindelige Drænledninger.

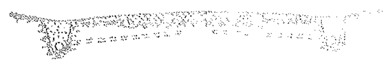


Fig. 83. Vej med Sidedræn i Stedet for Vejgrøfter.

Hvad enten man anvender aabne Grøfter eller lukkede Dræn ved Siderne af Vejen, er det som Regel formaalstjenstligt at dræne Jordlegemet under selve Kørebanens befæstende Lag ved to eller flere Dræn i Vejens Længderetning (Fig. 84 a). De kan udføres som rørlagte, stenfyldte Grøfter af ca. 30 cm Dybde, der graves med skiftende Fald i Vejens Længderetning, saa at de for hver ca. 50 m faar et Dybdepunkt, der afvandes til Vejgrøften. Er Jorden af leret Beskaffenhed, kan det tilmed være praktisk at føre Sugedræn ind under Vejmidten for hver 20 m eller at lægge et 5—10 cm tykt Lag Grus eller harpede Slagger som et Fladedræn under hele Kørebanens Stenlag. Undertiden kan man nøjes med et Fladedræn alene med Stikledninger til Grøfterne (Fig. 84 b).

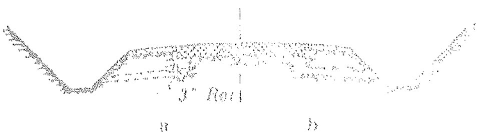


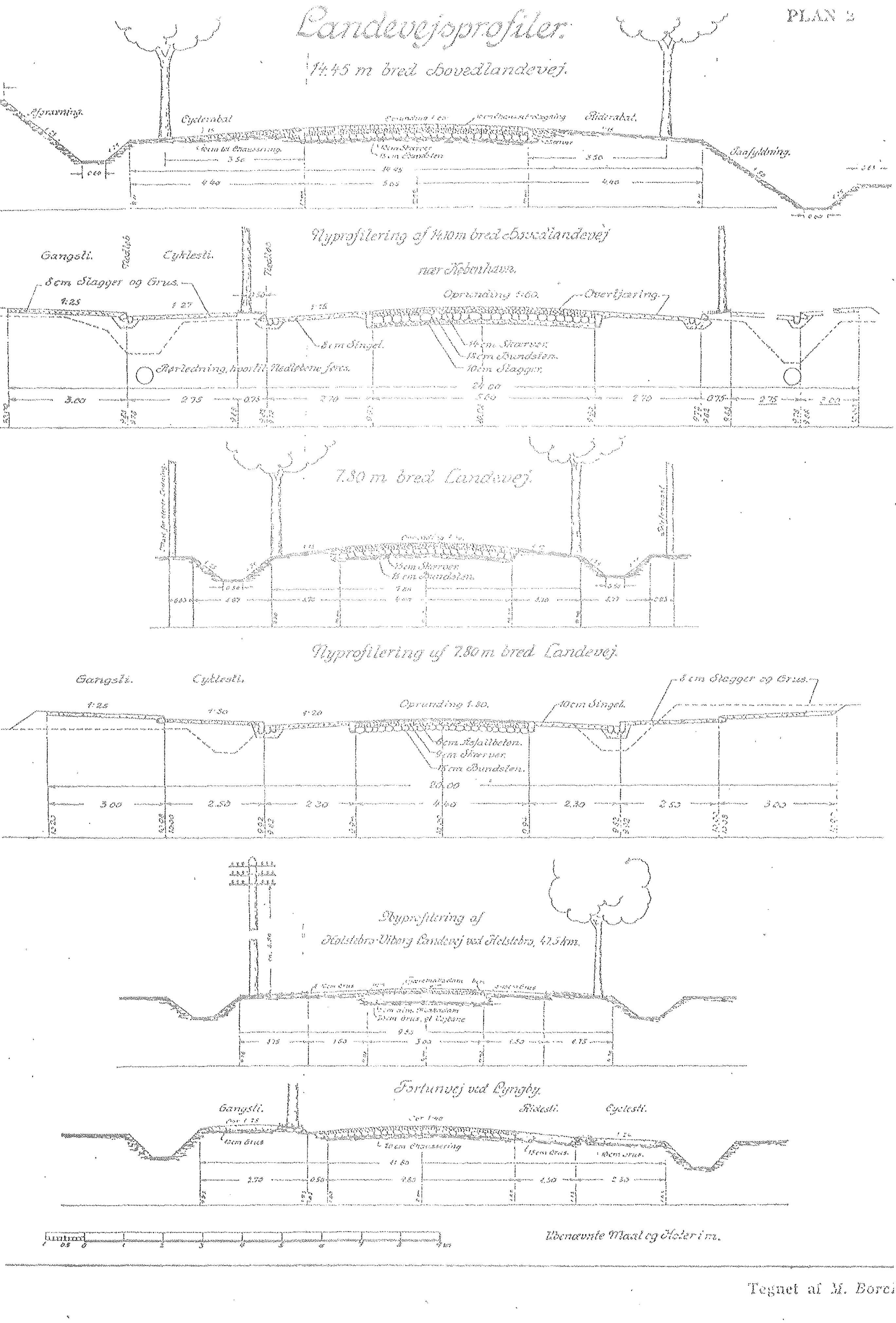
Fig. 84. Dræning af et Vejlegeme.

Efter Isvinteren 1923—24 blev adskillige Hovedveje her i Landet kørt itu, fordi Kørebanens befæstende Stenlag var beskadiget af Frosten, og fordi Grunden under Stenlaget blev udblødt ved det indtrædende Tøbrud og mistede sin Bæreevne. En saadan Opfrysning af Kørebanen og Udblødning af Undergrunden kan befrygtes selv under helt vandtætte Kørebaner, fordi Fænomenet beror paa, at Kapillarvand suges op fra Undergrunden under Frostperioder og fryser til Is i Jordlaget under den kolde Vejbane. Opsugningen vedvarer trods Frosten, fordi Vand, der er bundet ved Adsorption til Jordpartiklerne, holder sig flydende ved Temperaturer flere Grader under Nul. Der kan saaledes i længere Kuldeperioder dannes saa store Islager i de øvre Jordlag, at Vejbanen løftes enten pletvis eller i store, sammenhængende Partier, og ved indtrædende Tø, hvor Isen smelter fra oven, kan den store Vandmængde ikke undvige nedad gennem de frosne Jordlag.

Frostskader af denne Art*) kan imødegaas ved Anvendelse af groft, saakaldt frostsikkert Materiale, f. Eks. Sand, som Fyld under Vejbanen i 0,5—1 m Tykkelse. Endvidere kan man indlægge vandstandsende Lag af Tagpap, Bitumenplader, Lag af Singels el. l. i samme Dybde under Vejbanen. Og endelig kan man sænke Grundvandstanden paa Vejomraadet stærkt. Hensigten er ved alle tre Fremgangsmaader at standse den kapillære Vandløftning fra Undergrunden. Den foran beskrevne Dræning, direkte under Vejbanen, er naturligvis nyttig under Tøbruddet, men ikke tilstrækkelig i sig selv.

*) Se f. Eks. U. S. Department of Agriculture. Office of public roads. Bulletin Nr. 29—48.

PLAN 2



Tegnet af M. Borel

När det gäller byggande av större vägar ökar också svårigheterna att ernå en effektiv vattenavledning, detta särskilt om det förekommer starkt grundvattenförande lager. Man har härvid funnit att inläggning i vägkroppen av ett skikt med mycket god genomsläpplighet ("graded filter" eller "layered drain") torde vara det mest effektiva och samtidigt billigaste förfaringssättet. Metoden behandlas närmare i följande avsnitt, betitlat "The economics and practicability of layered drains for roadbeds" av ingenjörerna H.R. Cedergren och W.R. Lovering och hämtat ur Highway Research Record No. 215, 1968, s. 1-7.

This paper presents benefit-cost studies that demonstrate outstanding advantages for layered drains for roadbed drainage and the complete inadequacy of single-layer drains constructed of "well-graded" (low permeability) drainage aggregates. Discontinuation of the practice of using single-layer drains for roads where water removal is a problem is recommended.

Modern, wide multilane highways are considerably more difficult to protect from groundwater and seepage than older narrower roads. If any appreciable quantities of water must be removed from highways, the conventional single-layer drains are extremely uneconomical and quite ineffective. Both from an engineering standpoint and from economics, layered drains (often called "graded filters") are superior for protecting roadbeds from the damaging effects of water.

A two-layer drain system constructed early in 1967 in northern California is described. While this section of road has not been tested under rainy conditions, the rapid drainage potential was tested by pouring water over the open-graded drain layer and watching it emerge from the drain pipe within 2-3 minutes. This test section demonstrated that layered drains are perfectly feasible from the construction standpoint.

•AS THE highway system of the world requires the construction of multilane highways to greater widths, gentler slopes and milder curves in all kinds of terrain, the physical problems of developing stable roads have multiplied. This is equally true of subsurface drainage. Doubling the road width, for example, makes drainage about four times as difficult as before. Consequently, practices that worked when roads were only two narrow lanes do not work for four and six lanes. Greater amounts of groundwater and seepage enter wider roadbeds constructed in deeper cuts, and must be conducted greater distances for removal from places where it could cause damage or failure.

Designing adequate subsurface drainage systems has been considered primarily an engineering problem, one of using the proper filter criteria to select aggregates capable of removing troublesome groundwater and seepage without becoming clogged by adjacent fine-grained water-bearing soils. Early road builders, such as John L. McAdam of Britain and Pierre M. Tresaguet of France, must have instinctively known of the high water-removing capabilities of one-sized stone, as they used this class of material in their roads. These coarse materials had high permeabilities when first placed, but unfortunately there developed a practice of placing open-graded stone or gravel directly upon soft, erodible soils without the use of a layer of sand or graded material; hence these roads often deteriorated as soil worked up into the stone, making it about as impermeable as the underlying soil.

Because of these experiences with coarse, one-sized stone in drainage systems, and with the development of modern criteria for filters for earth dams, the practice developed of using well-graded "pervious" subbases and drainage layers for highway drainage, using washed concrete sand and comparable materials. As long as the quantities of water to be removed were small, little trouble occurred due to groundwater and seepage. Consequently, there developed a tendency to look upon these well-graded (low permeability) aggregates as adequate for underseepage collection and discharge.

Unfortunately, well-graded filter aggregates that are fine enough to hold in place fine-grained soils are too fine to pass much water. As a result, many roads and freeways throughout the world are deteriorating prematurely from a lack of subsurface drainage, even though they have been built with single-layer drains constructed with permeable aggregates.

A number of recent technical publications have pointed out that the proper solution to subsurface drainage of highways often is through use of multiple-layer drains (1, 2, 3), which were originally invented by K. Terzaghi (4) for the control of seepage in hydraulic structures such as sheet-pile walls and earth dams. This kind of drain, often called a "graded filter," is referred to in this paper as a "layered drain." It is composed of coarse, one-sized gravel or rock, enclosed within enveloping layers of finer material that serve as filters to prevent clogging of the inner conducting layer. Engineering considerations alone point up the great advantages of these drains for highway roadbeds. From theoretical, granulometric considerations, Winterkorn (5) demonstrated that one-sized, coarse rock is essential for the removal of seepage. These layers require filter protection. With the heavy emphasis on designing drains that will not clog, the economics of subsurface drainage systems have been largely disregarded. If one considers the potential water-removing capabilities of various kinds of commonly used drainage systems, it is found that as little as $3.50 can be spent or as much as $90,000 for two sections of subsurface drain having exactly the same water-removing capability. The lower cost represents a layered drain with an internal layer of 1-in. to ¾-in. diameter gravel or crushed rock sandwiched between two thinner layers of finer filter material. The higher cost represents a single-layer drain constructed of washed filter aggregate comparable to concrete sand, a class of material erroneously being used in many subsurface drainage systems. The purpose of this paper is to emphasize the need to look at what we are getting for our money when we design and build subsurface drainage systems for roads and other civil engineering works.

A METHOD FOR EVALUATING THE BENEFIT-COST FACTORS FOR DRAINS

In examining the benefit-cost relationships for subsurface drainage systems constructed of various grades of aggregate, it is important to keep in mind that subsurface drains serve two very vital functions:

1. They must provide filter protection to all soft, highly weathered rocks and erodible soils that are being drained.
2. They must remove all of the groundwater and seepage that reaches them without much buildup of head.

To provide filter protection, drainage layers must be designed on the basis of appropriate filter criteria (1, 3, 4, 6, 7) that assure that openings in the filter aggregate will be too small for the passage of adjacent soil particles. This function is primarily one of properly applying engineering principles. All of the cost studies presented in this paper assume that designs do provide the necessary filter protection.

To fulfill function 2, drainage aggregates serve as conductors or conveyors of water, much as sewer pipes or water pipes serve as conductors or conveyors of water. Although this capability is partially one of meeting engineering requirements, it is also one of economics (2, 3). It is important to keep in mind that a material that provides excellent filter protection may be a very poor conductor.

Subsurface drains often utilize pipes for part of the seepage conducting system, almost always after it has been collected by line drains or blanket drains that remove seepage from large surface areas of surrounding water-bearing soil. If the quantities of seepage are quite small, it may be possible for the aggregate seepage collectors and conductors to be a single layer of relatively fine-grained material comparable to clean, washed concrete sand. But, in most cases involving any appreciable quantities of seepage, it is more economical to utilize layered drains for the prime water collecting and conducting elements.

Assuming that a subsurface drain is properly designed to provide the needed filter protection, its cost can be determined in relation to its capabilities for removing water.

Any conveyor or conductor of any material can be rated in terms of the cost of moving a given amount of material over a given distance. Thus, in earthwork, it is customary to use the term "station-yard," and in freight hauling the cost is expressed by the ton-mile. Similarly, the water-carrying capabilities of drainage aggregates can be expressed in any convenient units of quantity and distance. In this paper, a number of classes of drainage aggregates, in a number of kinds of systems, are rated in terms of the cost of conducting a unit quantity over a given distance. The unit of quantity is 1 gpm; the distance is 100 ft.

The water-conducting potential of porous aggregate drains can be estimated with Darcy's law:

$$Q = kiA \tag{1}$$

This identity is not changed by multiplying the right side by unity, so

$$Q = kiA\,(L/L)$$

Hence

$$Q = \frac{kiV}{L}$$

And

$$V = \frac{QL}{ki} \tag{2}$$

In Eq. 2, V is the volume of filter aggregate needed to conduct seepage quantity Q a distance L under hydraulic gradient i in a material with a permeability k.

Eq. 2 can also be derived by considering that the quantity Q is being conducted by cross-sectional area A. If it is conducted a distance L, the amount of filter aggregate needed must be AL, which is the volume V in Eq. 2. In most subsurface drains, both Q and i will vary from point-to-point; however, Eq. 2 assumes these factors are constant. The solutions are therefore somewhat approximate.

SOME TYPICAL CASES

Using Eq. 2, the relative costs of a wide range of commercially available filter aggregates are compared in Figure 1. The required quantities of aggregates were calculated for hydraulic gradients from 0.02 to 1.0. All aggregates were assumed to cost $5.00 per cubic yard, in place. Over a range of filter permeabilities from under 1 ft/day to about 50 ft/day, the drains are assumed to be constructed as a single layer in which the total thickness is available for the discharge of seepage. With a filter permeability of more than 50 ft/day, it is assumed that layered drains are required to prevent piping or clogging and provide the needed capacity. This is a necessary assumption for filters draining highly weathered soft sandstones, other highly erodible rock formations, and all highly erodible

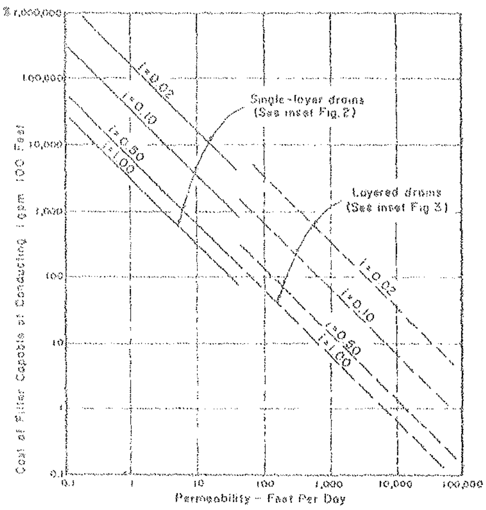


Figure 1. Cost of filter aggregate per seepage unit (1 gpm conducted 100 ft).

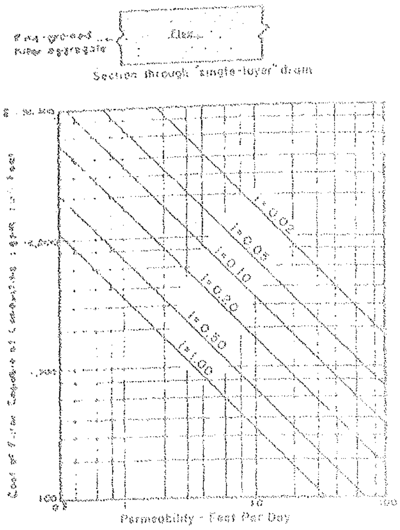


Figure 2. Cost of fine-grained aggregates in single-layer drains per seepage unit (1 gpm conducted 100 ft).

soils. The costs for layered drains in Figure 1 provide two filter layers totaling the same thickness as the inner conducting layer. Thus, if the conducting layer is 12 in. thick, the costs in Figure 1 for layered drains allow for an upper filter layer 6 in. thick and a bottom filter layer 6 in. thick, making a total thickness of 24 in.

Referring to Figure 1, it is seen that for a single-layer drain constructed with washed concrete sand having a permeability of 2 ft/day (corresponding to a class of material that is sometimes used for roadbed drains), the cost of conducting 1 gpm a distance of 100 ft (for a slope of 0.02) is nearly $100,000. If a cleaner, washed concrete sand or well-graded filter aggregate with a permeability of 10 ft/day is used, the cost is reduced to around $18,000 for each gpm conducted 100 ft.

In contrast with the astronomically high costs of single-layer drains compared to quantity of water transported, it is seen from Figure 1 that a layered drain containing a core of fine pea gravel with a permeability of 3,000 ft/day (on a 0.02 slope) is around $100 for each gpm conducted 100 ft. Also, a layered drain utilizing washed, screened gravel or ¾-in. to 1-in. diameter crushed rock (k = 100,000 ft/day) can conduct 1 gpm a distance of 100 ft for about $3.50.

A study of Figure 1 leads to the conclusion that whenever roadbed drainage layers a few feet in thickness are constructed with low-permeability filter materials, structural damage may be expected, if any appreciable rate of inflow occurs. The practice of using these well-graded materials for roadbed drainage should be discontinued as they are extremely uneconomical and do not protect roads from water damage. The use of these materials is justified only as a filter protection for a drainage layer of high-permeability aggregate.

Since the discharge capacities of aggregate drains increase in proportion to the hydraulic gradients that can develop in drains, steeply inclined drains (such as are frequently used in earth dams or in stabilization trenches in highway foundations) require less quantities of filter materials or less permeability than the nearly horizontal drainage blankets placed beneath roadbeds in wet cuts and below the natural groundwater level in flat terrain.

The charts in Figures 2 and 3 show the relative costs of single-layer and multiple-layer drains. Figure 2 shows the cost of single-layer blanket drains utilizing fine-grained aggregates capable of providing a high level of filter protection to adjacent erodible soils. Figure 2 is similar to the upper left portions of the chart in Figure 1, but is enlarged, and is in more detail to permit more accurate applications. Similarly, Figure 3 shows the costs of layered drains that utilize a core of coarse one-sized aggregate within protecting envelopes of finer material capable of providing high filter protection (shown in inset). Two protective filters are provided having a combined additional thickness that is equal to the thickness of

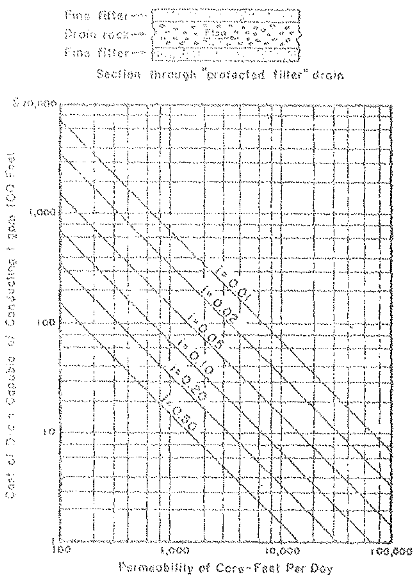


Figure 3. Cost of "protected filter" drains per seepage unit (1 gpm conducted 100 ft).

the inner conducting layer. Figure 3 is similar to the lower right part of Figure 1, but is enlarged and increased in detail to give increased accuracy. In normal highway design the subbase material may, in most cases, serve as the upper filter layer. These charts are presented as typical of conditions in blanket drains in which the quantity of water conducted is important.

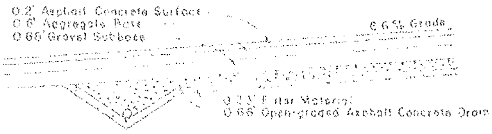


Figure 4. Longitudinal section of Humboldt County drain.

EXAMPLE OF A LAYERED ROADBED DRAIN

A two-layer graded structural section drain of the type discussed in this paper has been placed experimentally in Humboldt County in the north coastal area of California. A typical section is shown in Figure 4.

Geologically, this area consists of Jurassic to Pleistocene sedimentary deposits that have been folded and faulted. The rainfall is heavy, 40 to 80 in. per year. This combination results in many water-bearing formations and numerous spring areas. With these conditions, cut and fill slope stability is a serious problem and adequate pavement subsurface drainage a necessity.

The site chosen for the experimental construction was in a side hill cut area with heavy seepage from the bank, both above and below the pavement. The existing pavement had been built with a blanket of filter material to remove seepage. Failure of this filter material to effectively remove all of the seepage had resulted in the buildup of hydrostatic head beneath the pavement. Pavement failure was the result, with water rising through cracks in the deteriorated pavement.

To correct this condition, a two-layer drain was designed and built by County forces. Two additional purposes of this construction were (a) to determine the capability of this type of drain, and (b) to evaluate construction feasibility of layered roadbed drains.

The design of the drain included 0.33 ft of filter material on the prepared silty clay subgrade, and 0.66 ft of open-graded asphalt-concrete drain material. The drain was covered by the regular structural section of base and surface as follows (see Fig. 4): 0.88 ft of river-gravel subbase, 0.60 ft of aggregate base, and 0.20 ft of asphalt-concrete surface.

Since this was a small isolated project, it was not practical to specify special requirements for the above materials. The materials used, therefore, consisted of aggregates already available in stockpiles at a nearby commercial plant. A filter layer with a smaller amount of fines would have been desirable but the material used should be adequate for the site. The important criteria for the filter layer in a drain of this type are (a) that it must have a grading that will prevent migration of the subgrade soil into the drain layer; and (b) that it must have a permeability at least as high as the formation or soil supplying the seepage water (preferably several times as permeable). The filter material used met these criteria.

The drain rock used for the open-graded layer consisted of aggregate from the No. 4, or coarse bin, of a four-bin asphalt plant, mixed with approximately 2 percent of 85-100 penetration paving asphalt.

The gradings and permeabilities of the materials used as determined by tests by the California Division of Highways are given in Table 1. The overlying aggregate subbase had a gradation that did not sift appreciably into the open-graded layer,

TABLE 1

GRADATION AND LABORATORY PERMEABILITY OF MATERIALS USED

Sieve Size	Percent Passing		
	Filter Material	Asphalt Concrete Drain Rock	Aggregate Subbase
2 in.	100	—	99
1½ in.	98	—	93
1 in.	96	—	78
¾ in.	83	100	68
½ in.	76	75	55
⅜ in.	69	47	46
No. 4	46	14	32
No. 8	35	5	25
No. 16	27	2	19
No. 30	20	2	11
No. 50	13	2	5
No. 100	8	2	4
No. 200	6	1	3
Percent asphalt	—	2.2	—
Laboratory density, pcf	130 140	102 110	—
Permeability, ft/day	7 0.7	9000 6400	—

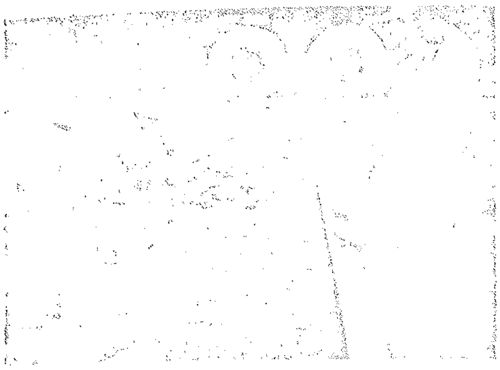


Figure 5. Placing filter material in transverse trench.

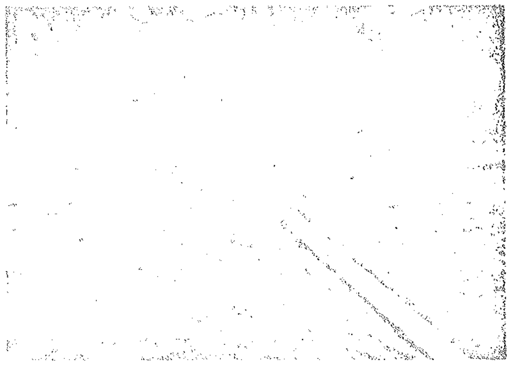


Figure 6. Placing open-graded asphalt-concrete drain material around pipe.

eliminating the necessity for a special upper filter layer. For this reason this drain is a two-layer drain, although it is in reality a true "protected filter" drain.

This drain was placed on a 6.6 percent grade and the length was only 150 ft. Because of the steep grade and short length, a perforated metal pipe (PMP) was not placed along the pavement edge, but a single PMP was placed as a transverse drain at the downhill end of the section. The PMP was placed in a trench having a depth 2 ft below subgrade elevation (Figs. 5 and 6). Figure 5 shows filter material being placed in the transverse trench, while Figure 6 shows the open-graded asphaltic-concrete drain material being placed over the filter material and around the PMP. A general view of placement of the open-graded drain layer is shown in Figure 7.

Construction was somewhat hampered by the steep grade and the fact that the site could not be by-passed with construction equipment. This necessitated rolling only in an uphill direction.

Compaction was with an 8- to 10-ton tandem Galion Rollomatic without ballast. This weight roller was heavier than desirable for compacting the open-graded asphalt-concrete mix in the thick section placed in the cross trench. Also, some difficulty was experienced in rolling up the grade on the first 4-in. lift of open-graded mix. The second lift was placed just before quitting time, and as a result was not compacted except by the Barber-Greene paver. The following morning, however, the surface could not be dented with the wheels of a loaded truck, proving the advantages of stabilizing open-graded layers with a low-asphalt content.

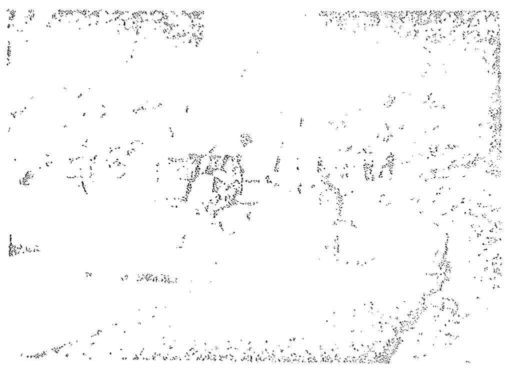


Figure 7. Placing open-graded asphalt-concrete drain layer.

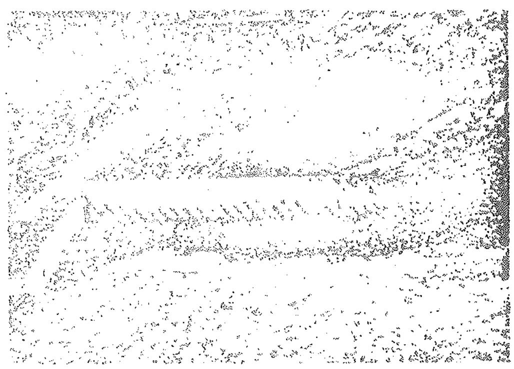


Figure 8. Flow from cross drain 2 to 3 minutes after sprinkling open-graded mix with watering truck.

The experiment indicated that construction of two-layer drains using an open-graded asphalt concrete as a drain layer is perfectly feasible. On future work, a lighter weight roller should be considered, possibly a light pneumatic roller. It is doubtful, however, that any difficulty would have been experienced on this project, even with the heavy roller, if the construction had been on more nearly level terrain.

The performance of the drain cannot be properly evaluated until after at least one rainly season; however, water put on the surface of the open-graded asphalt-concrete drain material with a watering truck demonstrated that the drain layer has a high capacity for removing water (Fig. 8). The flow shown developed within 2 to 3 minutes after applying the water.

SUMMARY

Aggregates for subsurface drainage systems for highways and other civil engineering works often represent a substantial part of the total cost of a job. An important question to be asked about any construction material is "does it give full value for the money spent?" When this question is asked about subsurface drainage aggregates, some surprising answers are obtained. As conveyors of seepage, conventional single-layer drains constructed of washed, fine-grained aggregates are enormously expensive. When any appreciable quantities of groundwater and seepage must be removed by subsurface drains constructed of selected aggregates, layered drains offer the best engineering solution at the least cost. The project described in this paper demonstrates the practicability of this kind of construction.

Just as the hauling of construction materials can be evaluated in terms of the cost per unit of material hauled and the distance it is hauled, systems for conveying seepage can be rated in terms of the cost of conducting a given quantity a given distance (see Figs. 1 to 3).

All aggregate drains that are designed for the removal of groundwater and seepage for the protection of roadbeds and other civil engineering structures should be designed using appropriate filter criteria that assure permanent functioning without piping or clogging. But, in addition, the systems should give an adequate return for the money spent. Consideration of the potential returns in terms of capabilities for conducting water is an aspect of subsurface drainage that has received very little attention. When this factor is considered, it points out that if any appreciable quantities of water must be removed, layered drains offer financial advantanges that must not be overlooked.

With the seepage flows normally encountered, a layered drain using the minimum practicable lift thicknesses of drain rock will provide a very large safety factor. This is an important advantage. If a drain is filled to capacity or near capacity, slight variations in the permeability of the filter layer, on grades, can cause uplift of the pavement structure.

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III. Dränering av trädgårdar

I princip råder det inga skillnader mellan dränering av åkerjord och dränering av trädgårdar. Oavsett om det gäller odling av jordbruksgrödor, köksväxter, prydnadsväxter eller fruktträd krävs en efter klimatförhållandena och markens fysikaliska beskaffenhet väl avpassad dränering för att ett fullgott resultat skall kunna påräknas, och oavsett ändamålet kan samma rörmaterial användas, betong, tegel eller plast. I vilketdera fallet måste man sörja för en effektiv ytvattenavledning om sådan erfordras. Dagvattenbrunnar, stensilar och grusfiltra kan ordnas på samma sätt som vid dränering av åkerjord. Likaså måste en efter markförhållandena, främst markens genomsläpplighet och förekomsten av förtätningszoner, lämplig dräneringsintensitet - dräneringsavstånd och dräneringsdjup - väljas för ernående av en tillräckligt snabb grundvattenavledning. Då odling av trädgårdsväxter (häri inkluderat fruktträd) är en mycket intensiv form av växtodling och det är fråga om högvärdiga produkter, spelar inte dräneringskostnaderna relativt sett samma roll som inom jordbruket. På grund härav och för att vara på den säkra sidan brukar man inom trädgårdsodlingen und i övrigt lika förhållanden vanligen tillämpa en något intensivare dränering. Sålunda rekommenderar Richard Lehr (Baurat, Garten- und Landschaftsarchitekt) i sin ovan citerade Taschenbuch für den Garten- und Landschaftsbau (Berlin & Hamburg 1968) vid tvärdränering följande dräneringsavstånd och dräneringsdjup vid en medelnederbörd av 600 mm. (Om marklutningen överstiger 2 % föreslås avstånden kunna ökas upp till 15 %.)

Jordart	Dräneringsdjup i m			
	0,8	1,0	1,2	1,4
	Dräneringsavstånd i m			
Styv lera	5,5 - 7,0	6,0 - 8,0	6,5 - 8,5	7,0 - 9,5
Lera	7,0 - 8,0	8,0 - 9,0	8,5 - 10,0	9,5 - 11,0
Lerig mjäla	8,0 - 9,0	9,0 - 10,0	10,0 - 11,0	11,0 - 12,0
Mjäla	9,0 - 10,5	10,0 - 12,0	11,0 - 13,0	12,0 - 14,5
Sandig mjäla	10,5 - 12,5	12,0 - 15,0	13,0 - 17,0	14,5 - 19,5
Mjälig sand	12,5 - 15,5	15,0 - 19,0	17,0 - 23,0	19,5 - 27,0
Sand	15,5 - 19,0	19,0 - 25,0	23,0 - 27,0	

Som framgår av tabellen räknar Lehr med ett mera markant samband mellan dikesavstånd och dikesdjup på lätta än på styva jordar, vilket ju också är i överensstämmelse med de olikartade hydrologiska förhållandena beträffande dessa marktyper. Vi kan emellertid jämföra med de i det följande återgivna uppgifterna av Schatz , som närmare ansluter sig till inom jordbruket använda dräneringsintensiteter.

Ett problem vid dränering i trädgårdar, särskilt fruktträdgårdar, har i många sammanhang diskuterats. Detta gäller rotinväxningen i rörledningarna och möjligheterna att gardera sig häremot. Att helt förhindra sådan är knappast möjligt. Vad gäller gräs och örter torde problematiken vara ungefär densamma som inom jordbruket; rötterna går ned till avsevärt djup, varför det icke är möjligt att genom ökning av dikesdjupet nämnvärt motverka inväxningen. Men i de flesta fall utgör den heller icke något större problem, såvida inte ledningarna är vattenförande även under den egentliga vegetationsperioden. Beträffande rötterna av träd och busker ligger förhållandena annorlunda till. Hos vissa trädslag förefinnes en påfallande benägenhet att växa in i ledningarna. Man har med varierande resultat prövat att impregnera rören med exempelvis karbolineum före nedläggningen (se följande artikel av J.Henze), man har försökt förhindra rotinväxningen genom att täcka rören med koksaska, grus eller sågspån och man har vid dränering utefter alléer o.d. radikalt tätat rörfogarna. Men i sistnämnda fallet fungerar ju då inte heller ledningen som en dräneringsledning. Det lämpligaste förfaringssättet vid dränering av fruktträdgårdar är att lägga ledningarna så långt ifrån trädraderna som möjligt, dvs. mitt emellan dessa (jfr följande artikel av Braams och Butijn).

Som en allmän regel gäller att om man kan befara att dräneringssystemen kommer att bli utsatta för speciella påfrestningar, det kan gälla risk för inslamning, rotinväxning eller järnutfällningar, bör man eftersträva att ha korta ledningar, gott fall i dessa (4 à 5:1000) samt rensningsmöjligheter (rensbrunnar). Och sist men inte minst: noggrannhet vid arbetets utförande.

I det följande har medtagits ett utdrag ur Gartentechnik av trädgårdsarkitekt Rudolf Schatz om avvattning i trädgårdar (Dritte Auflage Berlin & Hamburg 1953). Första upplagan kom ut 1938 vilket torde förklara att boken i vissa avseenden är föråldrad. Dagvattenbrunnarna i Tafel 24 torde sålunda med fördel kunna vara av samma utformning som vid åkerjordsdränering. De av Schatz angivna lerrören (Steinzugrohre) tillverkas ej längre i Sverige, man kan använda vanliga betongrör (lantbruksrör eller mufrör). Beträffande Tafel 25 är de nederst anförda ledningstyperna knappast aktuella. Den föråldrade uppfattningen som Schatz förfäktar, att dräneringsledningar och avlopp skall läggas på frostfritt djup, har man ju numera frångått. Men han är i gott sällskap, bl.a. har Schroeder i sitt omfattande arbete Landwirtschaftlicher Wasserbau (Berlin-Heidelberg-New York 1968) gjort sig till talesman för samma sak: "Eine auch im kältesten Winter frostfreie Lage der Dränrohre ist dringend erwünscht, da während der langen Lebensdauer einer Dränung immer einmal mit dem Eintreten eines besonders strengen Winters gerechnet werden muss und da die durchlässigen Wandungen der Dränrohre meistens Wasser enthalten, das beim Gefrieren sprengend wirkt" (s.297). Denna fara är praktiskt taget obefintlig för ett i marken nedlagt rör, detta försåvitt inte ledningen är full med vatten. Men detta får heller inte förekomma under vintern.

A. Ableitung des Oberflächenwassers

Bei Gartenwegen wird das Regenwasser durch das Quergefälle seitlich gesammelt, von wo es durch das Längsgefälle weitergeführt und in bestimmten Abständen in die tieferliegenden Rasen- oder Gehölzflächen abgeleitet wird. Bei größeren, ebenen Rasenflächen sind an diesen Stellen muldenartige Vertiefungen vorzusehen. Geschlossene Steineinfassungen müssen entsprechende Schlitze aufweisen. Um ein Ausspülen des seitlichen Wegestreifens zu verhindern, werden offene Rinnen (vgl. S. 58 und Tafel 21) angelegt.

Bei steileren Wegen müssen je nach dem Gefälle in Abständen von 5—20 m quer zur Wegerichtung Auskehren (= Abschläge) aus Steinplatten, Rundhölzern u. dgl. eingebaut werden, die das Wasser der einzelnen Wegestrecken abfangen und zur Seite ableiten (vgl. Tafel 21). Bei Treppen erhalten alle Steinstufen eine leichte Neigung nach vorne, damit sich auf der Auftrittsfläche keine Wasserlachen bilden können. Bei größeren Treppenanlagen wird das sich über den Stufen sammelnde Wasser gleich am Treppenfuß seitlich abgeleitet; ebenso ist, wenn oberhalb einer Treppe ein steiles Wegestück anschließt, knapp vor Beginn der ersten Stufe eine Ableitungsmöglichkeit vorzusehen.

Soll das Oberflächenwasser nicht unmittelbar in das Gelände abgeführt werden, so sind entweder bei günstigen Bodenverhältnissen Sickergruben anzulegen oder es erfolgt die Ableitung mittels Rohre in eine Vorflut, die z. B. ein künstlich angelegter Sickerschacht, eine Teichfläche, die Straßenkanalisation usw. sein kann.

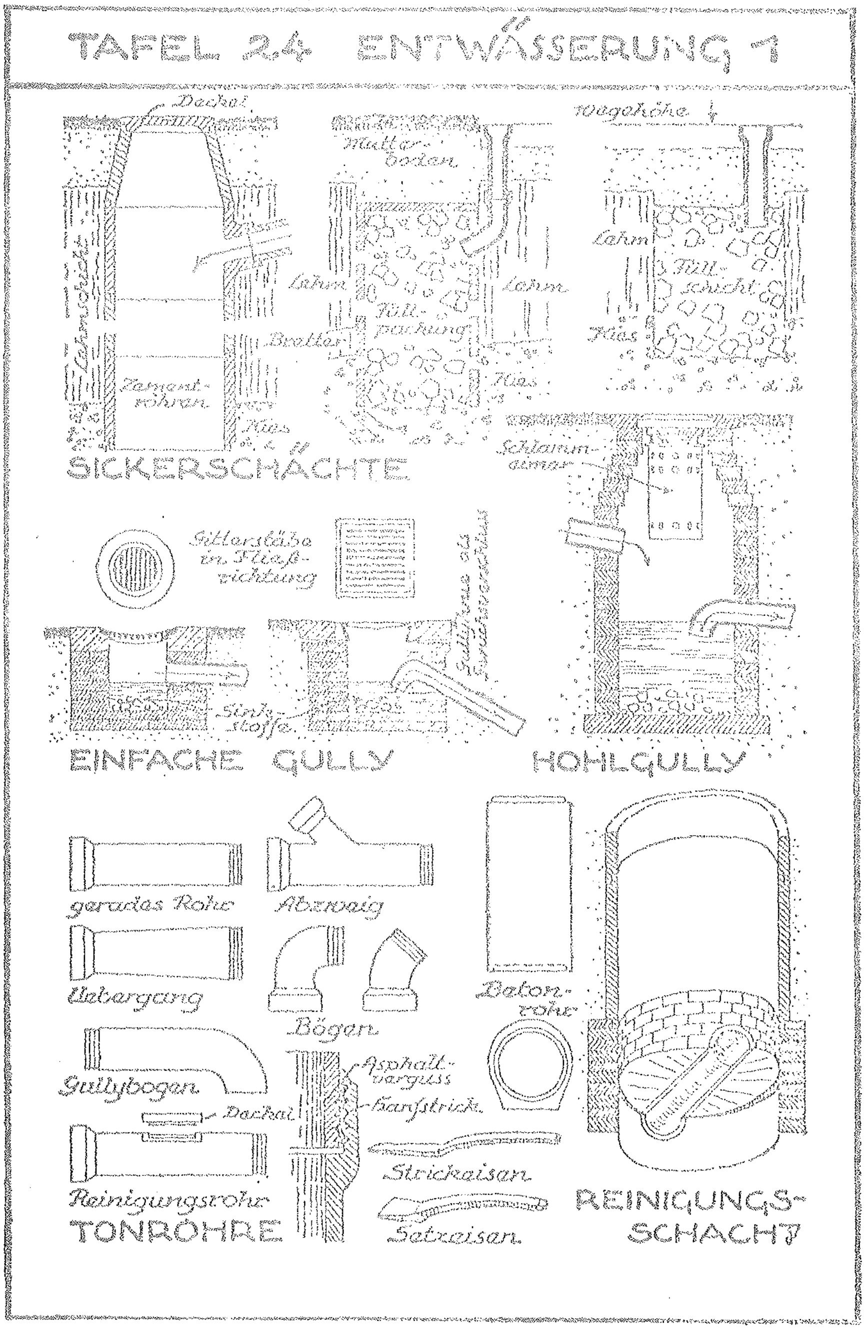
1. Sickergruben (vgl. Tafel 24)

Die einfachste Form einer Sickergrube in durchlässigem Boden ist die Anlage einer entsprechend großen Ausschachtung, die mit Brettern abgesteift und mit Steinbrocken, grobem sandfreiem Bauschutt u. dgl. ausgefüllt wird. Durch die Steinpackung wird das Wasser in seiner Strömung gebrochen und im Boden verteilt.

Soll über der Sickergrube Kulturboden oder eine Rasenfläche liegen, so wird die Steinpackung ungefähr 30—40 cm unter der Erdoberfläche erst mit einer Kiesschicht, dann mit einer doppelten Dachpappenlage abgedeckt und darauf die Muttererde aufgetragen. Die Abbildungen der Tafel 24, rechts oben, zeigen auch verschiedene Möglichkeiten der Wasserzuleitung mittels Tonrohre, deren obere Öffnung durch ein siebartiges Gitter abgeschlossen wird.

Um eine größere Wassermenge auf einmal aufzunehmen und diese dann erst allmählich in den durchlässigen Untergrund ableiten zu können, werden auch Sickerschächte ohne Füllung angelegt. Die Abbildung der Tafel 24, links oben, zeigt einen solchen Schacht, hergestellt aus im Kanalbau gebräuchlichen Betonrohren.

Alle Sickerschächte müssen bis zu einer durchlässigen Bodenschicht hinabreichen, die oft 1—4 m und auch tiefer liegen kann. Bei sehr tiefen Sickerschächten ist es wegen der damit verbundenen großen Erdarbeit wirtschaftlicher, diese gleich größer anzulegen und dann von mehreren Seiten das Wasser zusammenzuleiten. Solche Schächte werden am besten aus Ziegelsteinen aufgebaut, die in der Höhe der durchlässigen Schicht entsprechende Sickerschlitze offen lassen.



2. Einfallschächte (Gullys) (vgl. Tafel 24)

Um möglichst wenig verschlammende Sinkstoffe in die Schächte gelangen zu lassen, werden günstig eigene V o r g u l l y mit Schlammfang angelegt, aus denen das von den Sinkstoffen gereinigte Wasser mittels Rohrleitungen in die eigentlichen Sickerschächte geleitet wird. Solche Gullys sind auch dann anzulegen, wenn ein Versenken des Oberflächenwassers in den Untergrund nicht möglich ist; in den Gullys wird das Wasser gesammelt, von Sinkstoffen gereinigt und dann der Vorflut mittels Rohrleitungen zugeführt.

Tafel 24 zeigt verschiedene Ausführungen von Einfallschächten. Die Ablagerung der Sinkstoffe erfolgt bei einfacherer Ausführung in einer Vertiefung unterhalb des Einlaßgitters, im sogenannten Sinkkasten, der öfters, besonders nach starken Regenfällen mit der Kloakenschaufel gereinigt werden muß. Fehlt bei Einfallschächten dieser Sinkkasten, so sind zwecks besserer Selbstreinigung die ableitenden Rohre entsprechend steiler zu verlegen und in den Leitungssträngen scharfe Krümmungen zu vermeiden. Bei größeren Hohlgullys (vgl. die Abbildung rechts) ist ein aushebbarer Schlammfang aus verzinktem Eisenblech angebracht, der ebenfalls von Zeit zu Zeit entleert werden muß.

Zur Ableitung des Wassers aus dem Gully dienen direkte Abzweigrohre (wobei Schwimmteile, wie Laub usw., in die Rohrleitungen gelangen können) oder Gullyknie, die zugleich durch das im Knie immer stehenbleibende Wasser einen Geruchsverschluß darstellen. Letztere sind bei unmittelbarem Anschluß an die Kanalisation stets zu verwenden.

Größere Sammelgullys, die die Aufgabe haben, bei plötzlichen Regenfällen oft beträchtliche Wassermengen zugleich aufzunehmen, um sie erst allmählich durch Rohrleitungen abzuführen, werden aus, mit Zementmörtel aufgesetzten Ziegeln oder Brunnensteinen, aus Stampfbeton usw. aufgebaut und erhalten oben einen Deckel sowie an der Innenwand zum Einstieg Steigeisen.

3. Rohrleitungen (vgl. Tafel 24)

Die Ableitung des Wassers erfolgt durch Ton- (Steinzeug-) oder Betonrohre. T o n r o h r e haben eine Länge von 30—100 cm und eine lichte Weite von 7,5 cm aufwärts. Sie sollen gut glasiert sein und beim Anklopfen hell klingen. Tafel 24 zeigt verschiedene Formstücke, wie Übergang, Knie, Abzweige usw. Zum Verlegen wird der Graben so weit ausgehoben, daß der Leger neben dem Rohr noch gut arbeiten kann. In lockerem Boden sind die Grabenwände gegebenenfalls mit Brettern und Brusthölzern abzusteifen.

Die Rohre müssen in frostfreier Tiefe, also mindestens 1,0 m tief und womöglich auf gewachsenem Boden liegen. Jede überflüssige Auflockerung der Grabensohle ist zu vermeiden. Bei Auffüllboden ist die Sohle vorher durch Stampfen gut zu festigen.

Für Gartenentwässerung kommen meist Rohre von 7,5—15 cm lichter Weite in Frage. Umfangreichere Entwässerungsanlagen müssen eigens berechnet werden. Je enger die Rohre sind, um so besser ist die Selbstreinigung von Sand, Sinkstoffen usw.; das Mindestgefälle beträgt 1—2 %. Bei starkem Gefälle kann der Rohrdurchmesser verhältnismäßig enger sein, da das Wasser mit größerer Geschwindigkeit durchläuft.

Das V e r l e g e n erfolgt immer von der tiefsten Stelle aus. Zur Verbindung werden die Rohre ineinander geschoben, und zwar so, daß das Wasser vom Kopfende zum Schwanzende fließt. Vor dem Verlegen ist jedes Rohr innen zu reinigen und die freie Öffnung während der Arbeit mit einem Rupfenpfropfen zu verschließen. Zu lange Rohre werden mit dem Meißel vorsichtig abgeschlagen.

Zur D i c h t u n g werden die Rillen in der Muffe und am Rohrende vor dem Zusammenbau mit Teer oder heißer Asphaltmasse bestrichen und sodann die Rohre ineinandergeschoben; dann wird ein teergetränkter Asphaltstrick von Daumendicke in die Muffe mit dem Strickeisen in 3—4 Lagen eingestopft und zum Schlusse mit Setzeisen und Hammer eingestampft. Dann wird die Muffe noch mit heißer Asphaltmasse mittels Gießring vergossen. Für einfachere Dichtung genügt auch nach der Stricklage das Einstopfen von Asphaltkitt oder das Auftragen von einer Wulst aus Zementmörtel. Eine Dichtung mittels Ton ist besonders in Geländen mit Baumbestand wegen der Gefahr des Einwachsens von Baumwurzeln ungeeignet.

Damit während des Eintreibens des Asphaltstrickes die Rohre satt ineinander verbleiben, wird jedesmal ein Brettstück zum Austemmen des Rohrendes in den Boden geschlagen. Bei längeren Rohrleitungen sind ungefähr alle 30—40 m, bei starken Krümmungen entsprechend enger, Flanschrohre mit Reinigungsöffnung vorzusehen und diese durch Einmessen oder sonstwie im Gelände kenntlich zu machen. Die Flanschscheibe wird mittels Messingschrauben unter Beilage von Kitt auf den Flanschring aufgepreßt.

Auch können [illegible] Überwege eingebaut werden, deren Öffnung mit einem Stöpsel verschlossen wird. Bei umfangreichen Leitungsnetzen sind besonders an Treffpunkten von mehreren Zuleitungsrohren oder vor Einleitung in Teichflächen Sinkkästen und in bestimmten Abständen Kontrollschächte einzubauen.

Um in den Sinkkästen eine gute Ablagerung der Sinkstoffe zu ermöglichen, soll der Zufluß um mindestens Rohrbreite tiefer liegen als der Abfluß.

Die Festlegung des genauen Gefälles der Rohre erfolgt durch im Graben neben der Rohrleitung einnivellierte oder eingetafelte Pflöcke oder es wird über je 3 Muffen eine konische Waaglatte (z. B. bei einer Länge von 2 m mit 4 cm Verjüngung), das sogenannte Prüfbrett, aufgelegt und damit das genaue Gefälle eingewogen.

Die Rohre müssen auf der Sohle satt liegen; unter der Muffe wird eine kleine Vertiefung ausgenommen. Nach dem Dichten werden die Rohre vorsichtig mit Erde unterstopft, dann wird, ehe der Graben unter schichtenweisem Einwerfen und Stampfen zugefüllt wird, das Gefälle mit dem Prüfbrett nochmals kontrolliert.

Bei *Zementrohren* muß ebenfalls die Spitzmuffe in die Richtung des Gefälles weisen. Unter jeden Stoß kommt eine Zementunterlage. Dann wird auf die untere Hälfte der Stumpfmuffe des schon liegenden Rohres sowie auf die obere Hälfte der Spitzmuffe des einzuschiebenden neuen Rohres gleichmäßig feiner, kiesfreier Zementmörtel 1 : 1 bis 1 : 2 aufgetragen und sodann das Rohr vorsichtig eingeschoben. Der Mörtel soll rundherum gleichmäßig aus den Fugen quellen, ohne viel nach innen einzudringen. Jetzt wird das neue Rohr auf Richtung und Gefälle nochmals geprüft, die Muffendichtung geglättet, dann der Boden vorsichtig von beiden Seiten hinterfüllt und eingestampft.

B. Senkung des Grundwasserspiegels

Bei seeartiger Versumpfung ist es oft möglich, die wasserundurchlässige Schicht zu durchstechen und das Wasser in tiefere, durchlässige Schichten abzuleiten. Zu diesem Zwecke werden in Abständen von 5 bis 30 m durch die undurchlässige Schicht Löcher gebohrt oder gesprengt und diese mit Steinbrocken, Reisigbündeln usw. ausgefüllt (vgl. die Abbildung auf Tafel 25). Feuchte Flächen am Fuße eines Hanges können trocken gelegt werden, indem wir am Hangfuß einen bis zur Gleitschicht reichenden Graben ausheben, der das Hangwasser aufnimmt und ableitet.

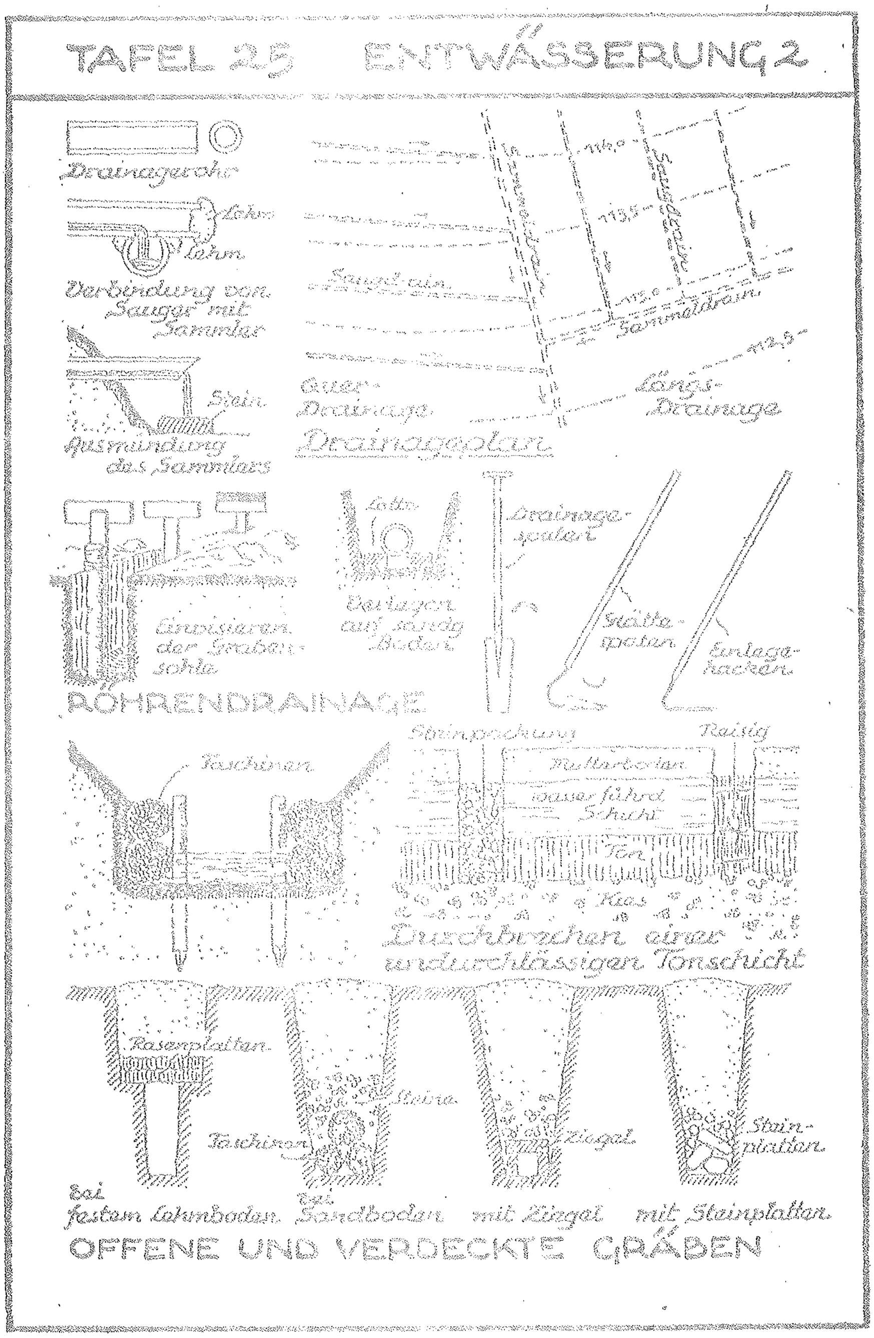
Handelt es sich um die Senkung des eigentlichen Grundwasserspiegels, so ist dies durch Röhrendränage sowie durch offene und verdeckte Gräben möglich.

1. Röhrendränage (vgl. Tafel 25)

Bei der *Röhrendränage* sind in einer bestimmten Tiefe unter der Erdoberfläche gebrannte, unglasierte Tonröhren mit einer lichten Weite von 4 oder 5 cm hintereinander verlegt. Diese stellen die sogenannten Saugstränge („Sauger") dar, in die das Wasser durch die Stoßfugen eindringt, innerhalb der Rohre abgeleitet und durch Sammelröhren („Sammler") einer Vorflut zugeleitet wird.

Die Vorflut kann ein Graben, Bachlauf, See usw. sein; jedenfalls muß der höchste Wasserspiegel der Vorflut immer noch 10—15 cm tiefer als der Auslauf des Sammelrohres liegen. Die Einmündung in einen Bach oder Flußlauf erfolgt in der Fließrichtung, gegebenenfalls ist in die Rohrleitung ein entsprechendes Bogenstück einzuschalten. Um ein Aufschlämmen des Bodens unter dem Ausfluß zu verhindern, wird unterhalb der Sammlermündung eine große Steinplatte eingebettet oder ein Steinbett errichtet. Das aus der Uferböschung herausragende Rohrende wird mit Pfählen versichert oder erhält einen Überbau aus Brettern und wird mit einem Drahtgitter verschlossen.

Die *Saugröhren* müssen zumindest in frostfreier Tiefe liegen; bei Garten- und Wiesenflächen ist eine Tiefe von 1,2 m und bei Flächen mit Baumbestand von 1,8—2,0 m zu wählen. Letztere Tiefe ist auch deshalb erforderlich, weil sonst die Baumwurzeln durch die Stoßfugen eindringen und durch die sogenannten Wurzelzöpfe die Rohre verstopfen könn-



ten. Aus diesem Grunde soll mit den Rohrleitungen nicht näher als bis 10 m an Bäume herangegangen werden. Gegen Verwurzelung wird auch empfohlen, die Rohrenden vor dem Verlegen in Karbolineum zu tauchen und die Rohrlage besonders über den Stoßfugen mit einer 20 cm starken Kies- oder Schlackenschicht zu bedecken. Das Gefälle der Sauger ist so zu wählen, daß sich keine Sinkstoffe ablagern können, es muß bei weiten Röhren wenigstens 0,1 %, bei engen 0,2 % (das wäre auf je 100 m Länge 10 bzw. 20 cm) betragen. Die Richtung der Saugstränge soll möglichst gerade sein, ihre Länge 200 m nicht überschreiten. Bei langen Strängen sind für den höher liegenden Teil Rohre mit 4 cm, für den tieferen mit 5 cm lichter Weite zu verwenden; zum Übergang dient das Übergangsstück.

Die beste Wasseraufnahme erfolgt, wenn die Saugstränge annähernd parallel den Höhenkurven verlaufen (= Querdränage). Ist jedoch das in Frage kommende Gelände sehr flach (unter 0,5 % Gefälle), so ist zwecks Erreichung des Röhrengefälles die Längsdränage anzuwenden, bei der die Saugrohre mit dem Gelände fallen. Bei einer Geländeneigung zwischen 0,5 und 2 % kann die Längs- und Querdränage gleichwertig Anwendung finden (vgl. hierzu den Dränageplan auf Tafel 25).

Folgende Tabelle gibt den Abstand der Saugstränge voneinander an:

Bodenart	Für Längsdränage m	Für Querdränage m
Schwerer Tonboden	10—12	10—15
Tonboden	12—14	12—18
Lehmboden	14—16	14—21
Sandiger Lehmboden	16—20	17—25
Lehmiger Sandboden	20—24	21—30
Leichter Sandboden	24—30	25—35

Die „S a m m l e r" nehmen das Wasser aus den verschiedenen Saugern auf und führen es der Vorflut zu. Das Gefälle der Sammler soll mindestens 0,2—0,4%, in sandigen Böden zur Vermeidung von Verstopfungen durch liegenbleibenden Triebsand 1% betragen.

Je nach der Anzahl der angeschlossenen Saugstränge ist der Durchmesser der Sammler zu wählen. Die Weite läßt sich wie folgt berechnen:

Es wird angenommen, daß in Gegenden mit normaler Niederschlagsmenge je 1000 m² Bodenfläche in der Minute ungefähr 4 Liter Wasser abzuführen sind; in niederschlagsreichen Gegenden erhöht sich die Zahl bis 6 Liter in der Minute.

Nachstehende Tabelle gibt die nötigen Röhrendurchmesser bei bestimmter Wassermenge und bestimmtem Gefälle an:

T a b e l l e ü b e r d i e i n 1 M i n u t e a u s D r ä n a g e r o h r e n a b f l i e ß e n d e W a s s e r m e n g e i n L i t e r n

Bei einem Gefälle von	Rohrweiten							
	4 cm	5 cm	6 cm	7 cm	8 cm	9 cm	10 cm	
0,1 %	—	[illegible]	[illegible]	33,0	48,0	66,0	90,0	Liter
0,2 %	3,0	15,0	28,8	43,0	69,0	90,0	132,0	,,
0,3 %	6,0	21,0	36,0	55,8	84,0	114,0	150,0	,,
0,4 %	12,0	[illegible]	40,8	64,8	90,0	132,0	168,0	,,
0,5 %	14,4	27,6	[illegible]	72,0	108,0	144,0	198,0	,,
1,0 %	20,2	[illegible]	[illegible]	[illegible]	150,0	204,0	270,0	,,
1,2 %	22,8	42,0	72,0	110,0	[illegible]	222,0	300,0	,,
1,6 %	25,2	[illegible]	[illegible]	[illegible]	192,0	258,0	348,0	,,
2,0 %	28,8	54,0	90,0	[illegible]	210,0	317,4	390,0	,,
3,0 %	36,0	67,2	[illegible]	173,4	258,0	360,0	480,0	,,
4,0 %	40,8	75,0	132,0	204,0	288,0	408,0	564,0	,,
5,0 %	45,0	85,2	[illegible]	228,0	330,0	468,0	612,0	,,
8,0 %	57,0	113,4	186,0	270,0	420,0	612,0	750,0	,,
10,0 %	66,0	120,0	210,0	330,0	480,0	660,0	900,0	,,

Die erste senkrechte Kolonne gibt das jeweilige Gefälle an; in der dazugehörigen waagrechten Zeile sind die Minutenliter für die einzelnen Rohrweiten angegeben. Für die Berechnung der nötigen Rohrweiten z. B. bei 1,2% Gefälle und 195,0 abzuführenden Minutenlitern erfolgt die Benützung der Tabelle so, daß erst in der senkrechten Kolonne das gegebene Gefälle (1,2%) und in der dazugehörigen waagrechten Zeile, die den abzuführenden Minutenlitern am nächsten stehende Zahl (hier 222,0) aufgesucht wird; senkrecht darüber ist dann die erforderliche Rohrweite (9 cm) angegeben.

B e r e c h n u n g s b e i s p i e l einer Dränage:

Eine 15 500 m² große Gartenfläche mit sandigem Lehmboden soll entwässert werden; die Niederschlagsmenge der Gegend ist verhältnismäßig reichlich.

Die Geländeneigung ließ eine Querdränage wählen, mit einer Saugdränhöchstlänge von 60 m; als Gefälle des Sammlers hat sich 0,5% ergeben. Da die S a u g e r eine Höchstlänge von 60 m haben, genügt eine lichte Weite von durchgehend 4 cm. Nach der Tabelle auf S. 71 beträgt der Abstand der Saugstränge für sandigen Lehmboden bei Querdränage 17—25 m; bei Gartenland die Tiefe 1,2 m.

Der Querschnitt des S a m m l e r s wird wie folgt berechnet: je 1000 m² sind bei reichlicher Niederschlagsmenge 6 l je Minute abzuführen, bei

15 500 m² also 6 l × 15,5 = 93 l je Minute. Da der Sammler 0,5% Gefälle hat, wäre am Ausfluß nach vorstehender Tabelle eine Rohrweite von 8 cm (entspricht der nächsthöheren Zahl von 108,0 Minutenliter) nötig. Nach ungefähr einem Drittel der Sammlerlänge kann, da jetzt nur mehr eine kleinere Fläche zur Entwässerung in Frage kommt, auf 7 cm und beim letzten Drittel auf 6 cm Rohrweite zurückgegangen werden.

Bei der Planung einer Dränageanlage ist vom Wasserspiegel der Vorflut auszugehen, um für die Rohre das entsprechende Gefälle zu erreichen. Für umfangreichere Anlagen geht der Projektierung eine Geländevermessung mit anschließender Herstellung eines genauen Kurvenplanes voraus, in den das ganze Dränageprojekt eingetragen wird.

Mit dem Verlegen der Rohre wird an der tiefsten Stelle begonnen. Auf diese Weise kann das sich sammelnde Wasser durch die schon gelegten Röhren abfließen. Der Graben wird mit dem Dränagespaten so schmal, als es die Bodenart erlaubt, ausgehoben; bei tieferen Gräben ist in halber Tiefe ein schmaler Auftrittsstreifen vorzusehen. Die Humusschicht wird talseits, die tiefere Schicht bergseits gelagert. Die Grabenbreite darf auf der Sohle nicht größer als der Rohrdurchmesser sein, damit die Rohre unverrückbar liegen bleiben. Auch sollen die Rohre wo möglich auf gewachsenem Boden liegen; Auffüllboden ist durch Stampfen gut zu festigen.

Die Grabensohle wird mit dem Schwanenhals zu einer halbkreisförmigen Rinne geglättet, dann werden die Rohre mit dem Legehaken eingelegt und fest aneinandergestoßen. Bei Triebsand ist es auch möglich, die Rohre auf 2 Latten zu verlegen. Der Eintritt des Bodenwassers erfolgt durch die Stoßfugen.

Um das genaue Gefälle einzuhalten, wird am besten am Anfang und Ende einer jeden Strecke ein Loch auf die erforderliche Tiefe ausgegraben und dort je ein Visierkreuz aufgestellt. Durch probeweises Aufsetzen des dritten Kreuzes während der Arbeit kann die Grabensohle genau in das geforderte Gefälle gelegt werden.

Tafel 25 zeigt auch die Verbindung des Saugers mit dem Sammler. In beiden Röhren wird mit dem Spitzhammer je ein Loch geschlagen, der Sauger auf den Sammler gelegt und die Fugen mit Ton gut verstrichen. Das offene Ende des Saugers wie auch dessen oberstes Ende wird mit einer Steinplatte und einem Tonpfropfen verschlossen. Größere Fugen zwischen einzelnen Rohren sind mit Rohrscherben zu überdecken. In Lehm- und Tonböden werden — um aufgeschlämmte Bodenteilchen nicht in die Rohre gelangen zu lassen — die Stöße vor dem Zufüllen mit einer Lage Torf oder Schlacke überdeckt.

Das Zufüllen der Gräben mit Erde hat vorsichtig zu geschehen, damit sich die Rohre nicht mehr verschieben können. Erst wird der Boden von den Seiten abgestochen und neben die Rohre gestopft, dann die ausgehobene Erde lagenweise eingefüllt und festgestampft und zum Schluß der Mutterboden oben aufgebracht. Der so zugefüllte Graben ist durch die Bodenlockerung anfangs etwas überhöht, bis sich die Füllerde wieder endgültig gesetzt hat.

Die beste Zeit zur Ausführung aller Dränagearbeiten ist der Herbst, weil da der Grundwasserstand am tiefsten ist.

2. Offene und überdeckte Gräben (vgl. Tafel 25)

Eine einfachere Form der Untergrundentwässerung ist die mit offenen oder überdeckten Gräben.

Die Ableitung mittels offener Gräben kann nur dort erfolgen, wo der Platzverlust keine Rolle spielt, so also z. B. in großen Parkgeländen, bei Moorkulturen usw. Auch kommt sie in Geländen mit reichlichem Baumbestand zur Anwendung, wo eine Röhrendränage durch Einwachsen der Baumwurzeln leicht wirkungslos werden kann.

Bei leichtem Boden werden die Grabenböschungen mit Rasenplatten abgedeckt und in ihrem unteren Teil durch Faschinenbündel vor dem Ausspülen geschützt (vgl. die Abb. der Tafel 25). Die Faschinenbündel haben eine Länge von ca. 3 m und einen Durchmesser von 20—30 cm; zu ihrer Herstellung wird Reisig in an Ort und Stelle errichtete Faschinenkreuze eingelegt, mit der Würgkette zusammengepreßt und in Abständen von ca. 30 cm mit Drähten abgebunden. In die Grabensohle werden Pflöcke eingeschlagen und die Bündel dahinter eingebaut. Das Längsgefälle offener Gräben darf nur ganz gering sein, da sonst durch die Wasserströmung die Grabensohle aufgerissen wird. Bei größeren Höhenunterschieden sind über Rundholzstufen führende Abstiege einzubauen, wobei die Auffallstelle mit einer Steinpflasterung zu versehen ist.

Bei überdeckten Gräben werden diese so schmal wie möglich ausgestochen, an der Grabensohle ist die Möglichkeit eines Wasserabzuges mit entsprechendem Längsgefälle zu schaffen.

Tafel 25 zeigt verschiedene Ausführungsmöglichkeiten. Bei festem Lehm- oder Tonboden wird der eigentliche wasserleitende Graben ganz schmal mit fast senkrechten Wänden ausgestochen und mit Rasenplatten abgedeckt. Bei leichteren Böden kommt auf die Grabensohle ein aus Ziegeln oder Steinplatten aufgestellter Abzugsschacht; dieses Verfahren ist vor allem dann wirtschaftlich, wenn Abbruchziegel u. dgl. an Ort und Stelle leicht zu haben sind. Bei Sandboden wird in die Gräben eine Packung von Faschinenbündeln eingebaut und diese mit einer Kiesschüttung abgedeckt.

Überdeckte Gräben haben eine Lebensdauer von ca. 5—8 Jahren; sie kommen also z. B. bei Pachtgeländen in Frage. Für Daueranlagen ist die Röhrendränage stets vorzuziehen.

Nedan följer en artikel av J.Henze: "Besteht eine Verwachsungsgefahr von Dränanlagen durch Baumwurzeln" i Erwerbsobstbau 1963, nr 5, sid. 122 - 123, där han redogör för vissa erfarenheter från Tyskland och Holland.

Dränanlagen können je nach den Boden- und Witterungsverhältnissen sowohl Grundvoraussetzung für einen erfolgreichen Obstanbau und im anderen Extremfall die letzte Intensivierungsstufe sein. Besonders dringend werden den Wasserhaushalt des Bodens betreffende Maßnahmen heute z. B. nach WEISSENBORN (1) im Alten Land und nach ROELOFFS (2) in Schleswig-Holstein, wo sie wahrscheinlich in Zukunft eine Existenzfrage entscheiden.

Da gefragt wird, ob in Obstanlagen verlegte Dränstränge durch Hineinwachsen von Baumwurzeln außer Betrieb gesetzt werden können und wie es sich gegebenenfalls verhindern läßt, wurden vom Institut für Obstbau in Bonn Erhebungen im Raum Meckenheim und Befragungen in deutschen und holländischen Obstanbaugebieten durchgeführt.

Freilegung alter Dränstränge

Die Ausgrabungen von Saugern und Sammlern aus 1 m Tiefe erfolgte im ersten der beiden untersuchten Betriebe in einer 53jährigen Boskoop-Anlage, die im 5. Standjahr dräniert worden war. Dabei sind die Stöße der Sauger mit Karbolineum getränkt worden. Die Dränstränge verliefen in einem Abstand von 1,50 bis 2 m entlang der Baumreihen. Je 22 Sauger-Rohre (ϕ 4 cm) wurden neben alten Boskoopbäumen und nachgepflanzten 5jährigen Birnen auf Sämling freigelegt und untersucht. Im gleichen Betrieb erfolgte eine Begutachtung von 10 Sammler-Röhren (ϕ 8 cm). Dieser Strang verlief im Abstand von 2 m parallel zu einer 50jährigen Hauszwetschen-Reihe. Der Boden bestand an den drei Ausgrabungsstellen in den obersten 20 cm aus einer stark humosen Schicht. Darunter lag bis 65 cm Tiefe eine Lehmschicht mit Steineinschluß und unter 65 cm herrschte strenger Lehm vor.

Im zweiten Betrieb wurde eine 35 Jahre alte Dränanlage untersucht, deren 5 cm weite Sauger-Rohre in einer Tiefe von 1,25 m verlegt worden waren. Zum Zeitpunkt der Ausgrabung war der Baumbestand — Schattenmorelle auf Vogelkirsche — 6 Jahre alt. Die nachgegrabenen 8 cm weiten Sammler-Rohre verliefen in einer 4jährigen Apfelanlage von Goldparmäne auf M IX. Die humose Lehmschicht dieses Bodens hatte eine Mächtigkeit von 25 cm. Ihr folgte bis 60 cm Tiefe eine Lehmschicht bei tonigem Lehm als Untergrund.

Ergebnisse und Befragungen

Prüfungen der Ausläufe sowohl der nahezu 50 Jahre als auch der 35 Jahre alten Dränanlage ergaben einen einwandfreien Betrieb. Weder in die bei der Verlegung imprägnierten, noch in ungetränkte Rohre waren Wurzeln hineingewachsen. In einzelnen „Wassersäcken" konnte dagegen eine geringfügige Verschlammung festgestellt werden. Die Beobachtung des Wurzelverlaufs der Obstbäume ergab, daß bei den vorliegenden Dräntiefen von 1 m bzw. 1,25 m nur ein geringer Anteil der Wurzelmasse überhaupt bis in diese Tiefen vorgedrungen war. Solche Befunde wurden auch von HILKENBÄUMER (3) erhoben, der die Hauptwurzelmasse von Obstbäumen auf verschiedenen Unterlagen zwischen 20 und 40 cm Tiefe fand. Lediglich Einzelwurzeln, vor allem von Sämlingsunterlagen in den ersten Standjahren, dringen unter Vernachlässigung dieser Wurzelpartien im fortgeschrittenen Alter gelegentlich tiefer in den Boden ein. Solche Wurzeln konnten auch an den freigelegten Dränrohren beobachtet werden. Einzelne Rohre waren von wenigen feinen Wurzeln umwachsen.

Die gleiche Feststellung konnte auch an flacher gelegenen Dränsträngen, z. B. in holländischen Treibhäusern für Trauben, die gleichzeitig einer Flüssigkeitsdüngung dienten, gemacht werden. Hier hatten Faserwurzeln die Rohre filzartig umsponnen, ohne jedoch in die Stöße hineingewachsen zu sein. Auch bei Dränanlagen im Kölner Raum, die vor allem der Beseitigung der häuslichen Abwässer dienten und somit zumindest zeitweise nährstoffreiches Wasser führen, kam es nie zu einer Beeinträchtigung durch Wurzeln. Allerdings war bei diesem Verfahren eine Zusatzmaßnahme getroffen worden, die evtl. auch für eine Dränung von Obstanlagen Bedeutung haben kann. Die Rohre waren mit einem 10 cm starken Kiesbett unterlegt.

Häufig wird die Ansicht vertreten, daß besonders dort Wurzeln — evtl. andere als von Obstbäumen — in Stöße einwachsen, wo Dränstränge noch Wasser führen, wenn der darüber liegende Boden schon trocken ist. Vorhandene Wurzeln würden dann zur Deckung ihres Wasserbedarfs an die Tonrohre heran- und evtl. in sie hineinwachsen. Wenn aber unter den Rohren eine Kiesschicht liegt, so ist sie so lange oder gar länger feucht, als in dem Rohrsystem noch Wasser fließt. Die Wurzeln dürften dann keinen Anlaß haben, in die Rohre hinein zu wachsen.

In der Regel brauchen für die Dränung von Obstanlagen keine solchen oder ähnlichen Zusatzmaßnahmen getroffen werden. Sie brauchen höchstens dort erwogen zu werden, wo Dränstränge in der Nähe anderer Gehölzarten verlaufen. Während nämlich die Wurzeln der relativ empfindlichen heimischen Obstarten auf durchlüftete Bodenpartien angewiesen sind, streben diejenigen wasserliebender Gehölze besonders bei Pappeln, Weiden, Erlen, aber auch bei bestimmten Sträuchern — z. B. bei solchen, die Hecken oder die „Knicks" in Holstein bilden — wasserreichere Bodenzonen an. Hier erscheint auch das Tränken der Stöße mit Karbolineum oder speziellen Präparaten zweckmäßig.

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Den följande artikeln rörande dränering av fruktträdgårdar som skrivits av B.W.Braams och J.Buitijn har hämtats ur den holländska tidskriften Meded. directeur van de tuinbouw, vol. 21, 1958, s. 763 - 770. Förf. diskuterar här en rad olika faktorer som påverkar valet av dräneringsintensitet (avstånd och djup). En sammanfattning på engelska följer i slutet på uppsatsen.

Ontwatering heeft in de eerste plaats tot doel te voorkomen dat de wortels van onze cultuurgewassen zich gedurende lange tijd in het grondwater bevinden. De wortels kunnen namelijk alleen goed functioneren wanneer zij over voldoende zuurstof beschikken.

Voor de draagkracht van de grond en de grondbewerking is het eveneens wenselijk hoge grondwaterstanden te vermijden. In bijzondere gevallen kan het doel van de ontwatering zijn de scheuring van de grond te bevorderen en in gronden die niet scheuren de mogelijkheid te scheppen voor een betere structuur. Ook hier is het uiteindelijke streven: optimale groei en optimaal functioneren van het wortelstelsel.

Over het algemeen wordt ontwaterd met behulp van greppels of drainreeksen. In sommige gevallen is de aanwezigheid van in goede staat verkerende scheidingssloten tussen de percelen reeds voldoende. Het zal bekend zijn dat met het oog op de mechanisatie en ook om andere redenen in de moderne fruitteelt aan drainreeksen de voorkeur wordt gegeven boven greppels. Begreppeling is echter niet altijd te vermijden. Zij kan noodzakelijk zijn op percelen met een slappe ondergrond, waarin geen drainreeksen kunnen worden gelegd. Vaak is het echter mogelijk de greppels te vervangen door sleuven met takkenbossen, die met grond worden afgedekt. Dichte gronden, waar het neerslagwater over de oppervlakte of door de bovenste grondlaag zijwaarts afvloeit, zijn vanouds begreppeld. Veelal liggen de akkers dan min of meer rond. Vanwege de bezwaren tegen begreppeling streeft men echter toch ook voor deze gronden naar een oplossing waarbij het oppervlakkig afstromende water in buizen wordt opgevangen. Men kan in vele gevallen drainreeksen onderin de greppels leggen en deze aanvullen met snoeihout, takkenbossen of ander doorlatend materiaal. Men spreekt dan terecht van ondergrondse greppels.

Voor een eenvoudige en heldere uiteenzetting over de grondslagen en de uitvoering van het draineren kan worden verwezen naar Van der Zaken [5].

Aan welke eisen moet de ontwatering voldoen?

Het is zeer moeilijk om vast te stellen, welke eisen het gewas aan de ontwatering stelt. De omstandigheden lopen zover uiteen, dat een algemeen geldige omschrijving niet gegeven kan worden. Niettemin hebben waarnemingen aan gewas en grondwaterstand tot een zekere empirische kennis geleid, die kan worden geformuleerd in ontwateringsnormen.

Zo is het in het grootste deel van ons land gebruikelijk voor bouwland een drainagesysteem te ontwerpen, dat bij een grondwaterstand van 50 cm beneden het maaiveld tenminste 7 mm water per etmaal afvoert (Boumans [1]). De ervaring leert dat wanneer deze norm wordt aangehouden en de onderzoek- en berekeningstechniek op de juiste wijze wordt toegepast (meestal volgens de methode Hooghoudt [2]), de ontwatering voor akkerbouwgewassen goed voldoet. In enkele gevallen is met metingen bevestigd dat de grondwaterstand dan zelden boven 50 cm stijgt en dat de afvoercapaciteit voldoende is (Wesseling [4]).

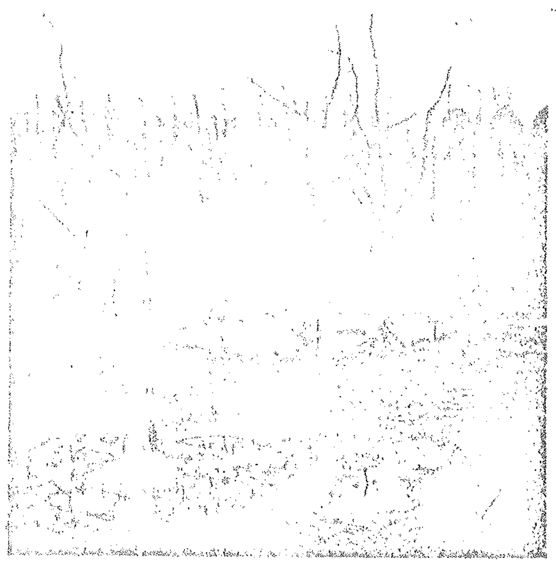
In de fruitteelt wordt een grondwaterstand van 50 cm beneden het maaiveld echter nog als hoog beschouwd. Meestal wordt aangenomen dat speciale maatregelen overbodig zijn, wanneer het grondwater in natte perioden niet hoger dan 60 cm beneden het maaiveld stijgt. Over de in het drainage-ontwerp toe te passen ontwateringsnorm bestaat nog geen communis opinio. Dat voor de fruitteelt een strengere norm geldt dan voor de akkerbouw, kan zeer goed worden verdedigd. De vruchtbomen hebben in tegenstelling met de meeste akkerbouwgewassen een uitgebreid wortelstelsel dat ook in het natte seizoen tegen wateroverlast moet zijn gevrijwaard. Bovendien is in een fruitopstand veel kapitaal geïnvesteerd, waardoor de risico's groter zijn dan bij akkerbouwgewassen. Zolang experimenteel of theoretisch afgeleide gegevens over de ontwateringseisen in de fruitteelt ontbreken, heeft het zeker zin na te gaan welke ervaringen onder verschillende omstandigheden zijn opgedaan en op grond daarvan voorlopige normen te formuleren. De schrijvers zijn van mening, dat een afvoer van 7 mm/etm. voldoende is en dat deze norm moet worden gehandhaafd; temeer daar voor de vaststelling van de drainafstand thans veel gebruik wordt gemaakt van grafieken die op deze afvoer zijn gebaseerd. Ten aanzien van de grondwaterstanden die nog net toelaatbaar kunnen worden geacht, ligt de zaak echter anders. Het is waarschijnlijk dat hoge grondwaterstanden in de periode december tot en met februari voor de fruitteelt weinig of niet schadelijk zijn, mits althans de bovengrond droog en goed begaanbaar blijft. De kritieke tijd is waarschijnlijk het voorjaar en daarom richten we ons speciaal op de maand maart. Daar de wortels reeds in maart actief zijn, moet de ontwatering in deze maand aan zekere eisen van het gewas voldoen. Is de ontwatering in het voorjaar voldoende, dan zal dit hoogstwaarschijnlijk in het najaar en de winter en in natte zomers ook het geval zijn.

De schrijvers stellen als ontwateringsnorm een afvoer van 7 mm/etm. voor bij een grondwaterstand van 50, 60 of 70 cm beneden het maaiveld. Welke van deze drie mogelijkheden voor de fruitteelt zal moeten worden gekozen, hangt af van de diepte van de beworteling, de aard van de grond beneden de bewortelde zone en de snelheid waarmee het grondwater in de zomer pleegt weg te zakken. In tabel 1 zijn de fruitteeltgronden ingedeeld naar de bewortelingsdiepte van de gewassen. De achter de verschillende gronden vermelde getallen begrenzen de laag, waarin 90 % van de fijne wortels zich heeft ontwikkeld of kan ontwikkelen.

De eerste categorie, met een bewortelingsdiepte van minder dan 30 cm, moet voor de fruitteelt zeker ongeschikt worden geacht. De tweede en derde categorie kunnen worden onderverdeeld naar de aard van de ondergrond, waarbij onderscheid wordt gemaakt in een 'droog' en een 'nat' type. Hiermee is bedoeld dat die ondergrond potentieel droog of nat is zoals dat tot uiting komt tijdens de teelt. Ondiepe gronden met een ondergrond van zand zijn vaak droogtegevoelig en moeten niet dieper ontwaterd worden dan strikt nodig is. Op deze profielen wordt in natte perioden een grondwaterstand van 50 cm beneden maaiveld toelaatbaar (en soms zelfs wenselijk) geacht. Ondiepe gronden met een ondergrond van zavel, klei of veen worden hier als natte typen beschouwd. De oorzaak van de ondiepe beworteling kan bij voorbeeld zijn: een niet gerijpte ondergrond, een wel gerijpte maar gereduceerde ondergrond, een te gering poriëngehalte in de ondergrond, of veen

Tabel 1. Indeling van de fruitteeltgronden

Categorie fruitteeltgronden	Bewortelingsdiepte
Te ondiepe gronden	< 30 cm
Ondiepe gronden	30-60 cm
Matig diepe gronden	60-90 cm
Diepe gronden	> 90 cm



Bij zo hoge grondwaterstand in de winter heeft ook de structuur van de grond veel te lijden

met ongunstige eigenschappen (niet veraard veen). In tal van gevallen is enige verbetering te verwachten bij diepe ontwatering. Overigens leidt de ondiepe beworteling vaak tot droogtegevoeligheid. Voor de ondiepe gronden van het natte type, alsook voor de matig diepe gronden op zand wordt in de ontwateringsnorm een toelaatbare grondwaterstand van 60 cm voorgesteld. Voor de matig diepe gronden met een ondergrond van zavel, klei of veen, dus die van het natte type, zal een ontwateringsnorm van 70 cm wenselijk zijn.
Voor de categorie diepe gronden verdient een diepe ontwatering zeker steeds de voorkeur. Voorgesteld wordt 70 cm als toelaatbare grondwaterstand aan te houden. Het is niet bekend of de bomen wellicht gunstig reageren op een nog diepere ontwatering.

Tabel 2. Voorgestelde ontwateringsnormen voor de fruitteelt

Ontwateringstype	Bewortelings-diepte	Grondwaterstand (afvoer tenminste 7 mm/etm.)
Ondiepe gronden op zand	30–60 cm	50 cm – maaiveld
Ondiepe gronden op zavel, klei of veen	30–60 cm	60 cm – maaiveld
Matig diepe gronden op zand	60–90 cm	60 cm – maaiveld
Matig diepe gronden op zavel, klei of veen	60–90 cm	70 cm – maaiveld
Diepe gronden	> 90 cm	70 cm – maaiveld

Hoe wordt deze ontwateringseis in de praktijk verwezenlijkt?

Op de meeste goede fruitteeltgronden zal men streven naar een zodanige ontwatering, dat in natte perioden de grondwaterstand in de regel niet boven 60 à 70 cm – maaiveld komt. De drainreeksen zullen in zo een geval dieper dan 70 cm moeten liggen. Bij een draindiepte van 1 meter is dan een drukhoogte van 30 à 40 mogelijk. Met drukhoogte wordt aangeduid het verschil tussen de stand van het grondwater midden tussen twee drainreeksen en de diepte van de reeksen. De drukhoogte bepaalt de kracht waarmee het water tot afstroming naar de drains wordt gedwongen. Zij is tevens een van de factoren, waarvan de onderlinge afstand tussen de drains afhangt. In een goed doorlatende ondergrond kan bij verdubbeling van de drukhoogte de drainafstand circa anderhalf maal zo groot worden genomen. Wanneer diep gedraineerd wordt, kan de drainafstand dus ruimer zijn, wat een besparing op de aanlegkosten kan betekenen. Het verdient dus aanbeveling vooral bij diep bewortelbare profielen na te gaan of een diepere ligging van de buizen, dus een grotere drukhoogte, mogelijk is. Bij goed vochthoudende en diep bewortelbare profielen zal men wel tot een draindiepte van 1,30 m kunnen gaan. De afwatering zal dan echter in veel gevallen moeten worden verbeterd, eventueel door onderbemaling.
Er zijn omstandigheden waaronder het ongewenst is diep te draineren:

De afwateringstoestand

Het is over het algemeen gewenst dat de uiteinden van de drainreeksen boven het slootwaterpeil blijven. Onvoldoende bemaling en een te hoog polderpeil beperken dus de draindiepte. Dit komt vooral voor in gebieden waar het polderpeil mede wordt bepaald door de aanwezigheid van grasland.

De mechanische uitvoering van drainage

Verschillende typen draineermachines werken niet dieper dan ca. 1 meter. Kiest men een machine die wel dieper graaft, dan kan dit belangrijke extra kosten meebrengen.

De droogtegevoeligheid

In zeer veel gronden is het grondwater onmisbaar voor de optimale vochtvoorziening van het fruitgewas. Wanneer men diep draineert, wordt meer vocht afgevoerd dan strikt noodzakelijk is. Door minder diepe ontwatering kan een groter deel van het neerslagoverschot worden behouden voor het groeiseizoen, wat met name voor droge gronden met een beperkte bewortelingsdiepte van betekenis is.

Door deze omstandigheden moet de drukhoogte die in de drainageberekening wordt toegepast, zeer vaak beperkt blijven tot 30 cm, op droge gronden soms zelfs tot 20 cm. Dit heeft tot gevolg dat nauw moet worden gedraineerd.
Van groot belang voor het bepalen van de gewenste drainafstand is verder de doorlatendheid van de grond. Boven de grondwaterspiegel wordt deze gewoonlijk geschat, beneden de grondwaterspiegel gewoonlijk gemeten volgens de boorgatenmethode (Boumans [1]). In een homogeen opgebouwd profiel is de gewenste drainafstand evenredig met de wortel uit de doorlatendheidswaarde. De vaststelling van de doorlatendheid levert nogal eens moeilijkheden op, omdat slecht doorlatende lagen niet altijd gemakkelijk als zodanig kunnen worden herkend. Voorts kan de doorlatendheid sterk veranderen met de tijd (bijvoorbeeld in gronden die sterk krimpen en zwellen). Deze grootheid moet dan ook met voorzichtigheid worden gehanteerd.

Situatie in enkele fruitteeltcentra

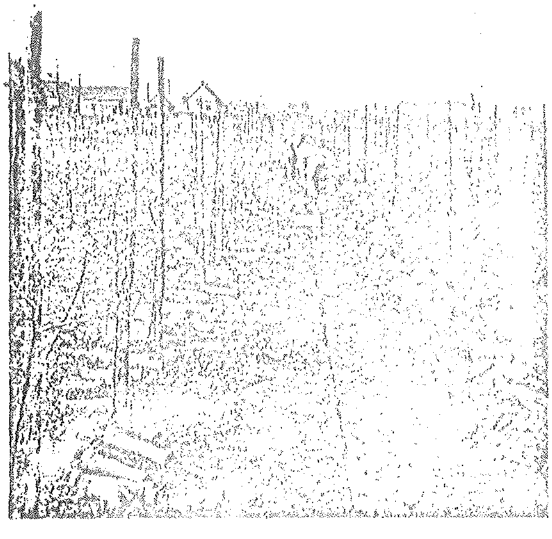
In 1957 is op initiatief van de Directeur van het Proefstation voor de fruitteelt te Wilhelminadorp een onderzoek ingesteld naar de ervaringen met drainage in de fruitteelt. Er werd een enquête gehouden onder de bodemkundig gespecialiseerde assistenten van de Rijkstuinbouwvoorlichtingsdienst. De resultaten zijn samengevat in een gestencild rapport [3]. Daarin worden voor de belangrijkste bodemtypen waarop fruitteelt wordt bedreven, richtlijnen voor een drainageontwerp gegeven. Onderzoek naar de doorlatendheid blijft evenwel onmisbaar, onder meer omdat de doorlatendheid van de ondergrond ook binnen een bodemtype sterk kan variëren en de doorlatendheid van de bovengrond mede afhankelijk is van de structuur en daarmede van de behandeling en de vroegere gebruikswijze van het perceel. De bodemkundige indeling in genoemd rapport levert echter wel belangrijke gegevens voor de wijze van ontwatering op. De in het voorgaande vermelde ontwateringsnormen zijn hieraan getoetst.

Een groot deel van de fruitteeltgronden in Zeeland bestaat uit matig diep gronden met een ondergrond van zand (type 3 uit tabel 2). Een deel kan geacht worden te behoren tot type 1 (de plaatgronden). Deze gronden zijn vaak droogtegevoelig, verdrogen soms zelfs sterk. Een ondiepe ontwatering kan er toe bijdragen dat de gewassen het groeiseizoen ingaan met een grotere vochtvoorraad in de grond. De drainage moet dan niet dieper worden aangebracht dan voor een voldoende ontwatering in natte perioden noodzakelijk is.

Op de diep bewortelbare gronden, zowel in het zeekleigebied als elders, komt droogteschade vrijwel nooit voor. Hier zal men zonder bezwaar diep kunnen draineren, en dit verdient dan ook alle aanbeveling. Hetzelfde geldt voor de veel voorkomende profielen met een slecht bewortelbare tussenzone en daaronder een betere ondergrond.

Ondiepe of matig diepe profielen met een ondergrond van klei of veen (typen 2 en 4 uit tabel 2) komen in het zeekleigebied veel voor. Met een diepe ontwatering zijn hier reeds veel goede resultaten bereikt. Na oxydatie kan rijping van de klei of veraarding van het veen intreden.

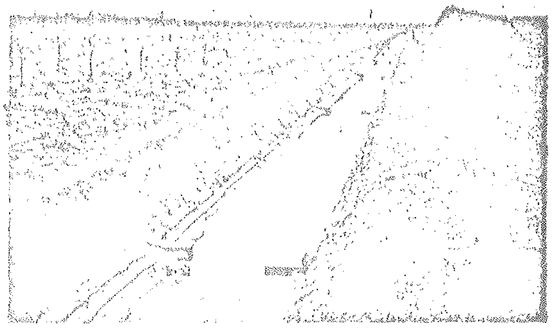
Ook in het rivierkleigebied komen tal van matig diep bewortelbare gronden voor, en wel van de typen 3 en 4. De dunne stroomruggronden en de overslaggronden hebben een ondergrond van zand en zijn vaak relatief hoog gelegen. Ze kunnen soms, wanneer het gebied een goede afwatering



Bij een bestaande aanplant kunnen de drainreeksen het best midden tussen twee rijen bomen worden gelegd

heeft, ongedraineerd blijven. Diepe ontwatering zou dan tot grotere droogtegevoeligheid leiden. De zwaardere gronden echter zijn vaak van oudsher nat en hebben meestal een klein luchtvolume. Wanneer deze grond voor fruitteelt wordt gebruikt is een zeer goede ontwatering nodig. Hier wordt een stand van 70 cm beneden het maaiveld als hoogst toelaatbare grondwaterstand aanbevolen. Al vaak is gebleken dat een goede ontwatering van deze gronden de bewortelingsmogelijkheid verbeterde.

Het feit dat hoge grondwaterstanden kunnen samenvallen met hoge rivierstanden en dientengevolge met kwel, is een argument temeer om de hoogst toelaatbare grondwaterstand in het riviergebied op 70, in een enkel geval op 60 cm beneden maaiveld te stellen.



Ondiepe drainage op een jonge ontginningszandgrond. De sloot kan worden onderbemalen

Voor lage zandgronden is een hoogste waterstand van 50 cm beneden het maaiveld veelal bevredigend. Voor zandgronden met een dik humushoudend dek zal dit 60 cm of meer moeten zijn, al naar de dikte van het dek.

De grootste moeilijkheid bij het opstellen van richtlijnen voor drainage op basis van het bodemtype vormt de drainafstand. In het genoemde rapport zijn voor de drainafstand op verschillende bodemtypen grenswaarden aangegeven die berusten op praktijkervaring en globale kennis van de optredende doorlaatfactoren. Tot een nauwkeurig en verantwoord advies komt men op deze wijze echter niet. Niettemin is van de in dit rapport verzamelde gegevens gebruik gemaakt om het in de volgende paragraaf behandelde schema te toetsen, dat op hydrologische en teelttechnische overwegingen berust.

Samenhang van drainage-ontwerp en beplantingssysteem

Het wordt meer en meer gebruikelijk bij nieuwe beplantingen een haagsysteem toe te passen. De bomen worden op de rij nauwer geplant, terwijl tussen de rijen een grotere afstand wordt aangehouden: in de meeste gevallen 3 à 5 meter. Het is wenselijk dat de drainreeksen in dezelfde richting lopen als de rijen en zoveel mogelijk midden tussen de rijen liggen. Dit om te voorkomen dat de wortels van de vruchtbomen de drainreeks binnengroeien en om het opgraven van de drainbuizen bij verstoppingen te vergemakkelijken. Het binnengroeien van vruchtboomwortels komt in de praktijk meestal weinig voor, bij windschermen

Tabel 3. Drainagemodellen en de bijbehorende bodemtypen

	Drainafstand (r = afstand tussen de rijen)	Drainafstand in meters	Hydrologische karakteristiek van het bodemtype	Draindiepte in cm
A. Profielen zonder slecht doorlatende lagen tot ca. 1,5 m diepte				
1.	4 à 6r	16 à 25	Zeer goed doorlatende grove zandgronden	60 à 70
2.	4 à 6r	16 à 25	Zeer goed doorlatende gronden (40 à 50 cm klei of zavel op grof zand)	60 à 70
3.	4 à 6r	16 à 25	Zeer goed doorlatende gronden (60 à 70 cm lichte klei of zavel op grof zand)	70 à 90
4.	3r	12 à 15	Goed doorlatende zandgronden	70 à 90
5.	3r	12 à 15	Goed doorlatende zavel- en kleigronden	90 à 120
6.	2r	8 à 10	Matig doorlatende lemige zandgronden	80 à 100
7.	2r	8 à 10	Matig doorlatende zavel- en kleigronden	90 à 120
B: Profielen met slecht doorlatende lagen				
8.	2r	8 à 10	Goed doorlatende klei-, zavel- en zandgronden met slecht doorlatende ondergrond beneden draindiepte	80 à 110
9.	2r	8 à 12	Slecht doorlatende klei-, zavel- en zandgronden met goed doorlatende ondergrond	90 à 120
10.	1r	5 à 7	Klei-, zavel- en zandgronden met slecht doorlatende ondergrond boven draindiepte	60 à 90

echter is het risico groter. Het is dus zaak zoveel mogelijk te vermijden dat drainreeksen de windschermen kruisen. De tussenschermen lopen evenals de boomrijen meestal noord-zuid, zodat bij draineren in deze richting ook zoveel mogelijk de windschermen worden vermeden. De drainreeksen liggen dus bij voorkeur noord-zuid en op een onderlinge afstand die een veelvoud is van de rijenafstand. Veelal zal men een keus moeten doen uit 2, 3, 4 of 5 keer de rijenafstand. (Bij een spillenaanplant met 4 meter tussen de rijen dus draineren op 8, 12, 16 of 20 meter.)
Daar de drainafstand als het ware gestandaardiseerd is naar het beplantingstype, is het ook mogelijk de hydrologische verscheidenheid der gronden terug te brengen tot een aantal modellen met de bovenvermelde gestandaardiseerde drainafstanden. Dit is gedaan in tabel 3, waarbij rekening is gehouden met de in tabel 2 voorgestelde ontwateringsnormen. Geen rekening kon worden gehouden met een eventuele hogere ligging ten opzichte van de omgeving. Dan kan soms aanmerkelijk ruimer worden gedraineerd, namelijk wanneer er ondergrondse afvoer plaats vindt en het ontwateringssysteem dus minder wordt belast. In tabel 3 is uitgegaan van een rijenafstand van 4 à 5 meter, zoals thans meestal voorkomt bij beplantingen op zwakke en matig sterke onderstam. Hierbij is vermeld op welk profieltype de onderscheiden drainafstanden kunnen voorkomen. Voorts is nog globaal aangegeven welke draindiepte onder deze omstandigheden wordt toegepast.

Het is niet mogelijk grenzen voor de doorlatendheid van de profielgroepen van tabel 3 aan te geven, omdat de andere in het voorgaande beschreven omstandigheden een grote invloed op de doorlatendheid hebben. De tabel geeft dan ook slechts een globaal overzicht en kan niet voor het oplossen van incidentele gevallen dienen. Aan elk drainage-ontwerp zal een nauwkeurige opname van de bodemkundige, tuinbouwkundige en cultuurtechnische omstandigheden vooraf moeten gaan. Onderzoek naar de doorlatendheid is hierbij onmisbaar.
De achter 1, 2, 3 en 4 genoemde gronden zijn meestal droogtegevoelig. Drainage kan achterwege blijven als de afwatering prima in orde is en geen hoge grondwaterstanden voorkomen.
De nummers 9 en 10 hebben betrekking op gronden voor sterkere onderstammen, waarop dus ook een rijenafstand van 6 en 7 meter kan voorkomen.
De beste fruitteeltgronden zijn die achter de nummers 5, 6 en 7. Deze gronden worden om de twee of drie rijen gedraineerd. Vele ervan zouden met succes nog dieper kunnen worden ontwaterd door drainage tot op 1,30 m diepte, maar de omstandigheden, met name sloten en polderpeilen, laten dit vaak nog niet toe.

Samenvatting

Op grond van waarnemingen en ervaring worden normen geformuleerd, waaraan de ontwatering in de fruitteelt zal moeten voldoen. Hierbij wordt een globaal onderscheid gemaakt naar de grondsoort. De omstandigheden die van belang zijn bij het ontwerpen van drainagesystemen volgens deze normen, worden in beschouwing genomen. Vooral de doorlatendheid van de grond, de gewenste ontwateringsdiepte en een aantal factoren van technische aard bepalen hoe een systeem moet worden uitgevoerd. Ook wordt de vraag besproken, of diep of ondiep moet worden gedraineerd. Hierbij spelen de eisen van het gewas en de uitvoeringsmogelijkheden een rol.
Het bodemkundig profielonderzoek levert gegevens die eveneens waardevol zijn voor het ontwerpen

van een drainage. Voor het vaststellen van de gewenste reeksenafstand moeten echter ook metingen van de doorlatendheid van de grond worden verricht.
Voorgesteld wordt de drainage in boomgaarden aan te passen aan de beplanting en de drainafstand af te ronden tot een veelvoud van de rijenafstand. Een voordeel hiervan is dat de uiteenlopende hydrologische eigenschappen van de gronden in een schema kunnen worden ondergebracht. Drainafstanden van 4 à 6 maal de rijenafstand komen voor op veelal droogtegevoelige gronden. Op de beste gronden zal de drainafstand meestal 2 of 3 maal de rijenafstand zijn, althans bij een rijenafstand van 4 à 5 meter.
Drainafstanden kleiner dan 8 meter komen onder verschillende omstandigheden ook voor. Veelal zal op deze gronden gebruik worden gemaakt van sterke onderstammen.

Summary

Drainage in fruit-growing

As a result of experience and observations a few criteria of drainage have been laid down for fruit-growing.
A rough distinction is made here as to the type of soil. The circumstances are considered which may be of importance in making tile drainage systems according to these criteria.
In particular the soil permeability, the desired drainage depth and a number of factors of a technical nature determine how a system must be implemented. The question is also considered of whether deep or shallow drainage must take place. The crop requirements and the possibilities of implementation play a part in this.
Pedological profile research gives data which are also valuable for planning a good drainage system. To determine the tile spacing, measurements of the permeability of the soil must also be made.
It is suggested that in orchards drainage should be adapted to the planting lay-out and that the tile distance should be rounded off to a multiple of the distance between the rows. An advantage of this is that the divergent hydrological qualities of the soil can be incorporated in a scheme.
Tile distances of 4 to 6 times the distances between the rows are found in soils which are very permeable and often susceptible to dryness. In the best soils the tile distance will generally be 2 of 3 times the distance between the rows, at any rate when this distance is 4 to 5 metres. Tile distances smaller than 8 metres are found in soils with low permeability. Much use is made in these soils of vigorous root stocks.

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Innan vi lämnar avsnittet om trädgårdsdränering kan det vara av intresse att ta del av några mera praktiskt betonade synpunkter. Den följande artikeln, betitlad Orchard drainage, har skrivits av R.G.Cahill, Horticultural Instructor, och är publicerad i Journ. Agr. West Austr. 2, 1961, s. 529 - 532.

Då och då finner man uppgifter i litteraturen att man vid läggning av dräneringsledningar skall dra isär rören något för att vattnet med säkerhet skall kunna komma in i dessa. Det är just vad man inte skall göra. Vad man då med säkerhet vet är att riskerna för inslamning i rören därigenom i hög grad ökas. Mr Cahills uttalande på denna punkt får följaktligen stå för hans egen räkning.

UNDERGROUND drainage of orchard land is an essential feature of fruitgrowing which is overlooked by many orchardists. Soils should be adequately drained to cope with all winter rains.

Even in years of sub-normal rainfall many orchards in the south-west of Western Australia suffer from adverse effects of water-logging with resultant root damage. Well drained soils allow better root development over a greater volume of soil, giving a larger root zone from which to draw moisture during summer.

The symptoms of water-logging can often be easily recognised. In other instances where it may not be directly obvious, only a slow decline of the trees will result. Bad drainage is often seen in the poor weed growth in orchards.

Apple trees may show delayed foliation in the spring and later yellow and sparse leaves lacking normal tree vigour. Such trees are first likely to appear in isolated patches on, or at the foot of, slopes which may appear well drained.

This is due to an uneven depth of heavy clay subsoil, or rock formation approaching nearer the surface at some points than others. Water penetrating to this layer will move along its surface and collect in ponds behind the ridges.

To effect drainage, channels must be cut through these clay or rock bars. Results of this are clearly visible in the accompanying pictures. The presence and location of the bars is readily determined by forcing a probe made of a 5/16 in. steel rod into the ground at likely spots when the ground is wet.

It must be made quite clear that drainage of the soil only removes excess water and does not take away water which would have provided summer moisture for tree growth. When rain falls on the ground it wets the soil to field capacity, after which further water will drain away in the drainage system. The remaining moisture is only removed by root absorption or evaporation. Bad drainage causes a depletion of oxygen in the soil with subsequent ill effects on root growth and hence on tree vigour.

There are a number of methods in use for draining orchards.

The use of jarrah saplings—two placed in the drain bottom with a third placed on top—has proved quite effective. There is little need to remove the bark and the sapling tops can be used to lay over the top of the saplings prior to filling with earth. The box type drain made from slabs of timber has also done good service in many orchards and endured for years.

But as drainage is something which only wants to be done once in the lifetime of an orchard, the best service will be obtained from the use of agricultural pipes. Terra cotta pipes appear to be the best. Use of cement pipes should be approached with caution because soil often has a corrosive action on cement.

The pipes should be carefully placed in the dug drain leaving a 1/16 in. gap between pipes to allow water entry. Over each gap is placed a shovel full of coarse blue metal or washed gravel. This gives good water penetration while stopping clay or soil from clogging pipes.

In the Bridgetown and Boyup Brook districts poor drainage occurs mainly as odd patches in an orchard and a central drain through these parts drained to the most convenient point is usually sufficient. If the area to be drained is large, spur drains connecting with the main drain can be used.

When considering the number and depth of drains, the soil type and the area to be drained must be the governing factors. Where impermeable clay subsoil occurs close to the surface little lateral movement of water is obtained and close drains will be required. In some circumstances a drain every second row may be needed. In this type of soil the subsoil is usually within two feet of the surface and a drainage depth of 2 ft. 6 in. to 3 ft. is desirable. On lighter loam soils where side movement of water can be assured less drains would be needed to drain the area. In such soils the clay subsoil is usually deeper and drains could with advantage be dug to four feet.

If the orchardist cannot see his way clear to install underground drains in the first year of the young trees' life it is strongly advised that open drains either dug by hand or formed by a single furrow plough be used to drain off as much excess water as possible.

Too many weak sections both in old and young orchards can be traced to bad drainage. Remember that by rectifying this trouble early you will make your trees repay you early.

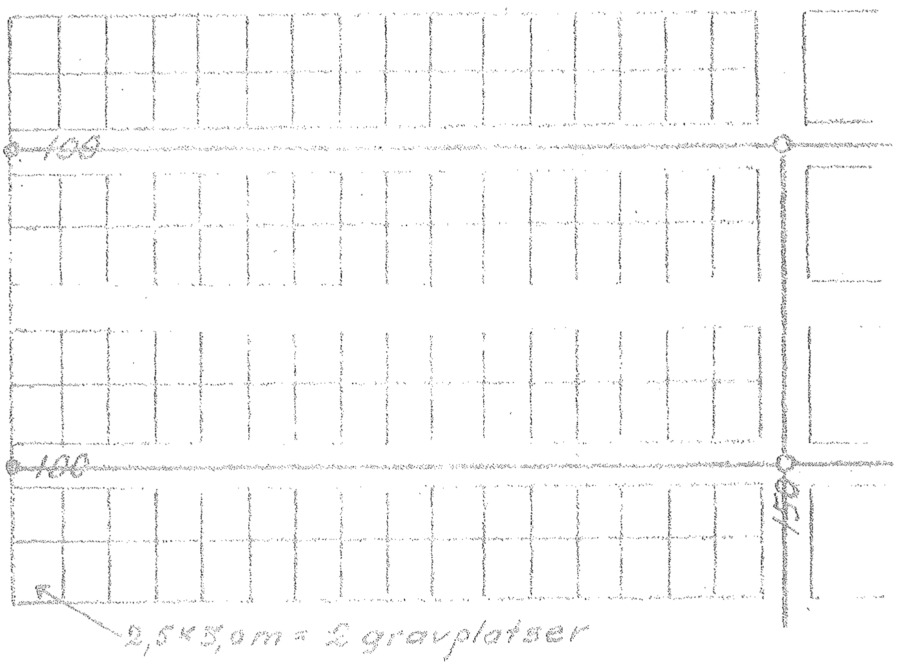
IV. Dränering av kyrkogårdar

Vid nyanläggning av kyrkogårdar försöker man i görligaste mån finna sådana platser där markförhållandena är lämpliga, om möjligt en relativt lätt kalkrik jord. Men de lokala förhållandena kan vara sådana att man tvingas att mer eller mindre göra avkall på denna fordran. Stundom måste ren lerjord tagas i anspråk för ändamålet. Under alla förhållanden är det emellertid av största vikt att erforderlig dränering av området verkställes. Om det i samband med kyrkogårdens anläggning blir fråga om mera betydande schaktningsarbeten, bör vad tidigare anförts uppmärksammas, att dylika arbeten genomförda med modern teknisk utrustning kan leda till att vissa delar av området kan få de naturliga hydrologiska förhållandena ändrade i negativ riktning med ökat dräneringsbehov som följd.

En dräneringsplan över en kyrkogård måste utformas med hänsyn till bl.a. de topografiska förhållandena - de naturliga eller de av människan mer eller mindre modifierade. Som följd härav bör projektering av dräneringen och planläggningen i övrigt ske parallellt. Visserligen bör man lägga dräneringsledningarna så djupt att de går fria vid gravgrävningen - gravdjupet skall enligt gällande bestämmelser vara 2,0 m, dubbelt gravdjup 2,5 m och tredubbelt 3,0 m, och dikesdjupet brukar vara ca 0,5 m djupare än angivna värden - men man vill ogärna att täckdikena ligger rakt under gravarna, även om detta ur dräneringssynpunkt vore det mest effektiva. Risk föreligger för att rören kan rubbas vid gravgrävningen, som ju numera vanligen utföres med grävskopa. Man eftersträvar att dräneringsledningarna ligger i vägar och gångar inom området, där de är bättre skyddade. Vid regelbundet utformat gravfält (intensivbeläggning) blir som följd härav dikesavståndet en multipel av bredden av två gravrader (se skissen på följande sida).

Vad här sagts gäller nyanläggning av kyrkogård. Vid omdränering eller förbättring av dräneringen på en äldre kyrkogård ligger givetvis förhållandena annorlunda till. Då måste man så långt möjligt anpassa dräneringen efter de rådande förhållandena med avseende på gravläggningen, vilket ofta kan vara ganska komplicerat.

Det är emellertid ej alltid som ett planerat kyrkogårdsområde i sin helhet kan tagas i anspråk som gravfält. Bortsett från att en sådan koncentrering ur estetisk synpunkt är föga tilltalande kan grundförhållandena lägga hinder i vägen. Här och var kan hård bottenmorän

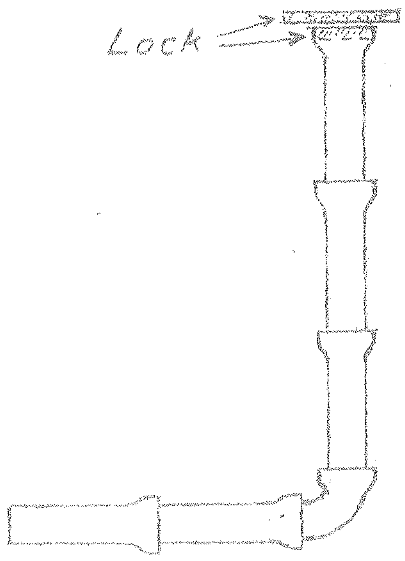


Skiss över begravningsplats
Skala 1:400

eller fast berg sticka upp närmare markytan, vilket givetvis påverkar planeringen och därmed även dräneringsplanen. En noggrann sondering av hela det för en kyrkogård föreslagna området måste därför föregå projekteringen och djupet ner till hårt underlag kartläggas. Sådana områden där det lösa jordlagret är för grunt för kistgravar kan ofta vara lämpliga som plats för urngravar. Dessa upptages till ett djup av högst 1 m, varför ett dräneringsdjup av ca 1,2 m här är tillfyllest. Då urngravar vanligen upptages genom handgrävning, behöver hänsyn ej tags vid dräneringen till hur dessa kommer att läggas.

Självfallet måste man vid dränering av en kyrkogård liksom vid varje annan dränering ta vederbörlig hänsyn till ytvattenavledningen. Erforderliga dagvattenbrunnar måste alltså nedsättas. Dessa kan utformas på konventionellt sätt. Beträffande dimensioneringen av ledningar behöver man strängt taget ej räkna med väsentligt starkare avrinning än från åkerjord - man har ju som regel inga eller i varje fall obetydligt med hårdgjorda ytor på en kyrkogård. Å andra sidan vill man inte att vatten ens tillfälligtvis samlas på ytan av en kyrkogård. Man brukar därför öka på dimensionerna en del, till ungefär det dubbla mot vad fallet är vid dränering av åkerjord.

Eftersom det blir fråga om stora dikesdjup på en kyrkogård och till följd härav ganska kostsamt och besvärligt att rätta till even-



Spolbrunn

tuellt uppkommande felaktigheter på dräneringen, är man givetvis angelägen om att få så god hållbarhet som möjligt på denna. Man föredrar ofta betongrör framför tegelrör såsom varande mera motståndskraftiga mot mekanisk påverkan, exempelvis vid gravgrävning - plaströr bör nog undvikas vid kyrkogårdsdränering - och man vill i görligaste mån sörja för att de förblir funktionsdugliga under lång tid. Vid läggningen bör rören täckas med ett ordentligt lager grus eller kanske ännu bättre först makadam och ovanpå denna ett gruslager. Därigenom har man väl sörjt för att en effektiv grundvattenavledning skall ernås. Vidare kan man utan större kostnad ordna med möjligheter för rensning av ledningarna genom att som bredvidstående skiss visar låta dessa gå upp nära markytan i sin övre ända. För att ge ökat skydd och för att underlätta att finna röret vid sondering kan man lämpligen ovanpå locket som är inpassat i muffröret lägga ett större betonglock, helst med ett tunt jordskikt eller gruslager mellan locken.

Av väsentlig betydelse för att dräneringen av en kyrkogård skall hållas intakt under lång tid är att man har gott fall i ledningarna. Om möjligt bör man försöka få ett fall på 4 à 5:1000 i grenledningarna och helst ännu större i stammarna. Vid mera markerad marklutning bör man liksom i andra sammanhang använda tvärdränering. Önskemål ifråga om gravrader och vägar kan dock medföra att dräneringsplanen blir i viss mån "tvångsstyrd".

I det följande återges avsnittet om utstakning, planering, terrassering och dränering av en kyrkogård i "Handbok i kyrkogårdsvård", utgiven under redaktion av Else Dahl (Svenska Kyrkans Diakonistyr. förlag, Stockholm 1943). Framställningen är visserligen i en del avseenden föråldrad - bl.a. har man numera helt andra tekniska resurser för arbetets utförande än då boken skrevs för snart 30 år sedan - men då något nyare arbete på området tyvärr ännu inte har utkommit, har det ifrågavarande avsnittet medtagits här.

Ett par direkta felaktigheter bör kanske påpekas. Ett grendike (sugdike) uppsuger som bekant inte vatten ur jorden såsom V.Månsson vill göra gällande. Och ifråga om en ordentlig packning av återfyllnadsjorden i dikena (med järnstöt!), vilket han starkt betonar vikten av är detta naturligvis alldeles riktigt ifall man redan från början vill ha en dålig effekt av dräneringen, annars inte.

a. Utstakning, planering och terrassering.

Av N. A. Blanck och G. V. Walberg.

Förarbeten Innan anläggningsarbetet igångsättes, måste markområdet för den blivande kyrkogården, om det är belamrat med skräp eller överflödig sten, befrias därifrån. Finnes mångårigt ogräs i större mängd, är det nödvändigt att helträda området minst ett år i förväg. Ännu bättre är att odla ogräskvävande växtslag, t. ex. potatis, som skördas tidigt på hösten, eller också beså fältet med en kväveupptagande växt, t. ex. lupin eller vicker, som nedplöjes före frömognaden. Det senare sättet bör i synnerhet tillrådas på lätt och mullfattig jord.

Utstakning Vid arbetets början skall arbetsritning i skala 1:100 eller 1:200 (se sid. 117) jämte arbetsbeskrivning (se sid. 116) finnas tillgängliga på arbetsplatsen.

Ägogränsmärkena skola vara tydligt utsatta, så att de kunna tjäna som utgångspunkter vid områdets utstakning, varvid gränserna först markeras, därefter huvudgångarna och övriga huvudlinjer av planen. Där marken är ojämn, företages avvägning och utsättas höjdmått. Dessa arbeten böra utföras av fackman. De verkliga fixpunkterna bruka i allmänhet angivas av stadsingenjören i stad, där sådan finnes, eller eljest av person, som därtill är bemyndigad. Som fixpunkt kan även användas annan fast punkt i terrängen eller å närliggande byggnader; höjden å densamma är då godtyckligt vald. Angivna höjder avse färdiglagda ytor i resp. gångar. Gräsmattorna beräknas ligga omkring 4 cm högre än gångarna. På slät mark utföres dränering (se sid. 149) samtidigt i både huvudgångarna och sidogångarna. Om större bortschaktning av jord måste företagas, dräneras ej, förrän schaktningsarbetet är färdigt. Det är av vikt, att dräneringen från början får den önskade sträckningen. En dränering, som kommer att ligga under ett gravkvarter, blir ytterst svår att rensa upp eller eljest reparera, och det bör således tillses, att inga rörledningar dragas fram där gravplatser sedermera skola upptagas. Även vattenledning bör nedläggas, sedan de större schaktningsarbetena utförts, men innan planerings- och planteringsarbetet påbörjats.

Planering Områdets planering utföres på olika sätt, allt efter den för handen varande terrängen. Är marken jämn eller svagt kuperad, bortschaktas matjorden från gångar och vägar samt grävas grunder för blivande byggnader och murar. Allt användbart material tillvaratages. Matjord flyttas till de områden, där matjordslagret är mycket tunt, sten och lera användas vid anläggandet av vägar eller på andra platser, där man önskar fast grund. Entreprenören eller den person, som har att ansvara för arbetet, bör noga underrättas om var den uppschaktade jorden och övrigt material skall läggas, så att ej onödigt förflyttningsarbete måste företagas eller icke önskvärd jord kastas ovanpå redan för plantering färdigberedda jordstycken.

Är det blivande kyrkogårdsområdet starkt kuperat, måste ofta stora jordflyttningsarbeten företagas, ibland även terrassering (se sid. 147 f.). Bådadera äro dyrbara men ofta nödvändiga, om man skall få en väl anlagd och i möjligaste mån användbar kyrkogård. För att markytan skall bliva jämn, förflyttas jord från högre till lägre belägna platser. När schaktningsarbetet är av den omfattning, att större mängder jord skola bortföras från ett område eller påföras ett annat, måste man gå till väga på sådant sätt, att matjordslagret bibehålles överst. Förfaringssättet är följande: jordområdet indelas i strängar om cirka 1,5 m:s bredd. Från den första strängen bortföres matjorden och lägges i hög. Alven bortschaktas resp. ditforslas, och matjorden från nästa sträng påföres. Sedan fortsättes med alvens schaktning och matjordens påförande sträng efter sträng, tills den sista är färdig för påförande av matjord. Härtill användes den uppschaktade jord, som först blivit lagd i sträng. Med ovan beskrivna förfaringssätt blir transporten av jord den minsta möjliga. Mångenstädes förekommer det, att man av sparsamhetsskäl underlåter att omflytta alven och matjorden, men då arbetet är av stor betydelse för de delar av kyrkogården, där träd och buskar skola planteras, kan det ej nog rekommenderas. De flesta växter trivas illa, där matjordslagret är tunt, och även om jordförbättring företages efter planteringen, blir resultatet sällan gott. Före schaktningsarbetets påbörjande uppluckras matjorden genom plöjning, och de större gångarna utstakas.

Vid förflyttning av jord användas vanligen skottkärror eller tippkärror, vilken metod är bäst men också dyrast. En s. k. mullskopa kan användas, där nivåskillnaderna äro relativt små och matjordsdjupet tillfredsställande och där det endast gäller förflyttning av mindre mängder jord. Ett sådant förfaringssätt blir billigare men tarvar stor noggrannhet vid utförandet.

Återstående med planeringen sammanhängande arbeten såsom gödsling, jordbearbetning etc. återfinnas behandlade i detalj i respektive kapitel.

Om lutningsförhållanden och terrassering

Där markens lutning är stor men ej överstiger 1:5 och terrassering icke anses alldeles nödvändig, böra gravplatserna förläggas på sådant sätt, att gravarnas långsidor bliva parallella med markens lutningsriktning. Följden blir annars, att de enskilda gravinnehavarna frestas att själva anordna terrassering på sina gravplatser. Detta kan i hög grad skada totalintrycket av kyrkogården, i synnerhet om gravplatserna ordnas utan sakkunnig hjälp.

Terrassering bör alltid företagas, där lutningen är större än 1:5. Visserligen fördyras härigenom anläggningen, förbindelsen mellan kyrkogårdens olika kvarter försvåras, men flera viktiga fördelar vinnas: dels kvarligger vägmaterialet bättre och dels kan man åt gravplatserna giva en planläggning, som lättare och vackrare ansluter sig till deras regelbundna form etc., dels utgöra terrassanordningar ur estetisk synpunkt sett verkningsfulla motiv. Varje terrass bäres upp antingen av en slänt eller en mur.

Terrassens plan kan naturligtvis läggas horisontellt, men detta är av flera skäl mindre önskvärt. Dels innebär det en ökad kostnad för jordflyttning och dels förorsakar det horisontella planet en synvilla, så att det tyckes luta mot markens naturliga lutningsriktning; dessutom får ytvattnet svårt att avrinna. Det framgår alltså av ovan uppräknade fakta, att det är mera ändamålsenligt, om åt terrassen kan givas en svag lutning. En eller flera gravrader kunna anordnas på varje terrass,

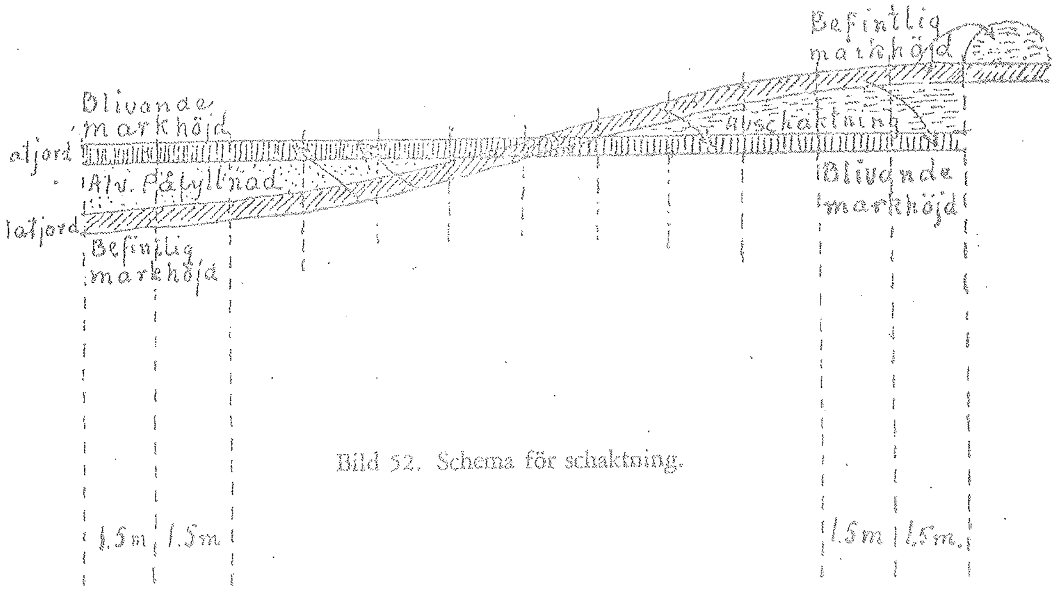


Bild 52. Schema för schaktning.

men varje rad bör ligga innanför (ovanför) en väg och luta mot denna. Läggas gravplatserna nedanför vägen, komma de att slutta från denna och gravstenarna att stå för lågt. Härigenom bliva dessa gravplatser på allt sätt sämre lottade än de som ligga ovanför en väg.

Vid valet mellan mur eller slänt bör hänsyn tagas till varjehanda olika omständigheter. Om jorden är lös, grusig och mullfattig samt utrymmet begränsat eller det kan förutsättas, att svårigheter kunna uppstå vid den framtida skötseln av slänten, äro murar att föredraga. Kostnaderna ställa sig dock lägre vid anläggning av slänter, och mångenstädes kunna dessa sägas smälta vackrare och mjukare in i terrängen. I varje särskilt fall fordras emellertid ekonomiska kalkyler, ty endast med stöd av sådana kan man bedöma fördelen av det ena eller andra systemet. Till sist må framhållas, att även omgivningen spelar en viss roll för valet.

Stödjemurar för terrasser äro av två huvudtyper, som sedan kunna variera mycket, dels s. k. kallmurar, dels murar, sammanhållna av murbruk. Den förstnämnda typen är mycket användbar och ställer sig betydligt billigare i utförande, då grunden ej behöver nedföras till frost-

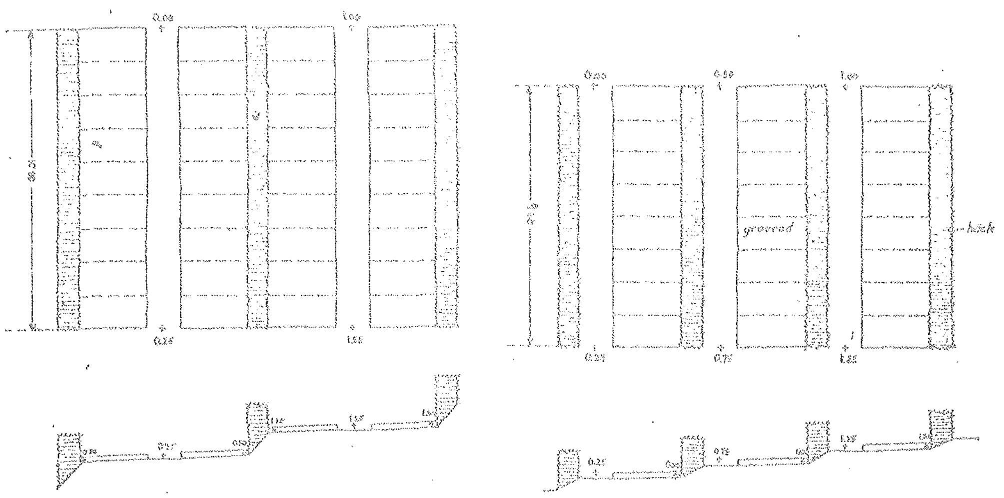


Bild 53. Exempel på terrassering.

fritt djup, men den passar icke i vilken miljö som helst. Om uppförande av murar, se sid. 168 ff.

Krönet av en terrassmur — om denna är en kallmur — eller slänt kan förses med en häck, gärna av blommande växtmaterial. I en kallmur kunna de öppna fogarna fyllas med jord, vari man planterar vissa slag av mindre växter, t. ex. Sedum. Tyvärr ställer sig ett sådant arrangemang ganska dyrbart i underhåll.

Om anläggning av slänter se gräsmattor (sid. 249 ff.).

b. Dränering.

Av Victor Månsson.

Allmänna synpunkter

Med dränering förstår man utförandet av sådana anordningar, som avse bortledande av vatten intill ett visst djup från ett markområde, antingen för att i görligaste mån hastigt uttorka marken eller för att avleda överflödsvatten, som av en eller annan orsak är till skada.

Yt- och grundvatten

Man skiljer mellan två slag av vattenförekomst i marken: ytvatten och grundvatten. Ytvattnet tillföres marken direkt genom nederbörden. En del av detta vatten sjunker så småningom, beroende på jordlagrens beskaffenhet, ned i grunden och bildar där grundvatten. Resten av ytvattnet avdunstar eller avrinner på ytan till lägre belägna ställen. Grundvattnet kan påträffas på högst olika djup, beroende på markens förmåga att kvarhålla eller bortleda detsamma. På samma ställe kan grundvattnet vid skilda tider stå olika högt, högst på våren efter snösmältningen samt efter starkare regn, lägst under den varmaste och torraste delen av sommaren.

Jordarters vattengenomsläpplighet

Genom dräneringen avses huvudsakligen att påskynda ytvattnets avrinnande och att sänka grundvattenytan till det djup, som för varje särskilt fall är behövligt. Olika jordarter hava olika förmåga att genomsläppa vatten. Lerjorden, speciellt den styva leran, är den tätaste av alla jordarter och utövar följaktligen det största motståndet mot vattnets avrinnande. Därnäst i motstånd kommer sandblandad lera, dy- och mossjordarter, lerblandad sand, kvicksand, finkornig, hårt packad sand, finkornigt grus samt grovkornigt grus och stenmaterial. Ju mindre vattengenomsläppande jordarten är, desto tätare måste dräneringssträngarna ligga.

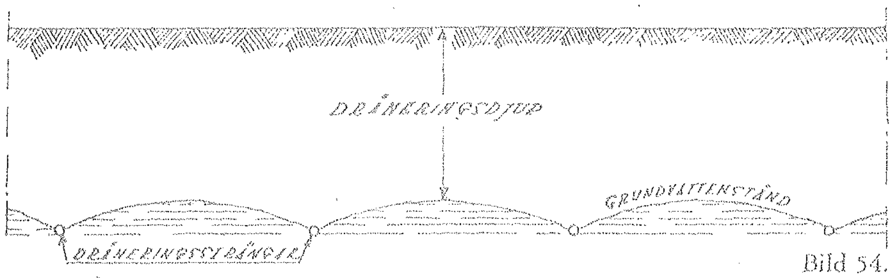


Bild 54.

Dräneringsdjup

Då dräneringssträngarna ligga på ett visst avstånd från varandra och jordarterna enligt det föregående utöva motstånd mot vattenavrinningen, blir dräneringsdjupet mindre än strängarnas djup. Man måste därför placera rören djupare än det för fallet i fråga behövliga dräneringsdjupet.

Om t. ex. ett dräneringsdjup av 2 meter önskas, och avståndet mellan strängarna är valt med hänsyn till de olika jordarternas beskaffenhet, så måste rören ligga på ett djup av minst 2,3—2,4 meter, enligt vad man funnit genom åtskilliga undersökningar och försök.

Dräneringssystem; sug- och stamdiken

Dräneringssystemet består huvudsakligen av två delar: sugdiken och stamdiken. Sugdikena uppsuga vattnet från marken, och stamdikena uppsamla sugdikenas vatten samt leda det vidare till närmaste öppna vattendrag eller avloppstrumma. Stamdikena kunna även tjänstgöra som sugdiken. Stamdiket, som mottager vatten från flera sugdiken, måste dimensioneras grövre än dessa. Är markområdet, som skall dräneras, av större omfattning, kunna flera stamdiken sammanföras till en gemensam större ledning.

Sugdikenas läge och riktning

Om markens lutning är obetydlig, läggas sugdikena ungefär i markens lutningsriktning, s. k. *längsdränering*. Är däremot lutningen stark, bör man lägga sugdikena snett mot fallet. Denna senare anordning kallas tvär- eller sneddränering. Ovan sagda gäller för en dränering, där sugdikena kunna läggas efter fritt val, men detta är icke alltid förhållandet. För en begravningsplats t. ex. böra sugrören om möjligt placeras i gångarna, dels därför att de skola vara åtkomliga för event. upprensning av slamavsättningar, vilket de icke bliva, om de placerats under gravarna, och dels därför att de då ej bliva utsatta för åverkan vid upptagande av nya gravar. Givetvis måste man se till, att rören komma att ligga i fallets riktning, och endast undantagsvis och för korta sträckor kan man lägga rören mot det naturliga fallet.

Stamdikenas läge

Som stamdikena skola uppsamla vattnet från sugdikena, böra de framdragas i fältets lägsta delar. Vad som förut sagts om sugdikenas placering gäller även för stamdikena.

Sugdikenas inbördes avstånd

Som förut påpekats, är det inbördes avståndet mellan sugdikena beroende av markens större eller mindre genomsläpplighet för vatten. Den styva lerjorden utövar det största motståndet, varför i sådan jord rören böra ligga tätast. Följande siffror kunna vara vägledande.

I styv lerjord	bör	avståndet	mellan	rörsträngarna	vara	högst	10—13	m.
» vanlig	»	»	»	»	»	»	14—15	»
» sandbl.	»	»	»	»	»	»	15—17	»
» lerbl. sandjord	»	»	»	»	»	»	18—20	»
» sandjord	»	»	»	»	»	»	22—30	»

Sugdikenas längd

Sugdikena böra i regel icke göras längre än 100—125 meter å lerjord och 150 meter å sandjord.

Fallet

Sugdikena böra ej läggas i mindre lutning än 3 : 1000, annars kan fara för rörens igenslamning uppstå, därför att vattnets hastighet blir för liten. För stamdiken kan för de flesta jordarter fallet inskränkas till 2,5 : 1000, men för kvicksand och kvicklera är detta fall otillräckligt. För dessa jordarter bör fallet ökas betydligt, dock beroende på rördimensionen. För mindre rör måste fallet därför vara större än för grövre rör.

Rördimensioner

Rördimensionerna angivas av inre diametern, vanligen uttryckt i tum. Vid val av dimension är det vattenmängden och lutningen, som äro de avgörande faktorerna. Ju större lutning ett rör har, desto större vattenmängd pr tidsenhet förmår det framsläppa, varav följer, att ju hastigare man vill bortleda vattnet från ett visst område, desto större lutningar resp. rördimensioner måste man tillgripa.

För dränering av åkerfält har man funnit, att dräneringssystemet är tillräckligt dimensionerat, om det från varje hektar av fältet kan bortleda 0,65—0,8 liter vatten i sekunden. För begravningsplatser bör man nog räkna med mer än fördubbling av dessa siffror, därför att man betydligt hastigare vill avleda vattnet från ett sådant område än från en vanlig åker. Följande tabell visar den rördimension, som behöver tillgripas för att avleda 2 liter i sekunden från ett område av en viss storlek, då rörledningens bottenlutning är känd.

Fall på 100 m. Meter.	Avdikad areal, då avrinningen utgör 2 sek.-liter per hektar. 2″	3″	4″	5″	6″
0,1	—	0,38	0,80	1,54	2,30
0,2	0,18	0,56	1,14	2,04	3,25
0,3	0,22	0,68	1,40	2,50	4,10
0,4	0,26	0,80	1,62	2,90	4,80
0,5	0,30	0,88	1,80	3,22	5,25
0,75	0,36	1,04	2,20	4,00	6,45
1,00	0,42	1,20	2,55	4,60	7,40

Det är naturligtvis av största vikt, att man dimensionerar ledningarna och i synnerhet stamledningarna för den maximivattenmängd, som svarar mot lutningarna, ty om någon del är underdimensionerad, förmår just denna del icke avleda den avsedda vattenmängden från ovanför liggande ledningar, vilka därigenom icke kunna fullt utnyttjas. Har man överdimensionerat någon del av en sträng, är detta tydligen till ingen nytta, enär denna del aldrig erhåller så mycket vatten, som den förmår framföra. I intetdera fallet har man således fått full valuta för kostnad och arbete.

Dräneringens planläggning och anordning

För uppgörande av dräneringsplaner i allmänhet fordras sakkunskap, och detta gäller i synnerhet dräneringsplaner för kyrkogårdar, varför sådana förslag böra överlämnas till fackutbildad person. Kostnaden härför är i förhållande till dräneringskostnaden obetydlig, men ändamålsenligheten och verkan av dräneringen bli med säkerhet många procent större, då arbetet utföres efter en med sakkunskap uppgjord plan.

För uppgörande av dräneringsplan för en kyrkogård erfordras följande grundmaterial:

1. planritning över den blivande kyrkogården, helst i ej mindre skala än 1 : 250, upptagande alla fasta föremål såsom byggnader, inhägnader, häckar och övriga planteringar samt vägar, gångar, gravplatser etc. På denna planritning skola även nivåkurvor med en ekvidistans av 0,25—0,50 m vara inlagda. Dessa nivåkurvor skola vara hänförda till en i närheten av platsen befintlig fixpunkt, vars läge och höjd på kartan angivas.
2. noggranna och fullständiga uppgifter över:
   a) jordlagrens beskaffenhet och genomsläppningsförmåga;
   b) högsta grundvattenytans läge för området ifråga;
   c) angränsande marks beskaffenhet och lutningsförhållanden;
   d) i närheten belägna öppna diken eller täckdiken, deras storlek, lutningar och högvattenstånd.

För utvidgning av en äldre kyrkogård tillkommer dessutom uppgift om den där befintliga dräneringen.

Dräneringssträngarnas läge, djup och utförande

Till sugdiken användas i regel vanliga tegelrör och till stamdiken tegelrör eller allra helst lergodsrör.

Som förut är nämnt utläggas rören i gångarna och helst i mitten av dessa, dels därför, att de då äro lättare att återfinna, än om de placerats vid ena eller andra sidan, och dels därför, att om de av en eller annan orsak måste upptagas, man då icke förstör häckar eller andra föremål vid gångarnas sidor.

För att hindra, att vattnet från högre belägna markområden, som ligga utanför kyrkogården, översvämmar densamma, brukar man utföra s. k. *avskärande diken*. Dessa rördiken måste, för att göra full tjänst, vara dimensionerade för sitt nederbördsområde. De avskärande dikena läggas i regel helt utanför eller alldeles i gränsen av kyrkogården. De tillkopplas vanligen det övriga systemet, men om det gäller större vattenmängder, är det lämpligare att bortleda detta vatten till närmaste vattendrag eller kloak.

Ledningsdjupet är beroende av gravarnas djup, då meningen med dräneringen är att torrlägga gravbottnarna. Vid ett gravdjup av 2 m måste dräneringssträngarna läggas på ett djup av minst 2,3—2,4 m för att tillräckligt dränera gravarna. Före utläggningen av rören avjämnas bottnen noggrant med särskild dikesskopa. Rören utläggas därefter med början från lägsta punkten omsorgsfullt med ändarna stumt och tätt emot varandra. Sista röret i varje sträng tillstänges i sin övre ända med en flat sten eller dylikt. Rören läggas med fullständigt jämn lutning mellan brytpunkterna. Omkring och ovanpå rören påfylles helst ett c:a 20 cm tjockt lager av grov koksaska, som noga tillstampas, dock försiktigt, så att ej rören rubbas ur sina lägen. Koksaskan hindrar i viss grad igenslamning av rören samtidigt som den, på grund av porositeten, hjälper sugdikena i deras funktion samt hindrar trädrötter och dylikt att intränga. Ovanpå koksaskan påfylles sedan den uppgrävda jorden varvtals med ordentlig tillstampning av varje varv för att minska de oundvikliga sättningarna hos jorden.

Vid kopplingen av sugrören till stamledningarna bör man helst använda specialrör av glaserat lergods. Dessa rör äro utförda med olika böjningsvinklar och dimensioner för grenröret, så att de passa för kopplingar av olika rördimensioner.

Inspektionsbrunnar och utlopp

Inspektionsbrunnar eller rensbrunnar böra anordnas dels vid början av varje stamledning samt dels vid alla krökar på stamledningen, detta för att man lätt skall komma åt att rensa ledningen, om den blivit igenslammad. I vissa fall anordnas brunnar även vid sugledningarnas koppling till stamledningen. Brunnarna utföras antingen av cement- eller lergodsrör eller gjutas på platsen av betong. Brunnens botten bör ligga c:a 50 cm djupare än det lägsta röret för att tjäna som uppsamlare av slam. När slamavsättningen i brunnen nått närheten av det lägsta röret, måste brunnen upprensas, vilket lämpligast sker med särskild rensskopa. Brunnen, vars inre diameter icke göres under 30 cm, täckes med i handeln förekommande brunnsavtäckning, s. k. däxel, av järn. Denna däxel ställes på en kring brunnen gjuten betongsarg, så anordnad att däxelns höjdläge kan justeras efter gångens höjdläge. Om brunnarna utföras av rör, böra skarvarna tätas med cement eller annat tätningsmedel. För brunnsbottnen gjutes en 15—25 cm tjock platta av betong, på vilken rören placeras vertikalt. Bottenplattan göres något större än rörens yttre diameter. Dräneringsrören böra dragas c:a 1 cm innanför brunnens inre vägg. Mellan brunnsvägg och rör tätas ordentligt. Vid ledningsutlopp i öppet dike anordnas ett särskilt s. k. »öga», som vanligen utföres av betonggjutning. Denna betonggjutning bör nå in i dikesslänten till frostfritt djup. Vid rörmynningen insättes ett galler av järn för att utestänga råttor, sorkar och andra djur.

Vid stamledningens tillkoppling till befintligt kloaksystem bör denna alltid göras vid en inspektionsbrunn och utföres i övrigt som ovan beskrivits.

Vid starka regnflöden, då en stor del av ytvattnet avrinner i gångar och vägar, föres vattnet till brunnarna betydligt hastigare, än om det så småningom skulle uppsugits av sugdikena. Därför böra stamledningarna dimensioneras för betydligt större vattenmängd än den från sugdikena kommande. Man bör räkna med en ökning av vattenmängden från sugdikena av upp till 100 %.

Dränering med sugbrunnar och täta rör

Förutom den tidigare omtalade dräneringen med vanliga tegelrör kan det i vissa fall vara nödvändigt att utföra dräneringen på ett helt annat sätt, nämligen när marken är av sådan beskaffenhet, att man kan befara ett snabbt igenslammande av rören, eller ock där man måste ta hänsyn till större träd, vilkas rötter kunna nedtränga till rören och borra sig in i desamma.

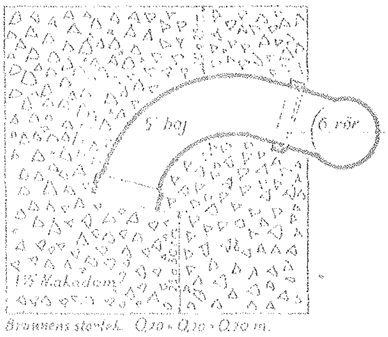


Bild 55 a. Sugbrunn.

För att erhålla en fullt tillförlitlig dränering under sådana förhållanden är det tillrådligt att lägga rörledning med flänsrör av cement eller glaserat lergods. Rören täras väl i alla fogar med starkt cementbruk. För insugning av grundvattnet göras sugbrunnar på c:a var tionde meter, vilka utföras på sätt som framgår av vidstående bild.

Bottnen i dessa brunnar göres 30—40 cm djupare än rördiket samt fylles med 1½" makadam. För att underlätta grundvattnets tillrinnande bör, som förut nämnts, utefter rören läggas ett lag av slaggaska eller stritt grus.

Principerna för avvattning och torrläggning enligt detta system äro desamma, som förut beskrivits. Genom att använda större dimensioner å rören samt lägga desamma djupare kan man givetvis öka det inbördes avståndet mellan dräneringsledningarna.

Dränering av områden, som ligga lågt i förhållande till befintligt avloppssystem

I vissa fall kan ett område, som i stort sett är synnerligen lämpligt till begravningsplats eller utvidgning av sådan, dock ha det stora felet, att det ej kan avdikas till föreskrivet djup, beroende därpå, att närliggande avloppsdiken ej hava det erforderliga djupet och ej heller kunna sänkas. Under sådana förhållanden kan det i vissa fall vara lämpligt att genom särskilda pumpanordningar sörja för en effektiv utdikning. Principen härför är att dräneringssystemet, utfört på tidigare beskrivet sätt, utmynnar i en samlingsbrunn, som ligger djupare än rörens lägsta punkt, och att vattnet från brunnen pumpas upp i det naturliga avloppet. Härtill användes helst en elektriskt driven pump, som automatiskt reglerar vattenståndet i samlingsbrunnen. I övrigt hänvisas till »Handledning vid dikning» av lantbruksingenjör I. Aspegrén.

Arbetsbeskrivning till dräneringsplan för kyrkogård.

Vattnet avledes från den södra gränsen till ett öppet dike. Å bild 55 b är denna ledning betecknad A—B—C och lägges med 5" och 6" rör.

Norr om kyrkogården lägges ett 1,75 m djupt dike för att upptaga det grundvatten, som kommer från de högre liggande markerna. Övriga ledningar läggas i huvudgångarna för att lättare vara tillgängliga vid eventuella fel. För att hindra trädrötter att tränga ned till rören skall närmast dessa läggas ett lager av slaggaska, detta även för att mera effektivt kunna avvattna området.

Dikningen skall utföras så, att den blivande gravbottnen blir fullständigt torrlagd. Minsta djupet skall därför vara 2,4 m under markytan. Rörledningarnas lägen angivas å bifogad plan. (Bild 55 b.)

Rörens höjd över horisontalplanet är å ritningen angiven med siffror inom enkel cirkel, och deras ungefärliga lägen under befintlig markhöjd med siffror inom dubbel cirkel.

Utstakning av dräneringsledningarna skall utföras fullt exakt efter arbetsplanen till kyrkogårdsanläggningen, så att alla ledningar komma att ligga mitt i angivna gångar. Grävningen får ej påbörjas, förrän såväl lägen som höjdprofiler blivit godkända av kontrollanten.

Rörledningarna skola läggas till det djup, som angives medelst siffror inom enkel cirkel, och avse dessa höjder invändiga bottnen av rören över horisontalplanet. *Fixpunkten* för avvägningen finnes å hörnet av gamla muren och är +8,35.

Alla rör skola vara raka samt av prima välbränd kvalitet och hålla de föreskrivna invändiga rördimensionerna, som å ritningen äro angivna med siffror, utvisande tumsbeteckning. Vid läggningen av rören tillses, att ett jämnt fall erhålles mellan de olika punkter, där höjder äro angivna. Alla sammansättningar skola noga tillpassas, och vid anslutningar eller böjar skola grenrör eller böjar av betong komma till användning.

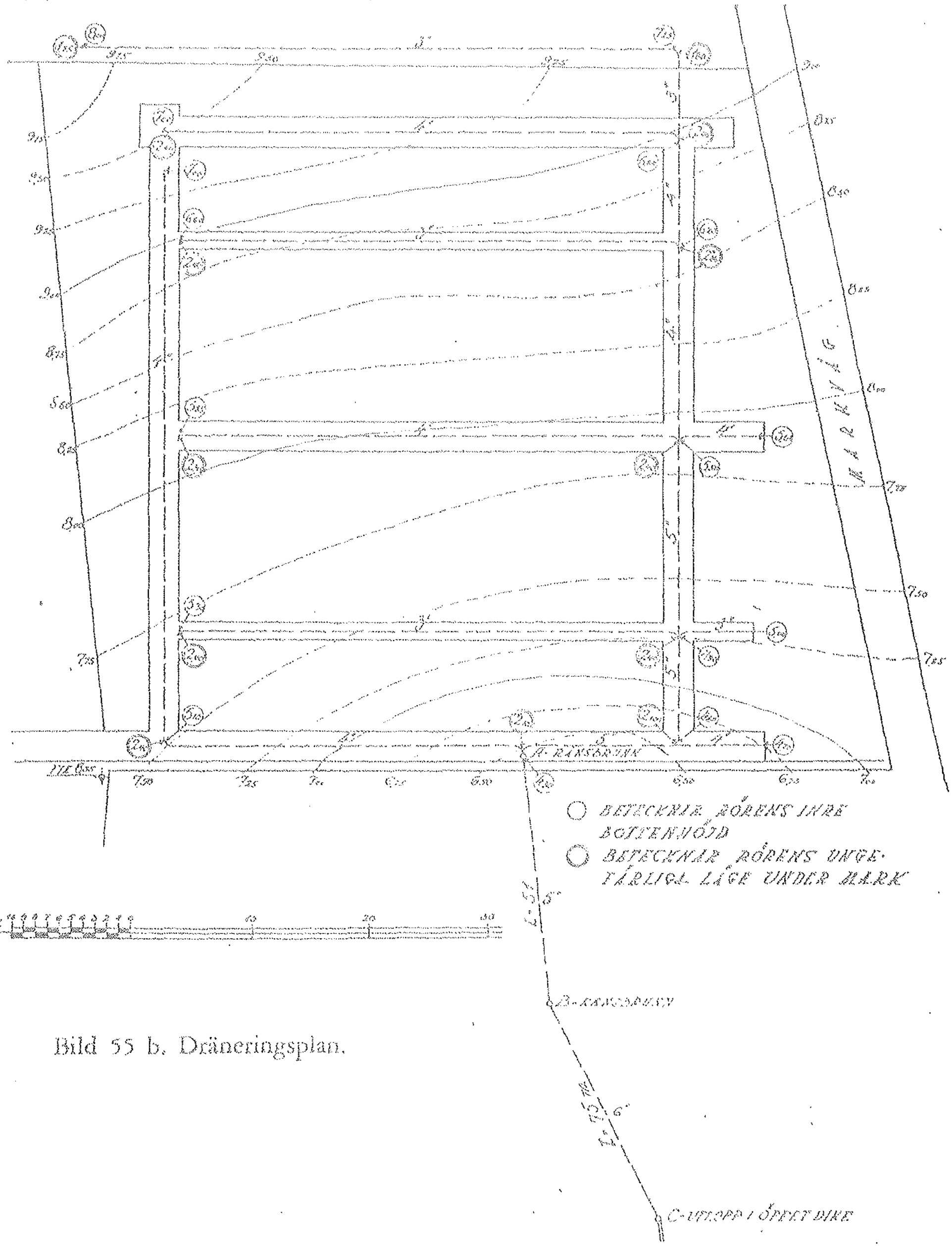


Bild 55 b. Dräneringsplan.

Vid A och B insättas intagningsbrunnar av betong med en inre diameter av 0,6 m och botten 0,5 m under rörens underkant. Brunnarna skola förses med lock av armerade betongskivor med falsar och något kupig översida.

Igenfyllning av groparna får ej ske, förrän ledningarna blivit godkända av kontrollanten. Vid igenfyllningen tillses, att rören ej bliva rubbade ur sina lägen eller på annat sätt skadade.

Omedelbart ovanpå rören skall läggas ett minst 20 cm tjockt lager av grov koksaska innan jordpåfyllningen verkställes. Fyllningen pålägges därefter varvtals samt packas hårt samman med järnstötar.

Anläggningens utförande kontrolleras av särskild kontrollant, som utses av kyrkorådet. Det åligger kontrollanten att noga tillse, att ritningar och beskrivning efterföljas. Entreprenören är därför skyldig att ställa sig till efterrättelse de anvisningar, som lämnas av kontrollanten.

Det följande utdraget har hämtats ur Hans-Kurt Boehlke: Der Gemeindefriedhof (Köln 1966). Härvid har utöver de delar som berör dränerings- och avvattningsförhållanden även medtagits vissa avsnitt rörande planering och dimensionering av kyrkogårdar.

2.001 Hygienische Forderungen Der heute wieder erhobenen Forderung, daß der Friedhof in enger Beziehung zur Wohnsiedlung seines Einzugsbereiches stehen muß, werden häufig hygienische Argumente entgegengehalten, die von der naturwissenschaftlichen Forschung jedoch nicht mehr als Problem angesehen werden. Besonders das 18. und 19. Jahrhundert sah ja in der Leichenbestattung innerhalb des Wohngebietes oder doch in seiner unmittelbaren Nähe eine Gefährdung hygienischer Art durch Bakterien, oder sagen wir heute besser durch Mikro-Organismen, also Bakterien, Viren usw., und die sogenannten Leichengifte. Der moderne Hygieniker sieht diese Gefahren allerdings als nur gering an. Folgende Medien können die durch Leichen verursachte hygienische Gefährdung weitertragen: Der Boden, in dem die Toten beerdigt werden, das Wasser als Grundwasser und die Luft, denn ein lockerer Boden hat immer kapillare Luftbewegungstendenzen. In der Verunreinigung der Luft – man sprach vom sogenannten Miasma – sah man früher eine ganz wesentliche Gefahr. Die hygienische Wissenschaft vertritt dagegen heute die Ansicht, daß über die Luft keine Infektion und keine Gefährdung des Menschen eintreten kann. Dasselbe gilt durch Mikro-Organismen im Boden. Der Boden ist eine ausgezeichnete Abschließung eines Infektionsherdes. Während der Fäulniszeit der Leiche, die etwa 3 Monate umfaßt, sterben nach Aussage der heutigen hygienischen Wissenschaft die möglichen Krankheitserreger ab. Auch hier bestätigen natürlich die Ausnahmen die Regel, so sind etwa Tuberkelbakterien und Milzbrandsporen länger lebensfähig. Der moderne Hygieniker sieht jedoch in jedem Dunghaufen, in jeder Jauchegrube oder Sickergrube bei nicht kanalisierten Häusern eine größere Gefahr für den Boden als in einer selbst schwer infizierten Leiche.

Das Grundwasser dagegen kann in jedem Falle durch Mikro-Organismen verunreinigt werden. Jedoch ist auch hier nach Meinung der Hygieniker die potentielle Gefahr gering. Sie kann praktisch ausgeschlossen werden, wenn man die Friedhöfe so anlegt, daß der Höchstwasserstand des Grundwassers etwa 50 cm unter der Grabsohle liegt. Auf überschwemmungsgefährdeten Gebieten sollte man daher nach Möglichkeit keine Friedhöfe anlegen.

Auch die Gefahr der Verunreinigung des Bodens und des Grundwassers durch die sogenannten Leichengifte wird heute gegenüber den früheren Annahmen für gering erachtet. Die Leichengifte entstehen während des etwa dreimonatigen Fäulnisprozesses, wobei vor allem durch den Verfall der hochkompliziert aufgebauten Eiweißmoleküle giftige Zwischenstufen während der Verwesung entstehen. Aber auch im Hinblick auf die möglichen Gefährdungen ist die Forderung an die Hygiene mehr eine ästhetische Forderung. Allein wegen der Vorstellung einer möglichen Verunreinigung des Grundwassers durch den immer wiederkehrenden Prozeß der Verwesung von Leichen auf einem Friedhof, sollte man Wasserförderung in der Nähe der Bestattungsplätze vermeiden. Das bedeutet, daß man bei der Wahl des Standortes eines neu anzulegenden Friedhofes die Fließrichtung und Flußstärke des Grundwassers feststellen und berücksichtigen muß.

Aus der unmittelbaren Nachbarschaft von Siedlung und Friedhof ergeben sich heute etwa folgende h y g i e n i s c h e F o r d e r u n g e n: Nach Möglichkeit wähle man einen leichten Boden, da in ihm Fäulnis und Verwesung schneller vor sich gehen. Der Grundwasserstand soll möglichst niedrig gehalten werden, jedenfalls darf er nicht höher als 50 cm unter der Grabsohle sein. Der Grundwasserstrom ist vorher zu untersuchen, er soll nicht zu schnell und vor allem nicht in Richtung auf Wasserentnahmestellen, also in Richtung der Wasserwerke und Wassersammler laufen. Man soll nach Möglichkeit kein überschwemmungsgefährdetes Gebiet und auch nicht ein zu steiles Hanggelände wählen, falls man nicht terrassiert, damit nicht bei zu starken Regenfällen Gräber freigewaschen werden können. Beim Überpflanzen des Friedhofs mit Baum und Strauch ist eine lichte und luftige Überpflanzung vorzuziehen; durch die Bewachsung soll jedenfalls die Feuchtigkeit nicht zu stark gehalten werden, da alle Feuchtigkeit eine schnelle Verwesung verhindert. – Grundsätzlich darf man feststellen, daß die moderne Hygiene keine Bedenken gegen Friedhofsanlagen innerhalb des Siedlungsraumes hat.

2.01 Friedhof und Landschaft Das Dorf und auch die kleine Stadt braucht Grünflächen, zu denen ja auch die Friedhöfe gehören, kaum zur Erholung der Einwohner, gegebenenfalls jedoch zur Gliederung des Siedlungsraumes und besonders als maßstabgerechte Verbindung zur offenen Landschaft. Gerade aber diese Landschaftsbezogenheit verbietet dem ländlichen Bereich Grünanlagen, die nichts weiter als dekorativer Zusatz sind.

Fast stets wird es zu einer Bereicherung von Friedhof und Landschaft führen, wenn man bei der Geländewahl für einen außerhalb der Siedlung oder auch nur am Ortsrand anzulegenden Friedhof von der Natur angetragene Stimmungsträger klug nutzt, so etwa ein hainartiges Gehölz, eine Waldlichtung, einen Wald als Hintergrundskulisse. Überall dort, wo der Friedhof aus dem Ort herausgenommen werden muß und damit die durch unmittelbare Nachbarschaft bedingte ständige Verbindung zwischen den Lebenden und den Toten entfällt, kann durch die Anlage des Friedhofes auf der Kuppe eines benachbarten Hügels oder auch an einem Berghang eine optische Verbindung zwischen der Gemeinde der Lebenden

Der Friedhof als Teil der Landschaft (Seeg im Allgäu)

und dem Acker der Toten hergestellt werden, die wieder eine direkte Beziehung schafft. Bewußt als Menschenwerk kenntliche Hervorhebungen, wie etwa die künstlichen Kirchhofshügel in den Küstengebieten Norddeutschlands können zum Wahrzeichen einer Landschaft werden. – Das Anbinden nicht nur an waldartige Gehölze, gegebenenfalls auch an Knicks oder Gärten, das Wahrnehmen eines landschaftlich reizvollen Zugangs, alles das kann den landschaftlichen Stimmungswert eines Friedhofs erhöhen.

Zum pflanzlichen Einfügen in das Landschaftsbild gehört es, daß man bei den Friedhöfen, die mit vorhandenen Waldungen in Beziehung gebracht werden, nicht nur deren Gehölze aufnimmt, sondern auch weithin die Unterpflanzungen der vorhandenen Waldflora anpaßt. Heidefriedhöfe zum Beispiel sollte man wirklich nur in Heidelandschaften anlegen. Vielleicht darf man pauschal sagen, daß die Um- und Bepflanzung der Friedhöfe sich dem Charakter der Landschaft anpassen sollten. Selbst ein auf freiem, flachen Feld angelegter Gottesacker, dem ja beim Dorffriedhof gewichtige bauliche Akzente fehlen, kann mit entsprechender Einfriedigung, Randpflanzung und vielleicht auch hainartiger Überpflanzung zu einem das Flurbild belebenden Anziehungspunkt werden, der unter Umständen sogar einer kargen Landschaft Ansehen und Reiz zu verleihen vermag.

Der sinnvollen Einpflanzung in die gegebene Landschaft widme man daher ernsthaftes Bemühen. Das gilt nicht nur für die Baum-, Strauch- oder Heckenrandbepflanzung des Friedhofs, die ihn nicht nur als das Besondere aus der Landschaft heraushebt, sondern ihn auch in sie einbezieht durch die Verwendung der in der umgebenden Landschaft vorkommenden Laubgehölze. Es ist in jedem Falle verfehlt, wenn man durch eine Fülle hoher „Lebensbäume“ und anderer immergrüner Gewächse die Friedhofsstimmung südlicher Länder nachahmen will. Wird jedoch unter entsprechender Anleitung und nach der Planung eines erfahrenen Friedhofsgestalters die Eigenart des jeweiligen Geländes nicht nur berücksichtigt, sondern genützt und etwa vorhandener schöner Baumbestand oder sonstige landschaftliche Stimmungsträger, reizvoller Zu-weg und andere Besonderheit klug wahrgenommen, dann kann der Dorffriedhof ebenso wie der der ländlichen Stadt das Landschaftsbild harmonisch beleben und bereichern.

Die Landschaft selbst wiederum kann man in den Friedhof einbeziehen durch das Schaffen schöner Ausblicke aus dem Friedhof durch Blickschneisen, Lichtungen, das Einbeziehen vorhandener Gewässer usw.

Richtig angelegt und mit entsprechender, möglichst der umgebenden Natur entnommener Um- und Bepflanzung wird der Friedhof nicht nur innen einen wohltuenden Raum bilden, sondern sich nach außen körperhaft – weit mehr als der Friedhof in der Stadt – aus der landschaftlichen Umgebung klar herausheben und daher trotz inniger Verbindung ein bedeutender Akzent sein. Die sinnvolle Gestaltung und Pflege des ländlichen Friedhofes ist daher zugleich Pflege des heimatlichen Landschaftsbildes.

2.02 Flächenberechnung Sind alle geländemäßigen und sonstigen Voraussetzungen geklärt, müssen insbesondere Überlegungen über die erforderliche Größe des Friedhofs angestellt werden. Dabei sind etwaige Erwartungen auf ein Anwachsen der Gemeinde zu berücksichtigen. Aber selbst, wenn mit einem Anstieg der Bevölkerungszahl in absehbarer Zeit nicht zu rechnen ist, sollte man nach Möglichkeit doch Grundstücke um den Friedhof soweit wie möglich mit Bauverbot belegen oder in den Besitz der Gemeinde bringen, nicht nur, um Lärm und Unruhe vom Gottesacker fernzuhalten, sondern vor allem im Hinblick auf ein vielleicht wesentlich späteres Erfordernis der Friedhofserweiterung.

Der Geländebedarf richtet sich nun nach der Einwohnerzahl, ihrer durchschnittlichen Sterblichkeit und der ortsüblichen Ruhefrist. Die Ruhefrist ist weithin von der amtsärztlichen Anordnung abhängig, die sich wiederum nach der Bodenbeschaffenheit und damit nach der Zeitdauer des Verwesungsvorganges richtet. Ruhefristen für das Reihengrab über 30 Jahre sind heute selten. Im ländlichen Bereich sollte man jedoch diese Zeitdauer auch nicht unterschreiten.

In einigen umfangreicheren Fachbüchern sind ausführliche Berechnungsvorschläge für die Friedhofsfläche angeführt und erläutert. Ihrer wird sich der mit der Planung beauftragte Gartenarchitekt gegebenenfalls bedienen. Damit die Verantwortlichen in der Gemeinde jedoch ungefähr die benötigte Fläche überschlagen könne, seien hier die gängigsten Faustregeln genannt, wobei von der auf dem Lande vorherrschenden Erdbestattung ausgegangen wird, ohne nun zwischen Erwachsenen- und Kindergräbern, Wahl- und Reihengräbern zu detaillieren. Die im folgenden genannten, oft zu recht unterschiedlichen Ergebnissen führenden Faustregeln geben immer nur einen groben Überschlag, da unter anderem auch die Geländeverhältnisse weitgehend die Belegungsdichte bestimmen; auf einem Friedhof in der Ebene erreicht man normalerweise eine größere, auf einem Hangfriedhof eine geringere Belegungsdichte.

„Die Friedhofsfibel" von R. Pfister nennt eine alte Faustregel, die mit 80 Gräbern für 100 Einwohner, also mit 33 Ar Friedhofsfläche für je 1 000 Einwohner rechnet, wovon etwa 20 Ar reine Belegungsfläche sind. Mindestens ein Drittel des Gesamtgeländes werden hier also für Wege, Grünflächen, Freiplätze usw. gerechnet. Auf 30 Ar Bruttofriedhofsfläche für 1 000 Einwohner kommt auch Hans Schwenkel mit sehr ausführlichen Berechnungen in seinem Buch „Der Friedhof auf dem Lande".

Valentien errechnet in seinem gut ausgestatteten Friedhofsbuch die Brutto-Friedhofsfläche, indem er die Zahl der Todesfälle in 30 Jahren mit 4 qm (der Bruttofläche pro Grab) multipliziert; das entspricht einer etwa 60 %igen Belegungsausnutzung des Friedhofsgeländes. Das dürfte im ländlichen Bereich der grobe Durchschnitt sein.

Da die durchschnittliche Sterbeziffer bei etwa 1–1,2 % liegt, lautet die wohl am häufigsten verwandte Faustregel für die Flächenberechnung: Sterbeziffer (ca. 1 v. H. der Einwohnerzahl) × Brutto-Grabfläche (Netto-Grabfläche + 50 v. H. für Erschließungswege, öffentliche Pflanzflächen usw. = 4,5 qm) × Ruhefrist (durchschnittlich 30 Jahre). Das Ergebnis sollte überall dort, wo nicht ausschließlich Reihengräber üblich sind mit 2 multipliziert werden. Das entspricht der zusätzlichen Inanspruchnahme zunächst nicht genutzter, später allerdings den Flächenbedarf wieder verringernder Begräbnisplätze bei Familien-Wahlgräbern. Solche Familiengrabstätten werden aber heute auf dem Lande bevorzugt. Für 1 000 Einwohner würde die Formel lauten: (10 × 4,5 × 30) × 2 = 2 700 qm Friedhofsfläche.

In diesen Berechnungen sind also bei grobem Überschlag neben dem für die eigentlichen Gräber benötigten Netto-Geländebedarf die notwendigen Flächen für Erschließungswege, Freiplätze, öffentliche Grünpflanzungen, so vor allem die Randpflanzungen usw. einbegriffen. Örtliche Verschiedenheiten und Gewohnheiten, so besonders bei den Ruhefristen und dem Verhältnis der Wahlgräber zu den Reihengräbern, vor allem aber die oft sehr unterschiedlichen Bedingungen des Geländes werden stets eingehende Berechnungen des planenden Fachmannes erforderlich machen.

Liegt etwa eine kleine oder mittlere Stadt im unmittelbaren Einflußgebiet einer Großstadt mit Krematorium, dann muß gegebenenfalls wie in der Großstadt selbst der Anteil der Urnengräber in die Flächenberechnung einbezogen werden. Dabei ist gegebenenfalls zu beachten, inwieweit die Urnen in der Erde oder in Columbarien (Urnenhallen) beigesetzt werden.

2.020 Erd- und Feuerbestattung. Es liegt auf der Hand, daß für die Beisetzung einer Aschenurne in der Erde weit weniger Platz benötigt wird als für die Beisetzung eines Sarges mit der Leiche eines Erwachsenen oder auch eines Kindes. – Unsere Friedhöfe sind im Laufe der letzten 150 Jahre immer mehr zu öffentlich-rechtlichen und, sagen wir es ruhig, zu Sanitäts-Anstalten geworden. Das Bestattungs- und Friedhofswesen wird damit zugleich zu einem nüchternen Akt behördlicher Verwaltung, für die hygienische, sprich gesundheitspolizeiliche und soziale Gesichtspunkte maßgebend sind. In unseren Industriestädten wird das vorhandene Landreservoir von der dynamischen Wirtschaft, dem Verkehr und dem Wohnungsbau mit Beschlag belegt. Für die damit zugleich notwendige Erweiterung und Ergänzung der Friedhöfe ist dann jedoch kaum noch Gelände zu beschaffen. Ist es da verwunderlich, wenn in manchen Städten insgeheim von der Verwaltung und auch von den Stadtplanern der Feuerbestattung das Wort geredet wird? Für die Beisetzung einer Urne, ob in der Erde oder im Columbarium benötigt man etwa nur ein Drittel der für die Erdbestattung erforderlichen Fläche. In zahlreichen Großstädten ist daher in den letzten Jahrzehnten auch ein erheblicher Anstieg der Kremationen zu verzeichnen. Der Anteil der „Feuerbestattung" liegt in manchen Städten schon über 50 %.

Der Einäscherung eines Toten steht nach dem letzten Konzil auch die katholische Kirche nicht mehr grundsätzlich ablehnend gegenüber, zumal ihre vorausgegangene Ablehnung eigentlich nur einer Abwehr des Freidenkertums des 19. Jahrhunderts entsprang.

Bis in das 3. vorchristliche Jahrtausend läßt sich in Mitteleuropa die Leichenverbrennung zurückverfolgen. Seitdem laufen Erd- und Feuerbestattung in unserem Kulturbereich eigentlich stets parallel. In allen Teilen Deutschlands hat man Brandgräber aus ur- und frühgeschichtlicher Zeit gefunden. Seit der Christianisierung überwiegen dann die Erdbestattungsgräber, weil in zahlreichen Gegenden Mitteleuropas in der unmittelbar vorausgegangenen Zeit die Totenverbrennung vorgeherrscht hatte und man nun diesen Brauch als heidnisch verdammte. In der Zeit des Klassizismus, in der ja auch das Freidenkertum sich immer mehr ausbreitete, trat durch bewußtes Anknüpfen an antiken Brauch die Totenverbrennung immer stärker in das Bewußtsein vor allem der Gebildeten. Die besonders im 18. Jahrhundert verbreitete Furcht vor einem scheintot Begrabenwerden und die im 19. Jahrhundert in den Vordergrund rückenden hygienischen und ästhetischen Momente führten bald, etwa gleichzeitig in Italien, England und Deutschland, zu einem Wiederaufleben der Feuerbestattung. Im Unterschied zu den historischen Leichenverbrennungen auf hölzernen Scheiterhaufen werden nun jedoch Krematorien, 1878 in Gotha das erste in Deutschland, errichtet, in denen die Einäscherung nicht durch direkte Einwirkung der Flammen, sondern durch erhitzte Luft erfolgt. Fast alle Großstädte können heute mit Koks, Gas oder Elektrizität geheizte Krematorien aufweisen.

Für den ländlichen Bereich sind bei den Vorüberlegungen für Planung und Ausbau eines Friedhofes die zahlreichen unterschiedlichen Gesichtspunkte, die durch Erd- und Feuerbestattung auftreten, kaum von einschneidender Bedeutung, da auch für die kleine Stadt die Anlage eines Krematoriums zu kostspielig ist und erst recht auf dem Dorffriedhof die Beisetzung von Urnen auswärts Eingeäscherter zumindest in absehbarer Zeit so gering sein wird, daß deswegen kaum besondere Flächenberechnungen angestellt werden müssen.

2,120 Geologisches Gutachten Die Eignung eines Geländes für Begräbniszwecke wird weitgehend durch die Beschaffenheit seines Bodens, d. h. dessen mineralogische Zusammensetzung und Durchlüftung, und die Grundwasserverhältnisse bestimmt.

Für das Begräbnis sollen nur solche Böden benutzt werden, die für die Leichenzersetzung durch Verwesung geeignet und fähig sind, die Zersetzungsprodukte bis zum völligen Verfall in organischen Verbindungen zurückzuhalten. Nach Möglichkeit soll dieser Vorgang durch die Beschaffenheit des Bodens noch begünstigt werden. Am besten eignen sich trockene Böden mit einer gewissen Luftdurchlässigkeit möglichst bis zur Tiefe der Grabsohlen. Geeignet sind leichte bis mittelschwere Böden, besonders gut Sand- und lockere Kiesböden, auch Kalkböden. Vorzüglich sind Böden, die aus Kies und Sand oder aus Kies und Lehm bestehen, aber auch Humusböden, die reichlich mit Kies und Sand gemischt sind. Weniger geeignet sind Böden mit hohem Tongehalt, wie schwere Lehm- und Mergelböden. Einer schnellen Verwesung entgegen stehen sogenannte schwere, d. h. nasse, bündige und nicht lufthaltige Böden mit hohem Tonanteil, wie Lette. Sie sind für Friedhofszwecke ebenso ungeeignet wie Böden mit zu hohem Grundwasserspiegel (der nicht höher als 50 cm unter den Grabsohlen sein sollte). Daher sind Moor- und Torfböden, angeschwemmtes, aus Kies und Geröll bestehendes Land und Böden, die in weniger als 2 m Tiefe dicke und durchlaufende Gesteinsschichten aufweisen, ungeeignet; sie besitzen nicht genügend Filtrierfähigkeit, um Verwesungsprodukte vom Grundwasser fernzuhalten.

Über die Nichtverwendungsfähigkeit von Böden, in denen das Grundwasser bis zur Höhe der Grabsohlen oder gar in die Zersetzungszone hineinreicht und in denen der Grundwasserstrom eine Richtung auf Wasserentnahmestellen einnimmt, wurde ausführlich schon unter den hygienischen Forderungen im Abschnitt über „Friedhof und Siedlung" hingewiesen.

Wegen der möglichen Grundwassergefährdung sind also höhergelegene Grundstücke solchen in Senken vorzuziehen. In jedem Falle sollten stets Probebohrungen an verschiedenen Stellen des vorgesehenen Grundstückes bis mindestens 2–2,5 m Tiefe vorgenommen werden, um Bodenproben zu entnehmen und zugleich die Untergrund- und Grundwasserverhältnisse zu analysieren. Dabei muß auch die Geschwindigkeit und Richtung des Grundwasserlaufes festgestellt werden. Gegebenenfalls kann aber ein als ungeeignet befundenes Gelände bei nicht vorhandener Ausweichmöglichkeit durch entsprechend hohe Geländeaufschüttung und Drainage oder entsprechende Entwässerungsgräben friedhofstauglich gemacht werden.

Die Bodeneignung für die spätere Bepflanzung des Friedhofes ist gegenüber seiner verwesungsfördernden oder -abträglichen Beschaffenheit nur von zweitrangiger Bedeutung, da hier durch Bodenverbesserung, gegebenenfalls durch nur dünnschichtigen Humusauftrag, ein ausreichender Pflanzenwuchs sichergestellt werden kann. Die Auswahl standortgerechter Pflanzen muß nach pflanzensoziologischen Gesichtspunkten erfolgen.

2.34 Drainage Das geologische Gutachten (2.120) hat wasserführende Schichten des Friedhofsgeländes ausgewiesen, oder bei notwendigem Anschnitt des Geländes sind wasserführende Schichten zutage getreten. In solchem Fall ist eine Entwässerung durch Drainage meist unerläßlich.

Heute wird fast ausschließlich Röhren-Drainage verwandt. Sie muß frostfrei mindestens 0,80 m, im Mittel 1–1,30 m tief verlegt werden. Die Saug-Drains mit einem Mindestgefälle von 2 ‰ saugen das Wasser aus dem Boden, die Sammel-Drains, Mindestgefälle 1 ‰, leiten es weiter.

Nach Möglichkeit sollen die eigentlichen Belegungsflächen keine Röhrendrainage bekommen; u. U. ist es aber notwendig, Saug-Drains bis an die Gräberfelder heranzuführen und mit der Belegung dann am äußersten Sauger zu beginnen. Das Heranführen der Drainage an die Wasserschöpfstellen ist angebracht (2.37).

In manchen Fällen, besonders bei möglichem Anschluß an vorhandene Gräben oder Wasserläufe, können zum Auffangen und Weiterleiten des Oberflächenwassers offene Gräben zur Entwässerung angelegt werden. Sie bedürfen aber eines erhöhten Pflegeaufwandes.

Nedan återges ett avsnitt om dränering av kyrkogårdar jämte tillhörande plan över ett dränerat gravfält, ingående i ett stencilerat kompendium "Om kirkegårder og gravplasser" av landskapsarkitekt Karen Reistad (Vollebekk 1967). Som synes är bestämmelserna om gravdjup något olika i Norge och i vårt land. Den medtagna planen avser uppenbarligen en mycket svårgenomsläpplig jord som fordrar en intensiv dränering. Med den föreslagna utformningen av planen torde det dock vara nästan nödvändigt att gräva gravarna för hand, då användning av grävskopa kan medföra risk för rubbning av rören. Sedan kan man också fråga sig vad som motiverar dubbla rörledningar.

Drenering

Hvordan er den grunn som tenkes lagt ut til gravplass - egner den seg for det helt spesielle formålet?

For å kunne ha en berettiget mening om dette må det som skal foregå i jorden med nedsatt kiste og innhold, analyseres.

Etter loven skal det vaere minst 1,0 m jord over kostelokket. Kisten er vanligvis 0,60 m høy, altså 1,60 m gravdybde. Minste fredningstid av kistegrav er 20 år. Under normale - dvs. gunstige forhold - vil likets bløte dele og det meste av kisten vaere omdannet til jord i dette tidsrom. Grovere knokler vil alltid finnes i tidligere benyttet grav når denne åpnes for ny begravelse, selv om det er gått 30-40 år og mer siden siste gravlegging.

Graveren har streng ordre om å plassere disse restene i bunnen av graven og dekke til med jord før ny kiste senkes.

Dette med skikket jord for gravlegging er avgjørende for en praktisk, økonomisk og verdig drift av kirkegården.

Minimum jorddybde for kistegraver er 1,60 m. Det sier seg selv at hvis gravplassarealet er utlagt over fjell eller grunn jord - må det fylles til krevet høyde. Over større arealer vil dette bli så kostbart, at det ikke bør komme på tale. Skal det fylles, må det vaere med skikkede masser.

Med uskikket jord menes lere - jo tettere, jo verre. Det kan dreneres påpeker ekspertene. Det kan den, men fullgodt har det vanskelig for å bli.

Et slikt arbeid krever den største nøyaktighet av planlegger - og **ikke minst** av dem som skal utføre arbeidet.

Såkalt kontaktdrenering er påkrevet på tett jord - dvs. drensgrøft **mellom 2.hver** gravrekke, med direkte innslag fra gravens bunn til drensgrøften, som ligger på ca. 1,80 m. Den direkte kontakten fra bunnen skjer først når graven er åpnet.

Av dette vil det fremgå, at det er dreneringsopplegget som er bestemmende for kirkegårdens utforming og planlegging. Gravretning øst-vest må ofte fravikes i slikt tilfelle, da terrengformasjonen er bestemmende.

Selv om de forberedende arbeider er utført så godt som råd er, kan det ikke regnes med at denne dreneringen virker tilfredsstillende i rimelig fremtid - synkning, telehiving og andre forhold bevirker skade, slik at 2. belegging blir den siste. Ofte vil drenssystemet ikke kunne brukes til 2. belegging.

Disse avgjørende forhold for kirkegårdens bruk og drift blir oversett - en kirkegård er en kirkegård, og viser den seg å vaere vannsyk, kan den jo dreneres senere. Ja, kan den det? Drenering av gamle, vannsyke kirkegårder er ikke forenlig med gravfred. Det er ikke til å unngå at drensgrøfter må legges gjennom graver, for kistene er satt ned med betydelig avvikning fra gravrekkene - man støter på gamle - ikke oppløste kister. Luften har ikke sluppet til - det hele står hermetisk bevart.

Kirkelovens § 42 krever at grav ikke skal berøres av grunnvann.

Graven som tas opp på tett lerjord, blir en brønn, hvor kisten senkes. Og her blir den stående i årrekker, vel bevart - stikk imot både praktiske, estetiske og kirkelige forutsetninger.

Myrjord er ikke stort bedre - der nytter det ikke med vanlige drensrør, selv om de legges på fast underlag.

På steder hvor det ikke finnes annen utvei enn å benytte myrlende til gravplass, har man funnet frem til en metode med å fjerne massen over hele arealet, kjøre på kultlag under gravdybde - og fylle jorden tilbake.

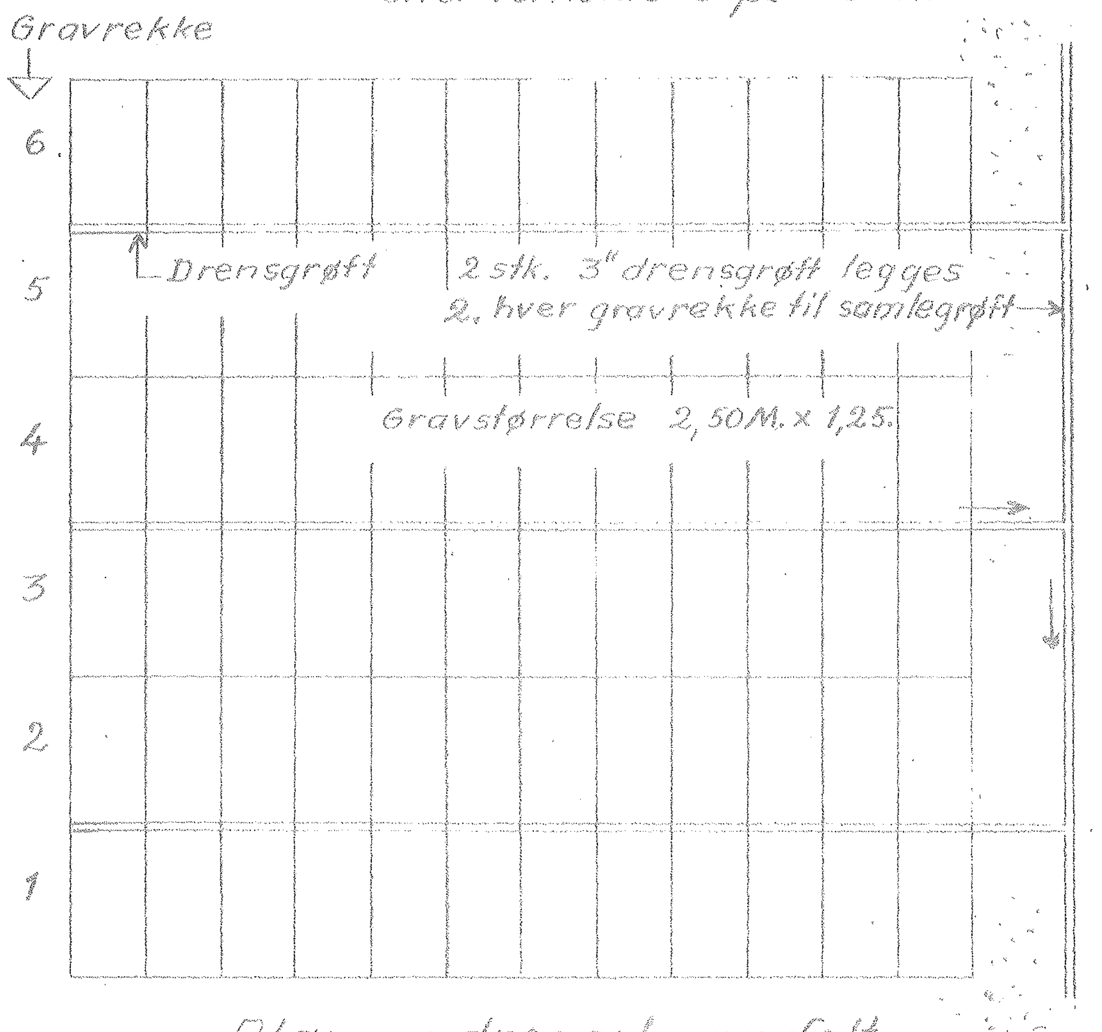
Myrlende som blir drenert, vil synke betydelig i løpet av 6-8 år - opp til 60 - 80 cm. Dette må det tas hensyn til ved gravlegging på myrlendt areal.

Sandmorene - sand med grus - er det idéelle for kistegrav. Drenering av bunnen er ikke nødvendig. Det nedsatte omdannes slik at graven normalt kan benyttes på ny etter 20 år.

Ett meget viktig moment - hvis forholdene forøvrig ligger til rette for det - kan dobbelt gravdybde - 2,20 m nyttes. (1,60 m + 0,60 m).

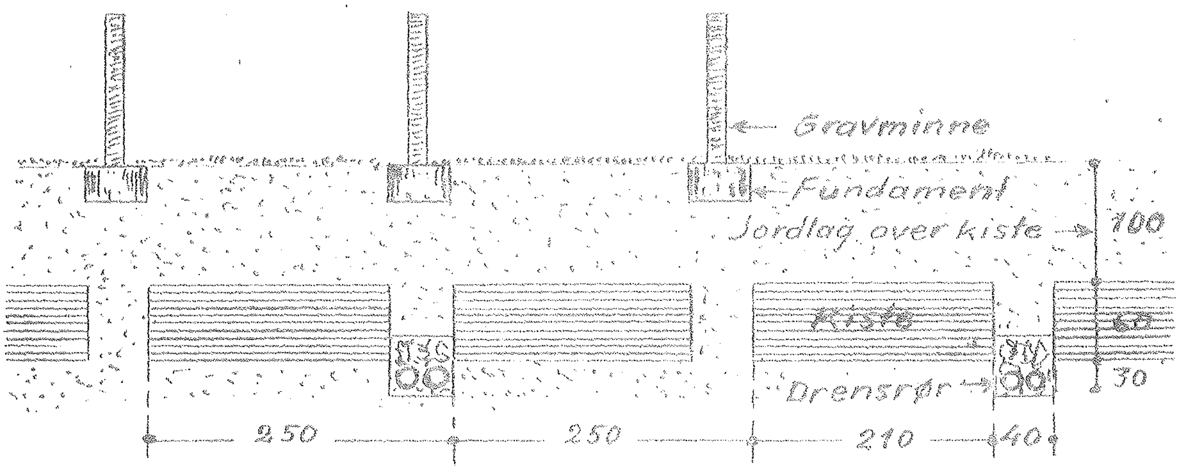
Familie- eller festegrav er vanlig gravform. Sjelden tillates festet mer enn to graver i dagen. Ved dobbelt dybde erstattes to graver i dagen med én. Grav nr. 2 - den øverste - kan brukes når som helst, uavhengig av 1.ste begravelse og dens turnus. Det sier seg selv at dette gjelder familiegrav.

Drenering: Rørdimensjon og fall avpasses
efter forholdene på stedet.



Plan av drenert gravfelt.

Snitt gjennom drenert gravfelt.



(Efter K. Reistad: Om kirkegårder og gravplasser
Vollebekk 1967.)

V. Dränering av idrottsplatser, tennisbanor m.m.

Vid projektering av en idrottsplats eller överhuvud taget en plats för någon sport- eller idrottsutövning på terra firma är det självfallet nödvändigt att sörja för att området blir tillräckligt effektivt dränerat. Det är ju ofta fråga om ganska betydande kostnader som måste nedläggas på ett dylikt område innan det kan utnyttjas för avsett ändamål, och då kan man helt enkelt inte tillåta att brister i dräneringen äventyrar dess användning.

Liksom vid varje annan dränering gäller det att se till att förekommande vattentillrinning från omgivningen avskäres, detta såväl beträffande ytvatten som grundvatten. Sådan tillrinning kan förekomma antingen på grund av de naturliga lutningsförhållandena eller till följd av att man runt området uppfört byggnader av något slag (läktare e.d.). Sedan är det en annan sak att placering av erforderliga nedtag för ytvattnet (dagvattenbrunnar) inom en idrottsplats måste göras på sådant sätt att de inte blir till hinders.

Vad sedan själva det projekterade området beträffar, bör man ur dräneringssynpunkt skilja mellan mer eller mindre hårdgjorda ytor, såsom löparbanor och tennisbanor, och ytor med vegetation (gräsmattor, fotbollsplaner). För att börja med de sistnämnda måste liksom ifråga om åkerjord dräneringen vara mer intensiv, ju styvare och svårgenomsläppligare jorden är. Idrottsplatser anlagda på lerjord är väl knappast idealiska, men de lokala förhållandena blir ju oftast bestämmande. Att lägga dräneringsledningarna särskilt djupt på en idrottsplats finns ingen större anledning att göra. Visserligen varierar uppfattningarna om dräneringsdjupet en hel del, såsom framgår av de följande litteraturutdragen, men ett dräneringsdjup på 80-90 cm torde som regel vara fullt tillräckligt. Och som en allmän hållpunkt: ju styvare jord, desto grundare diken. Däremot är det viktigt att ha relativt tätt mellan dikena; Schatz (1953) rekommenderar 5-8 m avstånd på medelstyva jordar, vilket förefaller rimligt. Att i tveksamma fall tillämpa en "stegvis" dränering såsom Barnard (1967) föreslår kan givetvis diskuteras. Det hela får väl då bedömas utifrån hur man ser på ekonomien contra riskerna för att platsens utnyttjande kommer att fördröjas. Har man anlagt en gräsmatta vill man ju ogärna efteråt skära sönder denna genom dikesgrävning. Det lämpligaste är otvivelaktigt att från början genomföra en så pass intensiv dränering, att man är övertygad om att den snabba och jämna upptorkning av planen som eftersträvas också ernås. För att underlätta upptorkningen är det emellertid av stor vikt att återfyllnaden i dikena utgöres av ett lättgenomsläppligt material, detta särskilt om jorden i sig själv har mindre god genomsläpplighet. I facklitteraturen har denna fråga varit föremål för livliga diskussioner (se de följande utdragen). Det material som därvid bör komma till användning blir naturligtvis beroende på vad som står till buds. Finns grus inom någorlunda räckhåll, är grusfyllnad i diket ända upp till matjordslagret utan tvekan en både effektiv och varaktig åtgärd.

För att få en fullgod dränering av områden med ytbeläggning (löparbanor o.d.) får vanligen mer genomgripande åtgärder vidtagas. Här räcker det knappast med att ha ett väl genomsläppligt fyllnadsmaterial i själva diket utan det blir ofta fråga om att anbringa ett lager av dylikt material inom hela det speciella området, såsom bl.a. Schatz (1953) och Savage (1965) föreslår (se litteraturutdragen). Här är det naturligtvis också angeläget att i den mån så låter sig göra med hänsyn till banornas utnyttjande anordna direkta nedtag för ytvatten i dräneringssystemet.

För såväl gräsmattor som belagda ytor kan dräneringsledningarna utgöras av betong, tegel eller plast. I sistnämnda fallet bör dock tillses att grovt material, såsom skärvsten eller makadam inte ligger direkt mot röret, utan detta bör skyddas mot mekanisk påverkan genom ett gruslager.

I det följande har medtagits några utdrag ur facklitteraturen som berör problem i samband med dränering av områden av här ifrågavarande slag och som därför kan vara av intresse. Närmast följer ett utdrag ur Gartentechnik av Rudolf Schatz (Berlin & Hamburg 1953), dvs. samma arbete som i vissa delar medtagits i avsnittet om dränering av trädgårdar. Det nedan återgivna utgör huvudparten av kap. VIII Sportplatzbau.

A. Rasenplätze

1. Der Fußballplatz

Geringstes Maß: 60 × 90 m; größtes Maß 75 × 120 m; deutsches Normalmaß innerhalb einer 400 m langen Laufbahn: 70 × 105 m. Richtung der Längsachse: Nord—Süd.

Der Fußballplatz wird als genau ebener Rasenplatz angelegt; als Übungsplatz, besonders auch bei schwerem Boden, erhält er ein Längs- und Quergefälle von 1—1½%, was einer mittleren, dachförmigen Überhöhung von ca. 30 cm entspricht.

Der Boden muß so beschaffen sein, daß die Fläche nach einem Regen rasch wieder abtrocknet und spielfähig wird. Leichter Boden mit durchlässigem Untergrund wird je nach dem Kulturzustand gegraben, geholländert oder rigolt, letzteres besonders bei stark verunkrauteter Rasennarbe. Mittelschwerer Boden erhält bei viel benützten Plätzen eine Röhrendränage in einer Tiefe von ca. 1,2 m; der Sammler verläuft in der Richtung der Längsachse, von dem die Sauger fischgrätenartig in einem Abstand von 6—8 m abzweigen. Bei sehr schwerem, undurchlässigem Boden wird die ganze Fläche auf ca. 50 cm Tiefe ausgekoffert. Auf der Sohlenfläche werden gleich wie bei der Röhrendränage Gräben mit entsprechendem Längsgefälle gezogen und mit grobem Schotter ausgefüllt; eine bessere Ausführung sieht gleichzeitig eine Einlage von Dränageröhren vor (vgl. Tafel 29 rechts unten). Dann wird die ganze Fläche 20 cm hoch mit grober Schotter- oder Kiesfüllung überzogen und diese gut eingewalzt. Über diese Dränageschicht wird 30 cm Humusboden aufgetragen, wozu auch der Aushubboden, vermengt mit lockernden Zusätzen wie Kompost, Torfmulle, Sand usw., mitverwendet werden kann.

Die G r a s n a r b e soll dicht und fest sein; magerer Boden muß vor der Aussaat eine entsprechende Verbesserung durch reichliche Gaben von verrottetem Kuhdünger und durch Einharken von Dungerde in die Oberfläche erhalten. Über die einzelnen Arbeiten der Aussaat, Samenmischungen usw. vergleiche den nächsten Abschnitt.

Die frische Rasenfläche ist die erste Zeit zu schonen und darf erst nach dem dritten bis vierten Schnitt zum Spiele freigegeben werden. Ein im Frühjahr angelegter Platz kann daher frühestens August—September benutzt werden. Nach jedem Schnitt ist sorgfältig zu walzen und die ganze Fläche bei Trockenheit stets reichlich zu wässern. Das Verlegen fertiger Rasenplatten an Stelle der Aussaat ist nicht zu empfehlen, da die Oberfläche immer ungleich ausfallen wird und sich dann überall Wasserpfützen bilden werden.

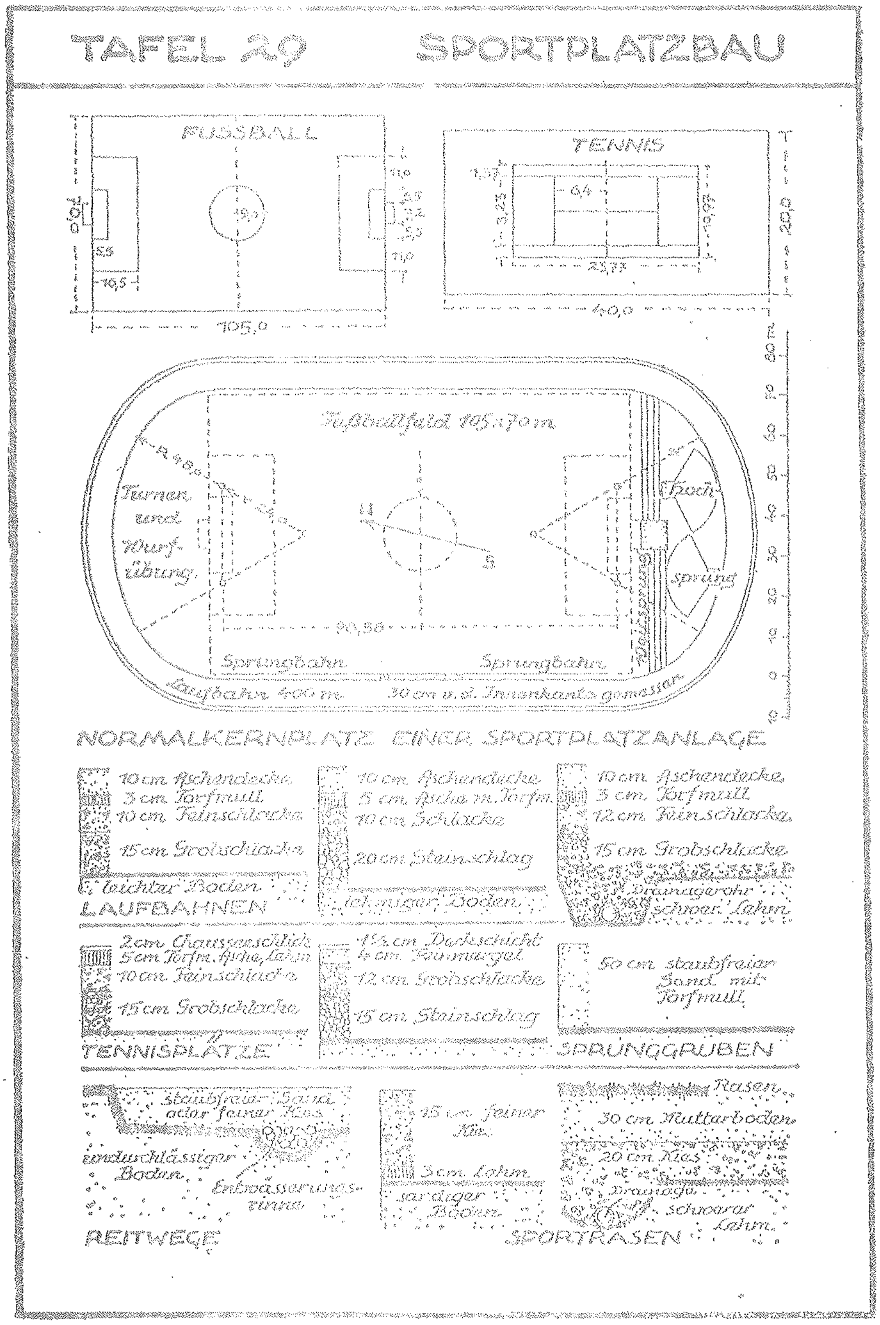
Als wichtigste Pflegearbeiten seien genannt: An trockenen Tagen muß die Fläche morgens oder abends (nicht während der heißen Mittagszeit) reichlich bewässert werden. Der Rasen ist besonders bei wenig benützten Plätzen regelmäßig mit Sense oder besser mit Hand- oder Motorrasenmäher zu mähen und dann zu walzen. Alle Unkräuter, die Blattrosetten bilden, sind auszustechen. Moosstellen werden aufgeharkt und mit Kainit oder über Winter mit Kalk gedüngt. Die ganzen Flächen sind besonders über Winter reichlich mit verrottetem Stalldünger zu versehen. Beschädigte Rasenstücke werden durch Rasenplatten, die in ähnlicher Sonnenlage gewachsen und vollständig unkrautfrei sind, ausgebessert. Vor den Toren, wo der Rasen besonders stark beansprucht wird, ist es günstig, die Fläche schon bei der Anlage etwas zu überhöhen, damit das Wasser gut abläuft und sich keine Pfützen bilden können.

Zu der A u s s t a t t u n g der Fußballplätze gehören: 4 Flaggenstangen von mindestens 1,5 m Höhe; 2 Tore aus Kantholz 10/10 bis 12/12 mit einer lichten Weite von 7,3 m und einer lichten Höhe von 2,4 m. Nach hinten ist der Torraum durch ein Netz abgepflockt.

Sollte es sich für notwendig erweisen, Fanggitter anzulegen, so sind diese hinter den Toren am höchsten (bis 5 m) und in dieser Höhe ca. 40 m breit; an diese schließt ein Gitter von ca. 3 m Höhe an, das auch noch ein Stück um die Ecken geführt wird. Das erste Gitter ist aus gut verzinktem Draht 4,2 mm mit einer Maschenweite von 50/50 mm, das zweite aus einem 3-mm-Draht mit Maschenweite 40/40 mm. Die Befestigung der Gitter erfolgt an eingegrabenen Holzsäulen mittels starker Spanndrähte.

2. Verschiedene Rasenplätze

Ähnlich den Fußballplätzen werden folgende Plätze angelegt: H a n d b a l l (Abmessungen gleich wie beim Fußball); S c h l a g b a l l (65 × 25 m, Schrägfeld 25—30 m lang, 45—50 m breit; die Rasenfläche soll fest sein, sonst besser als Tennenplatz anzulegen); S c h l e u d e r b a l l (Spielfeld für Erwachsene 15 × 100 m, für Kinder 12 × 75—90 m); H o c k e y (Länge 90 m, Breite nicht unter 50 m; Längsachse: Nord—Süd; kurz geschorener Rasen, aber auch Tennenplatz möglich); B a r l a u f (25 × 20 m); P o l o (275 × 183 m; gepflegte ebene Rasenfläche, eingefaßt mit einer ca. 30 cm hohen Hecke. Die durch die Ponnyhufe beschädigten Stellen sind immer wieder sofort auszubessern); K r o k e t t (20 × 8 m, kurz gehaltener Rasen, auch feine Kiesfläche möglich); G o l f (bewegtes Gelände von 30 ha Fläche und mehr; 18 Holes (Male)); Green = 100—300 m² große horizontale Fläche mit kurz gehaltenem Rasen und Loch in der Mitte).



B. Tennenplätze

1. Verschiedene Tennenplätze

Sie sind in ihrer Herstellung ähnlich gut befestigten Fußwegen. Auf leichteren Böden genügt eine Füllschicht von 12—15 cm aus Schlacken, Ziegelbruch oder Kies, in 2—3 Sortierungen eingebracht; bei schweren Böden ist eine Schotter- oder Röhrendränage, wie bei den Fußballplätzen beschrieben, einzubauen. Auch muß hier die Grobschicht eine Stärke von 15—20 cm aufweisen. Die Füllage ist in dünnen Schichten einzubringen und einzuwalzen. Als oberste Lage hat sich eine Mischung von lehmigem Sand mit feinerem Kies in einer Stärke von 3—5 cm und leichter Kiesabdeckung (feinste Sorte) gut bewährt. Da die Zuschlagsstoffe sehr ungleich sein können, ist das Mischungsverhältnis erst auf kleiner Fläche auszuprobieren. Erhält die Mischung zuviel Lehm, so wird die Oberfläche bei Regenwetter schmierig, bei Trockenheit hart und rissig; bei zuviel Sand stört die starke Staubentwicklung und bei zuviel Kies wirkt die Platzfläche zu scharf.

Für eine gute Ableitung des Oberflächenwassers durch ein leichtes Längs- und Quergefälle ist zu sorgen; umgekehrt ist bei längerer Trockenheit zur Erhaltung der bindenden Feuchtigkeit öfters leicht zu wässern, damit die Oberfläche die gewünschten Eigenschaften behält. Tennenplätze kommen vor allem für Ballspiele, bei denen der Ball von der Oberfläche abspringen muß, in Frage, so z. B. für F a u s t b a l l (66 × 28 m), T r o m m e l b a l l (20 × 50 m) oder S c h l a g b a l l; diese zwei sind aber auch als feste, kurz gehaltene Rasenfläche möglich. B a s k e t b a l l erfordert eine Fläche von 14 × 26 m mit ringsum mindestens 2 m Auslauffläche; Zielbretter 1,8 m lang, 1,2 m hoch auf 2,75 m hoher Befestigungsvorrichtung; Rasenplatz nicht möglich.

2. Der Tennisplatz

Ein Tennenplatz von besonderer Ausführung ist der T e n n i s p l a t z (Normalplatz für Doppelspiel: 20 × 40 m; Übungsplätze 18,5 × 38 m; eigentliches Spielfeld 10,97 × 23,77 m bzw. unter Weglassung der zwei Seitengalerien für Einzelspiel 8,23 × 23,77 m; für Privatgärten können die festgelegten Maße, besonders auch die Ausläufe um das Spielfeld, entsprechend verkleinert werden. Längsachse: Nord—Süd).

Nachstehend sind einige Befestigungsmöglichkeiten bei l e i c h t e m , d u r c h l ä s s i g e m B o d e n angegeben:

a) als Füllschicht 15—25 cm Schlackenbett in 3 Sortierungen, als Deckschicht feiner bindiger Mergel mit 1—1½ cm Kiesabdeckung oder 5 cm Mischung aus 3 Teilen bindigem Lehm und 4 Teilen gesiebtem Kies (harter Kalkstein- oder Porphyrgrus hat sich auf die Dauer als zu hart erwiesen);

b) als Füllschicht 15—20 cm Grobschlacke, darüber 10 cm Feinschlacke (staubfrei), darüber 5 cm einer Mischung aus Torfmull, Asche und Lehm und als Abdeckung 1½—2 cm Straßenschlick, überzogen mit feinem Tenniskies oder einer solchen Decke aus 1 Teil Lehm, 1 Teil Straßenschlick, vermengt mit etwas Klinkermehl;

c) als Füllschicht 10—15 cm Grobschlacke, darüber 5 cm mittelfeine Schlacke in Haselnußgröße, darüber 3 cm Schlackengrus in Erbsengröße, vermengt mit Lehm- oder Straßenschlick und als Abdeckung eine dünne Lage von feinem Tenniskies oder als oberste Schicht 5 cm von nicht zu kleinem Kies, gesättigt mit Lehmboden, überzogen mit Straßenschlick und feinem Tenniskies.

Bei s c h w e r e m , u n d u r c h l ä s s i g e m B o d e n muß die ganze Fläche entsprechend tief ausgekoffert und mit einer Wasserabzugsmöglichkeit durch schottergepackte Gräben, Dränageröhren usw. — wie bei den Fußballplätzen angegeben — geschaffen werden. Auch die 15—20 cm starke Grundpackung aus grobem Schotter, Ziegelschlag, Steinschlag von Weichgestein usw. muß vorgesehen werden. Bei vielbenützten Plätzen kann auch eine direkte Packlage aus Weichgestein eingebaut werden. Hartgestein für Packlage oder Grundbau hat sich als zu fest und zu unelastisch erwiesen.

Auf den sorgfältig eingebrachten Grundbau kommen Füllungen wie bei den leichteren Plätzen angegeben, wobei aber für die unterste Groblage oft eine Stärke von 10—12 cm schon ausreicht. Alle Materialien sind in dünnen Schichten einzubringen, von denen jede gut eingewässert und eingewalzt werden muß.

Die Gesamtstärke beträgt bei leichten Böden 20—25 cm, bei mittleren 30—35 cm und bei schweren Böden mit der Grundpackung bis zu 50 cm. Auch ist es möglich, nur die Fläche unterhalb des eigentlichen Spielfeldes stärker und die Auslaufflächen schwächer zu befestigen.

Die Oberfläche der Decklage soll nicht federn, aber auch für den Schuh nicht hart sein; sie muß nach einem Regen rasch abtrocknen und darf vor allem nicht kleben. Umgekehrt muß sie eine gewisse gleichmäßige Feuchtigkeit halten, damit bei trockenem Wetter kein Staub entstehen kann. Die Farbe ist so zu wählen, daß die Bälle gut sichtbar sind. Die Mischung wird am besten erst auf einer kleinen Fläche ausprobiert, ehe der ganze Platz angelegt wird.

Die Decklage wird mittels genau eingewogener Ziehlatten abgezogen; sie darf während des Bauens nur mit weichen Schuhen ohne Absätze betreten werden. Es ist zweckmäßig, die Walze vom Rande aus mit Seilen zu ziehen.

Bei genau ebenen Plätzen ist peinlichst zu beachten, daß sich keine Wasserpfützen bilden. Es werden daher auch Plätze mit einem leichten Gefälle zur Ableitung des Oberflächenwassers angelegt, und zwar entweder mit einem dachförmigen Gefälle von der Mitte nach allen vier Seiten (nach den Längsseiten 5 cm und den Querseiten 10 cm) oder einem zweiseitigen Gefälle von je 10 cm vom Netz ab. Unter besonderen Verhältnissen sind an allen 4 Ecken Sickerschächte oder Einfallschächte mit Ableitungsmöglichkeit vorzusehen. Die Auskofferung erfolgt genau im zukünftigen Profil, die Überhöhungen sind daher auch schon im Koffer zu berücksichtigen. Bei Auffüllboden ist die Koffersohle besonders gut zu befestigen.

Als wichtigste Pflegearbeiten seien genannt: Der Platz muß im Frühjahr nach dem letzten Frost gut abgewalzt werden, wobei alle Löcher mit dem Material der Befestigungsschicht sorgfältig ausgebessert werden müssen. Bei stark benützten Plätzen muß täglich der Kies mittels Besen ausgeglichen und an Fehlstellen ersetzt werden. Bei trockenem Wetter ist die Decklage durch Besprengen gleichmäßig feucht zu halten. Nach dem Wässern oder nach Regentagen ist der ganze Platz mit einer 200—300 kg schweren Walze zu walzen. Die Walze soll zweiteilig sein und stark abgerundete Mantelkanten besitzen, damit sich beim Wenden der Kies nicht zusammenschieben kann. Jede Schadstelle der Decklage ist sofort auszubessern. Unkräuter usw. müssen durch chemische Mittel wie Unkraut-Ex usw. sofort beim Erscheinen entfernt werden. Gegen Moosstellen ist an trockenen Tagen Kainit oder Viehsalz zu streuen.

Die Spiellinien (vgl. die Linienzeichnung auf Tafel 29) werden am Boden als 3—4 cm breite, weiße Streifen mittels flüssiger Schlämmkreide, einer Mischung von Firnis, Schlämmkreide und Kalkmilch oder durch Aufstreuen von pulverisiertem Gips, einer Mischung von zerfallenem Ätzkalk mit Schlämmkreide und Alaun usw. aufgetragen. Bei den in der Zeichnung angegebenen Abmessungen ist die Strichbreite mit inbegriffen. Um das Liniennetz immer wieder genau festlegen zu können, werden an den Platzgrenzen Pflöcke eingemessen, von denen aus die Eckpunkte mittels gespannter Schnüre immer wieder bestimmt werden können. Eine Festlegung der Eckpunkte durch Pflöcke, eingetriebene Nägel usw. innerhalb des Spielfeldes ist unzulässig.

Zum Aufbringen der Markierungsstreifen bedienen wir uns einer Markierungsmaschine oder der Puderkrippe (2 schräggestellte Bretter von 3 bis 4 m Länge sind so untereinander verbunden, daß ein 3—4 cm breiter Spalt offen bleibt. Die Krippe wird genau an die Schnur angelegt und die flüssige Markierungsfarbe mittels Pinsel oder das Markierungspulver mittels Blechbüchse mit durchlöchertem Deckel durch den Spalt dünn auf den Boden aufgetragen. Der pulverförmige Streifen wird vorsichtig mit einer feinen Brause angefeuchtet). Nach jedem Besprengen und Walzen der Decklage ist das Liniennetz nachzubessern bzw. zu erneuern.

Zu der Ausstattung der Tennisplätze gehören: das Spielnetz mit den 2 Randpfosten (für Doppelspiel 12,8 m lang, an den Pfosten 1,07 und in der Mitte 0,91 m hoch) und das Fanggitter (3,5—4 m hoch), das um den ganzen Platz geführt oder auch nur an den Schmalseiten und einem kurzen Stück der Längsseiten angebracht wird. Im letzteren Falle bliebe zu beiden Seiten ein mittlerer Streifen von ca. 8 m frei. Das Gitter besteht aus gut verzinktem Draht 2,5—3 mm, mit einer Maschenweite von höchstens 40/40 mm. Die Befestigung erfolgt mittels Spanndrähten an Holzsäulen oder in Betonfundamenten eingelassenen Eisenträgern.

C. Aschenbahnen

Die Abbildung der Tafel 29 zeigt einen Normalkernplatz einer Sportplatzanlage. Die Länge der L a u f b a h n beträgt 400 m, 30 cm von der Innenkante gemessen; sie setzt sich zusammen aus 2 geraden Stücken von je 98,58 m und 2 Korbbogenkurven, deren erstes und letztes Viertel einen Radius von 24 m und der mittlere Teil einen Radius von 48 m aufweisen. Die Längsachse soll Nord—Süd verlaufen. Die Breite der Laufbahn beträgt 5 × 1,25 = 6,25 m (neuerdings wird eine Breite von 6 × 1,25 = 7,50 m angestrebt). Die fünfreihige Laufbahn ist an der westlichen Längsseite zu einer K u r z s t r e c k e n b a h n von 6 × 1,25 = 7,50 m Breite und 130 m Länge erweitert, um auch den 110 m Hürdenlauf einschließlich Startraum und 10 m Auslauf aufnehmen zu können. Innerhalb der Lauffläche ist ein F u ß b a l l f e l d 105 × 70 m sowie innerhalb der Korbbögen Flächen für H o c h s p r u n g , W e i t s p r u n g , ferner für T u r n - und W u r f ü b u n g e n angeordnet. Auf der Fußballfläche können auch alle übrigen Rasen-Ballspiele stattfinden. Zwischen Fußballfeld und Laufbahn verbleibt an der Westseite ein 1,5 m breiter Streifen, auf welchem 2 S p r u n g b a h n e n angelegt werden, sowie an der Ostseite ein 0,5 m breiter Streifen, der zur Aufnahme der Unterflurhydranten für die Bewässerung der Aschenbahn und des Fußballrasens dient. An der Westseite würden sich dann noch die Hauptzuschauerplätze anschließen. Die Laufbahnfläche erhält nach den neueren Bestimmungen an den Kurven keine Überhöhung mehr; würde diese dennoch gewünscht, müßte sie nach eigenen Berechnungen festgelegt werden.

Je nach Bodenart muß der Laufbahnkörper stärker oder schwächer befestigt werden.

Bei l e i c h t e m B o d e n genügt eine 15 cm starke Schlackenschicht, die in verschiedenen Sortierungen eingebracht und mit 10—12 cm Aschenmischung abgedeckt wird. Bei m i t t l e r e m B o d e n , z. B. lehmigem Sand, kommt auf die Koffersohle eine 15—20 cm starke Lage aus Grobschlacke, Ziegelbruch oder Steinschlag aus Weichgestein, dann 10 cm Schlacke in 2 Sortierungen, darüber eine 3 cm starke Schicht aus Torfmull oder Gerberlohe bzw. aus einer Mischung von Asche mit Torfmull und als Decklage die 10 cm Aschenmischung. Bei s c h w e r e m B o d e n ist im Koffer an der Bahninnenseite ein Entwässerungsgraben mit Dränageröhren (vgl. Tafel 29, rechts) und entsprechender Ableitungsmöglichkeit vorzusehen. Die unterste Dränageschicht hat eine Stärke von 15—25 cm und besteht aus Grobschlacke, Ziegelbruch oder Weichgestein, darüber kommt die Feinschlacke usw. wie oben bei mittlerem Boden angegeben.

Die A s c h e n s c h i c h t setzt sich zusammen aus ca. 6 Raumteilen staubfreier Kohlenasche (Koksasche ist zu leicht und daher ungeeignet) + 3 Teilen Waldboden oder sandigem Gartenboden + 2 Teilen feingesiebtem Lehm und 1 Teil gesiebtem Kies. An Stelle von Kies ist auch die Beigabe von Ziegelmehl oder feinem Schlackensand möglich. Eine andere Mischung wäre: 14 Teile feine, staubfreie Asche, 6 Teile feingesiebter Lehm, 1 Teil Torfmull mit einer Abdeckung von feinem Ziegelmehl. Alle Zuschlagsstoffe werden durch ein 5-mm-Sieb gesiebt; der Lehm ist trocken fein zu zerreiben.

Die Oberfläche der Aschenbahn soll in sich gebunden, glatt und fest, dabei aber doch elastisch sein, so daß sich der Fuß des Läufers flach eindrückt. Damit die Oberschicht möglichst lange feucht bleibt und ihre geforderte Elastizität ähnlich einem guten Waldboden beibehält, erfolgt die Einfügung der Torf- bzw. Loheschicht; diese stellt zugleich eine gut federnde Polsterschicht dar. Alle Lagen sind in kleinen Schichten einzubringen und gut festzuwalzen. Das richtige Mischungsverhältnis für die Zusammensetzung der Laufbahn muß unbedingt vorher auf einer kleinen Fläche ausprobiert werden.

Die Aschenbahn wird seitlich durch imprägnierte Holzbohlen, Zementsteine usw. gefaßt. Die Lauffläche erhält kein eigenes Quergefälle. Das von den Zuschauertribünen kommende Oberflächenwasser ist durch Pflasterrinnen abzuleiten, damit die Laufbahn nicht überschwemmt werden kann.

De följande båda utdragen har författats av Colin Rogers, Playing Fields Officer, Lancashire; det första (I) betitlat The drainage of sports fields on clay soils, ingående i Parks & Sports Grounds, Aug. 1964, s. 823-832, och det andra (II) med titeln Some aspects of sports field drainage, likaledes i Parks & Sports Grounds, June 1966, s. 715-724. I den första av dessa uppsatser uppehåller sig Rogers vid problematiken rörande dränering av idrottsplatser anlagda på lerjord och understryker kraftigt att det härvid långt ifrån är fråga om enbart ytvattenavledning (surface drainage) utan framför allt grundvattenavledning (under-drainage, subsoil drainage). Detta är givetvis alldeles riktigt; eftersom dylika områden skall vara så plana som möjligt, kan det inte bli fråga om någon mera betydande avrinning på ytan (detta gäller gräsplaner) utan den fallna nederbörden nedsjunker på stället och överskottsvattnet tar sig i huvudsak vägen genom jorden ned till dräneringsledningarna.

I den andra artikeln kommer Rogers in på problemet med äldre dräneringsledningar som satts ur funktion och som kan ställa till svårigheter om de ligger djupare än det nya dräneringssystemet. Hans erfarenheter härutinnan ger vid handen att det tydligen kan vara ett verkligt problem, annars kan det ju förefalla som om en intensiv nydränering av ett dylikt begränsat område och med god genomsläpplighet i återfyllningsmaterialet skulle elimineras den negativa effekten av de gamla avskurna ledningarna. Vi har emellertid likartade problem vid dränering av åkerjord; ett öppet dike som läggas igen utan rör och med de nya täckta ledningarna skärande detta utgör inte alltid en fullgod lösning av dräneringen.

I.

THERE is no doubt that efficient drainage is an important factor in the successful upkeep of any sports field, and in those parts of the country with heavy soils and a high rate of rainfall it is a matter of absolutely vital importance. Drainage is one of the more costly operations in grounds construction and it is a sphere of work in which faults in planning or in execution are difficult to correct in future years. In view of this, it is rather surprising that there is comparatively little written information available on the subject of sports field drainage, particularly as applied to clay soils where the problem of dealing with water is most acute. Unfortunately, it is not a sphere of work which readily lends itself to experiment—the effectiveness of a drainage system can only be judged over a period, and where results are disappointing, errors in technique which may have been the cause are most difficult to pinpoint and assess. It is understandable, therefore, that there should be divergence of opinion among those connected with grounds construction and maintenance on the essential requirements of sports field drainage, and it is in the hope that an exchange of views may help to solve some of the problems that the ideas contained in this article are submitted.

The aspect of drainage work on which there are the widest differences of opinion is that of the appropriate depth of drains in clay soils. It is easy to see that on clay lands the situation differs from that on permeable soils. In the latter, where the water table rises progressively from a lower impervious layer, drains are laid with the object of intercepting the water and preventing its reaching the surface.

In an undrained clay soil, only the top soil is relatively permeable and the water table is virtually on the surface when ever appreciable rainfall occurs. It is often argued that where the subsoil is impervious there is no virtue in laying drains at a greater depth than is necessary to ensure the safety of the pipes, and it is even stated that any greater depth would result in loss of efficiency. It is difficult to understand the basis of this latter argument where porous backfilling material is employed, as is usually the case in sports grounds drainage. It would seem obvious that once the water reaches the drain trench, it can reach the pipes just as readily whether the column of porous material is one foot in depth or four.

It is less easy to disprove the contention that any depth greater than the frequently-advocated 12in. to 18in. is purposeless, and therefore wasteful of labour and materials. When it is pointed out that in agricultural practice depths of 30in. to 36in. are normal, one is apt to get a reply to the effect that what is needed in sports grounds work is rapid SURFACE drainage and that "we are not interested in under-drainage as the farmer is". This is an argument with which the writer cannot agree; he has yet to meet the farmer who is not just as anxious to get water away from the surface as the sports ground supervisor is. What is perfectly true is that the farmer may not consider the INTENSITY of drainage required on sports grounds an economic proposition in his case—but that is quite a different matter.

When it is suggested that it is valueless to sink pipes into a subsoil which is impervious to all intents and purposes, an important factor is being overlooked. This is the improvement brought about in the soil by the drains themselves. It has always been the contention of the old agricultural drainers, doubtless based on accumulated experience, that a newly-laid system is never fully effective at once but that a gradual improvement over a period of years should be expected. Various periods are quoted, three years, five years or even twenty years, possibly depending on the soil characteristics, and if one asks why, one is told that the land must "learn to bleed". A more complete explanation of the improvement may be that given in the first of an excellent series of articles on drainage by A. L. Turner in *The Groundsman*. One cannot do better than quote Mr. Turner's actual words:—

> "In heavy soils . . . improvement by drainage can be said to be due chiefly to the fact that plant roots and earthworms can penetrate more deeply into the subsoil, which becomes broken up and organic matter becomes added to it—drainage therefore permanently increases and deepens the vegetable soil. This formation of new vegetable soil is aided by the expansion sideways of the ground over the drain trench and the fact that in thaw it does not contract to its original position—the excess pore space of the drainage run is thus more evenly distributed throughout the whole field. Of course this is a long-term factor and can be assessed not in terms of years but in decades."

The concluding sentence may seem a little disconcerting but fortunately we have means of speeding up the process.

When one thinks about it, it is illogical to imagine that drainage taking place in the top soil alone could ever be entirely satisfactory. A sports field cannot have a pronounced gradient—1 in 60 would be a normal maximum—and the top soil overlying clay is usually of a heavy nature and often meagre in depth. Assuming a reasonable interval of 18 feet between lateral drains and a movement of water in a downhill direction for the greater part of that distance, one would be expecting miracles of porosity in the top soil if it is to absorb the result of a day's heavy rain and discharge it conveniently down a gentle incline to a drain at an average distance of three yards away! Certainly, this may well be the situation when ground is first constructed—but it would be a sorry thing if no subsequent improvement could be expected.

Although we may think of a heavy clay subsoil as being impervious in its undisturbed state, this is seldom completely true in practice. Fissures, embedded stones, worm holes and variations in structure all permit a movement of water, providing the water has some sort of outlet. In clay land, when it has been drained, the easiest outlet is provided by the pipe drains themselves, and it is reasonable to assume that effective drainage is achieved by the formation of minute passages through the top soil and subsoil in the direction of the drain trenches. It would be expected that this would first take place in the immediate proximity of each drain, where the fissuring would extend to the full depth of the trench wall, the effect decreasing with the increasing distance from the drain.

If an improvement does actually take place in the manner suggested, it can do so down to the level of the drains or only fractionally deeper. Within reason, therefore, the greater the depth of the drain, the greater will be the volume of semi-permeable soil created after an appropriate period. (Nevertheless, there is almost certainly an optimum depth below which the gain will be small, probably depending on soil structure and climatic considerations.) During dry periods between periods of rainfall, water drains from the pores and fissures and is replaced by air. When the next rainfall occurs, these spaces will act as a reservoir and, in well-drained land, can absorb an appreciable amount of water before field capacity is reached. It is quite common to see muddy strips running parallel to lateral drains and midway between them, a likely indication that the drains are too shallow or too widely spaced.

In the case of a newly-constructed games field where major levelling work has not been necessary, a possible reason for the failure of a field drainage system to work effectively may be the presence of an older agricultural system at a lower level, the outlet of which has become obstructed. The old drains may be widely spaced and the new system intensive but in none of the many cases the writer has seen has the new system dealt with the saturation resulting from the obstructed drains. It is as though the water has "learned to bleed" to the original drains; these are invariably found to be charged with water while the new pipes are practically dry. Good drainers are always on the look out for earlier systems and, when they are found, make every effort to keep at a slightly lower level and to pick up the old drains wherever the new lines cross. Sometimes tragic cases occur where the original deep outlets are no longer available and the new system is, of necessity, at a higher level. In such an instance, the only course of action possible is to construct a small vertical shaft at each crossing point.

What, then, may be considered the ideal depth for drains in clay soils? It is difficult to arrive at a compromise between the dictates of efficiency and economy, but it is suggested that a depth of three feet to invert should be the general aim, with a normal minimum of 30 inches.

Unlike agricultural land, the sports ground has not the benefit of periodic cultivations, nor are deep-rooting crops with their soil breaking properties grown in rotation. Moreover, the sports ground tends to be subjected to traffic in unfavourable conditions—which seals the surface and inhibits natural aeration, especially in the early stages of turf establishment. Natural improvement in the manner described by Mr. Turner may therefore be slow and some means of speeding up the process is required. This is provided by mole draining or subsoil shattering in the course of construction.

In agricultural circles, mole draining has been carried out as a drainage technique in its own right for a long time and it is possible that the farmer might regard the modern practice in games field construction of moling at close intervals over an intensive tile system as an extragavence. However, the farmer does not have to contend with the compacting effect of the heavy machinery used in present-day grounds construction. Mole channels will only persist in a subsoil of uniformly high clay content, and in other cases the process must be regarded as one of shattering rather than moling. It is thought that shattering is best done in two directions to form a diamond pattern, so that the collapse of a channel is less likely to cause a hold-up of water at that point. The accompanying picture shows a modified subsoiler foot designed for use where drastic shattering is thought necessary and which has been employed to good effect.

In the writer's own district, until comparatively recently, a great deal of drainage work was done by hand and the traditional tapering trench was used. The bottom was just sufficiently wide to take the tile, thus reducing the risk of displacement during backfilling. The width at the top was about 14 inches, allowing the drainer to stand within the trench to grade the bottom by means of a scoop or "shell", an absolute essential for drains of adequate depth. Whatever may have been the reasons for the employment of the tapered trench in agricultural practice, it certainly has advantages so far as sports field work is concerned. By its use, a minimum of imported backfilling material is required and there is a minimum of surplus subsoil for disposal. Moreover, in a tapering trench there is a resistance to the settlement of the filling material. Annoying depressions in the trench line and the need for periodical reinstatement are avoided and the filling material remains uncompacted, thus facilitating the passage of water to the pipes.

Mechanical excavation has now largely displaced hand work. It is unfortunate that many highly efficient machines now available are only suited to the excavation of a parallel-sided trench—which is apt to be too wide at the bottom for economy and too narrow at the top for easy working. It is possible to obtain a tapered bucket for use with the digger type of trenching machine. The one illustrated is designed specially for clay soils but does not require an ejector and cuts a trench little inferior to those excavated by hand. One hears with regret that with the advent of machine excavation less regard is being paid to the formation of a uniform bed for the tiles. A 3 inch diameter tile does not give scope for shoddy laying and work of this description is expensive at any price!

If it is true that water can be induced to move through a heavy clay subsoil, one is inclined to wonder if the use of porous backfilling material in the drain trenches is as important as many of us have believed. Agricultural practice appears to vary; in areas where suitable material has been readily available (e.g., clinker ash from nearby industrial centres) it has regularly been employed, but in less favoured districts it has not been regarded as essential—and there is no evidence that drainage has been less effective in those parts. In the course of new drainage work one frequently finds earlier systems, often unsuspected, with outlets obstructed and suffering from the neglect of years, but still capable of moving an amazing amount of water when freed. In some instances, a system laid for agricultural purposes and in good condition may prove adequate for games purposes, but often the drains are too widely spaced and need to be supplemented. The significancant point is, however, that these drains will have been working very effectively without the help of porous backfilling. Any doubts one may have about the efficiency of these old drains in collecting water are quickly dispelled when one sees the appalling mess which occurs when one of them becomes obstructed.

A short while ago, the writer was privileged to see in operation drainage work by an ingenious machine which forces the ground open to permit tiles to be laid on a properly-formed bed and then allows it to close again as the machine progresses. Knowledgeable friends, who have games fields under their charge which have been drained by this method, state that work carried out several years ago is still very satisfactory indeed, despite the fact that no porous backfilling material was used.

At one time, only a few years ago, suitable backfilling material in the form of clinker ashes was available in many districts at low cost. Now the situation has changed; it is difficult to obtain ashes, even of moderate quality, and the cost has risen appreciably. Material containing any quantity of fine particles will frequently result in obstructed drains. Material containing too great a proportion of large pieces may permit water to pass too rapidly, and silt may be deposited when its velocity is reduced on reaching the pipes. The ideal material, ranging in content from small to coarse, has usually to be specially screened and is priced accordingly.

In present circumstances, the purchase and placing of imported filling material and the removal of the surplus excavated clay is apt to cost at least as much as the excavation of the trenches and the provision and laying of the pipes. Thus, if drains without porous filling were regarded only as half as efficient as those with imported fill, a system of equal efficiency could be provided at no greater cost by reducing the intervals to half. In practice, however, if there is indeed a reduction in efficiency, it is nothing like so great as this. There is, moreover, another factor: drainage work has often to be carried out under appalling ground conditions and the damage done to the soil structure in the process of placing imported material and removing surplus can be very great indeed. In these circumstances, the loss of drainage properties in the soil is likely to be greater than any gain through the porous material.

The writer and his colleagues have been responsible for the drainage of many acres of games fields on heavy soils. During the past few years some schemes have been carried out using porous material and some without, according to local circumstances. In all cases, drains have been laid at normal intervals, usually 18ft. Usually, but not always, shallow mole draining or subsoiling has been carried out over the tile drains. In some instances it may yet be too early to judge results but, up to the present, no striking difference in efficiency has been observed between the two methods, even where they have been employed on the same site.

It has been suggested that non-porous backfilled systems will show deterioration in future years when the effect of the mole draining is lost. The writer believes, on the contrary, that the critical time is in the early period of use when it is all too easy to seal the surface and so inhibit the formation of natural drainage passages in the soil. It is suggested, therefore, that money saved by the omission of imported filling material could well be spent on suitable grit, coarse sand or other soil ameliorants to be worked into the surface layer before sowing. Should deterioration be apparent at some later date which cannot be relieved by deep piercing, shallow mole draining can be carried out using equipment now available which causes little disturbance to the surface.

A few further points may be mentioned: porous backfilling is, of course, essential where a drain has to act as a trap drain, preferably carried right to the surface. Porous backfilled mains from which mole draining may be started are thought to be preferable, although this may not be absolutely essential where an intensive tile system is used. It is highly desirable that some sort of filtering material—inverted turf, hay, straw or fine brushwood—should be placed over the pipes before backfilling with clay. Besides acting as a filter, such material is thought to attract worms which probably play an important part (some people say an essential part) in the establishment of efficient drainage. The condition of the subsoil when it is returned is thought to be important: it should not be in a saturated and soggy condition, neither should it be in the form of hard-baked lumps.

It would be rash to appear dogmatic on any matter concerning grounds work—the permutations of factors which can affect an issue are without number—but conclusions reached on the basis of recent experience are these: that whether or not porous backfilling material plays any part in the efficient working of a drainage system, still more important factors are the adequate depth of the drains, care and accuracy in the laying of the pipes and the maintenance of soil conditions suited to the establishment and retention of a vigorous turf cover.

II.

"EFFICIENT drainage is one of the most important factors in soil fertility. It is of special importance to anyone connected with sports field management because of the traffic to which sports turf is subjected in unfavourable weather conditions. The effects of this are cumulative—the puddling of the surface layers of the soil when the ground is in a saturated state prevents the passage of water and creates conditions conducive to further puddling. This leads to a situation unpleasant and unsuitable for future play, but there is also another aspect: the exclusion of air from the grass roots and from the soil bacteria has an inhibiting effect on growth—and a deep-rooted, vigorous turf cannot be maintained in such circumstances. Drainage has, therefore, a direct bearing on the permissible intensity of games use. With the certainty of increased demands for the wider and more intensive use of school playing fields in the near future, the importance of any aspect of our work which affects the durability of turf surfaces cannot be over-emphasised.

"Field drainage is one of those spheres of human activity in which there are few hard and fast rules which can be said to apply in all conditions. There are as many variations in the behaviour of water in soil as there are in soil types—obviously, because the type of soil is one of the factors governing the behaviour of water. But even allowing for this, the position is constantly changing: there may be improvement as the land 'learns to bleed', as the old drainers used to say, or there may be deterioration due, for example, to the compaction mentioned earlier. When a new drainage system is first installed its level of efficiency will be far from that which it should ultimately attain. It is only by observation over a period that we can judge whether or not it is going to be a success—and even then allowance has to be made for the innumerable permutations of weather, plant growth, intensity of use and so forth.

"The Playing Field Officer has a special advantage in the study of land drainage. Either in person or through knowledgeable members of his staff with whom is is in constant touch he is able to observe and assess schemes laid down over a number of years, to differing specifications, in a wide range of soil types and with varying degrees of games use.

"Those of us who have responsibility for games fields in Lancashire—with that county's high rainfall and what is, perhaps, more important, its high frequency of rainfall—can claim more frequent opportunities for observation and assessment than can our fellow members in those parts of the country having a kinder climate. Most members of the County playing fields staff have the keenest interest in the subject of drainage and many of the ideas contained in this Paper are the results of collective observation and experience, for which I am greatly indebted to my colleagues, past and present.

"When I agreed to present this Paper, I decided not to attempt to cover Drainage as a whole but to concentrate on some of its aspects with which my colleagues and I have had most experience. Most of my remarks can be taken to apply principally to the clay soils on which very many of our playing fields in Lancashire are sited and which are responsible for a large proportion of our drainage problems.

"One of the first things I learned when I first came to work in Lancashire was the importance of relatively deep drainage, even in the heaviest clay. The reasons for this may not immediately be clear. When one considers a permeable soil, in which the water table rises progressively from lower impervious strata, it is obvious that the deeper drains are placed, the sooner will the rising water be intercepted and carried away. In an undrained clay soil, on the other hand, water does not readily penetrate below the level of the top soil and after quite a small amount of rainfall the water table is virtually on the surface. On the face of it, one might be forgiven for thinking that there is no virtue in placing pipes any deeper into the subsoil than is necessary for their protection. To say this, however, is to overlook the improvement in the permeability of the soil brought about by the drains themselves—and this, indeed, is the vital factor.

"One does not learn very much about the behaviour of drains in clay soils from the study of a newly laid system. Initially, the drains will only take water from the relatively-permeable top soil and the only areas of ground which will be really dry will be those immediately above the drain trenches. It is the earlier systems—including the old agricultural drains which may be discovered in the course of laying a new system—which give us the clues to the way in which drains function. It may sound a little incongruous, but it has been those which have *not* been functioning for some reason which have taught me most. One has only to see what happens when the outlet to one of these old drains becomes obstructed to appreciate how efficient they are when they are functioning properly.

"A new drainage system installed at a shallower depth than an earlier system no longer functional is never successful. Mr. M. C. Livesley, in his book 'Field Drainage', quotes a case where there had been three systems, one on top of the other. It was only when the original system was located and the obstructed outlet cleared that the field in question began to drain properly. In my own experience, I have seen innumerable examples of the same thing, although none as striking as Mr. Livesley's. Even a single obstructed drain underneath a new system is sufficient to give untold trouble which cannot be eradicated until the old drain is located and provided with a free outlet.

"Instances of this sort led my colleagues and me to the conclusion that a properly-installed drain in a clay soil eventually forms what I will call, for want of a better term, a 'field of influence'—rather like a magnetic field—peculiar to itself and little affected by any other drain, especially one at a higher level. We have held this belief for a number of years but it was only this last winter that an incident occurred which, to my mind, put the matter beyond doubt.

"A games field which has been constructed recently by contract, by the 'cut-and-fill' process, has an embankment on one side, about five feet in average height. Shortly after the field was handed over for local maintenance, wet spots were noticed at the foot of the bank and subsequently complaints about waterlogged gardens were received from the occupiers of houses on adjoining land. Investigation indicated a series of agricultural drains, at intervals of 21 feet, which were presumed to have been cut in the course of levelling and subsequently blocked in the process of forming the embankment. When our drainers came to tackle the job, not all of the drains were found with equal ease; some had been cut off nearer to the boundary than others. It happened that, in one section, alternate drains were missed in the first instance and were left to be dealt with later. The drains first exposed ran at full-bore for an hour or so and at ½-bore for two to three days. About a week later, the drainers came back to the three drains which had been missed. When eventually exposed, these ran just as strongly and for just about the same time as the others. In other words the freeing of the first drains could have had negligible effect on those adjoining.

"Circumstances were such that the drains could not have been more than 50 yards long to the point at which they were broken. The pipes were only of 2in diameter and we calculated that each drain could only have held about 20 gallons in the pipes themselves, assuming it to be full for the whole length. The trenches had not been filled with porous material, so that the very large quantity of water which ran off could only have come from the land itself.

"It will be appreciated that the rather unusual circumstances favoured this fortuitous demonstration—the fact that the drains were not joined up to a main but ran independently to a bank where their behaviour could be observed. It will be appreciated, also, that had the subsoil been of a permeable nature instead of heavy clay, each drain, when opened, would have relieved succeeding ones.

"If our contention is true—that when a drainage system becomes well-established, water must reach the drains through the intervening 'blocks' of clay subsoil—it will be apparent that the deeper the drains are placed, the greater will be the volume of subsoil influenced by the drains. The effect does not appear to be proportionate, however; drains at less than two feet depth do not seem to 'draw' water from any appreciable distance. A possible explanation would be that a cross-section through our so-called 'field of influence' is not an inverted triangle (with the drain at its apex) but an area bounded by two parabolic curves, the shape of which is governed by the characteristics of the soil. This is, of course, pure conjecture, but the fact remains that shallow drains do not seem to have appreciable influence on an area much wider than the trench in which they are placed. The fact they also silt up more quickly is besides the point.

"In practice, the choice of depth and spacing is a compromise between ultimate efficiency and immediate economy—bearing in mind that with a games field it would be quite unreasonable to wait for full efficiency to develop. Our own practice is to lay at a depth of about three feet to invert, with a spacing of from six to eight yards. We usually draw a subsoiler or a mole plough over the tile drains— but as the depth achieved with our present equipment is limited to about 14 inches maximum, the operation can be considered one of soil shattering rather than moling.

"If it is true that water must travel through several yards of clay subsoil to reach the drains, one cannot help but wonder whether porous backfilling material in the trenches is as important as was once thought. For my own part, when material of excellent quality was available at reasonable cost, I never thought of challenging the practice. But when suitable material became scarce and the price exorbitant, we thought about the many agricultural drains we had found, all working efficiently without any type of imported filling, and we began to dispense with it ourselves—at first on an experimental basis and later as standard practice. During the last five years we have laid many thousands of drain pipes, some with porous filling and some without, sometimes on the same piece of land, and I can honestly say that there has been nothing to choose between them as far as efficiency is concerned. The cost and effort involved is another matter.

"The cost of excavating trenches by normal methods, and providing and laying the pipes, is roughly similar to that of the provision and placing of porous backfilling material and the carting away of surplus subsoil. Thus if drains without porous backfilling were only half as efficient, one could halve the intervals between drains without additional expense. In practice, however, I see no reason to do this—and I prefer to spend any money saved in this way on the provision of soil ameliorants to facilitate the passage of water through the top soil itself.

"In comparing the two practices, there is another aspect to be considered. The placing of porous material and the disposal of the surplus involves considerable traffic over the land, often when it is in a most vulnerable condition. If, indeed, there is any gain in the use of porous filling, it is a question if this is not offset in many instances by the damage to the soil occasioned by its use.

"Reverting to our own practice, we prefer not to put clay directly on to the pipes but usually cover them first with a thin layer of hay, straw, fine brushwood or inverted turf to act as a filter. Some drainers maintain that these materials serve to attract earthworms—which undoubtedly play a very important part in land drainage—and there is a good chance that this is correct. The condition of the clay when returned to the trench is probably important; I do not like to see it in large lumps, nor do I think it good if it is broken down too finely. Something between the two would seem to be ideal.

"Porous backfilling is, of course, essential where drains are widely spaced to act as mains for mole drainage, although we do not think it necessary when we mole over a normally-spaced system. All trap drains need porous filling, carried right up to the surface. In my opinion, the quality of the material is quite important; if too coarse a material is employed, the rapid passage of water will carry silt to be deposited in the pipes; if it contains too great a quantity of fine particles, the material will provide its own silt to block the drains.

"In some unstable soils of a silty nature—where the soil is continually on the move—or where pockets of running sand are encountered, it is desirable to use porous material over the pipes—and sometimes underneath them as well. In the few examples of this soil type I have come across, this has been most effective and is a practice I would always advocate.

"If there is a situation worse than undrained land in need of drainage, it is land which contains an existing drainage system no longer functioning for some reason or other! It would seem that when a drain is blocked, the 'field of influence' operates in reverse, possibly due to capillary action, in the area adjoining the obstruction. If it is possible to put in new drains below the old ones, so as to pick them up wherever the lines cross, there is no great difficulty. But where it is impracticable or uneconomical to go to the depth of the old drains, every endeavour should be made to see that the outlets are clear, at the very least. A case in point is in the 'fill' area of a 'cut-and-fill' project; where the fill is shallow I can state emphatically that an obstructed existing drain can and will affect the finished job, despite a complete system we may lay subsequently at a higher level. I do not know how long such effect may last but, bearing in mind the cumulative effects of bad drainage, there is reason to believe that it may last for a longtime. Even where the fill is deep there may still be some effect. In any event, if only to be on the safe side—and for the sake of easy working in unfavourable weather conditions—I think it well worth while to ensure that existing drains have a free outlet in all cases.

"If a watercourse or ditch is to be culverted and the new line does not follow the original, it is advisable to lay agricultural pipes in the old waterway and to ensure that any drains which discharge there are picked up. The cost of doing this at the time of construction is nothing like as great as that of locating the drains subsequently if trouble occurs.

"It would now appear obligatory, under the Land Drainage Act of 1961, to seek the consent of the appropriate drainage authority before a watercourse or ditch may be culverted, although I understand that this is not being enforced everywhere at the present time. In the case of minor waterways, this may seem somewhat superfluous, but if, as I assume, the object is to ensure that pipes of adequate size are employed and that installation is at the proper level, my personal reaction is one of regret that this provision was not in being and rigidly enforced years ago.

"Only a few years ago, the greater part of the games fields with which I was associated were bounded by farm land, the owners of which had a common interest with the County Authority in keeping drainage in good order. Now the situation has changed; many of those fields are now surrounded by housing estates and most of the new school sites now reaching us are part of new urban development.

"There is a complete lack of understanding—to say the least—on the part of builders as to the requirements of land drainage and the neglect of the most elementary precautions to deal with water has been detrimental, not only to neighbouring owners of land, but also to the eventual occupiers of the dwelling houses concerned. On innumerable occasions we have received complaints from householders about water allegedly coming from playing fields, only to discover that the trouble was caused by the disruption of agricultural drainage which originally served the land occupied both by the games field and by the houses.

"There is also the problem of the loss or the complete neglect of ditches or carrier drains on which playing field drainage is dependent. There is now legislation designed to protect all parties. The new Building Regulations, which came into force on 1st February, 1966 require the developer to deal with any drains found in the course of building work, so as to prevent dampness within the buildings. This is undoubtedly an important step forward as far as the eventual householders are concerned, although it does not appear to call for an existing drainage system to be dealt with as a unit and it does not purport to deal with the drainage interests of a neighbouring landowner.

"The Land Drainage Act of 1961 contains provisions to prevent anyone from obstructing a watercourse—and the definition of a watercourse, taken from Section 81 of the 1930 Act, includes any passage through which water flows. Any occupier of land affected can appeal to an Agricultural Land Tribunal, giving the name of no more than one person thought to be responsible for the obstruction, and the Tribunal will arrange investigation and take appropriate action from there onwards. Alternatively, appeal may be made to the local authority or more usually, to the drainage authority, to exercise powers under another Section of the same Act. The important thing is that the land affected need not necessarily be agricultural land, thus giving those concerned with playing fields a measure of protection not previously enjoyed.

"It appals me to see some of the places in which houses are now being sited in hilly districts, whether the adjoining land is occupied by games fields or by agriculture. In this connection and in many other ways, it seems regretable that the modern tendency is to dispense with ditches as carriers of land water. A properly constructed and maintained ditch is a positive trap for water moving over the surface of land, and no trap drain, however well maintained, is a complete substitute. There are circumstances in which it is impossible to avoid surface run-off—for example, when there is a rapid thaw of snow overlying frozen ground. Whatever the legal position may be in such circumstances, one feels a moral obligation to take all reasonable steps to avoid shedding water on to neighbouring land.

"The difficulties with ditches in present circumstances are painfully obvious. First, there is their maintenance—although here I must say that it is by no means impossible to construct a ditch which requires no more than a minimum of upkeep. Then there is their vulnerability to obstruction by thoughtless neighbours and mischievous children, which can completely rule out their use in some situations—a blocked ditch can be infinitely more dangerous than no ditch at all! Where a ditch is really needed but cannot be used for one of the reasons mentioned, some sort of surface inlet, in addition to the customary trap drain, is advisable. Here again, the difficulty is to find a form of inlet which is mischief-proof—and I feel that this aspect is one which would repay careful study by members of this Association.

"While one may agree with the importance of dealing with existing drains in land being developed as a playing field, the difficulty has often been to find out where they are before the land is disturbed. Recently, however, there has been a revival of the ancient technique of 'dowsing'—but instead of using the traditional hazel twig, metal rods are employed. The technique is already familiar to many Playing Fields Officers, some of whom, I know, have elaborate instruments made for the purpose. But for the benefit of those who do not already use it, I will give a brief description.

"Any pieces of wire can be pressed into service for dowsing, but I use two copper-coated welding rods, ⅛in diameter and about three feet long, with the last 7in bent at right angles to form crude handles. The operator walks slowly over the land with a rod held loosely in each hand, parallel to the ground and to each other and about 14 ins apart. When the operator is over some buried object, the rods will swing together and cross. Experts can distinguish between various hidden materials by elimination; a piece of the same material held in the hand in contact with one of the rods will cancel the reaction of the rods.

"Not all people are able to use dowsing rods, but most can to some degree. In almost every case, at least one member of a playing fields staff will be found to have the aptitude. The behaviour of the rods differs with the individual and it is well to practice with known buried objects.

"Here I must give a word of warning: one can be caught out badly on occasions! Sometimes the rods will react for no apparent reason and one may have a costly search for a drain which does not exist. Why this should happen is a matter for conjecture—I can think of one or two possible reasons—but one thing *can* be said for certain: if a drain *does* exist, the rods will not fail to find it. Now this old practice has been revived, there can be little excuse for overlooking existing drains.

"Finally, I would like to say that, in my opinion, whatever modern methods may be used to install drains and whatever form the pipes themselves may take, the principles of drainage are still the same. The advent of modern labour-saving machinery should mean that the standards of workmanship of the traditional methods can be maintained or even improved upon. Regretably, this is not always the case and some shocking examples of bad work are often seen. Field drainage is an expensive business, even by modern machinery, and the effects of ignorance or carelessness can be even more expensive. If our field drains are to be laid, as our forbears laid theirs, to last for the lifetime of our successors, there is absolutely no room for anything but the highest standards of installation—and nothing else is either satisfactory or economical.

De båda följande artiklarna kan kanske på sitt sätt vara ägnade att belysa frågeställningarna i samband med dränering av idrottsplatser o.d. (playing fields). Den första, författad av G.K. Barnards och betitlad Drainer's dilemma - cutting costs in clay, är publicerad i Parks & Sports Grounds, July 1967, s. 855-859, innehåller en hel rad frågor. Mr Barnard är som synes allmänt missbelåten över enligt hans uppfattning kategoriskt och utan motivering gjorda uttalanden från fackmannahåll angående erforderlig dräneringsintensitet - uppfattningar som till yttermera visso går starkt isär. Här skjuter dock Barnard över målet, så ligger det hela inte till. Det finns inga en gång för alla givna regler, utan dräneringsintensiteten måste avpassas efter förhållandena i det enskilda fallet med beaktande av de särskilda krav som härvid ställes på dräneringen.

Den följande artikeln utgör ett svar på Mr Barnards frågor. Den har skrivits av R. Dunn, Playing Field Superintendent, Renfrewshire och försedd med rubriken Antedote to a drainer's dilemma samt ingår ävenledes i Parks & Sports Grounds, Sept. 1967, s. 1077-1081.

IT has been said that every man is his own drainage expert and it is certainly true that land drainage is a highly controversial subject. Past practice and experiment over many generations have concentrated on agricultural-type drainage but, in spite of this long history, no two authorities agree in detail. It is not surprising, therefore, that when we come to the comparatively new sphere of playing field drainage there is serious disagreement, even over fundamentals.

The issue is not just that of the technical superiority of one system over another; it is complicated by the relative costs. As will be seen later, on the basis of our present knowledge there is virtually no way of equating expense with efficiency. Hence the purpose of this article: to take a fresh look at the whole problem of lateral drainage, both from the technical and the financial standpoints to see if some relationship can be established.

First of all, I had better define what I mean by a lateral. In section 5 of "Playing Fields and Hard Surface Areas" (Building Bulletin No. 28 of the Department of Education and Science) para 146 describes a lateral as a run of (3in) plain, cylindrical, claywire pipes to BS.1196. To this, I would also add 2in plastic pipes which serve the same purpose.

Should you have any doubts as to the importance of lateral drainage, the Bulletin dispels this in no uncertain terms: "It is only on rare occasions that school playing field sites do not need a comprehensive drainage system". Furthermore, it rightly stresses that the demands made on a playing fields drainage system are more severe than those made on an agricultural system and it points out that a vigourous grass sward, fit to withstand hard use at all times of the year, cannot be produced or maintained unless surplus water can be removed fairly quickly. It is recommended that laterals should be of 3in tiles laid 24in deep and that the trench should be backfilled to the top of the sub-soil with permeable fill.

In recent years, contractors quotations for such work have varied between 10/- and 12/6 per linear yard.

The general recommendations relating to the distance between lateral drain-lines on various soil types are as follows: 12ft to 15ft in clay; 15ft to 30ft in clay loams; 30ft to 40ft in light loams. The examples given in the diagrams (Nos 28 to 30) show laterals at 15ft, 40ft and 25ft respectively. If we cost these on the basis of the above quotations, in round figures, the cost per acre would be £500, £200 and £300. Since the fields are 7, 10 and 13 acres in extent, the cost of laterals only would be £3500, £2000 and £3900 respectively.

It is at this point that we are faced with our first 'drainer's dilemma'. On technical grounds it has been made abundantly clear that we cannot afford not to drain but, with figures like those given above, can we really afford *to* drain? When you consider that an authority constructing about 100 acres per year would have to face a bill of something like £30,000 solely for lateral drainage—and this on top of the other development costs: earth-moving, main drainage, preparation and seeding, cricket and athletics facilities, etc.,—the magnitude of the problem becomes apparent. If, as they say, money talks, then these figures, if you accept them as valid, positively shout for the investigation into the efficiency of such costly systems. Are we getting value for money?

Here we come up against the second drainer's dilemma: if the drainage lines are put in at the closest recommended interval, the system is likely to be very efficient, but there is always the suspicion that the distance apart might have been doubled with very little loss of efficiency. As an example, consider the distances apart recommended for clay loams: 15ft to 30ft. Admittedly these are general recommendations from which can be selected whatever may be relevant to a particular case but still the problem remains: how does one decide what is relevant? Laterals at 15ft intervals over 10 acres may cost £5000; put them at 30ft intervals and you save £2500. What is the basis of choice? It is as insubstantial as the sums involved are substantial.

A further side-light on this problem is provided by the Bulletin itself. The recommended distances apart for light loams are 30ft to 40ft, yet diagram 28 shows a light loam drainage system at 15ft intervals. No doubt there were other factors which made this desirable and it would be interesting to know what they were, but it does underline the need for a positive approach, especially where such a large amount of money is involved.

Bearing these facts in mind, is there any logical way of arriving at an acceptable distance apart; acceptable, that is, on both technical and financial grounds? The recommendations I have seen relating to clay soils vary between distances of 10ft and 40ft apart. It may be significant that these dimensions are always stated as a fact and left without explanation, as are the financial implications. So far as we are concerned, this really means that we must make our own decisions.

What we must first make sure of is that sufficient pipes are provided to cope with the expected rainfall over the area concerned, the object of lateral drainage being to convey it away as quickly as possible. Rainfall reaches the laterals either by running off the surface of the ground or by first percolating through the top-soil and then running along the top of the sub-soil until it reaches a drain-line. Percolation through the sub-soil is negligible and, once a field becomes saturated, the drains must be capable of dealing with a very high rate of run-off. At a gradient of 1 in 100, a 3in pipe running at full bore will discharge about 2000 gallons per hour—the equivalent of about one-twelfth of an inch of rain per acre, per hour. Even allowing a generous safety margin of 50 per cent, six 3in pipes could easily cope with ¼in of rain per acre, per hour. Six runs evenly spaced over a square acre (the same basis that has been used for the previous calculations) would be 35ft apart.

At first sight, this figure would appear to support the views of those who recommend distances of up to 40ft apart, but it must be admitted that these are in the minority. Most authorities recommend distances between 10ft and 20ft apart and there is no doubt that these figures have been derived from practical experience. In the present context it would be foolish to ignore such a weight of opinion and a valid system could only be one which recognises the possibility of closer runs being necessary and makes allowance for this.

From the financial point of view, a framework of 3in laterals at 40ft apart is an economic proposition. Later on, it is a matter of simple observation to determine how many intermediate runs (making 20ft apart) are required and also the positions in which they will prove most effective. At distances closer than 20ft, mole-drainage is probably the most efficient and economical solution.

In the absence of a magic formula which will solve all our drainage problems at a glance, this does seem a very acceptable alternative—the lowest possible first cost, plus the opportunity to provide additional drainage in the very places it is needed most. Solving the problem in this way means that every penny spent has usefully contributed towards a really efficient solution. Instead of having to make what, in our present state of knowledge must be a 'guesstimate' of the correct distance apart—and accepting the financial consequences—we start by using the maximum distance apart as the essential framework of the system then, when experience has indicated with certainty what additional work is required, further expenditure can be justified by the facts of the case. The decision then becomes a positive one and guesswork is eliminated altogether.

It can be seen that this method introduces an additional phase into the installation of the drainage system. In the first phase provision is made for an adequate outlet, interceptors to take the run-off from higher land, conveying pipes to connect land-drains or springs discovered during the course of construction and for the installation of a main pipe of sufficient bore to cope with the above, plus the anticipated amount from the area drained by the laterals.

Such works are normally undertaken at the time the field is constructed. Where the levels have not been disturbed, the second phase could also be carried out at the same time. Where major earth-moving has taken place and there is some danger of subsidence affecting the efficiency of the drains, the second phase may be carried out separately. This consists in the provision of laterals at 40ft intervals and possibly mole-draining between the runs if this work has not been included with the earth-moving.

The third, additional phase is the installation of further laterals when the need for them has been determined by observation.

So far, we have considered the design of the system in its relationship to the cost of the work and our costing has been based on the current rates for 3in drains laid 24in deep and, initially at any rate, 40ft apart backfilled to the top of the sub-soil with permeable material. Can we carry our investigation a little further than this? In addition the practical techniques with a money-conscious eye?

First of all, let us take a close look at the width of the trench. In most specifications this is left to the contractor who is required to: 'excavate a trench of the minimum width necessary for the proper laying and alignment of the pipes'. A pipe of 3in bore has an outside diameter of about 4in so a trench width of 6in is perfectly adequate where the soil is firm. Less firm soils would probably require an 8in trench and the conditions obtaining when the work was carried out would also have a bearing on this.

The importance of minimum width lies in the fact that the excavation is much reduced. This is of great value where the spoil has to be taken off site and the trench filled with porous material. Trenches wider than necessary create too much excavation and cause additional cartage of spoil and aggregate. This compacts the ground excessively and costs a small fortune in backfill material.

Where these smaller trench sizes are concerned, the best type of machine for the job is a trencher employing the endless-chain principle. By this means, a trench as narrow as 4in can be cut quite cleanly provided that the walls are sufficiently firm to stand up. An added advantage is that it can operate on established turf, leaving hardly a mark. If the work is to be phased in the manner suggested above then this is an essential requirement for any machine.

The depth of the trench must be our next consideration. Up to the present we have assumed a depth of 24in but can we take this for granted when recommended depths vary between 18in and 48in? On what grounds can a positive decision be made? We have a few practical pointers: if it is intended to make effective use of the mole-plough we should allow at least 18in over the top of the pipe, 21in if possible. Too shallow a trench may not give sufficient protection against the ground-presure exerted by machinery. This may cause clay pipes to break, or become displaced and plastic ones to kink or split. A depth of 24in would seem to cover these points quite adequately, but there is one other factor which deserves consideration—the effect the depth of the trench has on the long-term improvement of the drainage properties of the top-soil, for which purpose a trench of 36in minimum depth is recommended.

At this point, financial considerations intervene and, as far as drains with completely porous backfill are concerned, the increased cost of excavating and filling to a greater depth than 24in has to be balanced against possible long-term advantages—a point which is dealt with in more detail a little later on.

The use of a trench 6in wide by 24in deep has the effect of reducing machine time on excavation, reducing the amount of excavated material which has to be disposed of and reducing the compaction caused by cartage of the excavated material from site. It also paves the way for a reduction in the amount of backfill required and its cartage on the site. Overall labour costs are reduced commensurately.

With some notable exceptions, the weight of opinion favours this idea of filling the trench completely with porous material topped by not more than 6in of top-soil. The biggest snag in this method is the cost of the material. Except for a diminishing number of favoured localities, sources of cheap and effective backfill materials have vanished and, even where they can be found, transport to the site greatly increases the cost in many cases. This fact alone makes the possibility of providing lateral drainage without the use of porous material a matter for serious consideration.

Basically, the argument for dispensing with such material rests on the observed fact that functioning agricultural drains, over a period of time, effect a permanent improvement in the drainage characteristics of the surrounding soil. This is particularly the case with deeper drains and the tradition that the depth of the drain is related to the distance between the drain runs may be a practical expression of this idea.

Exactly how this effect is achieved is not certain but it is not unreasonable to suppose that the natural physical, chemical and biological processes which affect clay soils are initiated by the act of cutting the trench and laying the drain. Where aeration and drainage are present the soil tends to become warmer and the natural processes are speeded-up. The introduction of organic materials such as hay, or turf to cover the pipe must, in such an environment, encourage the activities of the micro-organisms which break down these materials. The same conditions also favour the activity of earthworms and the beneficial role of the earthworm in improving drainage has been well studied and documented. Grass roots strike down more readily along the lines of the earthworm burrows, their growth and decay providing food for the worms and soil organisms, their concerted action bringing about a progressive improvement in the texture of the soil. Such natural processes work very slowly and we cannot afford to wait for a generation to allow them time to become fully effective. In fact, unless there is some way of providing for immediate improvement, the 'no backfill' method is a non-starter so far as the drainage of playing fields is concerned.

Fortunately, there do seem to be two ways in which speedy improvement can be achieved. One is the amelioration of the top-soil by the introduction of gritty and/or humus-forming materials and the other is by the use of the mole-plough to shatter the sub-soil. When contemplating the 'no backfill' method, mole-ploughing does seem to rank as a basic essential and the improvement of the physical properties of the top-soil also seem to be highly desirable.

If the foregoing analysis is correct, the financial issue becomes slightly more involved and may briefly be re-stated as follows: 'cost of supplying and placing porous backfill and disposing of excavated material *v.* cost of deeper drains, mole-ploughing and amelioration of the top-soil.

Technically, the issue is somewhat different. The 'no backfill' method practically eliminates cartage on site and the consequent deterioration of the top-soil as a result of compaction. This is no small consideration since drainage works have mostly to be carried out under adverse soil conditions. By way of contrast, the addition of suitable materials makes a positive contribution to the improvement of the top-soil. Of course, the mole-plough can be used in conjunction with both methods, and advisedly so, since it also has a positive duty to perform in the shattering of the sub-soil. If used with the porous backfill method its cost must, of course, be added to that side of the financial equation.

At the beginning of this article, we started with a counsel of perfection. It is very proper that we should have done so for, unless we have a high standard in view, nothing worthwhile can be achieved. Nevertheless, such propositions are subject to what, I believe, is called by the economists the Law of Diminishing Returns. By way of explanation: if a perfect job costs £1000 and a 90 per cent job costs only £500, then by doubling the outlay we have only succeeded in making a 10 per cent improvement. This is really the big question before us today. With costs soaring, can we afford absolute perfection and, if not, how far should we be prepared to go?

In the foregoing paragraphs, two alternative methods of achieving the same end have been analysed from both the technical and financial points of view. Both are open to criticism and it would be of the greatest service to all concerned if those readers of the PARKS & SPORTS-GROUND who are interested would write in with their criticisms, comments and, if at all possible, their costings. For myself, up to now I have always favoured the porous backfill method, but the 'no backfill method—on paper at any rate—does seem to offer some advantages. Is it really as efficient as it appears? Would it, in the long term, cost more or less? What are the efficiency/cost relationships of the two methods? Is there room for a compromise solution?

Can you help to solve the drainer's dilemma?

Och nedan följer Mr Dunns svar på de uppställda frågorna. Här må endast den kommentaren göras att tubulering på för idrottsändamål iordningställda gräsplaner är en åtgärd vars lämplighet synes kunna ifrågasättas.

I FIND the article by G. K. Barnard in the July issue of the PARKS & SPORTS GROUNDS on the topic of playing field drainage most interesting. Whilst by no means an authority on the subject, I feel my observations—like Mr. Barnard's—may stimulate further discussion on a very important and expensive operation in playing field construction.

On being confronted with this question of drainage and relative costs I would ask myself the following questions:—

1. How much drainage in linear yards of 3in clayware pipes is required to collect water from an acre of land and tranfer it to a main drain?
2. Having decided the above—How best to ensure that surface water reaches the drains quickly, in order that playing conditions are impeded for as little time as is absolutely necessary.
3. How to instal the drainage system in a manner which involves as little financial outlay as possible without detriment to the function of the system.
4. How to arrange future maintenance in such a way that the chosen drainage system is permitted to function to it's full extent in spite of top or subsoil compaction.

It is I am sure, the purpose of all who are responsible for the provision of playing fields to decide the answers to the foregoing questions, and it is in so doing that controversy arises. Let us therefore consider them in order.

How Much Drainage?

If it can be agreed that a 4in drain at a fall of 1-100 is capable of serving 4.125 acres in districts where average rainfall is anything up to 60in per annum, we have a starting off point.

Next we have the question of lateral drainage. Mr. Barnard points out that "at a gradient of 1 in 100 a 3in pipe running at full bore will deal with approximately 1/12in of rainfall per acre per hour, and goes on to explain how drain runs at 35ft apart will cope with ¼in rainfall per acre per hour allowing a margin of 50 per cent. These facts I am sure answer the first question. Six drain lines of 3in diameter, 70 yds long and 35ft apart will collect more than ¼in rainfall per acre per hour and pass the water to the main drain.

Surface Water

The problem here is the one which is least simple to argue upon. How best to instal the lateral drains, and how best to ensure the free passage of water through the subsoil.

Distance Apart

Let us assume we have agreed on a spacing of 35ft at a crossfall of 1 in 100.

Depth

The object of our drainage is to lower the level at which water is likely to lie. Unfortunately drains 2ft deep do not have this effect on clay soils for any appreciable distance on either side of the pipe especially if compaction has been brought about in the grading procedure. The problem then is one of lowering the saturation plane. It is generally agreed that if the subsoil can be made permeable to a depth of 15-18in from the surface and the drain lines are clear, that no saturation will be experienced on the playing surface. Hence the reasons for spacings up to 40ft being recommended in light soils. Lateral drains therefore need not be deeper than 2ft.

Permeability

Ameliorants we will all agree provide a very suitable remedy to lack of porosity in clay structures, and although very expensive are worthy of consideration. On extremely heavy soils however vast quantities are required and the cost is frequently prohibitive, coupled with the problem of incorporating to depths of 18in. Subsoil cultivation at 2ft. 6in centres, 15-18in deep and crossing the line of the laterals at a 60 deg angle, has the effect of shattering clay subsoils and without doubt lowers the saturation plane.

Width of Trench

The basic purpose of excavating the trench is to permit the laying of drain pipes, and therefore a width of 6in should be all that is required. It is important however that the correct type of trencher is used and that the trench is straight in line with the bottom free of undulations and trimmed to the specified fall.

Backfilling

It is generally specified that trenches should be backfilled to 6in from finished level with an approved porous aggregate. It is worth considering the necessity for this, or indeed the benefit, if the subsoil is being made permeable to a depth of at least 15in. Backfilling to 12in of the surface would seem sufficient and would still permit the subsoil shoe being drawn through the fill. This would involve placing of subsoil excavations on the topsoil which is not good practice, and for this reason I would be inclined to adhere to the former method of 6in from the surface, at least until a means is known which would avoid contamination of the topsoil.

Cost

The question of cost is of the utmost importance, but should not take precedence over provision of a good drainage scheme. Let us make a comparison between a fairly average specification and some of the suggestions which have been made here:—

(a) Excavate drain trenches at 21ft centres and at 60 deg angle to the main drains. Trenches to be 24in deep and not more than 18in wide. Allow for removing excavated subsoil to another part of the site as directed, spreading, levelling and backfilling trenches to 6in from finished level with approved porous aggregate. Return topsoil previously laid aside.

(b) Excavate trenches at 35ft centres and at 60 deg angle to main drains. Trenches to be 24in deep and 6in wide. Otherwise as (a).

The savings which might be expected from adopting method (b) would be as follows:—

The cost of excavating, removing, spreading and levelling of subsoil should be reduced by ⅔rds, as would be the cost of supplying and placing of porous aggregate, due to the difference in width of trench. This only leaves the supplying and laying of drain pipes and handling of the topsoil at similar costs as in method (a). It would therefore seem right to expect an overall saving of half the cost per linear yard.

Take into account the fact that only six drain lines per square acre would be required in method (b) as opposed to ten lines in method (a), and the cost of installing 280 lin. yds is saved.

At 10/- per lin yd method (a) would cost £350 per acre (700 lin yds)

At 10/- per lin yd method (b) would cost £210 per acre (420 lin yds)

Reduce the cost per lin yd in method (b) by half in accordance with foregoing details and a further reduction to £105 per acre is brought about. In each case the cost of sub-soiling would be additional.

The savings which seem possible by installation of a system incorporating wider spacing and narrower trenches, on the proviso that subsoiling is part of the specification in any construction of playing fields, are therefore £245 per acre.

Avoiding Failures

A major cause of failure of many playing field drainage systems is the amount of wear and tear to which they are subjected. Twenty two enthusiastic participants in a football match, one of several played each day in the week on every possible occasion during the winter months, coupled with the frequent passage of a tractor weighing upwards of 2½ tons in the course of maintenance operations, do much towards bringing about a state of compaction between the surface and the drains. The resulting lack of porosity can mean that rainwater finds it extremely difficult to reach a perfectly good drainage system. This physical condition is offset in the topsoil by various types of spikers and other aerating equipment, though often not to a great enough extent in a normal maintenance programme. The subsoil unfortunately receives litle or no aid in this respect, and it is most important that this too is retained in a permeable condition. I feel therefore that much more consideration should be given to the undoubted value of subsoil cultivation, as part of the regular maintenance work.

It would seem that to give considerable thought and finance to the provision of a functional drainage system, and then to permit this expensive network of drains to be virtually sealed off by compacted layer, is "money down the drain".

Having set out what in my opinion is a feasable means of cutting costs without detriment to function, I would like to comment on four of the very controversial points raised by Mr. Barnard and many others concerned with field drainage.

The Number of Drains recommended

It would appear that although many authorities on this question put forward figures on how much water various diameters of pipe will cope with at specific falls, few say definitely what numbers should be laid, "due to differences in soil types". I may be sticking my chin out, but feel that if as Mr. Barnard points out, a specific number of drain lines will carry off the said amount of rainwater there should be no need to incorporate any more, no matter what kind of soil in which they are laid. The question then becomes how to get the water to the drains. I will be very interested in any response to this statement.

Deep Drainage

The question here I feel is not so much whether deep drainage is functional or beneficial as whether it is necessary, due to the initial cost of installation. If we can agree that rainfall can be dealt with in the manner described in system (b), then I feel that we have achieved the purpose very economically and that deep drainage becomes a non-runner.

Mole Drainage

This system is to be recommended mainly for it's economy, and has proved successful on fields which overly a smooth clay subsoil. Unfortunately too many of our playing fields have to be constructed on areas where cut and fill is required, with resulting areas of underlying rock, gravel or otherwise unsuitable material.

Ameliorants

These are highly recommended and I would be foolhardy to disagree on the benefits of incorporating the most suitable ameliorant in a specific soil structure. Again however I would point out the problem of incorporating ameliorants at depths which would render them of greatest benefit, particularly on established playing fields. Soils to which ameliorants have been added are not completely immune to 'panning' and subsoiling is often desirable. This being so I feel that only in very extreme cases can amelioration be economical.

The foregoing paragraphs have been written in an attempt to arrive at firstly, a decision on what minimum requirements are desirable concerning the various aspects of sports field drainage with a view to reducing costs, and secondly whether or not there is any need to elaborate on these basic requirements to improve function.

The only elaboration I believe necessary is the use of the subsoil process as and when desirable as part of the maintenance programme.

It would be gratifying to feel that this article had solved the 'Drainer's Dilemma', but I envisage considerable criticism and coments from other readers interested enough to participate in further discussion. I do however trust that soon all who are concerned with the provision of playing fields can become united in their approach towards the function and economy of drainage.

Som avslutning på detta avsnitt har på följande sida medtagits en artikel betitlad Land drainage of sports pitches with particular reference to hard tennis courts and bowling greens by Peter K. Savage, publicerad i Park administration, Nov. 1965, s. 48-50.

LAND drainage is an inexact practice based on rule of thumb principles rather than on scientific theory. There are so many variables involved that drainage pecifications can not be arrived at by consulting a set of ables nor can any hard and fast rules be laid down as to ne correct practice in any given set of circumstances.

Partly as a result of this and partly because the basic rinciples behind land drainage are frequently insufficiently nderstood drainage is often omitted altogether unless there ; evidence of water actually lying on the surface. Again, rains are in many cases put in "to be on the safe side" vithout much rhyme or reason and as a consequence time, noney and energy are often wasted unnecessarily.

This article is not intended as an exhaustive study of the ubject but it is hoped that a brief examination of the basic rinciple may reduce some of the confusion often associated vith land drainage.

The first point to be clearly understood in that the rimary function of land drainage is to prevent the *rise* of ub-soil water above a reasonable level by conducting it way and discharging it at one or more convenient points; ot as is sometimes believed, to carry off surface water in he first instance.

Given a reasonably permeable soil and a steady downpour f rain, water reaching the surface will rapidly penetrate o the subsoil and the level of water in the sub-soil will ontinue to rise until it reaches the surface and flooding ccurs.

Figure 1 shows the effect of three rows of pipe draining aid some distance below the surface of the soil. As the ub-soil water level rises it eventually reaches the invert evel of the pipes and at the point of contact with each pipe ; then able to flow away in the direction of fall of the pipes. Between the rows of pipes, however, the water will continue o rise until the hydrostatic hand (or water pressure) is ufficient to overcome the resistance offered by the soil articles between the pipes and to push the water hori-ontally, or nearly so, in the direction of the pipes.

In this way the flow of water will continue until the verall water-level is reduced to the invert depth of the ipes.

From the foregoing it is obvious that the more porous r permeable the soil the quicker will this chain of events ake place and the lower will be the "head" of water neces-ary to produce the desired effect. Similarly the closer the ows of pipes are together the lower the "head" or, to ut it another way, the flatter the curve of saturation.

Surface drainage by direct gravitational penetration is bviously effective only along the lines of the pipes and t is clear that the provision of porous filling *above* the rainage pipes does not assist the horizontal movement f water as described above. Such filling does, however revent silting up due to fine soil particles entering the pipes t the joints so is worthy of consideration on that score lone.

The internal diameter of the drainage pipes is dependent pon many variable factors, viz., the permeability of the oil, the distance apart of the rows of pipes, the total length f pipe etc., but it is the writer's belief that 3in. internal iameter is more than adequate in most cases and a recently ntroduced continuous polythene drainpipe has an internal iameter of less than 2in. Maximum water absorption s achieved in this case by means of parallel rows of evenly pacer perforations running along the length of the pipe. An optional wrapping of fibreglass may be used to prevent ilting up if filtration is thought to be desirable.

Saturation

Hard Tennis Courts are a special case. It has been pointed out how the more permeable the soil in between the pipe so the flatter the curve of saturation becomes. If the soil were to be replaced by a porous substance such as clinker or coarse ash then the curve of saturation would be considerably flattened and the drainage more rapid as a result. This is not practicable over a large area but since Hard Tennis Courts require a firm foundation for the playing surface it is possible to use materials for this purpose which will in addition facilitate the horizontal movement of water and improve the drainage flow. In this case a porous filling above the drainage pipe is desired for obvious reasons.

Fig. 2 shows a typical cross section of a hard tennis court with the flat-topped saturation curve clearly distinguishable.

In addition to the sub-soil drainage of tennis courts it is also advisable to shed the surface water by laying the courts to a uniform fall overall. This means the playing surface will be on an incline and three main methods of producing this incline are given below:—

(1) The face may be from end to end if the courts (i.e. in the direction of play).

(2) The face may be from side to side of the courts (i.e. at right angles to the direction of play).

(3) The face may be along the diagonal.

Recommendations regarding the amount of gradient vary. In some cases a fall of not less than 1:120 and not more than 1:60 is suggested but even 1:120 can *appear* excessive, especially if the surrounding ground slopes in the opposite direction and a fall of 1:240 should be sufficient if the surface is well laid and without local depressions or undulations.

Opinions differ as to the best direction for the gradient. The main factor so far as the players are concerned is the relative height of the net. With an end to end fall of 1:240 the relative height of the net (taking a mean) is about two inches more or less than the measured height, dependent upon the service end. With a cross fall of 1:240 the relative height of the net varies about 1¾ inches along its length and with a diagonal face the mean variation is roughly 1⅜in. plus or minus according to the direction of play. Frequently the deciding factor must be the natural slope or otherwise of the site beforehand, the gradient being arranged so as to reduce the amount of earth moving and/or retaining walls etc.

Generally speaking, there is no point in providing a diagonal fall over more than four courts side by side or less than two courts side by side nor is there any point in a diagonal fall over more than two courts end to end.

Figure 3 shows a typical drainage layout for two tennis courts.

Sprayed

Bituminous limestone surfacing as laid in dull and unattractive and after a period of mean becomes duller and greyer. Thus it is quite usual for such courts to be sprayed with green bituminous paint to give a grass green effect once the initial curing or weathering has taken place. This often gives rise to the question, "Why go to all the trouble of putting drains underneath the tennis courts only to choke the pores on the surface and prevent the water soaking away?"

Notwithstanding the fact that (a) a great deal of the surface water is shed by the gradient and (b) the sub-soil drainage is designed to prevent a *rise* in water level *above* a certain point this fear is completely unfounded so long as the bituminous paint employed is applied by means of so fine a spray that only sufficient material is deposited to adhere to the aggregate and no excess material is allowed to clog the intensities. The recommended rate of application is 5 gallons per 75 yds. super (or 40 gallons per count approx.) and it can be safely assumed that the drainage properties of a green sprayed tennis court are unimpaired *provided the correct material is correctly applied.*

One of the difficulties arising from the drainage of bowling greens is the almost inevitable subsidence which may occur over the drainage pipes. A series of parallel rows of pipes is often recommended under the green connecting with a ditch drain. Generally speaking, however a ditch drain alone should be adequate given sufficient fall (not less than 1:160) and assuming the foundation material is suitable.

Foundation materials are frequently specified as "clean boiler clinker ash 3in. to $\frac{3}{4}$in. gauge .... blinded with a layer of fine boiler clinker ash $\frac{3}{4}$in. to fine" but, in non-industrial regions particularly, this graded clinker is almost impossible to obtain and when available is excessively costly. Many alternatives are offered and it is well to consider the requirements before accepting substitutes. From a foundation point of view a good firm "key" is required and the material must not move once it has been consolidated. Most 3in. to $\frac{3}{4}$in. gauge material offered as a substitute for clinker will satisfy this requirement and is sufficiently porous to present no drainage problems either. With the blinding mixture, however drainage often becomes a problem as domestic ash and other soft dusts tend to bind together and prevent the movement of water. It is therefore essential to choose a blinding mixture with adequate drainage properties; even if it costs a little more volume for volume.

Drainage water must be conducted away from the lowest point in the drainage system and fed into a ditch, surface water drain or, failing either of them, to a soakaway or sump. Fig. 4 shows the cross-section of a simple soakaway constructed of pre-cast concrete sections. The number and diameter of the sections can be varied so as to comply with the condition that 5 cubic feet of sump is required for 100 square yards of surface to be drained; (sump capacity being measured below the invert level of the outface). It pays to err on the generous side as the land immediately adjoining the playing area will also be feeding water into the sump via the outermost run(s) of pipes. This is a factor often ignored when estimating drainage requirements.

In a brief introduction such as this it is not possible to deal with such matters as type of pipe, methods of laying, depths of drains etc.—all of which are valid and vital to the subject but it is hoped that this may form a basis for further study of an often neglected subject. □

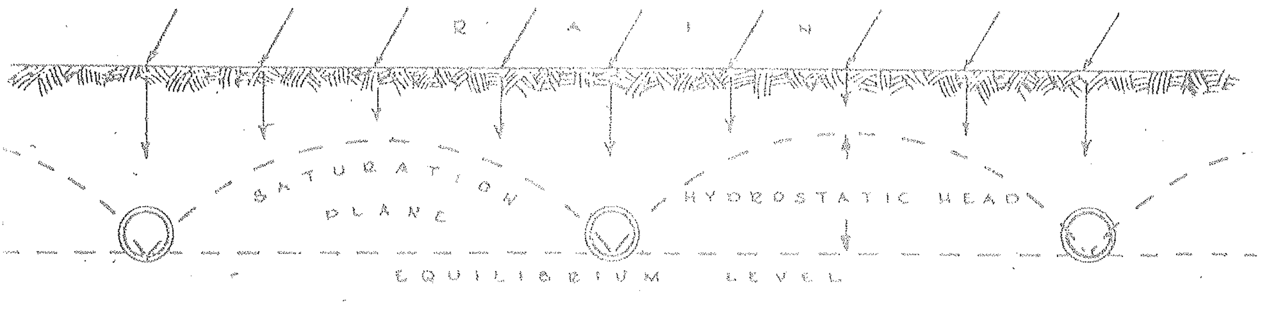


Fig 1

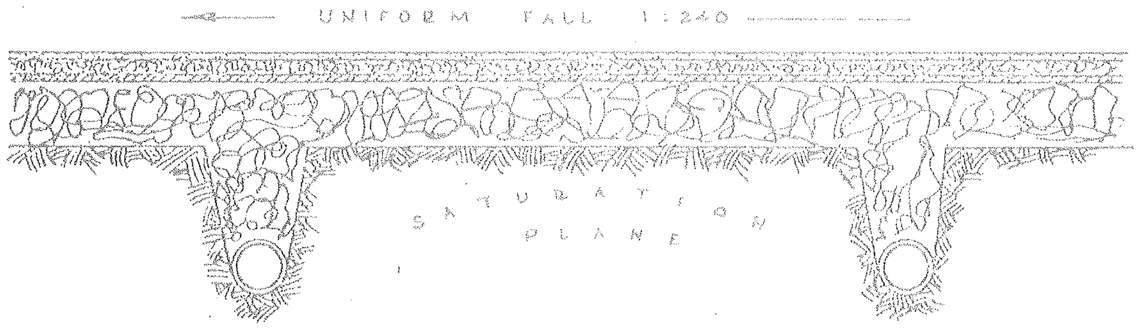


Fig. 2

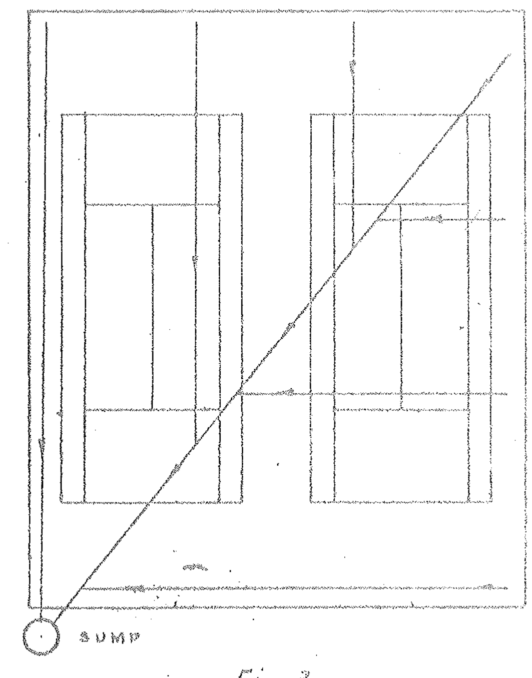


Fig. 3

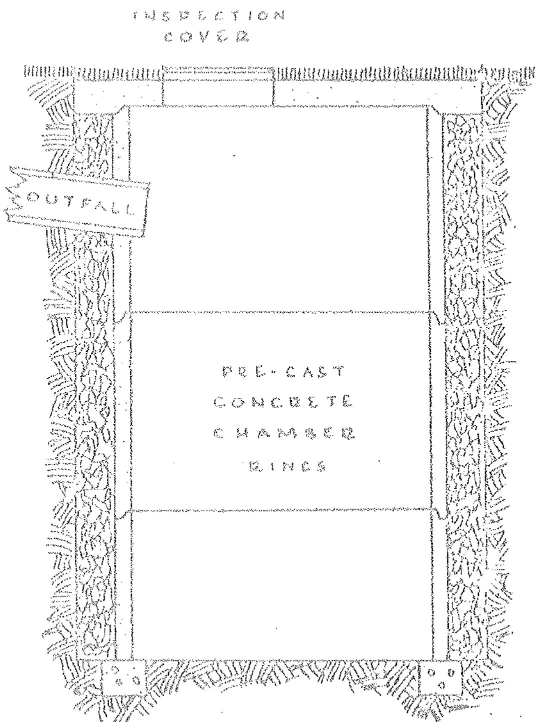


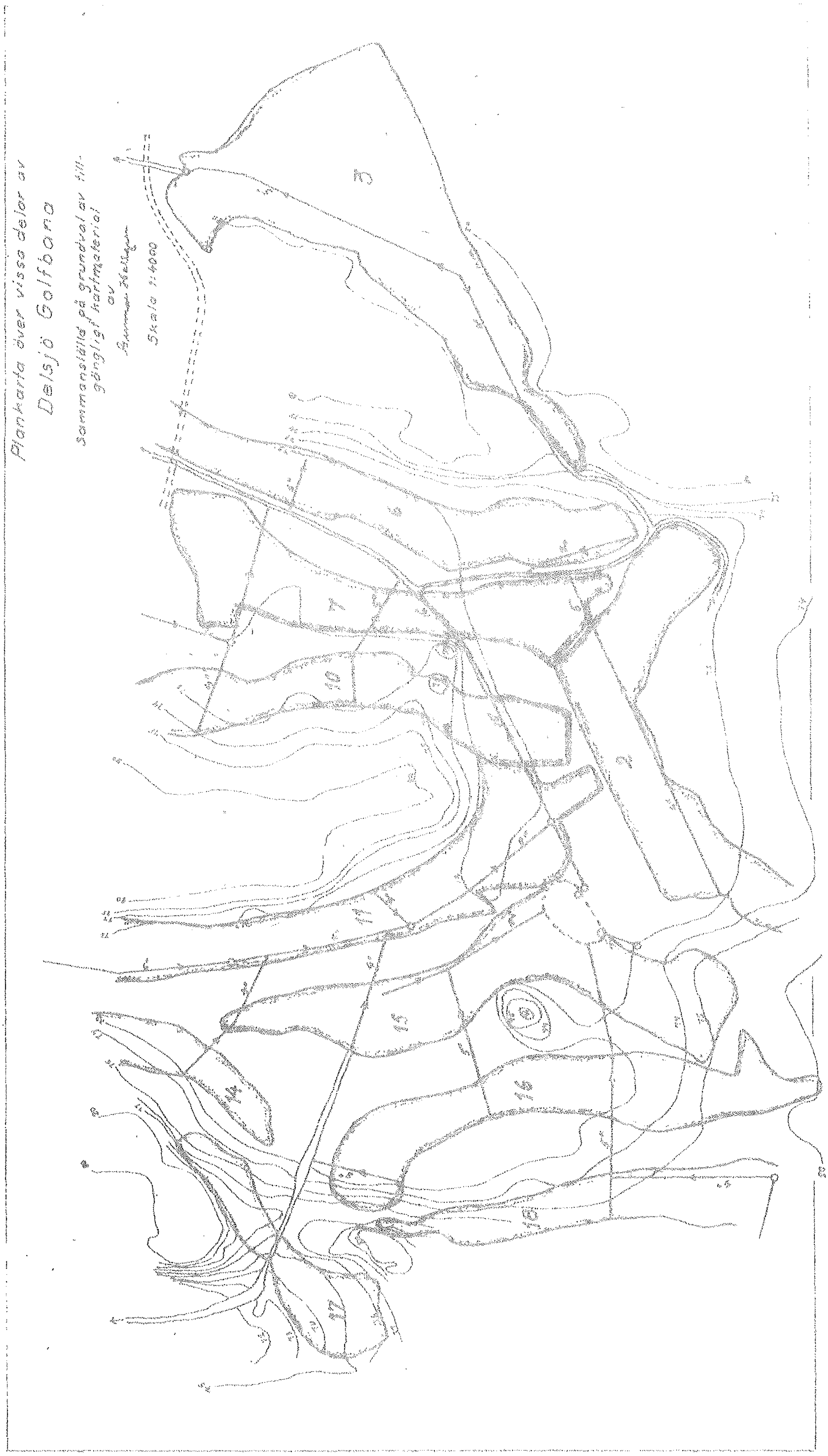
Fig. 4

VI. Dränering av golfbanor och gräsplaner

Vad i det föregående sagts om avskärning av tillrinnande vatten från omgivningen vid dränering av idrottsplatser o.d. gäller i minst lika hög grad vid dränering av golfbanor och andra större gräsplaner. Det är här ofta fråga om ganska kuperade områden med åtföljande vatteninfiltration på de ytor som skall dräneras. Särskilt beträffande golfbanor är detta fallet (jfr plankartan på följande sida över en 18 håls golfbana där höjdskillnaderna som synes är ganska betydande). Om man ej vill ha några öppna laggdiken - på en golfbana och ofta även på andra anlagda gräsplaner i kuperad mark vill man gärna undvika detta - kan avskärningen av såväl yt- som grundvatten från omgivande högre belägen mark ordnas exempelvis genom att lägga dräneringsledningar utmed kanten av området och efter ett gruslager närmast röret fylla diket upp till markytan med makadam. En sådan anordning fungerar även då marken är tjälad, vilket inte är fallet med grusfiltra. (Det bör observeras att på plankartan är endast stammarna och de öppna och täckta avloppen inlagda, däremot inte grendiken eller täckta kantdiken.)

En golfbana i kuperad terräng kan vara vansklig att effektivt dränera. Självfallet vill man kunna utnyttja den under så stor del av året som möjligt. Följaktligen vill man ha en snabb upptorkning såväl på våren som efter inträffade regnperioder under spelsäsongen. Å andra sidan vill man inte ha några till dräneringen hörande tekniska anordningar som kan vara hindrande vid banans användning. Speciellt gäller detta naturligtvis fairways och greens. Samtidigt är det dessa ytor som fordrar en verkligt effektiv torrläggning. Om jorden här är relativt svårgenomsläpplig, torde det vara lämpligt med en förhållandevis grund dränering (70-80 cm) men korta dikesavstånd, 7-8 m eller mindre samt efter rörläggningen fylla dikena med ett lätt genomsläppligt material, grus eller singel, upp till matjordslagret (jfr Wusser 1961).

Vad avrinningsintensiteten beträffar, har man i princip inte att räkna med nämnvärt starkare avrinning än från åkerjord under i övrigt likartade förhållanden. Eftersom man på golfbanor och andra anlagda gräsplaner inte vill ha någon ytvattenansamling, är det dock tillrådligt att överdimensionera ledningarna en del, förslagsvis efter en ungefär dubbelt så hög avrinningsintensitet som för åkerjord. På sådana ställen där nedtag för dagvattnet i dräneringssystemet är behövliga och de inte är till något hinder bör naturligtvis brunnar eller stensilar nedsättas.


Plankarta över vissa delar av
Delsjö Golfbana
Sammanställd på grundval av tillgängligt kartmaterial
av
Skala 1:4000

Samma regel gäller här som vid varje annan dränering, man skall inte tvinga vattnet att ta den längre vägen genom jorden om det kan ledas direkt ned i ledningssystemet.

Rent allmänt kan sägas att en gräsplan eller gräsmatta fordrar en lika god dränering som åker i cirkulationsbruk, om man vill hålla den i gott skick. Denna regel tillämpas långt ifrån alltid, vilket det ej är svårt att finna belägg för snart sagt var man än färdas. Och när det gäller gräsplaner för sportutövning av något slag tillkommer kravet om en möjligast jämn och snabb upptorkning efter riklig nederbörd. Under sådana förhållanden blir en relativt intensiv dränering vanligen ett oeftergivligt krav. Detta framgår också med all tydlighet av de i det följande återgivna litteraturutdragen. Det första av dessa ingår i kapitlet Drainage (sid. 13-22) i Lawns and Sports Grounds av Martin A.F. Sutton (Reading, England 1962).

DRAINAGE

IF RAIN IS FREELY ABSORBED by the soil, leaving no stagnant pools in wet periods, the efficiency of natural drainage may be inferred. It must be clearly understood, however, that good turf cannot be maintained on poorly drained soil, and where lawns and sports grounds have to be laid out on such land a proper system of artificial drainage is necessary.

The extent to which playing fields are used for winter games has increased enormously in recent times and the need for effective drainage is greater than ever. Where the subsoil is at all heavy, it is imperative to drain a sports ground intensively if provision for maximum play during winter is an important consideration.

The effects of poor drainage lead to a great restriction of the playing season, with sodden ground unfit for use over prolonged periods. There is poor recovery after winter, with late spring growth, and the turf is soft and weak, and often infested with moss. As a rule, root-growth is extremely limited and efforts to invigorate the turf with fertilizer prove very disappointing.

Another feature of poorly drained ground is the extent to which the turf suffers in drought owing to non-availability of subsoil water. Coupled with this is the expansion and contraction which take place within the soil. In wet weather the ground swells, but in periods of drought it shrinks to such an extent that deep fissures appear. This continual movement makes it difficult to maintain a proper level on playing areas.

How the Need Arises

The need for an improvement in drainage arises in more than one way. A poor top-soil structure or worn-out sward with shallow root development hinders the percolation of surface water. In other cases, the soil is porous but there is a high water-table, or flow-off from adjacent ground. The chief cause of defective drainage, however, is the presence of a non-porous subsoil which impedes the movement of surface water after it has passed through the top soil.

It is not always easy to determine the underlying cause of defective drainage, nor indeed to decide whether artificial drainage is at all necessary. In many cases a number of factors are involved and each must receive detailed consideration before a decision can be reached. The need for an improvement in drainage is often suggested by the natural vegetation of a site, and in this connection the presence of the undermentioned plants should be noted:

> RUSHES, FEATHERY MOSS, CREEPING THISTLE, HORSETAIL, COLTSFOOT, CARNATION GRASS, CREEPING BUTTERCUP (IN QUANTITY), SELF-HEAL (IN QUANTITY).

Among the grasses there are several which have a preference for saturated ground and perhaps the most notable is Tussock Grass or Tufted Hair Grass (*Deschampsia cæspitosa*), a strong-growing plant which forms very distinct patches of dark-coloured stiff-leaved herbage. Among the fine-leaved species is a pale-coloured grass known as Velvet Bent (*Agrostis canina*) which also flourishes in rather wet ground.

The general colour of the herbage is a useful guide, as plants growing in wet soil often show a characteristic yellow or purple tint. Almost certainly you will find poor root-growth, and perhaps a layer of peat just beneath the surface.

To test the rate of flow, holes about 12 inches square by 18 inches deep can be dug at strategic points, and in poorly drained soil they often fill quickly with water. Thereafter, the rate of flow may be observed, but it should not be inferred that the disappearance of water in any given time is necessarily a measure of drainage efficiency. If, however, the water-level is much the same after several hours there is almost certainly a lack of natural drainage. Blue or grey coloration of the subsoil is also strongly suggestive of poor natural drainage, and the presence of fine, rusty streaks almost certainly puts the matter beyond dispute.

Before draining any particular site, certain conditions are essential to success. They are:

1. A suitable outlet or discharge area for surplus water.
2. Absence of large-scale winter flooding.
3. No unbroken rock or pan close to the surface.
4. A good contour, *i.e.* absence of pronounced undulation and preferably an even fall towards the outlet point, ranging between 1 in 100 and 1 in 50.

It will be appreciated from the foregoing remarks that a very full investigation into all the circumstances must be made before a single drain is laid, and in large-scale work a grid of levels taken at 50- to 100-foot intervals must be available in order to determine the direction and pattern of the drains.

Drainage operations, where necessary, should be completed as long as possible in advance of sowing grass seeds, as the tracks can seldom be filled so firmly as to prevent the ground from sinking afterwards. The work should therefore take precedence over all other operations, except where a considerable amount of levelling is involved; in that case, drains may be laid in the excavated area as soon as levelling is completed, but on built-up ground it may be advisable to wait a year or two before putting in drain pipes.

Extent of Drainage

The extent to which the site must be drained depends on a number of circumstances. First of all, there is the nature of the subsoil and height of water-table. Then the average local rainfall must be taken into account, together with the purpose for which the ground is required. Obviously, a site required principally for summer games will not require such intensive drainage as one on which winter play is going to be heavy. Another very important factor is the gradient of the site. An even fall of appropriate nature not only assists surface drainage, but greatly influences the extent of subsoil drainage by allowing the pipes to be spaced more widely and at a uniform depth. It is calculated that the efficiency of drainage is nearly twice as great with drains laid at a gradient of 1 in 100 compared with 1 in 300. For some games a dead-level surface is imperative, but in all other cases where drainage is required it is desirable to provide as great a slope as is consistent with the use to which the site will be put. Tennis courts and cricket pitches may have a fall of up to 1 in 100 without interfering with the comfort of the players, while the limit for a sports ground generally is between 1 in 50 and 1 in 60.

Methods of Drainage and Outlets

There are many ways of dealing with sites in order to provide better drainage. The principal methods applied to lawns and sports grounds are (*a*) trench or pipe drainage, (*b*) porous layer drainage and (*c*) mole drainage, and the respective merits of each method are discussed hereunder. First of all, let me say that, however a site be drained, it is imperative to have a proper system of main drains as well as a good outlet. The latter should be as high as possible above the level of the stream or ditch into which the drainage water is to discharge and where there is no danger of the end pipe becoming blocked or obscured. For that reason, the outlet must not be sited near trees or hedges. It usually consists of the end pipe made secure by a ring of concrete 18 inches across and some 6 inches thick, or a properly constructed 'headwall'. In the case of extensive drainage systems, it is important to provide a manhole or silt chamber about 6 to 10 feet from the outlet; the intervening pipes should be of the collar pattern so that they may be secured together to form a rigid connection with the outlet, which should be provided with a grid or other device to prevent access by vermin. If there is any danger of backflow during winter, the outlet may be covered with a valve consisting of a loose flap which shuts tightly against external pressure.

Alternative Disposal of Drainage Water

If the main drains cannot discharge into a stream or ditch, it may be possible to connect up with existing surface water drainage subject to agreement with the local authority. In the absence of a suitable discharge area, the only alternative is the construction of sumps. It is important for the sumps to be of adequate size, *i.e.* about 6 cubic yards for every 100 superficial yards of surface to be drained or 300 cubic feet per acre, the latter volume representing a hole about 6 feet square by 8 feet deep below the level of the outlet pipe. It is, of course, very advantageous if the sump can be dug deeply enough to reach a porous stratum, and it should be filled with brick, rubble, stones, coarse clinker or other similar material. The results obtained with sump drainage are notoriously unpredictable, and this method is therefore not resorted to on a large scale if there is the slightest hope of an alternative. It is, however, often employed on a small scale to deal with local wet spots on sports grounds and in the case of lawns where it is impossible to obtain an outfall for drains.

Main Drains

Having determined the means by which the drainage water can be disposed of, the next step is to lay the main drain or drains, following as closely as possible the natural or predetermined slope of the ground. For a lawn or a sports ground up to 5 or 6 acres in size, one main drain of 4 inch pipes will probably be sufficient. In the case of a larger area, it is generally recommended that one main drain be provided for every 5 acres, using 6 inch pipes where the drainage water from more than one section is to be carried through to the outlet. This obviates the need for extended branch drainage and no single branch drain should, if avoidable, be longer than 100 yards. Very large areas need to be further subdivided and a separate outlet provided for every 20 acres if the 6 inch mains cannot conveniently be led into a larger pipe, of, say, 9 inches or 12 inches, before reaching the open drain or water course into which the drainage discharges.

The depth of a main drain depends to some extent on gradients but the chief controlling factor is the depth of the branch drainage. In earlier systems of drainage, the main drains and branch drains were laid to the same depth but this often led to arrested flow. A far better plan and the one accepted as sound practice today is to make use of gravitational flow between the branch drains and the main drains. To ensure the best results it is important that the depth of the main drain or drains be at least 6 inches below that of the branch drains, and from 24 to 30 inches to the bottom of the trench is usual. If the pipes are well covered with porous material, it will greatly assist future extensions to the drainage, or the employment of mole drains.

Pipe Drainage

I now come to the point where a decision must be made as to the method of drainage, and if expense permits the usual choice will be that of pipe drainage. This entails cutting parallel lines of trenches to a predetermined depth and laying pipes therein, covered with porous material to within 6 inches of the surface. Cylindrical pipes of burnt clay are commonly used, with the alternative of concrete pipes for which additional porosity is claimed. Pipes constructed with pitch fibre are also available for land drainage, and are of low cost and very light to handle. These pipes are drilled at frequent intervals to facilitate the entry of water and have been used in industry for some time. Their application to land drainage is, however, a comparative innovation.

It is universally accepted that a 3 inch pipe is the minimum size for branch drains. The pattern that the drains shall take is a much-discussed question. The most familiar arrangement is the herring-bone system where the branch drains are disposed on both sides of a main drain, but the disadvantage is that the main drain has usually to pass through the centre of a playing area so that drainage investigations, repairs and additions cause serious eruption. A far better plan, where possible, is to use the unilateral system, whereby the main drain is located at the side of the area with branch drains connected thereto as shown on plate 3. This system is open to extension in a number of ways in order to cater for various situations and gradients.

Star Drainage

Another system of drainage is the star or fan pattern, in which branch drains are led to the outlet in radial fashion. The disadvantage of this method is the unequal spacing and length of the branch drains, and it is not therefore usually applied to large areas. For local drainage of wet spots, however, the star pattern may be extremely useful, as a supplement to [illegible].

Cut-off Drainage

Mention should be made also of the cut-off system, whereby drains are laid along the margins of a site. The chief purpose is to intercept the flow of water from higher ground, and the pipes used may be of 3, 4 or 6 inch diameter according to the estimated flow. As a rule, cut-off drains are dealt with independently of the general site drainage and are taken direct to a suitable outlet, but there are cases in which cut-off drains can be incorporated into a main drainage scheme, and in fact become an important part thereof.

Interval between Branch Drains

The circumstances which control the distance between the parallel lines of branch drains have already been mentioned. On a heavy clay soil the interval should obviously be as little as possible, and from 10 to 12 feet apart is often allowed for lawns, tennis courts and cricket tables. Where an ash foundation is to be provided, the interval can be up to 50 per cent greater. Indeed, it is a common practice to drain a cricket square on an ash foundation by means of a single marginal pipe and this system is often extended to bowling greens where the subsoil is not heavy.

On large lawns and sports grounds generally, branch drains may be laid at intervals of 1[illegible] to [illegible]5 feet according to the nature of the soil, requirements of the games, and the available gradient. The number of pipes required for the branch drains can easily be determined if the area (in square yards) be divided by the distance between the drains (in yards). This gives the total length of the drains in yards, and to find the number of foot pipes required the resultant figure must be multiplied by three. If 18 inch pipes are being used, the yardage figure is multiplied by two. The main drains must, of course, be measured independently.

Depth of Branch Drains

So far as lawns and sports grounds are concerned, there is nothing to be gained by laying drain pipes very deeply. The average depth for branch drains is about 18 inches, but whatever their depth it is extremely important for the main drain to be about 6 inches lower. This ensures rapid flow of water from the branch drain to the main drain and helps to keep the former clear of sediment. Theoretically, the angle of junction should be 40 degrees, but a great deal of freedom may be allowed in this matter if the proper relation between the depth of the branch drains and the main drains is carefully observed, and the angle of junction is not actually opposed to the direction of flow. Right-angle junctions of main drains are sometimes unavoidable, but in all such cases there should be an inspection pit or manhole at the point of connection. This may be a concrete or brick structure of rigid type, or merely a loose brick chamber some 2 feet square, but in either case the outflow pipe should be at least 6 inches below the inlet pipe, and the floor of the chamber some 6 to 9 inches below the bottom of the outlet pipe.

Gradients

The amount of fall that can be given to each line of pipes must be decided by the nature of the site and the extent of the drainage scheme. In many cases, there will be sufficient gradient for the pipes to be laid at a uniform depth from the surface throughout. With a flat site, it is necessary to obtain some fall for the drains by deepening the trenches towards the outlet points, and for a tennis lawn or similar area 1 foot fall in every 100 feet may be regarded as satisfactory. It might not be possible to secure this gradient in a large-scale drainage scheme, but the branch drains should have as much slope as the site permits and in no case less than 1 foot in 300 feet. The question of giving the drains a high rate of fall artificially is not so important as that of making whatever fall there is even and regular throughout.

Connections

Much has been written about connections between drain lines, and a great deal of time has been spent and drain pipes wasted in endeavouring to provide for the flow of water from one pipe to another. The truth is that elaborate junctions are unnecessary where the correct relation between the depths of the pipes is observed, and if the last branch drain merely rests on the main drain below, with appropriate porous packing, all should be well. It is unnecessary also to allow an appreciable gap between the pipes when laying drains, as this facilitates the entry of silt. If the pipes just touch one another, there will be more than adequate entry area for water since it is impossible to ensure absolute contact all around the bore.

Cutting and Laying

The trenches should be as narrow as possible, consistent with the size of pipe, and in this connection the use of a trench-cutting machine is extremely helpful. Before laying any pipes, check the bottom of excavation by means of boning rods to ensure an even fall. If the bottom of the trench is firm and dry, the pipes may be laid directly thereon, otherwise an inch or so of fine ash should be put down first in order to ensure accurate alignment. Stabilize the pipes by carefully packing the sides with stone or rubble and cover with graded clinker or stone to within 8 inches of the surface. Follow with 2 inches of fine ash or sand and complete with 6 inches of top soil. All materials should be carefully consolidated by treading and light ramming but not subject to severe compression.

Final Notes on Pipe Drainage

However carefully the work be carried out, the trenches may sink a little during the first twelve months and, therefore, some surface reinstatement may be needed. This can be accomplished by carefully lifting and re-laying the turf or by means of top-dressing. For the latter purpose, a mixture of equal parts good top soil and fairly coarse, gritty sand is suitable.

Pipes with cemented sockets must be used near hedges, shrubberies and trees to prevent roots from forcing admission and choking the drain. The outlet must never be allowed to become blocked, and should be examined periodically to ensure that it is working efficiently.

Porous Layer Drainage

The porous layer system of artificial drainage entails inserting from 4 to 6 inches depth of graded clinker or stone between the subsoil and the top soil, supplemented by a modified system of drains. From 70 to 100 cubic yards of porous material would be needed for an average tennis lawn, or 800 to 1,000 cubic yards per acre. If finance permits, the porous layer should be covered with 6 inches of light soil specially imported for the purpose, but should this be out of the question the existing surface soil must be replaced and improved in texture by incorporating as much sharp, gritty sand as possible. In cases where the top soil must be removed to allow levelling adjustments it is a comparatively simple procedure to introduce a porous layer, otherwise the expense of stripping and replacing top soil must be considered from the point of view of drainage alone.

Porous layer drainage is very effective, but the cost is high. It is therefore only resorted to on a large scale where the soil is of an exceptionally heavy character or where the water-table is very high. This system of drainage, however, is almost universally applied to important playing areas such as bowling greens, hard tennis courts and cricket squares where rapid drainage is the first consideration.

Mole Drainage

Where the cost of cutting trenches and laying pipes is too heavy, mole draining often proves a useful alternative. This system of drainage is carried out by means of a mole plough, which creates channels 3 to 4 inches in diameter from 12 to 18 inches below the surface. To obtain successful results, the ground must slope sufficiently and the subsoil must be of a plastic, clayey nature, free from stones and pockets of sand. An even gradient is necessary otherwise the drains will rise and fall and the low places will become boggy patches. It is essential, also, to have an adequate outlet for the mole drains, which may be either an open ditch at the side of the area or a main drain of 4 to 6 inch pipes constructed for the purpose. By means of equipment now available it is possible to carry out mole drainage with minimum surface eruption and to make direct connection to an existing piped main drain without opening up, provided there is plenty of porous material over the main drain.

The limit of slope for successful mole drainage is usually put at 1 in 150, while each drain should not exceed 150 yards. If drainage over a greater span is required, additional main drains or other means of dealing with the outflow must be provided.

As the cost of mole drainage is low, the drains can be spaced closely and from 6 to 15 feet apart are common intervals. Mole draining at even closer spacing is sometimes practised as a means of breaking up an intractable subsoil and the resultant shattering of the ground on each side of the mole channel is extremely beneficial. The actual drain lines may not persist long, but the increased porosity of the subsoil can last for many years.

Life of Mole Drains

With appropriate soil conditions, the average life of mole drains is said to be ten years, although instances are known where they have worked efficiently for upwards of thirty years. It is, however, advisable to allow for repetition of mole drainage every fifth year.

Moles and Main Drains

A combination of piped mains and mole branches is often a very useful means of draining large areas initially, and in the course of time any section may be converted to pipe drainage, thus spreading the cost of the more permanent system over a number of years. In addition, mole drainage is often an extremely useful supplement to pipe drainage and greatly increases the effect thereof. The moles may be drawn parallel with the existing pipe drains, or they may even be drawn crosswise if the drains are laid at sufficient depth and there is plenty of porous material over them.

Effects of Drought

In deciding upon any form of drainage, the requirements of the turf during dry weather must be taken into account. Little or no anxiety need be felt where the annual rainfall is high, but in other districts it is possible to overdrain, and a very elaborate system may do more harm than good in the absence of an adequate artificial water supply in times of drought.

Time Lag

While there is usually a fairly rapid response from mole drainage, especially if the channels are close together, it is important to bear in mind that drainage by agricultural pipes does not reach maximum efficiency at the outset. A period of twelve months or more is required before the drains exert their full drawing power. The true function of drainage is often not fully understood and it is apt to be regarded as a means whereby a heavy waterlogged area can be quickly transformed into clean, dry springy turf. Unfortunately, this is not the case. The real purpose of drainage is to check the rise of subsoil water and it does little to intercept rainfall. In the circumstances, no system of artificial drainage—however comprehensive—will function adequately if the top soil is non-porous. In all cases of inadequate drainage, therefore, improvement of the surface soil is just as important as the installation of drains and is, in fact, sometimes of itself a complete answer to drainage difficulties.

Treatment of the Top Soil

In addition to the improvement which results from mechanical treatment under suitable conditions, there are certain dressings which increase the porosity of the top soil. They include such inert substances as sharp, gritty sand and agents which alter the soil structure chemically. Details of the principal soil conditioners as they affect various sites in preparation for lawns and sports grounds are given below:

Sharp, gritty sand, 50 to 100 tons per acre
Processed sewage, 4 to 10 tons per acre
Charcoal (¼ inch), 1 to 2 tons per acre
Fine peat, 2 to 5 tons per acre
Gypsum (calcium sulphate), 2 to 5 tons per acre
Sulphur, ¼ to ½ ton per acre
*Ground limestone (calcium carbonate), ½ to 2 tons per acre
*Slaked or hydrated lime (calcium hydrate), ⅜ to 1½ tons per acre

* For acid soil (*p*H 5·5 or lower).

Necessity for Plans

To conclude, I would emphasize the necessity of preparing a plan whenever a drainage system is instituted, revised or enlarged. This will greatly simplify the work of extending the drainage, should it become necessary, while it is essential for proper maintenance.

Maintenance

To maintain a drainage system in good working order, the outlet should be examined regularly to ascertain if the outflow is proportional to the amount of rainfall. It must always be kept clear of leaves and other debris.

Clear out inspection pits or ditches periodically, and examine the ground in winter for waterlogging. This may reveal blockages or displaced pipes, which must be attended to and rectified without delay. In particular, recent constructions should be inspected carefully for sinkages, which may well result in the displacement of drains and creation of boggy areas.

Another cause of blocking is from the roots of trees or hedges, and drainage in the vicinity should be examined frequently.

Silting up may occur after a lengthy period, especially in soils containing much iron or peat. The remedy is to clear the drains with rods before the accumulation becomes serious.

In the general upkeep of lawns and sports grounds which have been drained, the chief requirement is to maintain the surface soil in as porous a condition as possible, so that rainfall may reach the subsoil rapidly. This entails regular aeration and frequent ameliorative dressings. In all cases where pipe drainage exists, rolling should be reduced to the absolute minimum necessary for the particular purpose in view.

Det följande utdraget har hämtats ur I.Greenfield: Turf culture (London 1962), avsnittet Drainage, sid. 95 - 103.

If the soil is heavy and pools of water collect after rain, or in the winter, it is obvious that drainage is necessary; good turf can never be established in poorly drained soil. Factors indicative of bad drainage are waterlogged, soft, spongy soil, surface pools, and the presence of weeds such as rushes, sedges, woodrush, self-heal, and certain moss species.

Turf will not grow well or be resistant to wear and tear under conditions which destroy soil texture and structure. Lack of aeration and bad drainage causes poor root development, leading to turf deterioration and disfigurement; this, coupled with the effects of wear and tear, results in shorter-lived turf characterized by poor growth, lack of drought resistance, and incapacity for rapid recovery.

A badly drained surface hinders both men and machines; the soil is colder, spring growth slower, and moss, algae, and pre-disposition to disease, are encouraged. The natural characteristics of badly drained soil—mottling, crowstones, and colouring of the subsoil profile—have been described in Chapter I, page 7.

The advantages of draining may, therefore, be summarized as follows:

1. The soil is firmer, warmer, and of better texture and structure.
2. Good aeration promotes desirable soil bacterial activity and healthy grass growth, and leads to a reduction in weed population and turf disorders, in general.
3. Increased root development facilitates better utilization of fertilizers and increases drought resistance.

Drainage operations should be undertaken before returning the topsoil. If, however, drainage is required on sites where levelling is unnecessary, the various operations involved in penetrating the topsoil to reach the subsoil cause disturbance of the ground, which takes some time to settle, and, therefore, should be carried out in the initial stages of site preparation.

Types of Drainage

Drainage problems can be approached in two ways: either by reducing the height of the water table by means of drains, or by the incorporation of porous materials to improve soil texture and thus promote surface drainage. It is important to distinguish between surface and sub-surface drainage and whether one, or both, are deficient.

1. Surface Drainage

If surface drainage is poor or impeded, standing pools of water occur on the turf, and the soil, on inspection, appears structureless and compacted. The results of compaction have been studied on a *Poa pratensis* sward in America; the harmful effects are clearly shown by the following figures:

	Uncompacted	Compacted
Soil porosity, %	33·1	6·1
Infiltration (in./hr.)	1·4	0·24
Maximum run-off	0%	88%

This condition is frequently induced on heavy soils subjected to repeated wear and tear throughout the year, by both men and machines, often under wet conditions.

Provided there is no deep-seated drainage problem below the surface, i.e. broken or choked drains, or an undrained clay subsoil with a high water table, much can be done to improve surface drainage and aeration. These will be discussed in detail under turf management, but mention should be made here of the value of hollow tining, spiking, and slitting, which, carried out on established turf at the right time and coupled with the application of a lightening top dressing, such as sharp sand, can do much to improve the surface drainage, firmness, and earthworm control. The effect of aeration, particularly the use of hollow tine and slitting implements that make holes and slits in the compacted surface, is to allow both free access of air and better drainage, with resultant root development and increased bacterial activity; in addition, the slight pruning action encourages root growth. Top dressings should be evenly applied and well brushed into the holes or slits. Although these measures help to improve surface drainage, a more radical approach is sometimes necessary.

A common cause of poor surface drainage is a soil which lacks a good crumb structure, and the factors influencing this property will be discussed later. On some heavy clay land, the soil adheres in large clods that, on drying, hold together firmly except for a few large cracks. The type of clay is termed deflocculated, and is in contrast to flocculated clay that, in the dry condition, exists in small crumbs. The difference between these types of soils may be conveniently summarized as follows:

Flocculated	Deflocculated
1. The crumbs, on wetting, swell less readily, and do not disperse in water—they are water-stable.	1. The clods swell readily, dispersing to paste or mud—they are water-unstable.
2. Crumbs rigid, and only sticky or mouldable at high water content.	2. Are more fluid, sticky and mouldable, at all levels of water content.
3. The tilth is mellow, crumbly, not sticky, workable, and tools can be used on it in quite wet conditions.	3. The tilth is poor, and the soil sticks to tools even in mildly wet conditions, and on sports turf, to football boots, etc.
4. Drainage is good, open, and porous.	4. Drainage is bad.
5. Aeration is good.	5. Turf is poorly aerated.

First, the depth at which the drains should be placed; this is determined by the type of soil. The heavier the land, the nearer the drains should be to the surface: generally they are placed at 1-2½ ft. in heavy soil, and at 3-4 ft. in medium and sandy loams.

Similarly, the distance apart is determined by the texture of the soil; the heavier the land, the nearer should the drains be spaced together. In predominantly clay soils, they may be placed as near as 10 ft., although 15-20 is more usual; on medium soils, the figure is 25 ft., and on light land, at 30-60 ft.

A gradual, even fall to the ground is necessary for rapid draining; a gradient of 1 in 100 is ideal, although 1 in 300, or in some cases 1 in 600, is adequate when dealing with larger areas.

The fourth major point concerns the outlet of the drain, and unless this is clear and unobstructed, the whole object of the system will be defeated.

TILE DRAINAGE

This system is most widely used to drain small lawns and is also the most satisfactory for draining larger areas, unless a very heavy clay subsoil renders mole draining satisfactory and economic. Tile draining consists of laying a series of main drains (or only one in the case of a small lawn), which may run either straight down the slope in the direction of the fall, or diagonally in the direction of the slope. On larger areas, it is more usual and necessary to add to a series of main drains a number of laterals that enter the mains at an angle of about 40°.

With regard to the depth and distance apart of tile drains, a plan, aiming at maximum effectiveness, may have to be scaled down or replaced by an arrangement designed to be most economic for the prevailing conditions. Theoretically, deep drains, widely spaced, should have the same effect on the water table as shallow ones closer together, but this is only true in the lightest soils. On heavy soils, water hardly percolates the subsoil, but runs along its surface down the line of greatest slope, until it reaches a drain line, where it percolates through the trench filling to the pipe. This means that various rules of thumb like 'a tile line will drain one foot on each side for each inch in depth' are unreliable, and figures such as the following—from J. A. S. Watson in 'Science and Practice of British Farming'—are not easily applicable to sports turf:

Soil	Depth in ft.	Distance in ft.
Clay	2 –2½	12–20
Medium loam ..	2½–3	20–30
Sandy loam ..	3 –4	30–40

As a general recommendation, best results are obtained from shallow (1½-2 ft.) drains set as close together as economic considerations will allow.

The essential aim of drainage concerns the rapid removal of water, and it is for this reason that trenches should run diagonally to the line of greatest slope to ensure the quick and efficient interception of surface water. The laterals, in turn, run into the main drains. Naturally, contours are an important determining factor in deciding the exact drainage pattern to use.

Four in. tiles are more efficient than 3 in. ones, while a 3 in. tile, at a gradient of 1 in 300, can drain half an acre easily; a 4 in. one, which is nearly twice as large in cross section, easily carries the 2,250 gallons per acre per hour, which is probably a safe minimum drainage figure. Drains consisting of 4 in. tiles are, therefore, preferable throughout; but if costs are prohibitive, the major drains can be composed of 4 in. tiles and the minor ones of 3 in. tiles.

The following figures, based on Dr. E. C. Childs's (Journal of Agricultural Science, 1943), will indicate the amount of water removed, bearing in mind that a quarter of an inch of rain, spread over one acre, produces 5,670 gallons of water.

Pipe Size (in.)	Water removed (1000's of gallons per hour)			Acres cleared of ¼ in. rainfall in a day		
	Gradient 1 : 500	Gradient 1 : 200	Gradient 1 : 50	Gradient 1 : 500	Gradient 1 : 200	Gradient 1 : 50
4	1·7	2·7	5·4	7	11	23
6	5·4	8·5	17	23	36	72
9	16·5	26	52·5	70	110	220

These figures are based on a permeable soil, which implies that all the rain percolates to the drainage channels quickly.

In practice, the soil retains much of the water, at least temporarily, as the following table indicates:

Average rain retention

Soil Class	Average storage capacity/cu. ft. In.	Gal.
Fine sandy soil ..	¾	0·5
Sandy loam ..	1¼	0·9
Loam	1½	1·13
Silt loam/Silty clay	2	1·31

Thus the pipe sizes quoted above provide adequate drainage when ⅜ in. of rain falls in a day, the additional ⅛ in. usually being retained in the soil.

Gradient requirements for mains and laterals conflict, because, while the laterals are small and require steep gradients (1 in 50 or 1 in 75) for efficient working, it is also desirable that the water should run faster in the main drains to prevent silting at the points where the laterals join the mains.

Tiles may be constructed of three different materials. The traditional type are constructed of porous clay, and make contact with adjacent tiles by means of a butt joint. More recently, a stronger, heavier, and more expensive tile has become available, consisting of impermeable concrete with butt joints. Finally, there are drains with permeable concrete walls, which admit water but not silt. These are more expensive than the other two, but are commonly used for main drains and for lowering the water table. Salt-glazed Y-shaped tiles are useful at the junctions of major and minor drains, while a proper manhole silt chamber is desirable where the main drains meet. Pitch fibre pipes, successful in the U.S.A., have been introduced into Great Britain. The basic raw materials used in their construction are wood cellulose fibre and carefully refined, inert, coal-tar pitch. These are blended in the proportion 25:75 by weight, respectively, and form permanent, tough, and resilient pipes that are unaffected by corrosive soil conditions, insects, or fungus growth. They are light—one man can carry 32 ft. of a 4 in. pipe—and the joints, which tree roots are unable to penetrate, can be made watertight.

PATTERNS FOR TILE DRAIN ARRANGEMENT

Tile drains may be laid in patterns according to the contours of the ground and the outlets available (see Fig. 20). The commonest system is the 'herring-bone', which consists of a number of mains laid parallel and fed by subsidiaries, generally not more than 30 yd. in length, thus providing a large number of relatively short drains. This arrangement is useful on gently sloping playing fields to obtain the requisite fall without placing some of the drains inconveniently deep. However, the many connections increase the risk of silting and make the herring-bone pattern hard to construct by machine.

The 'grid' method, which is easily made by machine, is preferable where the ground falls away from the centre with a uniform gradient of not less than 1 in 300. The branches discharge into one side of the main or mains near the boundary of the site.

A 'fan-shaped' pattern may be used on either large or small sites provided there is a suitable gradient; there is no main drain, but a number of subsidiaries all converge on, and discharge at, one point on the boundary of the site.

'Natural' drainage, where the drains follow the natural contour of the ground, is suited more to ornamental than sports turf.

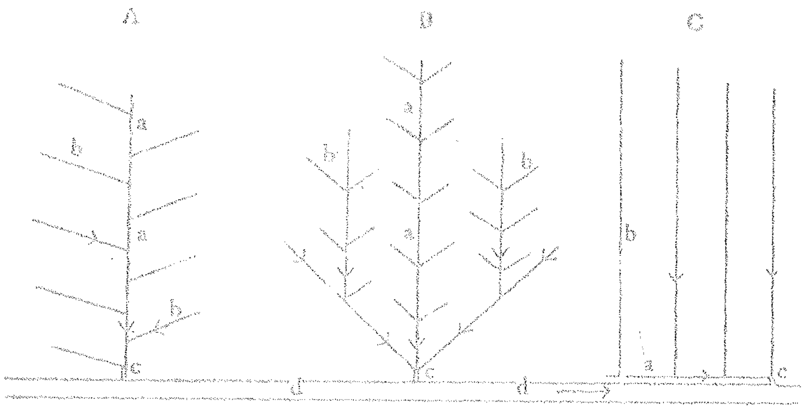


FIG. 20: DRAINAGE SYSTEM PATTERNS.

A. Natural B. Herringbone C. Grid

(a) Mains
(b) Subsidiaries
(c) Outfall
(d) Stream or ditch

In all drainage schemes, an even fall should be maintained, sharp bends avoided, and the mains sited 6 in. below the laterals which should be spaced at the correct distance apart, according to the general soil and situation. Socketed pipes, cemented together, should be employed in the vicinity of tree roots, or in silty soil, which may penetrate and block the drains.

The outfall should consist of at least 4 ft. of impervious (concrete, iron, or salt-glazed stoneware) pipe, with a concrete surround for a distance of 2 ft., a header wall, and some degree of protection against erosion of the bed and sides of the stream into which the pipe leads. The pipe should be at least 6 in. above the stream bed, and also above the water level.

An efficient method of improving sports turf drainage consists of preventing the entry of water by means of an intercepting (French) drain, rather than allowing it to enter and then inserting drains by which to remove it. Wherever there are springs, due to changes of geological strata, or a nearby hill, or ridge and furrow land leading downwards towards the site, a trench should be dug down to the level of the impervious subsoil and filled with permeable rubble to prevent the water from reaching the site. The top of intercepting drains should not be covered with topsoil or turf if this can be avoided.

Where a marked slope necessitates terracing and separation of playing fields by means of steep banks, an intercepting drain should be placed at the top and the bottom of the slope to prevent erosion and accumulation of water.

PRACTICAL INSTRUCTIONS FOR LAYING TILE DRAINS

Although tiles may be laid after subsoil levelling, it is essential to ascertain that the ground has settled thoroughly before work commences. Where, on the other hand, established turf is being drained, a line of sods, about 1¼-1½ ft. wide, is removed, and a trench cut, usually about 1 ft. wide and tapering towards the bottom edge, with a narrow ledge on each side of the soil surface. If done by machine, a trench as narrow as 6-7 in. is satisfactory. The topsoil is thrown to one side and the subsoil to the other. After the channel is formed, it must be checked for cleanliness and evenness of gradient. The only accurate method of securing a regular gradient is the sight rail and boning rod system. The sight rails (each consisting of two posts firmly planted) are placed at the lower and upper ends of the drain length at such a height that their upper edges will represent an imaginary line parallel to the intended drain. The depth of outfall and top may be fixed by sighting along the upper edges of the rails, and, subsequently, the intermediate second member of the boning set may be inserted. Water is poured down the channel to determine that the rate of flow and the degree of fall are adequate.

Working from the outlet, the pipes are then laid close together and covered successively with stones, clinker of less than $1\frac{1}{2}$ in. size, and fine ash. Best results are obtained if all the subsoil is removed and replaced with stone and ash, prior to the top 6 in. (only 4 in. in heavy soils) of topsoil, and then turf, being placed on top. The outfall, wired over to prevent the entry of vermin, should enter the ditch at a point well above the water level. It is preferable to work between October and May, but on established turf, it is more convenient to complete operations between October and February, thus allowing time for satisfactory turf establishment over the drains before the beginning of the growing season. Drainage projects should be constructed in a series of short-term operations, capable of completion in 2-3 days, as the onset of bad weather causes rapid deterioration of a half-completed scheme. Appropriate trench cutting and tile laying machinery, handled by specialized drainage contractors, represents the most effective method of dealing with large areas (Plate 15).

MOLE DRAINAGE

Mole drainage, better known to farmers than to groundsmen, has much to commend it, being relatively simple and inexpensive to construct. Drains are made by drawing at a depth of 18-20 in., either on a cable or behind a tractor, a knife-shaped coulter that has, on its lower end, a steel cartridge-shaped rod. The channel made by the compaction of the soil around the cartridge is generally 3-4 in. in diameter. In addition, a shattering effect is exerted on the surrounding soil, and the crack to the surface made by the coulter facilitates drainage.

The method is only suitable on well-established uniform clay soils which are free from stones, pockets of sand, and boulders; recently graded land is quite unsuitable due to its unsettled nature. The clay texture must be such as to allow the formation of a permanent channel that will retain its shape for some years: Gault, Kimmeridge, London, Oxford, Lias, Wealden, and boulder clays are often suitable for mole drainage, but local variations may affect the permanence of the channel from between 1-15 years. Soils with high clay and low sand contents are necessary to achieve success, and the best results are obtained where the clay fraction exceeds 45 per cent, the sand being less than 20 per cent. Mechanical and textural analysis of the soil should be made and interpreted by an expert, before a mole drainage scheme is undertaken.

The gradient of the site should be uniform and not less than 1 in 200, the ideal being 1 in 100. The fall should be even, and the moles spaced not more than 6-9 ft. apart in heavy clay soils, and 12-15 ft. in lighter ones. Mole draining is best carried out in the autumn and the winter months, and a cable-and-winch to draw the coulter is preferable to a tractor, especially in bad weather. To minimize tractor compaction, the formation of irregularities by the passage of the coulter, and the opening of a wide crack by the hawser, mole draining, followed by rolling, should be done when the surface is firm, and the subsoil reasonably moist. It is important to draw the mole uphill, as, if drawn in the reverse direction, the channels tend to silt up more quickly. Care should be taken that each succeeding pull does not close the last mole.

The mole drains may empty directly into a ditch, and in practice the mole is started in the ditch and drawn uphill to the top of the slope; the last few yards before the outfall should be tiled and covered with wire. An alternative is to combine moles with tile drains; in this case, there should be an outfall of 3 in. from the moles to a main which should be tiled and covered with stones, hardcore, or clinker, in order to prevent silting up. These systems are not permanent, but providing they are constructed properly, should last for five or even · n years.

Other drainage methods include stone drains, rubble drains, clinker drains, and brushwood drains.

DITCHES

In both tile and mole drainage systems, the ditches play an important part and should be carefully maintained and reconditioned, being kept free from weeds, bushes, and rubbish. They should have a satisfactory fall and lie below the level of the drains discharging into them.

A plan of the system must be kept for reference, and any previous layout, which may be incorporated in a new scheme noted, and either used or disregarded. The drains should be properly maintained and inspected at regular intervals after laying; tiles, in particular, should be checked for free water flow and the presence of tree roots; 'silting up', or the presence of other blockages, can be judged by the reduction in outflow of water.

Det sista här medtagna utdraget vilket speciellt behandlar dränering av golfbanor ingår i Turf management av B. Musser (New York & London 1961), sid. 56 - 62.

SURFACE DRAINAGE OF GREENS AND TEES. The principal causes of bad drainage on greens and tees are poor surface contours, soil compaction, impervious subsoil, and seepage. Good architectural plans should provide designs for the surface contours of greens and tees that avoid pondlike depressions in which water can stand. Contours that concentrate water in relatively narrow runoff channels of low gradient are undesirable. They should be broad and shallow with a grade of at least 1 per cent to permit water to flow out of the turf at a reasonable rate. Surface contours should be designed so that most of the water is taken off where traffic is least concentrated. Draining water to the front of a green should be avoided, whenever possible. Most of the traffic onto the green is from the front; so concentration of water at this point intensifies compaction problems.

In many cases the best remedy for poor surface drainage on established greens and tees is reconstruction. (Other improvements, such as correction of physical condition and provision for underdrainage, can be made at the same time.) Installation of tile drains is seldom satisfactory for the removal of excess surface water. This is particularly true where poor drainage is due to a combination of bad surface contouring and tight soils. Unless grades are relatively sharp, water will not flow rapidly enough through the turf to the low point above the tile to prevent soil saturation. Percolation through tight soils to the tile is so slow that drainage conditions are not adequately improved except in the narrow strip immediately over the tile lines.

UNDERDRAINAGE OF GREENS AND TEES. Provision for adequate subsurface drainage of greens and tees should be made when they are constructed. Some type of underdrainage is necessary, except where foundations are composed of material through which water can move rapidly. Where tile drains are used, tiles should not be smaller than the 4-in. size. Lines should be at least 2 to 2½ ft. below the final surface. The sides of the trenches in the subgrade should be gently sloped toward the tile and the trenches backfilled with cinders or some other type of highly porous material to within 8 to 10 in. of the surface. Compacted pockets in the surface of the subgrade will trap the water and should be avoided. Spacing between lines can be from 10 to 25 ft., depending upon the type of foundation soil in which they are set. When greens are built up so that the outlets can be opened at the foot of slopes, each tile line can be installed independently of the others and sloped from the center in both directions. A connecting system should be provided when the water must be carried to a low point such as a creek or ditch. All connections should be made outside the area of the green whenever practicable.

A second method of providing for good underdrainage of greens and tees has been recommended by the United States Golf Association Green Section. It consists, essentially, in constructing the subgrade at a minimum elevation of 14 in. below the finished grade. The subgrade next is contoured to conform with the contour design of the finished grade. Trenches for receiving tile lines are cut into the subgrade to the necessary depth to provide a fall in the lines of from 0.5 per cent to 3.0 per cent. Suitable types of drain tile (clay, concrete, plastic, or asphalt paper) are laid on a firm bed of ½ to 1 in. of gravel, or directly on the bottom of the trench if the soil is of such character as to make washing into the lines unlikely. Joint fitting and protection against soil and root penetration should be as previously outlined. Tile lines should be spaced at a maximum distance of 20 ft. The trenches are backfilled with some type of highly porous material, such as pea gravel, clean pit-run gravel, or crushed stone, and a 4 in. layer of the same material spread uniformly over the entire subgrade. This should be covered with a layer of finer textured material to a depth of 1½ to 2 in. The particle size of this material should average from 5 to 7 times smaller in diameter than that of the base course. A minimum of 12 in. of prepared topsoil should be used for the surface course. This allows for 4 in. of settling to meet the finished grade requirements (see Chap. 6, page 130, for details of topsoil preparation).

Correcting Poor Drainage on Established Greens or Tees. The successful correction of poor underdrainage depends (1), upon a correct diagnosis of the cause, and (2), upon the choice of a method that will produce the desired improvement. Poor drainage due to compaction in the top four or five inches of the surface layer of soil can be corrected by the use of various types of aerating equipment. Where the trouble is confined to limited areas, the tubular tine fork is suitable for opening drainage channels through the compact layer. Mechanical aerating equipment can be used to advantage on larger areas. The holes it makes always should be filled by working top-dressing into them, except after late fall aeration. When aerated at this time they should be left open over winter to take advantage of freezing and thawing action to improve physical soil condition (see Chap. 7).

Greens or tees located along the side or at the bottom of hills may be wet because of seepage from the hill. The seepage can be trapped by placing a tile line between the green and hillside, in a direction to cut across the line of water movement. The tile must go down to or below the water-bearing strata and the trench backfilled to the surface with porous material. A porous backfill is important and necessary. Otherwise the water will flow across the top of the tile and into the green or tee. Seepage water moves under pressure from above.

It is difficult permanently to improve the underdrainage of greens and tees that have been constructed with heavy impervious soils. The successful functioning of tile drain, mole drains, or other drainage methods will depend upon the rate at which water moves through the soil to the lines. In some types of heavy clay soil, a good crumb structure develops upon drying. Channels to the tile are formed which increase the rate of water movement through the soil. Tile drains function satisfactorily on such soils. Installation methods outlined for new construction are suitable. Soils that are plastic and sticky or have been severely puddled during construction operations develop satisfactory structure for good water movement very slowly. In extreme cases, they may never open up sufficiently for drains to function properly. Before an expensive program of drainage correction is undertaken, it will be wise to make a thorough examination of the soil. A core of plugs should be pulled for this purpose to a minimum depth of 2 to 2½ ft. The assistance of a drainage engineer, or some other individual familiar with drainage problems, should be sought to determine whether the soil is such that tile drains will operate successfully. If the verdict is negative, the only alternative is complete reconstruction.

Fairway Drainage. Fairway-drainage problems are similar to those of greens and tees. Inadequate surface drainage, surface compaction, impervious subsoils, and seepage are the major causes of waterlogging that prevent good turf development.

As previously noted, the ponding of surface water in depressions may be due to the development of surface compaction. It also may be due to impervious soils below the root zone. In either case soils in such areas become saturated and turf either scalds, smothers, or freezes out. In irrigated sections the pocketing of surface water is particularly serious. In addition to the usual types of injury to the turf, toxic concentrations of soluble salts frequently develop in such areas. Where surface compaction is the chief source of trouble, it can be corrected effectively by the use of the turf Aerifier if the soil below is sufficiently porous to permit good water movement. When set to its full operating depth, the spoons on this machine usually penetrate through the compacted zone. Periodic use of equipment of this type is necessary.

Where water ponds in surface depressions because of impervious subsoils, subsurface drainage plus surface grading, where practicable, is the best remedy. In Northern regions, where water collects in depressions when the soil is frozen it causes freezing out of the turf. Tile drains are of no value under these conditions since they do not function when the ground is frozen. Surface grading or the use of tolerant grasses such as the bents is the only satisfactory solution.

Tile systems or open ditches can be used to correct poor drainage caused by impervious subsoils or high ground-water levels. Tile drains are preferable wherever suitable outlets can be provided and soils are of such structure that water will move out of them into the tiles. Soils also must be of such texture that fine particles will not flow into the tiles and clog them. Intercepting tile lines for seepage areas, as described for greens, also are suitable for fairways. Where fairways are constructed on heavy soils that require uniform drainage over the entire area, a simple system of two or three lines of tile running lengthwise of the fairway usually is satisfactory. Each line may have its own outlet, or the lines may be connected to a main at the lower end. Types of tile systems and methods of installation have been outlined.

Open ditches can be used to drain fairways where tile drains are not satisfactory because of high ground-water levels or unsuitable soils. These may be shallow swales that are completely turfed and are designed to carry off surplus water in periods of excess precipitation. Open ditches may be constructed also to carry a constant flow of water as previously discussed. They sometimes can be designed as hazards when used for fairway drainage.

Drainage of Traps. When traps must be placed on impervious soils, they should be designed with the trap floor sloping toward an open side through which water can drain out of the sand. Otherwise tile drainage is necessary. The floor of the trap should be sloped toward the tile line and the tile laid in a shallow trench running in the direction of the long axis of the trap. The principal problem in trap drainage is to prevent sand from getting into the line through the joints. Various methods have been used. Joints have been covered with pieces of sod or carefully packed with a good grade of loam topsoil. Strips of tar paper or asphalt-treated burlap also can be used satisfactorily to cover the joint. A tar-treated fiber conduit, with holes on the underside and convenient slip collars that completely cover the tile, has been developed. It provides good protection against clogging.

VII. Dränering av flygfält

I detta sista avsnitt skall frågan om dränering av flygfält något behandlas, liksom i de föregående huvudsakligen genom vissa utdrag ur facklitteraturen på området.

Efter vilka linjer dräneringen av ett flygfält skall utformas blir beroende av om det är ett fält med hårdgjorda landningsbanor (runway field), där de mellanliggande gräsbevuxna områdena inte användes, eller ett fält utan dylika banor (all over type of field). Den senare typen, dvs. ett i sin helhet gräsbevuxet fält, kan komma ifråga huvudsakligen som övningsfält och för lätta plan, bl.a. för segelflyg. För att få en jämn och snabb upptorkning på ett dylikt fält, som självfallet bör vara möjligast plant, måste man räkna med en efter markens beskaffenhet påkallad dränering efter ungefär samma normer som för varje annan gräsplan (jfr litteraturutdragen i föregående avsnitt). Visserligen anser Horner (1944, se följande utdrag) att en hög markfuktighet under korta och oregelbundet inträffande perioder ej motiverar nedläggning av betydande kostnader på dränering av ett dylikt område, men det måste åtminstone under våra klimatförhållanden ifrågasättas om man kan underlåta detta. Frågan återfaller givetvis på vilka anspråk man ställer på fältets användbarhet för avsett ändamål.

Då man som nämnts eftersträvar att ett dylikt helt gräsbevuxet fält skall vara så jämnt och plant som möjligt, har man inte att räkna med någon större ytvattenavrinning utan överskottsvattnet kommer i huvudsak att nedsjunka på stället. Och man vill helst inte heller ha några brunnar inne på ett dylikt fält (om sådana skall nedsättas, måste de ligga precis i markytans plan och vara försedda med körbart lock). Stor vikt måste läggas på att få god genomsläpplighet i återfyllnaden. En bra lösning bör vara att fylla med grus eller makadam upp till matjordslagret, alltså samma förfaringssätt som på fotbollsplaner o.d. Då emellertid detta drar ganska stora kostnader kan man beträffande lerjordar måhända enklare få en nöjaktig lösning av problemet genom att utföra dräneringen vid en tidpunkt när jorden är möjligast starkt uttorkad. Denna är då mycket söndersprucken och sönderfaller i kokor, och den goda genomsläpplighet som återfyllnaden då har kan förväntas bli bestående under avsevärd tid, i all synnerhet om marken som på ett flygfält skall vara permanent gräsbevuxen.

Den andra typen av flygfält, runway fields, med hårdgjorda landningsbanor är dock den helt dominerande och den enda som kan komma ifråga för trafikering med tyngre flygplan. Här liksom beträffande motorvägar o.d. som trafikeras med tunga motorfordon ställes stora krav på de underliggande jordlagrens bärkraft och stabilitet. I mångt och mycket är problematiken ifråga om dränering av större hårdgjorda vägar och landningsbanor på flygfält densamma och de behandlas också ej sällan gemensamt i facklitteraturen (jfr det följande utdraget ur West: Drainage for highways and airports).

Om den underliggande jorden är kompressibel, antingen in situ eller till följd av omgrävning, är det viktigt att man i möjligaste mån först eliminerar den sättning som annars oundvikligen uppstår till följd av den tunga trafiken på en landningsbana. Den del av sättningen som yttrar sig i form av en sammanpressning av de underliggande jordlagren beror på att porvattnet under det ökade trycket pressas ut. Då motståndet mot vattenrörelsen i en finkornig jord är stort, kommer det att ta avsevärd tid innan stabilitet har uppnåtts. För att påskynda utpressningen av vatten och därmed sättningen kan man använda vertikal-dränering (djupdränering). Denna kan utföras genom att borra hål i marken till erforderligt djup och fylla dessa med sand. Porvattnet rör sig då i horisontal riktning till sanddränerna och genom dessa till ytan.

En annan metod för djupdränering har för ett 20-tal år sedan utexperimenterats av överingenjör W. Kjellman vid Statens geotekniska institut (beskriven i institutetsmeddelande nr 2 1949). Grundtanken i metoden är den att eftersom det största motståndet mot vattnets rörelse från grunden upp mot markytan möter i själva grunden, bör dess väg här vara så kort som möjligt, dvs. dränerna skall stå tätt. Varje sådan kommer då att föra en helt liten vattenmängd. Vid denna metod användes pappstrimlor som nedföres i jorden medelst en speciell neddrivningsanordning. Sättningen påskyndas om extra fyllnadsmassor påföres vilka sedan viss sättning uppnåtts åter avlägsnas.

När man talar om dränering av ett flygfält tänker man väl dock inte i första hand på dylik djupdränering - detta är ju en alldeles speciell dräneringsform - utan på avledning i vanlig ordning av förekommande ytvatten och grundvatten. Självfallet är det också i form av ytvatten från de hårdgjorda banorna som de höga avrinningsintensiteterna uppstår. Detta ledes direkt i brunnar utmed landningsbanan försedda med järngallerlock. I amerikansk litteratur talar man härvid om storm drain system. Dimensioneringen av dessa ledningar, som kan bli mer än en meter i diameter, måste avpassas efter frekvensen av häftiga regn samt deras varaktighet (jfr de följande litteraturutdragen). På ett livligt trafikerat flygfält vill man naturligtvis inte att nederbördsvatten ens kortvarigt skall förekomma på landningsbanorna utan det bör omedelbart avledas genom tillräckligt dimensionerade täckta ledningar.

Beträffande grundvattenavledningen (sub-surface drainage) lägges stor vikt vid att ingen infiltration av grundvatten från omgivningen in under banorna får förekomma, utan en effektiv avskärning av detta skall ske. Naturligtvis måste man i det sammanhanget också se till att inte regnvatten från landningsbanorna får strömma fritt ut på omgivande gräsbevuxen mark och härifrån i form av grundvatten kommer tillbaka in under landningsbanornas hårdgjorda lager. Om detta förhindras genom ett välordnat system för ytvattenavledning kan man liksom ifråga om helt gräsbevuxna flygfält räkna med att det endast blir den direkt på gräsmattan fallna nederbörden som i mån av behov måste avledas. Som framgår av litteraturutdragen räknar man i allmänhet inte med att de mellan de hårdgjorda banorna befintliga gräsbevuxna ytorna, vilka på det hela taget ej trafikeras av några fordon, kräver någon mera intensiv dränering.

De nedan medtagna litteraturutdragen torde ge en tämligen god bild av de principer som tillämpas vid dränering av flygfält, i samtliga fall av typen runway field. Närmast följer ett utdrag ur Eugen M. West: Drainage for highways and airports ingående i Highway engineering handbook utgiven av Kenneth B. Woods (New York Toronto London 1960).

I. INTRODUCTION

The field of drainage is very broad in scope, embracing such fields as hydrology, meteorology, geology, statistics, and others, in addition to the most often recognized field of hydraulics.

Since water is almost certain to be encountered over the entire range of any highway or airport project, drainage is basic in every phase of the design. Whether it be subsurface water originating below the pavement, storm water falling upon the pavement and adjacent areas, or water courses intersected by the project, a systematic drainage design must be made in order to ensure adequate and lasting performance.

There are two basic steps in the solution of surface-drainage problems: *hydrologic analysis* and *hydraulic design*. A good drainage design involves an accurate prediction of the magnitudes of peak rates of runoff for various intervals of expectancy (hydrologic analysis) as well as the design of facilities to accommodate the runoff (hydraulic design). A close correlation between these two basic parts is necessary in order to arrive at a balanced design whereby costs can be weighed against the protection provided.

Recent increases in highway construction and the development of higher types of highways have resulted in more emphasis on the drainage phases of highway design. With approximately 25 per cent of the total construction cost of highways being spent on drainage structures, there is little room for many of the antiquated concepts and rules of thumb of the past. In past years the highway engineer had very little or no hydrologic data to base hydraulic design upon and justifiably used empirical formulas and rules of thumb. However, in recent years drainage research and hydrologic data collecting have been accelerated, thus reducing many of the unknowns. For a good many locations ample hydrologic data are available, and recent studies have made possible the application of gauged data to some areas for which direct records are available. Research and further expanded data collecting presently under way undoubtedly will extend present knowledge and bring about still better methods of approaching the problems of hydrologic analysis.

II. TYPES OF DRAINAGE PROBLEMS

A. Bridge Waterway Openings

In a majority of cases the height and length of a bridge depend solely upon the amount of clear waterway opening that must be provided to accommodate the flood waters of the stream. Actually, the problem goes beyond that of merely accommodating the flood waters and requires prediction of the various magnitudes of floods for given time intervals. It would be impossible to state that some given magnitude is the maximum that will ever occur, and it is therefore impossible to design for the maximum, since it cannot be ascertained. It seems more logical to design for a predicted flood of some selected interval—a flood magnitude that could reasonably be expected to occur once within a given number of years. For example, a bridge may be designed for a 50-year flood interval; that is, for a flood which is expected (according to the laws of probability) to occur on the average of one time in 50 years.

Once this design flood frequency, or interval of expected occurrence, has been decided, the analysis to determine a magnitude is made. Whenever possible, this analysis is based upon gauged stream records. In a number of the streams in each state a series of gauges are maintained and periodic measurements are available. (This work, done principally by the U.S. Geological Survey and the U.S. Corps of Engineers, is published annually in the *Water Supply Paper*.) In addition, for several states, flood-frequency curves for gauged streams have been published by the U.S. Geological Survey.*

In areas and for streams where flood frequency and magnitude records are not available, an analysis can still be made. With data from gauged streams in the vicinity, regional flood frequencies can be worked out; with a correlation between the computed discharge for the ungauged stream and the regional flood frequency, a flood frequency curve can be computed for the stream in question. Methods for dealing with flood-frequency problems are presented at length in several sources, such as Dalrymple, "Regional Flood Frequency" (1).†

B. Highway Culverts

Any closed conduit used to conduct surface runoff from one side of a roadway to the other is referred to as a culvert. Culverts vary in size from large multiple installations used in lieu of a bridge to small circular or elliptical pipe, and their design varies in significance. Accepted practice treats conduits under the roadway as culverts, for all sizes and shapes up to 20 ft in total span. Structures of greater span are treated as bridges. Although the unit cost of culverts is much less than that of bridges, they are far more numerous, normally averaging about eight to the mile, and represent a greater cost in highways. Statistics show that about 15 cents of the highway construction dollar goes to culverts, as compared with 10 cents for bridges. Culvert design then is equally as important as that of bridges or other phases of highways and should be treated accordingly.

C. Municipal Storm Drainage

In urban and suburban areas, runoff waters are handled through a system of drainage structures referred to as storm sewers and their appurtenances. The drainage problem is increased in these areas primarily for two reasons: the impervious nature of the area creates a very high runoff; and there is little room for natural water courses. It is often necessary to collect the entire storm water into a system of pipes and transmit it over considerable distances before it can be loosed again as surface runoff. This collection and transmission further increase the problem, since all of the water must be collected with virtually no ponding, thus eliminating any natural storage; and through increased velocity the peak runoffs are reached more quickly. Also, the shorter times of peaks cause the system to be more sensitive to short duration, high-intensity rainfall. Storm sewers, like culverts and bridges, are designed for storms of various intensity-return-period relationships, depending upon the economy and amount of ponding that can be tolerated.

The hydraulics of storm sewers and appurtenances is probably more critical than that of bridges and culverts, since the systems are more sensitive and complex. It is not uncommon to find cases where ponding is excessive on a roadway or street and yet the drainage system is not taxed to its full capacity, indicating improper inlet spacing or other improper hydraulic considerations.

D. Airport Drainage

The problem of providing proper drainage facilities for airports is similar in many ways to that of highways and streets. However, because of the large and relatively

* These, as well as all other USGS publications referred to herein, are available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

† Numbers in parentheses refer to corresponding items in the References at the end of this section.

flat surfaces involved, the varying soil conditions, the absence of natural water courses and possible side ditches, and the greater concentration of discharge at the terminus of the area [illegible] some phases of the problem are more complex.

For the average airport the overall area to be drained is relatively large and an extensive drainage system is required. The magnitude of such a system makes it even more imperative that sound engineering principles based on all of the best available data be used to ensure the most economical design. Overdesign of facilities results in excessive money investment with no return, and underdesigning can result in conditions hazardous to the air traffic using the airport.

In order to ensure surfaces that are smooth, firm, stable, and reasonably free from flooding, it is necessary to provide a system which will do several things. It must collect and remove the surface water from the airport surfaces, allowing a minimum to enter the subsurface; intercept and remove surface water flowing toward the airport from adjacent areas; collect and remove any excessive subsurface water beneath the surface of the airport facilities and in many cases lower the ground-water table; and provide protection against erosion of the sloping areas. To design facilities which will achieve these ends requires a proper understanding of the factors involved in drainage and the use of all available hydrologic data. This text should be interpreted merely as a guide, and local Civil Aeronautics Administration, U.S. Weather Bureau, and U.S. Corps of Engineers Offices should be consulted for the information pertinent to the particular design problem.

E. Roadway Surface Drainage

Roadways are built with crown or cross slopes to provide lateral or oblique drainage flow to the sides of the pavement, and in the case of curves, lateral or oblique flow due to superelevation of the pavement and shoulders (see Sec. 22 on Geometric Design). It is common practice to allow the water to flow from the pavement, across the shoulders, and down the side slopes to the natural drainage area or to side ditches. Where good slope protection is provided and the flow from the pavement is distributed as a fairly uniform sheet of water, erosion is not excessive. In places where this is not possible and concentrations of flow occur, it is necessary to provide other means of protecting the side slopes and shoulders.

Several techniques used to prevent harmful erosion are employed in conducting the storm water from the roadway. One of these is to provide a curb along the outer edge of the pavement to conduct the flow to catch basins or other collecting devices, from which it is removed and led down the slopes to a ditch or to a natural drainage area. This type of curb has its disadvantages, since the water on the pavement edge creates some hazard to traffic, especially when frozen.

F. Ditch and Slope Drainage*

A highway cross section normally includes one and often two ditches paralleling the roadway. Generally referred to as side ditches these serve to intercept the drainage from slopes and to conduct it to where it can be carried under the roadway or away from the highway section, depending upon the natural drainage. To a limited extent they also serve to conduct subsurface drainage from beneath the roadway to points where it can be carried away from the highway section.

A second type of ditch, generally referred to as a crown ditch, is often used for the erosion protection of cut slopes. This ditch along the top of the cut slope serves to intercept surface runoff from the slopes above and conduct it to natural water courses on milder slopes, thus preventing the erosion that would be caused by permitting the runoff to flow down the cut faces.

Extreme care must be taken in the use of crown ditches, however, to prevent a condition [illegible] that which an attempt is being made to cure. In cases where crown ditches are [illegible] long, and slopes excessive, unless properly considered in the design, erosion [illegible] become concentrated and severe.

Side ditches should be designed not only to accommodate the flow, but also to provide waterway sufficient to prevent erosion of the roadway shoulder and undercutting of the toe of the slope. The design procedures are the same as for open-channel flow, using Manning's formula and conservative values of the roughness factor, which are included in this section under Hydraulic Design Principles, Art. V.

G. Subsurface Drainage

To prevent excess moisture in the subgrade, which will ultimately cause a loss in stability through low resistance to wheel-load displacement, it is necessary to ensure proper subbase drainage facilities.

Moisture in the subbase falls into two categories: *free water* and *capillary moisture*, both of which the engineer must consider in a proper design.

Free water either originates under the pavement or has penetrated the subbase through perviousness of the pavement or of the shoulders and pavement edges. Capillary moisture is the result of capillary action, by which small particles of water are drawn from free water or from wetter strata and become attached to the soil particles

* See also "Roadway Drainage Maintenance" in Sec. 28.

The initial step in preventing poor subsurface conditions is to control the free water, thus reducing the source of capillary moisture. This can be accomplished by intercepting surface water before it is allowed to enter the subgrade. The serious effects of capillary water can further be reduced by providing subdrains to lower the water table, by providing a more pervious subbase material, and by using subgrade soils which require relatively low amounts of moisture for binding. Volumetric changes of soils, the effects of frost action, and the like are presented in more detail in Secs. 8 and 13.

Varying types of subdrainage installations can be used, depending upon the conditions which they are intended to control or correct. Detailed recommendations for various types can be found in highway standards and in other publications listed in the References at the end of this section.

H. Channel Relocations

It often becomes necessary to relocate portions of natural water courses to make way for a roadway or an airport. Often drainage structures, both large and small, can be eliminated by relocating reaches of existing streams to keep them on one side of the roadway rather than crossing back and forth. At many structure sites the field investigations indicate that channel relocations and improvements above and below the structure may provide a better situation from the hydraulic standpoint. A decrease in initial cost of the structure installation is possible; however, maintenance and possible future cost should not be overlooked in considering the feasibility of this choice. Also, considerable caution should be taken in dealing with the changing of natural water courses. Such an undertaking requires thorough engineering analysis.

There has been a tendency to measure, from a cross section of the existing channel taken at some point, the area below some high-water mark whose validity may be questionable and to design a new channel by merely providing equal or greater cross sections. Yet this alone does not represent a design by any approximation and can in some cases produce disastrous results. The consideration of area alone is by no means sufficient, since channel capacity and flow characteristics depend upon many other factors. These factors may not be the same at all locations on the new channel, and some velocities can cause severe damages regardless of how large the cross section. Velocity, for instance, depends upon roughness, shape of the cross section, slope, and discharge, in addition to area.

In channel relocations where long reaches of the stream are eliminated, the effect of changes in storage can become a severe problem. An alteration in storage capacity could jeopardize the high-water clearance for the roadway and the structures. Providing more uniform shapes and slopes of the new channel with smoother channel linings will tend to cause higher velocities, and these may present scouring problems in the new channel and at the toe of the embankment. Generally, natural channels have become more or less stabilized through the normal course of nature, and experience indicates that new channels rarely stay as constructed. They have a tendency to undergo a change, the degree depending upon the similarity of the conditions provided to those required by nature. This change can cause an appreciable maintenance problem.

The relocation of channels requires a hydrologic and hydraulic analysis similar to that required for bridge and culvert design.

I. Erosion Protection

Generally, if the design of a drainage structure is properly made, there will be little or no source for erosion. In the special cases where the structure itself cannot be adequately designed to prevent erosive conditions, the design should provide additional protective facilities.

Whenever possible, culverts should be designed for discharge velocities within a range that will not scour the channel at the outlet. The same principle holds for channels and ditches. Whenever the hydraulic design permits, the best protection is to provide a situation that will not produce scouring velocities; however, in many cases the velocities cannot be controlled in the design and additional protective measures become necessary.

The protection of shoulders and slopes from runoff from the roadway surface should also be kept in mind in the design stage. Normally, collection and distribution of the surface water can protect these areas; but when the analysis indicates that scouring conditions are prevalent, special provisions become necessary. These may include providing a special channel lining, providing ditch checks, and installing stilling basins at culvert outlets. Additional information on erosion protection is included in Art. IV on design in this section, and specific treatments are included with the discussion of the other drainage problems in Secs. 14, 27, and 28.

III. HYDROLOGIC ANALYSIS

By definition, "hydrology is the science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the earth" (2). Since it deals with the occurrence and movement of water upon and beneath the earth's surface, this science is of utmost concern to drainage engineers. A thorough treatment of the field is beyond the scope of this handbook, but references are given at the end of this section (2-5).

Some of the basic elements of hydrology with which the drainage engineer must deal are those concerning rainfall and runoff. Of particular concern are the relationships between peak rates of runoff and the frequency and intensities of the rainfall producing these runoff peaks.

A. Rainfall

Practically all applications of hydrology, and particularly those pertaining to the design of drainage structures, are dependent upon correlations between rainfall and ultimate surface runoff. Hydrologic "analysis" for this relationship involves as many direct measurements as feasible, estimates of conditions that are not directly measurable, and calculations of the probable occurrence of rainfall based on past records.

The three features of rainfall precipitation fundamental to hydrologic problems are:

INTENSITY: The rate at which rain falls for a given period, usually expressed as inches per hour.

DURATION: The time during which rainfall prevails at that rate, usually expressed in minutes.

FREQUENCY: The probable period of time within which combinations of intensity and duration repeat themselves, usually expressed in years. Frequency should not be interpreted to mean an exact periodicity. For example, the assignment of a 50-year frequency to an event means that the event will reoccur or be exceeded on the average of once in 50 years, and if past records are repeated, the chances are 1 in 50 that it will occur in a particular year. The prediction depends upon the laws of probability, and, actually, the chances are only about 64 in 100 that the event will occur in a given 50-year period.

Through a network of automatic rainfall-recording devices the U.S. Weather Bureau and others have compiled a rather long period of record of rainfall duration and intensities. From these records a number of publications of rainfall-intensity-frequency curves are available, most of which are for specific localities. However, a nationwide coverage was published by the U.S. Department of Agriculture in 1935, "Rainfall Intensity-Frequency Data" by David L. Yarnell (6). Only recently the U.S. Weather Bureau published new rainfall-intensity-frequency relationships for the entire United States (7, 8). In some cases it is desirable to compute rainfall-intensity-frequency curves from data taken at the site or in its vicinity. To explain the probability theories involved in computing such curves is beyond this text.

B. Runoff

A portion of the precipitation occurring as rain, frozen rain, or snow is returned to the atmosphere through evaporation and transpiration, and some infiltrates into the ground as ground water. The remainder flows over the surface, beginning with a thin sheet of flowing water and progressively increasing from small tributaries to major streams. This portion is referred to as *surface runoff* (or "discharge," as it is called by the U.S. Geological Survey and other agencies that measure and record the data at various locations).

There are a number of factors which influence surface runoff. Some of the more prominent ones are topography, soil type, size and slope of the area, land use, and antecedent moisture conditions, all of which have considerable effect upon the amount of the total rainfall that infiltrates into the ground.

The *infiltration capacity* for a specific area is the maximum rate at which rain can be absorbed into the soil; it varies with the conditions of the rainfall and the antecedent moisture condition. During a storm of considerable duration, the rate of infiltration is usually large at the beginning, becomes lower, and finally remains virtually constant after a prolonged period. The intensity has an effect also in that a smaller portion of the total precipitation has an opportunity to enter the ground when rainfall is of high intensity and short duration than when intensity is lighter but with a long duration.

From the standpoint of rainfall-runoff characteristics, infiltration represents a reduction in the percentage of the total precipitation falling on a drainage area that contributes to the surface runoff which the area produces.

Surface runoff is that portion of the total precipitation remaining after the losses have been deducted. Waters that originated as surface runoff, plus the subsurface runoff entering a flow channel, constitute the total quantity that must be accommodated by a structure during a period of rainfall. However, the problem in the design of drainage structures is not so much concerned with the total amount of water to be accommodated as with the peak rate at which it must be handled. Drainage structures must be designed to carry *peak rates* of runoff (*peak discharge*). Neither the duration of a peak rate nor the total amount of runoff is of any actual concern in determining the required waterway opening.

A number of methods are used in estimating runoff, some of which have more merit than others. The engineer should understand the limitations of each method and select the one which is most suitable for his particular situation. It must always be remembered that runoff predictions for the future are subject to the laws of chance.

C. Use of Stream-flow Records

The most reliable basis for determining runoff from a given drainage area is a long-term record of actual measurements. An increasing number of streams are being gauged by the U.S. Geological Survey and other agencies. Many of these long-term records are available through the publication of *Water Supply Papers*. However, a proposed drainage structure seldom falls at the location of a gauging station. In many instances it is not even on a stream that is being gauged. Also stream gauging has been somewhat limited to the larger tributaries, and a relatively small amount of data for streams having less than 10 sq miles of drainage area is available. However, a program for gauging small watersheds has been accentuated in very recent years, and data are becoming available.

A detailed discussion of the applications of gauged data to the design of drainage structures is too lengthy for presentation in this book. A thorough treatment of the subject has been presented by Dalrymple in the *Proceedings* of the Highway Research Board (9).

D. Observations of Existing Structures

In the absence of actual flow data, structures already in place on the stream, above and below the proposed location, may provide sufficient information for a design. This method should be used with caution, however, since the record of past performance is often of questionable reliability. It is also difficult to make any approximation of the flood frequencies involved; and factors which might have affected the stage-discharge relationship may not be apparent—such factors as excessive drifts and ice jams, changes in the watershed, and many others.

Whenever such methods are used, the engineer should carefully analyze the existing structure and channel. Size, shape, and slope of structure, entrance conditions, skew, and channel conditions above and below the structure are especially important. Methods for computing the peak flow through existing structures are dependent upon the type of structure, whether it has been operating with full or part-full flow and all conditions which control its performance. For culverts, methods of making such an analysis are published by the U.S. Geological Survey, in Circular 376 (10), and for bridges by the U.S. Geological Survey, in Circular 284 (11). Other sources are listed in the References.

E. Analysis of the Natural Channel

When no existing structures are available, the *slope-area method*, based on Manning's formula, will provide a means of estimating the discharge for a stream at any selected point. In using this method it is first necessary to determine the slope of the energy gradient (S, in Manning's formula) for a selected reach of the channel near the proposed structure site. This is done by constructing a profile of high-water marks on both sides of the channel, extending for some distance from each end of the reach. The formula is then used to compute the discharge for several cross-sectional areas, normally taken at breaks in the high-water profile.

The length and location of the reach selected should be based upon the apparent accuracy of the high-water marks and the accuracy desired for the computed discharge quantity. A length of 200 ft is generally accepted as the necessary minimum. Friction losses are computed from estimates of the channel roughness factor (Table 12-7).

The slope-area method is at best only a source of a fairly reliable approximation. If it is to be used to its maximum effectiveness several precautions are mandatory:

1. Care must be exercised in selecting the particular channel reach to be used as the prototype in the calculations. The straightest and most uniform reach in the vicinity of the site—and one that is, preferably, contracting—should be selected. An adjustment must be made to determine discharge at the actual structure site when either above or below the reach selected. This is done by multiplying the discharge obtained for the prototype reach by the two-thirds power of the ratio of the drainage area at the structure site to the drainage area at the selected reach.

2. The high-water marks should be selected for clear definition and high reliability, preferably at points where velocities are not appreciable.

3. The reach selected should have fairly uniform channel lining and banks, to facilitate the selection of a roughness factor.

The reach having been selected, the average area and wetted perimeter can be determined and the hydraulic radius R computed. From the profile of high-water marks the fall over the length of the reach can be computed and can be assumed to be the same as S for Manning's formula. The value of n is selected from tables of roughness coefficients (Table 12-7).

Substituting these variables in the formula

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

A first approximation of discharge can be made. This discharge divided by the cross-sectional area at the upper end and lower end of the reach will give the velocity at each end, and thus the velocity head $V^2/2g$ for each.

The difference in velocity head is computed:

$$\frac{\Delta V^2}{2g} = \left[\frac{Q/A \text{ (upper end)}}{2g}\right]^2 - \left[\frac{Q/A \text{ (lower end)}}{2g}\right]^2$$

In the first approximation it was assumed that the fall in feet was equal to the slope of the energy gradient. Subtracting the difference in velocity head $\Delta V^2/2g$ from the fall used in the first trial gives a new energy gradient S from which a second approximation of discharge is made.

This process can be continued using the discharge in the second approximation as an assumed discharge in the third calculation and the third for a fourth, until the assumed values are essentially the same as those calculated. An average is then made of the final trial calculations for all of the subreaches between the cross-sectional areas and accepted as the discharge for the site in question.

In addition to the formal method given, several procedures are available for making quick design approximations. In these procedures Manning's or the Chezy formula for open-channel flow and the orifice-and-sluice-gate formula for conduits are used. These are valuable only for preliminary study. Formulas, charts, and nomographs are presented under Hydraulic Design Principles, in Art. IV of this section.

F. Rainfall-runoff Methods

Frequently, when there is no gauged record and other structures are not present peak flow quantities must be estimated in some other manner. The most common methods utilize rainfall intensity-duration-frequency relationships and make adjustments for infiltration rate in determining the peak flow rate.

Several basic assumptions are necessary to use these methods. It must be assumed that peak rates of runoff coincide with peak rates of rainfall, that all portions of the watershed contribute to the peak rate of runoff, that the infiltration rate used will be constant, and that the rainfall intensity is uniform over the entire watershed; and factors such as antecedent moisture and channel storage are neglected. These basic assumptions indicate the limitations of such methods and the limited manner in which they should be used.

The initial step in this type of design is to select the rainfall intensity that corresponds to the frequency of the peak runoff storm which the structure is to accommodate. A considerable amount of rainfall data has been collected for a number of years, and several sources of intensity-frequency curves are available. Perhaps the most widely known and used of these in the past has been *U.S. Department of Agriculture Miscellaneous Publication* 204, published in 1935 (6). More recent studies by the U.S. Weather Bureau have resulted in a broader coverage of rainfall relationships and utilize a longer period of record. One of their more recent publications is *Technical Paper* 25 (8). Various state agencies and others have published material on rainfall in specific areas (7, 12, 13) which usually represent a more dense coverage of stations and are not merely based on a few first-order statistics in each state. When the area in question is an appreciable distance from a first-order station shown in a general publication for the entire United States, it will be more practical to use frequency relationships from locally published sources or to prepare these from data at local stations. Methods of preparing curves are not included; however, a number of methods have been presented by others (2-4, 13, 14).

Before any attempt can be made to select a numerical value for rainfall intensity it is necessary to arrive at a *duration*, or length of rainfall at a given intensity, since rainfall intensity varies with the duration.

One of the basic assumptions in a rainfall-runoff method is that the design storm will be of a duration great enough to allow water to be arriving at the outlet of the watershed simultaneously from all parts of the drainage area. The minimum duration of the rainfall intensity selected then should be the time it takes for the farthermost water in the drainage area to reach the structure site, usually referred to as time of concentration. Otherwise, part of the area will not have contributed to the peak flow at the site when the intensity ceases.

The "time of concentration," then, is the time interval required for water to flow from the most remote point in the drainage area to the outlet. The time of flow in the channel can be approximated by computations of velocity, and some data are available in approximating the overland flow portion of the time. Formulas and charts for approximating times of concentration have been developed (15-19), some of which are included in this section.

The selection of the frequency for the storm on which the design is to be based is identical with the selection of peak discharge frequency discussed in Art. III. The tables included herein (Table 12-3) should be used only as a guide in this selection, with individual situations taking precedence according to the risk of economic loss and damage involved.

Two methods of evaluating some of the variables relating rainfall and runoff will be discussed in the following pages. One of these has been called a "rational" and the other a "semirational" method (20).

Based on a direct relationship between rainfall and runoff, the rational formula used is municipal and airport drainage design (14, 21, 22). Since it rests on the same assumptions as other rainfall-runoff methods, care should be taken to limit its use. Also, it neglects factors which may be of small importance in some instances and of great importance in others. It does not take into account either the retarding effect of channel storage or the variation of rainfall intensity throughout the area during the time of concentration and consequently can produce exaggerated runoff values even when exact values for rainfall and imperviousness factors have been used. Considering also that antecedent watershed conditions are ignored, the error would increase with watershed size. The method, therefore, is more reliable for smaller built areas. Solutions by this method should be confined to areas under 1,000 acres.

The method is expressed by the equation:*

$$Q = CIA$$

where Q = runoff, cfs, for total drainage
C = a coefficient representing the ratio of runoff to rainfall
I = intensity of rainfall, in. per hr (taken from curves similar to Fig. 12-1)
A = drainage area, acres

The value of C is selected on the basis of the type of drainage area, and a weighed—or "averaged-out"—value is often used where the cover varies widely. Tables are included as an aid in the selection of this value (Tables 12-4 and 12-5).

G. Peak Rate of Runoff Curve

The curve shown in Fig. 12-2 is based upon studies conducted by the U.S. Department of Agriculture, Soil Conservation Service (23), and adapted to highway culvert drainage by Carl F. Izzard of the Bureau of Public Roads (24, 25). It is recommended that the use of this curve be limited to watersheds smaller than 1,000 acres and to farmed or wooded lands in the Eastern and Middle Western United States where the rational method is not applicable because of the wide variation of the runoff-coefficient conditions of the watershed at the time the storm occurs.

The curve gives peak rates of runoff that may be expected to be equaled or exceeded on the average of once in 25 years on mixed-cover agricultural watersheds in the humid section of the United States and in localities where the rainfall factor is 1.0. By using the suggested factors the curve can be adjusted for other conditions of rainfall (Fig. 12-3), land use, and design frequencies, as shown in the table and example in Fig. 12-2 (24).

Although this curve is based on stream-flow data, it should not be substituted for such data when available for a particular site. Also, its records of runoff from smaller watersheds are not extensive enough to furnish proof that the same empirical relationships apply in arid as in humid regions.

The values of some of the factors are tentative and subject to change; therefore, the results should be used with caution (25).

Similar methods for use on watersheds within areas of specific soil types have been published for the Allegheny-Cumberland Plateau and the glaciated sandstone and shale areas (26). These should be consulted for drainage problems within those areas.

* Actually, the formula is not dimensionally correct, in equating 1 in. per hr per acre to 1 cu ft per sec. The error is within 0.8 per cent of the numerical results, however, and can be considered as correct for all practical purposes.

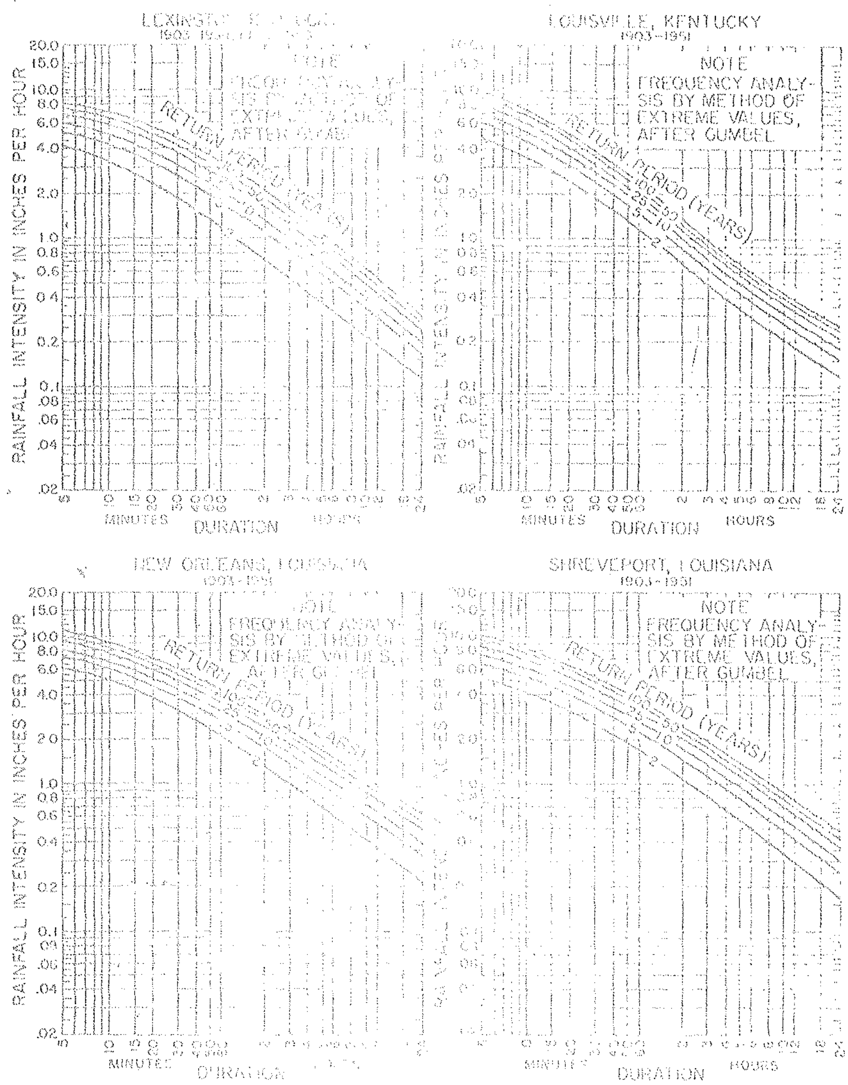
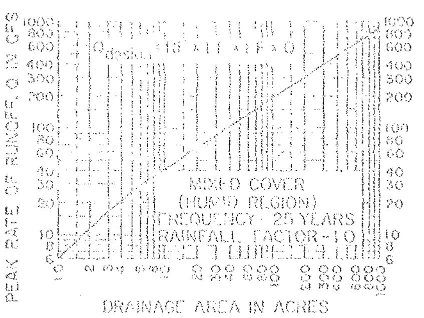


Fig. 12-1. Rainfall intensity-duration-frequency curves. (*Ref. 8. Courtesy of U.S. Weather Bureau.*) These are only 4 of 200 rainfall intensity-duration-frequency curves for stations distributed throughout the United States, Hawaiian Islands, and Puerto Rico included in the reference cited.



Land-use and Slope Factors (LF)

Land slope	Steep, over 3%	Flat, 0.2%	Very flat, no ponds
100% cultivated (row crops)	1.2	0.8	0.25
Mixed cover	1.0	0.6	0.2
Pasture	0.6	0.4	0.1
Woods, deep forest litter	0.3	0.2	0.05

Frequency Factors (FF)

Frequency, years	5	10	25	50
Factor	0.6	0.8	1.0	1.2

Rainfall Factor (RF): See Fig. 12-3

Example:
100 acres near Nashville, Tenn., cultivated land sloping about 0.5%, design frequency 10 years

Solution: (see equation on graph)

$Q_{10} = 1.2 \times 0.9 \times 0.8 \times 190$
$= 170$ cfs

(Accuracy of basic data does not justify carrying more than two significant figures)

Fig. 12-2. Peak rates of runoff for watersheds under 1,000 acres. (*Source: Derived in part from Potter "Surface Runoff from Small Agricultural Watersheds," Research Report No. 11-B, Highway Research Board, 1950. Land use and slope factors for flat and very flat land slopes are estimated and subject to revision when observed data become available.*)

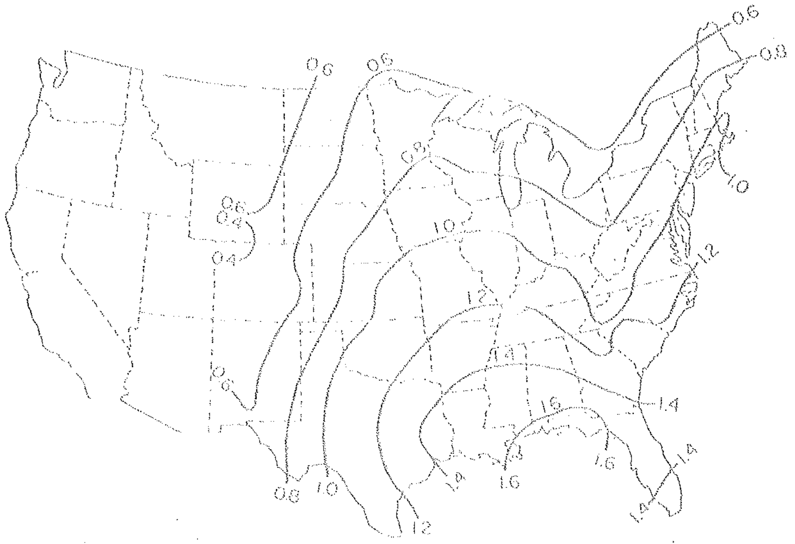


Fig. 12-3. Rainfall factor, for use with Fig. 12-2 in estimating peak rates of runoff. (*Ref. 24*, [illegible]. *Courtesy of ASCE.*)

Det följande avsnittet ur The drainage of airports (Bull. No 14, Vol 42 Univ. Illinois. 1944) har författats av W.W. Horner, konsulterande ingenjör i St. Louis och baserat på ett föredrag som han hållit i the Civil Engineering Department vid universitetet i Illinois.

I. Introduction

1. *Objectives of Airport Drainage.*—The objectives of airport drainage may still be set out in about the same terms as stated by the Joint Engineering Committee in 1931.* "Drainage systems are proposed to remove surface water, intercept seepage, and stabilize ground through the lowering of ground water levels." Really, there are only two objectives:

(a) The reduction in soil moisture of the upper soil horizon, in the interest of better stabilized soil and of increased bearing power. This objective applies equally to the sub-grades of runway pavements and to the surface soils, either between runways or for all-over landing fields.

(b) The removal of surface runoff, during and shortly after periods of precipitation, to the extent necessary to permit landing and take-off safely. The actual extent and detail to which the achievement of these objectives should be undertaken must be determined separately for each airport after an analysis of probable operation and a full study of rainfall occurrence and soil characteristics. A good approach to a decision in this matter is contained in Table III of Chapter XXI, War Department Engineer Manual.

2. *Source of Water.*—The *surface water* for which drainage capacity must be provided consists of that part of the rainfall on the field which does not pass underground through the process of infiltration, and also surface runoff arriving at the field from other adjacent areas. The *sub-surface water* may be either that part of the rainfall on the field which has passed into the soil through infiltration, or may be migrating ground water below a general fluctuating water table.

*Report of Committee on Airport Drainage and Surfacing, U. S. Department of Commerce, Aeronautic Branch, December 1, 1931.

II. Sub-surface Drainage

3. *Necessity for Sub-surface Drainage.*—The extent to which sub-surface drainage is needed or justified has been a matter of controversy between airport engineers from the beginning, and real engineering practice in this direction is only now emerging from the realm of generalized opinion. The engineering of the earlier airports, particularly prior to 1930, commonly involved the installation of sub-

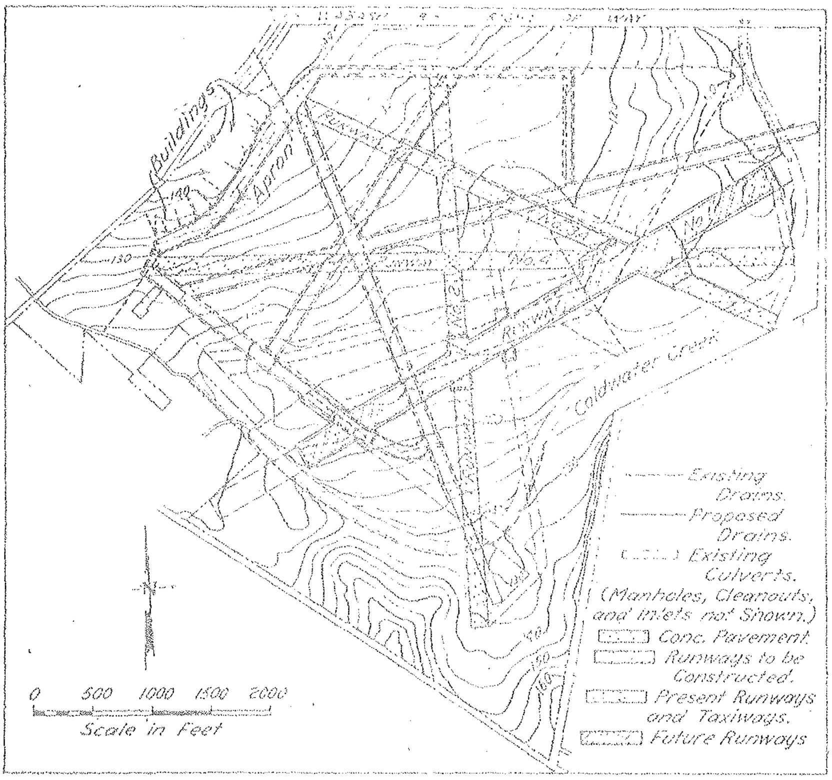


Fig. 1. Drainage Plan for Improvement of St. Louis Municipal Airport (Lambert Field)

surface drainage systems modeled largely on agricultural drainage practice. This was due in part to the availability, and presumed competence, of agricultural engineers who worked out this problem; it was probably due to an even greater extent to the promotional activities of the industries supplying pipe.

Many of the earlier fields were provided with gridirons of such pipe, which in some cases produced results considered highly satisfactory. The principal detrimental effect of such installations was the concurrent assumption that they rendered any considerable surface water drainage unnecessary. Today engineers are fairly well away from the idea that surface drainage can be taken care of in any considerable part by routing it through the soil to sub-surface drains.

Sub-surface drainage need be and always should be considered in connection with site selection. The selection for an airport site of water-logged or swampy land, which would obviously require extensive sub-drains to lower the water table, would rarely be justified unless it were feasible to fill over it to a considerable depth. It is extremely rare to find any justification of the selection of a site that would require complete sub-surface drainage to produce a stable surface; consequently, sub-drainage for the purpose of lowering the water table will generally be carried out only where needed for some small portion of an otherwise satisfactory area.

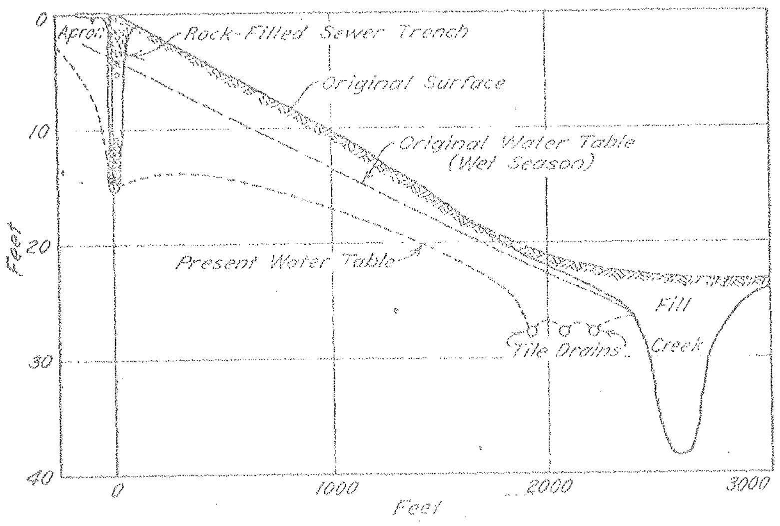


FIG. 2. CROSS SECTION OF LAMBERT FIELD

Lambert Field at St. Louis is a good example of this situation. Originally Cold Water Creek lay across the middle of the airport. In the development plan, this Creek was detoured around one side. A small portion of the land near the original creek banks, where the soil was somewhat finer than average, had a high water table over most of the year. While this area was raised by 3 or 4 feet in the course of grading, it was considered desirable to install several lines of tile drainage prior to the filling (see Fig. 1).

On this project the field had a natural satisfactory slope of about 1 per cent. The soils to a considerable depth were silt loams largely from basal loess, with a very good transmission and percolation capacity. Normally, the water table in the wet season varied from 3 to 5 feet below the surface except in the area referred to, where the low transmission capacity forced it up. In the course of laying out the surface drainage system it was decided to refill all trenches with crushed stone, and this, among other things, has acted to lower the water table within the field materially; particularly along the edge of the apron, the relatively deep sewer line with crushed-stone backfill tended to cut off ground water migrating from the uplands outside the port area. The effect has been particularly satisfactory, and the soil surface at this port has a high stability throughout the year (see Fig. 2).

The question of sub-surface drainage may be approached also through soil types. It is almost invariably a fact that those soils which become unstable when wet have a high silt or silt clay content which results in their also having a low infiltration capacity and a low water transmission capacity. Therefore, infiltration during rainfall does not result in a great increase in soil moisture or any considerable amount of free water which can be removed by drainage system. It is further true for such soils that it is difficult to remove free water from them without permitting some of the soil to escape into the drains.

At the other extreme of the soil classes, the coarse-grained soils will generally have a high percolation capacity, and, if the water table is at a reasonable distance below the surface, free water will percolate to it readily and the addition of under-drains would add little to the picture. With such soils no sub-surface drainage system would be justifiable unless for the purpose of lowering and maintaining the water table at a satisfactory depth below the surface.

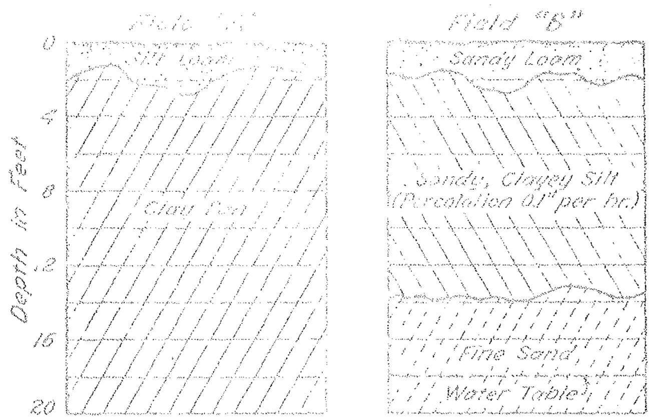


FIG. 3. SOIL HORIZONS, MILITARY FIELDS A AND B

On runway fields, handling planes of the heavier type, sub-drainage lines along the edges of the runways may occasionally be justified in order to reduce the possibility of lateral transmission of free water from the edge of the runway into the pavement sub-grade. For such fields, interrunway spaces are not in normal use, and no considerable expenditure can be justified to make them fully satisfactory for landing. The all-over type of field is useful only for training and light private planes, and a high soil-moisture content, for short and infrequent periods, would not involve a situation serious enough to justify large expenditures.

In the majority of cases the A horizons, or surface soils, because of their organic content, are more porous than the sub-soils. During prolonged wet periods infiltration into these upper horizons will be considerable and will be in excess of the capacity of the sub-soil to dispose of the water through percolation. Quite commonly, therefore, the surface soils will be unstable during wet weather to a depth of 8 inches or more. Under normal conditions this excess water will be removed in part by percolation but primarily by evaporation and transpiration. It could not be removed by sub-drainage systems any more quickly unless the sub-drains were spaced at close intervals such as 10 feet or less, which is completely impractical. The best procedure for improvement of this situation is to build up a strong stand of turf at the earliest possible time, and to rely largely on transpiration for the removal of excess water in the top soil.

An example has already been given in the case of Lambert Field, where sub-drainage was encouraged in the interest of maintaining the water table at a considerable depth below the surface, and effectuated almost entirely by refilling the trenches of the surface drainage system with coarse stone. Two examples of more recent practice are interesting.

Military Airfield "A"

This field covers about 4 square miles, and was developed as a runway field in one section and as an all-over field in the other sections. The surface soil, to depths varying from 1 foot to 3 feet or more, was a fine-grain silt loam having a low bearing capacity in its natural state when wet. It was underlaid by a clay-pan formation throughout, which was practically impervious and had a very low moisture content throughout the year. The only water table was an ephemeral perched water table in the surface soil at the end of prolonged wet seasons (Fig. 3). The surface soil had a fair infiltration capacity rate when

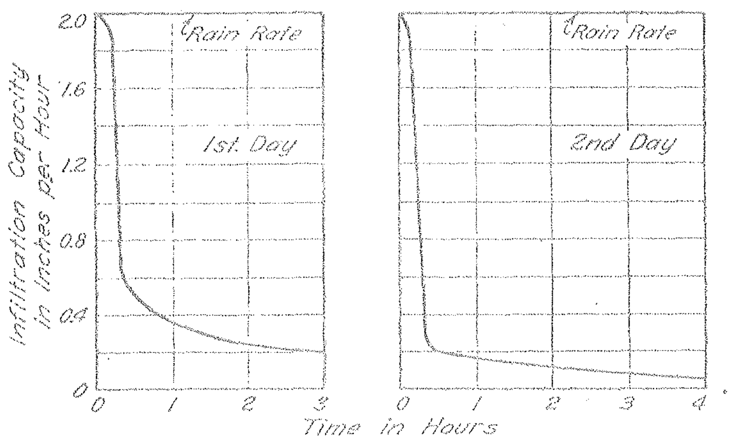


FIG. 4. INFILTROMETER TESTS, MILITARY FIELD A

dry, but a very low rate after an initial rain, as shown by the results of infiltrometer runs, and the rainfall generally had to be disposed of as surface runoff (Fig. 4). Because of the shallow surface soil and a general absence of free water in the lower portion of it, it was obvious that sub-surface drainage would accomplish little, if anything, and would be extremely difficult and expensive to install in such a manner as to prevent the entrance of the soil into the joints. For the all-over field it was accepted as inevitable that the upper 6 inches of the soil would become unstable in prolonged wet weather, and reliance was placed on the turf to remove the moisture by transpiration as quickly as possible. This field is in an area where the soil would never freeze to any appreciable depth. This same surface soil when compacted at optimum moisture content had a fair California bearing ratio (10 to 15 per cent) even when saturated. While it was required to design the pavement for saturated sub-grade conditions, it was quite clear that, because of the low transmission capacity of the soil, the moisture content of the sub-grade would never reach unsatisfactory values, except in narrow strips immediately adjacent to the edges of the runway. Accordingly no sub-surface drainage was installed.

Military Field "B"

This field has a deep surface soil of sandy loam, to an average depth of possibly 2 feet, over a B horizon of sandy clayey silt 7 to 15 feet in depth overlying fine sand reaching to a depth of 50 feet or more (Fig. 3). The normal water table is in this fine sand at from 15 to 30 feet below the surface. Infiltrometer studies were made of this soil during a wet spring period and showed mean infiltration capacities during the first hour of application to average about 0.5 inch per hour. Continuation of these runs indicated that, after 2 or 3 inches of water had been infiltrated, the apparent capacity dropped off to an average value of about 0.1 inch per hour. This latter rate clearly indicated the rate of percolation in the B horizon. This percolation however, even under these conditions, was at about as high a rate as water could normally enter sub-drains, and it was clear that the installation of the sub-drainage system could not appreciably reduce the soil moisture during such prolonged wet periods. Since the water table was far below the surface, no sub-drainage for the reduction of its level was indicated. Therefore, as in the previous case, it was clear that the drainage system would have as its only objective the removal of surface water.

In conclusion, it has become more and more evident that, for properly selected airfields, need for a sub-drainage system generally applies to isolated and relatively small parts of the area; but some improvement in sub-drainage facilities, if it can be produced without too great expense, may be justified to lower somewhat further a water table that might otherwise during wet periods rise to within 3 or 4 feet of the surface.

4. *Disposal of Surface Water Through Ground.*—While it has become clear that satisfactory airport drainage cannot be accomplished through the use of sub-drains entirely, or in greater part, yet, on an airport project where the soils are largely sands and gravels, it is very tempting to try to dispose of the greater part of the surface water through the ground. This possibility had serious consideration in connection with the design of two large projects, namely, the Washington National Airport, and the New Idlewild Airport in New York City.

The Washington National Airport was built up on the Gravelly Point shallows of the Potomac River by hydraulic dredging. The filling was carried out first for the runways by trenching out the existing Potomac River mud down to the old gravel, and thereafter filling in along the runways with the sand and gravel from the channel of the river. These fills were made for a width of about 500 feet with mixed dredged material, ranging from fine sand to boulders of 12 inches or more. The intervening field pockets were then filled by dredging in Potomac River mud. The level of the field is about 10 feet above ordinary river level of the Potomac, and it was anticipated that the water table in the sand-gravel fills would be only slightly above the river level.

It seemed that no sub-drainage would be needed in the runway fills, and that none could be installed in the pocket fills, which were liquid mud and are still in the process of consolidation. The work was carried out under the Washington National Airport Commission of which Colonel Sumpter Smith was Chairman, and on which the Civil Aeronautics Administration was represented, and acted as advisors on general airport planning. The selection and design of runway pavements was carried out by Mr. H. H. Houk, Chief Engineer, for the Commission, and the preliminary plans for drainage were prepared by the writer, as consultant. The plans provided for a relatively complete system of surface drainage, with the initial lines laid in the sand and gravel shoulders, parallel to the runway pavements. The complete plan involved inlets and laterals in the field pockets, but it was not expected that these would be constructable for several years. The detailed plans and the general supervision of construction was under the U. S. Army District Engineer at Washington. After the design and general plan of the surface drainage system had been completed, the District Engineer questioned the necessity for a positive system of pipe drains, and expressed the opinion that the surface water could all be disposed of by infiltration into the sand and gravel runway fills, and transmitted through these fills as ground water through an outlet at the runway ends into the Potomac River. Members of his staff had demonstrated that a bucket of water poured on the porous fill disappeared almost immediately. It was quite obvious that no such disposition could be made of the amount of surface water involved, and that there was a lack of realization of the mechanics of infiltration and ground water transmission. For example, it does not occur to the layman and quite often not to the engineer, that water discharged on a small porous area,

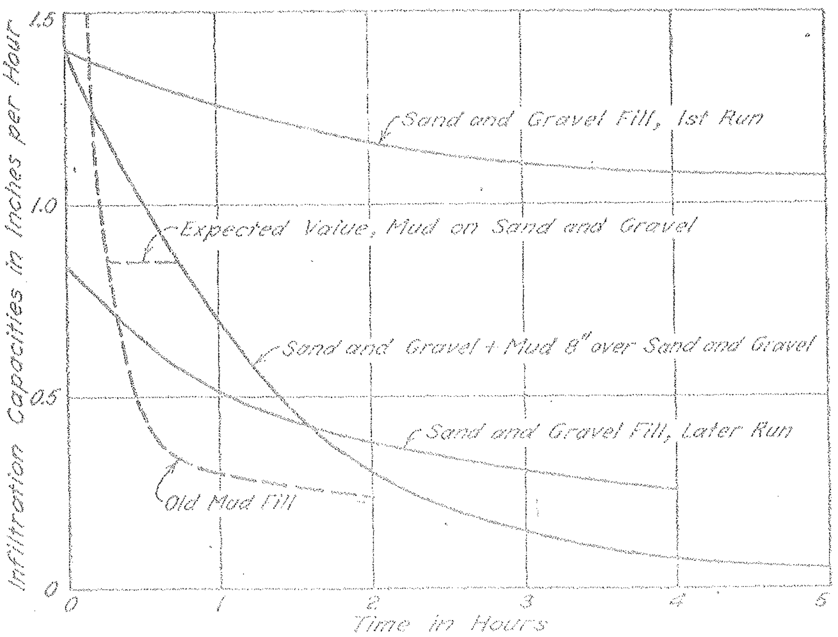


FIG. 5. INFILTRATION CAPACITY, SAND AND GRAVEL FILL, WASHINGTON NATIONAL AIRPORT

disappears quickly because the voids are empty and water can spread laterally in all directions, whereas water applied uniformly on large areas of this kind can only be disposed of by direct downward percolation.

A great deal of testing and research work had to be carried out before the local engineers became convinced that this idea had extremely limited possibilities. At the writer's suggestion, standard rainfall simulators were secured from the Soil Conservation Service and artificial rainfall was applied on 6 x 12-foot areas. The results were so interesting that they are rather completely summarized in Fig. 4.

It would seem that a sustained infiltration capacity of only a little over 1 inch was evidenced on the first application of rainfall, and that this dropped down to values comparable to those for an average soil on additional applications. Undoubtedly this reduction in capacity was due in part to the effect of rain impact in re-grading and choking in the fines; but it may also have reflected the limited storage available in the sand and gravel above a relatively high water table.

Actually it was not feasible to leave these sand and gravel shoulders exposed for infiltration purposes, and the original plan involved top soiling them. A second series of tests was run on an area where mud was incorporated with the sand and gravel in about equal amounts to a depth of 8 inches. The resulting infiltration curve is shown in Fig. 5. It is obvious that such a combination has a lower infiltration capacity than either the sand and gravel or the mud alone. A better method would be to place the mud top soil over the sand and gravel without mixing.

From these results it was clear that only a small part of the tributary surface runoff could be taken in through the sand and gravel surface, even if left exposed, and that the proposed system of pipe drains would be necessary and would be very little less in extent than originally contemplated.

The idea of disposing of surface water into the porous fill once having been proposed became extremely tenacious, and the District Engineer raised the second question, namely, if this water cannot be put in through the ground surface but must be taken into inlets, why not discharge it into the sand and gravel fill through porous pipes? Two objections were raised to this: (1) that the amount that could be so discharged would not be very great, and (2) that the sand and gravel fill had been shown to contain a large percentage of extreme fines, therefore porous pipe that could exude water might also under a reversal of conditions, say a high-river stage and no rainfall, introduce water and sand into the drainage system. The second objection was never received with much conviction, but the first was subjected to a series of full scale tests. For these tests a wooden box inlet was constructed to which there were attached several lengths of perforated metal pipe. The pipe and inlet were filled with water and the discharge into the sand-gravel fill was determined by the drop of water level in the inlet.

These tests indicated that, with a head of 2 feet on the pipe perforations, on the average, water could be discharged into the sand and gravel fill at a rate of about 0.15 cubic feet per second per 100 feet of pipe length. This value is on the order of 10 or 15 per cent of the tributary inflow.

While the quantity of water shown to be distributable in this manner by those tests had to be discounted because of the possibility of lower heads and the regrading and further compaction of the fill, and while the amount was a relatively small proportion of the required pipe capacities, nevertheless the decision would have been to use perforated pipe if it had been found to be economical. Actually it was found that the increased cost of perforated pipe more than offset the reduction in size, and the proposal in this form was abandoned.

After construction was actually started it was found that, as the result of infiltration, a high water table was being permanently built up in the sand and gravel fill, and that some sub-drainage would be necessary to keep the water table appreciably below the surface. Accordingly, while no change was made with respect to the main sewers, the smaller lines along the runways were constructed with partially open joints. This was accomplished by chipping out a part of the spigot of the concrete pipe on the two sides of the pipe, leaving out the cement mortar at those points, and covering the joint with wire mesh. The system appears to operate in the following manner:

At the beginning of heavy runoff, water percolates out from the pipe into the sand and gravel; shortly this becomes saturated and percolation is reduced to a small quantity; between rains, however, water percolates into the pipes and prevents the water table from rising appreciably above the level of the sewers.

Idlewild Airport

This project now under construction is probably the largest civil airport proposed in the United States. It is constructed on the old marsh, on the Long Island side of Jamaica Bay, which was originally at about elevation + 5 feet above mean low tide. The filling was carried out by hydraulic dredging from the Bay and the material is a fine beach sand similar to that at Rockaway Beach. The finished elevation of the field varies from 12 to 15 feet above mean low tide, thus requiring a depth of sand fill averaging 8 or 9 feet when compaction of the marsh mat is taken into account. Since the fill has a dimension

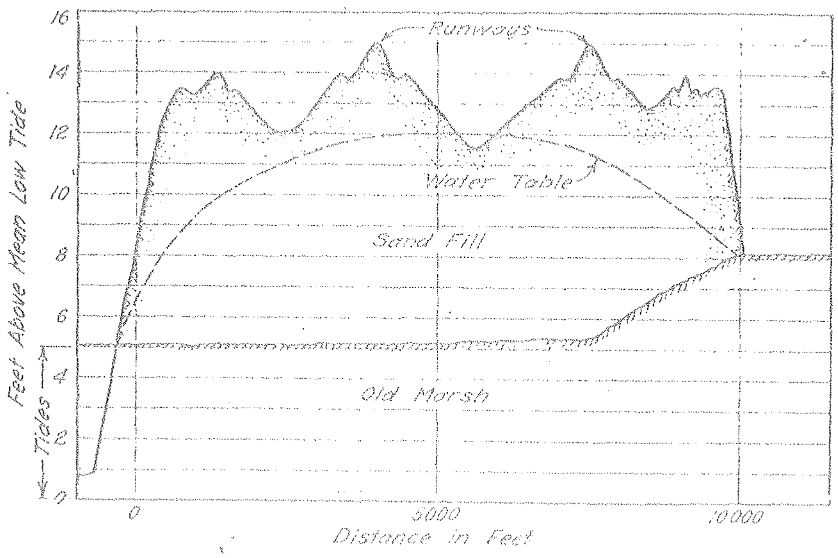


FIG. 6. WATER TABLE, IDLEWILD AIRPORT

of nearly 10 000 feet in each direction, the center of the sand fill is a long way from the outlet of ground water along the margin.

When the writer was called in as consultant on drainage, he recommended a positive system of pipe drainage to carry the whole of the expected surface runoff, and also called attention to the probability that a water table would be built up in the sand fill that would be very close to the surface. His function as drainage consultant was to determine the required capacities of the storm drains, actually to design one section of the storm drainage, and to set up a method of applying the design to the remaining sections. The details of this work are summarized in a later section of this paper.

As a result of the question which was raised about ground water, the engineer for the project, Mr. Jay Downer, installed, in September 1942, eight observation wells, and later installed eight additional wells. The ground water level was measured in these wells at intervals, and generally after each rainfall period. The character of the water table which was built up is shown in Fig. 6. As would be expected, this water table shows a slight but steady recession during dry weather, and a quick rise following rainfall. A 1-inch rain produces about 1 foot of rise in the ground-water table in the center of the field; a 3-inch rain is capable of raising it about 2 feet. The average water table in the center of the field is now about elevation 12, or very close to the intended finished grade in the field pockets. The engineers have under consideration the installation of some sub-surface drainage to accelerate ground water depletion.

In this project, as at Washington National, the possibility of disposing of rainfall into the fill appeared in an even more attractive form, since the whole of the interrunway space had been filled with porous sand up to the surface. Portable infiltrometers were set up on the undisturbed sand surfaces and infiltration capacity values were determined. The average results are shown in Fig. 6. Here again infiltration capacity was high on the first application but appeared to be reduced steadily thereafter. Actually these lower values occurred after a mounded water table had been built up around the infiltrometers, and really represented the rate at which the sand could distribute the infiltrated water, and not the true infiltration capacity of the sand surface. It seems probable that infiltration capacity would be sustained for several hours at rates of about 3 inches if storage space were available in the sand.

For this field there appears to be a very delicately-balanced condition, undoubtedly a large amount of rainfall can be disposed of into the sand provided the water table in the sand can be held down several feet by sub-drainage. It is entirely possible that all the rainfall on the sand surface can be satisfactorily disposed of in this manner. It is highly questionable, however, whether these sand areas can dispose of the run-off from the paved surfaces also.

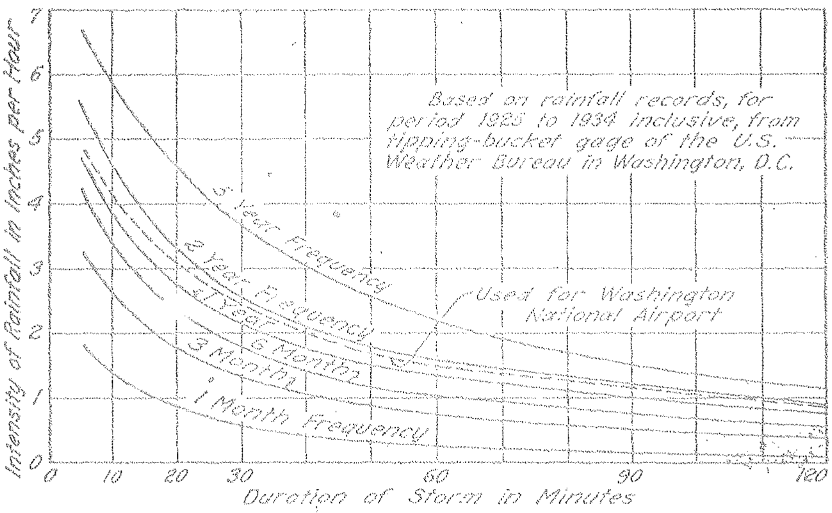


FIG. 7. RAINFALL INTENSITY CURVES, WASHINGTON, D.C.[1]

III. SURFACE WATER DRAINAGE

5. *Removal of Surface Water.*—The common, and generally the primary, problem in airport drainage is the removal of surface water to the extent required to permit safe and satisfactory landing and take-off of airplanes. Almost invariably it is necessary to investigate the adequacy of the water courses in the vicinity to determine whether some improvement of them is necessary for the protection of the field from floods and also whether they can satisfactorily serve as outlets for the field drainage system. Many airports are situated on valley lands, and it is quite common to find that these lands in the past have been subject to flooding from adjacent water courses, and channel improvement or leveeing of the field may have to be undertaken. Each such situation, however, is a separate problem, and should be considered as coming under the head of "flood protection" rather than airport drainage itself. In the discussion which follows, it is assumed that the field has been rendered free from flood hazards and that an adequate outlet for the field drainage is available.

6. *Rainfall.*—The origin of the water to be removed by a surface drainage system is obviously the rainfall on the field surface, and the first investigation must necessarily be to determine the rates and character of rainfall for which the system should be adequate. The most extensive study of rainfall occurrence is that which was made by

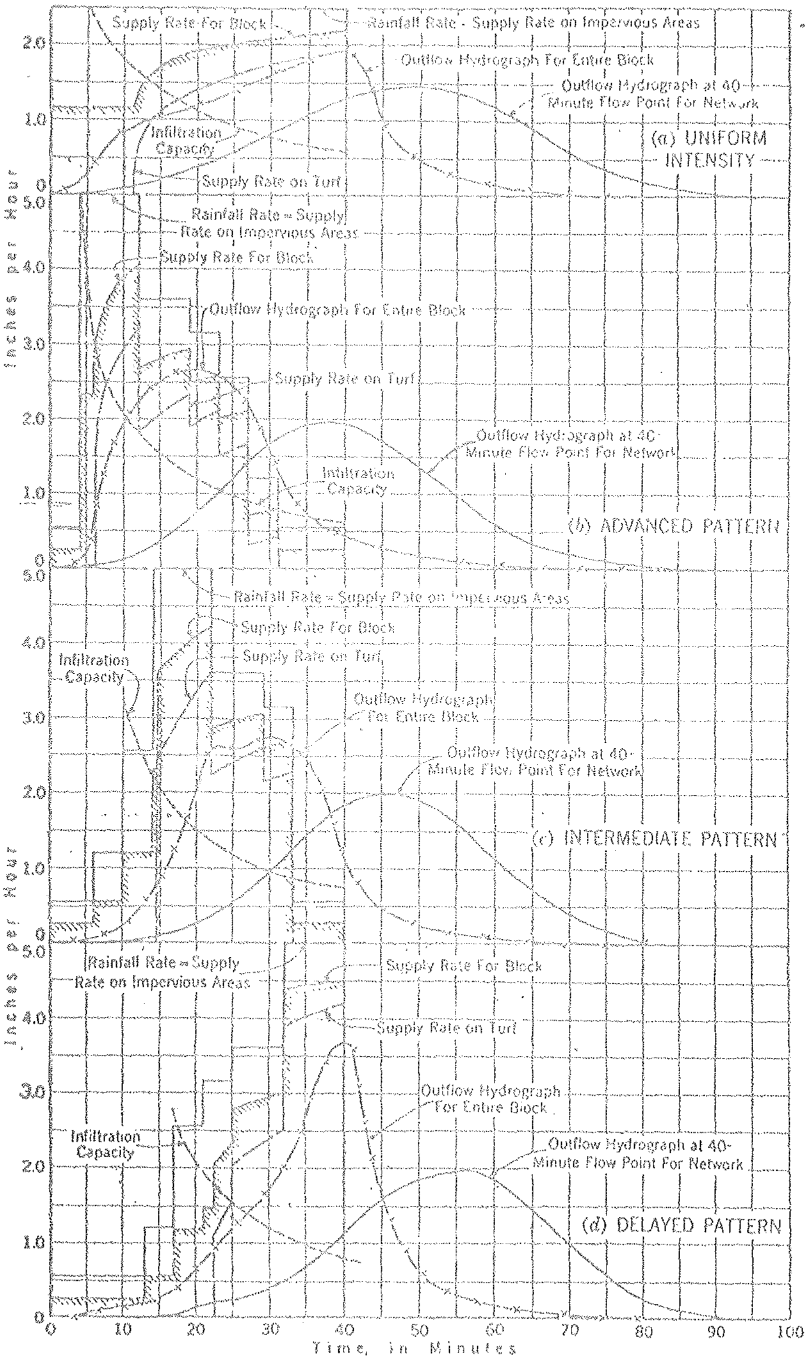


FIG. 8. RAINFALL CURVES; 40-MINUTE RAIN

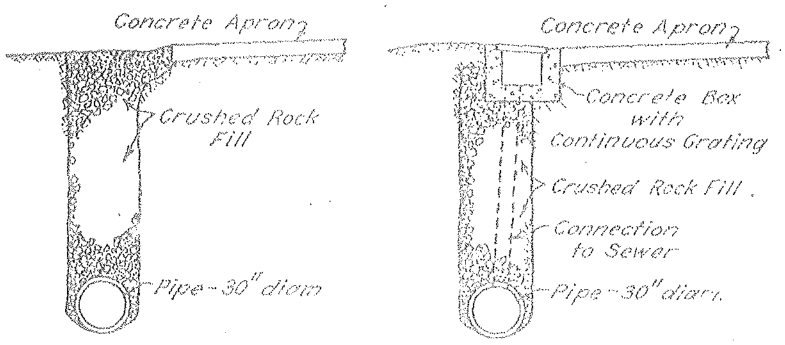


FIG. 12. INITIAL INTAKE INSTALLATION ALONG APRON, LAMBERT FIELD

Yarnell.* Municipal engineers have made more detailed studies for the larger cities; in Fig. 7 is shown a rainfall curve which was developed for Washington, D. C. However, similar curves can generally be prepared with sufficient accuracy from Yarnell's data. These curves must be interpreted as follows:

For a period of precipitation of 30 minutes, an average mean rate of rainfall of 2.55 inches per hour may be expected to be equalled or exceeded once in 2 years; note that this refers only to mean or average rate, and takes no account of the actual rates at which rain may occur within the 30 minutes.

In these studies it was found that precipitation practically never occurs at anything approaching a uniform rate for a period, say, of 30 minutes. The commonest type of precipitation involves a rate much higher than the average for a short part of the time, with this high rate occurring somewhat before the middle of the period. The actual pattern of rainfall occurrence is an important factor in determining the resulting rate of runoff as shown in Fig. 8.†

*United States Department of Agriculture, Miscellaneous Publication No. 204, August 1935.
†From "Surface Runoff Determination from Rainfall Without Using Coefficients," W. W. Horner and S. W. Jens. A.S.C.E. Transactions, Vol. 107 (1942).

Följande utdrag om dränering av flygfält har hämtats ur Airport planning av Ch. Froesch och W. Prokosch (New York & London 1946).

rainage

Almost every airfield will require drainage of water ·ising from one or more of the following sources:

1. Surface water from rainfall or snow.
2. Subsurface water.
3. Water draining into the airport area from adjoining land.

Wherever possible, airfield design should allow for ıtural drainage to accomplish the above. Artificial ·ainage must be designed and installed to take care ' water removal in excess of that hauled by natural eans. Since an elaborate drainage system may represent a large portion of the cost of airfield construction, becomes important to analyze the prospective site r its drainage characteristics.

Surface waters can be removed in only three ways: evaporation; by percolation through the soil; by nduction. In airfield design, the first way may be sregarded since, to have an all-weather field, surface ıter must be removed immediately and, therefore, no ne can be allowed for evaporation. Whatever water not absorbed by the soil itself through percolation ıst be carried away by drainage devices, such as tches or subdrains.

The foregoing paragraphs on *Grading* have indicated the necessity of making a comprehensive soil survey of the site so that embankments may be properly placed and compacted. The same soil survey should be used in the design of the drainage system to indicate the nature and extent of the drainage system required. The soils must be analyzed for their porosity. Furthermore, the various strata of soils must be charted and analyzed, since a shallow layer of porous soil underlaid by strata of clay will allow for surface drainage only to the extent of the top layer and, therefore, will cause subsurface drainage problems.

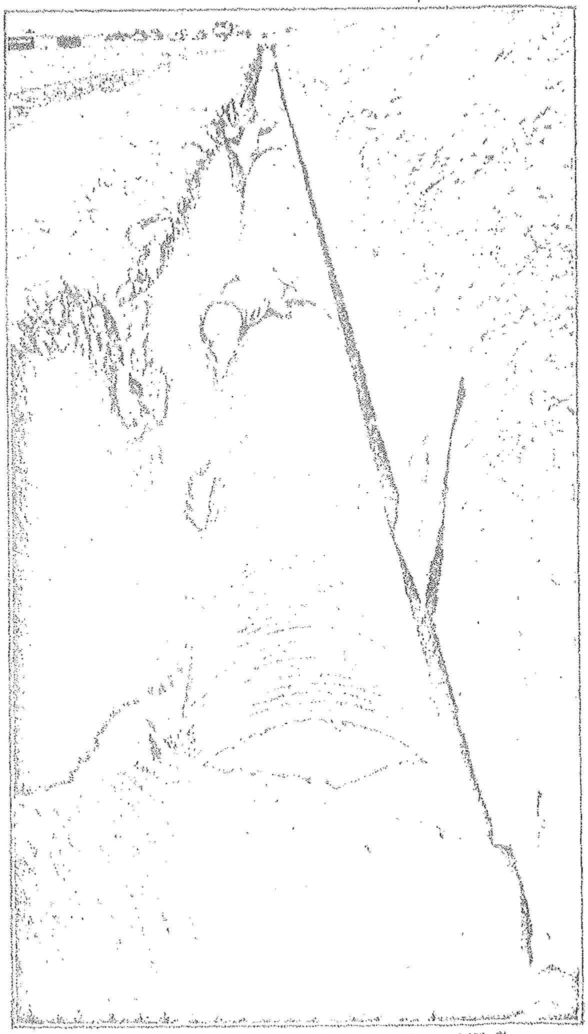
It becomes apparent, therefore, that the airport designer must have a survey showing the following: extent of principal soil types; available outlets for natural drainage; contour intervals. On this map should be superimposed the runway, apron, and building layout, indicating elevations of principal points. Cross-sectional and longitudinal profiles of runways and aprons must be drawn. Soil profiles, ground water profiles, and information on infiltration capacities of the soils in question must be available. In addition, the designer will require data on rainfall and snowfall collected over a 5- to 10-year period taken from

Weather Bureau observations in surrounding territories. And finally, temperature data, including the maximum depth of frost, should be available.

Subsurface drainage may be required to accomplish the lowering of the water table of the area and to drain waters resulting from percolation of surface waters through the soil. Determination of both these conditions may be made from the soil survey. Water which may drain into the airport area from surrounding territory should be disposed of by means of proper grading, ditches, or drains beyond the immediate runway area in order to prevent a possible loss of subsoil stability, or to keep the water table of the airfield area down to a safe level.

Whether runways are to be paved or sodded, surface waters must be removed quickly so as not to impair the operating efficiency of the field. Further, they must be removed in such a manner as to prevent erosion of the soil, and to prevent impairment of the stability of the embankment subsoil by softening. Runways should be crowned in the center sufficiently to discharge surface water to their sides. Concrete gutters, topped with removable concrete covers pierced with holes to admit drainage, may be placed alongside the runways. These gutters are connected to subdrains which carry off the water to discharge points. This method is expensive to install and is infrequently used. Another more common method is to carry the water from the runways across the shoulders to a shallow ditch running along either side of the runway; subsurface drains are placed under the ditch with inlets suitably spaced. A third, and the least expensive, method is to carry the water from the runway across the shoulder to a valley or ponding area where the water may collect (as in a catch basin). From this point the collected water may be carried away more slowly by means of subdrains. In addition to economies resulting from the use of smaller drainpipe sizes, this method allows for utilizing removal of water through the soil. However, care must be exercised to prevent soil erosion and soil softening when this method is used. This method is of particular advantage wherever large amounts of water, precipitated at a high rate (such as tropical showers), must be disposed of quickly. A fourth method of removing surface water from runways is by the installation of vitrified clay Web Skip-Pipe continuously along both sides of a runway. This pipe is comparatively easy to install, is low in cost, and is designed to withstand the heaviest aircraft wheel loads (Fig. 10).

Experience has proved that French drains will not perform satisfactorily for the removal of surface water from large areas such as airports because of their tendency to become filled with silt and because they may freeze in cold weather. Perforated corrugated steel pipe (with or without bituminous covering) may be used for subdrains where the action of the soil will not be corrosive. The subdrain may consist of corrugated iron, vitreous clay, or concrete pipe reinforced under runways, taxiways, ramps, and shoulders. All drainpipes should be of ample size to insure satisfactory performance under any conditions of peak water removal.



Courtesy American Rolling Mill Company

FIGURE 11. CORRUGATED IRON DRAIN.

Manholes, spaced at suitable intervals, should be provided to allow for removal of silt from the drainage system. All drainage pipes should be pitched sufficiently to prevent the collection of silt at any except predetermined points.

The methods of estimating run-off, sizing, and spacing of drains and inlets, and design of pipe are subjects beyond the scope of this book.

The surface drainage system should be kept entirely separate from that used for subsurface drainage. Subdrainage should be designed to discharge directly into outfalls. There are a number of common soil combinawhich will indicate the necessity of providing ·ains. Where pervious soils occur above and im- ous below, water will seep through the top layer, t on the impervious, and form unstable soil unless ved. Where soils are impervious above and per- below, trenches may be dug through the top allowing the water to drain to the pervious layer, › it may be removed naturally or by drains. Ir- ar strata of pervious or impervious soils may al- he collection of water in pockets or springs, which equire separate drains leading to the main drain- ystem.

the water table is close to finished grade, it may ril the stability of the surface, cause frost heaves, use flooding of the field during periods of exces- rainfall or spring thaws. A subdrainage system d then be installed to lower the table. If the ity of the subsoil is such that subdrains will not ice proper drainage and, therefore, permit the rance of frost heaves, such soil should be re- d and replaced with soil of th proper character-

Various systems of subsurface drainage are in common use, and are illustrated in Figs. 11 and 12. Pipes which may be used for this work are concrete pipe, vitrified clay pipe, unglazed drain tile—all laid with open joints; also corrugated metal pipe. Pipes are laid in open trenches surrounded with gravel or crushed rock. The back filling of these trenches should be compacted with the same care as that given to the construction of embankments in order to prevent future settlement.

In designing any drainage system, it should be borne in mind that the most frequent pavement failures in runways, taxiways, and aprons may be traced to the loss of stability of the subsoil, resulting from poorly designed, improperly placed, or inadequate drainage. Drainage problems should be given the most careful study not only to protect the initial investment but also to insure reasonable conditions of maintenance.

Slutligen har nedan medtagits ett avsnitt ur Airport drainage utgiven av Federal Aviation Agency (Washington 1960). Det kan vara av intresse att konstatera att den återgivna sektionsritningen över dränering av landningsbanor (fig. 25) vad avser grundvattenavledningen visar påfallande likheter med den efter Cedergren och Lovering (1968) återgivna sektionen rörande dränering av en större väg, highway (fig. 4 i nämnda utdrag).

An airport should have smooth, well-drained operational areas with sufficient stability to permit the safe movement of aircraft under all-weather conditions. Drainage is of vital importance in the development of an airport.

The drainage system should be built before or during the grading operations because draining and grading are interrelated. A well-graded airport is not an all-weather airport unless adequate provision has been made for the rapid removal of surface and subsurface water. A drainage system cannot be expected to function properly unless the airport area has been correctly graded to divert the surface runoff into the system. In the absence of adequate stabilization or pavement, drainage does not assure an all-weather airport, but it will shorten the interval of nonuse.

The design of adequate drainage for an airport is an important engineering problem because it involves the following considerations:

- Extensive areas.
- Varying soil conditions.
- Heavy concentrated wheel loads.
- Extensive paved areas for runways, taxiways, and aprons.
- Relatively flat longitudinal and transverse grades.
- Shallow watercourses.
- Side ditches.
- Concentration of outfall flow.

The large area that must be drained on an average airport requires an economically designed drainage system to realize the full value of the investment made. Sound engineering principles must be applied in the utilization of all available data, such as topographic maps; soil reports; determinations of water tables; intensity, frequency, and duration of precipitation; climate and temperature reports; and nature of the area surrounding the particular site

The topography of the site and the outlying areas affect the final layout of the runways, taxiways, aprons, and buildings. The location of these facilities will control the grading and the extent of drainage required. It is important that the grading of the airport be such that all shoulders and slopes drain away from runways, taxiways, and all paved areas. After final elevations on the airport have been determined, all surface flow of water onto the site must be intercepted and disposed of, any depressed or low spots on the site must be drained, and all surface runoff must be accumulated and directed into adequate outfalls.

Enough tests should be taken to identify all soil types because texture, permeability, horizon, and capillarity have a pronounced effect upon their drainability. Because of its effect on the stability of soils and on the ultimate design of the airport the water table should be accurately determined over the entire area. When a high water table does exist, provision must be made for either lowering it or raising the finished pavement grades.

In designing a drainage system it is important to determine expected precipitation at the airport site. Intensity-frequency data or precipitation may be obtained from several sources, such as: U.S. Weather Bureau, U.S. Department of Agriculture experiment stations, Soil Conservation Corps, State hydrographers' offices, State highway departments, or local drainage districts. These sources should be explored for records available for a particular location, because all computations in the drainage design for intensity-frequency, intensity-duration, frequency-duration, and supply data should be based on actual precipitation records.

Available climatological data should be studied, especially maxima and minima temperatures, particularly during the season when freezing and thawing normally occur. These data provide facts on depth of average frost penetration, normal amount of yearly snowfalls, and maximum and average depths of snow for winter months. In certain locations subject to warm (Chinook) winds after heavy snowfalls causing rapid melting and large flows, a study of snowfall records may reveal an unusual runoff condition.

The purpose of airport drainage is to dispose of water which may hinder any activity necessary to the safe and efficient operation of the airport. The drainage system should collect and remove surface runoff from each area, remove excess underground water, lower the water table, and protect all slopes.

Natural drainage normally does not meet these requirements. Artificial facilities must be sufficient to provide for present requirements and any future enlargements of the system. This may mean the installation of a portion of a drainage system to supplement the natural drainage on the site or it may call for a complete system to drain the entire airport area. A proper understanding of all contributing drainage factors determines the extent of the facilities required on each particular airport.

An inadequate drainage system can cause serious hazards to air traffic at airports. The most dangerous consequences of inadequate drainage systems are saturation of the subgrade and subbase, damage to slopes by erosion, loss of bearing power of the paved surfaces, and excessive ponding of water.

RAINFALL

The determination of the amounts of rainfall and runoff to be used as a basis for design of a drainage system is the primary step to be considered by the designer. The rate of storm runoff, including melting snow and ice which will flow into the system, must be established in the preliminary design stage.

Engineers have conducted many investigations and studies to find a basis for making reasonable estimates of the intensities, frequencies, and durations of rainfall for different locations. The investigations of David L. Yarnell, senior drainage engineer, Department of Agriculture, which were published as Miscellaneous Publication 204 (August 1935), represent many years of research. This publication should be an integral part of every drainage engineer's library. The data in this publication are generally accepted by drainage engineers as the most concise pertaining to the subject. The publication shows the average frequency at which excessive rates of precipitation occur in various sections of the United States and the intensity and duration of those rates. The data presented are fundamental for the adequate and economical design of airport drainage systems throughout most of the continental United States.

Mr. Yarnell's publication shows the isohyetal intervals on base maps of the United States for maximum precipitation of rainfall for different periods of duration and for different intervals of time. Charts for storms occurring once in 5 years, for 5-, 10-, 15-, 30-, 60-, and 120-minute duration and maximum 1-hour precipitation to be expected once in 2 years and 10 years, are reproduced in Figures 1 to 8, inclusive. Figure 9 shows a typical study which could be important in determining quantities of runoff for design purposes. Additional material in this connection is presented in Section IV.

The engineer should not rely solely on the data obtained from Department of Agriculture Miscellaneous Publication 204. He also should get in touch with the local Weather Bureau office, city engineer's office, State highway office, State hydrographer's office, and perhaps local drainage districts or utility companies to ascertain whether additional records are available for the location under consideration.

Recent investigations show that results of studies regarding the probable intensity, frequency, and duration of rainfall in particular locations are more likely to be correct and conservative if they are obtained from the records of many stations rather than of one station. The center and outer limits of storms can be accurately determined only through use of a closely spaced network of rain gages covering the vicinity traversed by the storm. More accurate predictions can be developed from the study of data for many stations in a larger area.

The importance of the rainfall-intensity factor is well known to drainage engineers, particularly in its relationship to total runoff. However, rainfall intensity and duration determine the amount of precipitation in any given storm. General storms are usually characterized by low-intensity precipitation of long duration, whereas local storms have high rates of rainfall for short duration. Either of these types can produce approximately the same amount of precipitation. Storms of the first type, however, usually are more destructive and are the ones generally considered in airport drainage design.

When practicable, the actual record of daily observations kept by the Weather Bureau should be studied. From these records may be obtained the data required in plotting an intensity-duration curve from which the rate of supply of runoff for the design may be determined. The curve is plotted from the records of excessive individual storms for the desired period of frequency. Similarly, as noted on Figure 10, a series of curves for different periods of frequency can be plotted from the records of excessive individual storms by the use of intensity per hour as ordinates and duration in minutes as abscissas.

When it is impracticable to obtain actual Weather Bureau data or any other supplemental records, the desired curves can be plotted by use of the charts in Miscellaneous Publication 204. This may be done by spotting the airport location under consideration on the base maps of the charts. At the start, obtain the intensity for the location in question by interpolating between the two isohyetal lines on the chart for 5-minute rainfall, in inches, to be expected once in 2 years. For example: the intensity from the chart is found to be 0.43 inch for the location used in the design problem of Section IV. This gives the 5-minute rainfall, in inches, to be expected once in 2 years. To convert this intensity to a 1-hour basis for plotting purposes, the quantity must be multiplied by $60 \div 5$ or 12. The result of $12 \times 0.42 = 5.16$ inches. Plot this intensity on coordinate paper (using inches per hour as ordinates and times in minutes as abscissas). Continue by noting the intensity from the charts for 10-minute, 15-minute, 30-minute, etc., rainfall in 2 years and plot this converted intensity on the coordinate paper for the desired location. This will give sufficient values on the coordinate paper to draw a smooth curve through the points. The curve will indicate the intensity of rainfall to be expected for any time interval from 5 minutes to 2 hours for a storm that might occur in 2 years.

The same procedure is followed for occurrences of 5, 10, 25, and 50 years, plotting the results on the same sheet of coordinate paper. Figure 10 is a graph exemplifying this method. The use of the data in design is taken up later under *Design of Drainage System* and is the basis for estimating runoff supply.

RUNOFF

After rainfall rates have been studied there remains a problem of determining what portion of the rainfall must be accounted for as surface runoff. The runoff rate depends on a number of conditions and is seldom constant for any given area during a single period of precipitation. The following factors have a pronounced influence on the rate of runoff for a single area:

- Intensity and duration of the rainfall.
- Type and moisture content of the soil affecting infiltration.
- Perviousness or imperviousness of surfaces.
- Slope or irregularity of surfaces.
- Extent and condition of vegetative cover.
- Snow cover.
- Temperature of air, water, and soil.

Many studies have been conducted during the last decade in attempts to determine a method for estimating the amount of runoff when affected by the varying factors actually met under field conditions. The studies have covered infiltration of soils; runoff from pavements, turf areas, plots of different lengths and of different slopes; rainfall characteristics as related to soil erosion; and numerous other conditions. Some studies have contributed valuable data toward a more comprehensive understanding of the complex problem. Until a more precise method for determining the amount of runoff from given areas is developed, the following is considered to be the practical course.

The Rational Method of calculating runoff is most universally applied and recommended by engineers in drainage practice. The method has come into favor because it enables the engineer to apply judgment directly to specific determinations which are subject to analysis after consideration of local conditions.

The Rational Method is based on the direct relationship between rainfall and runoff. It is expressed by the equation $Q=CIA$, in which Q= the runoff in cubic feet per second from a given area; C= a runoff coefficient depending upon the character of the drainage area; I= the intensity of rainfall in inches per hour; A= the drainage area in acres. The value of C to be used must be based on a study of the soil, the slope and condition of the surface, the imperviousness of the surface, and the consideration of probable future changes in the surface within the area. The value of I to be selected depends upon the curves for the intensity of rainfall plotted for the local vicinity and the assumed period of recurrence, as well as the period of concentration required for surface runoff to flow from the most distant point in the area under study to the nearest inlet structure or point of collection. Design should be governed by the greatest intensity of rainfall during this period of concentration and not by some intensity for a shorter period. The value of A is measured and can be accurately determined.

A frequency of 5 years is generally recommended for estimating runoff from airports since the damage or inconvenience which may be caused by greater storms is insufficient to warrant the increased cost of a system based on a design for storm occurring for a frequency of more than 5 years. The design should be checked, however, with storm runoff in excess of 5 years to ascertain whether serious damage would result from such storms.

RUNOFF COEFFICIENT

The runoff coefficient or factor, as it is sometimes designated, is the percentage of rainfall on a given area that flows off as free water. This percentage will seldom reach 100 percent, even with steep slopes, because impervious surfaces absorb some moisture and small depressions and irregularities hold back additional amounts. During a storm, the percentage of runoff will increase gradually as the soil becomes saturated, the impervious areas become thoroughly wetted, and all depressions filled. Then the percentage will remain fairly constant, varying directly with the intensity of the rainfall. The composite effect of all those factors must be taken into consideration.

Many authorities, such as Burkli-Ziegler, Kuichling, Bryant, Dorr, and Horner, have presented estimates for "values of relative imperviousness" for different types of urban surfaces, to be used in conjunction with their various formulas. These estimates cover conditions applicable to the design of drainage systems for large areas, usually within urban surroundings where the character of surface is different generally from those on airports.

From a study of these tabulations and other information pertaining to relative imperviousness of different surfaces, a table (Table I) has been compiled which appears more applicable to the conditions found on airports. The appropriate runoff coefficient should be selected from Table I for use in formula $Q=CIA$.

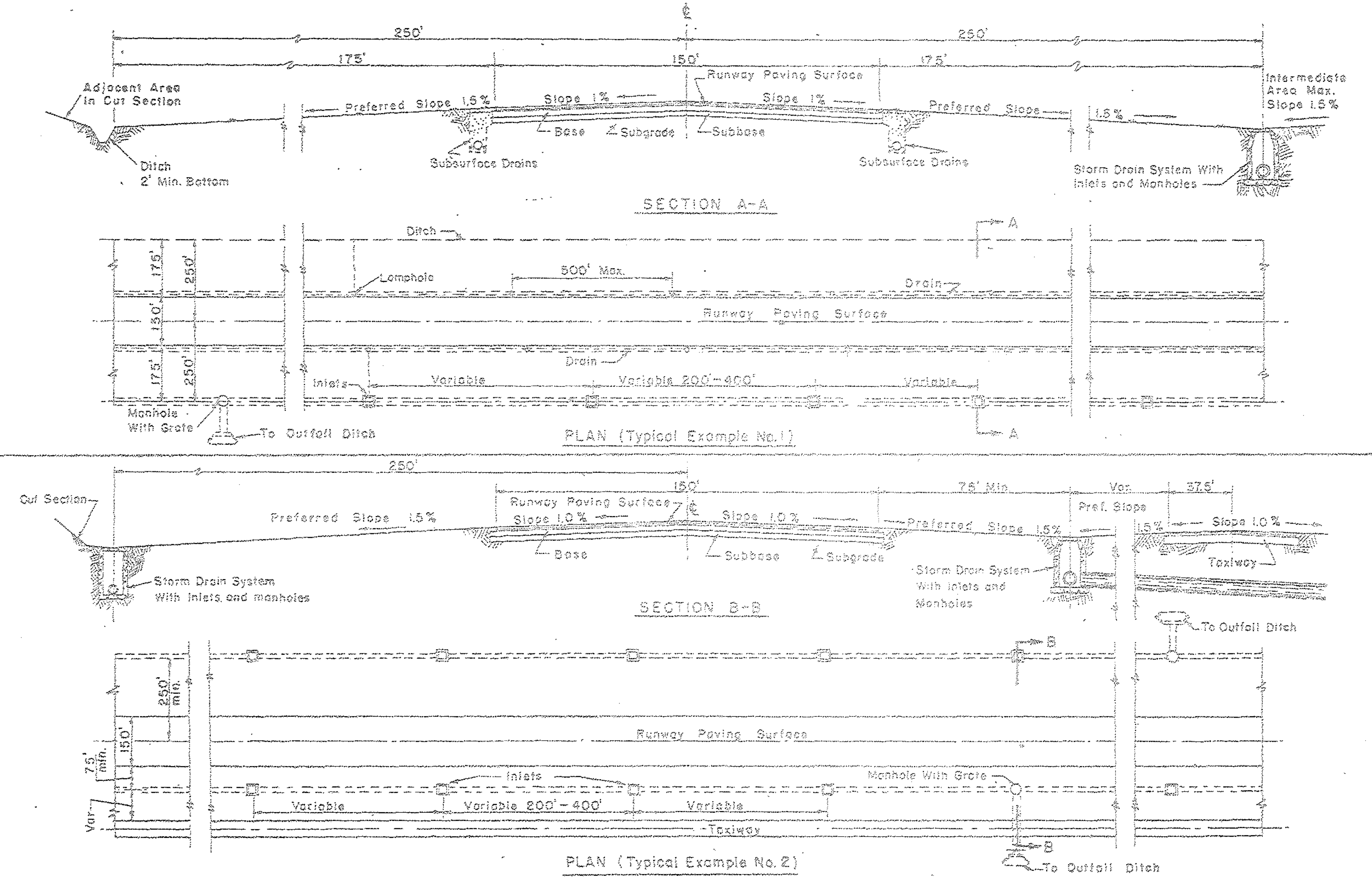
If the drainage area contributing to a certain inlet is composed of several surfaces for which different coefficients from this table must be assigned, the coefficients used in the formula should be a weighted average in accordance with the respective areas. For example, if a drainage area to an inlet consists of ½ acre of asphalt pavement having a coefficient of 0.90 and 2 acres of impervious soil with turf having a coefficient of 0.35, the average coefficient for the total area is equal to $[(0.90\times0.5)+(0.35\times2.0)]\div(0.5+2.0)$ or 0.46.

TABLE I

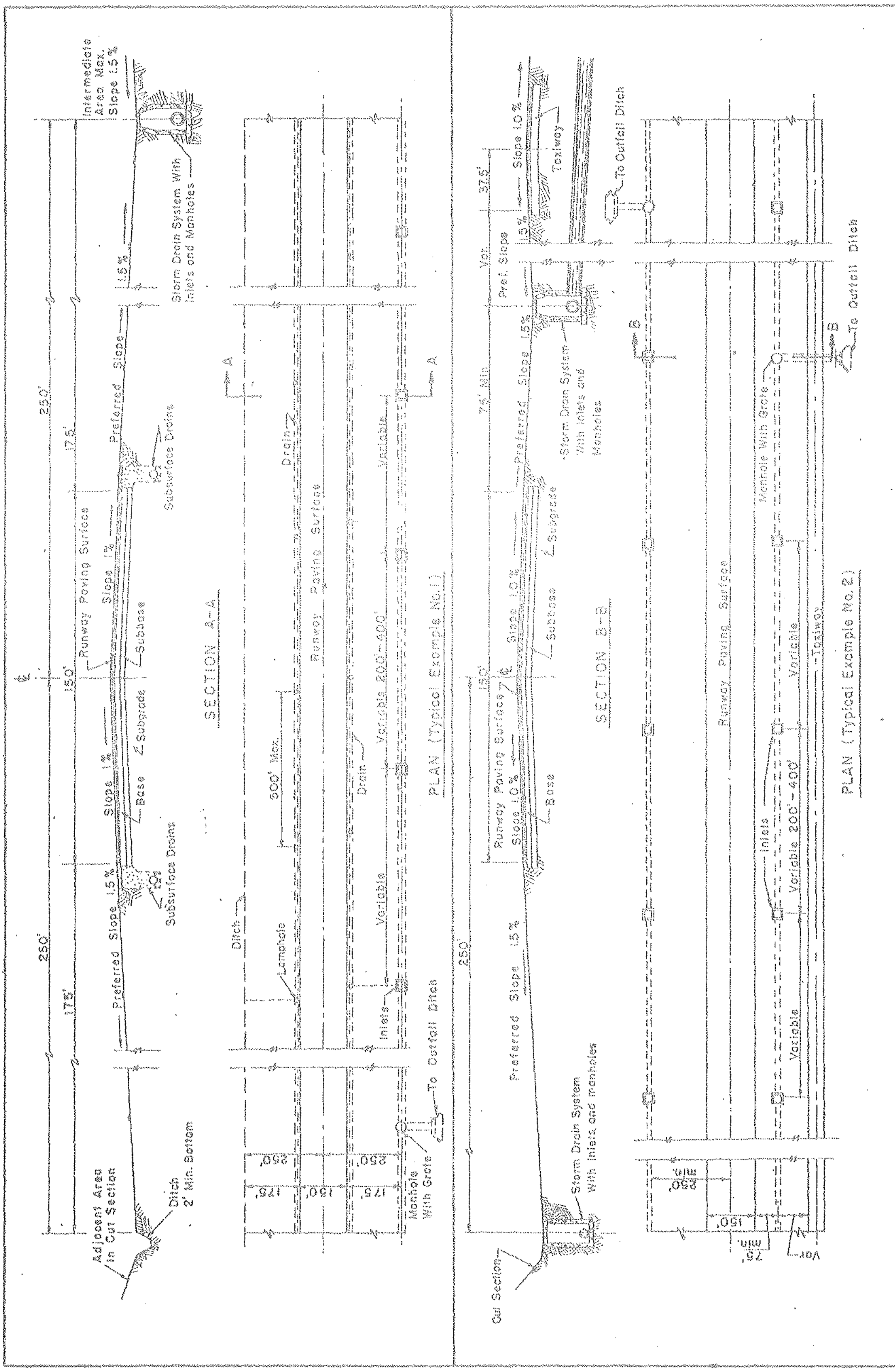
VALUE OF FACTOR "C"

Type of Surface	Factor "C"
For all watertight roof surfaces	.75 to .95
For asphalt runway pavements	.80 to .95
For concrete runway pavements	.70 to .90
For gravel or macadam pavements	.35 to .70
[1] For impervious soils (heavy)	.40 to .65
[1] For impervious soils, with turf	.30 to .55
[1] For slightly pervious soils	.15 to .40
[1] For slightly pervious soils, with turf	.10 to .30
[1] For moderately pervious soils	.05 to .20
[1] For moderately pervious soils, with turf	.00 to .10

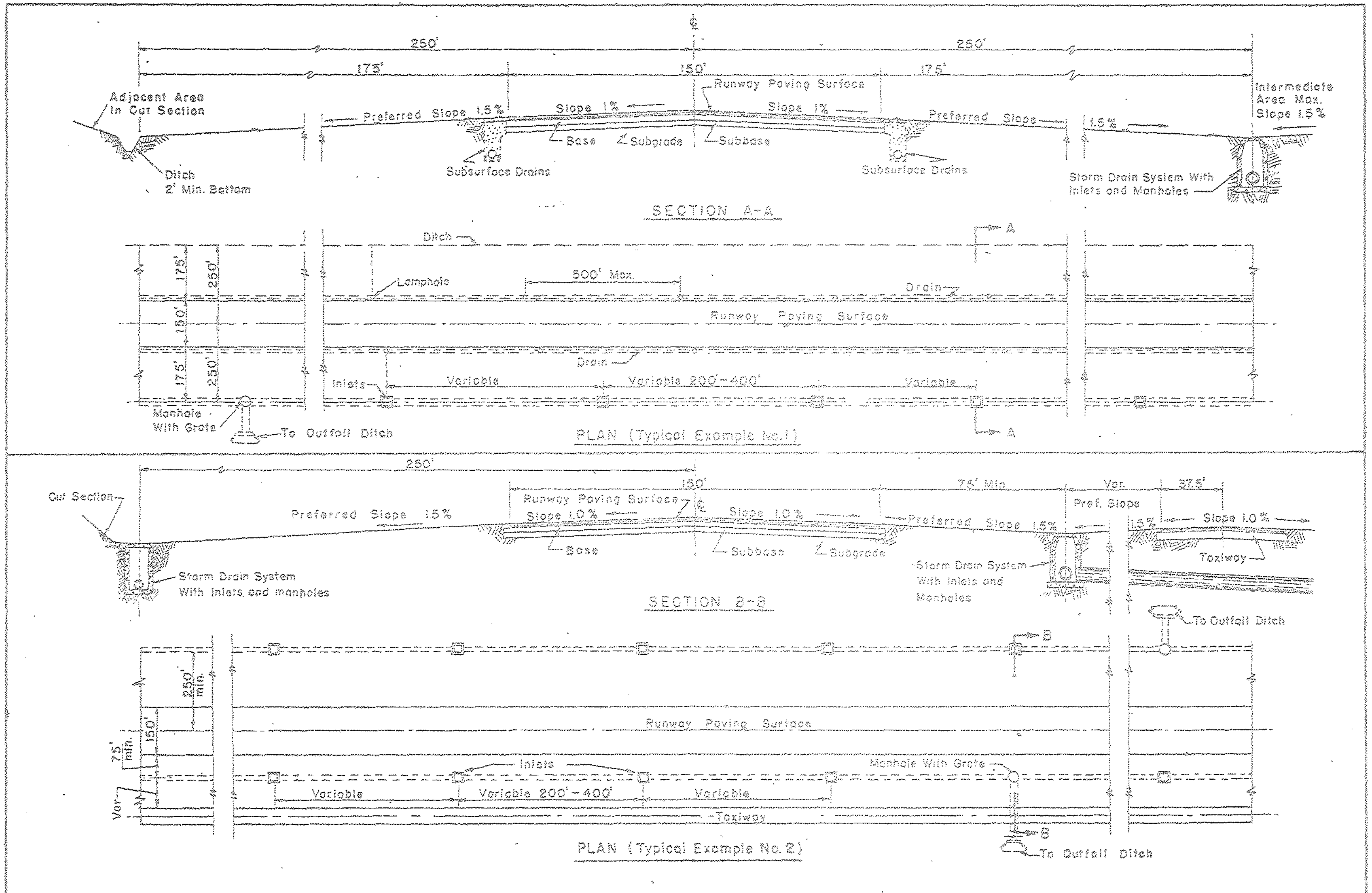
[1] For slopes from 1 percent to 2 percent.



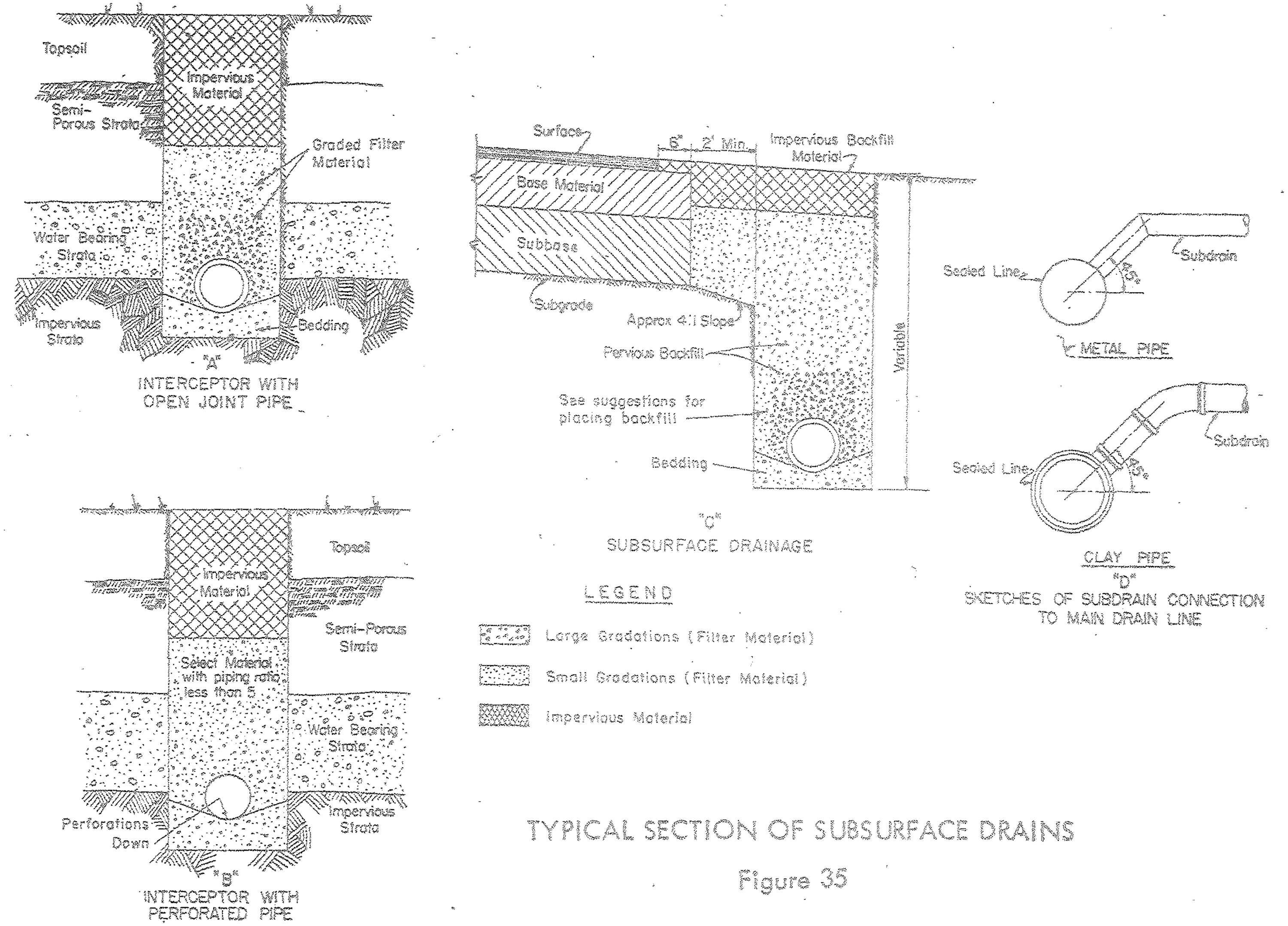
Typical Landing Strip And Runway Drainage
Figure 25



Typical Landing Strip And Runway Drainage
Figure 25



Typical Landing Strip And Runway Drainage
Figure 25



TYPICAL SECTION OF SUBSURFACE DRAINS

Figure 35

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