THE LAND USE FACTOR IN WHEATLAND EROSION CONTROL

By

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MUCH emphasis has been placed in recent years on the control and reclamation of eroded country by predominantly mechanical means. This method renders an invaluable service and is the only possible method of regaining soil stability in badly eroded country, results in the majority of cases being little short of spectacular.

However, whilst recognising the valuable and indispensable part mechanical means are playing in erosion control, it must be regarded more as a treatment for the advanced symptoms of erosion than as a prevention of the actual causes.

To combat soil erosion effectively an all-out effort must be made to correct those mistakes in past and present land use that have left as their heritage the reclamation problems that we face to-day. It is essential to prevent the occurrence of new erosion and to arrest the deterioration of lightly-eroded land while treatment of existing badly eroded country is under way; otherwise, year by year, the acreage requiring mechanical treatment will be rapidly expanding. It is true to say that on most farms the same procedure that has been the prime factor in reducing some of the best wheat country to a useless maze of gullies has been retained virtually unchanged to the present day. The majority of wheat country is showing some signs of erosion, even if very slight, and unless this potential menace is combated by a revised and modified system of farming and grazing,

Fig. 1.—Gullies can develop on very gently sloping arable land.

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the battle is going to be unduly prolonged and expensive. The universal adoption of a soil conservation system of farming has already been delayed too long.

The widespread occurrence of erosion in every wheat-growing area of the State affords ample proof of the extractive and exploitive nature of the present methods of production. We have wrested a bountiful harvest from the soil and have not been prepared to put something back to assure a continued and stable production. In isolated areas we have already so ill-treated the land that it is doubtful whether it would be economical to reclaim it.

The practice of the long bare fallow, the undulating terrain of the wheat country, and the erratic nature of the rainfall renders our wheatlands particularly vulnerable to erosion. The terrain and the rainfall are beyond our control, the only hope for retarding the onslaught of erosion, apart from areas where mechanical control is indicated, lies in improved cultural methods and the instigation of a sound system of land usage.

Important factors associated with the control of erosion by temperate farm husbandry and the employment of conservation farming methods are as follows:—

CULTIVATION ON EXCESSIVE SLOPES.

Advances in farm mechanisation, high prices for wheat, farm topography and size, coupled very often with a failure to recognise fully the dire risks they are running, have induced farmers to cultivate slopes of such a degree of steepness that serious erosion has resulted after two or three fallows. Very often, the paddock is put out of cultivation to arrest the erosion, but if gullying has occurred to any extent, the only result of the spelling is to slow down the rate of erosion in some small degree. A drought in this area, coupled with the comparative overstocking that occurs in time of drought, will complete the devastation of this land, even in the absence of any further cultivation.

Owing to differing soil types, farming practices, incidence and intensity of rainfall, it is impossible to give any certain degree of slope as an all-round maximum for safe farming; it will vary in different localities, different farms in the same locality and to some extent on different parts of the same farm. Factors such as rainfall, which varies in intensity and incidence year by year, further complicate the matter. In general, slopes exceeding 8 per cent. should be regarded with suspicion in any district and in some districts this figure is beyond the maximum for safety. If landholders refrain, however, from cultivation of excessive slopes and maintain a good grass cover on these slopes when the land below them is under fallow, the battle against erosion is already half won. If difficulty is experienced in grassing or preventing run-off from these uplands they should be contour pasture furrowed; if properly constructed these will give 100 per cent. control even with above average falls of rain.

It is realised that many farmers regard their higher country as the best wheatland and continue to farm it even when it is showing signs of serious erosion. The reasons generally given are that higher gravelly slopes give heavier and better samples, the crops stand up better and are not susceptible to rust and other fungus diseases, and flood damage and bogging in wet seasons is avoided. It is also held that occasional cultivation of wheatland is necessary to maintain good pasture species.

The reasons given are in the main part true, but many reasons for restricting cultivation on steep slopes can also be found. However, it is again stressed that the likelihood of causing erosion should be the only deterrent needed to keep the cultivation to the more gentle slopes at least. Soil lost by erosion is lost for ever, and where the top soil goes history has shown that man will soon follow.

To those who fail to realise the amount of soil and moisture that can be lost from bare-fallowed slopes the following figures will prove interesting. They were obtained as a result of research into run-off and soil loss at Wagga Soil Conservation Research Station, which is situated in the Riverina district of New South Wales. Results are therefore applicable to a large part of the southern wheat belt. The length of slope

Fig. 2.—This fallow is on steeper slope than Fig. 1. Following incorporation of the wheat stubble, it withstood 1,645 points of rain in the first three months of 1950 without damage.

was 136 feet, the slope 8 per cent. and the width of plot 8 feet. The treatment was bare fallow.

Date.	Points of Rain.	Lb. Soil Loss per Acre.	% Run-off.
8-12-47	259	7,879	43
13-12-47	123	5,819	56
21-12-27	91	8,470	62

It might be mentioned that the above figures are for three summer storms only; for two and a half months during the summer the maximum soil loss on any one plot was no less than 34,000 lb. per acre. Thus, it can be seen that cultivation on an 8 per cent. slope can result in serious soil loss if high intensity summer rains are experienced, and, generally speaking, cultivation on slopes approaching 8 per cent. should be restricted as far as possible.

A closer study of the figures indicates the cumulative effect of erosion. Once a paddock has washed it has been found by experiment and observation that further falls of rain cause soil loss out of proportion to the amount of rainfall. Thus, in the above case at Wagga, 91 points of rain falling at the end of the month caused more soil loss than 259 points falling early in the month. This is due in no small part to the previous rain establishing drainage lines in which the run-off from the following falls of rain is more quickly concentrated. Other factors such as compaction of the surface soil by the beating action of the rain also increase run-off and thereby soil loss.

LONG FALLOWS.

The usual procedure in preparing a field for a crop of wheat has been to plough in the latter part of the winter or early spring, followed by cultivation after significant falls of rain or at any time the fallow is in danger of being overgrown by rubbish. The rain and cultivation mellow the soil, bringing the cloddy mulch to the surface and leaving a fine firm seed bed underneath.

ig. 3.—Deep fertile soils being ravaged by run-off from steep slopes above. This is the penalty for indiscriminate cultivation of natural flow lines.

This long bare fallow has been one of the main contributing causes of soil erosion on our wheatlands. Until quite recently it was considered that the best fallows were those ploughed in mid or late winter and which were then cultivated frequently up till cropping time the following autumn. This attitude is now changing, but unfortunately the flying start it has given to the erosion problem will take a lot of making up.

At first glance it would appear that as the main erosion causing storms occur during the summer months from November to March, country ploughed in September-October would be as readily susceptible to erosion as that fallowed in June-July; in both cases the land is bare fallowed when exposed to the high intensity summer storms. This is not so, however; the long fallow is much more liable to erosion than the September-October fallow and this becomes more apparent when the problem is closely studied.

Land recently ploughed is rough and absorptive. It is turned up in sods and contains roots of grasses and other vegetable matter that binds the soil particles together and makes them resistant to weathering. The granular and cohesive structure of the soil is retained and the open rough nature of the ground permits the rapid absorption of heavy falls of rain.

By comparison, the early fallow, having received several workings before the onset of the summer storms, is by this time in a fine state of tilth and retains little of the erosion resisting characteristics of virgin land. It is these fine, overworked fallows that erode at an alarming rate if summer downpours are experienced.

This problem of arriving at the danger period of summer rainfall with a desirable degree of cloddiness, porosity and soil structure, is becoming increasingly difficult as the years go by. Constant cultivation under a long-fallow system has so pulverised the soil and reduced the organic matter content that the first ploughing is quite often too fine. This state of affairs is very apparent in old cultivation paddocks that have been long fallowed and overworked for years, especially when fallowed with a disc plough at high speed. The sod is shattered, and if fallowing conditions are on the dry side it soon becomes hard to recognise any sod formation at all; after one or two workings the fallow is in good sowing condition at the onset of summer, about six months ahead of time. This fine surface, in which the cloddy mulch has been broken down, leads to a caking of the top layers, even after a small fall of rain, and further falls cause excessive run-off and thereby erosion and loss of soil moisture.

SHORT FALLOWS.

Owing largely to the ever increasing popularity of sheep in the farming programme it is now becoming a common practice for the farmer-grazier to leave his fallowing until late September and October, usually following shearing in wheat-growing districts. Although this may be done not so much in the knowledge that this practice would minimise erosion as from the necessity of utilising spring feed that otherwise would be ploughed in, the system has a double advantage for both the grazing and farming portions of the rotation; spring feed is available for sheep and the fallow is left rough and absorptive for the summer rains.

It is usual for the period from October onwards in the wheat belt to be hot and comparatively dry, thus leading to very little growth on the fallow following the initial ploughing in October. The rain that does occur is usually of the high intensity thunderstorm type which causes excessive run-off and erosion and at the same time leads to very little pasture growth because of the excessive evaporation and heat of the summer months. This reduces both the need and cost of further cultivations.

In the mallee and marginal wheat areas the problem of wind erosion is also of concern. It is often found in conjunction with water erosion and the problem of reclamation is thereby further complicated. Again, it will be found that the long, bare, and finely worked fallow is the most susceptible; wind lifts the fine fertile particles from the surface soil and leaves coarse unproductive sand on top of the exposed subsoil. This problem of soil erosion by wind action receives scant attention in lush seasons, as the damage is concealed by abundant grass cover and the soil does not reach that stage of desiccation necessary for large-scale transportation. However, if we cast our minds back to the droughts of 1944 and 1946, we can have little doubt as to the seriousness of wind erosion in our western districts.

Old ideas are hard to change, especially when they have been tried and accepted by the greater majority of the farming population. From the point of view of erosion control and continued soil fertility, it is hoped that the short fallow, leyland farming system, will completely replace the interminable long fallow wheat rotation that has exhausted much of our best wheat country. It is realised that this move is now well established in some farming communities but its cause cannot be too strongly championed.

ONE-CROP FARMING.

"Wheat Sick" is a term that is heard frequently in any wheat-farming community to describe country utterly spent from years of continuous wheat production. Continuous one-crop farming robs the soil of its inherent fertility, breaks down soil texture and by continually killing out clovers and grasses makes way for the growth of poor class herbage when the land is eventually rested. When the rotation is widened to include a period of natural leyland erosion very often continues practically undiminished, the main regeneration being saffron thistle and skeleton weed, stinking love grass, etc., which afford very little true cover for the soil and are of poor feeding value. As the farmer sees small return coming from the natural leyland he sometimes waits impatiently until fallowing time and again puts the plough to work. Thus, the one-crop farming goes on year after year, and erosion accelerates alarmingly.

Fig. 4.—Cultivation up and down the slope leads to serious erosion. Where the furrows converge the soil has been stripped to plough depth.

The introduction of a diversified rotation is by no means an easy one owing to the limit placed on pasture establishment by the meagre rainfall in the more western wheat districts. We must rely mainly on three hardy plants, Wimmera rye, lucerne and grazing oats. The dryness of the climate makes the establishment of subterranean clover a gamble in all but the more favoured rainfall areas, and even so it will not thrive in some districts, *e.g.*, the north-west of the State. In areas of adequate rainfall, where it can be grown successfully, it is of great value in the rotation in restoring eroded country and building-up soil fertility, and should always be included in temporary pasture on arable land.

The adoption of a system of leyland farming is one of the most important erosion prevention measures throughout the wheat belt.

ROTATIONS.

Granted that it is essential to give land a spell between crops of wheat it then becomes necessary to utilise fully this time and acreage lost to wheat production in a profitable and practical manner. A period of leyland must come into this wheat, fallow, wheat rotation, in order to build up humus content, re-establish the granular soil structure and increase water-holding capacity and power of absorption, in short to bring back as many as possible of the vital soil characteristics that have been destroyed by continuous and uninterrupted wheat culture. Rotations given in this article are simple and straight-forward and are the accepted practice on leading farms in various wheat-growing areas. They are designed to bring about a return to soil fertility, encourage a diversified farm production and, above all, prevent or assist in controlling erosion.

GRAZING OATS.

Grazing oats, although similar to wheat in many respects can, if properly managed, provide a short-cut method of establishing a profitable leyland, and if followed by the recommended year of pasture, have a tonic effect on overcropped wheat land. They are also immune to many wheat diseases such as wheat rusts, foot rot and "take all" and so are also beneficial from the point of view of diseases control. They provide a greater bulk of palatable winter feed in a shorter time than any other pasture or fodder crop that can be grown in the wheat area. When sown after the early autumn rains they provide good grazing within six weeks of sowing and assure bulk feed throughout the winter and spring.

Grazing oats are most economically and quickly established on wheat stubble land; oats, being more adaptable than wheat, will do much better on a rougher preparation of the seed bed.

Heavy straw is sometimes a difficulty that has to be met at sowing time; however, it can be overcome by a little improvisation and it serves the valuable purpose of preventing erosion on the ploughed land from the time of ploughing until the oats are well established. The stubble land can be ploughed any time after harvest, weather conditions permitting. However, it is quite often left until about mid-February until the sheep have had a pick and the stubble is flattened somewhat; no hard rules can be adhered to, as the seasonal and straw conditions are very variable; sometimes the oats can be successfully sown in a "one hit" operation.

Oats can be sown following a good fall of rain any time after the first week in March. The best methods of sowing are as follows:—

(*a*) With a disc plough fitted with seed and fertiliser attachments. This implement is ideally suited for the operation but unfortunately is not available in any quantity.

(*b*) With the ordinary wheat drill or combine. If necessary all but the sowing tynes can be taken off the combine to allow the straw to pass through the machine. Some drills are fitted with a staggering device for sowing in rubbish. Excellent stands of grazing oats have been established in the Parkes district by sowing in stubble with the feet clear of the ground and covering the seed with disc harrows. It is imagined that an implement rarely seen now, the disc drill, would make an excellent job.

(*c*) Broadcast seed and fertiliser and cover with disc harrows; this is a very quick and cheap method of establishment.

The common practice of grazing the oats into the ground about October and then working with a scarifier in preparation for wheat next season defeats the whole purpose of the rotation. The compaction of the surface by the stock and lack of ground cover leaves the soil bare and very susceptible to erosion; the resultant fallow which will work up very finely is also very susceptible to erosion. The practice of burning the wheat straw and then sowing the oats is also to be deplored.

For the best results the land is not again put under crop for two years, the rotation then becoming grazing oats, improved leyland, wheat on short fallow. Of course the leyland portion of the rotation can be lengthened with further beneficial results, area of land permitting. When grazing it is of course essential to at all times keep surface cover on the ground by avoiding overstocking.

PASTURE ESTABLISHMENT WITH CEREAL COVER CROPS.

After a protracted period of wheat culture a rotation including a semi-permanent pasture of grasses and legumes is the best means by which fertility may be improved and erosion prevented. The most practical way to establish this pasture is to sow lucerne and Wimmera rye grass in the wheat stubble together with the cover crops of oats or wheat, or to sow with wheat as the cover crop in the usual farming programme. Where the natural clovers and trefoil have disappeared from the arable land add barrel or ball clover to the mixture. It has been found that trash in the

Fig. 5.—A disc plough fitted with seed and fertiliser attachment. An excellent type of implement for stubble farming and pasture establishment.

soil gives added protection to the pasture plants in their early stages and the full benefit of this is obtained by sowing on stubble. This is particularly the case with Subterranean clover and in any area where Subterranean clover can be grown it should be included in the mixture with Wimmera rye and the lucerne and other clovers can be omitted.

From the point of view of erosion control this method of establishment is to be preferred to sowing the lucerne, rye and clovers in specially prepared seed beds. Excellent results, especially with lucerne, are obtained by the latter method but the necessary bare and very fine fallow constitutes a serious erosion potential.

STUBBLE FARMING.

Much interest has been focused in recent years on the retention and utilisation of crop residues in the soil. "Trash Farming", as it is termed in the United States, appears to be rapidly gaining in favour in that country and many advantages are claimed over the clean tillage system. So far stubble farming has not made much progress in this country, mainly because of the lack of suitable farming implements.

There are two main systems employed in stubble farming, one in which the stubble is simply ploughed in and mixed with the soil; the other method is more correctly termed stubble mulch farming, in which the straw is retained on the surface of the soil after the usual cultivation.

The presence of straw and trash in the soil greatly reduces the vulnerability to erosion by keeping it porous and absorbent, minimising the effect of raindrop splash and presenting obstacles to soil and water movement. The soil, having absorbed more moisture, dries out less quickly and thus the fallow does not blow away as dust. The rotting of the straw in the soil also increases the organic matter content and fosters the

Fig. 6.—Stubble land can be used profitably and erosion prevented. Lucerne was sown into stubble with a light seeding of cereal cover crop. Parkes district.

development of useful soil organisms which greatly assist in building up soil fertility and diminishing erosion.

The more recent innovation of Stubble Mulch Farming, in which as much as possible of the stubble is retained on the surface of the soil during ploughing and cultivation operations, appears to hold out more advantages than the ploughing in of stubble and may prove in later years to become the accepted practice for wheat culture. As the system is in its infancy it is impossible at this stage to say how successful it will ultimately prove.

The effect of stubble mulching in reducing erosion and the loss of moisture from fallows is being investigated on Soil Conservation Research Stations under a wide variety of soil and rainfall conditions and the results of this research will be forthcoming in the near future. Some of the advantages claimed for this new system of farming are—

(*a*) Greatly reduces the risk of soil erosion by both water and wind. In the first instance the protective covering of straw breaks down the driving force of the rain, gently lowering it to the ground where it can be absorbed. The presence of straw also retards the flow of surface water and soil; where run-off occurs it will be mainly clean water.

(*b*) The presence of a mulch over the soil keeps it spongy and absorptive, making use of practically every drop of rain that falls.

(*c*) Affords protection for young crop and pasture plants after breaking through the surface soil.

(*d*) Keeps the soil friable and moist and prevents caking.

(*e*) Does not interfere with the production of a firm seed bed as the straw is on top of the soil or at least in the top inch or so.

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Fig. 7.—A close view of the pasture in Fig. 6.

(*f*) Does not have a temporary retarding effect on the availability of nitrates as happens when the straw is mixed with the soil.

(*g*) Builds up the organic matter and humus content of the soil as well as encouraging bacteria and other useful soil organisms.

FARMERS' RESPONSIBILITY.

The early stages in the development of erosion are usually not spectacular and are unfortunately passed over as a matter of little consequence; dams and fences silt up, water is noticed running in new courses and strips of fallow to plough depth only may be washed from the field. Further cultivation fills in these depressions to a large extent and the erosion problem is promptly forgotten until the next downpour is experienced; the gutters are then again washed out and may be enlarged. Once the watercourses become defined the erosion increases at an alarming rate and it is no time before the paddock is divided by a series of uncrossable gullies. It is usually not until this last stage is reached, in which the erosion actually impedes cultivation, that any measures are taken to halt the trouble. Reclamation at this stage presents a formidable problem which may entail the use of heavy earth-moving plant.

The farmer's responsibility in arresting the development of these early signs of erosion has hitherto been too lightly emphasised. Control of erosion must start on the farms immediately the first signs of soil loss become apparent; at this stage a display of initiative can prevent the trouble from growing into something he cannot handle. It is apparent that unless the average wheat farmer is prepared to adopt a more conservation-minded attitude in obtaining his livelihood from the land, many hundreds of thousands of acres now showing the first signs of erosion damage will rapidly pass into a class which can only be controlled by complete retirement from cropping or the construction of various types of earthworks.

Fig. 8.—Contour farming in the foreground and graded banks and waterways in the background form a new pattern of soil conservation farming.

In addition to the preceding avenues of erosion prevention outlined in this article, another very important method of minimising soil loss that can be implemented cheaply, quickly, and effectively by the farmer himself, is that of contour working.

CONTOUR WORKING.

In this system of working all the general farming operations of fallowing, cultivation and sowing are conducted at right angles to the slope of the land. After a preliminary survey to determine the best positions of the lands in regard to existing fences, ease of cultivation, rocky outcrops, etc., level land markers are run out; these may then be modified to eliminate sharp turns and bottlenecks as long as no radical divergence from the contour is effected. The width of the lands will depend on the uniformity of slope; on evenly sloping country lands of up to five chains and over can be obtained. Permanent land markers can be obtained with two blows of a disc plough along the contour line, this produces a broad low mound that is in itself an aid against further erosion. All future working is done to these markers until they are considered adequate for the job, the idea being to make them as broad as possible without adding materially to their original height. It has been found after a period of very severe test in the record rainfall summer of 1949-50 that a broad based bank so constructed will hold water right to the top and overflow along its length without appreciable damage. It can be crossed by machinery and stock without greatly impairing its efficiency and presents no difficulties in the efficient functioning of farm implements.

Whether or not these modified marker banks are included in the contour worked area the results so far obtained have been very encouraging. Each furrow turned by the plough or cultivation implement acts as a miniature contour bank in retarding the flow and absorbing water falling on the fallow. This greatly reduces the quantity of run-off and thereby automatically retards soil erosion.

It must be remembered that no one means by itself constitutes a sure method of preventing soil erosion; contour working may only partly control soil loss on areas subject to a heavy concentration of water from a large, badly-eroded catchment, or in other cases such as when unseasonal heavy rainfall is experienced on country in which the soil structure has been greatly impaired by continuous long bare fallow wheat production. The deterioration of farm lands by the loss of surface soil has been caused by the operation of an extractive farming system from the time the land was cleared and first put to the plough; it is merely wishful thinking to imagine that the problem can be solved by the construction of a few banks if the old farming system is to be retained unmodified.

It is only by adopting an all-embracing soil conservation land usage that a continuity and eventual increase in primary production can be envisaged. The adopting of such a policy entails adherence to general principles already discussed, viz.: restricted cultivation, at least so far as excessive slopes and natural drainage lines are concerned, shorter fallows, the initiation of a leyland wheat rotation, contour working of sloping country, pasture furrowing and careful grazing of upland country and a greater recognition of the value of crop residues.

CONCLUSION.

Many other factors, such as control of rabbits, location of farm roads, destruction of timber and natural windbreaks, badly located dams, gates and fences, firebreaks ploughed on steep country, are all points which need careful watching by virtue of their bearing on the erosion problem. However, in the wheat belt the key point of the whole problem lies in flaws in the present system of cultivation, one which provides us with plenty to-day, but which makes no provision for posterity.

The basis of good farming is not so much in production as in the continued ability to produce, and prospects of attaining the latter goal will become less and less if erosion continues to spread at an ever increasing rate through good farming country.

The man on the land has a heavy responsibility in seeing that the farm he leaves to his successors is in at least an equal, if not better, state as regards erosion and consequent production, than when he himself first started farming.

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PROTECTION OF WONGO CREEK CATCHMENT, MANILLA

by

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IN Vol. 5, No. 3, T. F. Mau, District Soil Conservationist, described in the article, "Protection of Keepit Catchment Area," the works programme for this area. The second part of his programme dealt with the control of creek catchments draining directly into the storage basin of Keepit Dam.

The purpose of this article is to describe in detail the planned and partly-effected control of one such creek catchment—that of Wongo Creek.

EROSION HAZARD.

Thirty-three thousand acres comprise the catchment of Wongo Creek; these areas are in the main excellent mixed farming areas with soils of great depth and remarkable fertility. The extent of erosion damage is directly proportional to this fertility. It has been justly claimed that the tributaries of Wongo Creek and Wongo Creek itself move more silt per acre into the storage basin of the dam than any other creek catchment. The extent of overall damage is frightening; it is almost impossible to find a single area over 150 acres in extent that does not show very active signs of erosion.

The hazard is further aggravated by the rabbit problem, which, in certain locations, is very grave. Although the landholders generally in this area are tackling the problems energetically and continuously, lack of adequate fencing materials is making the task difficult.

TOPOGRAPHY.

Wongo Creek Catchment is roughly oval in shape and is a self-contained valley (Fig. 2). The southern point of the oval is formed by the Namoi River. It is bounded on the western, north and north-eastern sides by steep and in some cases precipitous mountains. These form innumerable re-entrants, which, in turn, become watercourses and/or gullies, all draining into Wongo Creek. The 33,000 acres of the subject catchment are classified for convenience into four sections. The basis of this classification is percentage slopes.

Areas.	*Percentage Slopes.*
6,000 acres ..	25 per cent. and over.
4,000 acres ..	15 to 25 per cent.
10,000 acres ..	8 to 15 per cent.
13,000 acres ..	0 to 8 per cent.

PLAN OF ATTACK.

In planning soil conservation measures to deal with the catchment of Wongo Creek, we were helped by the knowledge that almost 100 per cent. co-operation from the landholders was forthcoming, consequently property boundaries were not serious obstacles. We knew that landholders were prepared to work on their holdings for the benefit of both themselves and also landholders situated below. The three main steps in the plan of attack were:—

A. Classification of land according to type of treatment.

B. Selection of key properties.

C. Operations.

A. Classification of Land According to Type of Treatment.

1. *In areas with slopes exceeding 25 per cent. (Fig. 3).*

Due to the exceedingly fast flows in all these re-entrants and tributaries, plus the large silt load which they immediately deposit upon reaching the more gentle slopes, where the velocity of flow is reduced, deposits are built up and finally the course of the creek or gully is altered. These changes occur very frequently, in some cases as often as twice in the one year. Therefore, the first step in control had to be in the headwaters of these watercourses. Ordinary means of control such as absorption banks, diversion banks and pasture furrowing were out of the question due to the steepness of the catchments involved. Nevertheless, the slowing down of the flows in these watercourses was essential before any effective control measures could be undertaken at lower levels.

A change in land utilisation, such as rigid stocking control, rabbit eradication and a change-over from sheep to cattle, would, in time, have allowed natural revegetation to slow the run-off from these catchments. However, a programme such as that would take years to implement, if the landholder was in the economic position to effect this change.

As the silt loads of Wongo Creek have to be reduced considerably, prior to the completion of Keepit Dam, in approximately

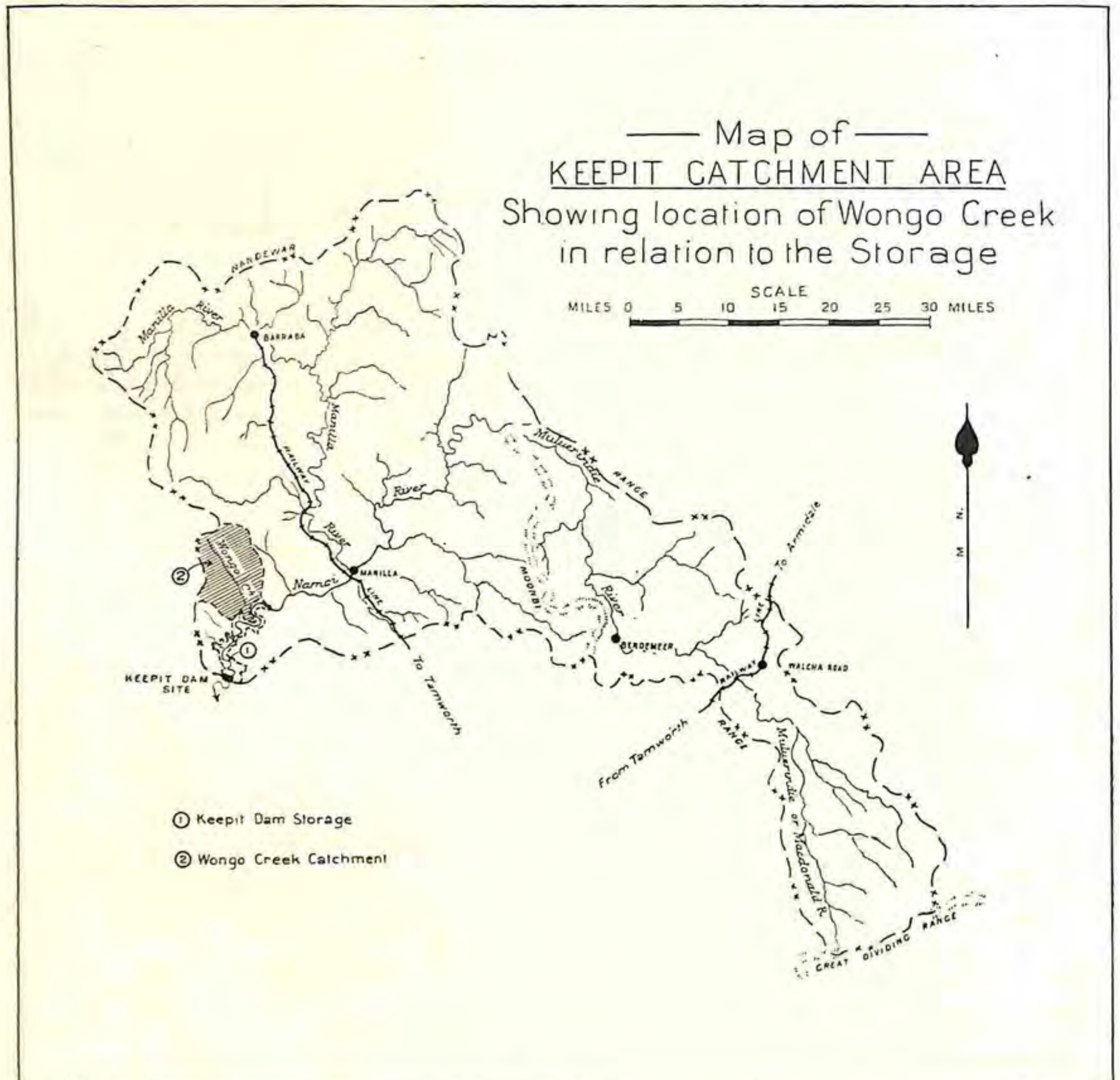


Fig. 1.

four years' time—time is the limiting factor. The slowing down of the flows in the watercourses had to be effective almost immediately, and this is being achieved by the construction of a series of silt dams. (See Fig. 4.)

These silt dams are located in the headwaters of key tributaries that contribute the maximum flows in the shortest periods towards the flow of Wongo Creek. The dams have catchments varying from 75 acres to 250 acres; critical run-off from these catchments would be between 100 and 500 cusecs; the time of concentration from 10 minutes to 35 minutes. The storage capacity is between 5 and 26 acre-feet. The

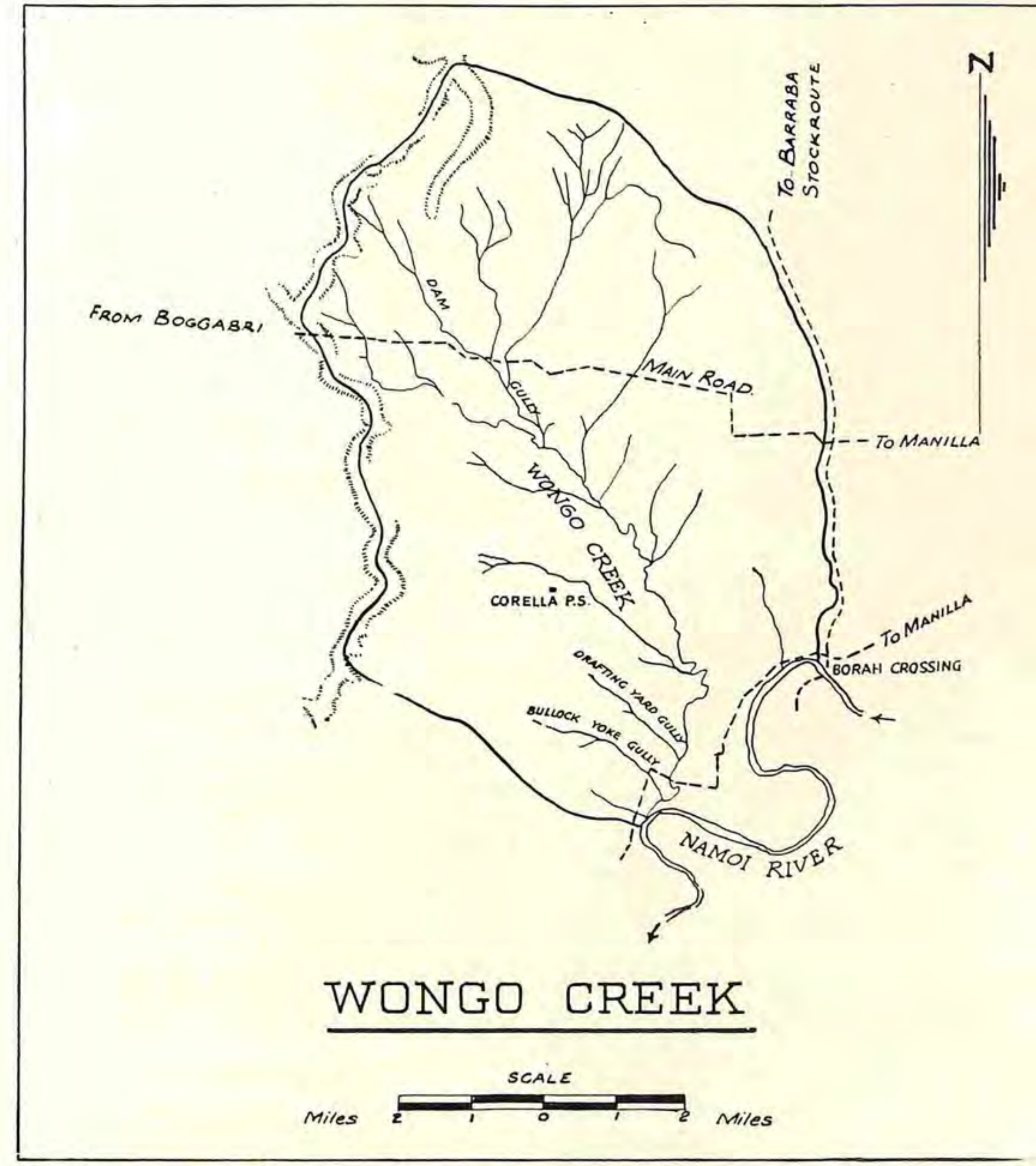


Fig. 2.

purpose of these dams is to take the full impact of a severe storm, say 250 points in half an hour, then discharge a proportion of the storm waters through the outlet provided (see Fig. 4), over a period of time, ranging from 12 to 24 hours, at a safe rate. A silt dam operating in this manner prevents the watercourse from running 5 to 6 feet deep over a very short period, but causes the watercourse to trickle for twenty-four hours after the storm has passed. This allows the banks and beds of the watercourse to stabilise. A series of such dams in conjunction with other works and land-use changes, must reduce the peak flows in Wongo Creek, thus reducing flooding and inundation at lower levels. Once having reduced the flows in the tributaries to innocuous levels, work can proceed at the lower levels with safety, with no possibility of these creeks changing their course.

2. *In areas with slopes from 15 per cent. to 25 per cent.*

The control methods in these areas are heavy earthworks such as absorption and diversion banks in association with light stocking and rabbit control. Stock carried are being steadily changed from sheep to cattle.

3. *In areas with slopes from 8 per cent. to 15 per cent.*

These rich intermediate slopes are generally the main grazing areas of a holding and consequently show every sign of erosion from sheet to deep gully erosion. The normal methods of control in these areas are a combination of absorption banks with silt traps, pasture furrowing and gully control. Coincidental with these mechanical means of control, land management is playing an important part in reclaiming these lands.

4. *In areas with slopes from 0 to 8 per cent.*

These gentle slopes represent the majority of the cultivation lands of the whole catchment. These slopes have soils that are deep and fertile with a high potential for production; consequently, they receive very little rest from continuous cultivation. The over-cultivation results in deep and frequent gullies with an overall top soil loss of at least 8 inches. The treatment of these cultivation areas follows the conventional pattern of waterways, graded banks with large holding dams for small irrigation projects and water disposal, in conjunction with modified cropping practices. The importance of handling these lands with care and consideration cannot be too strongly stressed.

At this point I should indicate that the above plan of control represents the basic classification of work being undertaken on these various land classes. It can be understood that not all types of work would be encountered on every holding.

B. Selection of Key Properties.

In selecting these properties for immediate treatment certain points had to be considered and certain questions arose; these were:—

Will this work control an important section of Wongo Creek and its tributaries?

To what extent will this work benefit landholders situated at lower levels?

To what extent will this work restore production on more or less unproductive lands?

How much co-operation will we receive from the landholder concerned?

Will this work demonstrate all the principles of mechanical means of control?

Will this work lend itself to extension at a future date?

Having answered these questions in respect of certain properties pre-selected from a topographical map of the area, five properties stood out. These holdings were —"Marathon", "Calool", "Glenbrae", "Corella" and "Sunnyside." The first three properties mentioned control most of the northern watershed, with "Marathon" embracing the most critical section of steep land. It is on "Marathon" that the majority of silt dams are at present located.

C. Operations.

Having selected these holdings the next step was the installation of major demonstrations on three of these properties. They were—"Calool", "Corella" and "Sunnyside",

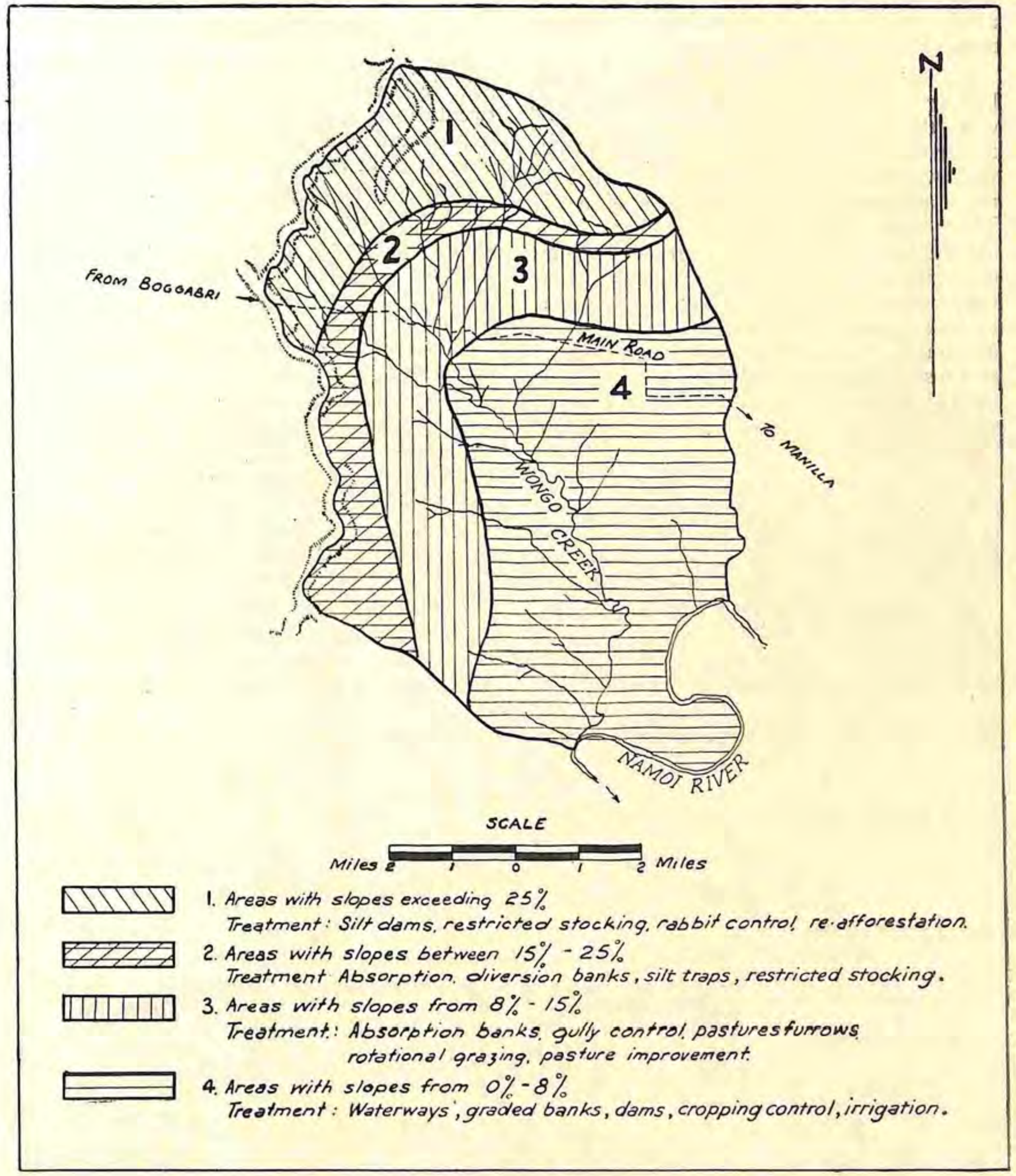


Fig. 3.

with "Glenbrae" to be commenced shortly. "Marathon", due to the tremendous enthusiasm and prior work of Mr. R. Heywood, the owner, was handled by means of a Minor Demonstration, with extension under the Plant Hire Scheme.

The next step in our operations was the linking up of the Major Demonstrations with the Minor Demonstrations. In the design of the major demonstrations provision was made to handle water disposal from adjacent properties in case of need. There are several instances where landholders have more or less integrated schemes of control. These minor demonstrations were extended under the Plant Hire Scheme to link up with one another. There are, of course, works which appear unrelated at present, but it is only a matter of time until they are linked up with future works which have already been planned as part of the overall scheme.

There are one or two operations that do not take place in the field but are none the less important. One of these is the plotting of all work, as it is completed, on a master plan. This plan consists of a large scale topographical survey plan of Wongo Creek Catchment. All planned work is correlated with all existing work. This operation not only makes the planning of the field details of control measures easier but gives a graphic illustration of the position in this area and our progress.

RESULTS ACHIEVED.

The 33,000 acres of Wongo Creek are held by twenty-four landholders; of these twenty-four properties, eleven have been treated and nine are awaiting treatment as soon as plant becomes available (Fig. 5).

Only four landholders have not yet voluntarily offered to co-operate. In twenty months of work, 4,190 acres of the most severely damaged land have been treated by mechanical measures on the eleven properties. Land-use measures designed to conserve soil have been adopted over extensive areas.

Of the proposed fifty silt dams, one has been completed, four others commenced and nine more located and the sites surveyed. The rate of construction of these dams is governed firstly by the availability of materials and secondly by climatic conditions. Work between December to March is out of question due to the frequency of high intensity rain storms.

At this stage a few observations on the effectiveness of the work on some locations may be of interest. Space does not

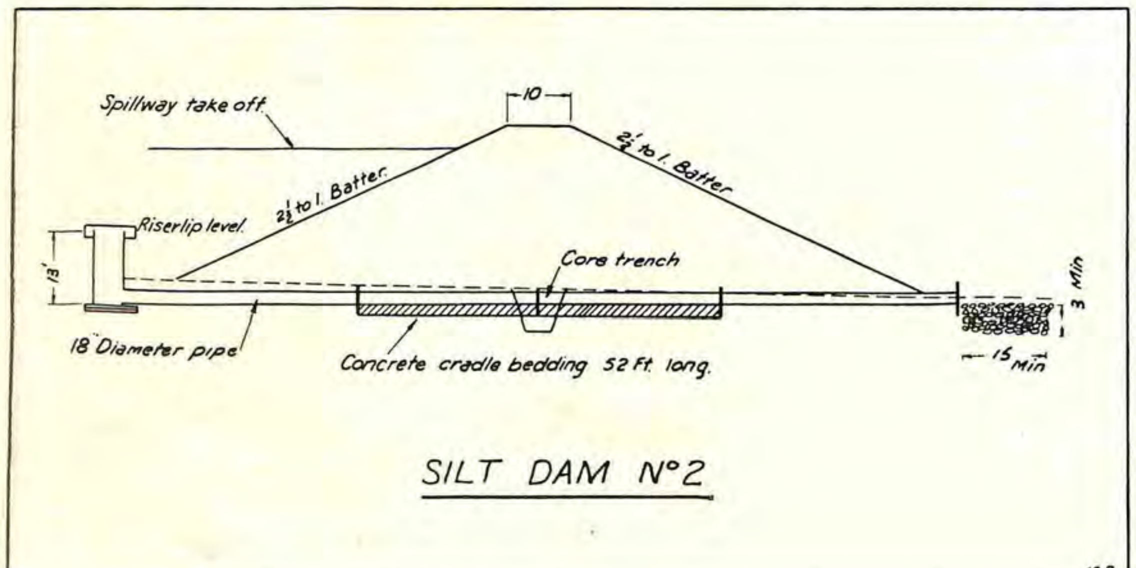


Fig. 4.

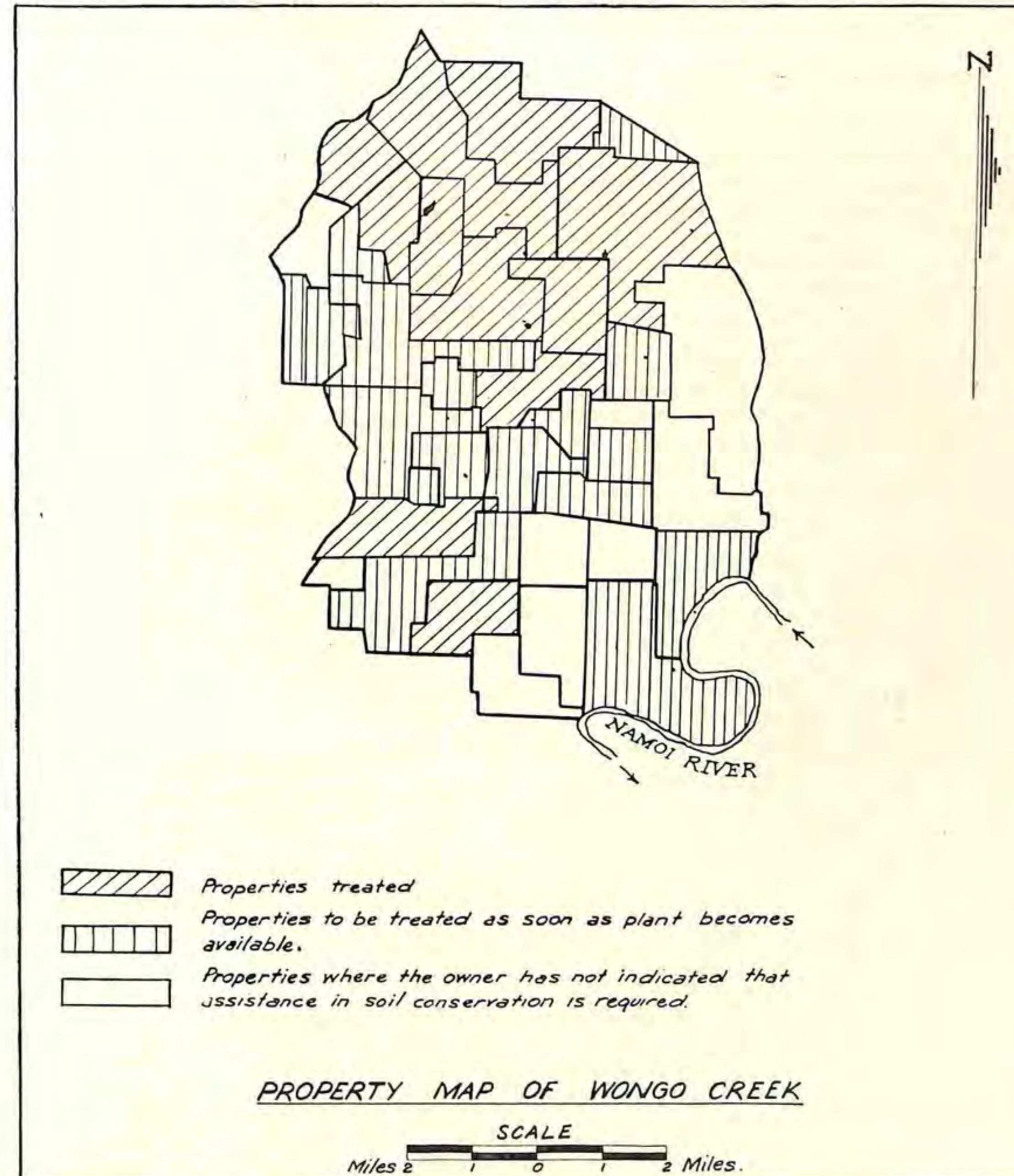


Fig. 5.

permit a detailed description of the four major demonstrations, the seven minor demonstrations and the eleven Plant Hire Schemes. Only brief notes on some of these can be given:—

1. *"Marathon"*—

Mr. R. Heywood is probably the pioneer in soil conservation practices in this district; he commenced work on his own as far back as 1937. He has in recent times, with the co-operation of the Service, completed quite an extensive project. Mr. Heywood intends in time to treat the whole of his 4,000 acre property. Some 800 acres were treated under the Plant Hire Scheme and of this total acreage 100 acres were excessively eroded, steep hillsides being denuded of all vegetation and serrated with deep frequent gullies. These 100 acres formed the catchment of a particularly fast-flowing creek. Forty to 50 points of rain in twenty to thirty minutes were sufficient to run this creek from 3 to 6 feet deep. This area was treated with heavy earthworks, mostly absorption banks and silt traps. These banks ranged from 4 feet to 6 feet and were located on approximately 6 feet to 10 feet vertical interval. The silt traps ranged in capacity from 750 to 2,500 cubic yards. Overflows of the banks were located usually on to stony outcrops of the main creek. Shortly after completion, this work was fully tested by a downpour of 217 points of rain in fifteen minutes. No appreciable run-off from this area was recorded, the creek being crossable on foot with the water barely reaching boot-top height. The weed growth in the creek bed was not disturbed. As a contrast an adjacent creek with a similar catchment, which had not been treated, was uncrossable even on horseback for a short period. This storm occurred on the 7th January, 1949; since that date there has been a permanent spring in the creek with the treated watershed providing quite an appreciable continuous stream under existing rainfall conditions.

As an important part of the reclamation programme, Mr. Heywood has fenced the area off and excluded all stock for the time being and a very noticeable amount of revegetation is already taking place.

2. *"Calool"*—

Very much the same thing can be reported about "Calool" demonstration, where 210 acres of hilly catchment were treated; in addition 70 chains of 60 feet waterway were constructed to provide safe water disposal for 140 acres of graded banks. "Calool" demonstration is a co-operative effort between Messrs. J. Armstrong of "Calool" and T. W. Abberfield of "Alexander Park", and the Soil Conservation Service. These landholders are extending the work under the Plant Hire Scheme.

3. *"Woodstock."*

This property is owned by Mr. W. R. Bryan and is an instance of practically complete control of the whole area of 655 acres. Mr. Bryan had a serious problem, where even the access to his homestead was in danger. After a preliminary consultation, when future land use was discussed fully, a scheme of control was decided upon and implemented with a minor demonstration plus extension under plant hire. The minor demonstration provided three waterways to carry the discharge from graded banks. Under the plant hire scheme absorption banks were constructed. Gully control is yet to be completed as soon as the waterways become operative.

PLANT AVAILABLE.

During the last twenty months two tractor units and dozers with associate equipment such as scoops, rippers and graders, have been employed. Two similar units have been operating on an adjacent creek catchment; these will be diverted later to Wongo Creek in order to intensify our efforts in the control of this catchment.

CONCLUSION.

In conclusion, I should like to thank all the landholders with whom we have been working, for their enthusiastic support and most helpful advice on local conditions and for some very good suggestions in connection with this work.

Lastly, I should like to take this opportunity to express my thanks to the survey staff for their invaluable assistance on many occasions.

MINOR FLOOD AND EROSION CONTROL DAMS

BY

A. W. MILLER, F.I.S., Senior Surveyor.

WONGO Creek, draining into the storage area of Keepit Dam, has some unique features calling for specialised methods of erosion control. The bulk of the 33,000 acre catchment is gently sloping arable or grassland on which the normal mechanical measures are quite successful, but around the perimeter is an area of steeper country where such methods are impossible. Run-off from this limited area of mountain is concentrated into a number of well-defined streams, and as is usual under these conditions deep active gullies are found as a continuation of the stream course through the flatter agricultural land below. Even when run-off from the 30,000 acres of gentler country is completely controlled, the discharge from the mountain streams will still be sufficient to maintain the principal gullies and the main branches in an actively eroding state. The obvious answer is to control the run-off from the mountain country (and that from the agricultural land as well, of course) when the whole course of the creek will be stabilised and its silt load, at present a source of serious concern, will be reduced to negligible proportions.

MECHANISM OF GULLY EROSION.

The mechanism of gully erosion is highly complex; but with some danger of over-simplification it may be subdivided into the three main processes of waterfall or head-ward erosion, vertical corrasion or deepening, and horizontal corrasion, or widening.

Waterfall erosion results in the upstream migration of a gully along the valley floor and is responsible for large soil movements. When the flow is small and the bed well grassed small waterfalls frequently migrate upstream with a distinct pond between them, and much of the soil is deposited again immediately below the pond. In an active gully, on the other hand, the soil is carried downstream for large distances suspended in the flowing water.

Vertical corrasion, as its name implies, is the process by which the gully bed, below the overfall, is deepened. In many active gullies it appears to play a minor part, for it will be observed that the depth frequently remains constant for long distances.

For some distance below the overfall the gully is frequently very narrow, but the process of horizontal corrasion soon commences its widening process and is responsible for colossal soil movements. The flowing water, deflected perhaps by some minor irregularity, impinges on the vertical wall of the gully, exavating a small cave at bed level. The superposed soil is thus left unsupported till it cracks under its own weight and falls to the gully floor where it may form a temporary dam deflecting the course of the stream to the other side, where the process is repeated. This undercutting and the fallen debris are shown quite distinctly in Fig. 1, a photo of one of the many gullied branches of this creek. In the first large fresh this obstruction will be swept away, but the process continues till the gully, originally a few feet across, has widened out to half a chain or even more. In a large gully system, which has been active for many years, it will sometimes be noticed that in the lower reaches the stream, now spread over a much wider channel, has been slowed down to such an extent that it can no longer transport the coarser particles, and a process of deposition sets in, and the gully bed becomes much shallower and may even fill up entirely.

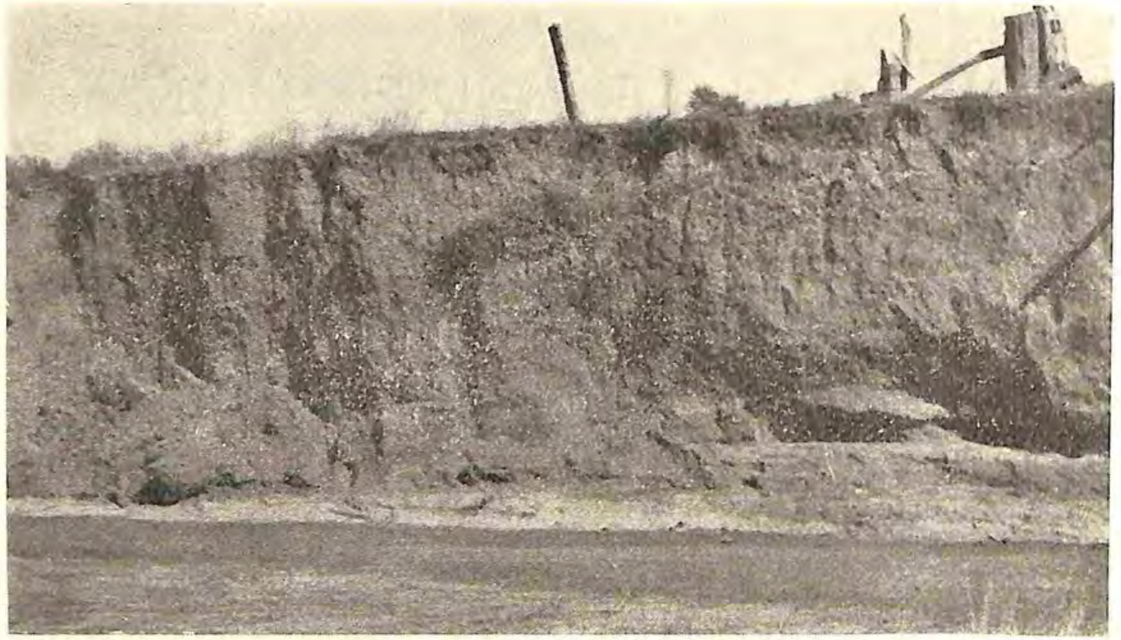


Fig. 1.—Showing undercutting and collapse of a section of gully bank.

ADVANTAGES OF FLOOD CONTROL.

With these facts in mind it is obvious that if the stream flow from the mountain country be cut off there is every possibility that the gully below can be stabilised and any soil falling in from the sides, instead of being carried downstream and into the Keepit storage, will remain in position to build up the level of the gully floor and nourish protective vegetation. Moreover, with the flow cut off or reduced to negligible proportions, it may become feasible to break down and fill in the gully through the agricultural land, making effective provision for the occasional flow with waterways, graded banks, farm ponds and the like. While the mountain catchment remains uncontrolled it would be impossible to attempt any such work on the major gully system below, and a considerable element of possible instability remains even in the control work on the inter-gullied area.

Also, but by no means the least important consideration, with discharges reduced to negligible proportions, fences will no longer be washed away with every rain, and it will be possible to maintain them as permanent rabbit-proof barriers.

METHOD OF CONTROL PROPOSED.

It was felt that something might be accomplished by the construction of a particular type of detention dam, whose function was to temporarily impound floor waters from the mountain catchment and discharge them slowly after the rain had passed, the intention being that the dam should always be substantially empty, except when flow actually occurred in the creek. This article is intended to describe the probable behaviour of one branch creek after the dam has been built, in order that a test of its probable utility may be made before construction commences.

The dam proposed has an earth wall through the bottom of which runs a concrete pipe. If the pipe is unobstructed at its upper end most flows would go straight through in undiminished quantity, except for the exceptional storm when the rate of discharge will be greater than the capacity of the pipe. If a small pipe were used water would be impounded for even moderate storms, but the head of water so built up would force it through under high pressure and there would be a real danger of active cutting at

the outlet, undermining the wall. A compromise may be reached by using a large pipe, able to withstand the weight of earth above, and allowing water to enter it through a small opening at the upstream end, thus ensuring that flow is by gravity only and not under hydrostatic head. The type of inlet structure used in the first dam of the type to be built is shown in Fig. 2.

In this region the stream beds are highly porous and it is probable that even without the pipe the dams would empty by seepage;

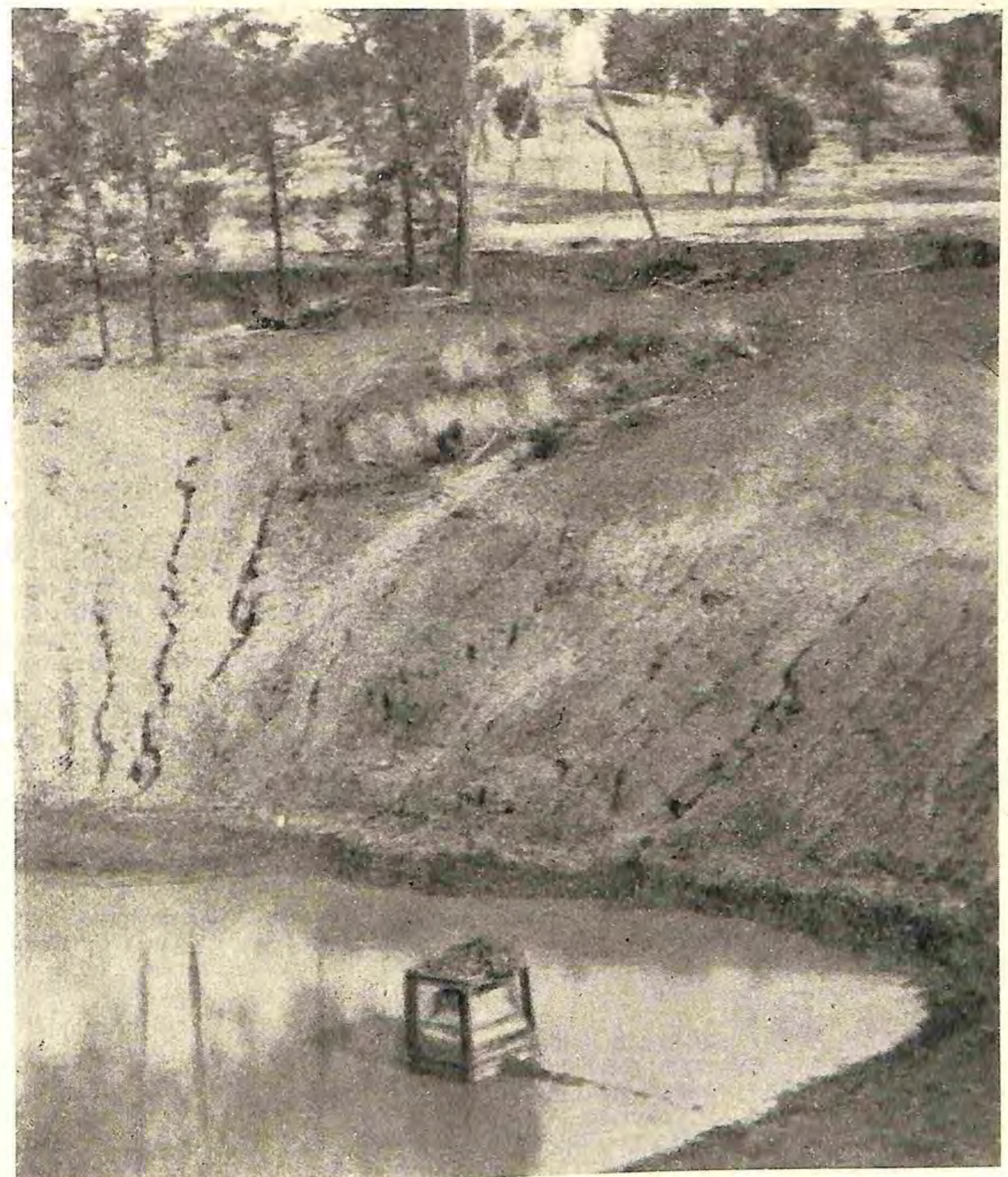


Fig. 2.—Showing inlet structure for emptying dam.

but there are two objections to depending entirely on this method. Experience has shown that after filling a few times such dams frequently seal and then hold water like a bottle. It is essential for their success that they should be substantially empty whenever a heavy flow occurs. Also with the dam emptying through a pipe the finer soil particles held in suspension will be carried through the dam to fertilise the gully floor downstream and to decrease the rate of siltation of the dam.

SILTATION.

The rate of siltation is an entirely unknown factor, but its effect in decreasing the storage available for flood control is most important. With a dam which is usually empty the problem of removing silt if, and when, the deposit becomes at all large, is much simplified. In passing, it may also be remarked that with the low flows to be permitted through the dam, little, if any, of the silt will be carried far, but practically all will be deposited within the confines of the gully downstream.

DEPTH STORAGE RELATIONSHIP.

In figure 3 is shown the relationship between depth of water in the dam and the amount of storage, expressed, not in acre-feet or cubic yards, as is usually done, but as depth of run-off from the catchment area of 105 acres. With a spillway at R.L. 1743 storage is the equivalent of 0.50 inches of run-off. It is obvious that all storms giving a total run-off less than this will be completely controlled, the maximum rate of discharge below the dam being dependent entirely on the characteristics of the inlet structure. How often may storms giving a run-off in excess of half an inch be expected to occur?

ESTIMATION OF TOTAL RUN-OFF FROM STORMS.

Data on run-off from catchments of this order just does not exist, and probabilities must be deduced from whatever other scanty information is available. At Cowra the Soil Conservation Service has been conducting a soil loss and run-off experiment for which six years of records are available. The plots are 1/40 acre in area, on a slope of 8 per cent. under various agricultural treatments. There have been eight separate occasions on which one or more of these plots gave a run-off in excess of 0.50 inches, the maximum ever recorded being 1.27 inches from a rain of 2.86 inches extending over three days. If this provides any guide, and I believe it does, the flatter slope being compensated by the smaller area, a run-off in excess of 0.50 inches from the one rain period may be expected on the average about once a year.

The Water Conservation and Irrigation Commission has taken stream flow measurements on the Manilla and Namoi Rivers whose catchments resemble that of the creek under consideration, and which are subject to a similar rainfall regime. From these flow records the discharges may be found, and expressed as inches of run-off from the catchment. From an inspection of the records it was apparent that in the vast majority of cases when heavy floods occurred in the Namoi or Manilla Rivers, the high stage lasted only a short time, and that almost all the run-off from flood causing rains passed down in two or three days. On the fourth day of flood the flow had usually dropped back to a very small proportion of the peak, and it was felt that the total flow for the heaviest three days was, if anything, an over-estimation of the total run-off from storms of a duration likely to tax the capacity of the structures in mind for Wongo Creek. In Tables I and II are listed in order of magnitude all the three-day discharges in excess of 0.50 inches run-off for the Namoi and Manilla Rivers respectively.

TABLE I.

Three-day discharges as inches of run-off of the Namoi River at North Cuerindi. Catchment area 970 square miles. Length of record 31 years 1916-1946.

1.449 inches	0.853 inches
1.186 ,,	0.847 ,,
1.171 ,,	0.776 ,,
1.095 ,,	0.625 ,,
1.062 ,,	0.602 ,,
1.004 ,,	0.518 ,,
0.863 ,,	0.515 ,,

TABLE II.

Three-day discharges as inches of run-off of the Manilla River at Wimbourne. Catchment area 770 square miles. Length of record 11 years 1937-1947.

1.068 inches
0.494 ,,
0.431 ,,

From 1936 to 1946 there were no three-day discharges from the Namoi aggregating half-an-inch of run-off from the catchment, and only one from the Manilla River. Apparently, half-an-inch of run-off can be expected on the average once in two years and about 1.17 inches once in ten years. The Cowra figures on a much smaller area (and flatter slope) are thus not irreconcilable with those from the Namoi, where the catchment area is very much larger, and I consider it may be confidently asserted that a dam with a capacity as great as half-an-inch of run-off from the catchment will not be filled by a single storm more than once (on the average) in two years. With an outlet capable of emptying the dam inside forty-eight hours it is unlikely to overflow more frequently than this. Such a capacity would thus be adequate for the purpose in mind, though further storage, if it may be readily obtained, is an additional safeguard.

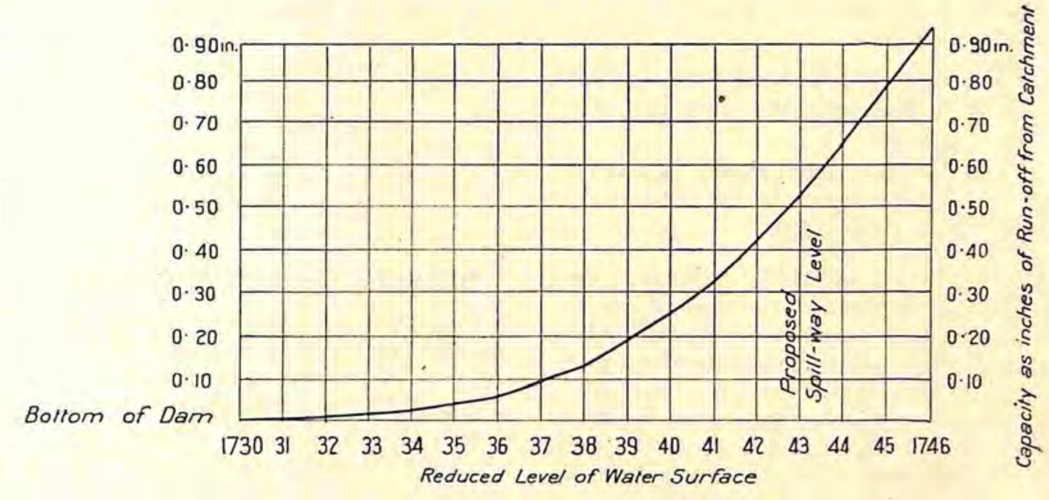


Fig. 3

Showing Variation of Capacity with depth of Water.

DEDUCTION OF FLOOD HYDROGRAPH.

What will happen in the more severe storms which are capable of filling the storage and causing an overflow? To protect the structure in such cases an emergency spillway must be provided. In order to study the probable behaviour of the dam and emergency spillway under these conditions it is necessary to determine the shape of the hydrograph, *i.e.*, the manner in which the rate of flow varies with the time. Before this may be done a number of assumptions must be made, some to simplify the problem and others to make it determinate. The resulting hydrograph will then be one appropriate to the purely hypothetical model of storm run-off and catchment. Although hypothetical it will not be unrealistic, and the conclusions to be drawn from it may be very valuable for design.

For the catchment under study the time of concentration, itself a largely hypothetical figure, but supposed to represent the time it takes water to flow from the farthest point of the catchment to the gauging station may be computed from the Bransby Williams formula:

$$T = \frac{0{\cdot}88\,L}{M^{\frac{1}{10}}\quad H^{\frac{1}{5}}}$$

where T is the time of concentration in hours.

L is the length from source to site.

M is the catchment area in square miles.

H is the average slope of the stream from source to site expressed as a percentage.

By considering individual tributaries, and using the same formula, the time of concentration for these may also be found, and by making certain plausible assumptions as to velocity of flow in the stream it is possible to divide the whole drainage basin into sub-units whose boundaries represent the limit from which flow will reach the gauging station in 5 minutes, 10 minutes, 30 minutes, with the furthest point of the catchment at the time of concentration, 35 minutes. This sub-division is shown in Figure 4, a plan of the catchment. If, now, the hypothetical storm be subdivided into intervals of 5 minutes, during which the rain (or rather unit rate of run-off) is supposed to be of constant intensity, at the end of the first five minutes the area below the 5-minute isopleth will be contributing run-off at a rate given by the product of the area by the rate of rainfall by the appropriate co-efficient. At the end of the second 5-minute period the rate of discharge will be that from area A appropriate to the second 5 minutes of storm together with that from area B between the 5 and 10-minute isopleths appropriate to the first 5 minutes. At the end of 35 minutes the total discharge will be the sum of the discharges from the seven areas.

G (first 5 minutes) + F (second 5 minutes) + E (third 5 minutes) + . . . + B (sixth 5 minutes) + A (seventh 5 minutes).

It remains to construct a model storm. From the examination of numerous automatic rain gauge charts I have formed the opinion that in general, though there may be some initial light rain, the heaviest rain often falls in the earliest part of the storm. Accordingly, the model decided on is one giving a once in ten years' fall for all durations from five minutes to twenty-four hours, giving 0.42 inches in the first five minutes, 0.19 in the second, 0.14 in the third, and so on with a total of 3.47 inches in twenty-four hours, as shown in Figs. 9.3, 9.8, and 9.10 of Section 2 of the report of the Stormwater Standards Committee of the Institute of Engineers, Australia(1). Appropriate coefficients of run-off may also be estimated for individual areas between the isopleths as shown in Fig. 4, taking account of the slope and nature of soil and cover.

DEDUCTIONS FROM HYDROGRAPH.

From the hydrograph determined in this manner (*vide* Fig. 5) it is seen that although the time of concentration is thirty-five minutes, maximum discharge occurs at the end of only twenty minutes. This is entirely the result of the effect of the particular storm model, in which a high initial intensity falls off rapidly with increasing time, upon the particular catchment. It is interesting to note in this respect that the Stormwater Standards Committee reports that the Bransby Williams formula gives times of concentration which are unduly long. Also using the standard Q = CIA formula, with a mean value for C and a value for I appropriate to a once in ten years storm of thirty-five minutes, there is a maximum discharge of 100 cusecs which may be compared with the maximum of 122 cusecs now found after twenty minutes. The two values are not so markedly discordant as to discredit the method of analysis followed.

If the streamflow should follow this pattern, a once in ten years storm would fill a dam with a capacity of half an inch of run-off in a little over forty minutes. But by then the rate of inflow into the dam has decreased to 55 cubic feet per second and is

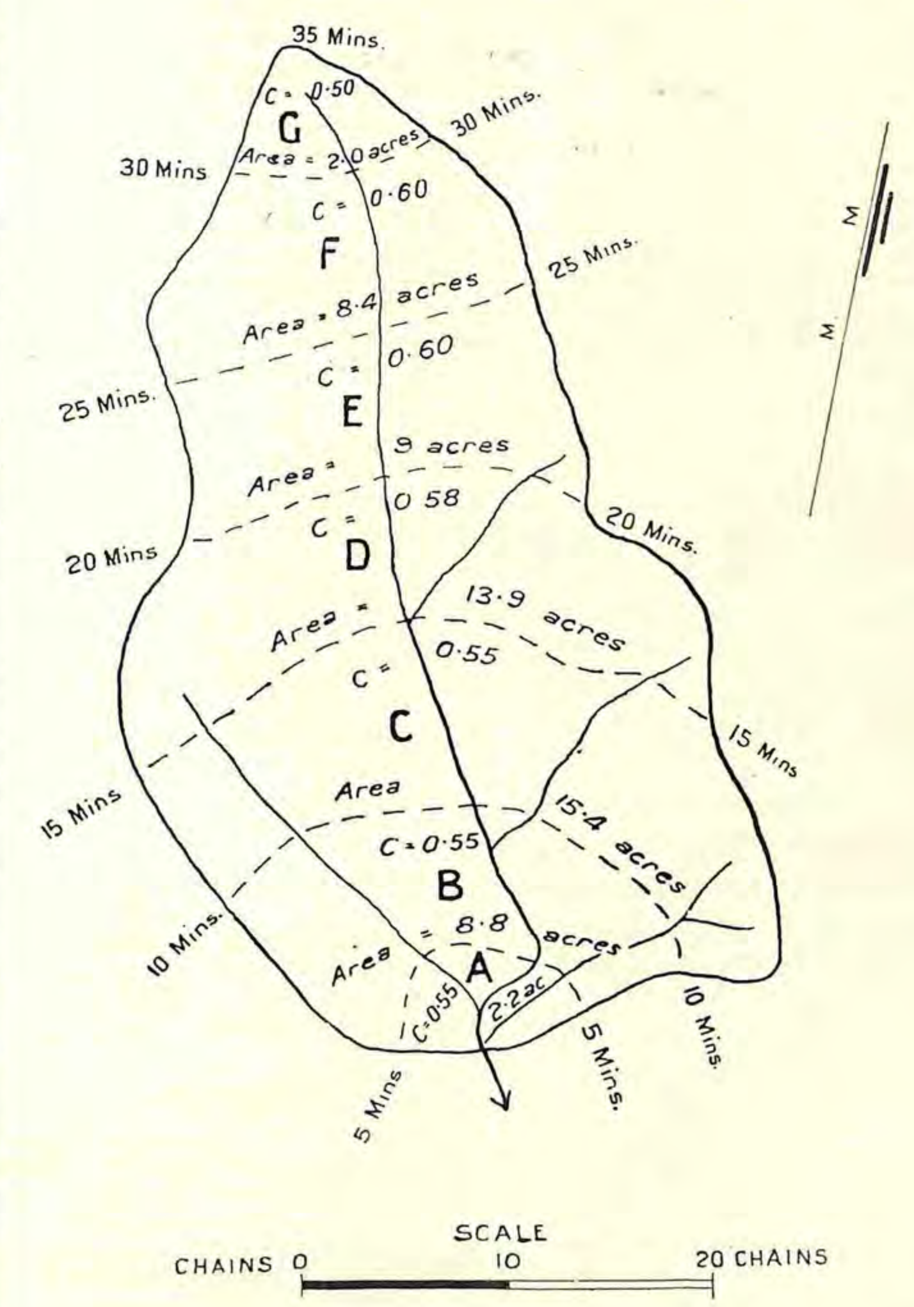
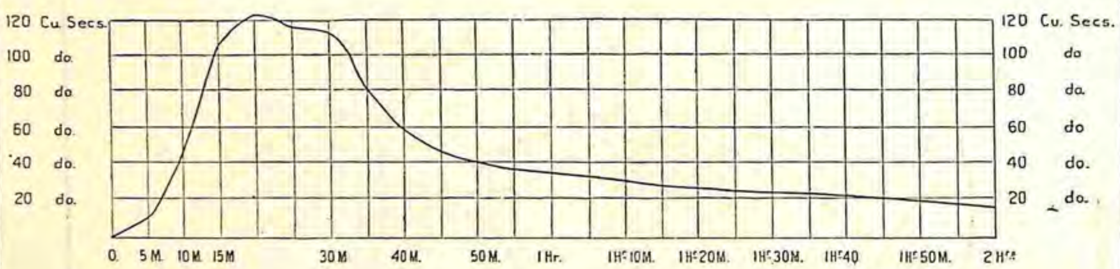


Fig. 4

falling steadily. Moreover, an appreciable rate of flow down the emergency spillway can only occur with a substantial depth in the channel and an additional entrance head, which is dependent on the design of the emergency spillway, but which is a not inconsiderable item. For instance, in this particular case a surcharge of one foot above spillway level which could readily and safely be secured by proper design would temporarily impound an additional 1.2 acre-feet, the equivalent of 0.13 inches of run-off. By the time this amount has been stored the maximum discharge will be only 36 cusecs, so that he dam has reduced the peak flow down the creek to only 30 per cent. of what it would be if the creek were uncontrolled. Even for the record breaker, which may be expected to occur only once in a thousand years, it appears that a structure such as this would still be able to reduce the peak flow slightly. It would, under those conditions, take about thirty minutes to fill and the reduction in peak flow would be only 10 per cent. but it is interesting to note that some reduction would be effected.

These investigations are largely hypothetical, a fact which will detract from their value in the eyes of the unthinking. Any rational person, however, who knows how difficult it is to estimate the amount of rain likely to fall, even when storm clouds are towering all around, who has scurried for home because he feared the creek would rise when only two or three big drops fell, or who has taken the risk that the storm would go round the other way, and ended up spending the night in town, will be more charitable. Opinions as to the probable behaviour of a creek can be nothing but opinions. Based, as this study has been, on clearly stated assumptions, and a logical development, they are open to critical examination and amendment. It must be admitted, however, that there is very sound reason to believe that structures such as that proposed can and will exert a profound influence in mitigating the erosion hazard in the gullies downstream and thus assisting materially in the stabilisation of areas much greater than the catchments above them.



Hydrograph of Hypothetical once in 10 Years Storm

Fig. 5

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ORCHARD PLANTING FOR THE PREVENTION AND CONTROL OF EROSION

BY

T. P. Taylor, H.D.A., District Soil Conservationist.

SOIL erosion is a problem that has been recognised as one of the most serious with which most fruit growers on sloping lands have to contend. Fruit growing, in the absence of irrigation facilities, requires adequate and reliable rainfall, and so the main fruit growing areas are found in the better rainfall regions of the State, which are along the coast, tablelands and slopes.

The country here is mainly undulating to hilly and on this account liable to erosion. Owing to the unreliable nature of the rainfall and where irrigation is not possible it has been necessary in many districts, such as Young and Bathurst, to adopt clean cultivation methods in order to conserve sufficient moisture to produce payable crops. Clean cultivation is practised for the destruction of spring and summer weed growth and the soil is left in a loose, open condition.

On these sloping lands it was inevitable that erosion would sooner or later take place if this practice was continued. Consequently, erosion has now become a serious factor in many of the fruit growing districts in this State.

Efforts to control erosion on established orchards in the better rainfall districts by abandoning or modifying clean cultivation methods and allowing some vegetation, in the form of pastures or cover crops, between the tree rows, have been successful in many cases. The construction of graded banks in established orchards, which is often difficult and requires the removal of some trees, has also given good results in the control of erosion and has been adopted in many districts.

Whilst it is true that in some cases erosion can be prevented by judicious cultivation and the use of some form of vegetation, it has become apparent that the best answer to the problem of erosion prevention and control in the majority of cases lies in the adoption of a system of contour planting and banking. Unless an orchard is contour planted in undulating country, or is planted on uniform slopes, little success is achieved in cultivating "across the slope." In practice, it is generally found that "across the slope" means cultivating up and down the "least slope" and in the majority of cases there is sufficient fall down this slope to result in quite a lot of erosion, especially in the drier inland districts, where it is essential to undertake frequent cultivations to conserve moisture.

CONTOUR PLANTING.

Contour planting, although comparatively new in this country, has been undertaken in other parts of the world for many years. In some cases the sole object was the prevention of erosion and in others to enable irrigation to be undertaken by running the water along the tree rows. It should be remembered, however, that there are many forms of contour planting for the control and prevention of erosion and that all call for special skill and experience in levelling before they can be undertaken. District and soil conditions, including slopes, have also to be taken into consideration and all orchardists are advised to seek expert advice and assistance before undertaking contour plantings.

Graded banks were the first mechanical measures introduced to prevent and control erosion on sloping arable lands. By constructing banks at regular intervals across the slope, run-off was reduced and erosion

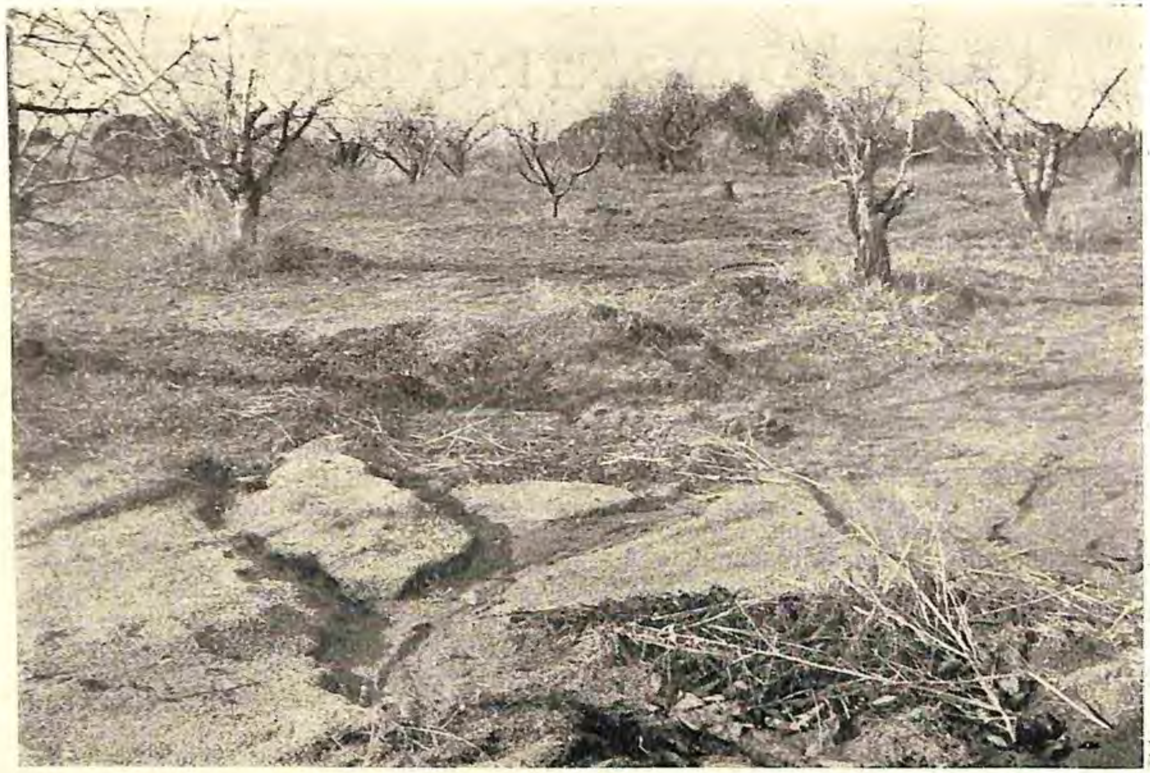


Fig. 1.—Orchard erosion. Contour planting and cultivation will prevent this occurring.

prevented by carrying the surplus water off the land at a reduced velocity which did not cause erosion. After these measures had proved successful on arable lands, they were introduced to orchard lands. It was often very difficult to construct banks in established orchards, and many trees had to be sacrificed to enable the banks to be made. On new areas these difficulties did not exist and the banks were constructed before the trees were planted. In all cases it was found that, provided the banks had been properly designed, constructed and maintained, and the surplus water safely disposed of, the system worked quite satisfactorily and erosion was prevented, or if present, brought under control.

Officers of the Soil Conservation Service will assist, without charge to the grower, in making surveys and laying out areas for contour planting and graded banking.

Square plantings were generally made when contour or graded banks were first constructed, but this gradually gave way to a modified form of planting in which the tree rows were parallel to the banks and were in line up and down the slope. Finally this alignment up and down slope has also been abandoned.

This system has become known as "contour planting" despite the fact that the tree-rows are often on a grade similar to that of the banks. Strictly speaking, contour-planting means planting on the level, *i.e.*, that the tree rows are level from one end to the other. The term "contour planting" has, however, been used when the banks have been constructed with a grade and the tree rows are parallel to the banks. When the tree rows have a fall the term "graded planting" would be better to indicate that this system has been used.

LARGE OR SMALL BANKS?

The construction of large contour or graded banks in orchards has some disadvantages, the main ones being the large amount of surface soil required to make the bank, the need for special machinery and the poor control and distribution of water. With large banks so many tree rows apart, run-off is only partially checked and often causes minor erosion between the banks, before it collects in the banks and is carried off or absorbed by the soil. This gives a greater amount of water to areas immediately adjoining the bank and less to those areas away from the bank.

The construction of small banks every tree row gives a much better distribution of water and makes the work much easier and more effective.

Of course, it is realised that in some established orchards, where erosion has already taken place, it may be practically impossible to construct small banks along every tree row and that the construction of large banks at intervals is the only means of solving the problem. In such cases large banks should be made and the erosion brought under control in this manner.

However, it was soon found that banks were not sufficient by themselves to control erosion, especially where bare cultivation and up-and-down-the-slope working, which meant crossing the banks, was continued, as erosion took place between the banks and siltation and overtopping occurred along them.

This difficulty was considerably reduced by contour cultivation and the discontinuance of working up and down the slope. It was finally overcome altogether, by planting the tree rows parallel to the banks, and not having them in line up and down the slope.

NEED FOR FUTURE CONTOUR PLANTING.

It is strongly recommended that all future planting of orchards and vineyards on undulating country should be on a system of contour planting to prevent erosion taking place. The fact that no erosion is in evidence now, or the soil appears to be a non-erodible type, should be disregarded entirely; it is well known that the various cultivation methods and traffic due to pruning, spraying, picking, and carting, that are necessary in all orchards, even though associated with modern ideas of cover cropping and minimum cultivation, are all conducive to erosion; it is a wise precaution to take the little extra time and trouble associated with contour planting to safeguard the orchard and prevent erosion occurring, rather than to wait and correct it in future. An orchard or vineyard is much different to an annual crop and should be regarded as something more or less permanent, in that it will last for many years and amply repay the extra care and attention given to its establishment.

WATER DISPOSAL.

In all forms of mechanical work, for the control or prevention of erosion, first consideration must be given to the provision of a satisfactory water disposal area. Very little is achieved if one area is protected from erosion at the expense of another. Wherever water is diverted, it is essential that it be diverted onto an area that will not erode. Satisfactory areas are adjoining pasture lands, where the water can be spread and absorbed, or special waterways to take the water into natural stable drainage lines. It is essential to see that waterways are protected by adequate vegetation, such as sown pasture, capable of carrying the flow. These should not be cultivated or ploughed but left as permanent well-grassed areas. Constructed waterways have level cross-sections, and are made wide enough to enable the water to spread and thereby lose velocity, and of sufficient capacity to carry the expected run-off from the area treated. Regular top-dressings with superphosphate are required to maintain a good protective sward of grasses and clovers on these areas. Natural drainage hollows make excellent waterways, provided they have not already been eroded, and it is recommended that these be reserved for this purpose wherever possible. It will also be found, in many areas, that the flow from the waterway can be effectively stored in a small dam, for stock or domestic use, and the building of such a dam considerably helps in any scheme of erosion control.

Much erosion was caused in the early days of contouring by allowing the flow from constructed banks to spill out onto unprepared headlands, lanes, etc., and in many cases considerable damage was done.

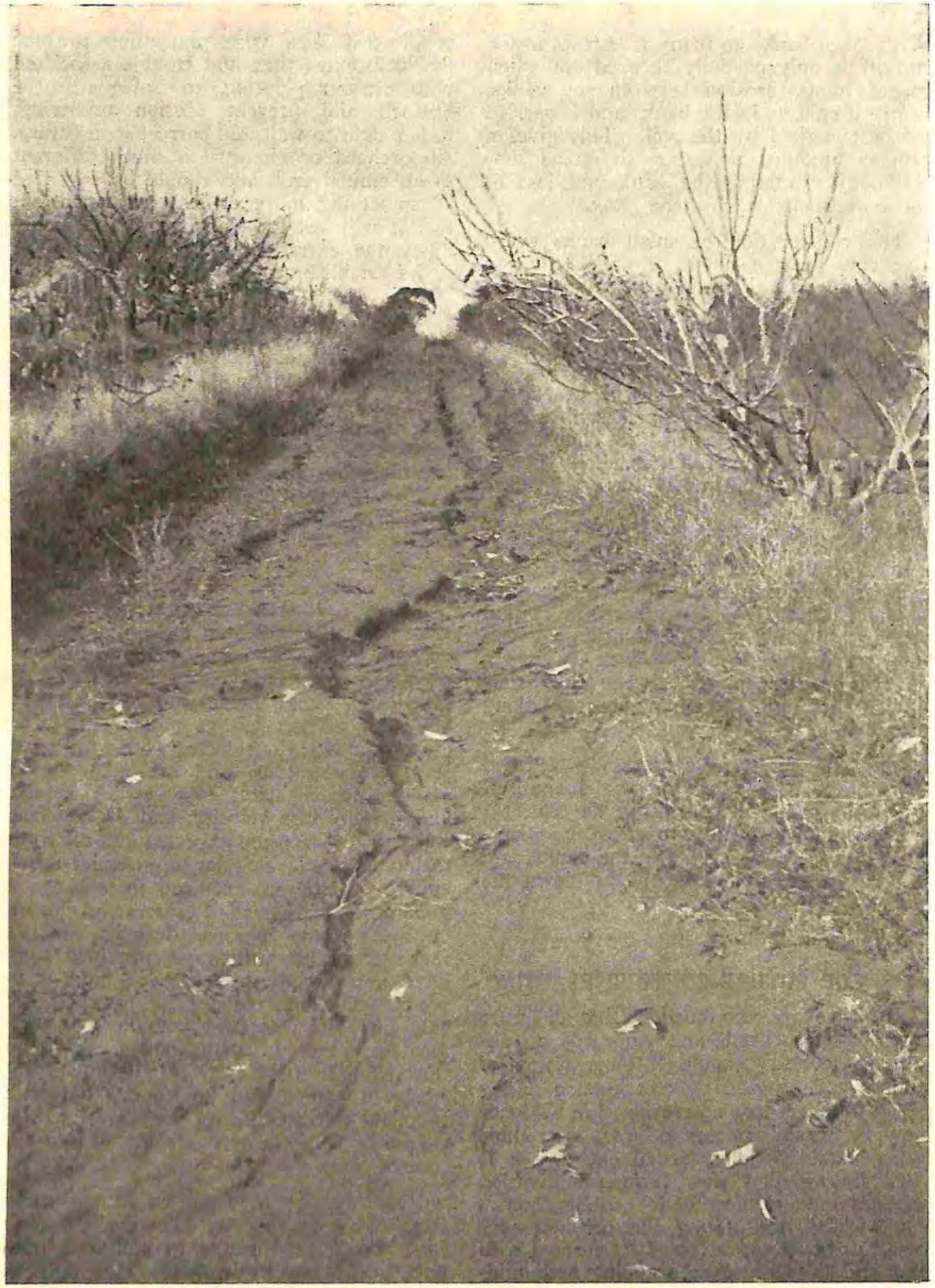


Fig. 2.—Erosion taking place, although this orchard is worked across the main slope and terraced.

Fig. 3.—Erosion such as this can be prevented and controlled by contour planting and cultivation.

It is now recognised that suitable disposal areas are essential if any system of banking is to be successful.

CONTOURING TO SUIT DISTRICT CONDITIONS.

From the knowledge already acquired satisfactory methods of planting orchards on the contour have been evolved which will be found quite suitable for the control of erosion and at the same time overcome the objections to earlier methods.

In modern contour planting, the trees are planted in rows on a definite grade or fall according to the district and local conditions, and small banks are constructed along each tree row. In the drier inland areas where rainfall is limited, level rows or contour plantings can be undertaken, with the object of retaining as much of the rainfall as possible on the land and in close proximity to the trees, so that it will soak into the soil and be available for use by the trees. Waterways should be provided at the end so that surplus water, in wet years, can be drained away. In dry years, irrigation water or rainfall could be held on the rows by closing, or partially closing, the ends of the banks and preventing or limiting run-off as desired.

In the better rainfall areas the rows are given a definite fall and provision made for the removal of surplus water. Grades of 0.5 per cent. to 1 per cent. are generally recommended and have proved quite satisfactory in most cases. In some special cases, however, steeper grades have been used with success, but it will generally be found that grades of ½ to 1 per cent. will prove quite adequate.

By making small banks every tree row, better control, distribution and absorption of water will be obtained. The absence of large banks makes the work much easier, and also does away with the necessity of moving so much of the surface soil into the banks. Small banks can be made by an ordinary single furrow or orchard plough, throwing a furrow up to the trees from both sides and leaving the "finish out"

Fig. 4.—A young orchard planted and worked on the contour. Notice the small banks being formed up along the tree rows and the drainage channel between the rows.

furrow between the rows, to provide a drain or channel to carry the flow of water. If, however, it is desired for any reason, the banks could be made between the rows and away from the trees.

In all systems of banking a diversion bank is generally required at the top of the planting area, to prevent overtopping of the first bank. The small banks, along each row, are only capable of handling the water that falls and flows from the *space between each row* and substantial diversion banks are required where it is necessary to protect any area from run-off from higher lands.

TECHNIQUE FOR LAYING OUT ORCHARDS ON THE CONTOUR.

To lay out an orchard on the contour commence by selecting a suitable base line, where the slope could be regarded as an average of the area to be treated. That is to say, that the steepest or flattest slopes would not be selected as base lines, even though they may provide ideal locations for access tracks, waterways or fence lines. By selecting an average slope to work from, it will be found that the contour lines will, in the majority of cases, not converge as would be the case if the flattest slope was selected, or diverge considerably as would be the case if the steepest slope was chosen. Along this base line, pegs are placed according to the distance apart it is desired to make the rows.

If the distance is 22 feet, then pegs are placed at 0, 22, 44, 66, 88, 110 feet and so on. The second row, that is the 22 ft. mark, is then surveyed and marked out with the predetermined fall. The third row from this, that is the 88 ft. peg, is then surveyed and pegged. Similarly every third row is surveyed and pegged. These surveyed rows are then marked by making a plough furrow with a single furrow plough. From these rows, which have been marked by a plough furrow, rows immediately above and below them are then pegged out parallel to the key rows by measuring 22 feet from it. This

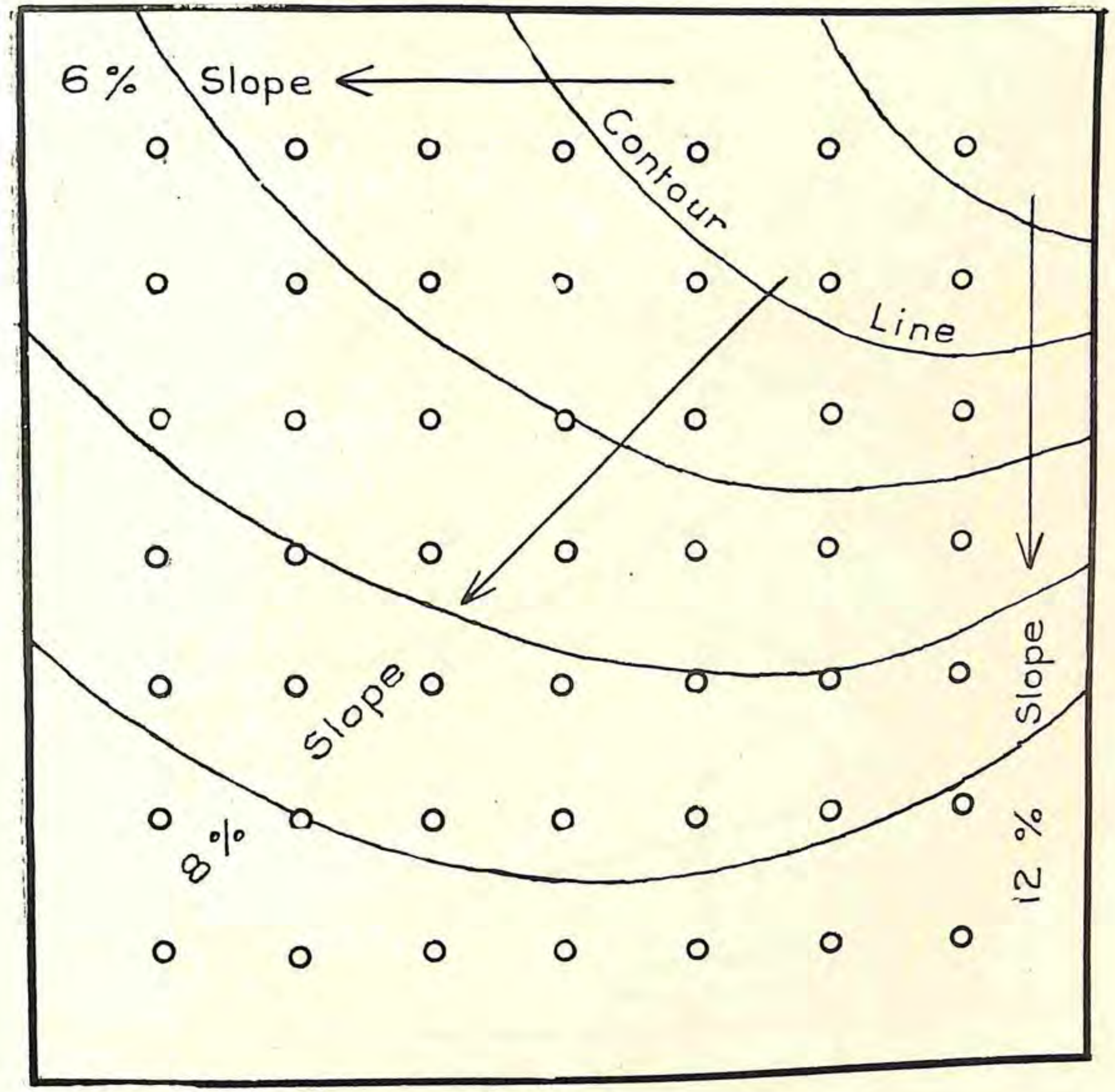


FIG. 5

then gives one true grade row (the surveyed row) and two assumed grade rows (one above and one below and both parallel to the surveyed row) which, in most cases, seeing that they are less than ½ chain apart, can be generally taken as accurate enough for practical purposes. Each surveyed row is similarly treated until the whole area has been covered and marked out. Every third row will be a surveyed row with two "assumed grade" rows between them, one parallel to the top surveyed row and the other parallel to the bottom surveyed row. Between the two "assumed grade" rows, short rows may be necessary if the slope of the land is not uniform.

Where the slope increases, it may be only possible to have one "assumed grade" row or a short row. Where it decreases, several short rows, in addition to the "assumed grade" rows, may be necessary. While surveying and pegging the tree rows, it is possible to bring about a certain amount of uniformity between the rows, by varying

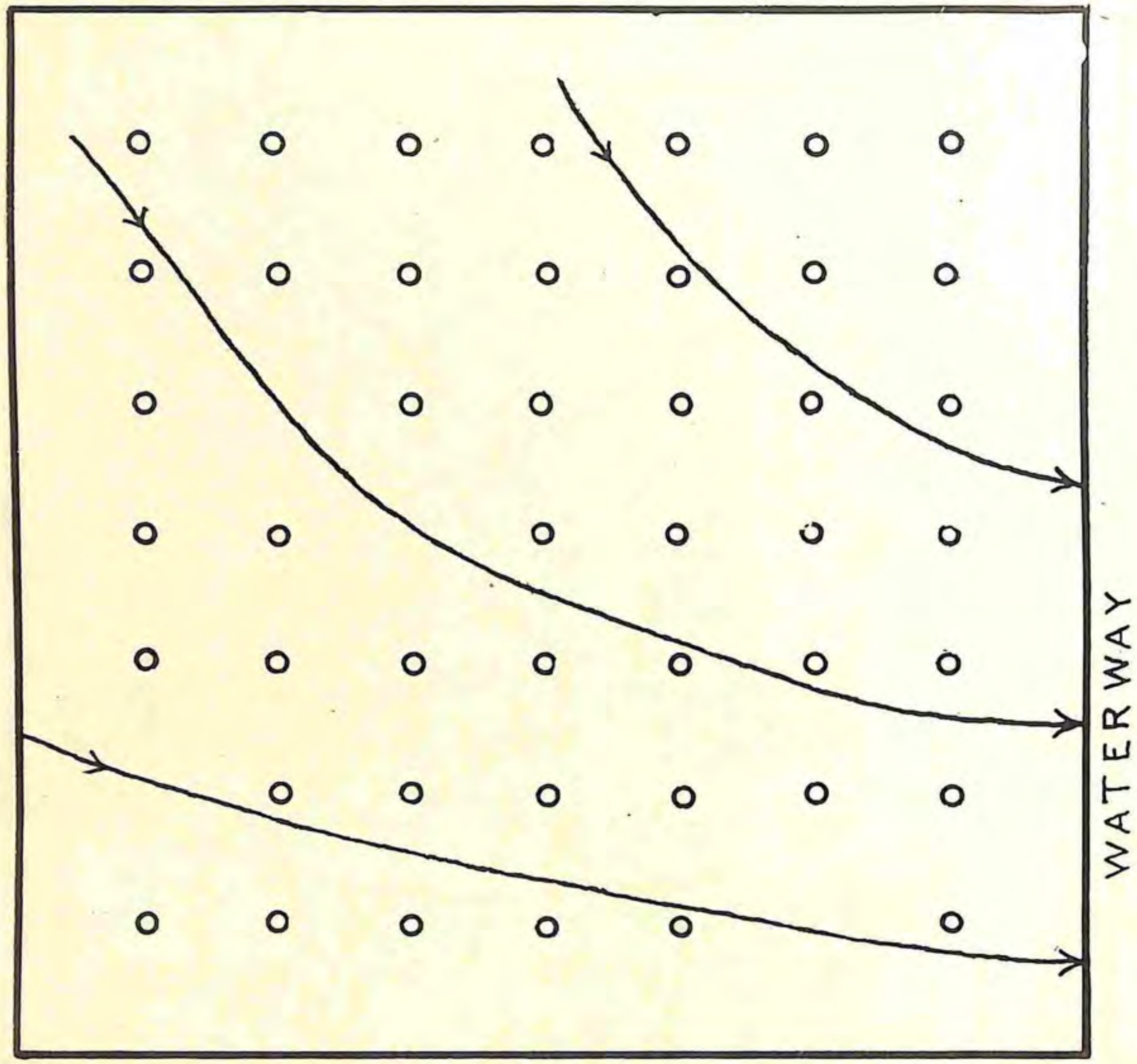


FIG. 6

the grade slightly, according to the slope. This is most desirable and should be done wherever possible, as it will help to reduce the number of short rows and make future working easier. However, it should be appreciated that "varying the grade" to obtain uniformity is something that only an experienced worker can do and should not be undertaken by those without experience in contour work.

Short rows are undesirable in orchards, but they are unavoidable in contour plantings, where the slopes are not uniform. Short rows can be fitted in, as required, where the slope flattens out and the distance between the "surveyed rows" increases. It will be found that these short rows can be graded similarly to adjoining rows. The flow from these rows is picked up by the lower row and, if necessary, a slightly bigger bank is made to carry the extra flow.

After pegging it is desirable to mark the rows with a plough furrow, as this gives a clear picture of the area and makes planting easy. Before this is done, the pegs should be sighted into positions, so that minor irregularities can be adjusted and the row ploughed out on an even curve.

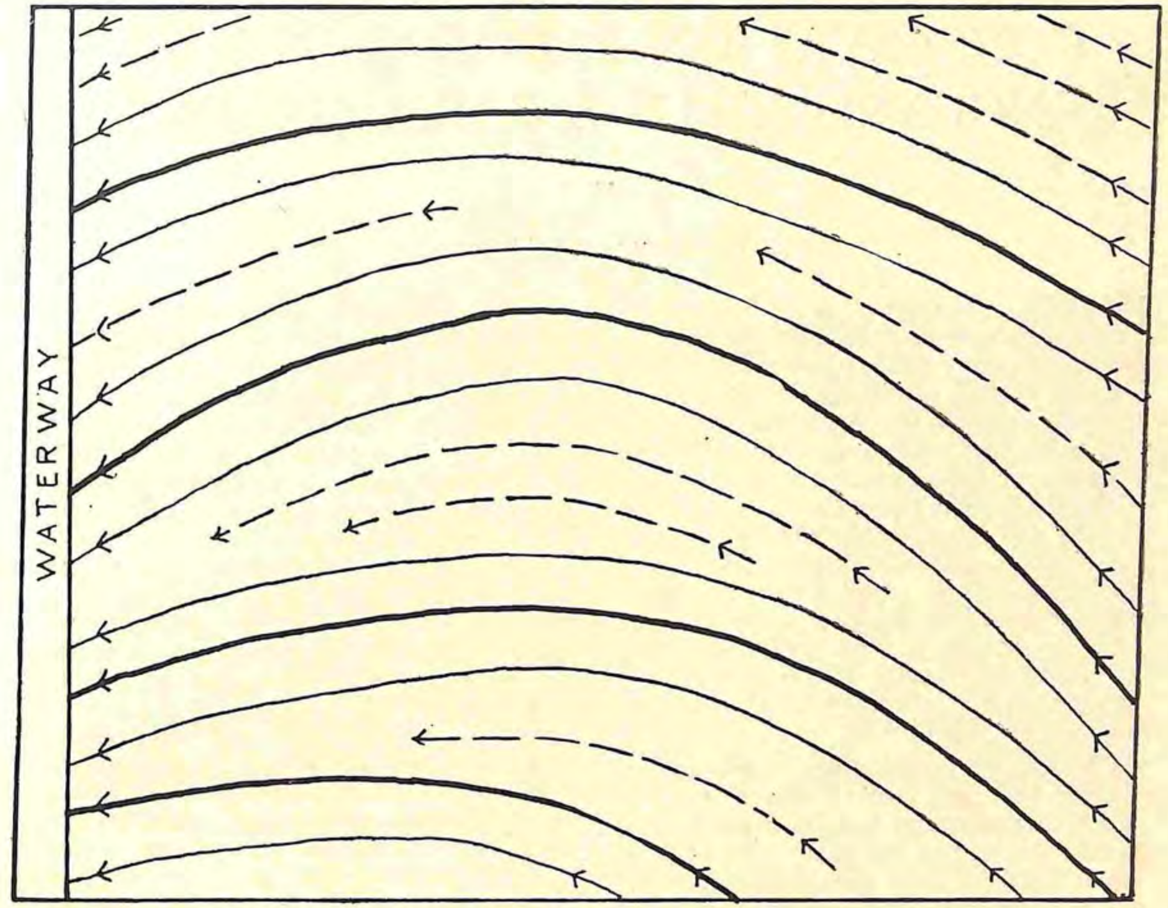


FIG. 7

The tree positions are then marked by measuring and pegging (or digging the tree holes) along the plough furrows, at the required distance apart. Care is required when planting the short rows not to plant too close to the adjoining rows.

It will be found that the distance apart of tree rows and also the spacings within the rows will have to be varied, to cope with the slope and layout. Contour planting cannot be done on a practical basis without some variation of the mathematical standards desired, and it will be found that both the rows and spacings within the rows will have to be varied. A variation of 10 per cent. is accepted as satisfactory and will be found necessary, in most cases, to obtain satisfactory plantings. If the rows widen a little, say to 24 or even 26 feet apart, then the spacings in the rows would be reduced to say 20 feet and *vice versa*. Special attention, of course, would have to be given to this matter and experience is necessary in deciding this.

By planting along each row independently, as mentioned above, it will be found that the trees are not in line up and down the slope. They will be in curved lines along the tree rows. This is a very desirable and important consideration, as it makes it impossible to carry out any cultivation or other operation unless "on the contour," as the only access is between the rows. This makes it desirable to divide the area, if large, into blocks, so that suitable access tracks may be left in convenient places, *e.g.*, such as along a ridge and where the run-off from the track can be turned into the banks at suitable intervals by small mitre drains.

CONSERVATION FARMING IN NEW ENGLAND WITH A FARM GRADER

BY

R. W. BERMAN, Field Officer.

BECAUSE of the lack of Soil Conservation Service plant to meet the demand for heavy earth-moving work in the New England District and because of the scarcity of private contractors with the necessary equipment who are prepared to undertake the construction of erosion control works, conservation farming in the New England District has been slowly developing with the aid of the smaller makes of "farm grader" drawn by wheeled tractors. These machines had been used for some years by some landholders in the district with varying success, but some excellent work has been undertaken by landholders of Graham's Valley, near Glen Innes.

The construction of graded banks in cultivation land and contour pasture furrows has been undertaken and, in general, good results obtained on the heavy soils of these farms. Grades used were generally steep, up to 1 per cent., and capacities of banks were not large, but the results obtained seemed to indicate that the farm grader as pulled by an ordinary wheeled farm tractor can be used to construct successfully quite extensive layouts.

The first such work undertaken by the Soil Conservation Service was the graded banking of some 150 acres of land prior to its first cultivation on the Pastoral Research Station of the Commonwealth Scientific Industrial Research Organization at Chiswick, near Uralla. Construction was just completed in time for the September-October floods of 1949, and excellent results obtained; only five breaks (and these due to a fault in construction near the outlets, not in design) occurred in thirty-six banks during a downpour of 11½ inches. The observations made at Chiswick have influenced the design of other layouts and the many jobs since undertaken have proved very satisfactory.

It is on land not previously cultivated that the farm grader can be most effectively used, and advantage is being taken of the possibilities of the machine by many landholders in the Waterloo and King's Plains areas. By constructing graded banks through their paddocks, under the guidance of the Soil Conservation Service, either before or immediately after the initial ploughing, these farmers have taken steps to preserve "new ground" from the ravages of erosion and have economised upon the necessity for using the heavier equipment essential for constructing a similar layout on *eroded* land. The presence of even small gullies makes the use of the farm grader very laborious, but where "new" land is being subdivided for cultivation the intelligent planning of a layout, including the preservation of certain natural depressions as waterways, the banking of the proposed cultivation land with the grader, together with the planned location of subdivision fences, has proved a sound and economical means of guarding against erosion. On older cultivation land the farm grader has been used quite successfully to build banks over gullies up to 2 feet deep. In one such case, on the property of G. Fulloon, Cressbrook, Armidale, the gullies were first filled by parallel ploughing and grading of the soil into the gully.

CAPACITY OF BANKS.

Upon examination it was found that the channels of the graded banks in existence in the district seldom exceeded a cross-sectional area of two square feet. This appeared to be due to the method of construction, and it was thought that this capacity could be increased by different methods. By aiming at a flat-bottomed, wider channel, banks were eventually constructed having a cross-section of about 8 square feet three months after construction. Settling appeared to have ceased at the time of taking the measurement. The degree of slope increasingly affects the efficiency of the machine and this is illustrated in Fig. 3. Relative measurements of bank, channel and batter of representative banks taken at random are also shown in this diagram. Owing to the limitations of the machine the maximum cross-sectional area obtainable in heavy soils appears to be about eight square feet on a slope of 4 per cent.-6 per cent. On slopes above 6 per cent. the maximum appears to be between five and six square feet.

Fig. 1.—Natural grass sward surveyed with level cross-section for a waterway on the C.S.I.R.O. Field Station, Uralla.

GRADES.

Because of the limited capacity available in these banks, grades used have been rather steep by usual standards, the limiting factor, of course, being the erodibility of the soil. This is somewhat modified by the unusual revegetative capacity of soils in the New England climate. The grades used at Chiswick were 0.5 per cent. throughout with the exception of the uppermost banks, which were diversion banks in pasture land and expected to re-grass themselves. These banks were put in on a grade of 1 per cent. The same grades were used at Cressbrook, Armidale, on light soil, but some scouring occurred on the 1 per cent. grades. After the success of the Chiswick banks during the floods of spring, 1949, the grades used were reduced to 0.4 per cent. and 0.8 per cent. for subsequent jobs. These grades have still proved adequate, having been severely tested by sharp summer storms, with much local flooding, on properties in the King's Plains area.

Uniform gradients throughout have been most favoured because of greater ease in laying out, but some attempt has been made to slightly flatten the grade on the upper reaches of the channels by the simple expedient of increasing the distance between

Fig. 2.—Construction of a graded bank at King's Plains.

readings as the higher end of the bank is approached. Instead of stepping the usual 17 paces right through, the distance is increased first to 18 paces, after the first few readings, then to 19 and finally, in the longer banks, to 20 paces. This last spacing has the effect of reducing a 0.4 per cent. grade to 0.325 per cent., as each addition of one pace to the distance between readings reduces the grade by 0.235 of 0.1 per cent.

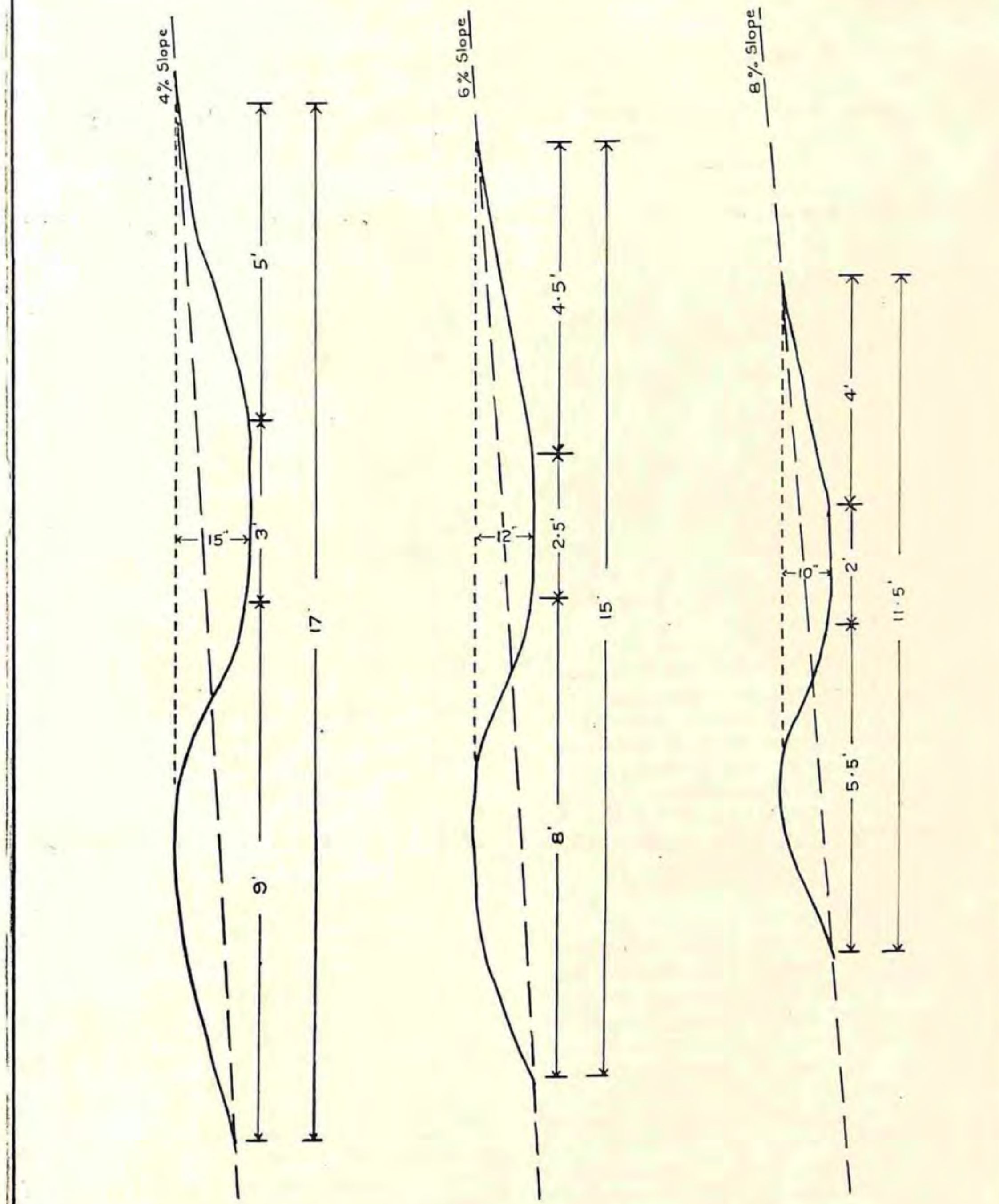
INTERVALS.

Bank spacing is usually governed by the need for preventing inter-bank erosion, but as wide spacing requires greater capacity in the channel to handle the run-off from the larger catchment, and the capacity of these channels is limited by the scope of the machine, the spacing in this instance has to conform with the average expected size of the banks. Intervals have been kept low, because of the small bank capacity, and the rule-of-thumb adopted at Chiswick, "never more than 5 feet vertical or 50 yards horizontal" has been adhered to.

It may be expected that with banks as close as these, and their narrowness preventing them being worked over, some inconvenience would result in cultural operations; however, this is offset by the more intensive forms of agriculture in the New England, and the greater variety of crops that can be grown together with the practice of strip cropping. In areas where the prevailing land slope has been variable, causing spacing in some places to greatly exceed 50 yards horizontally, although only as low as 4 feet vertically, and at another point in the same bank on steeper ground to be as close as 20 yards, the V.I. was increased to 6 feet and spur terraces built on the flatter ground towards the outlet.

METHOD OF CONSTRUCTION.

Generally speaking the farm grader is used in construction in similar manner to the larger grader terracer. All banks have been built from one side only and the usual number of trips necessary to build a bank is eleven. Almost all the work has been carried out in heavy black clays, and it is thought that a practised operator could undertake the work much more easily in light soil.



Typical Cross Sections of Graded Banks on "Leaweena" Matheson. 3 Months after construction

Property of C.L. Podmore - Kings Plains, Soldier Settler

Fig. 3.

Two things are apparent in heavy clay soils in New England:—

(*a*) Owing to the lack of weight on the machine it is impracticable to try to make the blade cut deeper than has been stirred.

(*b*) Unless the soil is very dry (which has rarely been the case in the last twelve months) there is very little settling, as the wheels of the tractor pound and compress the bank during construction.

The first step in construction is to cultivate the line of the bank, and the only implement of any use for this operation is the mouldboard plough. Assuming that a four-furrow plough is used, the first cut would be made below the line of pegs so as to leave the pegs still standing about one foot above the last furrow, the soil being thrown downhill. The return trip may be made below the first and throwing uphill to form a "back-up" over a strip of unploughed ground. This "back-up" would form the foundation of the completed bank. The third run should be made above the first, also throwing downhill although in subsequent runs above this it is immaterial in which direction the soil is thrown. The total width of stirred soil above the pegs should not be less than 10 feet. It may be necessary to allow the soil to dry before commencing to grade and should rain fall on ungraded ploughing a second ploughing may be required.

The first blow with the grader will deposit the soil on the "back-up" previously mentioned—for this blow the blade is set steep and narrow and cuts deeply. Thereafter, the job merely consists of scraping the soil across into the furrow thus formed and grading it up onto the growing bank. The last blow of all will scrape the channel clean and fill the furrow for the last time.

The farm grader, having little weight of its own, can be very unstable in operation if not set accurately for each blow. Greater stability is obtained and much better work done if the blade is set on the "wide cut" for all blows other than "putting up." The limiting factor here is the "liveliness" of the soil being worked. If it is sticking and will not run off the blade, the "narrow cut" must be used.

The machine behaves rather differently under various conditions—different soils, conditions of soil, various types of tractor and speeds. With experience several "do's and don'ts" have become apparent, and it is advisable to experiment a little when starting a new paddock or using a fresh type of tractor. A small-wheeled tractor always has trouble with wheel spin, but the lightest used (17 horse-power) proved powerful enough. The forecarriage of the grader should be dispensed with and the drawbar hitch made as high as possible to give maximum clearance under the beam. Keep the blade clean—if necessary clean after every trip. Too slow is better than too fast—especially in stony ground. Should the driver get into difficulties with the tractor slipping off the bank, which is more often the case with row-crop tractors, unhitch immediately, run forward and back into the correct position.

WATERWAY TRAINER BANKS.

No attempt has been made in this work to construct a level-section waterway. In all cases natural grass waterways were used and if no suitable depression or watercourse was available, levee banks were thrown up to contain a strip of natural grass as a waterway. The direction of the greatest fall must be determined by one of the various methods available and, when the side slope becomes too great, the waterway must turn to follow the natural fall. Trainer banks were also used to increase the capacity of a shallow water course.

These banks are constructed much as are the graded banks, except that height of bank is the only consideration and no thought need be given to a channel. Care must be taken that the bank is built well up on the bed of the waterway and no disturbed grass left inside the bank exposed to scouring. The drain left by the excavation of soil will collect water and may scour, so mitred inlets to divert the water onto the waterway are sometimes necessary.

DIVERSION BANKS.

This rather novel method of diverting water has, so far, proved very successful on one property at King's Plains. The problem was such that a large catchment

Fig. 4.—Bank construction on heavy black clay soils, using farm grader on ploughed strips.

Fig. 5.—The outlet of the graded bank in Fig. 4 into a natural grassed waterway. The bank in both left and right foreground is the trainer bank of the waterway.

Fig. 6.—A natural grassed waterway (middle of illustration) changing direction in accordance with level cross-section available. The trainer banks are pushed up from outside the waterway.

was shedding much water onto a proposed cultivation paddock. A shire road soon to be constructed would further aggravate the problem. It was decided that the farm grader could not build a bank large enough to control the run-off and protect the lower-graded banks unless it was at a grade too steep to be safe from scouring. It was decided to take some of the load off the uppermost banks. After the positions of the proposed road culverts were determined, three diversion banks were constructed. The natural grass cover which formed the channel was originally perfect and was left so, undisturbed by the operations. Each bank was 200 feet long, constructed just as the waterway trainer banks were, but on a grade of 2 per cent. (degree of slope 4-5 per cent.). These banks emptied onto safe well-grassed outlet areas. During heavy storms and prolonged wet spells in January and February, 1950, the scheme worked efficiently.

CONCLUSION.

The farm grader is an efficient and economical machine by which a farmer can, provided his farm is not badly eroded, construct quite extensive soil conservation layouts. It can be hauled by almost any type of ordinary wheeled tractor and can be operated single handed—the driver doing his own operating. It should be included in farming plants as an essential unit where the aim is prevention rather than cure. With experience and initiative on the part of the farmer he thus may eliminate the need for the use of heavy earth-moving equipment at a later date.

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RECLAMATION OF ERODED ARABLE LANDS IN THE CAMDEN DISTRICT

BY

J. J. HUSTON, H.D.A., Soil Conservationist.

DAIRY farming is the main agricultural occupation in the Wianamatta shale area, which comprises practically all of the land in the Camden, Campbelltown, Picton and Menangle districts. A large number of the dairy farms are situated on steep country. Many of these properties have a total area of 200 to 300 acres but have only 20 to 30 acres of land which can be cultivated without the risk of serious erosion.

Landholders in these districts find it necessary to crop the available cultivation paddocks constantly, in order to provide roughages for feeding their dairy herds during the drier months of the year. As a result of this constant use, most of the cultivation land has lost its fertility and is eroded or starting to erode. Where the grades are steep, the signs of erosion are more marked but all land which has been constantly cultivated for any length of time is showing definite signs of deterioration.

RAINFALL.

The annual average rainfall is 30 inches. This appears to be quite a reasonable rainfall, but it is the character of the rainfall that counts rather than the total annual precipitation.

Approximately two-thirds of the annual total falls in the first half of the year, giving rise to very favourable conditions for growth

Fig. 1.—Before treatment. Bare rilled land rapidly deteriorating in Camden district. August, 1949.

Fig. 2.—Same area as Fig. 1 in March, 1950—six months after treatment. A heavy growth of Japanese Millet, Rhodes grass and lucerne is evident.

in the late summer, autumn and early winter. Heavy storms provide a large proportion of the summer and autumn rainfall. Because this rain falls very quickly, much of the water is lost as run-off. At the same time this run-off causes considerable erosion damage to cultivation paddocks which have been freshly worked prior to planting crops.

In the second half of the year, when the rainfall is lightest, there is a very high incidence of westerly winds. Many small falls of rain have no beneficial effect as the moisture is evaporated in a few hours by the westerly gales which follow practically every rain change. The unfavourable rainfall which exists generally from July to December is one of the deciding factors against the economic establishment in these areas of introduced winter growing pastures.

REASONS FOR DECLINE IN FERTILITY AND EROSION.

Because they are particularly suited to climatic and seasonal conditions, crops like saccaline and oats are grown regularly on each paddock without rotation. A well-regulated rotation of crops would be the means of maintaining soil fertility; however, most dairy farmers prefer to grow only the above-mentioned crops to provide the necessary roughages for milking herds during the late winter, spring, and early summer months.

Frequently cultivation paddocks are left without any after treatment. After harvesting cattle are allowed to graze the crop residues, compacting the surface soil and leaving the land bare to the ravages of water erosion. A large percentage of the serious erosion in these areas can be traced to the failure of landholders to establish permanent cover on worn-out cultivation lands.

ECONOMIC CONSIDERATIONS.

Most dairy farmers consider that it is economical to buy concentrates but not roughages. Therefore, it is desirable that worn-out cultivation lands be renovated so that they will produce a heavy growth of pasture.

Practically all sloping lands in the Camden district benefit very considerably from the installation of level pasture furrows. In addition the establishment of suitable pastures is the only economic method by which worn-out cultivation lands may be restored to a worthwhile degree of fertility. Paddocks can then be grazed and the amount of organic matter added as droppings will considerably improve the fertility of the soil.

Fig. 3.—Contour furrows on bare land on Mr. C. C. Mulholland's property at Camden, September, 1949, before sowing.

If worn-out cultivation lands are cultivated they produce very poor crops. On the other hand, if reasonable pastures can be established, it is most likely that a greater bulk of suitable feed will be produced on the same land. At the same time, the risk of erosion will be minimised and a greater amount of moisture will be absorbed into the soil.

When a heavy growth of pasture is established on worn-out land, biological activity is increased within the soil. Moreover, the soil will be in a better condition for the profitable usage of commercial fertilisers such as lime and superphosphate.

SUITABLE PASTURES.

The most suitable pasture mixture for the reclamation of worn out soils in the Camden district is made up of—

6 lb. Rhodes grass (*Chloris gayana*).

2 lb. of lucerne.

1 cwt. superphosphate per acre.

This mixture should be sown in the spring or early summer, with a cover crop of 8 lb. of Japanese millet per acre. Rhodes grass has proved to be an excellent pioneer for reclaiming eroded lands. A single plant sends out many runners and when conditions are favourable, may cover an area of 8 or 9 square feet in a few months. Many local farmers are satisfied that this grass provides suitable feed for milk production, despite opinions to the contrary from landholders in the warmer and moister parts of the State.

Japanese millet as a cover crop provides protection from summer heat for the young lucerne plants and a rapid cover for newly worked land. Lucerne in the mixture adds to its balance as a feed because of its high protein content.

The above mixture is for spring and early summer sowing, and it is recommended that this mixture be used so that full advantage can be taken of the summer and autumn rains. If, however, pastures are being sown in the autumn for winter feed and protection of the land, the following mixture has been used with success—

2 lb. Wimmera rye grass per acre.

2 lb. subterranean clover per acre.

2 lb. prairie grass per acre.

1 cwt. superphosphate per acre.

Fig. 4.—Same area as Fig. 3 in March, 1950, six months after sowing. Note excellent growth of Rhodes grass and lucerne.

This mixture should be sown with a cover crop of half a bushel of oats and 4 lb. of purple vetch to the acre. It should be remembered, however, that this mixture will depend on good spring rains for best results, and as these are the exception rather than the rule at Camden, a certain amount of risk is taken where this pasture is sown. In any case, a mixture of Rhodes grass and lucerne should be sown along the pasture furrows during the following spring to ensure growth during the summer and autumn, when the rainfall is most reliable.

Immediately after the seed is sown, contour furrows are constructed on a vertical interval of 2 feet.

Many types of farm ploughs—both mouldboard and disc—have been used to make furrows of the right type and capacity. Where possible the furrows should have a water holding capacity of one cubic foot for each lineal foot of the furrow. The area should be carefully surveyed to ensure that the furrows are on the contour. When the furrows are completed with the plough, they should be checked—small blocks being made at intervals with a shovel—particularly on either side of old gully fills or natural depressions.

In addition to controlling erosion the contour furrows will ensure almost complete absorption of all rain that falls for the benefit of the pasture.

Enough seed of the pasture mixture is retained to sow along the furrows when they are completed.

It is emphasised that some maintenance work will be required to keep the furrows in good order so that they will absorb the water and control erosion. This applies particularly where the seasons are abnormally wet or where gullies have been filled prior to furrowing.

MANAGEMENT OF THE AREA AFTER TREATMENT.

The area should be kept free of stock until the pasture and cover crops are well established. If the Japanese millet does very well a few light grazings may be possible during the autumn following sowing. However for permanent cover a good seeding of Rhodes grass is most desirable during the first autumn and the pasture should be managed to ensure that this seeding does take place.

Fig. 5.—Untreated area, Camden district, August, 1949. Note bare eroded condition of land.

Fig. 6.—Same area as Fig. 5 six months after treatment. Rhodes grass and lucerne are making good progress.

Where the land has been badly eroded and the resultant growth is slow, stocking should not take place for a period of probably two years, depending on seasonal conditions.

Judicious management and regular spelling of the paddocks concerned will have a beneficial effect on the actual results obtained from the work.

An annual top-dressing of superphosphate at the rate of 1 cwt. per acre is recommended.

CONCLUSION.

The treatment of old cultivation lands by methods similar to those detailed above has been most successful in the Camden district.

Figures 1 to 6 show the progress of reclamation on Mr. C. C. Mulholland's property at Camden. The areas were treated and sown in September, 1949. Figures 2, 4 and 6, taken in March, 1950, show the heavy growth that has taken place on land which was useless from a production point of view six months before.

Landholders who have tried these methods are well satisfied with the results obtained. Erosion has been completely controlled and the fertility of the land is being restored. The pastures have provided excellent grazing for the dairy herd with increased milk production and better financial returns to the farmer.

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STUBBLE BURNING

BY

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FOR many years in the Gunnedah district it has been considered that the burning of the stubble from the previous crop is an essential preliminary to the preparation of a good seed-bed for another crop of wheat. Handling the stubble is a problem of considerable importance in the north-west of New South Wales where cereal crops are grown annually on the same land on short fallow. The advantages of this practice were so obvious that the insidious harm done thereby to the structure and fertility of wheat lands was largely or completely overlooked. It is the aim of this article to present in non-technical language some aspects of the question, to burn or not to burn, which to-day exercises the minds of many of the more progressive farmers.

ELEMENTS OF PRODUCTION.

The economic production of wheat on broad acres depends primarily on soil fertility and seasonal conditions. Soil fertility in turn may be considered under two headings, namely, physical structure or texture, and chemical make-up or availability of plant foods. Seasonal conditions may be taken to cover adequate rainfall, and the absence of damaging frosts, winds, hailstorms, etc.; it will be realised that most of these factors are to a certain extent interacting, and a dynamic rather than a static condition must be considered in dealing with the whole question of crop production. It is essential, moreover, to realise that we Australians, as a nation, hope to inhabit this continent for a long time ahead; our children's children will probably need to grow wheat, and the crops they will harvest will depend to some extent at least on our land-use policy to-day.

SOME EFFECTS OF STUBBLE BURNING.

From a purely short-term viewpoint there is little doubt that burning is the easiest and quickest method of getting a heavy stubble cover out of the way to allow low-cost bare fallowing. In the national interest, however, we must discard this short-term policy of exploitation for one of long-term conservation of soil fertility, which is our greatest national asset. It is probable that the full consequences of a stubble fire cannot yet be appreciated by either farmer or research worker, but certain facts have been established from which some conclusions are drawn and here presented.

Fire destroys organic matter and bacteria, thus greatly reducing the actual and potential humus content of the soil. The importance of an adequate supply of humus could be enlarged upon to the exclusion of other material from this journal; suffice it to say that without humus good tilth is impossible. Soils tend to set hard when dry, lose their water-absorbing and water-holding capacity, thus increasing run-off at the expense of moisture storage for future plant use, and when cultivated finally break down to a dust mulch with no cohesion between particles. Such a surface is highly resistant to rainfall infiltration, and run-off is encouraged; the small particles of soil are easily transported by low velocities of water, so erosion is doubly facilitated. In dry periods fine dust from fallows is blown away in clouds and many tons per acre of the best soil are thus lost every year from areas that can least afford any further drain on fertility. Cultivation costs are increased when humus is reduced; it is finally impossible to prepare a seed-bed of really good tilth no matter what expense is incurred. No mineral fertiliser or combination of same, in whatever quantities applied, can produce good crops from a humus-deficient soil. Nor will pastures grow sufficiently well on such soils to provide adequate protection against erosion, which causes a further loss of soil fertility and further advances the vicious circle.

FERTILITY MUST BE MAINTAINED.

Adequate amounts of humus, then, must be maintained in wheat soils if production is to be stabilised at economic levels. Stubble burning reduces humus, increases erosion and lowers productivity. Does the ploughing-in of stubble have the opposite and desirable effect?

STUBBLE RETENTION.

In considering this question it must first be realised that fresh stubble is not humus. Lyons and Buckman[1] state: " . . . Specifically, humus may be defined as a complex and rather resistant mixture of brown or dark brown amorphous and colloidal substances that develop synthetically as the original organic tissues suffer enzymic dissolution by the various soil organisms." Wheat straw contains much carbohydrate material and relatively little nitrogen; the bacteria which bring about decay of the carbohydrates must draw nitrogen from some source other than the stubble itself, and this source is normally the soil. If the soil is already deficient in nitrogen, the decay bacteria may actively compete with the growing crop for the small supplies of nitrogen available, to the obvious detriment of the crop. As soon as the initial decay processes are completed, however, this drain on the soil nitrogen ceases and the reverse process takes prominence as the nitrifying bacteria do their work. If ample supplies of nitrogen are available in the soil when the stubble is first turned in, there need be no period of competition; it is therefore a grave tactical error to allow fertility to fall seriously before steps are taken to correct the position. Lyons and Buckman[2] also indicate that it is important to note that the depth of black colour in a soil cannot be taken as an indication of high humus content. When soils are in good heart physically, chemically and bacteriologically, incorporation of stubble will help to maintain that desirable condition; soils of low fertility may need the addition of crop residues of a higher nitrogen content, such as green manure crops of legumes, young oats or long-term pasture sod, together with the droppings of grazing animals, to bring about a relatively early improvement in humus and nitrogen content. In many cases, even where soils were formed from calcium-rich materials, the addition of lime may stimulate bacterial activity and thus expedite and increase the formation of humus from raw organic matter. It is obviously of little value, however, to facilitate humus formation one year only to burn it all out the next year in a "good" stubble fire.

The importance of erosion control must be recognised in any programme of land-use. It is futile to improve the fertility of soil that is going to wash away in the first storm. The presence of stubble on the surface checks the movement of water and protects the soil from the pulverising or dislodging effects of raindrops, thus greatly reducing soil loss and encouraging infiltration rather than run-off. There is little doubt that stubble mulching alone would, on some areas of gentle slope, reduce soil loss to negligible proportions; in other cases, more intensive methods of soil conservation may be required.

CONCLUSION.

In short, while the incorporation of stubble into the soil is not the complete answer to the problem of maintaining fertility, it would seem that the pursuance of a programme of continuous stubble burning must lead inevitably to a breakdown of soil structure, loss of fertility and increased erosion. Reduced yields and increased run-off from many thousands of acres of once-friable and fertile soil, after only 15-20 years of stubble burning and bare fallowing, provide positive proof of this to all who have eyes and the will to see.

[1] Lyons & Buckman. Nature and Properties of Soils. 1943.
[2] Ibid.

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