

For consideration at the
Technical Committee Meeting
on 20th September, 1960.

DRAINAGE RESEARCH

Research interest on drainage problems has tended to shift in recent years. We are now less concerned with drainage as an integral part of the planting operations on the important 'wet' types, and are more interested in it as it affects the health, stability and yield of established crops. We shall also become increasingly interested in the maintenance or replacement of drains on areas being regenerated to a second rotation.

The following brief notes mention some, but not necessarily all, of the work on drainage now in hand, and also suggest the lines of future work which we think should prove profitable.

- (1) The Peats. Adequate drainage intensities for establishment have long been known and practiced. Experiments have shown responses in terms of faster growth to increased intensity and depth of draining - to, approximately, 2 ft. drains at $5\frac{1}{2}$ ft. spacing. (The Irish have responses to 3 ft. drains at this spacing!) Plainly, a search for an optimum intensity of drains for the early growth phase would be quite academic, since (a) it would probably be found at a level at which the pole crop would be unstable, and (b) it would almost certainly represent over-draining in pole stage and older crops. There are indications in certain Scottish experiments that it is possible to over-drain peats. The aim should be to find the best compromise. A number of experiments are under observation, and in certain of these, changes in the peat resulting from the combined action of the drains and the established crop are being studied by the Macaulay Institute.

Drain Maintenance. The cleaning of drains in established plantations is an expensive problem. The Machinery Research Officer has developed a tractor mounted appliance on the flail principle which shows much promise.

- (2) Shallow Peats over Heavy Tills. A high proportion of our spruce stands on amorphous *Molinia* peats over somewhat impeded glacial tills. This does not present a peat drainage problem in the strict sense, but rather the more general problem of rooting into impeded substrates. On some of these soils the wind stability and longevity of the crops are problematical. Deepening of the drains into the till with the aim of providing aerobic rooting conditions is one approach. Experiments on these lines have been conducted in pole crops of spruce at Newcastleton and Kielder. In order to observe direct effects on the water table, a system of observation wells was laid out. At Kielder, drains deepened to 24 in. lowered the water table by about 5 ins. as against the normal drainage system which is about 9 ins. deep. No such effect however was observed at Newcastleton, though this may have been due to imperfections in the experiment. It remains to be seen what effect the drain deepening at Kielder will have on the rooting and growth of the spruce.

Such experiments are not easy to conduct. Observations from boreholes or wells are often difficult to interpret. Further work of this kind is undoubtedly necessary.

- (3) Heavy Clays. Till recently, little forest experimental work has been done on the geological clays of the south. Old woodlands on such sites always show the remains of a drainage system. Foresters have usually taken the view that the drainage effect on heavy clays is limited to the removal of the surface water, and that the improvement of the site is only superficial. An experiment was laid down at Bernwood (Oxford) in 1954 in clear felled oak/hazel coppice on very tenacious Oxford clay. This compares drains 2 ft. deep at 1 chain and $\frac{1}{2}$ chain spacing. There is an 'undrained' treatment (the relics of the old system). A number

of species (coniferous and broadleaved) have been established in each draining treatment. Intensive observations of a considerable number of lined boreholes have been made, and some ancillary studies of soil moisture content and water movement (employing fluoresceine) have been carried out. The observations were extended to adjacent standing coppice.

There have been some very interesting indications. Drains 2 ft. deep at $\frac{1}{3}$ chain spacing have clearly lowered the water level in wet periods and one might estimate the gain in aerobic rooting conditions at about 6 ins. This has already significantly benefited young oak. On the other hand, the intensively drained soil appears to hold more moisture. It was also noticeable that the standing coppice shortened the period of winter water logging considerably, compared with the conditions in the 'undrained' felled area.

The principal suggestion which arises from the Bernwood trial is that on a heavy clay site such as this one wants the combined effect of a deep rooting species and an adequate surface draining system. It is clear from profile examinations that the fissuring in the clay brought about by the transpiration of the trees in dry summers is an important factor in the drainage. It is an open question whether this interaction can be economically utilised.

We have several heavy claysites where the rooting of spruces and certain other conifers is alarmingly shallow, and where windblow has started at a very early stage. Notable examples are Lennox in Stirlingshire (till) and Halwill in Devon (Culm). It is hoped to start work at both these sites. A possible line of approach is to combine adequate surface drainage with deep subsoiling or mole draining. There is of course little prospect of keeping mole drains open under a forest crop, but it might be possible to stimulate deep rooting of a suitable species and to maintain such rooting, once established, by surface drainage. Active liaison has now been established with the land drainage specialists of the M.A.A.F., and the loan of their tractor-mounted mole plough to lay out experiments at Halwill has been agreed.

Plainly if the transpiration of the crop is to be relied on to keep a fissure system open, the silvicultural treatment will have to be rather special. Clear felling will not be possible, and a substantial component of the crop may have to be selected for its rooting properties rather than for its productivity and value. Such trees as alders may be specially useful. This approach is probably most applicable where there is ordinarily a considerable deficiency of summer rainfall against evaporation.

- (4) Drainage and Regeneration. Some experimental work on artificial regeneration has already started in certain important types of forest. In pure spruce areas in the Borders drainage and other cultivation measures are being considered. The presence of stumps will make ploughing very difficult, and what preliminary work has been done leads us to suspect that regeneration of spruces following clear-felling may often be a more difficult operation than the original afforestation. In this we had efficient ploughing techniques which took care of draining and the provision of a favourable planting medium in one operation. How far we can (or should) repeat these operations remains to be seen. It may be that we shall have to separate 'drainage' - the maintenance or improvement of the principal drains, from 'cultivation' - the provision of adequate rooting conditions for establishment.

GENERAL

It seems probable that we shall find it profitable to devote more attention in future to studies of the rooting of the more important species in relation to drainage and other measures of cultivation. We also need to know more about the basic processes involved in drainage, especially where growing crops are reinforcing the action of surface draining systems.

(R. F. Wood)
(T. R. Peace)

1st September, 1960.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Regional Ditch Maintenance Machinery Demonstration
Fairoak Farm, Wiston, Steyning, Sussex
20th October, 1960

Brief particulars of Machines taking part

1. The "Shawnee", manufactured by Steel Fabricators Ltd., consists of a hydraulically operated back-acting trencher suitable for mounting at the rear of a wheeled tractor.
2. The "McConnel" ditcher is a power arm attachment to a standard wheeled tractor travelling parallel to the ditch. The arm drops a bucket into the ditch, and after it is filled, raises and empties it behind the tractor.
3. The "Sherma", manufactured by Bray Construction Equipment Ltd., is a hydraulically operated back-acting type of trencher that can be fitted with ditching and trenching buckets. Suitable for mounting on the rear of a wheeled tractor.
4. The "Massey Ferguson" digger, manufactured by Messrs. Massey Ferguson Ltd., is a hydraulically operated digging arm with bucket, for mounting at the rear of a wheeled tractor. The arm can be slewed through 185° , and the bucket tipped for emptying hydraulically. It has a reach from the tractor axle of $17\frac{1}{2}$ ft., a dumping height of 10 ft., and can dig to a depth of 12 ft.
5. The "Sapper" ditcher, manufactured by Messrs. Bomford & Evershed Ltd., consists of a frame which can be towed behind a medium powered wheeled tractor, and which carries a bucket. The bucket is drawn along the bottom of the ditch for filling, and is lifted by hydraulic power for emptying, spoil being deposited automatically at a pre-set distance from the edge of the ditch. Operation is by one man. The tractor must be fitted with dual hydraulic controls, so that the hydraulic ram of the ditcher can be operated independently of the tractor lift arms. Components are designed so that the machine can be assembled to work either left or right handed. Two types of bucket are available, one fitted with a cowl for use with sandy soil or slurry, and one a skeleton bucket for use in clay. The weight is approximately 9 cwt.
6. The "Kilworth" ditcher, manufactured by L. W. Hutt Ltd., is a scoop suitable for mounting at the rear of a wheeled tractor. The tractor, which is at right angles to the ditch, drags the scoop across the ditch; it is then turned and emptied at the near side by a trip lever. It is operated from the tractor's hydraulic system.
7. The "Baker" ditcher, manufactured by Whittington Engineering Co., is a rotating flail type of ditcher which is side mounted on a wheeled tractor. The operation of the ditching mechanism is continuous as the tractor moves forward parallel to the ditch.
8. The "Cole" ditcher, manufactured by Messrs. W. & D. Cole, consists of a scoop, or alternatively a scraper blade, attached to an arm, mounted on the usual three point linkage at the rear of a tractor and in line with it. The scoop has a capacity of 3 cwt., and can be adjusted to suit the slope of the bank: emptying is automatic. A tipping mechanism is incorporated which enables it to work in deep, narrow ditches, also safety claws for freeing the scoop should it foul an obstruction. Operation of the tractor is at right angles to the ditch.
9. The "Walker-Doe", manufactured by E. Doe & Sons, is a hydraulically operated back-acting type of ditcher for mounting at the rear of a crawler tractor.

10. The "Carter" ditcher, manufactured by Carter Bros. (Billingshurst) Ltd., consists of a jib to which is attached a hand-controlled scoop, for attachment to the linkage of a wheeled tractor. It is operated at right angles to the ditch.
11. The "Beofab" ditcher, manufactured by Beofabs (Engineers) Ltd., consists of a scoop 3 ft. wide, carried at the end of a lattice jib for mounting at the rear of a wheeled tractor and in line with it. Power for raising and lowering the jib and for tipping the scoop is hydraulic. The latter operates automatically. The reach, from pivot to scoop-cutting edge, is 13 ft. 3 ins. and the weight 390 lbs. Operation of the tractor is at right angles to the ditch.
12. The "Leeford" ditcher, manufactured by F. A. Hughes & Co., is a hydraulically operated ditcher which has a bucket mounted on a transverse boom which is in turn attached to the hydraulic lift at the rear of a wheeled tractor. In operation the tractor moves parallel to the ditch and the transverse boom extends over the ditch. The bucket slides along the boom from the excavating to the emptying position.
13. The "Dinkum Digger", manufactured by Whitlock Bros., is a hydraulically operated back-acter excavator which can be mounted at the rear end of a medium wheeled or crawler tractor. A grader blade or scoop can be fitted to the front end of the tractor. Its weight, with scoop, is 1,500 lbs. It can excavate trenches between 10 ins. and 30 ins. wide and up to 9 ft. deep.
14. The "Weldryte" ditcher, manufactured by Weldryte Ltd., is a cross drag scoop type of ditch maintenance machine which is attached to the hydraulic lift at the rear of a wheeled tractor. It is fitted with a release catch at the top of the 3 point linkage to assist penetration.
15. The "Arden" ditcher, manufactured by Richard Smalley (Engineers) Ltd., consists of an angle iron arm, carrying a bucket, for mounting at the rear of a tractor with three point linkage in line with it, which digs, cuts and tips automatically. It can clean or dig ditches up to $7\frac{1}{2}$ ft. wide and 5 ft. deep.
16. The "Graber" ditcher, manufactured by B. O. Sturgis, is a cross drag scoop type of ditch maintenance machine suitable for mounting on the hydraulic lift at the rear of a wheeled tractor.
17. The "Cub" excavator, manufactured by Priestman Bros., is the smallest of a range of draglines. Unlike the other machines, it is complete in itself, and is not an attachment to a tractor: it is thus primarily a contractor's machine. It is suitable for digging or cleaning ditches up to a considerable width. It can be fitted with a side arm attachment whereby the bucket, instead of being pulled across the drain, is pulled along it: this enables it to dig or clean out ditches of smaller section than can be dealt with by the normal direct pull bucket.
18. The "J.C.B." excavator, manufactured by J. C. Bamford Ltd., is a hydraulically operated back acter excavator, which can be mounted at the rear end of a Fordson Major or Nuffield tractor. A scoop can be fitted to the front end of the tractor. Its reach is 15 ft. and loading height 9 ft. 6 ins., it can excavate trenches between 10 ins. and 30 ins. wide at a single cut, and up to 11 ft. deep.

19. The Stanhay "Super Ditchmaster", manufactured by Stanhay (Ashford) Ltd., consists of a hydraulically operated grab hung from a slewing jib, which is raised or lowered by a ram attached to the slewing column. The grab will cut through clay and reeds and will hold slurry: it will not penetrate gravel. Its capacity is 3 cu. ft. Slewing is by power, through 275°. Support jacks at either side take most of the load from the tractor when at work. It may be fitted to most makes of wheeled tractor. The radius of the jib circle is 10 ft. 3 ins., it can be used in ditches up to 10 ft. wide and 11 ft. deep. A model, the "Ditchmaster", which is slewed by hand, is also available.

20. The "Berson" is a prototype machine, designed and built in the workshops of the Ministry of Agriculture, Land Drainage Division, at Peterborough. It consists of a scoop attached to an arm pivoting on a jib mounted at the rear of a wheeled tractor and at right angles to it, the tractor moving parallel to the ditch. Jib and arm are hydraulically operated, and the scoop is designed to turn and empty automatically on the near bank. It can work in ditches of varying widths and up to a depth of 5 ft.

Demonstration of the Beefabs Trench Cutter at the Forest of Ae on 8th Nov. 1961.

Description of Trench Cutter: The machine is driven by live power take-off from a Caterpillar Tractor. It incorporates a vertical screw or worm, revolving at high speed, which cuts its way through the soil simultaneously raising the loose spoil towards the surface, where it is thrown clear in an even spread on both sides of the drain by a revolving plate attached to the top of the screw shaft. The drain itself is shaped by a box-type plough share which is positioned behind the screw so that all loose soil gathered is lifted clear by the process mentioned above. A rear spoil adjustable deflector is fitted behind the box to eliminate soil falling back into the trench. (This deflector was removed for trials (b) and (c). R.L.).

There are six models in production:

Type	Top width of drain	Depth	Bottom width of drain	Price
A	14½ in.	12 in.	5½ in.	£194.10.6.
B	14 "	18 "	8 "	210. 5.3.
F	24 "	8 "	8 "	-
C1	24 "	16 "	8 "	226. 0.3.
C2	14 "	24 "	8 "	231. 5.3.
D	14 "	30 "	7 "	261.19.6.

Radial cutters are available for fitting to any of the above models.
Cutting width - 5 ft. for bracken, rough growth or grass.
Price - £59.17.0.

Type C1 was under trial at the Forest of Ae.

Tractor: The Caterpillar Tractor used was an American designed, German made, John Deere - Lams.

Total width - 61 in. (from outside edge of tracks).
Power - 50 h.p.
Track width - 14 in.

Performance on Different Sites

- a) Under P.37 S.S. which had received normal thinning treatment:
Soil - Thin layer of peat over boulder till.
Veg. - No surface vegetation.

Not a success due to the occurrence of numerous strong tree roots which caused the whole Trench Cutter to lift, causing extremely irregular depth and consequently digging power was reduced. In order to operate the machine at all it was found necessary to fell two rows of trees and this could hardly be regarded as practical even if the machine could be adapted to perform efficiently.

- b) In P.50 S.S. at pre-thicket stage:
Soil - Deep peat, drain bottoms reaching the mineral soil only occasionally.
Veg. - Rank growth of Calluna.

The spoil was dug out cleanly and thrown clear but the Calluna remained partially uncut and fell back into the trench taking some spoil with it. The machine proved most manoeuvrable in this thicket - stage spruce and although isolated trees were knocked over I would consider this to be comparatively unimportant. The small roots encountered here proved to be no obstacle to the machine. One felt that here, there might have been a case for employing a vegetation cutter or some form of disc to sever the heather completely as this might have prevented the uneven drain edges and fallback of soil. In my opinion, the model demonstrated did not go deep enough to give adequate drainage and although models C2 and D give greater depth they, unfortunately, produce

drains with a top width of only 14 in. (see table above), which I consider to be much too narrow for this type of ground. One favourable point was the speed at which this machine operated. One could visualise a large number of chains of drain being cut each day. (12 chains per hour including turning at headlands, etc., was considered quite a possibility. R.L.)

c) On open ground:

Soil - Shallow peat over boulder till.

Veg. - Molinia and other grasses.

Performed quite efficiently; but cutting drains in open ground such as this is hardly a problem and our present ploughs could cope quite adequately although they would leave a ridge which might be considered less advantageous than having the spoil scattered. On a timed run the Trench Cutter opened out 3.5 chains of drain in five minutes.

Conclusion

The Beefab Trench Cutter does not supply the answer to our drain maintenance problem. I do not think that its digging principle is as efficient as the ARPS Trench Devil (demonstrated at Le last month), under thinned-plantation conditions and on the type of soil encountered here - shallow peat over boulder till. It does operate at a fairly high speed but I doubt if this is an advantage as I feel that higher speeds impair the efficiency of the digging scroll especially when trying to get down into the boulder till. Speed did not appear to affect its efficiency on deep peat.

On the credit side, it is the most manoeuvrable drainer I have seen so far and I feel that the even spread of spoil, over a wide surface area, on both sides of the drain, is an extremely important point as it precludes the possibility of fall-back such as might be expected from spoil deposited in a ridge next to the drain (natural fall, pulled in by extraction, etc.). It also ensures that any machine which may be expected to come along at a later date can travel on an even surface.

William J. Blair
November, 1961.

Comment by R. Lines: The machine is reasonably compact which gives it a small turning circle. It is good in principle and a considerably modified version might be just what will be needed in the future when drain edges are not planted with trees. 22.11.61.

Distribution: C.R.O.
Silv.(S)
J.W.L. Schetsmeyer
Spere

DRAINAGE

Three operations are sometimes covered by the general term "drainage". These are:-

- (i) Cultivation. This distinction was made by Nisbet (1905, p.315), who wrote, "Strictly speaking, the word "Drainage" means only the drawing off of a surplus of water from the soil; and the aeration and changes with regard to conductivity of heat, and to other physical properties, are consequences of the operation not included in the idea of drainage at all. But all these main objects are comprised within the term "Soil preparation". (See also the attempt at definition and explanation of the terms "drainage" and "cultivation". M.V.E. 21.11.61).
- (ii) Interception of water from outside, e.g. surplus water running down a hill slope. "Spring water and surface drainage in hilly ground is caught and diverted by running a ditch of suitable dimensions along the slope of the hill just above the swampy ground". (Schlich, 1904, p.132-33). This function is fulfilled by an 'interception', 'cut-off', 'catch' or 'trap' drain.
- (iii) Drainage proper.
 - (a) Object:

(a) To remove water and thus to:- (b) Increase aeration (oxygen content) (c) Increase soil temperature (d) Increase depth of rooting	}	(Nisbet, 1905, p.315).
---	---	------------------------
 - (b) Method:

(a) By opening existing watercourses. (b) By breaking the pan or other impermeable layer. (c) By opening-out ditches at intervals.	}	(Schlich 1904, p.133)
--	---	-----------------------
 - (c) In addition, there is also a temporal distinction, between drains necessary to carry off flood water during periods of peak rainfall; and drains necessary to increase the volume of rootable subsoil, thus enlarging the reserve of aerated, moisture-containing soil upon which the tree crop can draw in times of water-deficiency.

DRAINAGE BY OPEN DITCHES

Three classes of ditches or drains may be recognised:-

1. Collecting drains ('feeders' or 'spurs').
2. Connecting drains ('leaders' or 'side drains').
3. Main drains (often a natural watercourse, or alternatively the line which a watercourse would take).

Sometimes an additional class, known as a 'relief drain' or 'carrier', which caters for overflowing, is recognised. (F.C., 1933, p.43).

A. Past Practice

Lay-out of Collecting Drains

"The more nearly horizontal they are, the greater is their effect in draining the land up to the next ditch" (Nisbet, 1905, p.318). "Maximum efficiency is secured if the slope of the feeders is as gentle as is consistent with a free flow". (F.C. 1933, p.44).

Thus the lay-out of the collecting drains is determined primarily by the desirable gradient of the drain. This must not be too steep (or it will erode) or too flat (or the flow will be sluggish and the drain will block). The determining factors are the nature of the soil and the amount and velocity of the water to be carried, the amount in its turn being determined by the rainfall and the size of the catchment of the drain. Brown (1861, p.143) gave 1:100 as the least gradient which will prevent drains being choked with mud and vegetable matter, and 3 or 4 in 100 (1:33 or 1:25) as proper gradients. Schlich (1904, p.135-136) suggests an average gradient of 1:100, greater on firm but less on loose soil. Nisbet (1905, p.318) indicates a gradient of about 2 or 3% (1:50 or 1:33). Steeper gradients are common in stony soils, where the risk of erosion is lessened, in Scotland; also flatter gradients are inevitable on deep peat, e.g. 1 in 2,000 or even up to 1:6000 or 1:8000 (Burckhardt), where the surface of the ground is almost flat.

Depth of Collecting Drains (expressed in inches).

Brown (1861, p.36) remarked "I can well remember when [drainage] was on such a shallow principle as to be quite inoperative. single cuts of some 12 in. deep were considered sufficient. Now, however, experience has taught us all, that where the land is relatively wet, from 30 to 36 in. in depth is absolutely necessary". In a later edition (1871, p. 160) he lays down 36 in. as the least depth and 48 in. as the greatest. (By this time Brown was emphasising the importance of "porousness to a great depth; and consequently, a large capacity for absorbing heat" - in other words, the necessity for good cultivation as well as good drainage). Nisbet (1905, p. 317) concluded "In heavy clay soil open drains sometimes need to be at least 4 ft. deep, while on light friable land a depth of 3 ft. may often be ample. The more argillaceous or mossy [clayey or peaty] the land, the deeper should the drains be. Drains only 2 to 3 ft. deep are not always able to dry and aerate the subsoil sufficiently for growing timber with profit".

More recently, during the period when turf planting was in vogue, a depth of at least 3 in. into the mineral soil below the peat was recommended (F.C., 1933, p. 43), or most recently, a total depth of 12 in. to 18 in. (F.C., 1958, p. 34).

The latter prescription amounts to the same if the peat is 9 in. to 15 in. deep, as is often the case. Thus it is evident that deep draining was recommended (and there is evidence on the ground that it was carried out) once upon a time, but that comparatively shallow draining was the practice in the nineteen twenties and thirties, Macdonald (1954) advocates no great deepening to begin with (provided the drain bottom is smoothly cleaned) but deepening after a number of years. Calculated depths for Cuthbertson ploughs are:- Type F - 18 in.; F Mark IV - 24 in.; D Mark V - 36 in. and D Mark VI - 47 in. (Type D pulled by two tractors in peat).

Spacing of Collecting Drains (expressed in feet).

"The distance between two successive feeders depends on the permeability of the soil, the depth of the ditches, the depth to which the land is to be drained, and the general fall of the locality; it will accordingly range between 30 and 100 ft." (Schlich, 1904, p.137). "The distance between drains depends entirely upon the nature of the soil. On stiff clay or other very retentive soil, they may be required only 33 or 36 ft. apart; but in sand or gravel 60 ft. may not be too far apart. In Scotland these are about the usual limits In the North German forests the distance does not as a rule exceed 33 ft. but is less in very binding wet soil where sideward percolation of water is slow". (Nisbet, 1905, p. 316). F.C. (1933, p.45) states that nothing can be said of the spacing, for conditions vary too much, but suggests 75 ft. as a usual maximum and 150 ft. as the extreme spacing. However, in turf planting practice, a spacing of 21 ft. was normal (31 chains per acre) partly because this spacing provided enough turfs of adequate size to plant trees at a spacing of 5 x 5 ft. Only an unspecified proportion of these drains was however maintained permanently. Grigor (1881, p.42-43) had noted that more advanced plantations needed less intensive draining than young ones.

Most prescriptions for the spacing of drains refer to covered (tile) drains, and data relevant to open drains of differing depths and spacings appears to be lacking.

Width of Collecting Drains, and Angle of Sides.

The width of the bottom has been determined by the size of spade used for bottoming, various authors quoting 6 in., 8 in., or 9 in. The bottom-width of the Cuthbertson type F plough is 12 in. (Types H and D = 8 in.). The width at the top of the drain will depend on the depth of the drain and the desirable slope of its sides. "A good practical rule for light land is to make all drains one-third wider at the top than in depth, e.g. a drain 3 ft. deep should have a top-width of 4 ft. to give the sides sufficient slope to support themselves without crumbling down. On stiff retentive land, however, whose sides are firmer and can do with less slope, it is usually sufficient to make the top-width only three-fourths of the depth.....while the walls of the small feeder-drains can be cut almost perpendicularly on very stiff land". (Nisbet, 1905, p.317). This rule results in drain side slopes varying from 63° to 76° if the bottom is 12 in. wide, or 60° to 73° for a 6 in. bottom width. Cuthbertson ploughs range from about 65° (Type F) to 74° (Type D Mark VI) in the slope of their sides. See graph for other details.

Length of Collecting Drains

"Short drains collect insufficient water; moss soon grows in the bottoms and in a year or two they become choked" (Macdonald, 1954). On the other hand, the length must not be so great that a drain is required to discharge more water than it can carry. In most forests, the topography is such that connecting or main drains occur at fairly frequent intervals, and the problem of over-long collecting drains does not often arise.

Dimensions of Connecting and Main Drains

These drains generally follow a natural watercourse line, but if the soil is soft and it is expected that drainage will materially increase the flow of water, it may be necessary either to lengthen the drain by diverting it so as to reduce the gradient, or protecting the drain by making sills or steps artificially. The size of the drain will be determined by the number of collecting drains which it serves and their sizes.

B. Experimental Work

The difficulty of separating the effect of draining the soil in situ from that of cultivation was emphasised by Zehetmayr (1954, p.30-33). Thus, though marked differences were indicated in an experiment at Ae (8 P.36) the cause was uncertain.

In the classic experiment on deep peat (Inchnacardoch 52 P.29), the drainage treatments were confounded with extra turf for planting, and thus closer spacing of the trees and a heavier rate of application of phosphate. Experiments in two Border forests (Kielder 54/49 and Newcastleton 12/49) showed that drain-deepening lowered the water table in some cases, though not in others, but that height and girth of dominant trees were not affected (Stewart, 1959).

Tests on the stability of trees in the Kielder (54/49) experiment have shown that in plots where drains were deepened, the trees resist a sideways pull more effectively and are significantly deeper-rooted (Macdonald, 1951; Fraser, in press). The effect appears to be limited to the roots, as the height and girth of dominant trees does not differ significantly between deepened and undepened drain plots.

An experiment at Ae (17 P.54) was designed to examine some of the problems raised in this paper, but it is as yet too young to have been assessed for results on the growth of the trees.

An experiment on a heavy (30% - 50%) clay under replanted old woodland at Waterperry (Bernwood 2 P.55) has shown marked improvement in soil conditions as a result of intensive and deep (draining 2 ft. deep and $\frac{1}{3}$ chain apart) (Fourt, 1961).

C. Present Practice based on Modern Ploughing

The aforementioned principles and practices are still generally applicable, but they need modifying to some extent to guide the use of tractor-hauled ploughs of modern size and capabilities.

At first, ploughs were used to replace hand-turfing, i.e. to make collecting and connecting drains as furrows, and using the ridges as turfs, but it is not always easy to make parallel furrows feed into main drains, and in fact it may even appear at first sight that an intensive pattern of furrows needs few main drains. In such cases, the question of permanent drainage has been left for later determination and action. This accords with the principle that drains should at first be shallow and later deepened as the tree roots cover the soil surface and begin to penetrate downwards, but such deepening has not been found easy to effect, because deepening is normally carried out by hand in an established crop of trees. Although attempts have been made to discover or develop machines suitable to do this work, little success has so far been obtained. It seems probable that the power required to deepen drains smoothly and easily is such that no machine capable of working quickly between closely-spaced trees is likely to be successful. Moreover in any case trees should not be positioned close to permanent drains if they are to be stable and resistant to windthrow.

If furrows are spaced at 5 ft. the distance ploughed is 130 chains per acre.

If every fourth furrow is maintained as a drain (spacing 20 ft.), the intensity of draining is 33 chains per acre, about equal to the length of drain cut before planting under the hand-draining system. At a spacing of 40 ft. there are 16 chains per acre: at 10 chains of drain per acre (often considered suitable in present practice) the spacing is 66 ft. Such an intensity is presumably designed to remove flood-water from a tree crop which is already adequately rooted, as no drain can be expected to remove water from subsoil 33 ft. away.

If it is agreed that trees must not be planted near to permanent drains for reasons of stability, then it follows that it should be easier to develop a machine suitable to clean or deepen drains, but the proposed permanent drains must be recognised and laid out before planting, in conjunction with the system of extraction roads and rides. (This does not, of course, preclude the possibility of additional draining if found necessary to supplement the original plan). However, if it is true that drains in clay soils and peat act slowly and take a long time to exert their effects over maximum distances, then it appears that gradual deepening as the crop ages is inadequate, and that, on the contrary, the roots should be encouraged to penetrate as deeply as possible from the earliest years. *yes*

The development of ploughs and ploughing patterns to provide a permanent deep drainage system has been in progress since 1949. Three ploughs are available: the Outhborton single mouldboard (Type F Marks I and II), double mouldboard (Type P Marks I or II) and the 'deep drainer', (Type D Marks V and VI, or S). Various ploughing patterns and methods of using the different ploughs have been developed, often resulting in the provision of a system of furrows running straight up and down the hill (i.e. the cultivation), crossed at intervals by deep contour drains (the permanent drainage system).

The problem is thus to determine a ploughing pattern giving a desirable depth of drains (both at the start, and later on if not the same) and their spacing, gradient and size over different soil types, on different slopes of land, under different rainfall regimes). This has to be considered in two parts; on the one hand for peaty-gley soils where there is a combined problem of draining both peat and mineral soil (at any rate in the early stages before the peat disintegrates), and on the other hand for deep peats where the mineral soil lies below any possible depth of rooting.

It is suggested that the proper procedure is to make drains before planting at such a depth and spacing that the soil will be adequately* aerated* down to the necessary* depth* to ensure future stability of the crop by the time the canopy has closed, when both the crowns and roots may be expected to have reached their maximum extensive development. (Additional cultivation may well be necessary to ensure quick establishment). The number of drains to be maintained should be such as to keep the aeration at a sufficient level (measured midway between drains) until maximum intensive root, crown and transpiration levels are reached, after which the removal of excess water may well be carried out by a much reduced intensity of drainage, roots being allowed to cross abandoned drains to increase stability.

It is assumed that on upland heaths the problem is one of cultivation rather than drainage.

The problem of maintaining and improving the drainage systems of crops already planted still remains, but it may be possible to obviate many of the difficulties in new plantations.

M.V. Edwards

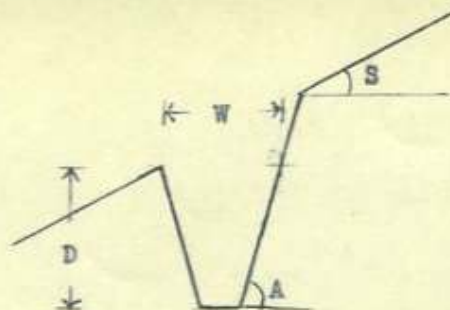
December, 1961.

* These limits to be postulated at definite levels (method of determining aeration to be specified) and tested both in existing crops and experiments and in new experiments.

REFERENCES

- BROWN, JAMES, 1861 and 1871. The Forester, 3rd & 4th edns. Wm. Blackwood, Edinburgh.
- BURCKHARDT, 1893 Saen und pflanzen (quoted by Nisbet, 1905).
- F.C., 1933 Forestry Practice, Bull. For. Comm. No. 14, 1st. edn. (only slightly modified in later editions and reprints).
- F.C., 1958 Forestry Practice, Bull. For. Comm. No. 14, 7th edn.
- FOURT, D.F., 1961 The drainage of a heavy clay site. Rep. For. Res. 1959/60, p. 137-151.
- GRIGOR, J., 1881 Arboriculture. Edinburgh. 2nd edn.
- MACDONALD, J.A.B., 1951 Plantations on peatlands. Rep. For. Res. 1949/50, p.33-35.
- MACDONALD, J.A.B., 1954 Preparation of ground and draining. Wood, Jan. 1954, p.8-10.
- NISBET, J., 1905 The Forester, Vol. I. Wm. Blackwood, Edinburgh.
- SCHLICH, SIR W., 1904 Manual of Forestry. Vol. II. Sylviculture. 3rd edn. Bradbury, Agnew, London.
- STEWART, G.G., 1959 Preliminary results of experiments in drain deepening in two Border forests. Rep. For. Res. 1957/58, p. 131-137.
- ZEHEIMAYR, J.W.D., 1954 Experiments in tree planting on peat. Bull. For. Comm. No. 22.

DEFINITIONS



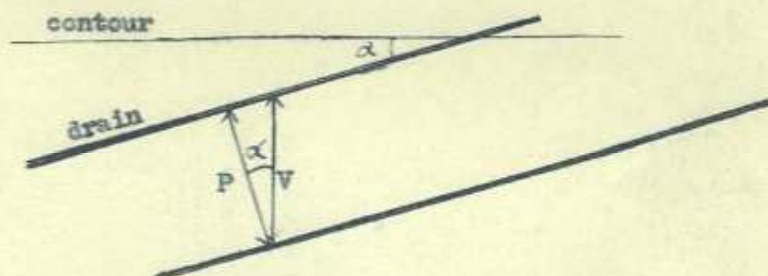
D = Depth

W = Width

A = Angle of side slope (batter)

S = Angle of slope of land

Gradients of drains to be expressed as "1 in x"
(angle in addition if Abney Level is used)

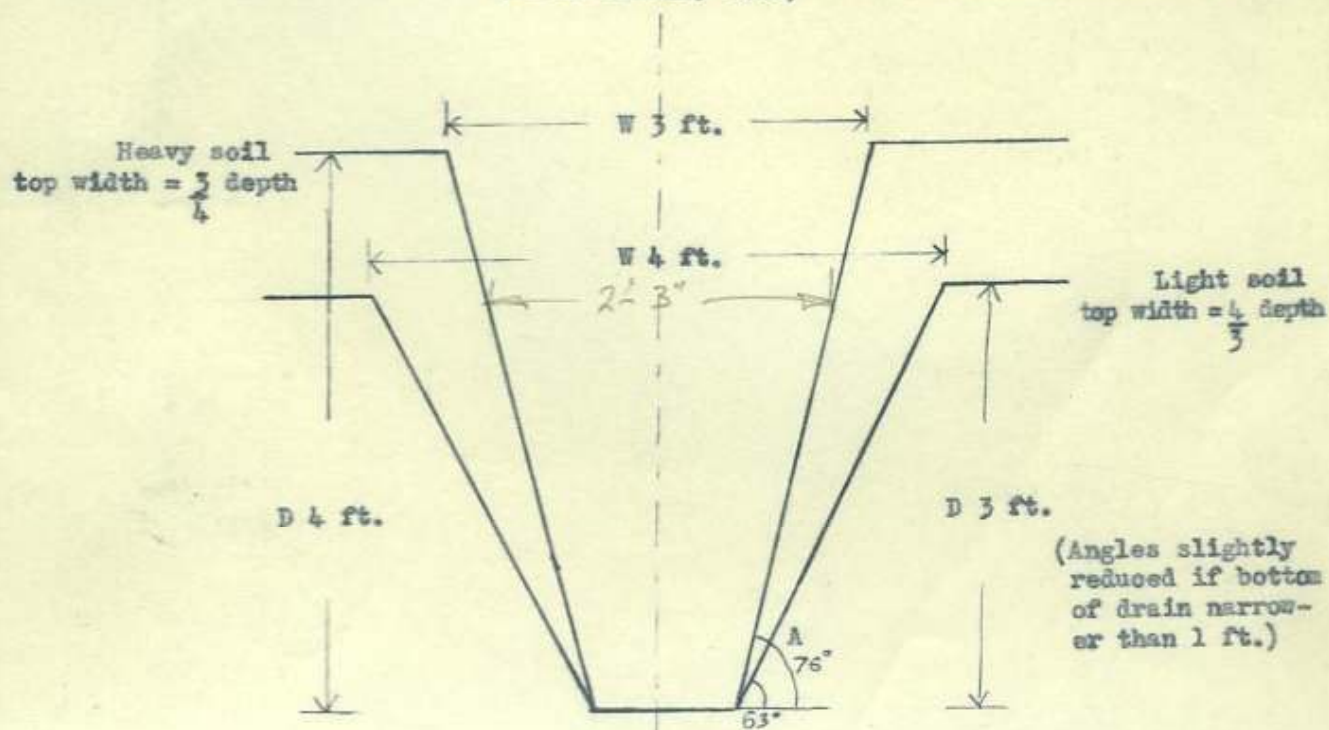


P = Drain spacing perpendicular to drains

V = Drain spacing (effective) perpendicular to contours.

α = Angle between drain and contour

WIDTH, DEPTH AND ANGLE OF SLOPE OF SIDES OF DRAINS ON HEAVY AND LIGHT SOILS (after Nisbet, 1905)



OBSERVATIONS ON FOREST LAY-OUT1. Introduction

In laying out a forest the final arrangement of roads, drains and compartment boundaries must be compromise between the demands, sometimes conflicting, of:-

- (a) Sub-division of the area into working units.
- (b) Fire Protection.
- (c) Access by road.
- (d) Access within stands.
- (e) Drainage.

Until now, it would be true to say that the first three of these has dominated the planning of forests, and it is accepted that road lines should act as compartment boundaries, and that where necessary they should act as fire lines.

Fire breaks and fire lines should be laid out with mechanical maintenance in mind. Where compartment boundaries do not also serve as road lines or fire breaks, their width should be kept to a minimum.

2. Drainage Layout

The object of a drainage plan is to achieve adequate drainage in the most economic manner, and it should also ensure that, once established, the system is easy to maintain.

The drainage plan should consider areas as a whole - not as individual compartments. Cross drains should be carried across rides rather than run into ride side drains, which are often too steep to carry the volume of water let into them without scouring.

Long runs are particularly important when considering mechanical drain maintenance. Another requirement for machine cleaning is that the drainside be clear of trees for at least 2'6" on either side of the drain. *1/2 to good deep drains*

Mechanical drain cleaning would most readily be applied in areas of uniform topography where the slopes are of moderate steepness (0° - 10°) and the soil is peat with the minimum of mineral and stony soils, for example the "Borders Type" found in South Scotland, North England and much of Wales.

Drain gradients should be sufficiently steep to maintain a free flow of water and the volume of water in the drain should be enough to keep it clean. Too rapid a flow, however, causes scouring particularly in clay soils. *no*

A system which satisfies these requirements is that in which ploughing is done up and down the slope and has cross drains across the slope running as closely as possible along the contours.

Drain density and depth will depend upon the site. One advantage of this system is its flexibility. As the site dries out drains can be abandoned or, alternatively, new drains can be cut without altering the system.

3. Access within Stands

The advent of greater mechanisation of extraction and new horse equipment means that more attention will have to be paid to the subject when planning forest layouts.

The main requirements for economic extraction, particularly of small sized poles, are:-

- (a) That poles are manhandled the minimum distance possible.
- (b) That the machine or horse is able to carry an economic load.
- (c) Extraction should do the minimum of damage to standing trees and the drainage system.

The distance travelled has less effect on the cost of extraction than the time taken to load and unload. The most important factor is free access to the material to be extracted.

The most convenient way of providing this access is by a system of racks. Until now, rackways have usually been spaced at two to three chains apart, and the extraction has either been hand extraction to rack and horse extraction by dragging, sledge or sulky or alternatively dragging from stump.

It is suggested that rackways should be closely spaced so that a larger proportion of produce lies close to the rack, cutting the amount of manhandling in the wood to the minimum, and eliminating dragging to allow bigger loads on sledge etc.

Where the cross slope is small, racks could be placed in the spaces cleared for drains. This would have the advantage of providing a reasonably graded access which, if it were placed on the lower side of the drain, would also be well drained and would result in the minimum amount of damage to the drainage system. The spacing of rackways would not necessarily coincide with drain spacing, and intermediate rackways might have to be cut.

On steeper cross slopes, ^{greater than 5°?} the racks would have to run up and down the slopes.

Conclusion

Information is still required on drain spacing, depth and gradients, and the spacing and gradient of racks also requires investigation. It is suggested that various layouts should be the subject of large scale trials - covering various stages of development of the stand.

(J. P. V.)

December, 1961.

File

FORESTRY COMMISSION RESEARCH BRANCH

EXPERIMENT PLAN : KERRY 8. F.Y. 61

PROJECT: Drainage 237.2

LOCATION: Kerry Forest, Cempt. 38.

- OBJECTS:
1. To assess the problems involved in putting in open drains mechanically, in stump covered ground.
 2. To assess the cost of making open drains in stump covered ground, using a Drott to clear drain lines and a Bamford Digger to cut the drains.
 3. To assess the amount of hand finishing required to establish satisfactory drains.
 4. To assess the stability of such drains.
 5. To observe the effects of drainage on the site, and subsequent tree growth.

- TREATMENTS:
- C - No Treatment - Control
 - D - Drainage carried out with contour open drains at approx. 2 chain intervals, and 2 ft. 6 ins. deep laid out so as to have a fall of approx. 1 in 200.

LAYOUT: The drains will be sited as in the plan on experimental file.

REPLICATIONS: Two

GENERAL: Date of Treatment, February, 1961.

The Main drain on the North side of the experiment will be cut first, so as to be approx. 3 ft. deep. All side drains will be cut from this working outwards, along the pegged drain lines.

Explosives will be used where necessary to remove the surface of rocky outcrops, where they obstruct the drains.

The drains will be finished by hand in order to create a slope to the side of the drains, and remove any spoil that has been left by the digger.

Bore-holes will be dug in each block during the summer after treatment and observations made in these during the winter, Sept. 1961 to March 1962

Drains will be inspected annually and maintained so as to have a clear run for the water. A record will be kept of all maintenance carried out.

Replanting will be done with S.S., at 6' x 6' but planting should not be brought nearer than 6' either side of each drain.

Brash will be removed from every alternate drain line, to get a comparison of performance of the Drott, for clearing stumps, with and without brash.

ASSESSMENTS:

1. Record of Establishment.
2. A report will be submitted after establishment, listing all practical difficulties that arose, and giving details of how they were overcome.
3. Details of the time and labour involved in each operation will be kept.

4. A record will be kept of the number and size of stumps removed from each drain line that is cleared of brash.

Stumps should be classed as follows:-

1" - 5" diam. 6"-10" diam. 11"-15" diam. 16"-20" diam. Over 21" diam.

5. Every Nth tree in each row will be marked and assessed so as to assess 10% of the trees planted for height growth and survival at the end of each growing season.
6. Bore-hole readings will be taken at 2-week intervals during the period Sept. '61 to March '62.
7. Root investigations will be made in due course once the tree crop has become established.

DURATION OF
EXPERIMENT:

The experiment will be reviewed in 2 years in the light of future, more detailed experiments, to decide whether continuation is necessary.

(A.I. FRASER)
for Silviculturist (S).

January, 1961.

DISTRIBUTION:

J.R.O.	- 1
Cons. N.(W). Via. C.R.O.	- 1
Silv. (S).	- 1
Silv. (N).	- 1
Mr. Holmes	- 1
Mr. Hampson	- 1
Mr. Overell	- 1
Mr. Evans	- 1
Mr. Ure	- 4
Mr. Cousins	- 1 (for ref.).
Dr. Hinson	- 1
Mr. Fourt	- 1
Spare	- 7

22

Comparison of drainage methods.Treatments:

- (1) One furrow of Single-Mould-Board Cuthbertson ploughing followed by 2 furrows of Double M.B.C. This gives 3 furrows for 5 rows of S.S. planted on the turf. The S.M.B. is 2 - 4" deeper than the D.M.B. at 12" - 14".
- (2) D.M.B.C. at usual spacing with 3' deep mains, parallel to furrows, at 5 chains/acre.
- (3) Ditto with 10 chains/acre of 3' deep mains.

Tree Crop:

The ploughing and draining was carried out before planting with Sitka spruce. These are now from 4' - 8' tall, generally healthy, but with only moderate leaders of 6" - 18". This is distinctly less than the best growth seen in the area.

Experimental:

The drains are at a fine angle to the contour, and the crop even, and with full stocking, Aspect is SE TO S, from 2° to 10°, and fairly regular.

Site Factors acting with the experimental treatments are "depth to mineral soil", and "depth of aerated or oxidised peat".

- (1) On areas of peat less than 14" deep, all the plough furrows approach or reach mineral material, itself fairly porous, and all the peat present is black and well aerated. It seems unlikely that treatment differences will be observed on these areas.
- (2) On areas of peat from 14" to 36" thick, the deep drains easily reach the mineral soil, itself a stony till, of moderate to low permeability. Below about 12" or so the peat is pale brown, unoxidised and smelling of reducing by-products. Little oxygen or water movement below this level can be expected.

Response to Treatment effects will probably be small, No. 1 being at a slight disadvantage, but only insofar as the other treatments benefit from water movements below the depth of the SMB, which is rather doubtful. No seepages could be seen below the junction of peat and mineral in the deep drains where a layer of unoxidised (light brown) peat occurs over the mineral or between it and the black-brown oxidised surface peat.

- (3) On areas of peat deeper than 3', the deep drains do not reach the mineral. As there is a tendency for the unoxidised layer to be closer to the peat surface (8-12") on this type, it differs little from type (2) above, except that the drains are wet and waterproof at most seasons, the floor not being porous.

As suggested above there is a peat depth/drain treatment interaction which is not experimentally compensated. The importance of this is reduced by the strong likelihood that on the thin peats the treatments offer little in the way of contrast as this peat is less noxious, has a better natural flora, and the mineral is brought into the seepage cycle by all the treatments.

The deeper peats offer some treatment differences, but these depend on the deep drains starting a seepage gradient in extremely soft, saturated, and at present stagnant peat.

Drainage of Peat:

It is suggested that this proceeds in 2 stages:

(1) Drainage by Gravity.

"Field

The artificial drainage system established at Ae is apparently as good as any such system can be. This will reduce the water content of the peat down to what on mineral soil would be called ~~Field~~ Capacity". It seems likely that even at this level, the peat will still be extremely wet. It has been suggested that where evapotranspiration plus drainage is less than rainfall, peat as well as water will accumulate.

(2) Drainage by Evaporation:

Reduction in moisture content below field capacity will be carried out by the natural vegetation. The "rougher" and more vigorous the canopy the greater will be the loss, and tree roots will probably root, and thus dry out, more deeply than many of the peat plants. Interception by Tree crowns should also help. The more vigorous the tree crop the more the surface peat will lose water which will let air in, and possibly initiate physical and chemical changes in the anaerobic peats below 10 - 12" depth.

Drain Cleaning On Peat

Dr. Hinson and I have discussed this and we feel that the cleaning of occasional up-and-down plough furrows can contribute little or nothing to the improvement of drainage, even if these furrows were previously obstructed.

We agree that any money spent would be more productive if used to make some new near-contour drains, 2 - 3 chains apart. However, it may well be just as important to spend drain-maintenance allocations on ride and especially, new road-side drains, the blockage or diversion of which is often the cause of wet patches, and subsequent windblow.

There is also the point that a deep drain along a road or ride can be cleaned or initiated by machines such as the "Denkum" or "Shawnee" tractor-mounted hydraulic-scoops.

Conclusions and Suggestions. Ae. Experiment 17.

- (1) The treatments on the experiment are rather similar, and may not produce much in the way of growth differences or fundamental information on the treatments great enough to measure under the existing condition.
- (2) The drains being efficient for their type-contour orientation and deep penetration, -the conditions capable of allowing the trees to play a major part in drying out the peat should be raised nearer optimal.
To remove any chance that variations in peat-fertility could affect tree performance now or later, and to separate these effects from drainage differences, a substantial dose of Phosphorus is suggested (4 oz. triple). *Potash may also be necessary.* Such an application may interact with the drainage treatments but the plots are large enough to "split" for ~~P~~ while retaining adequate cover for statistical analysis.
- (3) Although Fluorescein and Eosin investigations so far have not been successful, some thought is being applied to the subject of the detection of changes in peat oxidation, and moisture content. It is hoped to work out new techniques for the detection of reducing products such as H_2S which can aid and reinforce the powers of the human nose.

LENNOX

- (1) A preliminary survey for a Soils Section experiment was carried out and a plan made.
- (2) The new drain sides were examined and the appearance of a well-developed prismatic fissure system was welcomed. There is a tendency for the fissures to become oblique at 18" and below. Fissure sides were grey and slightly shiny with grey-brown mottle inside the units.
- (3) The major seepages were usually at the junction of loamy surface and clayey subsoil and aligned chiefly along the old plough furrow.
- (4) Fluorescein, rendered soluble with NaOH, was followed between sump holes to the new drain. Sump holes were on the line of the old plough furrows, aligned up and down. Eosin, though dissolving well in the unaltered water, was not recognisable in the drain, or where adjoining pits were used. Its red colour is hard to recognise after dilution in soils of similar hue.
- (5) Rows of holes below the cross drain showed marked ability to collect surface water, and $\frac{1}{2}$ chain is suggested as a useful drain spacing.
- (6) The survey included the first Silv. N Experiment Block, now rapidly diving under a cover of Junci. Block II seems an incredibly wet site and needs drains badly and has suffered from fine replanting in burnt patches, and also windblow.
- (7) While excavating in a good area on N.S. near the Silv. N Experiment, upwelling of water from drain floors was put down to the presence of stone drains still carrying a good flow. This question needs looking into.

J J Hunt

Diary for tour of Forestry Commission and Ministry of
Agriculture Drainage experiments

Persons present: Mr. A. N. Ede, Ministry of Agriculture Land
Drainage Division
Dr. W. H. Hinson, Soils Research
Mr. D. F. Fourn, " "

Thursday, 4th May

1. Mole Drainage Experiment - Halwill Forest

This experiment was laid down in January/February of this year, so that the mole drains have been in operation 2-3 months, during which time there has been about 12" of rain (equivalent to more than 1 million galls. on this area) ^{by 22nd} a dry spell in March, during which month less than 1" fell.

(1) The moles are all running to some extent and it was noticeable that those whose exit was well above the bottom of the main drain were running more than those opening lower down.

(2) Considerable silting up had occurred inside the mole channels and the exits of many have been reduced to about half the original size, where tiles have not been inserted.

(3) An excavation about half way up one mole revealed an almost perfect channel, through which water was passing freely, but a further excavation, nearer the top, revealed a considerable reduction in the area of the channel.

(4) There is little sign of fissuring in the clay yet, though it does not feel saturated, and it may well dry out in the near future if rain does not persist indefinitely. It is still early in the season and the large quantities of rain in the last month have maintained a high level of moisture in the top soil.

(5) The most significant difference between the moled and unmoled plots is the water in the plough furrow bottoms. More than 90% of the unmoled furrows had puddles standing along most of their length, while less than 10% of the moled furrows had puddles, most of which were very small.

Discussion

If this effect has been achieved by the water percolation through the mole slot, then there is every hope that any fissures that may develop, will have the same effect of allowing percolation, as well as allowing root penetration.

It remains to be seen whether the effect persists, and whether roots will take advantage of the fissures and drier conditions to penetrate downwards.

The most important effect to observe at present, is the date of opening and closure of fissures, as it is to be hoped that the presence of moles will bring about opening earlier, and delay closing until later, until with the addition of transpiration from the tree crop, they become permanent.

The species planted in this experiment, namely S.S., is not the most suitable as regards exploitation of these fissures. On the other hand, it is the most important species, for which these improvements were really intended, and if S.S. will react, then it can be assumed that almost any other species will.

2. Site for Proposed Extension of Mole Drainage Experiment - Halwill

This area of approximately 20 acres adjoining the present experiment, is a very suitable site, having uniform soil conditions as far as can be seen, and a moderate but uniform slope. Discussion and proposals for this site are at the end of the diary as they include many points arising from the other experiments visited later.

3. Ministry of Agriculture Experiment - Langabear

The main object of this experiment is to compare the effect of drainage and fertilisers on crop production. There are four plots:-

- (1) Undrained - unfertilised.
- (2) Undrained - fertilised.
- (3) Drained - unfertilised.
- (4) Drained - fertilised, each about 4 acres.

The drainage will be in the form of moles, and these are to be put in this year. Prior to moling, measurements are being made of rainfall, surface run off, and top soil discharge. Once the moling is done, discharge through the moles will also be measured, and their effect on the surface and top soil discharge will be observed.

The instruments used to measure these factors are too elaborate to describe in this diary, but details are available if required.

Also seen on this site were trials of different sized mole expanders and different slopes of mole channel from maximum possible to that necessary to obtain flow.

Some doubt about this in the long term
It would appear that 6" expander is better than the 4" as it leaves a larger hole once the clay has settled back. It would also appear that the greater the slope in the mole channel the better, as the more rapid flow of water resulting, prevents silting up and may even have a slight scouring effect, which would help to prolong the life of the mole. This could be seen by the greater quantity of spoil deposited at the exit of the steeper mole channels.

excessive gradient and consequent scouring undesirable
4. Fison's Experimental Farm - Northwick

The main object of visiting this area was to see a field that had been reclaimed by the installation of an intensive system of tile drains and to see an instrument for measuring discharge from sub-surface drains.

The field had originally been pure rushes Juncus spp. and had been disused for agriculture for some time. Now, one season after installation of tile drains at 16 ft. spacing and 2 ft. depth, the field had been cultivated and will shortly be resown. The sides of the main drain into which the tile drains have been fed already show a very pronounced fissuring system, and the clay is becoming distinctly crumbly.

The instrument used to measure discharge from the tile drains is again too elaborate to describe but details are available if required.

Friday, 5th May

5. Ministry of Agriculture Experimental Area - Tealham Moor, Somerset

The main object of visiting this area was to see an adaption to the mole plough for laying plastic pipes in the mole channel.

The machine is still in the prototype stage, but is extremely effective, laying a 3" diam. plastic pipe at a rate of about 3 chains per minute.

The/

The plastic pipe is made up of two strips of plastic 4" wide with slots on one side and tongues on the other. These are fed through a dye which forms the tube and fastens the plastic top and bottom. The end of the tube is anchored in the drain and the tractor moves forward, the plastic tube being pulled out of the dye, rather than fed through.

It is considerably cheaper than conventional tile drains, but even so it is expensive at present, costing in the region of 30/- per chain laid. However, there is every hope that as this goes more into production the price will come down considerably.

Discussion of points raised in relation to proposed extension
Mole drainage experiments at Halwill

1. It was generally agreed that the effect desired from mole drains is the formation of fissures in the clay, allowing root penetration, aeration, and improved percolation of water from the surface layers.

2. Open drains, regularly spaced and contoured would go a long way to removing the standing water in the top soil which seems to be an important factor in root death, and certain tree species might well develop roots into the clay without any further treatment.

3. Mole drains would probably increase this effect and may well enable other species to develop roots in the clay, particularly Sitka spruce, which is such an important species economically. They may also prevent closure of the fissures in the winter period by giving the water an easy escape route from the fissures, thus preventing saturation and swelling of the clay.

4. It was considered that if the mole drains did encourage rooting into the clay to the depth of the moles, then the risk of drought would be no greater than under normal conditions, as the moisture level below the depth of the moles would be unchanged. It may, in fact, reduce the risk of drought, as it is the top soil that would dry out most, and a tree with roots well into the clay would get some moisture from the capillary rise in the clay.

5. Besides studying the effect of the moles, it is important to know what factors affect the longevity of the moles, such as slope, depth and size, and it is considered worth studying the effect of depth and slope at least.

6. It was considered essential that all open drains to be used with moling or without should be dug mechanically by such diggers as the Dinkum, as this is considerably cheaper than hand, and enables sufficient depth to be made to have clear mole exits.

7. The effect of fertilisers in combination with drainage, on root development is little known, but this experiment should be used to study the interactions of these factors. It is proposed to use a range of tree species including some hardwoods, and so a very useful and interesting study can be made of the effect of both drainage and fertilising on the root development of a range of species.

8. Of the species to be considered, *P. contorta*, Lawsons cypruss, alder and birch are important species for exploiting heavy soils, while Sitka spruce is important as an economic species that suffers severely from windblow as a result of poor drainage. Another species worth investigating is *Thuja* which may also be able to exploit the heavy soils.

9. The most important treatments to investigate are ploughing as current practice, ploughing plus deep open contour drains, at regular intervals, and ploughing plus drains plus moles. Species and fertiliser applications would form sub-treatments.

10. Ideally, water movements on the site should be recorded for a season before installation of drains, so that the most suitable time table would be to prepare ground in late summer 1962, when ground conditions for drainage are the best and plant in F.Y. 63. This would also give one complete year for observations on the existing experiment before establishing the new one.

11. Modifications of the Mole to enable it to be used in combination with a plough, and also to be used on stump covered ground are important and these should go ahead as trials separately from the experiment.

A. I. FRASER
Assistant Silviculturist (S)

16th May, 1961

Distribution:

C. R. O.	1
Silv. (S)	1
Silv. (N)	1
Mr. Holmes	1
Mr. Rouse	1
Mr. Oram	1
Mr. Ede	1
Dr. Hinson	1
Mr. Fourt	1
Mr. Cousins	1
Mr. Baker	1
Mr. Williams	1
Mr. Beasley	1
Mr. Farrall	1
Mr. Walsh	1
Spare	<u>5</u>

20

Visit to see Drainage Research carried out by the
Agricultural Institute, Malohide, Co. Dublin

The Agricultural Institute

This is of very recent foundation, set up under Marshal Aid (Director Dr. T. Walsh). The headquarters are being established on a farm about 7 miles north of Dublin. Extensive glasshouses have been erected and are almost ready for use and the site is being prepared for erection of laboratory and administrative buildings. The staff are temporarily occupying the farmhouse. The Department of Agriculture has administered some Agricultural Research in Eire, notably at Johnstown Castle, Wexford which has now been placed under the authority of the Institute, in order to co-ordinate the work with the new projects to be initiated by the Institute.

Mr. Quinn is in charge of Soil Physics assisted by Mr. Calvin, and Mr. Burke who is at present in U.S.

Tour to Glenamoy, Co. Mayo

I. Experimental Farm, Ballinagh

Mr. Calvin met us in Dublin and conducted us on our outward journey. An important project receiving attention by the Institute, is the improvement of the heavy soils typical of the 'Drumlin' country and we were shown something of this on the way.

The 'Drumlin' country of parts of Longford, Van and Roscommon presents an unmistakable landscape of small rounded hills out up into very small fields by neglected hedges. The farms are small and frequently deserted with scrub invading what was formally very poor grazing with up to 50% or more Juncus. The animals are housed during the winter as the grazing would very quickly be ruined by trampling when wet - on mechanical analysis it is about 70% clay.

The Institute has purchased a farm near Ballinagh, has built a modern house for the farm manager and an extensive range of farm buildings were being erected. Trials of several techniques for improving the grazing and using the land for arable purposes had already been set up and were yielding very encouraging preliminary results. An experimental layout of mole drains was of particular interest to us. The old type of mole, mounted on its own pair of wheels had been used at a range of spacings down to 4 ft. and there was every indication that this close spacing was necessary. At this spacing the state of the ground was remarkably fair despite recent heavy rain; there was evidence of improved percolation from the smooth shape of the trace obtained from the flow recorders in the main drains. Evidence for the need for the close spacing was also shown by borehole records. Drainage in combination with phosphate applications changed the botanical composition and productivity of the sward showed a fantastic improvement. It was suggested that moling should be regarded as a normal cultivation and repeated as often as necessary.

These soils seem to be potentially of very high fertility and capable of developing an excellent structure. Wetting and drying had quickly broken down the spoil from the main drains into little cubes; the course of the slow running main drain from the whole farm was green with algae and the vegetation on the banks lush, as one would associate with the drainage from a muck yard.

II. Glenamoy Research Station, Co. Mayo

The station is situated 5 miles inland from the northern coast of Mayo and about 15 miles from the open sea to the west, on a broad expanse of blanket bog, at an elevation of 3-400 ft.

Some slightly higher hills can be seen to the west and rising ground some miles away to the north. The exposure is severe; met. office records indicate that the area is subject to comparable average wind speeds and frequency of gales to the Scottish western highlands. The scenery greatly resembles parts of Caithness. The rainfall has been locally recorded as about 45 in. mean over the last few years, but the met. office maps indicate an average of over 50 in.

The buildings are very attractive, white painted single storey structures which provide living quarters for Mr. O'Hara the Station Manager, clerical and assistant staff and on occasion visitors from Malahide, as the station is 30 miles from Ballina. There are some laboratory facilities and workshops for repairs to agricultural machinery and the like.

The site had been chosen as a typical example of Western Irish blanket bog combined with rather worse than average exposure. As far as could be discovered on a short visit at this time of year the botanical composition of the turf does not differ from the description given by Tansley for north-western Mayo with Sphagnum nigricans dominant. Tansley states that the same type of bog covers much of western and north-western Scotland, though there mainly dominated by Scirpus. Though the vegetation mat wobbles like a mattress it does allow one to walk on the bog where it is unbroken. The peat freshly thrown out by a machine is soft to the foot as Camembert cheese, dark brown with lighter threads of Sphagnum roots. Rather surprisingly water may be wrung out by hand, and it does not extrude between the fingers as much as would be expected.

The appearance of P.C. and S.S. planted for shelter belts and now up about 6 ft., suggests that it is not particularly difficult to establish these species on the bog using phosphate. Some browning probably due to salt laden winds was noticed. It is interesting to note that there is 40 acres of shelter belt to 100 acres of Farm!

The Experimental Plots, Glenamoy

Work commenced in April, 1954, the project being production of grass for grass meal. In August, 1955, following a change in government, this project was abandoned in favour of more general studies of improvement of grazing, general cropping, systems of stock management and special crops which might support industrial developments in the region, such as Bamboo for Fibre. In order to carry out this policy the station will become an experimental farm. Gain of weight of stock will eventually be the primary assessment of the plots. At present assessments of yield of dry matter from clipped quadrats are used. The devices in use for assessment of drainage effects are of particular interest to us. They are:-

- (a) Boreholes lined with 3" tiles. Metal rods driven into the mineral soil are used for the height reference. No appreciable peat shrinkage has occurred yet.
- (b) Flow recorders using an inverted V tank outlet of special profile to give a linear relation between flow and height of water in tank. This is recorded by movement of a float in a cylindrical baffle in the tank by means of a pen and drum. Weekly drums are used in the summer and daily drums in winter.
- (c) Evapo-transpiration meters. Metal drums about 14" diameter let into the bog, filled with peat and capped with natural sward. These were replicated and sited adjacent to boreholes. The water in the drums was adjusted frequently to the same height as in the boreholes in the surround. A small borehole in the contents of the drum was used for this purpose and an account kept of the net volume added or removed.

Some plots about 15 ft. square bounded by drains cut by hand to 3 ft. had been established. Good crops by any standard of potatoes and fair crops of various vegetables and cereals had been obtained under these conditions, with moderate amounts of lime and fertilizers. Copper deficiency has to be corrected for cereals or there is no grain at all, however this can be readily

achieved with 15 lb. per acre copper sulphate.

Larger plots about 1 ch. x $\frac{1}{2}$ ch. drained by ditches and by means of the Glenamoy plough were used to compare treatments aimed at improving the grazing. These included combinations of lime, phosphate and potash on the native sward and also surface reseeded. The results were very encouraging, but no treatment would permit winter grazing without destruction of the sward. Finally and of great interest to us there were trial plots drained by the Glenamoy plough at a range of spacings down to 4 ft. The improvement of the state of the ground in the intensive treatments was very marked despite recent rain. The observations of the boreholes, evapo-transpiration gauges and flow meters are claimed to indicate:-

- (a) Very close spacing of "underdrains" of 4 - 8 ft. is required for marked treatment effects.
- (b) Improved percolation due to treatment, very well marked (shape of flow recorder trace).
- (c) Total flow from the plots is independent of treatment, and changes in the moisture content of the peat due to treatment may be accounted for quantitatively by the evapo-transpiration as measured.
- (d) The borehole levels rose with distance from drains reaching the maximum at a distance of only 18" - 24".

The Glenamoy Drainage Plough

Construction

Accounts of this development have been published - Ref. A. Armstrong, J. J., Burke, W. and Quinn, E. A new drainage plough for peatland, Journal of the Irish Dept. Agric. 57, 1959. Ref. B. Annual study tour, Irish Forestry 17, (2) 60, 1960. The following notes should be read in conjunction with the above, if at all:-

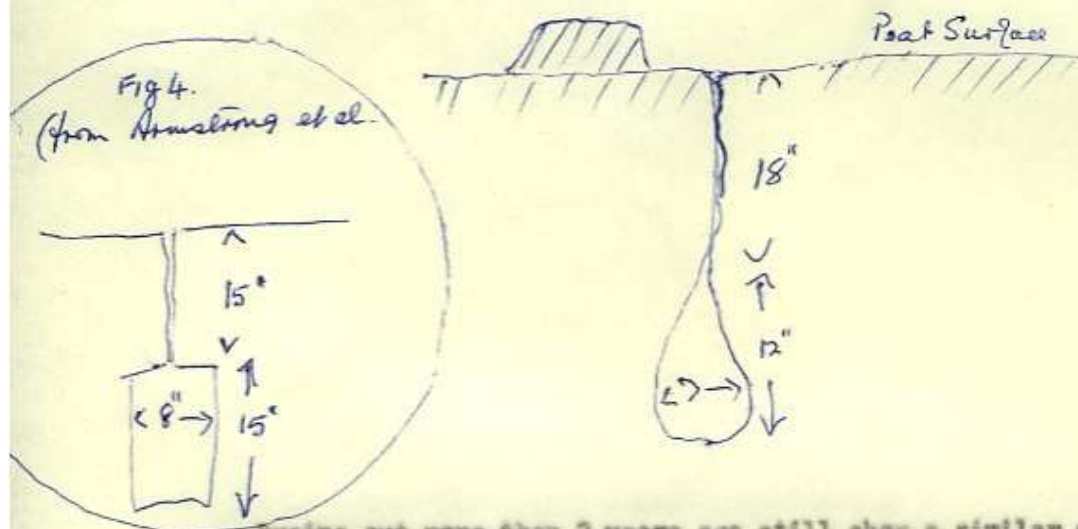
Ref. A. Fig. 2 should be interpreted as being the internal parts of the structure seen in Plate I. The only surfaces shown in Fig. 2 and 3 also visible in Plate I is the rear extension (D Fig. 2). The breast plates C in Fig. 2 are hidden behind large flat breast plates seen in Plates I and II. Part of the edge of the lining to the breast plates C Fig. 2, seen in section in Fig. 3, which forms one of the inner surfaces of the duct can be seen in Plate 4 forming a flat on the peat ribbon. The flat cheeks of the plough prominent in Plate I, the sole plate and the deflector seen pushing the peat to the left in Plates 3 and 4 have been omitted from the simplified diagrams. The width of the duct has been increased from 8" quoted in Ref. A to 13".

Ref. B. The plough is almost entirely $\frac{1}{8}$ " - $\frac{3}{16}$ " mild steel plate not $\frac{1}{2}$ " as quoted in B, who also misquotes the dimensions. The weight is said to be 3 - 400 lbs. The cover photograph of Irish Forestry shows a fine view of the plough in action; the small photograph top left opposite P. 60 in this journal shows the sole plate which cannot be seen in the other Plates, but the perspective used seems grossly to exaggerate the size of the plough compared with the tractor, and is obscure in that the lower point in the plough nearest to the tractor seems to be in the plane of the cheeks rather than a plane parallel to the sole.

Operation of the Plough

The plough readily pulls in when lowered by the moving tractor. Peat retaining the form of the duct extrudes breaking in pieces one to several yards long. The shape of the deflector could probably be improved to obtain a more continuous ribbon if required as a planting position for forest use. The peat remains in close contact with the rear extension right to the tip where the two faces of the peat immediately come into contact. Where an

open drain was crossed at right angles it was possible to see the shape of the channel and immediate flow of water. On Glenamoy bog the shape bears little resemblance to Fig. 4, but immediately assumes the shape shown below, owing to plastic deformation of the peat.



Drains out more than 2 years ago still show a similar shape, but have closed in somewhat more in some cases, but they are all still functioning.

The draught required for the drainage plough is said to be much less than for a Cuthbertson, but has not been measured. No trouble with bogging the tractor has been experienced. Regarding the possibility of the tractor sinking in at the rear when the plough is raised, it was pointed out that the linkage was fairly compact so no trouble of this kind had been experienced, nevertheless it would be possible to shorten the linkage still more.

Regarding the range of sites suitable for the plough, it was said that softer and wetter peat could be cut if the speed could be increased above normal ploughing rates. No difficulty was anticipated with firmer or more fibrous peat, but there had been little actual experience with such types.

An attempt had been made to use the plough on what is locally termed Slobland. This is a thin peat subject to salt water flooding. Apparently the dust was half in the mineral soil which extruded along with the peat. However the draught was increased so much that the tractor was not adequate for the job and the linkages frequently broke.

Application of Drainage Plough to Forestry

A trial of the machine at 5 and 10 ft. spacing in comparison with single and double mouldboard Cuthbertson ploughing had recently been set out by the Forest Service at Glenamoy. The peat ribbon was used as the planting position. Mr. Mooney (Senior Research Officer, Irish Forest Service) thought that if large areas of virgin blanket bog were to be afforested it was essential to know how these methods compared. He did not think the drainage plough was of application to the present planting programme.

Discussion and Conclusions

Compared with Cuthbertson type ploughing there are a number of hypothetical advantages and disadvantages. If the underground channels persist long enough the grade of draining achieved would probably be of a similar order to orthodox deep ploughing. However the ground area exposed to evaporation is less, but the

DWH/MJ

Our Ref. 40.3

23rd October, 1961.

Conservators N. S. E and W (Scotland)

Draining - Peaty gley or Peaty podsol soils

Research Branch and Work Study are together studying the problem of draining. Two points stand out strongly:

- 1) The very large annual expenditure on hand maintenance of drains (mainly the cleaning of furrows originally ploughed for planting). This emphasises the need for study, to examine the need for such great expenditure and means for reducing it.
- 2) The great diversity of drainage patterns (spacing, slope, depth, direction relative to contour) which exist. It seems probable that many of these old-fashioned patterns are ineffective and/or unnecessarily elaborate and costly, and that the layout and maintenance of such patterns are being continued unnecessarily. However, there are also more up to date areas which are locally considered to be examples of good draining, and these I would like to visit and discuss with the local staff.

May I ask for your co-operation in circulating field officers to send details of the location of such examples of good draining? Examples are needed to cover all the points of spacing, depth, gradient etc. and any other factors considered to be of importance, including such things as layout in relation to roads and racks.

for Silviculturist (North)

Copy to: D(S)

Cons. NE(E) and NW(E) for information. If you would like to co-operate we would be glad to extend investigations to Kielder, Kershope, etc.

C.R.O.

Silv.(S) 1

J.W.L. Zehetmayr

FOREST COMMISSION RESEARCH BRANCH

EXPERIMENT PLAN: HALWILL L. F.Y. 61

PROJECT: Drainage. 237.2.

LOCATION: Halwill Forest, North Down.

OBJECT:

1. To test the feasibility of superimposing mole drains onto the normal system of single furrow ploughing.
2. To observe the performance of the mole drains in the Culm measure soils.
3. To observe any effects that moling may have on water relations in the soil, and on subsequent growth of crop.

TREATMENTS:

P. Control. Normal single furrow ploughing at 6 feet spacing, and to a depth of 4 inches.

PM. Normal single furrow ploughing at 6 feet, to a depth of 4 inches, with moles pulled in at 6 feet spacing along each plough furrow. Moling will be to a depth of 20 inches.

LAYOUT: The layout will be according to the attached plan, designed so that ploughing and moling run at a slight angle to the contours, with a fall not exceeding 1 in 200.

REPLICATIONS: Two.

GENERAL: Date of treatment, January, 1961.

Treatments will be separated by 2 feet deep open drains, as indicated in the layout plan, and moles will be pulled in from these, uphill, terminating just before the next open drain is reached.

A 3" expander will be used on the mole plough. Wire will be laid through every 5th mole channel so that tests for blockages can be made at a future date.

Bore holes will be dug in each block during the summer after treatment and observations made in these during the following winter.

Drains will be inspected annually, and maintained so as to keep the mole exits clear. A record will be kept of all maintenance carried out.

Replanting will be done with SS at 6' x 6', but planting should not be brought nearer than 6' from any open drain.

Pits will be dug at the closed end of all moles laid with wire, so as to expose the end of the mole for ease of sampling. A tile should be placed in both ends of each mole laid with wire. The ends of the wire laid in the mole channels should be attached to stakes and clearly marked.

ASSESSMENTS:

1. Record of establishment.
2. Every n^{th} tree in each plot will be marked so as to have 108 marked trees/plot, and assessed at the end of each growing season for height growth, and survival.

3. Every 5th mole channel will be assessed for blockages (by pulling a bobbin through on the wire laid at the start) in the spring of each year. The length of the mole channel will be measured.
4. Bore hole readings will be taken at 2-week intervals during the winter following treatment, September 1961 to March 1962.
5. Fluorescine determinations of water movements will be made during the winter following treatment, September 1961 to March 1962.
6. Root investigations will be made in due course once the tree crop has become established.

DURATION OF
EXPERIMENT:

The experiment will be reviewed in 2 years in the light of future more detailed experiments, to decide whether continuation is necessary.

A.I. Fraser
for Silviculturist (S)

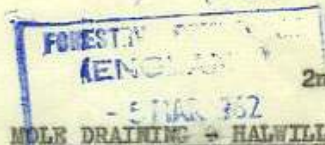
Distribution:

January, 1961.

C.R.O.	1				
Cons.S.W.(E) via C.R.O.	1	Mr. Holmes	1	Mr. Beasley	2
Silv.(S)	1	Mr. Rouse	1	Mr. Cousins	4
Silv.(N)	1	Mr. Oram	1	Spare	8
					<u>Total: 21</u>

1) Mr. Grainger - for info
2) Mr. Anderson
Mr. K. Baker via Mr. Cousins

Our ref: S.Ex.Hal.5



2nd March, 1962

DD

This note is to summarise our conclusions and decisions during the visit by Mr. Anderson, Fourt and myself to Halwill on 6th - 7th February.

We looked at the existing experiment and though a little disappointed in the performance of some of the moles, were encouraged to find that the water level in the bore-holes were on average 6 - 8" deeper in the moled plots than unmoled. In addition the plough furrows were more or less dry in the moled plots, compared with large pools of water in the unmoled.

1? It seems that the moles in the second plot treated, which are shallower, only about 15 are rather better than the deeper ones, in the unmoled plots where they are 18 - 20". This point will be kept in mind in the next experiment.

All the plants appear to be very good, but please ensure that manuring is carried out this spring, according to the Experiment plan addendum. I would also like a shallow trench to the top of the clay, and one shovel width - 9", dug round the unmanured control plots to eliminate root spread out of the plots. Plough furrows should form two sides of the plots.

As far as the new experiment is concerned we decided on the following approximate timetable:-

- Late March 1962 - Level site, peg out contours and main drains. Mark out grid and plot boundaries if time.
- April - If excavator is available commence digging main drain, from existing ditch in neighbouring field into our area at lowest point, and from then on as surveyed.
- April - May - Trial of Cuthbertson plough, as available and according to weather and soil condition.
- May - Dig remaining secondary drains, or plough them if Cuthbertson plough proves satisfactory.
- May - June - Put in mole drains into required plots followed by either complete cultivation with agricultural plough, or normal single furrow ploughing with Ransome solotrac, according to situation at time.
- June - Insert flow-meters on the drain exits from each plot, to record water flowing from that plot during summer and subsequent winter.
- Oct. - Nov. - Plant.
- March 1963 - Apply manure.

The operations will not take as long as indicated by this timetable, but allowance must be made for weather, mechanical trouble and of course your other commitments, so that this leaves plenty of room for flexibility.

I am expecting to have the level by 20th March so that the survey can start any time after that, and I will arrange for someone to come down from Alice Holt to assist you.

Handwritten signature: A. I. Fraser

A. I. Fraser
Assistant Silviculturist (S)

Copies to:-

Mr. Anderson }
Mr. Beasley } for info.

Some Statistics for Drainage Work in
the Forestry CommissionMr. E. F. Swainfield.
D(E).

1. Our accounts distinguish the making of drains in advance of planting and the maintenance and repair of drains in plantations. They do not identify separately the ploughing element contained in preparation of ground, which is so often in part a drainage operation.
2. The output of work on drains is measured in chains but no details about the specification of the work can be obtained from the accounts. This means that drain cleaning for instance may be merely the removal of brash or slash in one place and in another place may involve deepening and widening operations at the expenditure of vastly greater sums per chain. Although we are not certain of complete uniformity of compilation for figures of work done, it appears that the general desire is to pay for drainage work on piece rates and record quantities by linear measurement, against which payment is made. On the whole the costs per chain reported are fairly consistent year by year in any Conservancy both for new drains and drain maintenance.
3. We have extracted direct costs only, ignoring overheads. Direct costs cover sums expended on labour, P.V.M. and other (materials, contractual services).
4. It may be of interest to note the annual expenditure incurred on new drains relative to other establishment costs, and on drain maintenance relative to other forest maintenance and protection operations. These are shown in Tables 1 and 2 for F.Y.61 only. We are spending currently a little more on maintenance of drains in forests covering $1\frac{1}{2}$ million acres than on new drains on an annual planting programme of 60,000 acres.
5. Table 3 shows average expenditure, quantities and unit costs of drainage operations and areas of plantations by Conservancies.

Here we have suggested that drain maintenance may usefully be related to areas in the thinning stage, assuming first thinning takes place when the plantation is 20 years old. The wide variation in the quantities done suggests that in many instances this is not true and in order to provide a more realistic picture, information is required on the extent to which maintenance is carried out in plantations prior to closing of canopy, e.g. on heavy clay lands in E(E), or if, though it appears most unlikely, drains in thicket stage plantations are treated. It is difficult to assess the frequency with which drains are maintained since we do not know (a) the acreage over which drain maintenance is being done, and (b) the average intensity of drains laid down and now maintained in the area covered.

6. The meeting may be interested to comment on statistical gaps revealed. In particular the following questions might be considered.
 - (a) how should we measure output of new drainage works and of drain maintenance?
 - (b) do we need some assessment of drainage works by difficulty, class of land treated, and by specification of the work performed?
 - (c) what evidence can be collected on the optimum specification of a drain so that the total cost of initial cutting and of subsequent maintenance is minimised for a predetermined drainage effect?
7. Comments on the figures attached.

Figure 1: shows the Conservancies with lowest unit costs of prep. ground to be those where ploughing is a big item.

Figure 2: there is a general pattern of inverse correlation between cost per chain of new drains and chainage per acre. The cost per acre in the wettest Conservancies is, however, double that in the driest.

Figure 3: a similar pattern occurs with unit cost of drain maintenance and chainage per acre of older woods. Again the wetter Conservancies have the highest per acre charges - apart from N(S) which is odd man out.

Figure 4: unit costs of maintenance rise with unit cost of new drains - new drains cost on average about twice as much per chain as drains maintained. Presumably there are two factors operating here (a) there is no necessary connection between specification of recently made drains and of old established drains now being maintained, and (b), on the whole, Conservancies which, because of higher specifications and/or less efficient working, have high unit costs of new drains are also ones where maintenance costs are high.

8. The above observations are sketchy enough in all conscience, and their foundations probably rather shaky, but we still have only a minute part of the answer to the important economic question. This is to determine the relationship between intensity of drainage (suitably defined in terms of job specification and hence cost) and effects on crop yields over time (including necessarily predictions as to stability). Until we can quantify both costs and benefits for various drainage intensities we cannot hope to determine the economic optimum intensity of drainage.

(A. J. GRAYSON)
(S. WALKER)
13th April, 1962

TABLE 1

Drainage Expenditure in Perspective, 1961
ESTABLISHMENT

COUNTRY		TOTAL	Drains New	Fences New	Prep. Ground	Planting	B.U.	Plants	Weeding	Cost of Drains as % of Estab- lishment.
ENGLAND	Total Cost £000	1288	45	130	280	100	44	290*	399	3.5
Acreage F.61 17.9	Cost per planted acre £	71.9	2.5	7.3	15.6	5.6	2.5	16.2	22.2	
SCOTLAND	Total Cost £000	1143	127	154	197	160	33	305*	167	11.1
Acreage P.61 33.3	Cost per planted acre £	34.3	3.8	4.6	5.9	4.8	1.0	9.2	5.0	
WALES	Total Cost £000	808	37	102	135	76	26	205*	227	4.6
Acreage P.61 12.5	Cost per planted acre £	64.8	3.0	8.2	10.8	6.1	2.1	16.4	18.2	
GREEN BRITAIN	Total Cost £000	3239	209	386	612	336	103	800*	793	6.5
Acreage P.61 63.7	Cost per planted acre £	50.9	3.2	6.1	9.6	5.3	1.6	12.6	12.5	

* Costs of plants have been estimated on basis of trend of production costs F.Y.60 to F.Y.62 (budgets). These figures are nearer the real costs than the total of £1,502,000 noted in the F.Y.61 Annual Report which arises because of over-valuation of stocks and stock changes in previous years.

TABLE 2

Drainage Expenditure in Perspective, 1961

FOREST MAINTENANCE								OTHER SILVICULTURAL OPS.
	TOTAL	Drains	Fences	Fire Prot'n	Other Prot'n	Cost of drains as % of all maintenance.	Brush, Clean and Prune	
ENGLAND	375 74 1.81	86 .17 .41	70 .14 .34	97 .19 .47	122 .24 .59	23	193 .38 .94	
	<i>Total base £000</i>							
Productive Area	504,000 Acres. Cost per planted acre							
Older than P.41	207,000 Acres. Cost per planted acre							
SCOTLAND	361 .61 2.38	109 .18 .72	42 .07 .28	95 .16 .62	115 .20 .76	30	82 .14 .54	
	<i>Total base £000</i>							
Productive Area	594,000 Acres. Cost per planted acre							
Older than P.41	152,000 Acres. " " "							
WALES	186 .75 2.82	46 .19 .70	50 .20 .76	65 .26 .98	25 .10 .38	25	80 .32 1.2	
	<i>Total base £000</i>							
Productive Area	247,000 Acres. Cost per planted acre							
Older than P.41	66,000 Acres. " " "							
GREAT BRITAIN	922 .68 2.17	241 .18 .57	162 .12 .38	257 .19 .60	262 .19 .62	26	355 .26 .83	
	<i>Total base £000</i>							
Productive Area	134,500 Acres. Cost per planted acre							
Older than P.41	425,000 Acres. " " "							

TABLE 3

Drainage Expenditure by Conservancies. Average 1958 - 61.

	NEW DRAINAGE															
	TOTAL	NW(E)	NE(E)	E(E)	SE(E)	SW(E)		N(S)	E(S)	S(S)	W(S)		N(W)	S(W)		
Chains completed 000	270.4	10.0	26.7	6.3	3.8	5.0		57.9	28.5	52.6	42.0		21.3	16.3		
Total direct expenditure on new drains £000	183.6	8.0	12.7	10.0	4.0	6.9		42.2	19.2	24.2	21.9		19.6	14.9		
Cost per chain £	.68	0.80	0.47	1.59	1.06	1.39		0.73	0.67	0.46	0.52		0.92	0.91		
Average area P.58-61 000 acres	57.1	3.3	5.5	3.0	2.4	2.6		8.8	6.3	8.6	4.7		6.0	5.9		
Cost per acre planted £	3.1	2.40	2.32	3.37	1.63	2.58		4.80	3.05	2.80	4.61		3.27	2.51		
<u>DRAIN MAINTENANCE</u>																
Chains maintained 000	533.9	31.3	98.2	19.2	5.1	13.5		21.3	40.5	105.8	133.3		48.9	16.8		
Total direct expenditure £000	204.9	12.1	30.5	12.1	3.6	5.0		11.8	16.8	28.8	42.5		30.2	11.5		
Cost per chain maintained £	.38	.39	.32	.63	.69	.44		.55	.42	.27	.31		.62	.68		
Area of P.40 and older wood, 000 acres	378	31	37	56	15	21		45	46	21	40		37	29		
Cost of grain maintenance in these older woods per acre £	.54	.41	.82	.22	.24	.47		.26	.27	1.37	1.06		.82	.40		

NOTE: Certain of the figures above are not true averages of the four years as information has in some cases not been recorded. An average has been imputed where data for one or more years is missing.

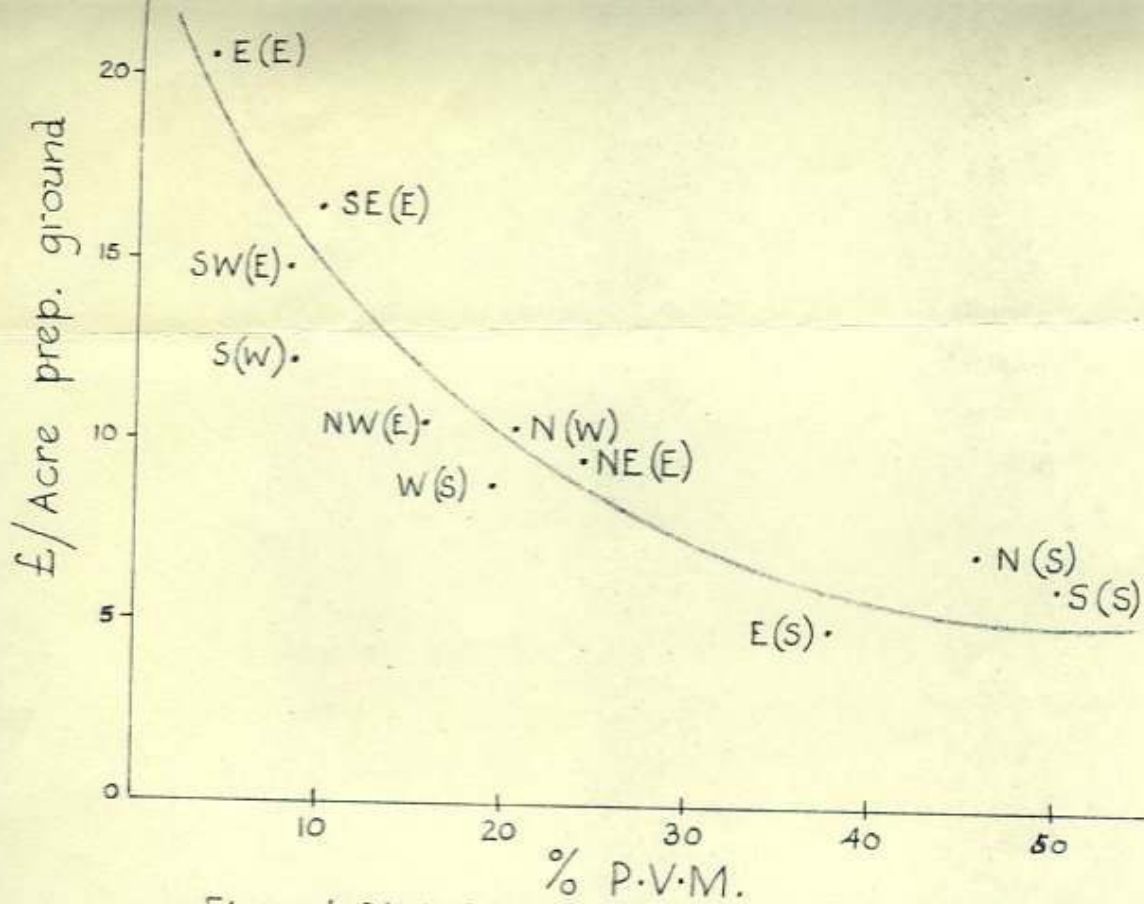


Figure 1. Unit Cost of Prep. Ground and % P.V.M. in relation to it.

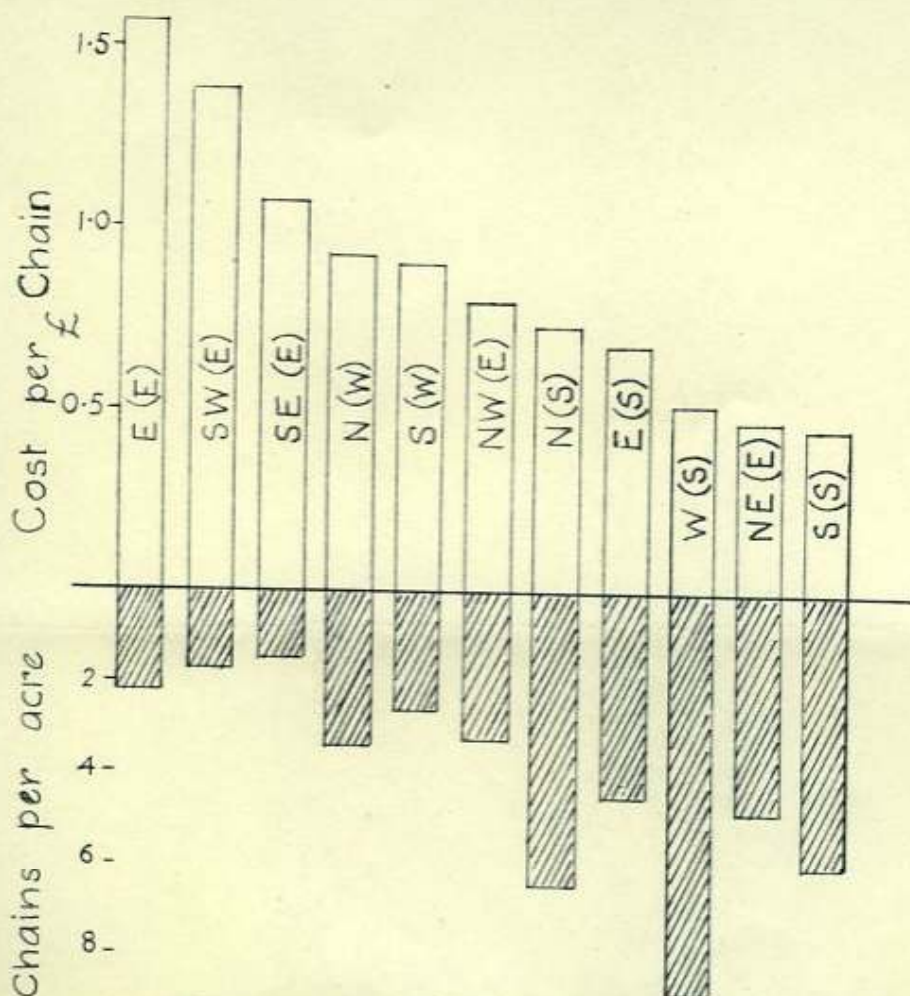


Figure 2. New Drainage. Cost per chain and Chains per acre by Conservancies.

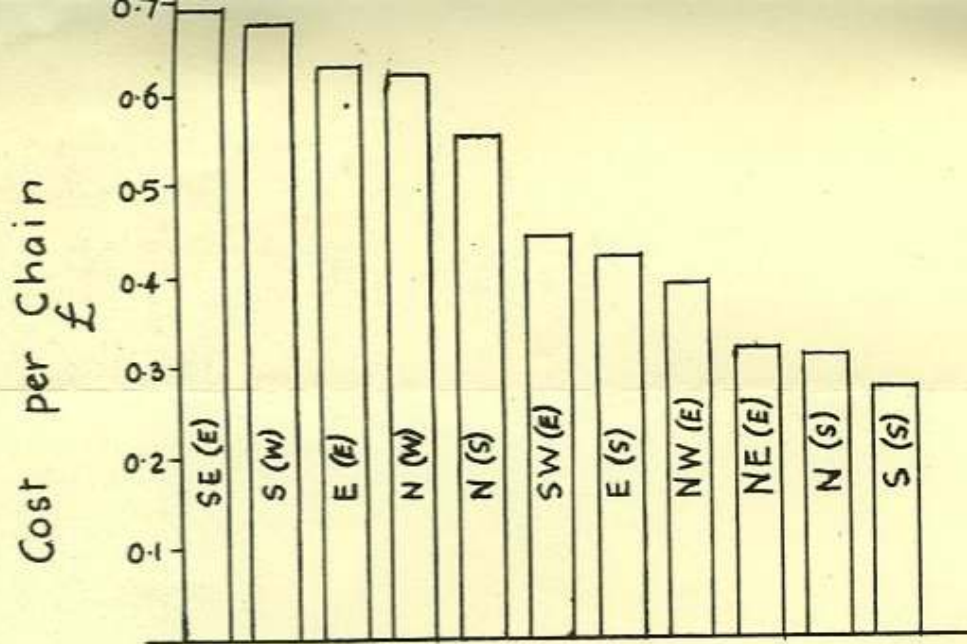


Figure 3. Drain Maintenance Cost per chain

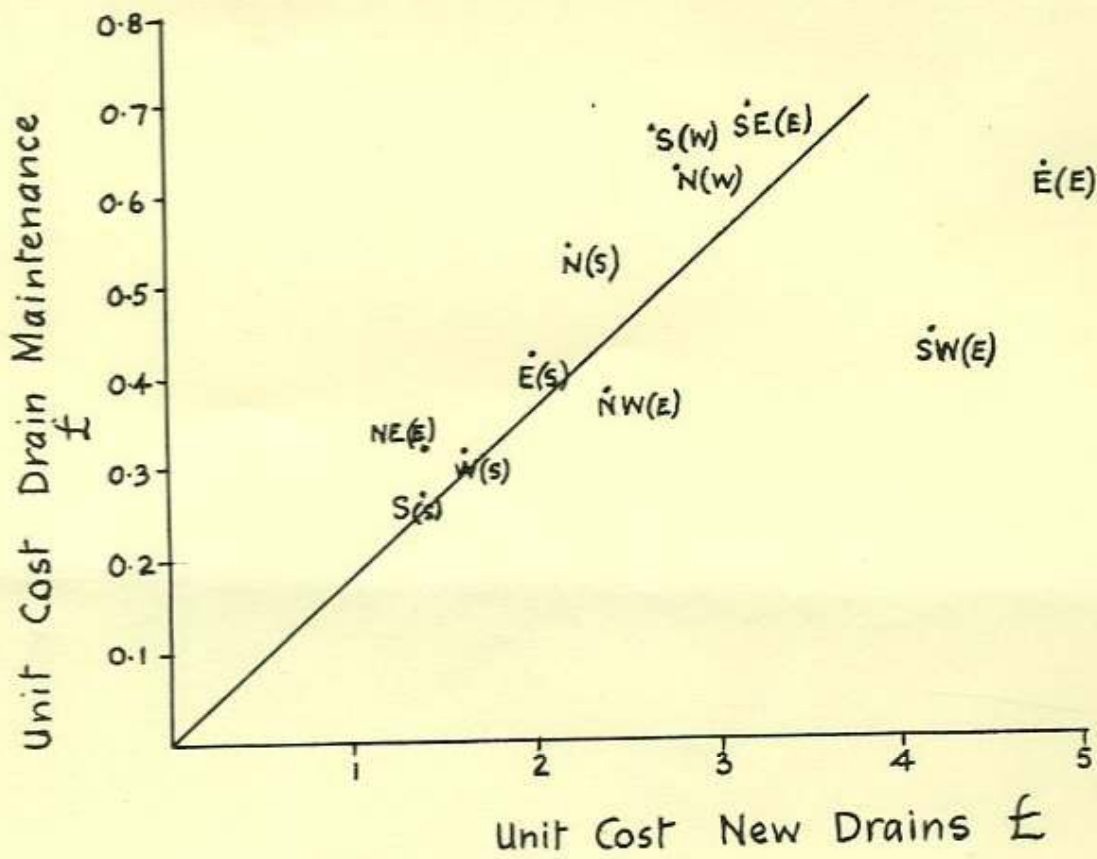


Figure 4

Messrs. Edwards
Holmes
Hinson
Fourt
Zehetmayr
Grayson
Shaw

Semple
Henman
Fraser
Neustein
Verel
Johnston



Ref: 1196/CRO.

Informal Meeting on Drainage Research
Alice Holt, 27th April, 1962

The principal objects of this meeting are:- to discuss our ideas about drainage as a cultural measure; to exchange views and reach agreement on the lines of future research; and to discuss the application of the best available knowledge in the field. The documentation has been very profuse, and no attempt will be made to summarise the papers. One or two further papers will be prepared for the meeting, these however will be short and factual. Dr. Binns and Dr. Hinson have undertaken to provide a few definitions to ensure that we are all talking about the same things, and Mr. Grayson will have some useful figures and/or diagrams to illustrate the extent and cost of drainage operations as they appear at the present time.

A few words may not be out of place on the present climate of opinion. Till quite recently, most forest draining operations had the restricted aim of removing surface water efficiently and cheaply to facilitate the establishment of plantations. Early experiments and much experience taught us how to do this, and from a number of influences, a set of practices familiar to most people has evolved. These may or may not be the best possible in any circumstances, but, for the limited objectives, they undoubtedly answer very well.

Existing drainage practices are now questioned from several directions. Plainly the most important questions relate to the basic objects of drainage. We are now concerned with drainage as it affects the root growth, stability, and yield of plantations. The design of drainage systems (apparently adequate for establishment) has been criticised in many cases when maintenance operations have commenced. It has often not been clear what proportion of the original system need be maintained, and in some cases few if any of the original drains have been aligned in such a way that their maintenance or deepening could have much effect on an established crop.

It is not easy to draw up an agenda for a meeting such as this to make the best use of the diverse experience and knowledge of the people attending. However, it is fairly clear that we should wish to reach some fairly definite conclusions on a number of points, and it is hoped the most important of these have been mentioned in the agenda. It is contemplated that under each head there will be some leading remarks from two or three people - not lengthy or formal contributions. Names have been mentioned where it is obvious that a particular person has something to say, but this is not intended to be in any way restrictive, and it is hoped that the meeting will be thoroughly informal and uninhibited.

1. Introduction, interests involved, agreement on scope of discussions.

Comments on extent and costs of drainage and maintenance operations (Mr. Grayson).

2. Fundamental aspects of drainage.

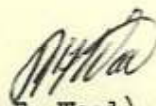
Terminology and definitions. Ground water and its movements in various types of soil. Hydrological considerations (Dr. Binns, Dr. Hinson).

Messrs. Edwards
Holmes
Hinson
Pourt
Zehetmayr
Grayson
Shaw
Semple
Henman
Fraser
Neustein
Verel
Johnston

File: 1196/CRO.

Meeting on Drainage

This meeting will now take place at Alice Holt at 9.30 a.m. on Friday, 27th April, which is a date suitable to all concerned.



(R. F. Wood)
for Chief Research Officer
27th March, 1962

Copy to: Director (H.Q.)

Mr. E. F. Granfield

✓ (Director (England) Office)

I attach 13 papers bearing on the Subject to be discussed. Unfortunately there are no copies available of the items ticked in the attached list but I will get copies made of any you would particularly like to have: *Dr. Harman C.R.O.*

MEETING ON DRAINAGE - DOCUMENTS

Attached

- 1954 Experiment Plan Ae 17, P.54 (Zehetmayr). This is an experiment on density of drains.
- 29.7.60. Minute of meeting with Ministry of Agriculture to discuss land drainage (Fraser). ✓
- 1.9.60. Drainage research. Paper for Technical Committee (Wood and Peace). ✓
- December, 1960. Border District Work Study Survey, Maintenance Assignment (Verel, comments from Holmes, Edwards, Fraser).
1961. Experiment Plan, Halwill 4, F.Y.61 (Fraser). This is an experiment on mole drainage. ✓
- 1.3.61. Visit to see drainage research carried out by the Agricultural Institute, Malahide, Co. Dublin (Hinson). ✓
- 1.3.61. Diary on above (Edwards).
- 27.3.61. Drainage and cultivation of deep peat. Agenda for meeting at Flanders Moss (Henman).
- 4/4/61* 9.4.61. Drainage and cultivation of deep peat. Minutes of meeting at Loch Ard (Flanders Moss) (Henman).
- 16.4.61. Diary of tour of Forestry Commission and Ministry of Agriculture drainage experiments (Fraser). ✓
- 12.6.61. Drainage - a comment (Semple).
- 21.6.61. Drainage - note following Programme Conference discussion (Holmes).
- 11.7.61. Drainage - a minute to C.R.O. (Edwards).
- 28.9.61. Drainage - a note following a query by C.R.O. about drainage prescriptions in Switzerland and Holland (Hinson - with comments by Fourt).
- 23.10.61. Draining of peaty-gley and peaty-podsol soils. A note to Conservators asking for information (Henman). ✓
- November, 1961. Paper on tree pulling (Fraser) giving evidence of effect of drainage on root depth and stability (Fraser).
- 14.11.61. Drainage prescriptions on heavy soils (Holmes - comment by Wood).
- Undated. Experiment 17 Ae - a report (Fourt) ✓
- Also see The Drainage of a Heavy Clay Site (Fourt), Rep. For. Res. 1960. ✓

MEETING ON DRAINAGE -
ADDITIONAL DOCUMENTS

Attached

January 1961	Expt. 8 F.Y.61 Kerry - Experiment Plan.	✓
1.6.61.	Expt. 8 Kerry. Report on Mechanical Drainage (Ure).	✓ to be returned after meeting - only 1/2 -
November, 1961	The Beofabs Trench Cutter - Report on trial at Ae (Blair).	✓
8.11.61.	Diary of visit to Kielder to see Melio drain cleaner (Henman, with comments by Fraser and Holmes).	
Dec. 1961	Observations on Forest Lay-out (J.P. Veal)	✓
Dec. 1961	Note by M.V. Edwards.	✓

3. Objectives of drainage as a forest operation on various types

Mineral Soils

Geological and boulder clays. Shallow peats. Other.

Deep peats

(Messrs. Edwards, Holmes, Henman, Fraser)

Are we clear what we are trying to accomplish under all conditions? What do we know about the practical limits of drainage operations? What do we know about the size of the benefits to expect?

4. Technical Advances. By Machinery Research (Col. Shaw)

Principal questions, (i) Have we sufficiently defined the drain we want for various conditions? (ii) Are there machines available to perform the various operations, including maintenance, on the principal drainage types? (iii) What direction should Machinery Research follow now in the field of drainage.

5. Technical Advances. By Work Study (Mr. Zehetmayr)

Principal questions, (i) What specifications should Work Study accept in investigating drain maintenance operations? (ii) What is the best way of collaborating with Machinery Research and Silviculture in such studies - especially in trials of Machinery?

6. Application of existing knowledge in the field

Special management considerations (Mr. Johnston)

Availability of information.

Publications etc.

Demonstrations, large scale collaborative trials etc.

Surveys of field practices.

(R. F. Wood)
for Chief Research Officer
11th April, 1962

Copies to: Director (HQ)
Mr. E. F. Granfield

To: Director

Forest Drainage Meeting
held at Alice Holt on the 27th April, 1962
Notes and comments on Minutes

1. I have now received a copy of the Minutes of this meeting; the Minutes are unsigned but I believe they were taken by Mr. Fraser. It is admittedly impossible to record everything which is said at such a meeting, but it seems to me that several important points have been missed, or only partially covered, and I have tried to make good these omissions in the notes which follow.
2. With regard to paragraph 1.4, I understood that it was agreed that in general ploughing should be shown as "cultivation" and that connecting and main drains should be shown as "draining".
3. The writer of the Minutes appears to be confusing two entirely separate effects in the second paragraph of 2.6. Structural improvements due to the drying out initiated by drainage affect permeability and thus future drainage; the increased water-holding capacity resulting from improved drainage is brought about by the increased rooting depth achieved.
4. With regard to paragraph 2.8, I gave my opinion of the present state of drainage in the Forestry Commission, and remarked that I thought we had been far too slow to take advantage of research and experience in agriculture. The principles of drainage are the same, and - apart from the fact that under-drains have no place in forestry - much of the practice of drainage should be the same. It surprised me that mole draining had not been carried out when establishing plantations on heavy clay (you may recall that I mentioned this after visiting Kesteven at your request), and that this had only recently begun to receive attention. There was no justification for the defeatist attitude with regard to the drainage of heavy clay which had persisted until recently; the literature on the subject was ample, and drainage of heavy clays had been common in agriculture for many years - in fact some of our most productive land (e.g. most of Essex) was in this category. I consider that agricultural research and practice combined with F.C. research now left no room for doubt that we should install much deeper drains - generally of the order of 2' 6" - than had been the practice in the past, and that every effort should be made to push ahead with this in the Border area, where forest officers were greatly worried by the increasing problem of windblow.
5. With regard to paragraph 2.11, it was pointed out by Mr. Williamson that there was a need for evidence of benefit to be obtained by improved drainage. After discussion it was agreed that F.C. experimental evidence combined with agricultural experience was sufficient to make recommendations that much improved drainage is necessary, and that we could not afford the time to wait for the results of further research, which should proceed concurrently with full scale drainage schemes.
6. I noted ~~in~~ down that the following questions were brought forward as requiring further research and investigation:-

- (a) at what stage in present growing crops does it cease to be worthwhile improving the existing drainage system?

- (b) broadly, what are the areas of each type of drainage problem?
- (c) what are the desirable depths and spacing under various conditions?
- (d) what would be the result, in terms of reduced number of trees blowing under given conditions, or in the height to which trees can grow, by say the 25% increased instability shown in the Kielder experiments (Fraser is shortly to have the results of these experiments published)?

7. It was stated that investigation had shown that some windblow alongside drains was due to damage to roots when the drain had been substantially deepened in a standing crop.

8. With regard to paragraphs 3.3 to 4.5, as I understood it, it was agreed that, although it was now accepted that deeper drains are generally required, this could not be achieved everywhere immediately, and as an interim measure it is necessary to maintain existing drains at 18", and to deepen others from their present depth of about 9" to 18", thus in many cases penetrating a few inches into the mineral soil below the peat. It is thus worthwhile developing a machine to maintain drains 18" deep, and with the money saved on mechanisation of this operation, together with some extra provision of funds, a proportion of the shallower drains would be deepened annually to the required depth of about 2' 6", until all the areas which required it had been so deepened.

9. When the subject of machinery arose I gave a brief description of the main types of machinery available, the type of work for which each is suitable, and the approximate cost of such work. I expressed the opinion that, except where there is a local drainage tradition and thus expert labour available, and where handwork is a useful means of keeping such labour fully employed, insufficient use is being made of the wide variety of machines available. All the worthwhile ones are available for hire, and it seemed to me that much more advantage should be taken of this, so that experience can be gained of various machines driven by highly skilled operators, and under local forest conditions. I mention that Director (England) was particularly concerned about the maintenance of drains in clay areas, heavily overgrown with brambles and other vegetation; some of these drains could not be maintained by machine because a tractor could not straddle them, and there was insufficient space alongside, but where there was room beside the drain I thought the Lincol was generally the answer, and where the drain could be straddled the F.C. Flail if ~~fully~~ developed might help, although I thought the semi-circular shape a fundamental disadvantage. (Subsequently I learnt from Col. Shaw that he is thinking of setting the Flail obliquely, to give a better shape, and I suggested to him that we should have full scale trials of the N.I.A.E. machine; arrangements are now being made to this end, and if successful it may be worthwhile mounting the machine centrally behind a tractor, which could then straddle the ditch).

10. With regard to paragraph 5.1, Mr. Verel made a very clear statement of the need for integrated planning of the drainage system, roads, and extraction racks. In supporting him I pointed out that the revised H.M.2 (on Road Planning and Construction) laid down that this should be done.

To: Director

Forest Drainage Guide for Field Staff

I think this is an excellent paper and although it appears to be very lengthy I do not think the subject can be dealt with adequately at less length; I do think, however, that a comprehensive index would be useful for users of the guide. My detailed comments follow:-

1. On page 3 the description of a water-table appears to me to be obscure, and I should think would only serve to confuse any one who did not know what a water-table was.
2. Page 13, first paragraph, regarding clearance. If trees are far enough away for stability, say 5' or 6', there would be space enough for a machine to straddle the drain, but this is not always possible, and it would be an advantage to allow 10 to 12 feet on the lower side, to allow a machine to work from that side. Although it is made clear on page 22 that drains cannot be combined with extraction work in steep country, because the drains and roads are both nearly on contour, it would perhaps be as well to add the word "where the terrain is flat enough to permit this" after the word "racks" on line 5 of this paragraph.
3. I do not know whether the definitions given for the various elements of a drainage system are in accord with forestry practice, but they do differ in various respects from land drainage practice, and this seems rather a pity, since we shall at times be dealing with outside bodies. For example the so called "receiving drain" is usually known as a "lateral" or "subsidiary drain" in land drainage practice. Similarly the so called "connecting drains" are usually known as "sub-mains". I cannot agree with the term "carrier drain" as a synonym for "relief drain", as the former term is generally used to describe a drain carrying water (often from laterals) to a main drain or other outfall, without itself collecting a significant quantity of water in its own length.
4. Again something is said about the dangers of too steep a gradient further on in the paper, but I think a warning should be given at the bottom of page 13 on this subject, where mention is made of main drains following the steepest fall of the ground.
5. The remarks regarding the 6" bed width in the paragraph dealing with cross sectional shape on page 14 are theoretically correct, but in practice a drain of this bed width quickly becomes shallow due to frost action on the sides, and other detritus. A bed width of 9", or preferably 12", is better.
6. On page 15, under the heading "Gradient", although it is right to point out the necessity of crossing the slope of the ground with drains, I consider this to be over emphasised. It is of ^{some} importance for surface water, but of less importance for ground water, since the latter flows under influence of a hydraulic gradient, and is thus not entirely dependent on surface gradients, in very flat land it is usually preferable for the drain to have all the available fall.
7. I cannot entirely understand the reference to model experiments on page 16 as I should be surprised if models can produce useful information on this

Forest Drainage Guide for Field Staff

subject, and in any case ample information should be available from established theory and practice.

8. The statement (top of page 18) that unduly close spacing is expensive and leads to waste of plantable land is true, but is it true to say that 12' drainage racks at one chain spacing represents 9% loss of plantable ground? Since early thinnings are often of less value than the cost of extraction, is there not some truth in the concept that the loss is more undesirably heavy side branching, than in the loss of area?
9. Page 19, first paragraph. It is true that quicker run off following draining can rejuvenate a stream, but this is usually less troublesome than the erosion of a badly sited main drain (e.g. Bear Down), and the emphasis seems to me to be the wrong way round in this paragraph. With regard to the fourth line, how can drains be led away from a stream, if the latter is in a valley?
10. The term "closed receiving drain" is an odd one, and I would suggest the more usual "under drain". I should have thought a 6" diameter mole too big except in peat; in my experience 4" diameter is usual in clay, and I think a larger mole would tend to collapse.
11. The end of the first paragraph on page 21 implies that for moving three rows of trees and draining in the centre of the space provided is more risky than leaving the crop undrained. This seems to be curious, and the inference is that it is better not to drain!
12. With regard to the last sentence on page 22, I can see no reason for not integrating ~~these~~ forest and road drainage systems, where advantageous. The rest of this paragraph is dealt with in H.M.2a, and reference should be made to this instruction.

Again something is said about the danger of too steep a gradient further on in the paper, but I think a warning should be given at the bottom of page 11 on this subject, where mention is made of main drains following the contour of the ground.

(E. F. Granfield)
Directorate Engineer

28.11.62

The remarks regarding the 6" bed width in the paragraph dealing with cross sectional shape on page 11 are theoretically correct, but in practice a drain of this width quickly becomes shallow due to frost action on the sides, and other causes. A bed width of 9", or preferably 12", is better.

On page 19, under the heading "Gradients", although it is right to point out the necessity of avoiding the slope of the ground with drains, I consider this to be over-emphasized. It is of less importance for surface water, but of less importance for ground water, since the latter flows under influence of a hydraulic gradient, and is thus not entirely dependent on surface gradients. In very flat land it is usually preferable for the drain to have all the available fall.

I cannot entirely understand the reference to model experiments on page 19 as I should be surprised if models can produce useful information on this

Interim Report on Drainage Experiment Halwill 5. F.Y. 62/63

This experiment is the first large scale drainage experiment that has been laid down using heavy machinery to dig the deep ditches required. It has also incorporated the use of shallow ploughing and mole ploughing, and from it much has been learnt that will be of value both for future experiments, and field application of the results.

The experiment, briefly, is intended to study the effects of intensive drainage, in combination with manuring and admixture with hardwoods, on the long term root development and stability of Sitka spruce. There are also included many short term observations on the soil and soil moisture and on the drain performance. It is too early to report on any of these things, but this report is intended to summarise the various stages of laying down the experiment and outline the important practical aspects of drainage.

The work done to date has suggested that the following procedure should be adopted when carrying out drainage work:

1. Mark out a square chain grid (probably only necessary on experimental areas, where it has great value for future referencing).
2. Using a level, peg out contours at 5' or other suitable interval depending on the slope.
3. Survey area, using the grid as a basis, and note position of contours, boundaries, ditches etc.
4. Draw a plan of the area, and mark on it the proposed ride, rack, and road layout, and the main drainage system. Add the subsidiary drains where necessary.
5. Using the grid, transfer the detail from the map to the ground. This method enables the most ideal combination of extraction and drainage system, but it may be considered only necessary to lay them out without previously preparing a plan.
6. Plough a shallow furrow along all roads, and rides, and along the main drains. This greatly reduces supervision later, and the ploughman can subsequently stop the ploughing on all boundaries.
7. Plough all the remaining ground before digging drains.
8. Dig main drains, and if the mole plough is to be used dig cross drains at the foot of slopes for pulling in the mole plough.
9. Mole plough (if this operation is to be carried out) starting from the prepared ditches which should be 30 - 36" deep. Moling should be done uphill.
10. If possible insert a 3" land tile in each mole exit, as soon as can be managed after moling, and before the mole channels close up. When the secondary drains are being out after moling, provided the tiles are laid out, the banksmen can locate each mole exit and insert a tile immediately, thus avoiding the need for extra labour. (see 12).
11. Dig the secondary drains in the moled area; if moling is not to be carried out, this operation will follow No. 8.
12. Insert the 3" land tiles in the mole exits of secondary drains.
13. Dig any other drains, such as roadside, boundary or cut off drains.

As the machinery required for this sort of work, cannot be used on these heavy soils in winter, it is essential that the whole operation be planned in advance and correctly timed.

- Items 1 - 5 above. Survey, planning and marking out can be done at anytime of year, but as the days are short and often wet in winter, the early spring is advised.
- Items 6 - 7 above. Ploughing. This should be carried out as soon as ground conditions permit, and will be in the spring or early summer.
- Item 8 above. Dig main drains. This operation should be started as soon as the ground becomes reasonably dry.
- Items 9 - 10 above. Moling. This operation should be done when the clay is nearly dry, though it will normally have to follow closely on the digging of main drains to prevent the loss of machine hours. The date will depend on the weather in the particular year but July - August seem the best.
- Items 11 - 13 above. Digging secondary drains and putting in tiles. This can be started as soon as moling is complete, and should be organised to finish before the autumn rains while the soil is still reasonably dry.

If the area involved is large, it may be better to do part of 9 and 10 and then 11 - 12 on that part then do some more 9 and 10 and so on.

General Notes

1. Marking out square chain grid. This operation was relatively fast once a technique had been developed.

A group of 9 ranging rods were laid out in a square 3 x 3, with one, in the corner of the area. These rods were then used for siting on, in order to place the remaining markers in by eye, at the measured distance of one chain. Occasional cross checking was carried out to ensure accuracy, but because the ground was sloping it was impossible to get the marks more accurate than being within 6" of their position. However this was considered accurate enough.

The grid will be marked permanently, and has already been found very valuable as a referencing system, and for taking photographs.

2. The levelling was done using a Watts Quickset level. This was set up about 2 ft. above the lowest point, which was then marked, and the reading on a levelling staff noted. The level was then swung round and the staff moved until a reading exactly 5 ft. less than the first reading was obtained; this gave the first point of the first contour. A short staff was then cut, and a clear mark put on it at the same height as the reading on the levelling staff. One person then walked more or less along the contour, and pacing intervals of about 10 yards. At each stop the staff was sighted in the level, and moved until the mark came level with the cross wire. A lathe was then used to mark each point, that lay on the contour. Once each contour was completed the level was moved to another point, about 2 ft. above the contour line, and the process repeated. The telescope was powerful enough to site to the edges of the field from the centre; a distance of about 180 yards, in each direction.

3. The survey was done, using the grid as a basis. The survey party of 3 men measured the distance from the field boundary to the 1st grid point, and then proceeded along the grid line, booking the distance of any important feature, such as contours ditches and banks, from the nearest grid point. This enabled the plan to be drawn very quickly

4. The plan was drawn, and the existing ditches marked on it. The position of the main drains was then decided on, taking into account the shape and size of the area and the existing ditches. The subsidiary drains were then marked, keeping them straight, but at the same time at a close angle to the contour. In very undulating country it would have been better to bend the drains, to conform to the contours.

Also included in the layout was the road and ride system, for future extraction of the crop.

5. The layout of the drains and roads etc., was relatively easy, using the grid system to locate the position on the ground.

6. The main drains and road lines were then marked on the ground using the plough. Careful supervision of this stage eliminated the need for close supervision when the main ploughing was done. The secondary drains were marked with a 4' stake at either end.

7. The ploughing was then done, with the furrows running more or less straight up and down the slope with the main boundaries already marked, instruction for the ploughman were straightforward. The plough used for both these operations (6 and 7) was a Ransomes "Solotrac" towed by a B.T.D. 6 tractor.

8 - 13. Drain digging and moling were carried out more or less simultaneously but various systems were tried out, which resulted, in the choice of the one recommended for future use.

The machine used for digging ditches, was a Shawnee Warrior hydraulically operated excavator, mounted on a County "Bogmaster" tracked tractor. This machine was new when the work started, and much mechanical trouble was experienced. However once almost every part had been replaced, the reliability improved, and the digging rates increased accordingly. Although the soil was fairly dry while the digging was done, when taking a full bucket load the weight of soil was evidently too much for the machine. Less trouble was experienced once the depth of the drain was reduced to 24" as in Block IV.

The moling was done with a normal mole plough and 6" expander, mounted on a TD 18 tractor by means of a new Ede linkage. This device enables a constant depth to be maintained in spite of surface irregularities.

It was originally intended to cut the secondary drains first and then pull in the mole channels from these. However, this was tried on the first block to have the secondary drains cut, and proved impractical because of the falling in of the ditch wall when the tractor passed over. It was therefore decided to mole first, and cut the secondary ditches later.

In Block I the subsoil turned out to be much wetter than was general over the rest of the area, and the moles were not a success. The walls of the mole channels became plastic very quickly, and tended to flow into the channel, blocking it.

This was not thought to be dependent on whether or not the mole exit was opened or not, as some were open at one end and yet still blocked up. This block has a slightly different aspect from the others, and receives more water from higher land than the others, so that the site was initially much wetter. A special cut-off drain has been dug in order to rectify this.

The 360 3" land tiles (Red bank) were laid in 14 hours, most of the time being spent in opening up the holes sufficiently to slide the tile in. The operation was not done until about a month after the moling, and it is thought that it would have been easier and quicker to do it immediately after moling, or when the ditches were opened up. The Banksmen could have been doing it thus avoiding the cost of extra labour. The rate of work, when not following the excavator is 25 tiles per hour.

The rates of digging, and the time spent by the digger under repair and maintenance are given in the following table.

Rate of digging

Type of Drain	Depth	Digger hrs	Chainage	Ch/hr
Main Drain	36"	142	97	0.68
Block I Cross drain (Clay wet)	30-36"	52.5	42	0.80
" II " "	30-36"	27	30	1.11
" III " "	30-36"	30	33	1.10
" IV " "	24"	26	41	1.58
Spare ground	24"	7	9	1.29
Cut off drain	30"	7	11	1.57
Total Cross drains		142.5	155	1.09
Total all drains		291.5	263	0.90
Best in one day	24"	7	17	2.31

Breakdown and Maintenance

Working hrs.	Breakdowns hrs.	Mechanics hrs.	Drivers repair hrs.	Hrs. waiting mechanic
291.5	136	39	43	54

Summary

The layout and installation of this complex drainage experiment has been successfully completed, and the original timetable and plan was found to be almost the ideal.

One or two modifications can be recommended to adopt if drainage of this sort becomes standard practice, and much useful information on technique has been collected.

prepared K.F. Baker 29.11.62
edited A.I. Fraser 6.12.62

for Silviculturist (South)

Distribution:

C.R.O. 1
Silv. (S) 1
Silv. (N) 3
Director (E) 1
Mr. Granfield 1
Mr. Anderson 1
Cons. S.W. (E) 1
Mr. Rouse 1
Mr. Inglis 1
Mr. Oram 1
Mr. Walsh 1
Mr. Beasley 1
Spare 5
Mr. Waller 1
Col. Shaw 1

Times and Costs

From the experiment it is possible to get some idea of the time taken for the various operations, and from this to make an estimate of the costs.

Operation & Description	Time	Amount of Work	Unit of Cost	Total Cost	Cost/ac
1. Marking grid.	18 man/hrs	22 ac	Overheads	-	-
2. Levelling at 5' intervals. (average slope 1:16)	12 man/hrs	22 ac	"	-	-
3. Surveying	12 man/hrs	22 ac	"	-	-
4. Drawing plan	8 man/hrs	22 ac	"	-	-
5. Layout on ground.		22 ac	"	-	-
6&7. Ploughing. Operator.	36 hrs	20 ac	9/- per hr	£16 - 4 - 0	2 - 16 - 8
B.T.D.6 Tractor & Solotrac plough. (5½ ft. spacing; 4-5" deep).	36 hrs	20 ac	22/6 per hr	£40 - 10 - 0	
8. Main drains. 36" deep.					
County tractor & Shawnee Warrior.	142 hrs	97 ch	25/- per hr	£177 - 10 - 0	12 - 18 - 2
Operator & Banksman.	142 hrs	97 ch	15/- per hr.	£106 - 10 - 0	
9. Mole ploughing operator	19 hrs	9 ac	9/- per hr	£ 8 - 11 - 0	4 - 17 - 0
TD18 Tractor & Mole plough.	19 hrs	9 ac	37/- per hr	£ 35 - 3 - 0	
10&12. Insertion of Landtiles	14 hrs	4 ac	6/- per hr	£ 4 - 4 - 0	2 - 3 - 6
Cost of Land tiles.	14 hrs	360 number	3d. each.	£ 4 - 10 - 0	
11. Secondary drains 24"-30" deep	135.5 hrs	146 ch	25/- per hr.	£169 - 7 - 6	12 - 6 - 4
County tractor & Shawnee Warrior					
Operator & Banksman.	135.5 hrs	146 ch	15/- per hr	£101 - 12 - 6	
13. Cut off drains & spare gr. County tractor & Shawnee Warrior.	14 hrs.	20 ch	25/- per hr	£ 17 - 10 - 0	1 - 3 - 7
Operator & Banksman.	14 hrs	20 ch	15/-	£ 10 - 10 - 0	

Operation & Description	Time	Amount of Work	Unit of Cost	Total Cost	Cost/ac
Totals.					
Ploughing -) Operator:) BTD6 & plough)	36hrs	20 ac.	31/6	£56 - 14 - 0	£2 - 16 - 8
Moling -) Operator) TD18 & Mole) plough)	19 hrs	9 ac	46/-	£52 - 8 - 0	£5 - 6 - 9
Insertion of land tiles	14 hrs				
Ditching -) Operator &) B'man) County tractor) & Shawnee.)	291.5 hrs	263 ch.	40/-	£583 - 0 - 0	per acre £26 - 10 - 0 £2 - 2 - 6 per ch.
Total of all operations		22 ac - 263 ch.		£692 - 22 - 0	£31 - 10 - 0

The charges used above are based on the average cost of operating the equipment in the Forestry Commission, and all include overheads.

To: Mr. Brimmer

Drain Cleaning - N.I.A.E. Machine

It appears following a discussion I had with Col. Shaw that the Roadless 4 x 4 tractor with low reduction gear box is required for trials with the N.I.A.E. drain cleaning machine. The minute from Machinery Research Officer, dated 1st February, reference ME.1/65, which Mr. Granfield passed to me refers.

The holding Conservancy, which apparently is S.E.(E) should now be asked to release the machine which apparently is P.C. No. 62/104 for this purpose which Col. Shaw advises me may take up to six months (but possibly less).

The machine should be delivered as soon as possible to the N.I.A.E., Wrest Park, Silsoe, Bedfordshire and identified for the attention of Mr. Walter Boa.

Col. Shaw explains that he is in contact with the N.I.A.E. regarding the fitting of the equipment and is dealing with the immediate arrangements concerning this. Consequently he as well as Mr. Granfield should be kept advised of the position.

It may be that the Conservancy ^{will have} ~~arranged~~ a programme already arranged for the machine but I gather that it is essential that the machine is released as soon as possible for the drain cleaning trials.

J
(Wm. C. Anderson)
18.2.63

RESEARCH BRANCHSHAWNEE WARRIOR DIGGERProgramme of Work and Demonstrations

This tackle is now in circulation again, and is at present in South (S) Conservancy. Its programme will be as follows:-

28-29th March, 1963. In transit to Flanders Moss via Chapelhall. Mr. Blane arranging transport.

1-12th April. Flanders Moss. Research and Conservancy demonstrations.

15th April. In transit. Flanders Moss to Forest, East Conservancy. Conservancy Engineers to arrange.

16-26th April. East Conservancy. Demonstration.

29-30th April. In transit. East Conservancy to Hamsterley Forest, North East (E) Conservancy. Conservancy Engineers to arrange.

1-24th May. Hamsterley Forest. Conservancy/Research drainage exercise.

27th May. To Silviculturist (S), or to be arranged.

It must be emphasised that delays due to weather or breakdown may disrupt this programme, which can therefore be only provisional.

Responsibilities and charges for the tackle are distributed as follows:

The machine and its equipment will be on charge to the Research Forester in whose area it is working. (See separate Instruction Sheet). Maintenance, repairs, cost of fuel and lubricants; - Silviculture Section, Research Branch.

Provision of operator and banksman, and their wages, subsistence, etc.; - Conservator.

D.W. Henman
for Silviculturist (North)
18th March, 1963.

Distribution:	Director (Res.)	1
	N.R.O.	1
	Dir. Engineer (S)	1
	Dir. Engineer (E)	1 ✓
	D.O. Loch Ard	1
	Silv. (S)	1
	Cons. N.E. (E)	2
	Cons., S. (S)	1
	D.O. Hamsterley	1
	Cons. W (S)	2
	Cons. E (S)	3
	B.R. Robson	1
	J. Keenleyside	1
	J.H. Thomson	1
	J. Weatherell	2
	37.3	5
		25



Notes on a visit to Lyndhurst on 24th-25th June, 1963

JS.

Drain Cleaning

Also present: Mr. Cadman } Part time
 Mr. Miltham }
 Mr. Verel
 Mr. West

Object

This visit was undertaken to test the following machines in soft peat:-

- (a) The F.C. Conveyor drain cleaner
- (b) " " Bucket and Rotor drain cleaner
- (c) " Melio machine with side wall modification

(a) and (b) were being tested in peat for the first time
 (c) had been modified after earlier tests.

Conditions

The site was at Dibden Bottom and consisted of 12-14 inches of peat over clay. The area was very wet having a floating mat of grass in places. All the machines were tested when mounted on a County tractor (16" tracks) fitted with extra low speed gearbox.

Results

1. The conveyor machine was tested in semi-completed form to determine if it was worth continuing.

The results showed that this machine can cut an original or deepen an existing drain and convey the spoil out of the drain. As this machine was only in test rig form the test was brief as mechanical trouble (a broken conveyor chain) quickly arose. Enough was done however to show that a lot of development work would be necessary.

2. The bucket and rotor machine which includes all the lessons learned on the original flail machines was most encouraging. On an old drain that had almost disappeared it cleaned and deepened to a depth of 18 inches throwing the spoil 40 yards down wind and cleaned at a rate of about 400 yards per hour.

The volume of spoil ejected was far greater than on any of the machines tried over the last several years and it was certainly the most spectacular.

There was a good deal of fall back into the cleaned drain but it is believed that this can be largely eliminated by deflectors in the light of experience. Depth (18") was not as deep as is now required and this will be increased. The result was that an inactive drain was turned into a free flowing drain in a few minutes with water flowing as soon as the machine had passed.

New side drains were cut and the machine showed that it can do this work but 2-3 cuts would be needed to get down to 18 inches.

The trial suggested the following alterations

- (a) A reduced rotor speed as the present rotor throws the spoil further than necessary. This will also reduce the power absorbed by the rotor.
- (b) Improved guarding to prevent fall back into the drain.
- (c) A deeper cut to achieve 24 inches with the width at the bottom reduced to 2-3 inches which conforms to the latest Research Branch requirement.
- (d) Improved bucket sides to give cleaner drain sides and hard tipping on the feeder screw though it is doubtful if the latter is necessary on peat.

3. The Melio machine which is exactly as tested by Work Study except for the addition of side walls at the lower end of the rotor to reduce the raggedness of the cut. In this form the machine cleaned and cut very well except that it did not eject anything like the quantity of spoil thrown out by the bucket and rotor. This leads to the suspicion that a good deal of the favourable effect is being obtained by squeezing the sides of the drain apart rather than by cutting. We know from past experience that this forcing apart has no lasting effect.

Conclusions

In view of the encouraging results on the comparatively simple and inexpensive bucket and rotor machine there is no object in pursuing the conveyor type. The rather spectacular debut of the bucket and rotor should be treated with some reserve until the full 24 inch drain has been achieved and endurance ability has been proved.

The Melio situation is much as it was. The side walls seen to be an improvement but the Work Study trials have shown that wear is rapid and replacement of wearing parts is a long and expensive job.

Further Action

Development work on the bucket and rotor is proceeding on top priority.

R. G. SHAW
Mechanical Engineer - H.Q.
June, 1963

DIARY OF S.A. NEUSTEIN AND D.W. HENMAN14th November 1963Kershope Forest

With Messrs. G.G. Stewart, T.C. Mitchell (D.O.), A.I. Fraser, Mr. Guthrie (H. For.), Mr. Haynes (Cons. Mech. Engineer), G.S. Forbes and I. Blakemore.

Morning: An interesting Conservancy-organised demonstration of various drainage machinery was attended. This was an unexpected opportunity for the Research staff and unfortunately provided yet another example of lack of liaison in the approach to this common problem. It is proposed to raise this matter with Director (Research) on 2nd December. A suggestion for a coordinated comparison of available machinery is made in an appendix to this diary.

Demonstration No. 1 (Compartment 93)

A Massey-Fergusson 702 tractor (c. 45 h.p.) and back-acting hydraulic digger of same make attempted to dig new drains in a windthrown area. This wheeled tractor, which was driven by a representative of Massey-Fergusson, had small non-powered front wheels and got bogged on its way to the drain line, and after extraction by a Bristol light crawler tractor got into difficulties again immediately.

Conclusions: The digging equipment was untested but probably adequate for the job in hand. The tractor was useless for this type of site.

Recommendations: A FordCounty Super-4 (54 h.p.) or Super-6 (100 + h.p.) tractor should be tried under similar conditions. These are 4-wheel drive tractors with powered steering and large wheels front and back. The large wheels and high clearance are suggested as superior to tracked tractors on stump-covered sites, providing the ground is not very soft. Any of a variety of diggers could be fitted.

Demonstration No. 2

Racks traversing original solo-trac ploughing had been felled in thicket stage NS (P.46). A Long-Wide tracked County tractor attempted to winch a single-mouldboard deep-draining plough. (This plough is the latest model made by Clark of Parkgate and is normally used with tandem tractors to produce cross-drains after S.m.b. or D.m.b. ploughing). The principle of winching D.m.b. deep ploughs is used successfully in Finland, (Lokomo plough, etc.) and if successful here would be faster and cheaper than back-acting-diggers.

Conclusion: A short drain of 36" depth was drawn through approximately 6 ins. of peat over 30 ins. of clay, but repeated stalling of the tractor showed it to be under-powered for this work and the demonstration was discontinued. The drain was of adequate depth but somewhat steep sided (too narrow at the top). Also the "spoil deflector" was incorrectly set for the depth of working and cut into the bank of the drain.

Recommendations: The principle of winch-ploughed deep drains has been insufficiently investigated in this country and deserves further trial. Where ground conditions do not allow full tractive effort (stumps or soft peat) this principle gives the most efficient application of the available power from a single tractor, - though something more powerful than the 54 h.p. County is required. The plough requires certain modifications for optimum winching performance but feasibility trials could be carried out without these.

The alternative is to direct-haul the same plough with two tractors

in tandem; this is common practice in new cross-draining but might be rather unwieldy in thicket plantation. (This plough and tractor are about to move to Kielder where a trial of the above could be made).

In view of the vast acreage of thicket-stage plantations in the Borders which urgently need improved drainage to promote later stability, a trial of these alternatives is of first importance and the result might well justify the purchase of a special winch-ploughing tractor.

Demonstration No. 3

A Track Marshall tracked tractor and Massey-Fergusson back-acting hydraulic digger operated on a site identical to that of Demonstration No. 2. It worked satisfactorily and without stoppages, producing a drain of 36" - 40" depth, 11" bottom width and 40" top width. The tractor easily traversed the small (3" - 4" diam.) stumps in the felled rack.

Conclusions: The hydraulic back-acting type of digger is known to be adequate for this job and choice of model will be dependent on relatively minor variations in price, specification, reliability, servicing requirement, etc., many of which factors will only become clearer after extensive continuous use of several models. The disadvantage of the back-acting principle is its slow working speed and resultant high drain cost compared with the continuous-action principle of ploughs, but there is no limitation to depth and the principle is more versatile. The most suitable type of tractor (i.e. tracked or large-wheeled) for mounting the digger will be very dependent on site conditions and comparative trials in several forests are necessary to determine the most appropriate tractor for each one.

Demonstration No. 4.

A reversible S.M.B. Cuthbertson plough had been winched as for Demonstration No. 2. After a short run in similar conditions the beam of the plough had stuck in the ground. Also the small clearance between plough and arch had quickly clogged with roots and debris.

Conclusions: A too shallow (18-20") drain was produced with difficulty. This equipment was obviously incapable of producing the desired drain specification.

Discussion and conclusions.

Subsequent discussion of the results of these demonstrations and other experience led to the following conclusions:-

1. At least three Border Conservancies with a massive drainage programme are interested in an early constructive conclusion of the present piecemeal, unintegrated trials of equipment.
2. Because of the widespread interest but restricted financial scope of separate Conservators the matter would be best settled by a combined comparative trial of equipment under the aegis of the Mechanical Development Committee or Machinery Officer (H.O.).
3. The subject of drainage of the post-planting stages could be seen in three distinct categories:
 - a) Post-afforestation to first thinning stage - the largest and most important category, requiring the most urgent attention. Here tandem ploughing with a deep plough in felled drain

lines should be tested. Also winch ploughing should be further investigated. The aim of these investigations would be to concentrate on ploughs as being a cheaper alternative to hydraulic diggers. Tracked tractors would be essential and would not be hindered by the small tree stumps involved.

- b) Second thinning stage to end of rotation. It appears less likely that drainage could effectively improve crop stability at this stage and the felling of drain lines would probably precipitate the onset of wind-throw. Hence this category forms a very low priority; if ever considered it might have much in common with the third category, below.
- c) Windthrown and felled areas. The existence of high (turf planted) stumps and massive root plates make the possibility of drain ploughing impossible. Hydraulic diggers are therefore essential but as yet it is not clear whether large universally-powered and steered wheeled tractors would be superior in manoeuvrability, running and maintenance costs to tracked tractors for mounting such diggers.

A draft proposal for a comparative test of equipment is given as an appendix to this diary.

Copies to:	Dir. (Res.)	-1
	Silv. (S)	-1
	Cons. N.W.(E)	-3
	Dt. Officer	-1
	Mr. Guthrie	-1
	G.S. Forbes	-1
	40.3	-1
	37.2	-1
	35.1	-2
	Other	-13
		<u>25</u>

PROPOSED COMPARATIVE TRIAL OF DEEP DRAIN MAKING MACHINERY

OBJECT: To form new deep drains (36") on new improved alignments, both in young crops and after clearance of the first rotation, and to deepen existing shallow drains on satisfactory alignments; all this on a variety of site types.

CROP TYPES

1) Post afforestation to first thinning stage.

The following equipment is considered worthy of inclusion in a comparative trial.

a) Ploughs: Deep draining plough. (ex Parkgate (S.M.B.) or Cuthbertson type S (D.H.B.) or, if obtainable, Finnish Lokomo Plough).

b) Tractors: Two tractors (Long wide County's) to tow the above in tandem.

A crawler tractor of approximately 100 h.p. with adequate winch (make ?) to winch the above ploughs.

c) Hydraulic Diggers. Various makes are available. Of these the Massey-Fergusson, the J.C.B., the Track Marshall, and the Shawnee should be considered.

These should be tried mounted on a 4-wheel-drive large-wheeled tractor of the Ford County Super-4 or Super-6 type as well as on a crawler because of the potential economies of wheeled tractors.

2) Cleared Areas (windthrown and clearfelled).

On these sites only the hydraulic diggers mentioned above need be considered. These must be mounted on both wheeled and crawler tractors and both should be compared for their manoeuvrability to traverse stumpy ground and for running costs. The following tractors should be considered:-

Long-Wide County Crawler
Short-Wide County Crawler

Ford County Super-4 (wheeled)
Ford County Super-6 (wheeled) possibly with wide-tread tyres.

SITE TYPES

1) Soils

The principal types are deep peat, clay and varying proportions of each in the drain profile, all in varying degrees of wetness. Plough performance in all-clay profiles is not fully tested; similarly wheeled-tractor performance on peaty profiles.

2) Slopes

All the work required is near-contour draining, i.e. on side-slopes of moderate steepness to flat. Digging and direct-haul ploughing are

unlikely to be affected by slope, but winch-ploughing may be.

GENERAL ORGANISATION OF TRIALS

Ideally, as much of the above tackle should be obtained on loan from whatever Conservancy possesses them, or hired if necessary, and assembled at one forest unit where Border and other staff concerned with this problem could inspect the equipment and its work out-turn. Thereafter, any items particularly favoured should be available for transfer elsewhere for trial on other site types.

Kershope has a large enough programme of draining in both of the above categories to support the initial comprehensive trial.



FORESTRY COMMISSION
Crown Office, The Queen's House, LYNDHURST
Hampshire
Telephone: Lyndhurst 300

Please address any reply to
THE DEPUTY SURVEYOR
OF THE NEW FOREST
and quote:
Your reference:

28/1/64

Dear Granfield,
I promised to let you
see the small addenda which we felt
were required to complete "Forest Drainage".

Although the points
made are so very obvious, they were
not clearly stated in the otherwise
excellent booklet. It is fortunate to
appreciate this elementary layout that
has got young foresters into trouble
so often!

Yours

Arthur Butler

To : All Foresters and Assistant Foresters (New)

Copies to : Mr. Hughes, Mr. Leslie

My : SF/6/1 DAM/UA

3rd January, 1964.

Research Branch Paper No. 26

Forest Drainage

The above booklet is an important one and I would like you to read it through carefully as the principles contained in it will be put into practice in future drainage operations in the New Forest.

Certain, most important, basic principles have been very clearly stated by the Deputy Surveyor as shown on the attached sheets. Will you please fix the attached into the publication - Sheet 1 on to the space available on page 10 and Sheet 2 on to the inside of the back cover.

(D.A.MITCHELL)
District Officer.

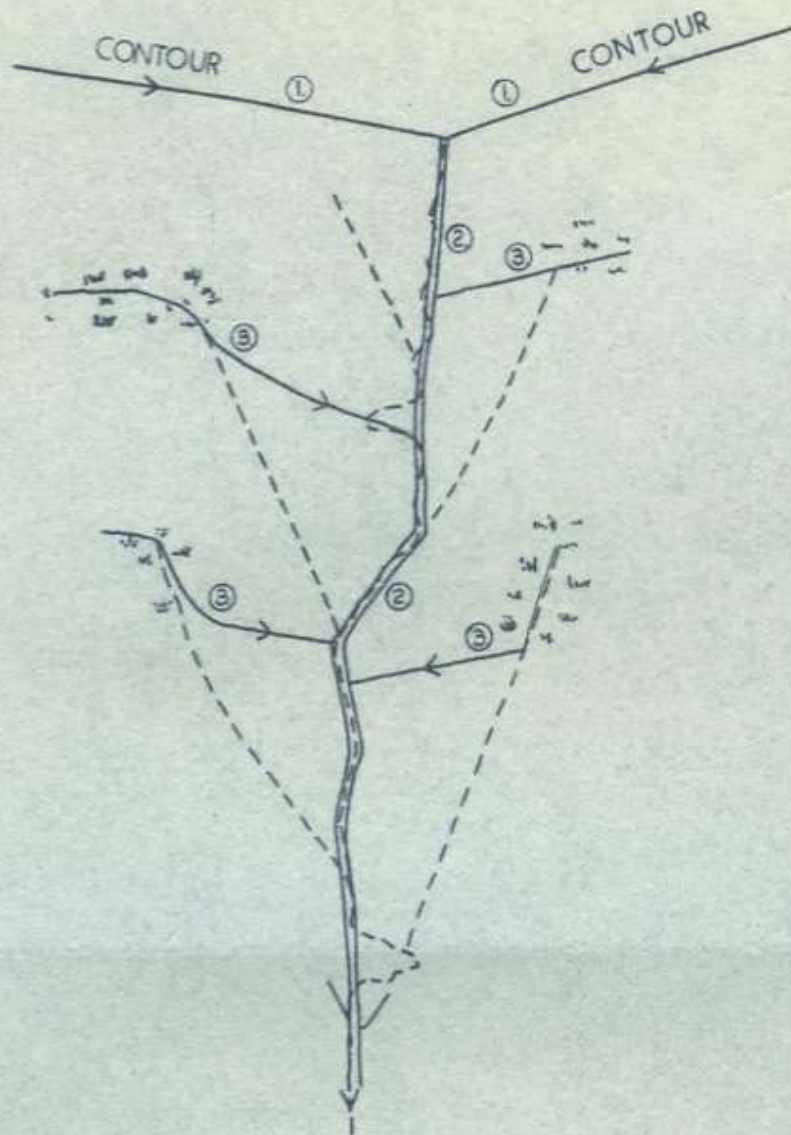
SHEET 1

FUNDAMENTAL PRINCIPLES OF DRAINING

A drain only serves the land BELOW it : hence the need for CONTOUR Drains. Drains running across the contours only serve to conduct water from a higher level to a lower level: they are only justified as MAINS.

In draining any wet area there are three primary operations, viz : -
(see sketch, last page)

1. To cut off the water seeping onto the area = CONTOUR DRAINS.
2. To let out the water lying on the area and to conduct the output of the Contour Drains, and other drains, away as smoothly as possible (MAIN DRAINS) . It follows that they must be wide enough to take the maximum spate. (In practice, often all that is needed is to straighten, widen and deepen existing water courses.)
3. To tap local springs which may not have been cut off by
(1) = INTERMEDIATE DRAINS .



① CONTOUR DRAIN

② MAIN DRAIN

③ INTERMEDIATE DRAIN

— = CORRECT DRAINAGE SYSTEM = 75 CHAINS

--- = WRONG DRAINAGE SYSTEM = 120 CHAINS



Consr. N(W)

ME31/2

Demonstration of Drainage Machinery
Dyfnant Forest - 2 p.m., 16th April, 1964.

Please note, as arranged, that the demonstration of drainage machinery is to take place at 2 p.m. on Thursday, 16th April, 1964. The following parties hope to attend the demonstration.

- (1) Col. Shaw, from H.Q., who arrives by train at Shrewsbury station at approximately 11.25 a.m. on the 16th April. Mr. Low is to arrange for Col. Shaw to be taken to Dyfnant Forest office - Llywdiarth Parc by 1.30 p.m.
- (2) Mr. E. H. Macmillen and Mr. E. F. Granfield from H.Q. and D(E) respectively. It is thought best for this party to accompany Col. Shaw by train to Shrewsbury and for Mr. Low to arrange for their transport to Dyfnant Forest office - Llywdiarth Parc by 1.30 p.m. along with Col. Shaw. However, confirmation has not been received of this proposal and you will be notified of any change as soon as possible. If the three officers travel by train then after the demonstrations Mr. Low will require to arrange for them to be taken back to Shrewsbury station in order to let them return to London that evening.
- (3) Party from South Wales Conservancy - this party is scheduled to arrive by car at Dyfnant Forest office - Llywdiarth Parc by 1.30 p.m. on the 16th April.
- (4) One or two representatives of the manufacturers of the Bogmaster Drain Cleaner have requested Col. Shaw if they can attend to see the application of their equipment. They have been asked by Col. Shaw to report to Chirk Depot by 11.30 a.m. on the 16th April and Mr. Low will arrange for them to be guided to Dyfnant Forest Office - Llywdiarth Parc by 1.30 p.m. on that day.

It should be noted that the location of Dyfnant Forest Office - Llywdiarth Parc is given by M.R.021153 - O.S. Sheet No. 117 (Bala and Welshpool - 1" to 1 mil) and the office telephone number is Llangadfan 217. The various parties should arrive by 1.30 p.m. and it is hoped that the demonstration will commence at 2 p.m. The equipment to be seen working will include

- | | | |
|--|---|--|
| (1) Short Wide County tractor with M.F.710 backacter equipment | } | Employed on the excavation of new main drains or realignment of existing main drains |
| (2) Long Wide County tractor with M.F.220 backacter equipment | | |
| (3) Croucher Drain Cleaner | } | Employed on the cleaning in existing drains |
| (4) Bogmaster Drain Cleaner | | |
| (5) Rotary Drain Cleaner | | |
| (6) Cuthbertson Deep Draining Plough | | |

C.D. MacMahon.

for Director, Wales
7. 4. 64

Directorate Development of Machinery R.M.12
Rear-mounted Lincoln Ditch Cleaner

This project is submitted under the R.M.12 procedure, and the paper is intended as a design study, to examine the problems and suggest possible solutions.

I. Object

I.1 The Lincoln requires a width of 11-12 feet from the side of the ditch, and so in its present form cannot be used for the maintenance of drains within the forest, nor can extra width along side drains be provided in time for mechanised maintenance by this means to proceed at the desired pace. However, experience to date with the machine on roadside drains, which it has been able to clean for something like 1/3rd of the cost of handwork, justifies its modification to enable it to straddle the drain, the cleaner being centrally mounted at the rear of the tractor, and this would enable the Lincoln to maintain the majority of drains in the Commission's forests.

I.2 The cost of drain maintenance with the Lincoln varies from 3/6d. to 5/6d. per chain according to the number of passes, amount of dead travelling, and ground conditions, and over a period of 753 hours a hired machine had an average output of 5.6 chains per hour. The number of passes varying from 1 to 3. No other machine has been able to approach these outputs and costs in the Forestry Commission, and the machine has been well proved outside the Commission, notably by Agricultural Contractors and Highway Authorities.

I.3 These facts justify the expenditure of a good deal of money and effort to adapting the Lincoln to deal with the enormous length of drains which the present side-mounted machine cannot tackle.

II. Development

It would appear that the best and quickest method of undertaking the required development work would be for the design to be undertaken by Mechanical Engineer, Headquarters in conjunction with Directorate Engineer (England), who would also organise field trials, and for the actual fabrication and fitting to be carried out at the Directorate Workshops. This would expedite the work without placing too heavy a burden on Mechanical Engineer, Headquarters or Directorate Mechanical Engineer (England).

III. The Tractor

III.1 The standard Lincoln is mounted on a David Brown TD.40 Tractor, and although this is a satisfactory tractor it is not a standard F.C. type and service facilities are not particularly good, and there is no real advantage in using a tractor of this make if the cleaner is to be rear-mounted, since none of the mounting brackets will serve in any case. The obvious choice would appear to be one of the tractors based on the Fordson Power Unit, as these are available with extra reduction gear boxes, are widely used in the Commission, and have a widespread service network.

III.2 The change to another type of tractor offers the opportunity to consider whether a wheeled tractor should be used, the County Super-4,

probably being the best for the purpose, as it has good ground clearance and 4-wheel drive with all wheels of equal size. A wheeled tractor would have the advantages of rapid movement in the forest between work sites, independent travel for moderate distances between the forests, and probably slightly lower running costs, but on the other hand would be less manoeuvrable than a tracked tractor, less able to cope with boggy ground conditions, more liable to slide into the straddled drains, and would have great difficulty in crossing any but the smallest drains. A wheeled hydraulic excavator is able to cross ditches up to 5' wide by using the front loader in conjunction with the rear-mounted digger, but a wheeled Lincoln would not be able to do this, and it would seem to be advisable to use a Crawler Tractor, at least for the initial development. It is possible to foresee a wheeled Lincoln equipped with some form of front loader (which could be useful on occasions for levelling old spoil banks, rehandling spoil, etc.) and hydraulically operated rear skids, but this would be an unnecessary and undesirable complication at this stage.

III.3

The County Swamp model with 6:1 reduction would be well suited to this work, although it might be argued that extended swamp model would be preferable. However, the shorter machine should be able to cope with a very wide range of conditions, would be cheaper and less cumbersome, and is thought to be the best tractor for the purpose, again, at least for initial development. The swamp model is advisable as it enables tracks up to 30" wide to be fitted, and the extra width of gauge (i.e. between centres of tracks) helps in straddling wide drains. At the same time, the track plates should not be too wide, as they would be very liable to damage by stumps, and the extra overall width would be undesirable; the best width to start with would probably be 20" or 24", but these could easily be changed for wider plates at any time.

IV. Mounting the Cleaner

IV.1

The natural position to choose is at the rear of the tractor and this has the advantage of allowing a simple drive from the P.T.O., if this is to be used. There are, however, two serious snags, the first of which is that the operator has to pay fairly close attention to the action of the cleaning chain on the ditch bed, and would find this very difficult over long periods if the cleaner is mounted fairly close behind his seat, except for stretches where the ground surface is very smooth and the ditch of uniform depth. The second difficulty is caused by the fact that Crawler Tractors when turning tend to rotate about their centre of gravity, and this means that everytime the tractor changes direction - whether caused by tendency to run off line or by a bend in the drain - the cleaner will be forced into the bank.

IV.2

It is difficult to predict the extent to which these snags would cause trouble in operation, and it may well be that a skilled operator would make light of them; for example, he could probably control the depth by feel, with an occasional glance behind, and would probably be able to keep to the line by means of the steering clutches, with negligible swing of the cleaner, lifting the latter and setting it in again at any major change of direction.

IV.3

However, it is worth examining possible solutions which would overcome

these difficulties and make operating simpler. The most obvious one is to mount the cleaner at the front of the tractor, but apart from the liability to damage it is doubtful whether any means could be devised of enabling the driver to see the bottom of the chain. One method of overcoming both problems would be to mount the cleaner at the rear but to operate the tractor in a reverse direction, providing suitable linkages to enable the driver to operate the controls while facing to the rear. Alternatively, as a means of overcoming the swing of the cleaner, it would be possible to mount it on a vertical pivot and move it laterally by means of a hydraulic ram. The necessity of adopting either of these expedients should be examined and discussed at an early stage of its design.

IV.4 In order to reduce the swing of the cleaner if a simple rear mounting is adopted, and in any case to improve balance, the cleaner should be fitted as near to the tractor as possible. On the other hand, the further away it is mounted the better will be visibility, the less spray and spoil will be thrown on to the operator and the machine, and the easier will be mechanical drive if adopted, so it is necessary to arrive at a reasonable compromise, having due regard to the effect on the optimum distance of decisions on type of drive and the other factors mentioned above.

IV.5 The standard Lincol can operate to a depth of 3' 6", and it would be undesirable to reduce this, while at the same time it is necessary to be able to raise the bottom of the cleaner at least 1' above ground level to enable obstructions to be cleared. This height range of 4' 6" creates design problems, particularly in view of the moderately close mounting which is desirable; the limited range of height over which drive to the chain is required should result in angularity within the range of universal joints, but nevertheless the difficulties associated with mechanical drive make it worthwhile to consider hydraulic drive. The latter would have the advantage of greater flexibility (e.g. easy modification to mounting distance), but the preliminary design will show whether it is necessary.

V. Cost

The total estimated cost is approximately £3,700, made up as follows:-

County Swamp Model Tractor with 24" tracks and 6:1 reduction	£1,930
Lincol ditch cleaning attachment (estimated)	£600
Materials for mounting brackets and arms, hydraulic rams, drive shafts and joints, etc.	£430
Labour in fabrication and fitting (including overheads)	£400
Allow for contingencies, 10%	£330
TOTAL	£3,700

(E. F. Granfield)
Directorate Engineer

Comparative Trial of Drainage Machinery - Kershope Forest -

7th and 8th May 1964

Atlas 1200 Digger. All Wheel Drive. 38.5 B.H.P.
Overall Width - 8'3"

Est. P.D.C. - 35/-d

Michigan 35A Tractor with Camberley Digger
(M.F.-220 Digger). 4 x 4 68 B.H.P.
Tyres - 13.00 x 24 Overall Width - 6'8"

Est. P.D.C. - 35/-d

Bristol PD 52 Crawler Tractor with PUP Digger.
32 B.H.P. Tracks-16". Overall Width - 5'8"

Est. P.D.C. - 20/-d

International B.T.D. 20 Crawler Tractor 124 B.H.P.
104 D.B.H.P. Tracks-24". Winch Line Pull - 33,000 lbs.

Act. P.D.C. - 37/6d

County Super-4 Tractor. With Shawnee Warrior Digger 4 x 4
52 B.H.P. Overall Width 8'1 $\frac{1}{2}$ " Tyres-23 1/18-26 Goodyear
Special Sure Grip TD-7 Tractor Tyres.

Est. P.D.C. - 15/-d

Track Marshall Crawler Tractor with M.F. 710 Digger
55 B.H.P. Tracks -16" Overall Width - 6'2".

Act. P.D.C. - 17/6d

County CD 50 Standard Swamp Crawler Tractor with
M.F. 710 Digger. 51.8 B.H.P. Tracks-30"
Overall Width - 8'1"

Prov. P.D.C. - 15/-d

County Extended Swamp Crawler Tractor with M.F. 220 Digger
51.8 B.H.P. Tracks-30". Overall Width - 8'1"

Prov. P.D.C. - 15/-d

County CD 50 Standard Swamp Crawler Tractor with Deep
Drainage Plough - R.H. & L.H. Throw
Tracks-30"

Act. P.D.C. - 15/-d

County Extended Swamp Crawler Tractor with Deep
Drainage Plough - R.H. & L.H. Throw. Tracks-30".

Act. P.D.C. - 15/-d

Notes of Meeting held at Kershope to discuss the proposed
Trial of Drainage Machinery - 5.2.64

Present: Director (England), Directorate Engineer, Conservator N.W.(Eng.),
S.F.O., D.O., Asst. Silv. (N), Head Forester, Forester.

The background of, and the need for, the proposals made in the
Research diary of 14th November, 1963 (~~copy attached~~) were briefly restated.

Director (Eng.) agreed that such a comparison should be made and
that Kershope was a suitable central site for it. Appropriate ground types can
readily be found, and good fuelling and workshop facilities are available.

In the course of the discussion the following decisions were
made :-

1. The equipment to be tested, together with their normal operators,
should be at Kershope for 10 to 14 days in order to ensure that
the machines can be thoroughly tested and provide at least
approximate information on out-turn by the final two days which
would be open to representatives of all interested Conservancies.
2. The 7th and 8th May, 1964 were fixed provisionally for the open
days.
3. Research Branch (North) would take the responsibility for the
general organisation of the trials. Naturally there would have to
be the closest liaison with N.W. (Eng) Conservancy staff regarding
sites and logistics. Also other Conservancies interested would
be expected to contribute generously with equipment.
4. Equipment:-

Finnish

 - a) It is most unlikely that a ~~Swedish~~ Lokomo winch plough will
be available by this date. A separate case is being prepared
for its purchase.
 - b) Directorate Engineer suggested that the differences between
makes of back-acting diggers was small and sufficiently well
known to make further comparisons between them unnecessary. This
was agreed.
 - c) North Wales who would be interested in these trials had long
and short County tractors fitted with diggers. Director (Eng)
agreed to initiate the loan.
 - d) N.W. (Eng) and N.E. (Eng) each had a 100 h.p. (+) crawler, -
a BTD 20 and a Challenger, respectively which might be tried to
pull or winch the Deep Draining plough.
 - e)//

*Research &
manage*

*BTD 20 only
I will manage on
receipt of notice
of loan by H.M.*

*I will mention position
from then on. See
rule 10. I think and
average trial*

- e) Because of the proven virtues of the Bristol tractor at Kershope it was decided that one should be included as a carrier of digging equipment. The manufacturers should be asked if they would like to demonstrate its capabilities. Alternatively one could be hired.
- f) It was agreed that a Drott "de-stumper" need not be tested. In the meetings' opinion it was not considered a likely tool.
- 5. The costs incurred in movement of machinery, wages and industrial subsistence will be charged to a "Suspense Account" by N.W. (Eng). The ultimate account to be debited was not decided. Director (Eng) undertook to clear the point with Controller of Finance. Directorate Engineer undertook to rapidly clear the procedural line of R.M. 12.

An
S.A. Neustein
Asst. Silviculturist (North)

County SDL 50 30" Tracks

£2334/19/- + £11/15/- P.T.O.
+ £13/2/6 Hand Chisel
- £25/10/- Drawbar.
+ £227/10/- Winch 4100 A overwind less rope.

Priestman Cub VI Excavator on 18" Crawlers
Equipped as Luffing including boom, autotrip
arm and $\frac{3}{8}$ cu. yd bucket. Cab heater, Counterweight

£3,982 - 14 - 5

Priestman Cub VI Excavator on 18" Crawler
with Dragline equipment 26 ft boom $\frac{3}{8}$ cu yd bucket.

£3906 - 10 - 0

Priestman Cub VI Excavator on 18" Crawlers.
Dragline with side arm boom and eqpt.

£4126 - 16 - 0

Face Shovel £ 705 extra.

24" Tracks £ 113 extra.

Massey Ferguson 205 Tractor £927/12/-
 $\frac{1}{2}$ lights, diff. lock.

220 Digger (Hydra-Slide £805/17/6 + fitting £10.
 $\frac{1}{2}$ Gides 12" Taper bucket.

702 Loader £280 + fitting £10.
48" Std bucket. £42.

Track Marshall 55 basic £1775

Extras: 16" tracks in line 14" Hour Recorder

H.D radiator guard. Pullhook £ 40

£1815

Barford Lincol Ditcher

£2441/19/6.

Croucher Ditch Cleaner

£420.

9. Small
crawler-mounted
hydraulic
excavator
(Bristol
PD.521 Pug
on 16" tracks)

new drainage of
any size in all
soil conditions
including moderately
soft peat (with clay
core) but maintaining

width depends on
that required for
soil disposal. At
Krocker width is
only 5'-8" so that
under extreme
conditions it can
work in a row
only 10'-12' wide

£1800

1/2 to 1 d.
per hour of
new drain
2'-6" deep

about 22/6

about 30/-
for 2'-6"
deep drain.

10. mobile

Maintenance of
shallow drains
in peat up to 18"
deep.

width of Krocker
plus clearance;
about 10'-12' in
all it mounted on
wheels (County).

£250
plus Krocker
(normally
long wheel
County £2385)

9 to 12 d.
per hour

~~41 to 51~~
about 27/6

41 to 51/-

11. "Shiva Holt"
3 rail drain
cleaner

Maintenance of
shallow drains in
peat and soft mineral
soil up to 18" deep.

No share

No share

5 d. per
hour

about 27/6

8/-

12. Barford
lunar

Maintenance of
drains up to 3'-6" deep
in soils substantially
rock-free.

works alongside
drain and requires
width of 11'-12'
from edge of
drain

£2442

average
5-6 d.
per hour
(actual including
spade about 30
d. per hr.)

~~27/6 to 30/-~~
26/- to 28/-

41 to 51/-

in
new
which
surface
maintains
under the

new drains of any size in all soil conditions including moderately soft peat (with the very best maintenance)

width depends on that required for soil disposal. But track width is only 5'-8" so that under extreme conditions it can work in a well only 10'-12' wide

£1800

1/2 to 1 d. per hour of new drain 2'-6" deep

about 22/6

about 30/- for 2'-6" deep drain.

could be useful on material soft peat where width is restricted.

Maintenance of shallow drains in peat up to 18" deep.

width of track plus clearance; about 10'-12' in all if mounted on wide country.

£250 plus track (normally long wide country £2385)

9 to 12 d. per hour

~~41-5/-~~ about 27/6

41-5/-

Quite suitable only for peat and for drains of inadequate depth; could be of some use to an interim measure but doubtful.

Maintenance of shallow drains in peat up to 18" deep.

No drain

No drain

5 d. per hour

about 27/6

8/-

Still under development; if thought of satisfactory conclusion could be useful as an interim measure for shallow drains.

Maintenance of drains up to 3'-6" deep in soils substantially rock-free.

works alongside drain and requires width of 11'-12' from edge of drain

£2442

average 5-6 d. per hour (actual working speed about 30 d. per hr.)

~~27/6~~ ~~201/-~~ 261- to 281/-

41-56/-

Skiddered by large wheels on numerous skids in double effect. very very useful where width is sufficient, and rear-mounted version under development.

14th February 1967

~~Mr. Carthwaite (B)~~

✓ M r. Granfield / (B) X

Drainage and Floods

... I know you want to come down to talk about this subject in the near future. The enclosed note may be of some use in preparation; it has in fact been written as a partial answer to enquiries from Messrs. J.H. James and J.R. Hampson. Perhaps you can suggest some dates?


(R. F. Wood)
Conservator Research

copies for information to
Messrs. J.H. James and J.R. Hampson



Drainage and Dangers from Flooding

This paper arises from correspondence with Mr. J.H. James and Mr. J.R. Hampson, and may be regarded as a preliminary note for further discussion, especially about the Research role in this question.

1. Current Research Our primary interest is in the biological, i.e. the crop aspects of drainage. The hydrological aspect is not our main concern, but we have plainly to pay some attention to it, firstly because hydrological study helps us to understand the soil water regime, and secondly for the obvious reason that we must know what effects our land management practices are likely to have on other people's interests.
2. The effects of land management practices on the water balance of catchment areas is primarily a subject for the Hydrological Research Unit, Natural Environment Research Council. The Unit has, we know, an experiment planned at Wark, Kielder on precisely this subject, i.e. the effect of drainage for afforestation on the flow characteristics of an upland stream. The Unit however is unable to give us any preliminary guidance on drainage and flash floods etc. which is rather disappointing, since it might be expected that they would be well placed to give advice on theoretical grounds at least.
3. Mr. James mentions the interest of Prof. Kidson in basic work in this field. Grants for University work on this topic would be best arranged through the Hydrological Research Committee of N.E.R.C., but it is likely that the Forestry and Woodlands Research Committee would be consulted. We are represented on the latter but not on the former. It is understood that the Hydrological Research Unit would welcome University work in this field, and I am sure it would be valuable to offer Prof. Kidson whatever practical facilities he would require, and to cooperate with him to the full.
4. On the publicity aspect, the most recent 'authoritative' paper is by Howe, Slaymaker, and Harding (Nature 5062 Nov.66) and it is felt here that this is misleading in several respects. It refers to 'drainage', but in fact at Hafren, the forest to which they refer, it is rather the whole plough system for which they give figures. In fact there has been little deep modern drainage at Hafren till recently. Noone will disagree that ploughing is likely to produce higher flow rates under certain conditions, especially for short storms before the soil is saturated.
5. However, they seem to assume that the whole system of plough furrows remains equally 'effective' up to the closure of canopy, but we feel this is almost certainly not the case. Plough furrows may run particularly freely for the first season or two, and one would expect a newly -ploughed area to produce flash runoff in the first season. Re-invading vegetation both in the furrows and on the ridges may however modify this fairly quickly.
6. Turning to drains 'proper' (which they do not distinguish), it is noted that they do not allow for any beneficial effect on the control of peak flows. Under conditions when the soil is saturated and a high rate of rainfall is being maintained, both drained and undrained ground may deliver water at a rate approaching the rate of accretion. However the drained condition is likely to reduce the peak by losing more water in the early stages of a storm (thus in fact lengthening the period of relatively high delivery). This may be regarded as a short term effect;

there is also the long term effect of the increased storage capacity of the soil. Both of these factors should have some dampening effect on peaks, while no doubt a good drainage system will maintain higher average flows for a given rainy period.

7. The authors do however make it abundantly clear in the latter part of their paper (we think they might have put it first) that serious flooding has been associated with abnormal storms. They also show that the incidence of intense rainfalls has markedly increased in the last few decades. Under conditions when the soils are waterlogged before heavy rain occurs, the whole of the fall has simply got to come off, and we should think in these conditions that hill drainage is not harmful.

8. It is generally accepted (and there is plenty of evidence for it), that the established forest will help considerably, but even the forester will not claim ^{when} that 6" or so falls in 24 hours after a wetish period, we can soak it all up.

9). Somewhere in the wave band (e.g. ploughed land subject to exceptional rainfall in a short time as compared with unploughed at times when neither area is fully saturated) one feels that we are liable to do something significant and possibly locally harmful. I think however we can completely put aside any ideas of drowning Shrewsbury or Newtown, great river floods are a response of the particular physiographic features of the catchment to abnormal rainfall, and a few hill drains have little or nothing to do with them.

10. The localised effect is probably of more importance to us. There does for instance seem to be some risk in ploughing a considerable area on an elevated plateau that we may re-route the natural distribution of the drainage from the top, and (temporarily at least) concentrate exceptional flows into smallish natural channels. If there is any choice in the matter, one would wish to spread the flow from drainage systems as much as possible and certainly to avoid concentrating into channels which have something particularly vulnerable beside them lower down.

11. Another point is equally obvious and is simply the question of scale. The higher the percentage of a given catchment we plough the bigger the effect on the flow characteristics of the stream, certainly for the first few seasons, and perhaps quite especially for the first. The engineer can work this out making various pessimistic assumptions. It seems unlikely that we ever drain and/or cultivate sufficient proportions of very large catchments to have highly significant effects on the flow characteristics of the larger streams, but perhaps more thought should be given to the smaller ones of a few square miles or less. It might well be worth looking at drainage proposals in this light and making some calculations on pessimistic assumptions of soil storage, storm intensity, and run off characteristics. It seems possible that we could reach some rule of thumb guidance for ourselves as to the proportion of given catchments which should be treated in a decade.

Deep Draining on Felled Sites

Harwood

History

The first serious blow occurred in 1960-61 and in the winter of 62 10 acres of P.31 SS in Compartment 27 was clear felled. The felling was done in the snow with Bushman saws and stumps were left high. The part which poor drainage had played in the blow was not wholly appreciated at that time. The compartment was not replanted immediately. This is important in the experimental context, since it supplied an area of high stumps and decayed brush on which to dig drains.

By 1966 further windblow had occurred and the zoning system was applied. Harwood is calibrated in the "Yellow inclined to Red" zone and a system of anticipatory clear felling was instituted. By the time deep draining was arranged we had two types of site on which work was required. These were:-

- a) Windblown, cleared 4 years previously with high stumps, decayed brush and dense weed regrowth in parts.
- b) Recently clear felled with fresh brush and low stumps.

One other factor distinguishes a windblown site from a felled site and it is that on the windblown areas stumps have been turned out by wind and then have fallen back on removal of the stem. Underneath each of these replanted root plates lurks a shallow quagmire which presents a hazard for machines.

Problems

These have been crystallized out as follows:-

1. Power required must be adequate to move the biggest stumps.
2. To provide a deep, large drain requires a big bucket, which in turn requires a powerful machine.
3. Given a powerful machine this usually means a heavy machine and this leads to difficulties in flotation and movement.
4. The machine with vulnerable hydraulics and in these conditions requires considerable protection from stumps and brush.

Specification

The original specification was for a drain with minimum dimensions, 30" deep, 12" bottom width and clean sloping sides to 30" width at top.

Subsequently at our request the bucket was modified to produce a "U" shaped profile of similar dimensions.

Improvements

1. Improvements to standard machine.

The J.C.B.6c on 24" tracks has ground pressure of $5\frac{1}{2}$ lb. $\square$

Tracks of 30" width have been fitted and ground pressure is down to $4\frac{1}{2}$ lb. $\square$
This has reduced bogging to almost nil, and has improved traction.

The standard underside was very vulnerable to high stumps which damaged the lower parts of the platform, and also too long lengths of slash which penetrate any crevice and damage the flexible hydraulic leads. All hydraulics have been re-aligned and guarded and most of the underside protected with $\frac{1}{4}$ " steel plate.

The standard straight sided bucket has been improved by welding curved "outriggers" to the front and extension "wings" to the top to give a much improved profile.

Digging techniques

1. Contractors find that fresh brash greatly improves the bearing surface. They anticipate that on deep peat with old decayed brash there are places where neither they nor anyone else could dig.
2. The 360° slewing action is important because:-
 - (a) Mineral soil from the excavated drain can be laid in front of the tracks to provide a better bearing surface, to level up the machine on uneven ground, and to effectively reduce the height of dangerous stumps.
 - (b) Obstacles in front can be cleared away.
 - (c) In windblown areas which have rootplates blown and then fallen back, soft areas occur beneath each plate. The contractors find that if they lift and replace these root plates upside down, a bearing surface is maintained and the obstacle of the high out stump is removed.
 - (d) If the machine tends to bog it can be helped out in the forward direction by using the jib in the front position as a lever to lift the tracks. This is not possible with a rear mounted excavator.

Points for further consideration:-

1. Slash should be left no longer than 6' - 8' since this can damage hydraulic leads, windows, and the operator.
2. Lost time should be reduced by fitting extra fuel tanks and thus reducing the number of times needed to run light to the compartment edge.
3. Experience last winter indicated that tracked machines can often work in these conditions to much better advantage when there is a covering of snow. Snow lifts the machine clear of obstacles and provides a steadier digging platform. Provided the alignment is staked beforehand, it presents no problem to digging.
4. The whole question of maintenance should be considered.

Results

1. With machine improvements the tendered price has dropped from £4 to £3.10.0 per chain and there is a possibility it could come down to £3 except on deep peats.
2. The straight sided drains were dug to 42" deep, but are suffering considerable fall in. Some are now bell bottomed with peat overhang. However many can tolerate this fall in which reduces the depth to 36" and the drains are still effective.
3. The 'U' shaped drains have now had about 10 months weathering and are still in first class condition. There is very little fall in and depth has not altered significantly.

MACHINERY DRAINAGE TRIAL

<u>FC</u>		<u>CONTRACTOR</u>
SUPER CTY 4		JCB 6c
MASSEY FERG 270 DIGGER		
80	TOTAL WORKING HOURS	80
102.8	CHAINAGE	114.3
1.28	" PER 4R	1.42
6.5	" PER ACRE	6.5
<u>MINIMUM SPECIFICATION REQUIRED DEPTH 30" TOP WIDTH 30"</u>		
32 1/2"	AVERAGE DEPTH	40 1/2"
36 1/2"	" TOP WIDTH	53 1/2"
10 1/2"	" BOTTOM WIDTH	12 1/2"
15.30 cu/yd	EARTH REMOVED PER RUNNING YARD	30.66 cu
£89.4.0	LABOUR CHARGE (INC TO BONOS)	£457.2.0 at 4 p
97.0.0	ADON	
35.13.5	LABOUR ONCOST £40	
£221.17.8	TOTAL	£457.2.0
2.3.3	COST PER CHAIN	4.0.0
14.1.4	" " 4CRE	26.0.0

Mr E F Granfield (B)

Forestry Commission
Priestley Road
Basingstoke
Hants

My ref: S 4/2/1

WORKING GROUP ON FOREST MANAGEMENT OPERATIONS

You will know that the Operational Efficiency Committee is to be wound up. The Working Groups will, however, continue to function and their role will be to advise appropriate Heads of Divisions on any matters on which the Divisions should have views as staff of their Commissioners. The Groups will also help to co-ordinate the views of other Divisions where matters of wide and common interest are involved.

The Working Group on Ploughing and Drainage has been re-named the Working Group on Forest Management Operations and the following interests are currently represented:

- Forest Management
- Research
- Work Study
- Civil Engineering
- Mechanical Engineering

One representative of Conservancy staff is a permanent member of the group (at present the Assistant Conservator (FM) S(S)) and representatives of any Conservancy with an interest in a topic under review will be invited to assist in particular studies.

The Group proposes to examine cultivation techniques prior to the establishment of second rotation crops and the appropriate Conservators are being approached.

C D BEGLEY
Forest Management Division
Chairman
Working Group on Forest Management Operations

14 August 1970

DISTRIBUTION:

Territorial Conservators
Headquarters List A

MEMBERS OF THE GROUP:

- Mr J N Kennedy
- Mr H V S Dier
- Mr E F Granfield
- Mr G G M Taylor
- Mr W C Anderson
- Mr D M Hughes
- Mr B Tipping