FOREWORD

BY

E. S. CLAYTON, H.D.A., Commissioner.

THREIS, the great French Prime Minister, once said—"The soil is the wet nurse of all the industries." He was undoubtedly correct. Man's history has shown that civilisations are built on the produce of the country behind them. Destroy the city and the back country will rebuild it, but despoil the back country and the city will disappear.

Nothing has ever succeeded over a period of time on a poor and worn-out soil. Our welfare, both as individuals and as a nation, depends irrevocably upon maintaining productive surface soil. The lessons of history and of our own experience up to date are vitally important to Australia. This country is now at a very important period of her development. Population and industry are expanding rapidly and it is inevitable that much heavier demands are going to be made on our soils for local requirements.

In the past the cream has been skimmed off the topsoil for export. We have lost enough good soil through faulty agricultural methods to realise that good lands are not indestructible, that they can be washed or blown away completely, that crop yields can go down on soils that have lost even only a few inches of the surface, and that farming is uneconomical on lands that have lost their productivity.

If this lesson has been learned there is still time to hold the productivity of our remaining good lands before they deteriorate any further. An increasing proportion of our produce will be consumed in Australia, and in a few years we will need every acre of good farming land to feed our people and our industries.

Although Australia has an area approaching that of the United States of America, the latter is incomparably better placed than Australia in the matter of area and fertility of good farming land in good rainfall zones. We have not the resources of land-plus-rainfall to produce comparable quantities of maize, wheat, cotton, potatoes, vegetables and other farm produce, and will not be also to support such a large population as the United States of America. We, therefore, have to conserve and wisely use what we have. We cannot afford to lose any land by faulty methods. Conservation methods should be applied to all our various types of land. Our arable country can be contour farmed, the range lands can be wrapped up in grass before they blow or wash away, and the steep mountain lands can be sheltered from the storms under the protection of the forest. This is also the best way to save our rivers and the alluvial lands which border them. From now on the way in which we use our land is going to determine our destiny.

The bulk of the lands are range country. The effects of grazing management are highly important not only on the amount and quality of the food produced but also on the density and condition of the sward and its effectiveness or otherwise as a protection to the soil against erosion. Some types of pastures are greatly benefited by resting at critical stages of growth. Such treatment has restored plant cover, which reduces run-off and erosion. It has resulted in more effective use of the rainfall and improved the stock-carrying capacity of the range. More thought should be given to management of pastures, particularly to systematic resting and to rotational grazing.

Soil conservation does not consist only of the eye-catching earthworks which are often necessary for the control of run-off water. It begins at home on the individual farm. In fact, this is the most important aspect of erosion prevention and correction. Special mechanical equipment is often necessary to correct the worst damage, but the function of such mechanical means is to supplement the widespread application of wise land utilisation and more effective use of vegetative cover to protect the soil.

These two general principles can be applied to individual properties. The lands should be used in accordance with their slope. The steep lands should not be cultivated but should be under permanent grass. Lands too steep, even for grass, should be kept under timber with fire and stock excluded. Good management plays a very important part in obtaining and maintaining vegetative cover to protect the soil. Crops, leys, pastures and stock should and can be managed to nurture and care for the soil and to make it even more productive and to keep it permanently in position in the fields. More of the rainfall can be made to go into the soil for the use of crops and pastures instead of allowing it to run harmfully over the surface.

This is the basis of soil conservation. It is not the spectacular portion, but it is effective and it is applicable on the individual farm. Very often it is only applied commonsense.

To reclaim lands that have been virtually destroyed by erosion is, of course, expensive, but the main work is and should be with the lands that have not yet been ruined but which will be, if not cared for. This is not expensive, and it is within the means of the average farmer, and it will pay both him and Australia handsome dividends.

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BODANGORA SOIL CONSERVATION DEMONSTRATION

BY

H. T. Nicholas, H.D.A., A.C.I.V., District Soil Conservationist.

It is of considerable interest to review a soil conservation demonstration after a period of four years. One is then able to indicate in a practical manner the results of the early design, establishment and subsequent working of the land. Bodangora demonstration area now gives us this valuable opportunity.

This demonstration is located on the Central Western Slopes on the Wellington-Mudgee road, adjacent to Bodangora. The farm, comprising some 400 acres of very rich land, is utilised for farming and wool growing purposes. The farming programme as planned has been maintained on the demonstration areas and the land was

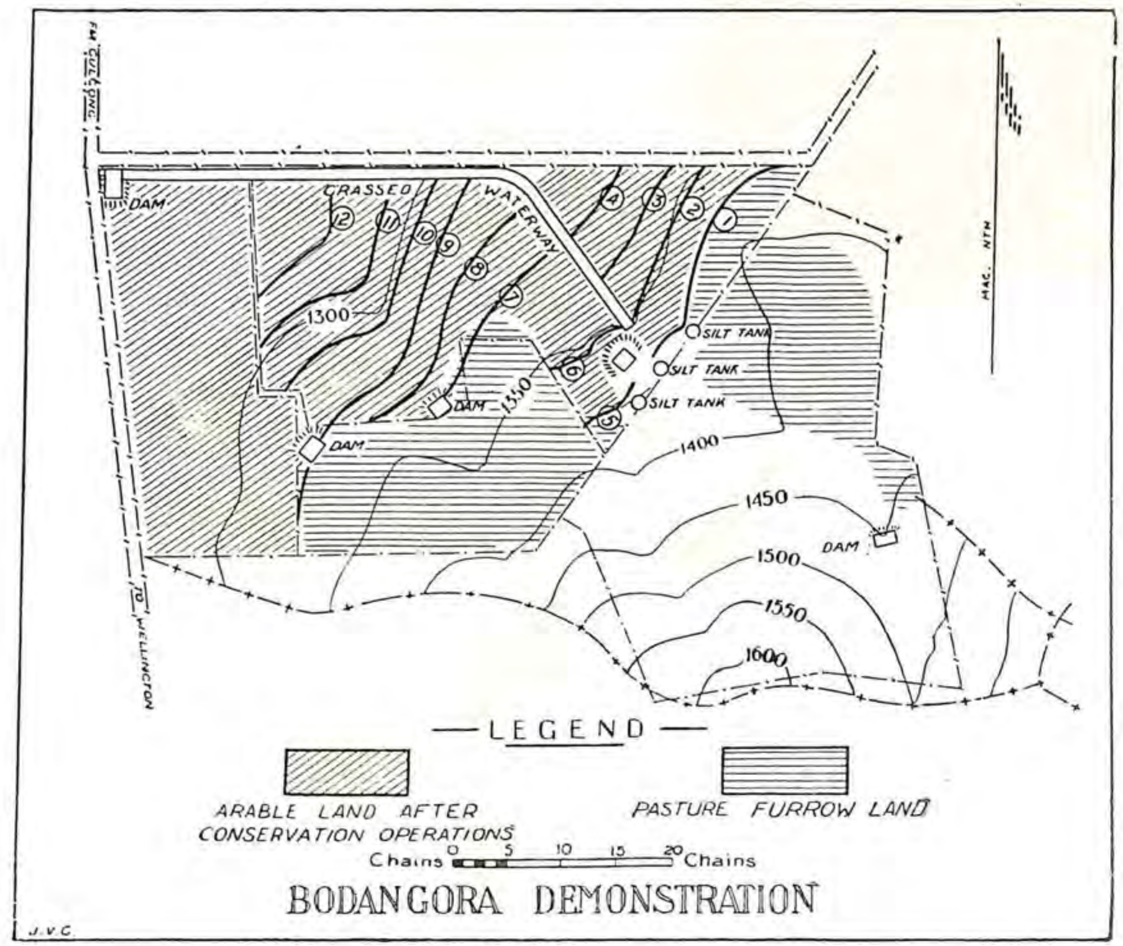

Fig. 1.

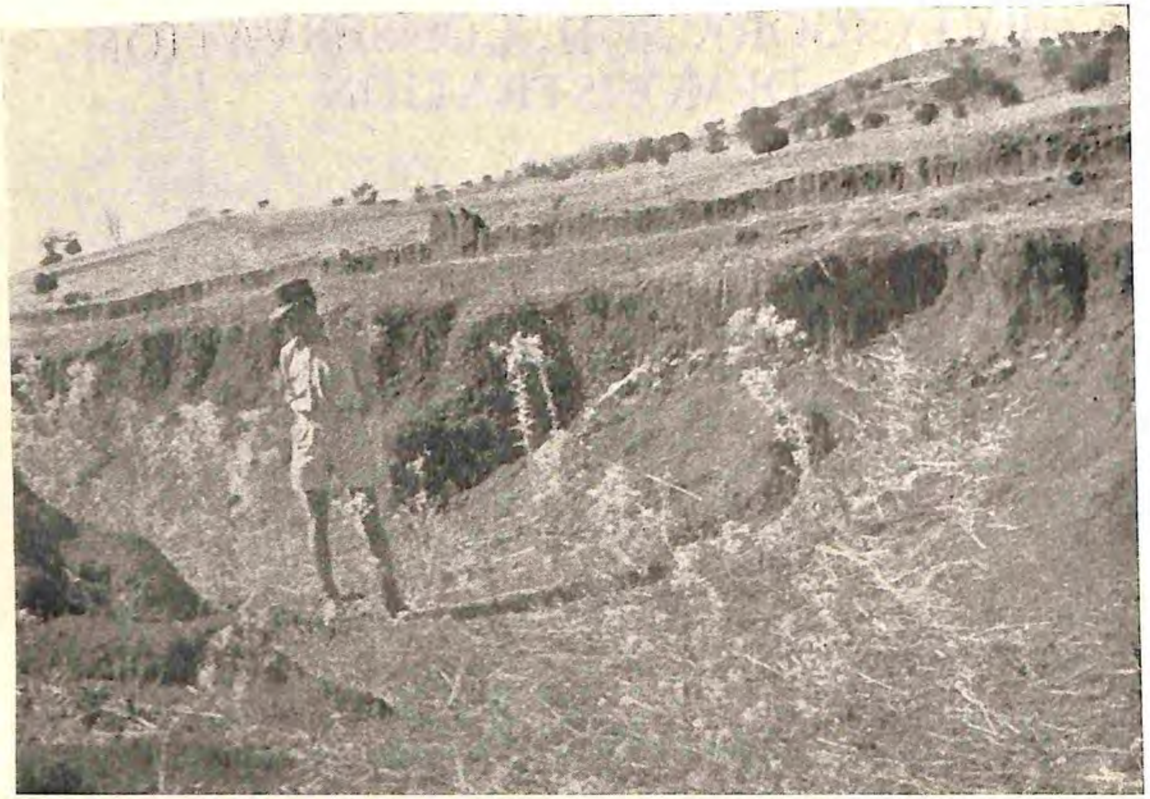

Fig. 2.—The demonstration site was badly eroded in 1946 prior to soil conservation work.

cropped to grain in 1948 and again in 1950. The stubble was not burned after the 1948 crop but the stubble paddocks were grazed to stock prior to fallowing operations. The land was fallowed during late 1949 and sown in the autumn of 1950. A very good crop is again in evidence during spring of 1950.

The waterway on this area is now very well established and carrying a dense sward of lucerne, with patches of Rhodes Grass and Kikuyu grass adjacent to the small dams.

RUN-OFF FULLY CONTROLLED.

In this demonstration, absorption of moisture was one of the outstanding features in the design, and it is interesting at this stage to record that during the past twelve months the rainfall in this area has been an all time record and only in one instance has the main dam at the bottom of the area in the north-west corner overflowed.

The small dams, strategically located on the southern end of Bank 9 and the southern end of Bank 7, and three silt tanks on the south-eastern portion of the cultivation, have, over a period of four years, acted efficiently as steadying agents, reducing the flow from severe storms, thus allowing run-off to gradually move along these graded banks before entering the waterway.

The vegetative growth on all these banks has provided remarkable feed for the small number of sheep carried on this property. These banks were constructed with a channel gradient of 0.5 per cent. throughout; the length of the respective banks can be found in Table 1.

TABLE I.

Details of Graded Banks.

Bank No.	Length of Bank.	Channel Gradient.	Vertical Interval.	Capacity Cusecs.	Estimated Maximum Velocity.
	feet.	per cent.			feet per sec.
1	1,265	0.5	...	9.1	1.5
1A	300	0.5	...	18	1.3
2	1,150	0.5	15	10	1.5
3	943	0.5	8.5	7.8	1.5
4	770	0.5	8.5	10	1.5
5	355	0.5	...	18	1.4
6	550	0.5	12	14	1.5
7	1,300	0.5	17	10	1.5
8	1,815	0.5	12	12	1.5
9	2,100	0.5	12	12	1.5
10	1,675	0.5	10	10	1.5
11	1,510	0.5	10	10	1.5
12	1,356	0.5	10	10	1.5

A significant feature in this table is the vertical interval between many of the banks constructed; it will be seen that the interval varied from 8.5 ft. to 17 ft. vertical between different banks; this is much higher than usually adopted, but suitable to the conditions prevailing on this particular area.

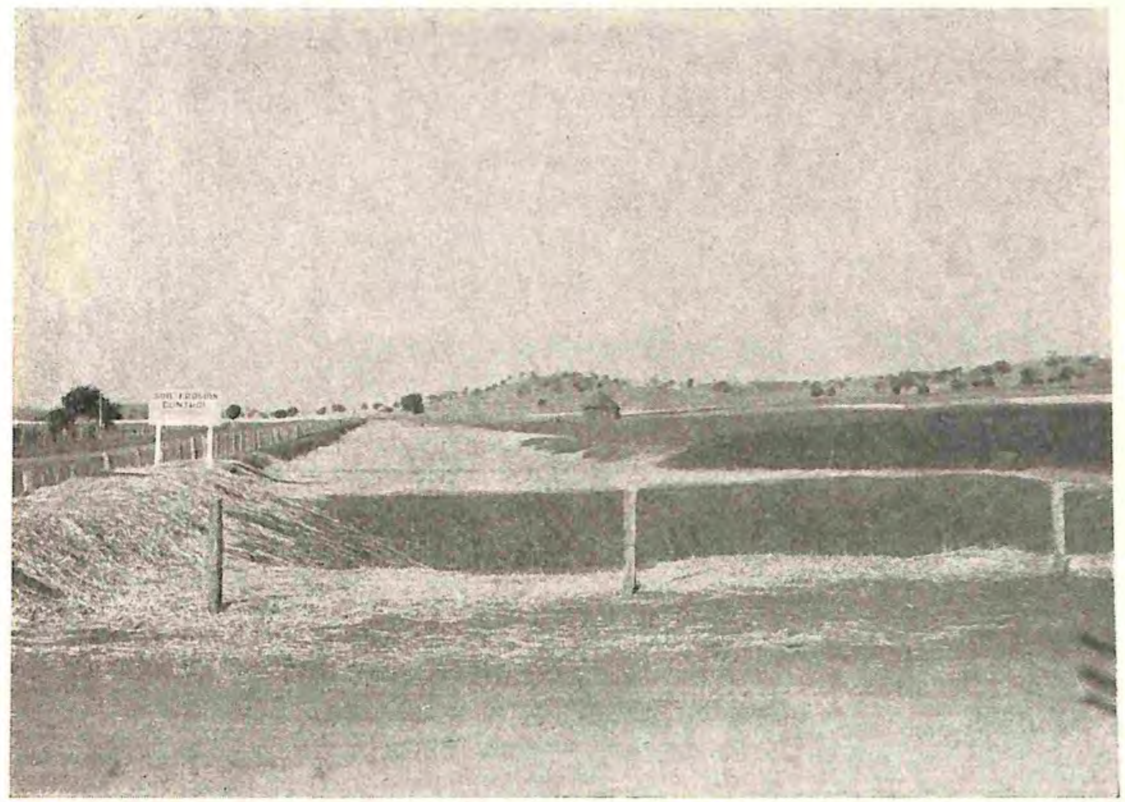

Fig 3.—The lower corner of the demonstration area on completion of mechanical work in December, 1946. The main waterway has been straw mulched.

CAPACITY OF STRUCTURES.

An examination of the various banks to ascertain the results has revealed in this instance that in every case the banks were capable of carrying the water flowing from the area immediately above the bank, being in effect the actual drainage catchment for each bank; this is a most important factor.

The graded bank, No. 7, with a vertical interval of 17 ft. had a small dam constructed at the southern end to increase absorption and reduce the immediate catchment flow, thus delaying run-off.

In the early stages of establishment severe storms caused rilling in the waterway, but this was attended to mechanically and, by careful management and very light stocking, this waterway has not only proved to be entirely satisfactory but has provided suitable feed for the house cow and an odd saddle horse or two.

The large dam in the main gully at the head of this catchment with a capacity of 2,200 cubic yards, has held water throughout this period and only overflowed on very odd occasions. The catchment area is small, being only 35 acres, but adequate to maintain a good water supply in this paddock.

TABLE II.

Details of Dams.

Dam No.	Capacity. cubic yards.	Drainage Area.
A	489	Approximately 90 acres.
B	269	Approximately 25 acres.
C	133	Approximately 14 acres.
D	420	Overflow of Dams Nos. A, B and C and cultivated lands.
E (silt tank) ...	60	
F (silt tank) ...	60	
G (silt tank) ...	30	
H	2,200	Approximately 35 acres, constructed by moving 600 yards of soil in a natural depression.

Fig. 4.—Complete vegetative stabilisation achieved by the end of 1948.

The overflow has continued down the main creek, and after passing the three silt tanks, has run into the main dam. From this dam it has seldom flowed onto the waterway, and with a thick mat of vegetative cover on this waterway, does not progress a very great distance but has supplied a thorough soaking for the lucerne and other vegetation growing on the area.

The two small dams hold water for long periods and overflow along graded banks No. 9 and No. 7 to the main waterway, finally reaching the dam in the north-west corner. Here the silt from the whole area will lodge. It is of importance to note that after four years very little silt has been collected, indicating little loss of soil from this experimental demonstration area.

WOODLOTS AND SHADE TREES.

The shade trees planted on this area during construction in 1946 and 1947 have now reached a height of some 7 ft. or 8 ft.

The original pasture furrows constructed in 1943 and 1944 by the owner, using a road plough and horses on those lands to the south above the cultivation area, are now so well grassed as to have virtually disappeared after having served a very valuable purpose.

The larger pasture furrows on the high country to the east, constructed with a grader and of much larger capacity in 1945 and 1946, are still very much in evidence and have contributed a great deal to the satisfactory soil conservation position on the lower lands.

CONCLUSION.

This was one of the earliest demonstrations of the Service in the Central West or indeed in New South Wales; a severely eroding area of low productivity has been transformed into a stable portion of the farm showing very high productivity. All operations designed to mitigate erosion have been thoroughly tested during the four-year period by storms and continuous rain of higher intensity and longer duration than usual. Results can be regarded as entirely satisfactory.

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THE CONTROL OF EROSION IN N.S.W.*

BY

R. E. ORR, A.S.T.C., A.M.I.E. (Aust.), Engineer.

THERE is nothing new about soil erosion. What is known as geological erosion has been taking place ever since the world began. In a natural, undisturbed environment, the dense cover of vegetation retards soil erosion to such a pace that new soil is generally formed from the parent materials, beneath the top soil as rapidly as the top soil is carried away from above. This more or less natural removal of top soil is known as geological erosion and can be regarded as a normal process. This type of erosion does not affect the productivity of the soil so that, except from an academic point of view, we are not vitally concerned with its processes.

When the natural vegetational cover is removed for special purposes the soil then becomes directly exposed to the abrasive action of the elements. When in this exposed condition transportation processes of an extremely rapid order are set in motion. This accelerated rate of erosion is the type commonly known to-day as soil erosion. Unless steps are taken to check its progress, it becomes the most potent single factor in the deterioration of productive land.

EARLY ATTEMPTS AT EROSION CONTROL.

Some erosion control methods were employed even in the earliest times. Phoenicia led the old world in the construction and cultivation of irrigated terraces. The Romans recommended the use of contour furrows and contour banks on the steep slopes. Peru, in South America, was the cradle of agriculture in the new world. The carefully planned system of stone terraces built by the Incas effectively held the soil on the steep slopes and thousands of acres of these terraces are still cultivated to-day.

The current erosion crisis in North America can definitely be attributed to the exploitation of land following European settlement. Farming on the North European type was introduced by colonists along the Atlantic sea board and spread westward. In the west cattle were introduced from Spain via Mexico and the cattle grazing area was extended northward and eastward. The two systems met in the Great Plains region. Farming, overgrazing and low rainfall conspired to create the American "dust bowl". National concern for soil erosion in America dates from an extraordinary occurrence on 12th May, 1934, when a single widespread duststorm carried away more than 300 million tons of soil from the "dust bowl" and blotted out the sun over about two-thirds of the continent. The United States Congress passed various Acts which set up the Soil Conservation Service.

EROSION IN NEW SOUTH WALES.

Land exploitation in Australia and the consequent erosion are comparatively recent. The first settlers attacked the forests with fire and axe to open farms and pastures and to supply the markets with eucalyptus, a timber which was hard enough to be used by British shipyards for making cog wheels. With the cutting of the forests, the flow of rivers became less regular, sediment blocked the channels and floods increased.

From about 1860 settlement of the area west of the Mountains was stimulated by the discovery of gold. Cultivation was commenced and new crops and animals were introduced. From there on the same old story can be told. The land was overworked and in many cases unwisely used. Serious soil erosion has been the result.

By 1938 the New South Wales Government realised that the position had become very serious and in that year the Soil Conservation Act was passed.

* This article forms the basis of an address delivered by the author to the Institute of Engineers (Aust.), Sydney Division, Highways and Local Government Branch, June, 1950.

EROSION SURVEY OF NEW SOUTH WALES.

A detailed survey was made during 1941-1943 of the Eastern and Central Divisions in order to ascertain the extent and severity of soil erosion. These two Divisions embrace virtually the whole of the State's agriculture and some 90 per cent. of the livestock. The area of these two Divisions is about 120,000,000 acres.

It became apparent in planning operations that the scale of mapping must be sufficiently broad to allow the survey to be completed in a reasonable time, yet sufficiently narrow to gain precise information as to erosion and land utilisation on individual properties.

A scale of two miles to the inch was decided upon, and the standard county map was used. The ninety-eight counties of the Eastern and Central Divisions formed convenient units for mapping.

For mapping purposes, eight erosion classes were used:—

A. Very badly gullied, production vitally affected.

B. Seriously gullied, production seriously affected.

C. Shallow gullies, sheet erosion serious.

D. Bottom lands badly gullied, sheet erosion only on the uplands. (A typical tableland erosion class.)

E. Sheet erosion only.

F. Moderate wind erosion.

G. Severe wind erosion.

H. No appreciable erosion.

The boundaries of all these classes were plotted on the maps in the field with the assistance of a one inch square grid which was superimposed over the map. Particular care was exercised in regard to the boundaries of the very severely eroded areas, viz., classes A, B and G.

In addition to mapping the whole area into these erosion classes certain special aspects of erosion could not be mapped on the scale used. These included river bank erosion, siltation of streams, detrital deposits, roadside and stock route erosion and any major erosion control scheme. Special notes were taken of all these in each county and included in the county reports.

Significance of Survey.

As can be imagined, the information which was recorded was rather extensive, but a very broad summary can be stated as follows:—

1. 882 sq. miles or 0.5 per cent. of the total area of the two Divisions is suffering severe and extensive gully erosion.
2. 30,171 sq. miles or 16.6 per cent. is suffering moderate gully erosion.
3. 36,888 sq. miles or 20.4 per cent. moderate sheet erosion.
4. 18,650 sq. miles or 10.3 per cent. moderate wind erosion.
5. 974 sq. miles or 0.5 per cent. severe wind erosion.
6. 93,666 sq. miles or 51.7 per cent. no appreciable erosion.

Most of the area of 882 square miles suffering severe and extensive gully erosion is beyond economic reclamation, although treatment may be essential to stop the rapid spread to other adjoining lands. From an economic production point of view, however, an area of over half a million acres of once fertile land has been lost to New South Wales. If the 30,171 square miles suffering moderate gully erosion is not treated within the near future there is a grave danger of a large portion of the State's land joining the half a million acres beyond reclamation.

The 20.4 per cent. of sheet eroding country and 10.3 per cent. of land suffering moderate wind erosion are not, as a whole, in immediate danger but the present land utilisation practices are rendering the country unstable and the early danger signs are everywhere apparent.

The 974 square miles or 0.5 per cent., suffering sever wind érosion, is also probably beyond economic reclamation, but here again drastic action is urgent to prevent the rapid spread of this type of eroding land to adjoining areas. Only 51.7 per cent. or a little more than half the total area of the Eastern and Central Divisions shows no visible signs of erosion but these may appear soon if due care is not taken.

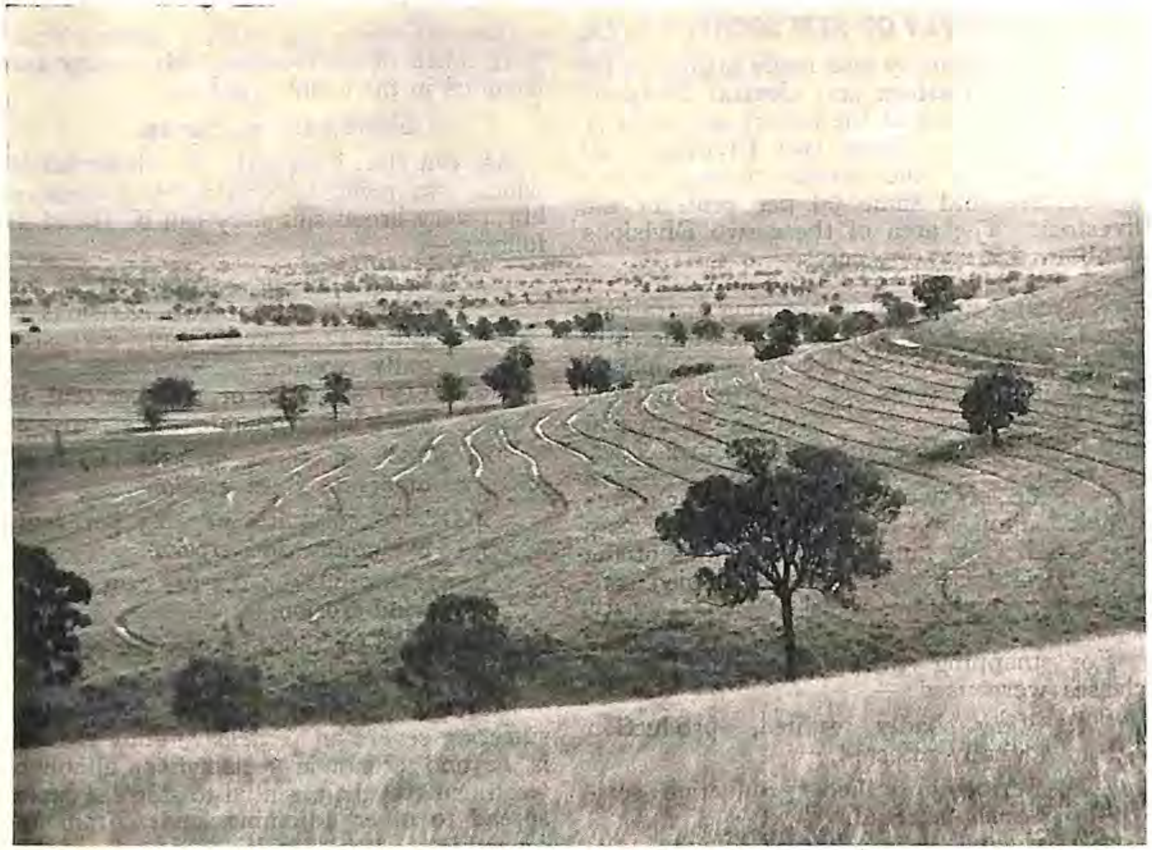

Fig. 1.—Pasture furrows in the Scone district.

When these findings are considered in relation to the fact that the whole of the agriculture and 90 per cent. of the livestock of New South Wales are located in these two Divisions, the imperative necessity for rapid stabilisation of huge areas of land should be apparent.

ROADSIDE EROSION SURVEY.

During 1946 a questionnaire was sent out to each Local Government Authority which it was considered would be vitally concerned with erosion along the sides of roads. The majority of the municipalities were not circulated but those whose areas extended out into agricultural lands were asked to fill in this questionnaire.

It will, of course, be admitted that this was not the best method of obtaining the overall picture of the problem, as various councils had different conceptions of the seriousness of soil erosion, but with all its faults it did give a reasonably satisfactory overall picture of the extent and seriousness of roadside erosion. Replies to the questionnaire were received from 131 shires and forty municipalities.

Generally speaking, those shire areas which are located on the Western Slopes are experiencing the greatest amount of difficulty in controlling erosion. A very condensed summary of the result of this survey is set out below:—

Classification.

Main and Trunk Roads	9,192
Highways	4,345
All other roads ..	76,003
	89,540 miles.

TABLE I.

Extent of Erosion.

Class.	Seriously Eroded Miles.	Slightly Eroded Miles.	Total Eroded.	Percentage of Total.
				per cent.
Highways ...	109	279	388	8·9
Trunk and Main Roads ...	412	820	1,232	13·3
All other roads...	2,679	6,799	9,478	12·5
Totals ...	3,200	7,898	11,098	12·4

TABLE II.

Main Causes of Erosion.

Cause.	Miles Eroded.	Percentage.
		per cent.
1. Road drainage entirely ...	3,217	29
2. Partly road and partly adjacent land drainage ...	4,440	40
3. Adjacent land drainage entirely	3,219	29
4. River and stream encroachment	112	1
5. Other causes	110	1
Totals	11,098	100

Causes of Roadside Erosion.

It can be seen from the above figures that the cause of roadside erosion can be subdivided into four main groups. The first of these and also the most important cause is due to a combination of run-off from adjacent private property and the road. This usually takes two main forms. Surface drainage flows in an uncontrolled manner; finds its way into natural drainage lines and eventually scours out a gully which either follows alongside the road or cuts directly across, necessitating a culvert or bridge. If the road is located on comparatively level country then the deposition of silt on the road surface often becomes a costly proposition.

As this paper is addressed in the main to a body of Highway Engineers, the methods of combating soil erosion in general and roadside erosion in particular will be dealt with more from the point of view of the Highway Engineer than otherwise.

MECHANICAL CONTROL METHODS ON PRIVATE PROPERTY.

There is only one successful way of correcting soil erosion. The water must be properly controlled right from the top of the catchment. The use to which the particular catchment is put has a very important bearing on soil erosion and this very frequently requires modification to correspond with the mechanical works contemplated.

The devices which have proved successful for controlling this problem are daily becoming better known, and increasingly employed by farmers. Pasture furrows are constructed on the higher sloped country, graded banks and waterways are adopted for the lower sloped ground. Other mechanical devices are used in special circumstances such as drop inlets, diversion banks, absorption banks, dams and gully checks. These devices must really be regarded as being a means to an end. The ultimate aim must be to establish and maintain an adequate vegetational cover. The mechanical works have the effect of increasing the time of concentration and decreasing the run-off. The increase in moisture content of the soil, together with a modification of the land use, will give the required natural protection against soil erosion.

The whole aim of mechanical works is to increase, as much as possible, the time which surface water will take to flow from an area. Many works already undertaken have been so successful in this respect that under normal rainfall intensities, no run-off has been observed.

When gullies are encountered on private lands these are usually graded down and can again be used for productive purposes. If the gullies are too large they are left in their existing state. A waterway is constructed to carry any surplus run-off and as the flow has been cut off from the gully it naturally sloughs in and heals up with natural vegetative cover.

Details of Mechanical Control Measures.

Of the various mechanical devices which are used the pasture furrow is the least expensive and has proved extremely effective. This consists of a furrow which is constructed as nearly as possible on a contour. If, due to obstructions, such as trees or boulders, the furrow departs from a contour, then small earth checks are placed at intervals along the furrow to prevent water from

Fig. 2.—A series of graded banks in the Tamworth–Manilla area. Cultivation takes place over the banks.

moving along it. The cross-sectional capacity of the furrow usually approximates 1½ sq. feet but this is frequently varied due to circumstances. The distance between furrows is also a variable but usually never exceeds 30 feet or is less than 12 feet. Overtopping of the furrows certainly does occur but maintenance has not proved to be an expensive problem.

As mentioned earlier most of the mechanical devices which are used to combat soil erosion are aimed at retaining the run-off on the land as long as possible so that a greater proportion of the rain will infiltrate into the soil. This is the effect which pasture furrows have. They also have another very important function. Pasture seeds which might otherwise be washed or blown away are caught in the furrow and this fact, together with the additional moisture which is available, causes very rapid pasture germination. Usually a very dense pasture sward grows in the furrow very soon after construction. This grassing effect has caused this type of furrow to be known as a pasture furrow.

Pasture furrowing is usually used on the higher sloped grazing lands. The slopes on which these would normally be used vary from 10 per cent. to 25 per cent.

Since the size and shape of a furrow are determined by the machinery used, the spacing is designed to correspond with the estimated run-off. The spacing can be conveniently estimated from the following equation based on intensity formula in the Institution of Engineers, Stormwater Standards Committee report.

In general $S = \dfrac{1452a}{C.P.F.T.^{0.31}}$ feet for the western section of N.S.W.

or $S = \dfrac{1452a}{C.P.F.T.^{0.4}}$ feet for the coastal section of N.S.W.

In practice the following approximations would suffice—

$S = \dfrac{656a}{P.F.}$ feet for western N.S.W.

or $S = \dfrac{400a}{P.F.}$ feet for coastal N.S.W.

where S = horizontal spacing between furrows
a = cross sectional area of furrow in square feet
C = Co-efficient of run-off (usually 0·5)
P = Constant of Locality
F = Frequency factor
T = Time of duration in minutes of rain giving a maximum volume of run-off. One hundred and twenty minutes is considered a suitable limiting value for T.

Absorption Banks.

Where the rugged nature of slopes prevents the economical construction of pasture furrows, absorption banks are usually constructed. The size and capacity of an absorption bank depends on the run-off volume to be expected from the slopes above it. Sometimes it may be necessary to construct several lines of banks if the catchment areas are too large. These banks, like pasture furrows, are constructed on the contour. In practice it is not possible to construct these perfectly level so that earth checks are usually provided at intervals to prevent water flowing along the bank. The ends of the banks are blocked up to prevent water escaping.

The cross-sectional area of an absorption bank channel required to protect a given area can be estimated from the following formula.

$a = \dfrac{30\ C.P.F.A.T.^{0.31}}{L}$ for the western section of N.S.W.

or $a = \dfrac{30\ C.P.F.A.T.^{0.40}}{L}$ for the coastal section of N.S.W.

where L = Length of bank in feet
a = cross sectional water carrying capacity of bank in sq. feet
C = Co-efficient of run-off volume (usually 0·5)
P = Constant of locality
F = Frequency factor
A = Area of bank catchment area
T = Time of duration of rain giving the greatest volume of run-off. One hundred and twenty minutes is considered suitable.

Absorption-Diversion and Diversion Banks.

It often happens in practice that ordinary absorption banks which are designed to pond water cannot be conveniently built or it may happen that the size required is too large and costly. In such cases an absorption-diversion bank or a pure diversion bank may be used.

The so-called absorption-diversion bank is built with a level grade but differs from a true absorption bank in that the water is allowed to flow out from either or both ends. If one of these banks is built with a slight grade, of say 1 in 1000, then it is known as a diversion bank. Where the batters of the channel section of these banks approximate 1 in 3 then the depth of channel required can be estimated from the following formula.

ABSORPTION-DIVERSION BANK.

$H = \left\{\dfrac{C.F.A.P.}{12T^{0.69}}\right\}^{2.5}$ for the western section of N.S.W.

or $H = \left\{\dfrac{C.F.A.P.}{12T^{0.60}}\right\}^{2.5}$ for the coastal section of N.S.W.

where H = Maximum depth in bank channel in feet
C = Co-efficient of run-off
F = Frequency factor
A = Area of bank catchment
T = Time of duration in minutes of rainfall which produces a maximum volume of run-off. One hundred and twenty minutes is considered a suitable limiting value for T.

Diversion Banks.

With a grade of 1 in 1000 the depth of channel required can be estimated as follows:

$$H = \left\{\frac{C.F.A.P.}{30T^{0.69}}\right\}^{\frac{3}{8}} \text{ for western section of N.S.W.}$$

$$\text{or } H = \left\{\frac{C.F.A.P.}{30T^{0.60}}\right\}^{\frac{3}{8}} \text{ for coastal section of N.S.W.}$$

where H, C, F, A, P and T have the same meanings as before.

Graded Banks.

Graded banks are in effect a series of small diversion banks constructed on cultivated areas. Pasture furrows are not suitable for use on arable land so it has been necessary to develop a different type of mechanical control. The land must remain so that cultivation can be continued, the number of obstructions or banks must, therefore, be kept to a minimum. These devices simply consist of a bank with a relatively large cross-sectional area and usually not longer than 2,000 feet. As no overtopping can be permitted within practical and economical limits on cultivation land, the banks are constructed with a slight grade.

These graded banks have been the subject of a great deal of experimentation in New South Wales to determine the most suitable cross-sectional shape, capacity, maximum length, spacing as well as the most suitable grades. Cultivation normally takes place right over the banks so that they must be capable of allowing farm machinery, including a header, to pass over them. This means that the cross section must consist of a series of vertical curves of rather large radius. It has been found that discharge velocities of more than 1.5 feet per second, cause an excess of soil movement so that when the banks are flowing to capacity the grade must be such that this velocity is not exceeded. The grade of these banks usually varies between 1 in 200 and 1 in 1000. The vertical interval between banks does not as a rule exceed 9 feet, and the catchment area of each bank does not normally exceed 10 acres.

Fig. 3.—A view looking along a newly constructed waterway in the Tamworth area. Note straw mulch in foreground.

Given a certain cross-sectional area for the bank, the length and the spacing, the required grade can be estimated from the following formula.

$$s = \left\{\frac{C.F.A.P.}{aKT^{0.69}}\right\}^{2} \text{ for the western section of N.S.W.}$$

$$\text{or } s = \left\{\frac{C.F.A.P.}{aKT^{0.60}}\right\}^{2} \text{ for the coastal section of N.S.W.}$$

where s = grade of bank in feet per foot

a = cross sectional area of channel in sq. feet (usually about 7 sq. ft.)

$K = \frac{1{\cdot}486r^{\frac{2}{3}}}{n}$ from Manning's Velocity formula where

r = hydraulic radius of channel (usually about 0·6 times the depth in feet)

n = roughness co-efficient of channel bed.

C, F, A, P and T have the same meanings as in previous formulae.

Waterways.

The general purpose of a waterway is to safely convey the water, discharged into it and from graded banks or diversion banks, down to a lower level where it can be safely allowed to spread over the ground. They are also constructed for special purposes such as a bye-wash from a dam.

These devices are simply a wide-grassed channel with level-cross section. They are constructed to any desired width depending upon the water-carrying capacity required. Small banks are provided on each side of the waterway to confine the flows. Level checks or spreaders are usually placed across the waterway a little below the outlet of each graded bank. These maintain an even depth of flow across the full width of the waterway. A layer of straw held down by wire netting is quite suitable. Other devices such as thin boards or galvanised iron strips let into the ground are also used on occasions. In order to prevent flows of water from damaging the waterway until vegetation has been well established, straw mulching is frequently resorted to. This consists of spreading straw mulch to a depth of 1 inch to 2 inches over the waterway after sowing appropriate vegetation. The straw is usually held in place by wire netting which is subsequently removed for re-use.

Apart from the location, the most important point to be considered in the design of an artificial waterway is the width required to ensure that the velocity of flow will not often reach a dangerous figure. The width should be sufficient to ensure that the velocity of flow will not exceed 5 feet per second more often than once in ten years. If the grass cover is good, velocities of 8 feet per second can be carried for short periods without damage.

The depth of flow should not exceed the depth obtained by solution of the following equation based on Manning's formula.

$$d = \frac{6{\cdot}17n^{\frac{3}{2}}}{s^{\frac{3}{4}}}$$

where d = depth of flow in feet

n = co-efficient of roughness of grassed waterway

s = grade of waterway, feet per foot

The time of concentration of the waterway for purposes of design should not be more than the time obtained by solution of the following equation.

$$T = \frac{L_B}{45} + \frac{L_W}{150}$$

where T = Time of concentration in minutes

L_B = Length of longest bank in feet discharging into the waterway

L_W = Length of waterway in feet.

When the maximum velocity, depth and time of concentration are known the required width of waterway can be estimated by the following formula.

$$W = \frac{2\,C.F.P.A.}{dV(3{\cdot}6+T)^{0.95}} \quad \text{for the western section of N.S.W.}$$

$$\text{or } W = \frac{2\,C.F.P.A.}{dV(2{\cdot}1+T)^{0.60}} \quad \text{for the coastal section of N.S.W.}$$

where W = Width of waterway in feet
C = Co-efficient of run-off (usually 0·5)
F = Frequency factor
P = Constant of locality
A = Total catchment area emptying into waterway
d = depth of flow in waterway (usually 5 ft. per second)
V = Maximum velocity of flow.
T = Time of concentration at end of waterway in minutes.

Coefficient of Run-off.

For soil conservation design purposes in New South Wales a coefficient of run-off of 0.5 has been generally adopted. It, of course, must be remembered that the use of this value for the co-efficient is restricted to areas upon which soil conservation measures are to be adopted. Soil conservation practices have a very definite effect on the proportion of rainfall which actually runs off an area. In practice it has been found that the adoption of a co-efficient of 0.5 is quite conservative for soil conservation design purposes.

Other Mechanical Measures.

We have now briefly dealt with the main mechanical devices which are used to help combat soil erosion. There are, of course, many other devices which are used but the broad scope of this paper does not permit of more than a passing mention of some of these. There is the erosion control dam which is designed to reduce the intensity and frequency of destructive discharge down a

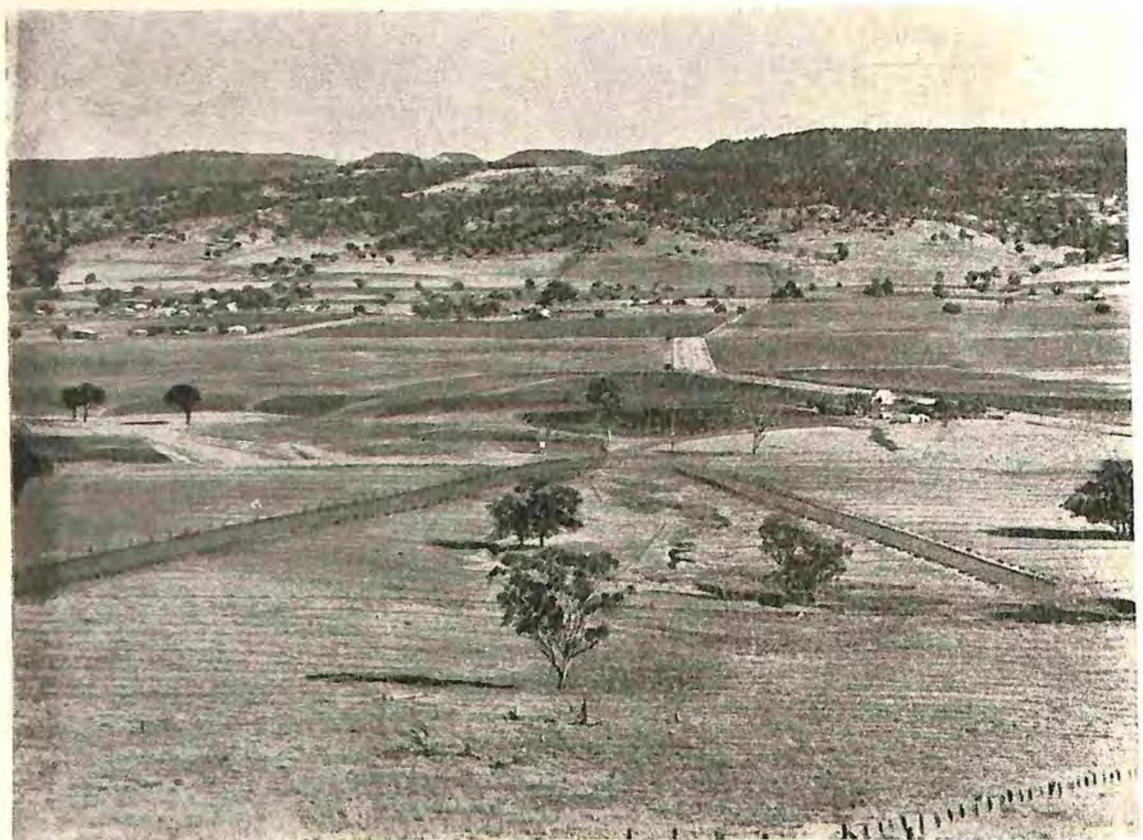

Fig. 4.—General view of an erosion control demonstration showing waterways, graded banks, pasture furrows and dam. The old gully in centre is no longer actively eroding.

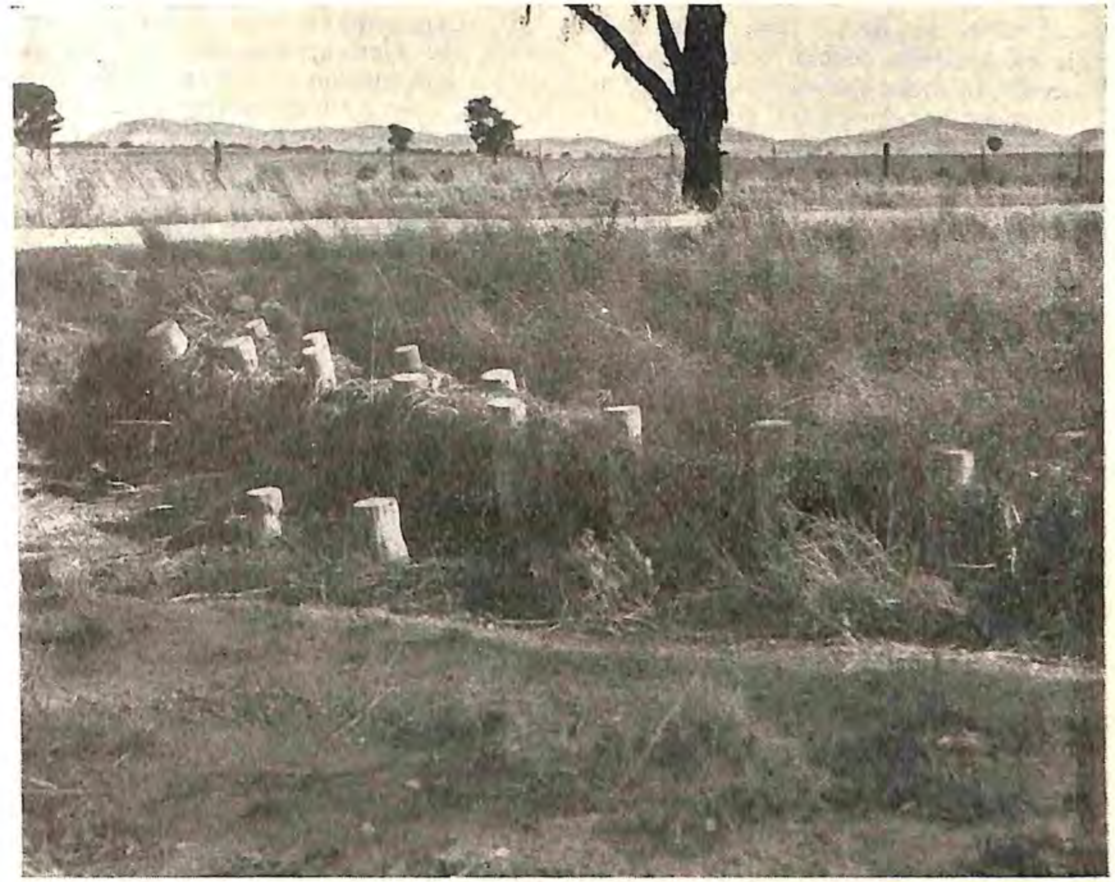

Fig. 5.—An experimental brush type roadside gully control structure in the Tamworth district.

gully. There are also many varieties of drop inlets and outlets. These are frequently used where a waterway discharges into a dam or creek. For special reasons small soil check dams are sometimes used.

Land Use.

The construction of mechanical control measures will not, as a rule, prevent soil erosion. In nearly all cases it is necessary to alter the method of farming. Cultivation must be restricted to slopes which are not excessive. An enormous amount of valuable top soil has been lost simply because the farmer had cultivated on slopes which should have been used entirely for grazing purposes. Very frequently grazing has been too intensive or clearing and grazing has been permitted on very steep hills which should never have been cleared of the protective timber. In order to control erosion on this very steep land it is usually necessary to exclude all stock and reafforest the area. The practice of contour strip cropping is strongly recommended as being a very effective method of retarding soil movement.

Generally speaking the adoption of a wiser land-use policy by the farmers has a more important bearing on the control of soil movement than pure mechanical measures. However, I do not propose to dwell on this aspect as engineers are generally more interested in the mechanical side of control measures which are adopted.

Roadside Erosion.

All of the above control techniques are being applied to the private lands throughout the worst-affected areas of the State as quickly as plant and personnel are made available. It is therefore only a question of time before the effect of run-off from these lands on roadside erosion will be greatly reduced. In order to keep pace with this development it behoves the road engineer to accept the challenge and develop more satisfactory and safer water disposal techniques on the roads. I suppose one of the most troublesome problems which engineers have to face, particularly in country areas, is how to dispose of run-off from the road area without causing erosion on adjacent lands. As the farmer becomes more soil conservation conscious this disposal problem will become more embarrassing to the engineer unless something is done.

According to Table II approximately 29 per cent. of all roadside erosion troubles are caused by the surface run-off from the road area itself. I mean by road here the full width from fence to fence. Roadside erosion usually takes the form of gullies alongside the road. In many cases these gullies are threatening to undercut the road formation. Road authorities usually become actively concerned when this happens and there is evidence all over the country where attempts have been made to stabilise a gully which has become dangerous.

These attempts to reclaim a gully usually take the form of small check dams. It must be admitted that a large number of these structures have not been successful. The reasons for these failures have been investigated in many instances and in most cases the failure can be attributed to an insufficient notch or spillway capacity. From an engineering point of view, these individual structures are quite small but if failures are to be avoided it is essential that they be designed and constructed along sound lines. A secondary form of stabilisation consisting of the planting of grass should also be considered.

There are many roadside erosion problems which the highway engineer has yet to solve. It is obvious that a costly concrete, stone or even bitumen paving of all areas which are subject to soil erosion would be beyond the financial resources of the community. It seems then that the highway engineer will have to turn to some of the cheaper mechanical devices which are used on arable or grazing lands. In many cases the construction of pasture furrows will prove very effective. Broad grassed waterways will possibly have to be provided next to the road to safely carry run-off. All open drains will possibly have to be graded so that dangerous velocities will not be reached. In the future it is possible that a better culvert design may be developed. The principle of "spread" rather than "concentrate" will have to be more widely applied.

CONCLUSION.

The successful control of soil erosion, whether on the roads or on the adjacent private lands, depends very largely on the co-operation which is achieved between the parties concerned. Soil conservation works certainly increase the amount of rainfall which is directly absorbed into the ground but there will always be surplus water which must be passed from one area to another. Sound soil conservation measures are now being increasingly adopted on the private lands and if corresponding control techniques are adopted on the roads then we will be well on the way towards successfully conserving for posterity the nation's most vital resource—the soil!

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ROLE OF MINOR DEMONSTRATIONS AND PLANT HIRE IN KEEPIT CATCHMENT AREA

By

E. T. Clark, H.D.A., Soil Conservationist.

In the discussion of the main Manilla and Namoi River Catchments in the article "Protection of Keepit Catchment Area", in Vol. 5, No. 3, T. F. Mau mentioned that "Major Demonstrations will be linked by a series of minor demonstrations and extensive hire work in the manner adopted for the treatment of creek catchments."

It is the purpose of this article to enlarge on this statement and emphasise the part played by the landholders in their willingness to co-operate in carrying out soil conservation work under the Plant Hire Scheme.

Soil conservation in co-operation with the landholders is now progressing rapidly throughout the Lower Slopes area, as a result of the early work undertaken by the Soil Conservation Service. This has been brought about following the Service's own work of foreshores protection and major demonstrations which, together, are playing a large part in the control of erosion, both in the foreshore and creek catchment areas.

MINOR DEMONSTRATIONS.

To connect up these valuable early works and to stabilise each creek catchment in turn, minor demonstrations are being carried out. They are proving their value mainly because they form focal areas of small sections which, if left, would result in extensive damage to other areas. For this reason, their part is of great importance in completing the control of the catchment areas. As these minor demonstrations are limited in size, not all the work necessary to make the area completely stable can be carried out in most instances.

PLANT HIRE WORK.

It is at this point that the landholder's co-operation in carrying out further work under the Hire Scheme is of untold value. This further section of the work has been made possible by:—

1. The introduction of the Amendment to the Soil Conservation Act, 1947.
2. Availability of Soil Conservation Service machinery for hire to landholders.
3. Provision of increased technical assistance to design the work and supervise installation.
4. The landholders providing, where necessary, seed to sow waterways, labour for sundry duties, fencing materials, altering fence lines, etc., to conform to the overall pattern of soil conservation land usage.

RESULTS OF UNWISE LAND USE.

There is very little land remaining under timber, even on the steepest country in this Slopes area of the Catchment.

In most instances, these lands show excessive run-off due to the following practices of unwise land use.

(*a*) In the early colonizing days of the district, timber destruction was carried out indiscriminately, extending in most instances to the summits of the hills, depriving the land of sufficient natural timber cover. There has been no thought of reforestation.

(*b*) Overstocking of the already sparse pastures with sheep and cattle.

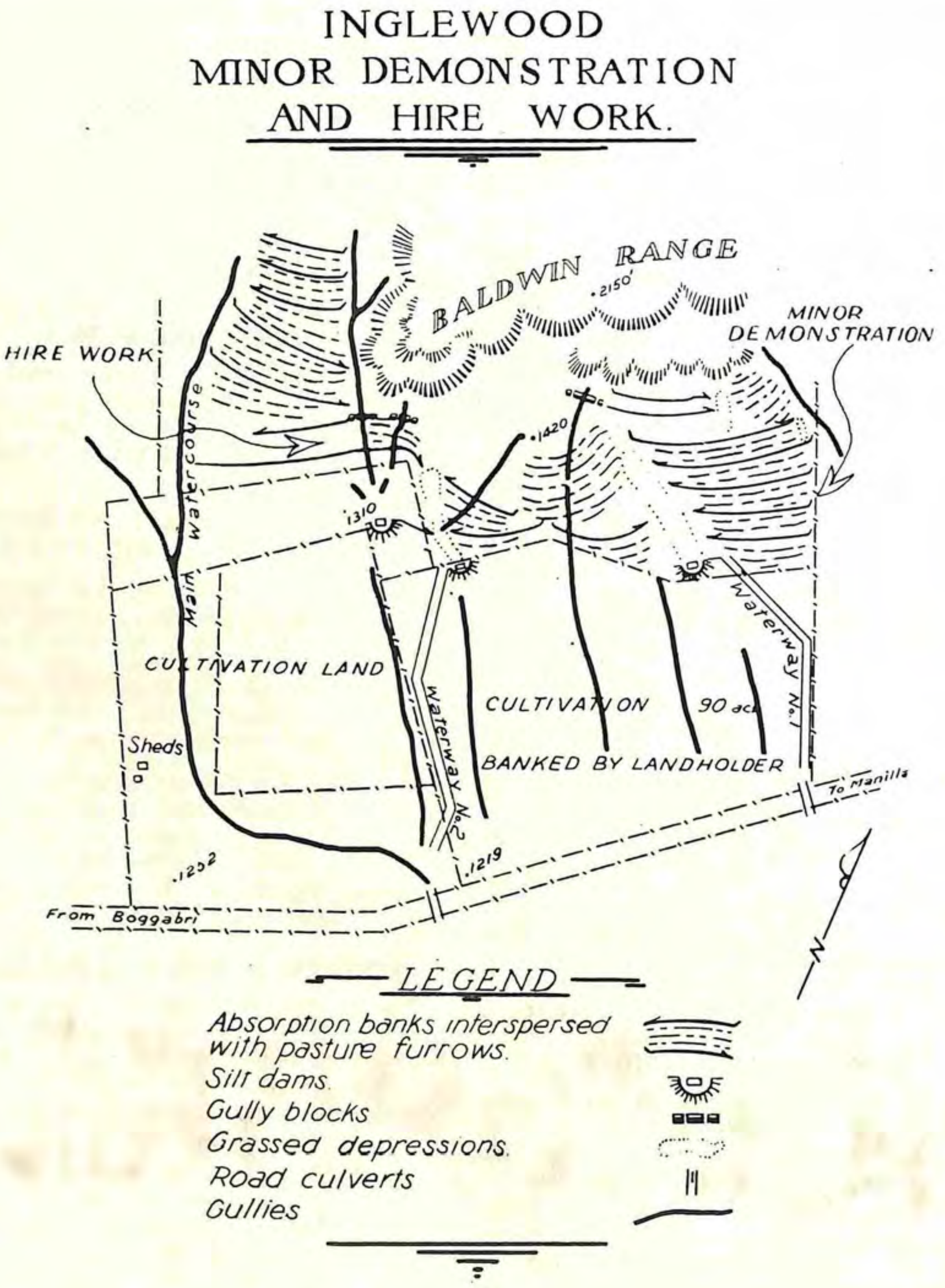

Fig. 1.

Fig. 2.—Gullies on grazing land in the Manilla district.

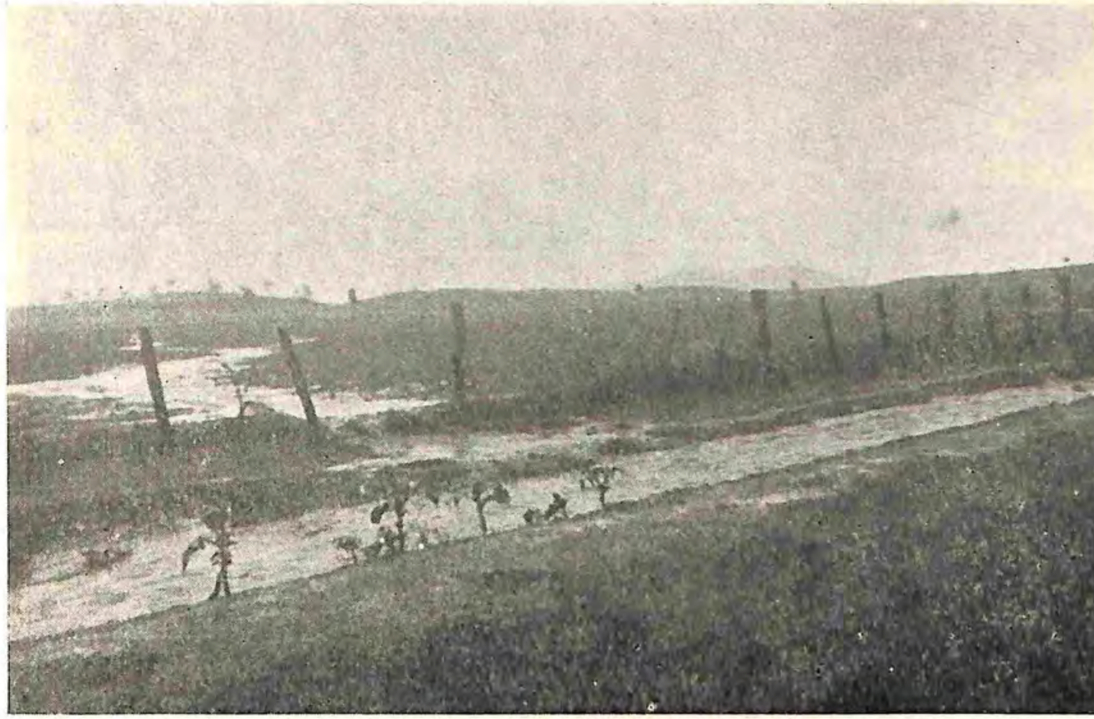

Fig. 3.—Run-off from arable land prior to the establishment of a minor demonstration on this area.

(*c*) Overcropping of all available arable land, very little consideration being given to rotational cropping or protection afforded by rotational grazing of idle cultivation land.

Due to the undulating and, in parts, steep nature of the upper slopes, run-off has had a chance to accumulate over large areas and increase to excessive proportions, due to the poor absorptive capacity of the surface soil, especially on "scalded areas"; this poor absorptive capacity is accentuated by lack of surface cover, causing untold damage to the arable land in the lower areas. Because of this, sheet and gully erosion has occurred, which in some cases has divided the paddocks into isolated areas, making these impossible or unprofitable to farm.

RECLAMATION.

To regain these areas and restore them to a workable size, the landholders are anxious to adopt soil conservation measures and it mainly is in these cases that work under the Hire Scheme is both popular and profitable. When linked with work carried out as a Minor Demonstruction, it forms a safe means of control, and an effective measure in the control of siltation within the Keepit Catchment Area.

AN EXAMPLE OF CO-OPERATION.

Within the Keepit Catchment Area a typical example of landholder and Service co-operation can be found in the case of Mr. A. G. Doring, "Inglewood", Manilla.

This landholder has a property of 1,440 acres made up of approximately 400 acres of cultivation on slopes under 8 per cent. and over 1,000 acres of grazing land on slopes from 6 to 60 per cent. The upper portions form part of the steep and precipitous Baldwin Range, which in this particular section rises 940 feet above the grazing land below.

Owing to its steep slope, rocky outcrops and absence of sufficient cover, this range forms a catchment on which the run-off

Fig. 4.—All the rainfall retained on the land after mechanical works have been undertaken.

Fig. 5.—A typical absorption bank, following heavy rain. The outlet is in the foreground.

would be nearly 100 per cent., being increased by the fact that all dead timber, both standing and fallen, was cleared many years ago to minimise rabbit harbour.

Consideration of these conditions, coupled with the fact that this area receives thunderstorms which at times have an intensity of 4 inches per hour, gives some idea of the damage done to the cultivation land and the Shire road which traverses the area. This road has in the past become impassible due to the excessive run-off from these areas.

Being very anxious to stabilise this area, Mr. Doring approached the Service for assistance in the form of a Minor demonstration, and to extend the work under the Hire Scheme.

PLAN OF CONTROL.

An intensive plan of control was drawn up consisting of:—

(*a*) Control of rabbits, judicious stocking, and wise land use practices on steep slopes by the landholder, in order to restore as much as possible of the natural cover. The area was too steep for any mechanical measures to be used to assist vegetative control of erosion.

(*b*) Gully blocks in the main gullies to check the accumulated run-off mainly from (*a*).

(*c*) Minor demonstration areas on lesser slopes, where mechanical measures could be used.

(*d*) Cultivation land to be graded banked by landholder after establishment of the waterways by the Service.

MINOR DEMONSTRATIONS.

Having the objective "to conserve as much water as possible on the land on which it falls", an intensive system of absorption banks, interspersed with pasture furrows, was carried out, in conjunction with carefully chosen grassed outlets on which to allow any overflow to find its way eventually to the silt dam.

Pasture furrows were installed where convenient on the adjacent areas not stabilised by absorption banks.

A waterway was constructed to act as a safe disposal area for the overflow of the dam mentioned, and to receive the graded banks constructed by the landholder in the cultivation land at a later date.

CONTROL BY HIRE WORK.

A small proportion of the necessary soil conservation measures were installed by the Service under the Minor demonstration scheme and further areas were then treated under the Hire Scheme by the landholder. These areas linked up with the minor demonstration, being mainly grazing land from which the run-off as before had caused sheet and gully erosion through the cultivation land below.

In this area intensive run-off had caused the formation of large gullies, necessitating the construction of gully blocks with graded outlets to convey surplus water to safe disposal centres. Control by absorption banks, interspersed with pasture furrows, was again carried out, linking up with a silt dam. A second grassed waterway on the other side of the cultivation paddock was constructed to serve as an outlet for any overflow from the dam and banks.

As this work could not be carried out by the landholder with ordinary farm machinery, the benefits of the Hire Scheme could be take advantage of, being supplementary to the previous work.

CONCLUSION.

Taking the situation generally, two conclusions can be arrived at:

1. Very difficult and extensive problems of erosion, and consequent stream siltation, can be tackled successfully where there is full co-operation between landholder and Soil Conservation Service and where all measures available are brought into play. These measures include complete vegetative and mechanical operations under the administrative set-up of the Demonstration, Minor demonstration, Plant Hire, and design and supervision under the General Extension Service Scheme.
2. Numerous landholders have undertaken Hire work in the Keepit Catchment Area under similar circumstances realising the value of the control work for their own particular problems as well as linking up with the major works already undertaken by the Service.

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INVESTIGATIONS WITHIN BURRENDONG CATCHMENT AREA

By

L. A. H. McCaffrey, B.Sc., Soil Conservationist.

TAKING the shape of an elongated oval whose major and minor axes measure 130 and 90 miles approximately, Burrendong catchment comprises 5,360 square miles of the Central Highlands of New South Wales. The proposed dam with its recently increased wall height is planned to impound about 600,000 acre feet of water contributed by two major rivers, the Macquarie and the Cudgegong. (Fig. 1).

The catchments of these rivers contain much land having undergone more prolonged use by agriculture, grazing and mining than any other in the State, with the exception of the coastal riverine lands. This fact, considered with the many variations of micro-climate, soil and landform, the basic "raw materials" used in primary production, presents many problems requiring critical examinations by the Soil Conservationist.

In this article an attempt will be made to describe how the physical aspects of these data are being resolved into terms sufficiently accurate to serve as a basis for the conservation of farming and grazing lands and to prolong the effective lifetime of Burrendong Dam by reducing the suspended silt load of the catchment streams.

OBJECTS AND SCOPE OF THE INVESTIGATIONS.

The immediate aim is to produce a map of erosion-hazard classes, each class of which will have its own combination of soil-losing factors. Soil erosion is a phenomenon which, in a given climate, reacts regarding its qualities to the naturally occurring association of slopes, soils and vegetation, superimposed upon which is man's use, *i.e.*, cultivation of all types and the seasonal practices associated therewith; grazing by stock and its characteristics from place to place; road making and mining. Before mapping hazard, then, it is necessary to have reasonably accurate knowledge of slopes, soils, land-use and vegetation.

Of these factors, slopes, soils and land-use are being mapped upon parish maps together with existing erosion. Existing erosion and its maturity are important since clues are given to the magnitude and nature of control work by its varying degrees of seriousness and its qualities are a summing up of the hazard factors producing it, both physical and human.

Vegetation is being mapped upon the land-use survey as regards the composition of the virgin and other timbered classes, but the various associations, as such, are not recorded upon the erosion hazard map.

Rainfalls are being analysed for reliability via the Dispersion Diagram system used with success by P. R. Crowe in his work upon the rainfalls of the United States Great Plains and the Indian monsoon lands.

GENERAL DESCRIPTION OF CATCHMENT FACTORS.

Geomorphology.

The Macquarie and Cudgegong Rivers and their tributaries are rejuvenated streams which, since Miocene times, have been steadily dissecting the western half of the Central Eastern monocline of New South Wales. Burrendong catchment then consisted of a gently rolling to slightly hilly peneplain in which the rivers flowed in broad, mature valleys. Contemporaneous vulcanism resulted in basalt and allied eruptive rock flows upon large areas of this surface and into many of its valleys. The rejuvenated streams have subsequently cut steep-sided valleys through this surface leaving hardened valley flows overlying old river gravel upon the shoulders of the new valley.

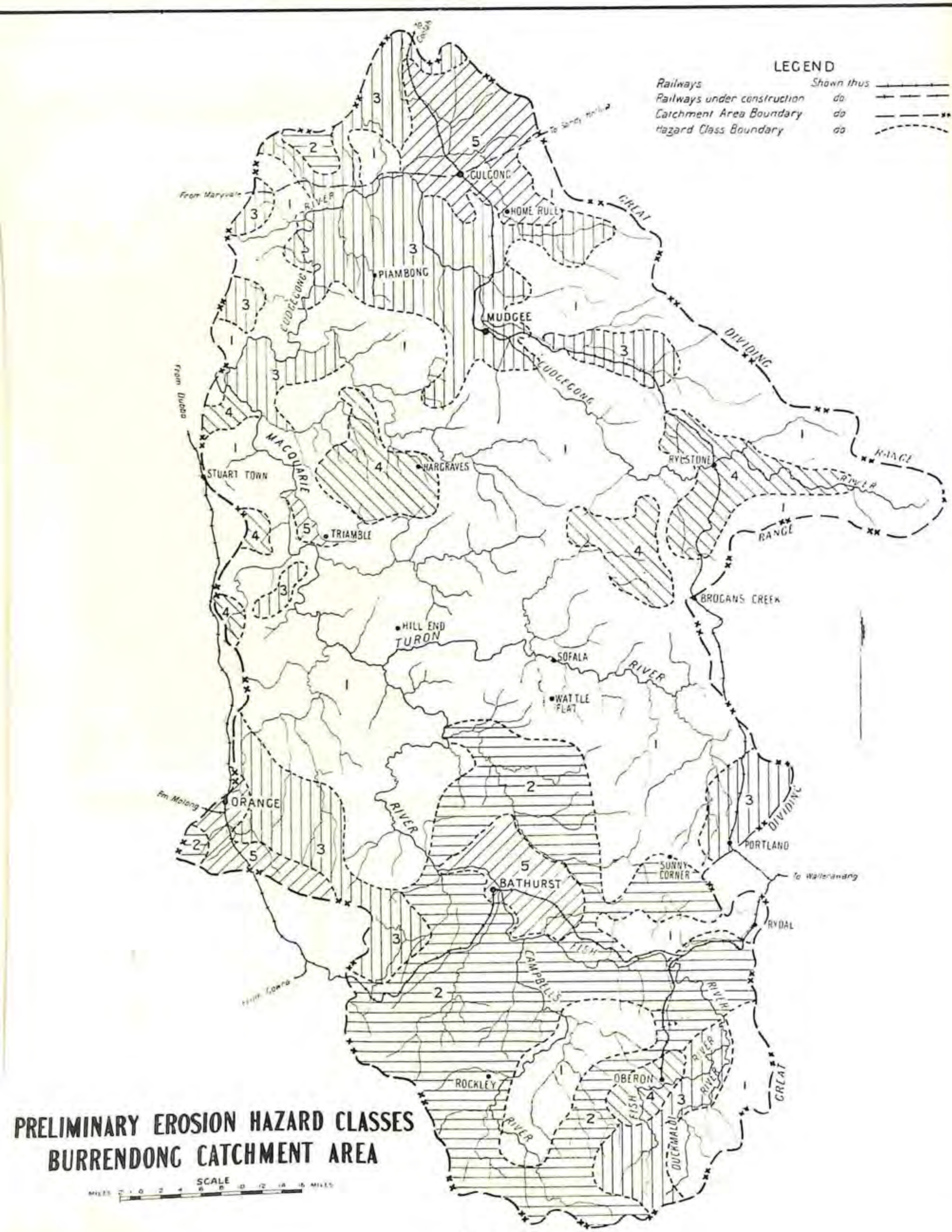
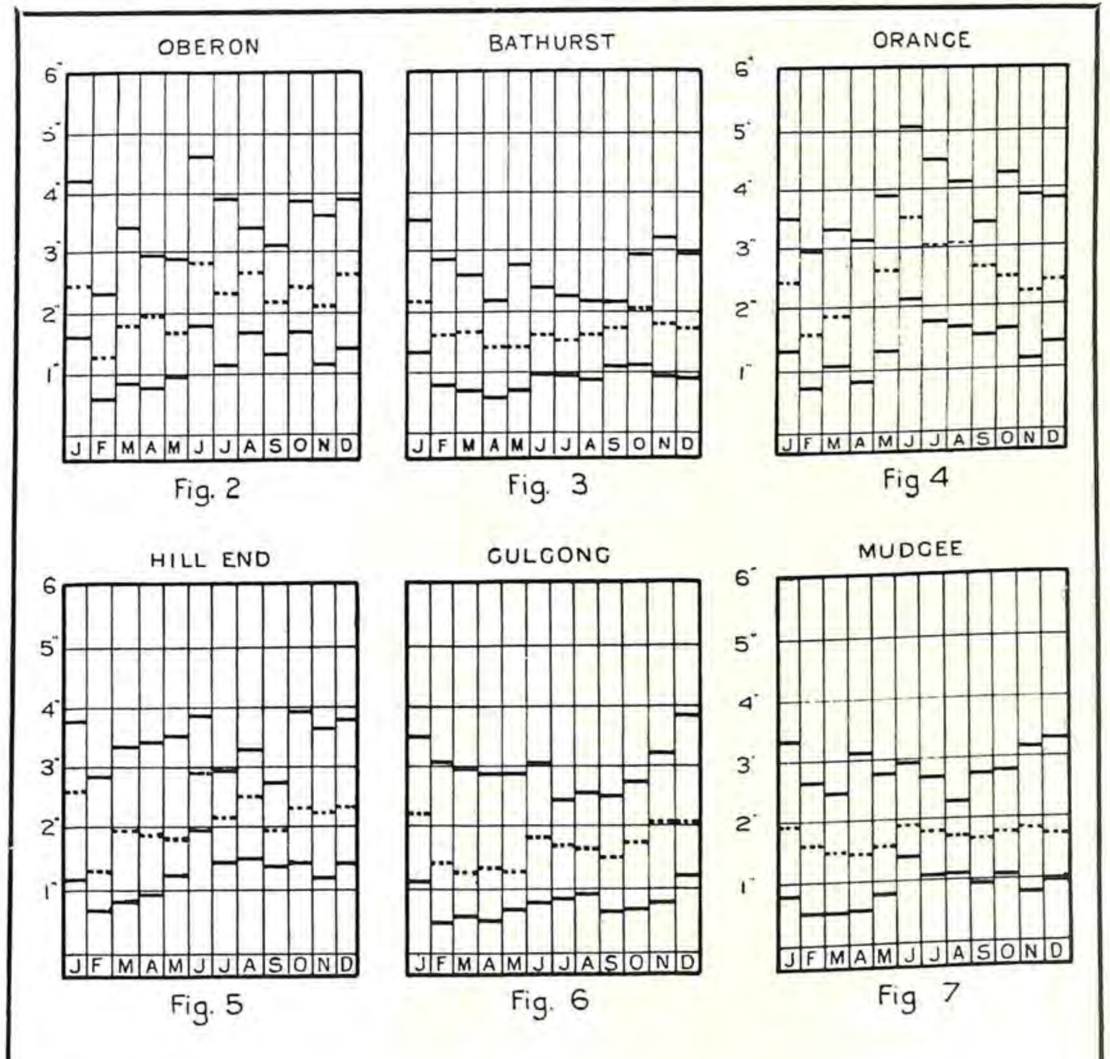


Fig. 1.

Normal erosion associated with the rejuvenation has removed much of these flows; the river valleys, particularly that of the Macquarie, for some 50 miles from the dam site, shows a mutilated valley-in-valley structure with remnant basalt "flat-tops" perched some 400 to 500 feet above the river's present level.

The Cudgegong river valley opens out in the neighbourhood of Gulgong, particularly to the north and east, owing to the presence of a large area of granite, a less resistant rock than the general slate-diorite complex which forms the basement rock over the greater part of the catchment. Granite also occurs extensively along the Macquarie valley in the neighbourhood of Bathurst with the similar result of undulating plain land.

All of the ancient Miocene surface is by no means consumed and large areas of flattish to strongly undulating upland exist at, for



RAINFALL DISPERSION

Diagrams for Catchment Area Weather Stations example, Hargraves at an elevation of from 2,700 to 3,000 feet; east of the Canobolas Mountains at Orange, at an elevation of 3,000 feet, north and east of Oberon, at elevations from 3,000 to 3,600 feet and in the Meadow Flat—Sunny Corner district at an elevation of 3,600 feet. All of these areas, or as they might be better termed, plateau remnants, are drained by small consequent streams whose gradients steepen markedly as they approach a major stream. Precipitous valleys are the rule in their lower courses.

The included map of the catchment (Fig. 1) depicts the approximate extent of these various types of landform and represents a basal map of hazard as far as pure landform can indicate. Detailed definition of such regions is proceeding in the mapping of hazard.

Climatic Investigations.

With only two limited stretches of extensive lowland, *i.e.,* Bathurst Plains and the Mudgee-Gulgong district, amid much roughland whose high points average 3,000 feet, the general climate is a highland one. Warm summers and cool to cold winters are the rule with snow falls common on land of 3,000 feet and more.

Rainfall analysis shows in the higher southern country a tendency to winter incidence with sporadic summer convectional falls of varying volume. The only two stations with long record are the lowland ones of Mudgee and Gulgong and they show a tendency to even distribution. Diagrams and descriptions are furnished to show these trends for the whole catchment.

Detailed, accurate climatic investigations are usually difficult in Australia owing to the scarcity of stations recording all necessary elements for any length of time. In Burrendong catchment only Bathurst is fully equipped, whilst only five record temperature in addition to rainfall. All other stations record only rainfall and these are often some distance apart. With these facts in mind, climatic investigations have been divided into two sections—

(1) Consisting in the establishment of a close network of landholders recording data for the S.C.S. Some of these landholders are already furnishing reports for the Commonwealth Bureau of Meteorology, but many are recording purely for their own information.

(2) Consisting in the analysis of all possible records collected from official and private sources of over thirty-five years' duration upon rainfall dispersion diagrams. This technique, developed by Crowe in his American and Indian studies, enables, firstly, the rainfall regime of a station to be summarised graphically and, secondly, immediate visual estimation can be made for reliability. The method is such that mathematical indices can also be easily calculated for the reliability. Constructional technique is to plot each month's fall in its appropriate column so that values appear in order of magnitude. The midpoint along the line of values is that of the median and the upper and lower quartiles bisect the divided column above and below this value.

In the following paragraphs the salient features of some of the catchment stations are pointed. Their accompanying numerals indicate their number of wet days—

(*a*) Oberon. (89) (fig. 2).

This very southerly station is at 3,000 feet upon the exposed Oberon plateau and is surrounded by broken land at lower elevations. The incidence of large falls in winter is shown, which tendency exists on to late summer. Autumn drought continues but with more reliability than any other highland station. Condensation of spring values is restricted to August and September.

(*b*) Bathurst (85) (fig. 3).

This station is situated upon the western margin of the 2,000-feet Bathurst Plains, which are of undulating land flanked on all sides by plateau highlands averaging 3,000 feet, but rising to 4,200 feet some 16 miles to the east. Even with its southern situation, no winter maxima are apparent, the tendency is rather towards a summer

maximum. Interquartile ranges are restricted in winter and early spring showing favourable reliability. Depressed values are shown for autumn.

(*c*) Orange (96) (fig. 4).

Situated at an elevation of approximately 3,000 feet on the western edge of the Orange plateau. Gently sloping land at a similar elevation extends for 30 miles to the south-east and east. Both west and north are well dissected plateau edges, whilst on the immediate west are the Canobolas Mountains reaching to a height of 4,570 feet. Winter incidence of rainfall is immediately apparent and the February drought likewise. Reliability in any particular season is not emphatic as to amount, but low volumes are infrequent. September shows the close grouping of median falls.

(*d*) Hill End (82) (fig. 5).

Topographically situated on the exposed plateau remnants divide between the Turon River and Pyramul Creek. The combination of height and exposure to westerly weather influence, together with a more southerly situation, are reflected in the increased volumes in every season and a peaking of the winter incidence. These facts are emphasised by the continuation of low values in February. Condensation of values approaching the median, as farther north, is shown in early spring.

(*e*) Gulgong (63) (fig. 6).

Topographic situation is along the northern slopes of a low hill with surrounding flat to gently sloping land to the east, south and north for approximately 15 miles. In the west and south the land is hilly to steep. The diagram indicates no well defined seasonal incidence as indicated by the monthly medians. Winter interquartile ranges are smaller than summer ones, with the amplitudes of the ranges in July and August the least. This indicates a

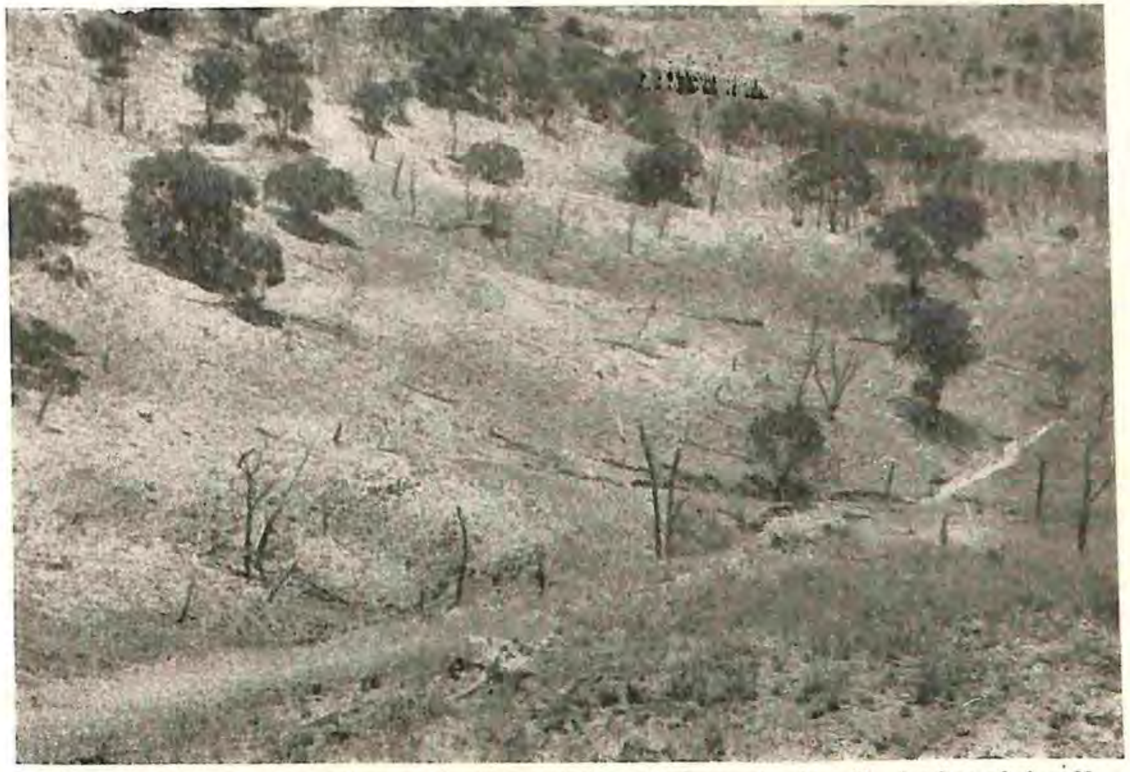


Fig. 8.—Moderate to severe sheet erosion in association with frequent gullies. Erosion hazard class II.

more constant mean dispersion in these months. Summer and autumn interquartile ranges are significantly larger indicating a less constant mean dispersion due to sporadic convectional rainfall.

(*f*) Mudgee (70) (fig. 7).

Situated in the broad middle Cudgegong valley shielded to the south, east and west by mountainous highlands approximately 3,000 feet, only some few miles from the town. The medium pattern is similar to that of Gulgong, 18 miles to the north, with the smallest amplitudes in the winter months and the least pronounced seasonal incidence of any catchment station. A similar depression of values is evident for the months of February, March and April. Comparing the lower quartiles for the late-autumn-early winter period, the diagram shows the marked transition to frequent high falls in the winter.

SOILS CLASSIFICATION.

It is not possible in the short time available for survey of each parish to produce a soil classification embracing the delineation of soils and types. A system has been developed which is based upon the common lithic characteristics of the soil-forming materials. Soils are then classified according to group, i.e., podsols and podsolic soils, red brown earths, etc. Thus a sequence of podsols, for example, may be mapped as developed from metamorphic, granitic, sedimentary or volcanic materials. Mature and sub-mature soils are mapped together and distinguished from skeletal. The scheme of classification is as follows:—

(A) *Mature and Sub-mature Soils.*

(*a*) *Red-brown earths and atypical red-brown earths.*

(i) Developed upon volcanic materials, especially diorite together with basalt, andesite and small areas of limestone. They are typically red to red-brown clay loams with usually slight eluviation of the A horizon and well structured B horizon. Carbonate accumulation is absent or in very tiny nodules. The majority of the soils of this class show atypical profiles and are confined to land of gentle to moderate gradients.

(ii) Developed upon granite or granodiorite. Textually they are gritty clay loams of light to medium red-brown colour. Distribution is very restricted.

(*b*) *Podsols and podsolic Soils.*

(i) Developed upon material derived from metamorphic rocks the principal one of which is Silurian slate with interbedded rocks of similar age: grits, flints, cherts, conglomerates and quartzites. Devonian sandstones also make a contribution. Profiles show A horizons ranging from the grey brown of the podsolic to the ash grey of the mature podsol. B horizons are either pale yellow or light yellow brown.

(ii) Developed upon granitic materials. A horizons may be grey or grey-brown, whilst B horizons are very variable. Northern catchment granites are characterised by stiff clay subsoils which set very hard when dry but become "like jelly" when saturated. Their colour is mottled yellow grey. Upland granites upon the southern catchment show the usual podsolic B horizons with frequent nodular to massive laterite ironstone present. Such soils are differently characterised in mapping by an appropriate symbol.

(iii) Developed upon material from sandstones, grit and conglomerates of the Hawkesbury stage of the Triassic sediments and the upper Permian Newcastle coal measures. Characteristically they are sands, sandy loams, gritty loams, etc., grey in colour overlying yellow sandy clays of low cohesive character.

(iv) Developed upon igneous materials such as dierite, basalt and andesite. They are confined to the high rainfall areas of the catchment (30 inches and over), or to limited lowlands receiving much run-off from neighbouring slopes. They are particularly well shown in the bottomlands at Orange, Oberon, Hargraves, Tallawang and other localities. A horizons are light grey to light grey-brown silt loams, underlain by deep yellow to orange B horizons with frequent enrichment of nodular to massive laterite ironstone especially where swampy conditions previously obtained.

(B) *Skeletal Soils.*

(i) *Red-brown earths.*

Developed on slopes exceeding 12 per cent. to 15 per cent. from igneous material and limestone. They are dark red to red-brown clays and clay loams mingled with much broken rock rubble and often weathering spheroids.

(ii) *Podsols and podsolic soils.*

Developed on metamorphic debris, these are grey to grey-brown silt loams only a few inches deep and mixed with much angular rocky fragments and traversed by angular reefs of rock or quartz.

Such a classification as this has proved itself easily usable in the field and it gives an accurate picture of soil character from place to place, and the system is sufficiently flexible to allow for additional soil classification to be added.

From time to time soils of unusual profiles are met, as for example podsol profiles in some alluvial materials with large calcium carbonate concretions in the yellow clay sub-soil; elsewhere soils (as at Orange, Mumbil and Tallawang) are formed upon material which may be fossil in character

Fig. 9.—An example in erosion hazard class III. Gullying of flow lines in bottom land.

Fig. 10.—Frequent gully erosion on over-cultivated red soil paddock. Erosion hazard class 4.

resulting from the erosional morphology of a different climate from that of the present day. Such soils as these are mapped with their nearest congeners.

LAND USE.

Types of land use in the Burrendong Catchment are being distinguished according to the following legend:—

(i) *Cultivation Land.*

This class includes all land which is regularly tilled or where the surface may be in an exposed condition for some time and in which the soil structure has been disturbed. A large proportion of such land lies in a weedy condition for some part of its lifetime. It has been shown by Research Station investigations to have higher run-off coefficient and greater soil loss than any other land use type.

(ii) *Improved Pasture.*

Includes land sown to non-indigenous grasses and herbs such as rye grasses, phalaris and Rhodes grasses, lucerne and clovers. It is a class where erosion hazard is usually low.

(iii) *Orchards and Vineyards.*

Land producing apples, pears, cherries and grapes with smaller areas devoted to other fruits. Erosion hazard has been pronounced in the past, but is being reduced by wiser husbandry methods.

(iv) *Natural Pasture.*

Land upon which natural grasses have been allowed to spread following the removal of thick timber. Principal associations observed are pure *Danthonia; Danthonia-Stipa and Stipa-Aristida* associations. Under optimum grazing conditions hazard is low, especially upon *Danthonia* land. The erosion hazard is pronounced with the association of steep slopes, high rabbit population and medium to heavy grazing.

(v) *Timbered Pasture.*

Land not having been "improved" as much as natural pasture and still growing more green timber than is needed for shade purposes. Very often the timber remaining is of value for milling purposes. Much standing or fallen dead timber may be present with good grass growth and hazard is usually slight.

(vi) *Timbered Land.*

Land either untouched by human hand or with thick second or third growth. Where stock have been denied entry the ground is well littered with dead leaves, twigs, fallen branches, etc. Where stock have free access to a belt of timber, the litter is absent or sparse and on steep slopes sheet, rill and gully erosion is often severe.

In the study of erosion hazard then, land use mapping is valuable as a provider of information regarding the type of surface exposed. In addition to field mapping stocking data is being collected (from Pasture Protection Boards) to show the intensities of grazing on catchment properties.

SLOPE CLASSIFICATION.

Land slopes are being mapped from a field survey and from contour interpretations of the 1 : 63,360 military maps, and four classes are distinguished, viz.:—

(*a*) Level to gently sloping land: 0-3 per cent.

(*b*) Undulating intermediate land: 3-10 per cent.

(*c*) Moderate to steep land: 20-25 per cent.

(*d*) Very steep land: 25 per cent. and over.

The 10 per cent. limit of class (*b*) may be considered the arable limit under any circumstances of conservation and erosion resistant soils. Arable land whose slopes approximate to this limit have been observed to have suffered considerable soil movement, especially where slopes are long and backed by steeper slopes.

SOIL EROSION MAPPING.

Mapping of actual erosion is carried out upon Lands Department Parish maps, upon which are placed markings corresponding to every gully and rill. These features are then distributed into frequency classes with respect to large gullies (deeper than 3 feet), small gullies (1 to 3 feet), minor gullies (up to 1 foot deep) and rills (transient scour channels). Since most of the areas suffering "frequent" gully erosion, both on pastoral and agricultural land are small in area it is difficult to show them as precise areas upon small scale county maps. They are therefore indicated by a filled-in black circle with appended script indicating the class of gully present.

The infrequent gully classes are defined in relation to combinations of parts or all of the watershed systems affected.

SEDIMENT LOAD STUDIES.

The two major streams, the Macquarie and the Cudgegong, are undergoing systematic silt sampling at such sites as Departmental officers are stationed. Research Station staff are collecting samples from the Macquarie at Wellington. Samples are only collected upon the arrival of an above usual flow and are analysed subsequently for silt content at Wellington Research Station.

APPENDIX "A".

Legend for Preliminary Erosion Hazard Classes.

(1) Steep, rugged, immature ridge and valley topography with skeletal soils and slopes of 25 per cent. and over. Very rarely any possibility of erosionally significant agriculture. Hillside rilling, gully and sheet erosion proceed rapidly once begun and are very difficult to control. Most land in this class is still timbered and lighlty grazed.

(2) Hilly to occasionally mountainous land with broadened sub-mature valleys. Soils sequential downslope from skeletal to deep mature. Slopes most frequently medium to short in length. This class contains intermittent large areas of land close to the arable limit with much of this cultivated, *e.g.*, orcharding land. Thick timber mostly removed, with grass covering non-arable land. Erosion types characteristic are moderate to slight sheet erosion with small watercourse and hillside gullies. (Figure 8.)

(3) Broad, near-flat floored valleys with hilly catchment divides and abrupt breaks of slope at their bases. Soils are deep mature to sub-mature except at the break of slope where rocky pediments exist giving skeletal soils. Sheet erosion evidenced upon slopes often with patchy scalded areas where slope run-off water meets the flatter land. Main watercourses frequently gullied. (Figure 9.)

(4) Long gentle convex slopes rising gradually to frequent isolated hills, soils uniformly mature apart from hill country. Erosion hazard heightens since most of the areas in this class are plateau uplands with high rainfall and extensive row crop agriculture, *e.g.*, Oberon district. Sheet erosion seasonally moderate to slight. Linear erosion forms are watercourse gullies and very often rills and minor gullies. (Figure 10.)

(5) Flat to gently rolling land with interlocking concave convex slopes, medium to long, with occasionally undulating abrupt rises. Extensive agriculture for oats and such crops. Erosion hazard probably the lowest of any class with small infrequent watercourse gullies a dominant form; sheet erosion slight to moderate.

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MANAGEMENT AND LAND USE IN RELATION TO EROSION CONTROL

BY

A. R. Tewksbury, H.D.A.,
Officer-in-charge.

Many people are inclined to view erosion control essentially as a mechanical measure.

The more we are in contact with erosion problems, however, the more we realise this is not necessarily so, but rather that the basis of soil conservation in many instances is one of wise land use and management in preference to the use of the bulldozer.

In this article it is the writer's intention to discuss three aspects of land management which are of considerable importance in erosion control, particularly in hilly grazing country.

All three are projects that a landholder may put into effect on his own initiative, without resort to mechanical works requiring the use of large earth-moving units.

The measures are:—

1. Decentralisation of stock watering facilities.
2. Contour roads.
3. Segregating steeply sloping areas by additional fencing.

DECENTRALISATION OF WATERING POINTS.

To illustrate this point an actual project already in operation will be discussed.

On "Wyndham," a grazing holding in the Merriwa district, the Manager has decided to decentralise the stock watering points. One section has already been completed and this is the forerunner of an overall programme to be carried out.

Formerly stock watering in one paddock were forced to walk two or three thousand yards to water at the south-western end of the paddock.

In hot periods stock were losing condition and would not water regularly because of the travelling; having travelled to water they were inclined to stay there for two or three days in preference to grazing back late in the afternoon. It was obvious that the stock were creating well defined tracks down to the water from the higher back country, and these tracks were fast becoming minor gullies; if continually used these would eventually produce a serious erosion problem.

It was decided that a bore should be put down on the lower sandstone country, where boring was easier than on the higher basaltic country, and the water table would be tapped at a more reasonable depth.

A bore 350 feet deep was sunk and a 10 h.p. Diesel-driven pump jack with 1½ inch delivery was installed. Water was then pumped to an 8,000-gallon tank with conical cover; to do this 2,200 yards of pipe were laid. The lift from the pump to the reservoir was 300 feet.

The 8,000-gallon tank now provided water centrally in this paddock, and served an adjacent one, the subdivision fence being only approximately 200 yards distant.

Separate troughing was erected in each paddock rather than use the subdivision fence as a common watering point, a procedure commonly used.

The 2,200 yards of delivery pipe when laid were provided with T-pieces at appropriate intervals for purposes that will be discussed later.

Splendid results have been obtained from this project and over a short period it has been noted that—

1. Owing to the dispersal of the troughing, stock have not concentrated and caused sheet eroded areas.
2. There has been a big improvement in the condition of the stock because of less distance to travel to water, especially in hot weather.
3. Where stock would formerly travel in large numbers over a great distance, on well defined tracks, they are now visiting the water points more often, in smaller numbers and on no specific track. This minimises the chances of tracks being made up and down the steeper slopes, finally causing erosion. Moving in smaller numbers and with greater regularity prevents horning, rushing and subsequent damage to troughing.
4. With the introduction of T-pieces on the main delivery line, the owner has at his disposal points where he can take off further water for additional troughing.
5. The T-pieces provide water points for bush and grass fire control.
6. The reservoir of 8,000 gallons being on the higher ground in the paddock, provides adequate water by gravity for a large-scale tree planting scheme which will be put into effect at a later date.

   In selecting trough and tank sites special attention has been given to using hard ridgy ground in preference to the heavier semi-self-mulching types.
7. Sheep having less distance to travel to water, and concentration on dusty tracks having been eliminated, the absorption of dust into the wool has been minimised.
8. Ewes with newly born, weak lambs, which cannot travel very far, are not absent from the lamb very long while watering, and consequently mortality from crows, hawks and foxes is less.

Fig. 1.—A contour track on Scone Research Station constructed immediately below a bank supporting a dense cover of Rhodes grass.

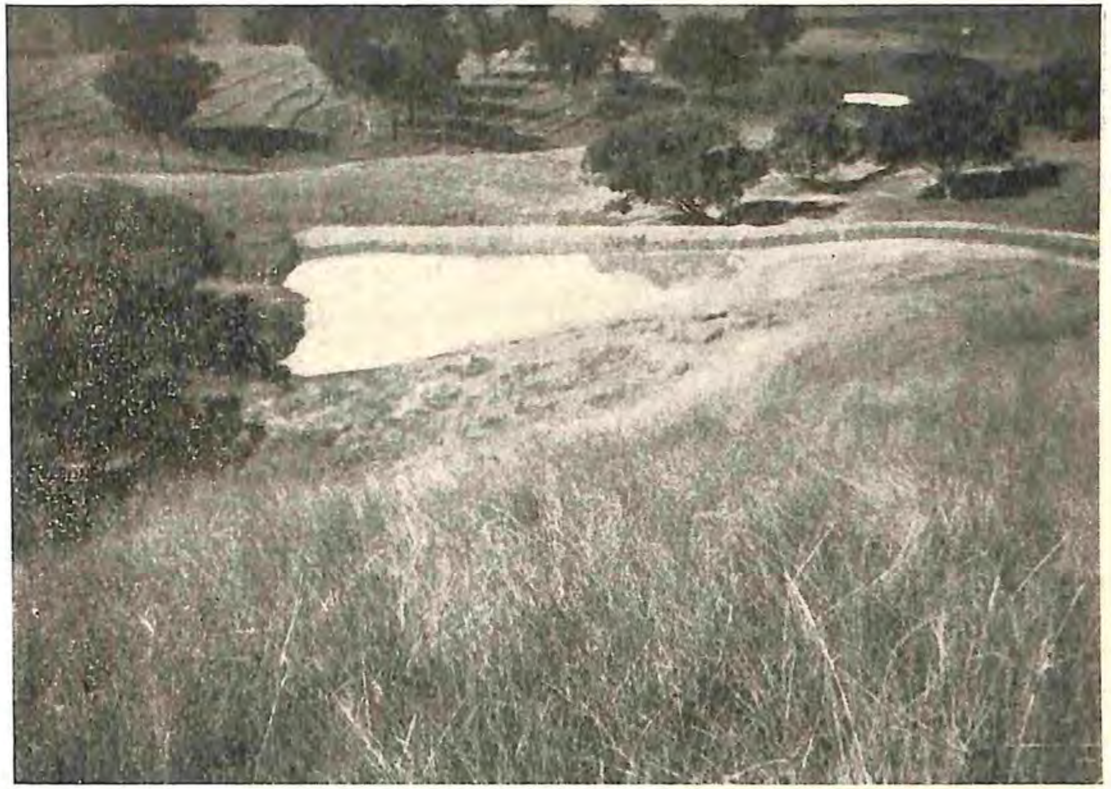

Fig. 2.—A dam on sheep country on Scone Soil Conservation Research Station.

Since the introduction of this scheme on "Wyndham" erosion problems have diminished. Although many of the results obtained from the foregoing are obvious to any competent stockman, especially in regard to animal management, it is interesting to note that other landholders are following on these lines with erosion control as their primary object.

CONTOUR ROADS.

On Scone Soil Conservation Station, on hilly grazing lands, a system of contour tracks has been located.

The reasons for constructing these tracks are as follows:—

1. To minimise erosion by wheeled vehicles travelling up and down steep grades.
2. To afford safe access to watering points, mills, troughing, salt troughs, buildings and experimental apparatus.
3. Provision of fire breaks.
4. To educate the stock to travel on the contour instead of up and down the slopes.

Construction of Tracks.

This is relatively simple. Having decided the point at which access is to terminate, a level line is pegged out at convenient intervals, using the dumpy level; this line will eventually emerge at or near the required point of origin. If the line arrives some distance away from the required point it is then necessary at some point in the proposed track to either drop or add elevation. This is done by making use of spurs, preferably of hard formation, rather than a soil type that is inclined to mulch or break down in structure after vegetation has been removed.

The track, when defined, may be left in grass and by constant use resolve itself into two wheel tracks with a grass buffer strip in the centre, or it may be graded off and formed if the side slope is steep enough to prohibit vehicular traffic.

Where graded tracks are constructed a larger area is stripped of vegetation and consequently run-off is greater and at some future time a table drainage system may have to be introduced.

This involves costs and a constant maintenance programme.

When surveying the tracks it is often necessary to avoid gully crossings if they are precipitous and active, and by making use of hard spurs these gullies may often be by-passed above their heads.

In the writer's opinion the advantages of contour roads more than justify their construction.

In addition to providing safe access through properties they also provide excellent fire breaks, especially where graded, and always give a contour line that can be ploughed either side for additional fire break width if necessary and still remain reasonably safe from wash in the event of heavy rain. These tracks in emergency provide quick access for vehicles carrying fire-fighting personnel, water-carts, etc., and also lead to water points and generally speed up and facilitate fire-fighting procedure.

Finally, in constructing these tracks an attempt is being made to educate stock to travel on the contour and not up and down slopes to eventually cause erosion by virtue of the tracks made by them.

The heavier soils in the Hunter Valley support a dense growth of Plains grass (*Stipa aristiglumis*) and sheep find it difficult in a flush season to find their way to water.

The stock soon learn by contacting a contour road they can travel in the clear and without effort; they commence looking for these tracks on finding that they lead to water or salt troughs and make an effort at all times to use such tracks.

It is obvious that stock will not use contour tracks only, but up to date results have been encouraging and if the construction of these tracks and their siting be explored a little more it is reasonable to expect that the procedure may have great possibilities.

Fig. 3.—Water is provided for the fenced-out steeper country by the construction of dams at the change of grade.

On Scone Research Station the introduction of contour tracks will provide safe access to six paddocks, four dams, two water reservoirs, all buildings and field experimental equipment.

SEGREGATING STEEP SLOPES.

In the Upper Hunter Valley and elsewhere, it often occurs, especially on river country, that fertile valuable flats are backed up by very steep and even precipitous back country.

Where this occurs and both flats and high country are being used as one paddock, very severe erosion often occurs.

In one instance known to the writer, a river flat of some 150 acres is backed by steep land rising suddenly several hundreds of feet. This is being used as one paddock to support sheep. The owner is stocking this area at the rate of 0.75 sheep to the acre.

The flats are heavily grassed now after several good seasons and the country is carrying the stock comfortably.

This, however, has not been the case in the past.

Stock grazing in this paddock naturally have concentrated on the lower alluvial country where feed was heavy and succulent, disregarding the light country in the rear except to camp in the foot-hills. Actually this landholder was stocking his flat at the rate of two sheep to the acre as the stock did not use the steeper slopes.

As drought periods came round, and feed became scarce, the stock, having eaten the flats out, naturally moved to the higher country to graze what dry feed was there.

This in turn was eaten off and the whole paddock was then in a highly erodible state.

After heavy rain the denuded steep country shed water freely, gullies ran deep and fast and deposited rubble and silt on the more fertile flats.

Eventually, after a number of years, the rubble and silt fans became gullies, and to-day these flats have gullies through them to the river and adjacent paddocks, up to eight feet deep.

This can be avoided by treating the steep light carrying country which has very little topsoil, and is erodible even when grassed, as an entirely different land use proposition.

Where the flats may carry 0.75 or 1 sheep comfortably over long periods, the back country may not support a sheep to 3 acres at any time. It may not be sheep country at all; cattle might do better and cause less damage.

If then this country were fenced out, leaving a little rising ground on the flats for stock camps and a balance of feed, and treated as a separate area, it could be controlled in such a manner that the flats below would not be damaged.

This, of course, necessitates water supply and fencing. Dams can be constructed at the change of grade for water supply for the higher country.

This would also provide additional water on the flats by gravitation and a scheme similar to that in operation on "Wyndham" would be in operation.

In this manner the landholder could always control the stock on his high country and so ensure that the valuable grazing land beneath would not be destroyed by erosion.

CONCLUSION.

It is realised that these projects present difficulties. Shortage of materials, labour problems and economic considerations influence landholders.

However, it is gratifying to know that many landowners in the Hunter Valley are now adopting these principles of wise land use and sound management on their holdings.

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GRAZING LANDS OF THE GOULBURN DISTRICT—EROSION AND SOIL CONSERVATION

BY

C. G. McMahon, H.D.A., Soil Conservationist.

GRAZING lands form a substantial portion of the Southern Tablelands region of New South Wales, of which Goulburn is the main centre. The topography is mainly undulating to hilly, with timbered slopes, which in many instances have been rung or cleared injudiciously, resulting in large volumes of run-off.

There is a wide variation in soil types throughout the region, soils varying in the majority of cases as the topography of the country alters.

In the vicinity of Goulburn, soils originate mainly from Devonian slate and shale; they vary considerably and are light-grey coloured shallow loams overlying a clay subsoil. Towards Crookwell and Taralga, red and red-brown clayey soils developed on basalt and lighter soils originating from slate and granite predominate; the latter are relatively low in fertility and these soils are most susceptible to varying degrees of erosion. Red and brown soils derived from basalt and light coloured podsolised soils of shale origin are also to be found in the Moss Vale and Robertson districts. Further south towards Queanbeyan and north of Canberra, light-coloured podsols of slate origin occur; these are of medium fertility, with fair depth on the higher country with fertile strips of alluvial soil to be found in the valleys and along creeks. At Gunning, soils of medium fertility of slate origin and loams derived from granite occur.

The incidence and reliability of the rainfall is also marked and the climate generally is characterised by long bleak winters, and short, cool summers. The average annual rainfall varies from 24 inches at Goulburn to 29 inches at Crookwell, where, in contrast to Goulburn the autumn, winter and spring incidence is almost ideal for pasture improvement work.

The annual average at Robertson is over 60 inches with heavier falls during the late summer and autumn, whilst at Moss Vale the average is about 39 inches and it is a well-known local contention that the rainfall decreases an inch per mile from east to west in this district. Towards the southern boundary at Braidwood, Queanbeyan and Bungendore, the rainfall is fairly evenly distributed and suitable for pasture improvement work; this applies particularly at Braidwood, where the average is about 27 inches per annum. Monthly rainfall figures are shown in Table I.

Native perennial grasses, *e.g.*, Wallaby or White Top (*Danthonia* sp.) provide good grazing during winter and summer; Spear grass (*Stipa* sp.), Wire grass (*Aristida* sp.) and Tussocky Poa (*Poa caespitosa*) prevail over the greater portion of Tableland grazing areas.

Valuable fertility building work is being carried out with pasture improvement methods using introduced species, viz., rye grasses, Subterranean clover and *Phalaris tuberosa*, which not only improve soil fertility and help to reduce run-off and erosion by improving the pasture sward, but also increases production by providing heavy grazing. Subterranean clover has proved itself in practically all areas with the exception of some unfavourable soil types, such as the hard compacted clay soils, and it is now indispensable, both as a pasture ingredient and soil improver, for providing vigorous vegetative cover to rapidly stabilise denuded areas and reduce run-off.

Fig. 1.—The effects of gully erosion on the Southern Tablelands.

Fig. 2.—The versatile grader ditcher, a useful implement for mechanical soil conservation work.

At Crookwell, where the rainfall during the April-October period is 22 inches, conditions are ideal for development of Subterranean clover. Here, due to suitable soil and rainfall, outstanding results have been obtained.

REMOVAL OF TIMBER.

Timber destruction in key areas and the malpractice of over-stocking, combined with the depredations of rabbits and effects of drought, have contributed mainly to the destruction or removal of valuable grass cover. This removal of grass cover with further soil deterioration and loss of fertility has brought about a set of conditions most favourable to soil erosion.

Incessant trampling of stock on denuded ridges and at heads of natural depressions results in the desiccation of the soil with harmful effects to both texture and structure; volumes of run-off concentrating in such depressions commence rilling, eventually developing into major gullying so prevalent in natural watercourses.

CONTOUR FURROWING ON GRAZING AREAS.

Whereas on the eroded arable lands of the State effective soil conservation technique involves mechanical work with heavy earth-moving machinery, it has been found from experience that on the Tableland grazing areas, in so far as the mechanical aspect of erosion control is concerned, a system of contour furrowing with lighter equipment has proved most effective in reducing run-off and assisting in the stabilisation or reclamation of severely eroded areas.

Close attention is now being directed by the majority of Tableland graziers to this particular aspect of soil conservation work, and the fact that a number have demonstrated their keen interest in the progress and success of the work by purchasing suitable machinery is significant.

Reduction of run-off and the effects of soil and moisture conservation have been most marked, particularly on grassland areas where soil cover has been seriously depleted due to the ravages of over-stocking, rabbits and drought. Contour furrow work has been most effective in the following instances:—

1. Where protective timber cover has been rung or removed, run-off water that would otherwise cause serious scouring of gullying has been arrested and encouraged to soak into the soil by a series of level furrows carefully constructed across the slope.

2. Control of gully erosion, the existence of which is so prevalent in natural depressions, is facilitated, as the greater bulk of the run-off, which previously found its way into depressions and ultimately cascaded over gully-heads, is now held on the catchment where final absorption takes place.

3. On large catchments of, say, 100 acres or more, this factor of water absorption has special significance, as it renders the construction of holding dams and diversion banks around gully-heads a much more effective and safer proposition. With the protection afforded by contour furrow work, the amount of run-off concentrating on lower lands is considerably reduced and the tendency towards overtaxing the capacity of a holding dam is therefore not so great.

Flow of water to the gully itself is cut off or reduced, which allows for natural healing with easier subsequent stabilisation by vegetative or mechanical means.

USE OF MACHINERY.

The landholder, in many cases, has been in the position to carry out the work using his own plant, whilst the Soil Conservation Service co-operated with the necessary technical assistance, planning and advice. Machinery found most suitable for the work consists of a farm tractor and a No. 69 road plough, or tractor with hydraulic mouldboard attachment, the front mouldboard on the attachment being first removed.

Generally it has been found that the work done by the plough can be improved upon by the use of a farm grader ditcher, and such work paid dividends in the Crookwell district during the phenomenal rainfall period of 1950. By the use of this implement the absorption capacity of the furrows can be increased considerably and run-off reduced.

This machine must be used with discretion, however, on certain soil types, as it

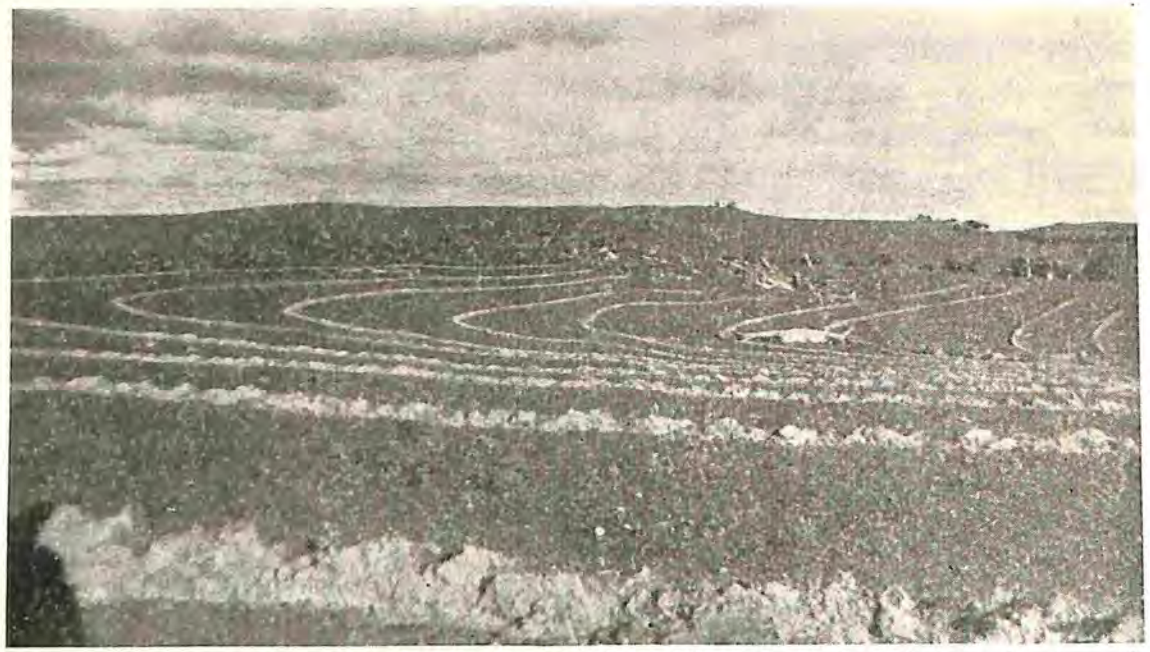
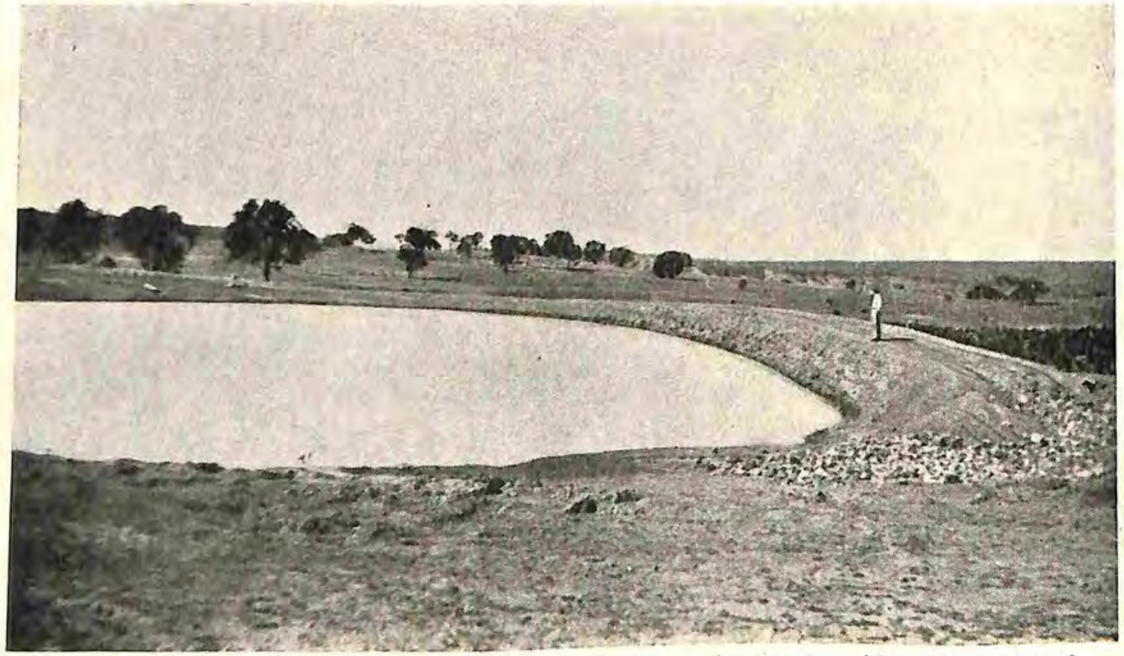


Fig. 3.—Soil conserved grazing land on Pomeroy, Goulburn, where pasture furrowing, top dressing and sowing introduced species has been carried out on the contour.

Fig. 4.—Valuable grazing land dissected by gully erosion in the Bungendore district. The erosion is the result of overclearing, overstocking and rabbit infestation.

Fig. 5.—Contour furrows on eroded areas adjacent to the country killing works, Goulburn.



F.g. 6.—A strategically placed holding dam on undulating grazing country with well constructed stabilised spillway.

has been found to have caused a hard compact surface which hinders water absorption and consequently adversely affects the establishment of stabilising grass cover.

STABILISATION OF MECHANICALLY-TREATED CATCHMENTS.

In order to complete the programme of soil conservation work on grazing land and expedite "grassing up" of the treated area, the establishment of a supplementary vegetative cover to support the actual mechanical work is of paramount importance.

As a result of demonstrational activity emphasising this aspect of the work, landholders arrange to topdress and sow the treated areas, usually in early autumn, providing soil and seasonal conditions are favourable.

Sowings of Subterranean clover at a rate of 3-4 lb. per acre, and Wimmera rye 2-3 lb. per acre, are usually made, the seed being mixed with the fertiliser and broadcast with the aid of a combine or spreader.

A broadcaster mounted on a "jeep" has been used to sow Subterranean clover seed on mechanically treated grazing land, the actual sowing being carried out on the contour. Another grazier carried out the complete liming of a treated area, using the same method of broadcasting and working continually on the contour.

It has been found that "combining" the seed and superphosphate direct into the soil has given satisfactory results, as the working tends to conserve moisture and gives protection to the seed until it germinates and becomes established. On the lighter soils where fertility is low it has been found that the estaglishment of the hardy, vigorous Subterranean clover is a necessary prelude to the later development of a first-class pasture, which demands a higher soil fertility for its establishment. This is due to its soil fertility building habits and its ability to increase the nitrogen content of the soil.

CONTOUR CULTIVATION IN THE ESTABLISHMENT OF PASTURE.

On many grazing areas the uncurbed influence of rabbits, in association with overstocking and over-clearing, has destroyed vegetative cover, leaving denuded and sheet eroded areas.

As a means of reclaiming such areas landholders are now adopting a programme of sowing pastures and sound pasture management, using the system of contour cultivation in the initial preparation for sown pasture.

Fig. 7.—Contour furrows decrease run-off in the Crookwell district and improve pasture growth.

Recently, in the Queanbeyan district, the preparatory ploughing and scarifying for sowing of improved pasture grasses, viz.: Subterranean clover and *Phalaris*, on 400 acres of undulating to hilly slate country, was carried out on the contour.

The normal cultivation followed surveyed lines, which were maintained at intervals of 1-2 chains, the horizontal distance being altered to give greater uniformity in accordance with variations in degree of slope.

No difficulty was experienced in subsequent sowing operations and during the process of cultivation all grassed drainage areas were left unploughed to prevent any erosion occurring on the lower areas and drainage lines.

The system of contour layout does not involve the use of expensive plant, and once survey is completed and contour lines marked the landholder can complete ploughing operations using his own machinery.

In addition to the contour preparation of land and establishment of sown pasture of appropriate species, the following factors are important in the soil conservation and wise land-use programme:—

1. Judicious stocking.—Considerable harm will result if stocking of the pastures is permitted before proper establishment. After establishment proper management involving judicious stocking will be necessary to maintain the pasture at a high level of production.
2. Regulation of stocking until such time as carrying capacity can be increased with prudence.—Regular topdressings of superphosphate are required by all pastures and an annual application at least of 1 cwt. superphosphate per acre is essential.
3. Construction of dams at strategic points in naturally grassed depressions for well-planned stock watering purposes and to act as buffers against surplus run-off which might ultimately cause rilling or gullying on lower lands.

The actual contour preparation entails comparatively little monetary outlay. In the mitigation of erosion it has been both effective and economical and is a plan which could be gainfully applied to grazing areas where successful pasture improvement work is contemplated.

CONCLUSION.

On grazing land on the Southern Tablelands effective and adequate soil conserving measures and sound pasture improvement work go hand in hand, resulting in the conservation of the soil and increase in its productive capacity.

This latter consideration has now special significance in view of the proposed early opening of the country killing centre at Goulburn, where an increased demand will exist for a continued supply of prime quality stock, which cannot be produced from pastures that have been allowed to deteriorate or from lands that have suffered from erosion.

TABLE I—Showing monthly rainfall averages.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average Rainfall Apr. to Oct.
Pomeroy	2·35	1·85	2·12	1·92	2·08	2·62	2·51	2·44	2·28	2·29	2·26	2·55	Not available.
	Average annual rainfall for 49 years—27·26 inches.												
Goulburn	2·54	2·17	2·08	1·77	1·96	1·98	1·73	1·87	1·90	2·18	2·0	2·26	13·38 inches.
	Average annual rainfall for 80 years—24·64 inches.												
Queenbeyan	2·19	1·72	1·94	1·68	1·76	1·89	1·53	1·68	1·70	2·17	2·10	2·04	12·56 ,,
	Average annual rainfall for 74 years—22·49 inches.												
Bungendore	2·48	1·57	1·80	1·75	1·83	2·16	1·88	1·95	1·87	2·11	1·87	2·03	13·64 ,,
	Average annual rainfall for 55 years—23·30 inches.												
Braidwood	2·60	2·29	2·54	1·99	2·53	2·10	2·02	1·83	1·90	2·19	1·98	2·54	14·55 ,,
	Average annual rainfall for 55 years—26·51 inches.												
Gunning	2·27	1·57	1·85	1·87	1·89	2·42	2·09	2·25	2·19	2·16	1·98	2·11	14·90 ,,
	Average annual rainfall for 59 years—24·65 inches.												
Crookwell	2·64	1·79	2·38	2·35	2·57	3·92	3·45	3·36	2·90	2·83	2·21	2·58	21·32 ,,
	Average annual rainfall for 61 years—32·98 inches.												
Taralga	2·70	2·12	2·30	2·32	2·33	2·93	2·75	2·41	2·30	2·35	2·26	2·47	17·25 ,,
	Average annual rainfall for 60 years—29·42 inches.												
Moss Vale	3·57	3·36	3·60	3·35	3·53	3·45	3·72	2·42	2·51	2·87	2·65	3·05	21·69 ,,
	Average annual rainfall for 72 years—38·08 inches.												
Robertson	5·66	5·48	6·77	6·09	4·91	6·53	6·66	4·27	3·05	3·73	3·16	4·17	31·03 ,,
	Average annual rainfall for 45 years—61·38 inches.												

FOREWORD

BY

E. S. CLAYTON, H.D.A., Commissioner.

ALL types of land users in New South Wales are becoming more conscious of erosion damage and are interested in taking steps to prevent such damage. Any land that is intensively used is vulnerable to erosion. It is particularly so if deprived of the protection of vegetative cover for long periods. Frequent and perhaps unnecessary cultivations also have a bad effect on the soil structure. It is for these reasons that some of the most serious losses of soil are occurring on the lands devoted to orchards.

Not only is production being lowered on the sloping lands but the lands themselves are being destroyed. The damage can be seen at its worst on some of the once deep rich volcanic soils on the North Coast which were devoted to banana growing. The disastrous combination of clean cultivation on steep slopes and heavy rains have in some instances finally taken bananas, soil and subsoil until only bare rock remains.

Losses occur, however, in all types of orchards and in all districts where the land is sloping and clean cultivation is practised. Sloping areas are generally chosen for orchards because of better water drainage and good natural air drainage for the avoidance of frost damage. The position at present is that in many orchards yields, health and vigor of trees are visibly affected by losses of surface soil. Also, as the best sites were generally chosen in the first instance, only steeper or less suitable lands still remain for new plantings in many districts.

In earlier years, before the danger of erosion was recognised, most old orchards were planted on the square. This, of course, hastened their deterioration. With new plantings the position is different. Soil Conservationists introducing safe water disposal and contour planting on a practical scale surveyed and laid out many new areas in New South Wales to guide and assist orchardists in this type of erosion control.

Growers have been very quick to adopt the new methods advocated, and many new orchards on sloping land have been laid out and planted on the contour with up-to-date provision for safe disposal of the run-off water. This method is giving good results, not only preventing loss of soil but also conserving water for the trees. A serious problem, however, is still presented by old orchards which were originally planted on the square and which are seriously eroded. One of the best means of overcoming the loss is to reduce cultivation and make as much use as possible of vegetative cover.

There has fortunately been a development which may have most important effects in this connection. It is the use of permanent clover or grass sod in orchards and the abolition of practically all cultivation. Credit is due to those orchardists who pioneered this important development. Their vision, ingenuity and ability have paved the way for great possibilities.

Mr. H. J. Braund, of Griffith, successfully developed sod culture on citrus under irrigation. Mr. W. Pascoe, of Orange, pioneered permanent sod culture on apples and pears with very great success. Mr. L. Cunich, of Orange, did the same with cherries. The achievements of these two orchardists of Orange are very important because the results were obtained under natural rainfall conditions, no irrigation water being available.

The possibilities of eliminating all cultivation and covering the soil with a protective coat of clover or grass are worth close study by all those interested in growing fruit trees. The clover or grass will protect the soil from erosion, and the absence of cultivation will reduce the loss of humus, and assist the recovery of the soil structure. On the other hand, the sod will compete with the trees for moisture and plant food. If irrigation water is available the position is much safer. The climate should be carefully studied. Many districts will be found too dry and too uncertain, but in rainfall zones that compare with, say, Batlow, the prospects are most promising. In this district where subterranean clover thrives many orchardists are already experimenting their way towards the permanent sod culture that will protect their orchards and keep them productive, even though they are unfortunately planted on the square.

▽ ▽ ▽

THE PERENNIAL SALTBUSH

Atriplex vesicarium—Heward

BY

G. H. Knowles, B.Sc., Soil Conservationist,
and R. W. Condon, B.Sc.Agr.,
Research Officer and Botanist.

Of the pasture plants of Western New South Wales, particularly the Hay Plain and environs, the most important plant from the graziers' point of view is the perennial or bladder saltbush. This is also true for large areas of level or gently undulating country surrounding the mountain range systems in the West Darling district. Before settlement by white man, it can be safely assumed that the perennial saltbush occurred in thick stands over the whole of these areas. To-day, due to over-grazing, and to some extent drought, good stands of perennial saltbush are a comparative rarity, it having been replaced by plants of much lower value, such as the copperburrs, and annual saltbushes and grasses.

In many ways the perennial saltbush is a remarkable plant, and as such it has been the subject of close study by research workers. This article is in the nature of a review of much of the information so gained, and is written with the view to giving the grazier an adequate picture of the plant, so that he may appreciate its real value, and so preserve and protect it wherever possible, and encourage its re-establishment where this is taking place.

The perennial saltbush belongs to the family Chenopodiaceae, members of which occur all over the world, for the most part on soils containing a high percentage of salt. Other plants of this family and which are therefore closely related to the saltbushes, and which are also very important components of our western vegetation, include the bluebushes (*Kochia* spp.) and the large group of copperburrs (*Bassia* spp.). It is also intended to discuss these latter groups of plants in following issues of this Journal, together with the important species of annual saltbushes.

BOTANICAL DESCRIPTION.

An erect bushy shrub 1½ to 2 feet high, almost white with a scaly covering on the leaves. Leaves ½ to 1 inch long, oval or rounded, flat and rather thick, with a thick stalk. Flowers diœcious (male and female flowers on separate plants), the male flowers in small clusters forming rather dense spikes, the female flowers solitary or very few in the axils of the leaves. The seed occurs between rounded spongy appendages which may be absent in some types, this fruit being ½ inch in diameter. The plant presents a very twiggy bush, its most important feature being its perenniality, its resistance to drought and its palatability.

It is often confused by the grazier with two other saltbushes, which will be discussed in a later article. These are—

(i) Flat-topped Saltbush (*Atriplex Lindleyi*).

This is a low monœcious plant (male and female flowers in the same plant) and differs from the perennial saltbush in its longevity, *i.e.*, it is an annual. For fruit see Fig. 1.

(ii) Pop Saltbush (*Atriplex spongeosum*).

This is also a low, monoecious annual, and mealy-white in appearance, as in the case of the other two species of *Atriplex*. The ripe dry fruit has the appearance of a sponge. For fruit see Fig. 1.

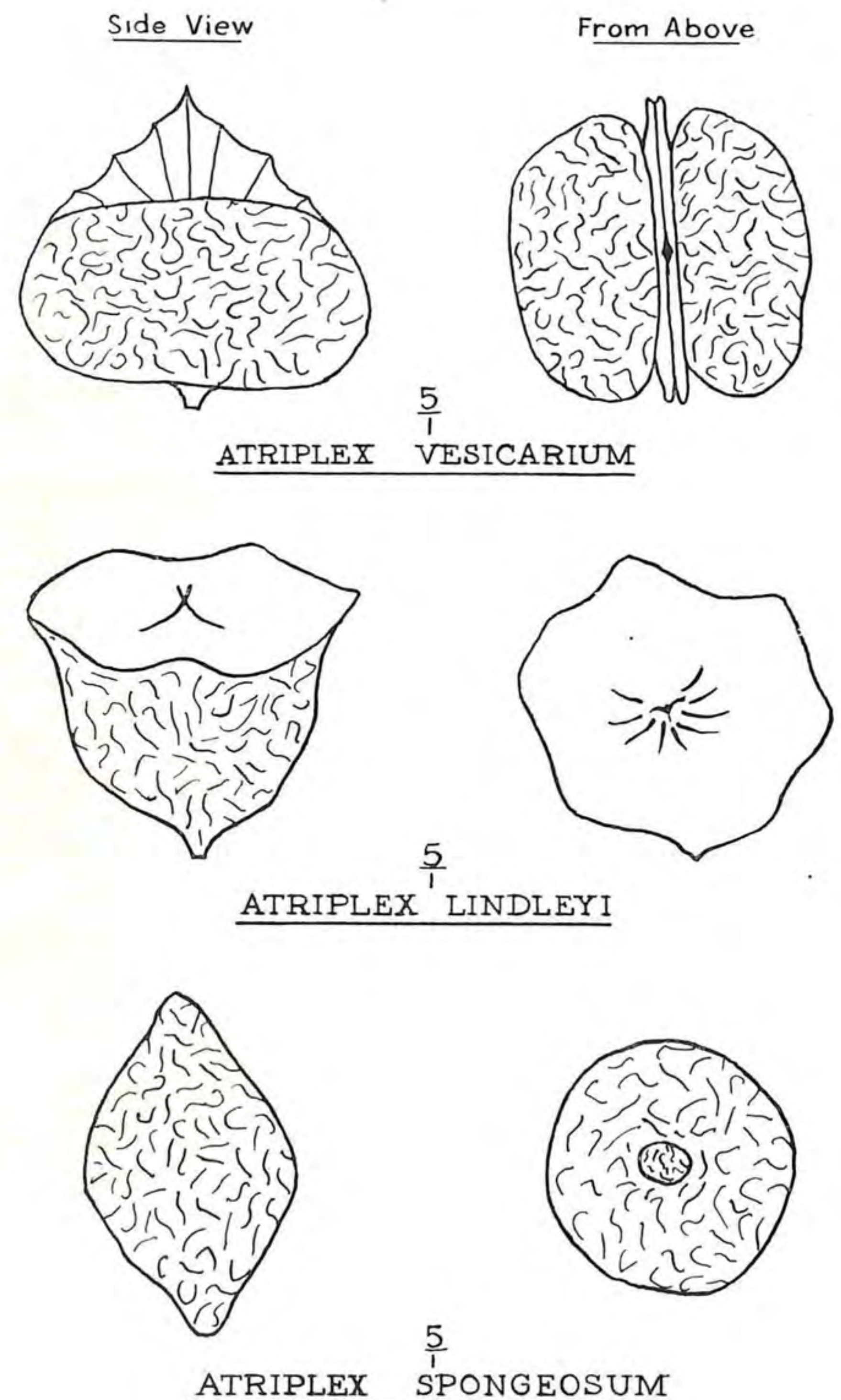


Fig. 1

OCCURRENCE.

The perennial saltbush forms what is known as an Association, which, broadly speaking, may be regarded as a community of plants which are in equilibrium with the climate, the soil and with each other. In New South Wales the *Atriplex vesicarium* (bladder or perennial saltbush) Association is found predominantly on flat or undulating country. The foremost example of this is found on the flat country included in the Hay Plain and environs extending from Moulamein to Ivanhoe, where this Chenopod is found at its best. The stands on undulating country are found west of the Darling, on those areas surrounding the mountain range systems, often in conjunction with the bluebushes (where the limestone layer comes close to the surface). Stands also occur on level heavy soils in scattered areas between the Bogan and Macquarie Rivers in the north-west portion of the State. The soil types on which it is found are predominantly heavy, varying from grey clays, through clay loams, to sandy loams overlaying clays.

In New South Wales it is found west of the 16 inch isohyet, but in South Australia the 12 inch isohyet is its limitation. The "bush" forms an open community, the plants being separated by areas of bare soil on which annual and ephemeral species will flourish after good rains. Thus a continuous cover is not formed but the individual clumps may be separated by bare patches of soil which are equal to or greater than the diameter of the bushes. The saltbush is gregarious, and often three to four plants occur in the one clump. This may be due to the fact that the bases of the bushes accumulate sand, and in so doing, provide seedbeds in which seedlings of various plants, including the saltbush itself, may germinate and flourish.

Fig. 2.—General view of *Atriplex vesicarium* Association near Mossgiel. —*Photo.* N. C. W. Beadle.

In true "bush" country, trees and shrubs are relatively unimportant components of the vegetation. However, they do appear, *e.g.*, along creeks and swamps (black box) and along sandy ridges—yarran (*Acacia homophylla*) and needlewood (*Hakea leucoptera*). The only tree which is found dotted over the Association without any apparent partiality to soil type is the miljee or umbrella tree (*Acacia Oswaldii*) and this is indeed a rarity.

Beadle regards the Association as an edaphic climax, *i.e.*, a climax which is governed by the soil conditions. Light sandy soils part with their water much more readily than heavy clay soils, and where the rainfall is scanty, as is it in Western New South Wales, light and heavy soils consequently support different types of vegetation (*e.g.*, mulga scrub on sandy soils), whereas in areas where high rainfall is experienced, light and heavy soils generally support a similar type of vegetation and any changes in vegetation are controlled by climatic rather than soil conditions.

In many instances the perennial saltbush occurs in Associations other than the pure stand. For instance, it occurs on heavy river soils timbered by black box (*Euc. bicolor*), on heavy soils timbered by gidgee scrub (*Acacia Cambagei*) and according to "old hands" once occurred in level flats between sand dunes in the mulga scrub country. Within the Association itself, Beadle considers that there are three main types, as follows:—

(a) The perennial saltbush—cotton bush (*Kochia aphylla*) type.

This type occurred originally within the pure stand on the very heavy soils in slightly depressed areas. Excessive grazing has led to the elimination of the perennial saltbush over extensive areas and its replacement by the cotton bush and associated species. This type is found mainly east of the Darling River.

Fig. 3.—*Atriplex vesicarium* Association on the gibber plains near Tibooburra. —*Photo.* N.C.W.Beadle.

Fig. 4.—A good stand of *Atriplex vesicarium* showing typical spacing of the bushes. —*Photo.* N.C.W. Beadle.

(b) The old man saltbush type (*Atriplex nummularium*).

This type is most frequently seen on the Hay Plains and almost entirely lacking in other areas of the Association, though it is probable that its scarcity is due to elimination by the introduction of stock. It shows no preference for soil type, being found on heavy grey soils and also on the red sandier types but always where there is accumulation of water.

(c) Perennial saltbush — bluebush (*Kochia sedifolia*).

The soils in the areas supporting this type are of lighter texture than the preceding types and contain a much higher percentage of lime throughout the profile. Country west of the Darling River, on the "gibber" plains and on the foothills of the Barrier Range, supports this type.

As a result of overgrazing and, to some extent, drought the perennial saltbush Association differs considerably from its original state, it having been replaced by a low-grade pasture of annual saltbushes, copperburrs, perennial grasses, or a mixture of these three groups. The stages in the degeneration of the perennial saltbush country are discussed in more detail below.

HABIT AND GROWTH.

The perennial saltbush is an exceedingly variable species. It is common knowledge that the forms associated with different types of soil not only differ in their degree of resistance to drought and to grazing but have distinctive characteristics in their growth and in the shape and size of the fruits and vegetative components. As far as can be ascertained there are three definite ecotypes with others known to exist. An ecotype is a sub-unit of the ecospecies (a species modified to fit its locality) resulting from the conditions of its environment.

(*a*) *On Travertine* (*or Limestone*) *Soils.*

In this case the perennial saltbush takes the form of an erect twiggy bush, with an average height of one foot and with a diameter slightly larger than this figure. The leaf form is variable in outline and the "bladders" on the fruiting calyx are small and sometimes absent.

(*b*) *On Silty Soils.*

This is a robust rounded bush, a little under 2 feet high and with very stout stems. The bladders on the fruiting calyx in this case are large and well developed. This is the form met with on the Hay Plain.

(*c*) *On Silty and also Sandy Soils.*

This also is a very twiggy bush, about 1½ feet high and with narrow lanceolate leaves. The bladders in this case are generally lacking.

Other ecotypes are known to exist, *e.g.*, those found around saltlakes, but these are not sufficiently well-defined as yet.

The perennial saltbush is an erect shrub which rarely exceeds two feet in height; however, the shrub does appear to increase in diameter considerably; under complete protection from grazing for five years some plants have reached five feet in diameter. The stems are rarely more than 1/3rd of an inch in diameter, and at all stages the wood is brittle and consequently very liable to mechanical damage. The majority of plants show a number of slender, freely branching stems rising from the base, which is usually surrounded by a mound of fine soil and sand deposited by the wind; the very young plants only show anything like a main stem. While most plants of a perennial nature in arid regions have a deep root system, the root system of *A. vesicarium* is found to be shallow, never penetrating the limestone layer, and being contained mostly in the surface twelve inches. However, surface extension seems to be extensive, some of the longer roots being recorded as 6 feet in length. There is no tap root, but a number of spreading laterals which branch at intervals. These branch roots produce large numbers of short-lived feeding roots, which are deciduous during drought and are renewed at the onset of rains. During drought they probably play very little part in the absorption of water.

LONGEVITY.

The life of a plant of *Atriplex vesicarium* is generally ten to twelve years. Studies on the Koonamore Vegetation Reserve in South Australia revealed this figure and these studies were conducted during a drought period. According to Beadle, the seed of *A. vesicarium* was found to have a life of five to six years. However, as the seed is generally destroyed by summer rains (see below) it cannot be expected to survive for this period under normal conditions. The bushes are therefore comparatively short-lived, and the perpetuation or maintenance of a stand of saltbush is dependent upon the germination and establishment of seedlings to replace the parent bushes; unless allowance is made for this fact the bush will die out under continuous stocking.

PALATABILITY.

Over considerable areas of arid Australia, the perennial saltbush is the most valuable plant from a fodder point of view. Where other forage (grasses and herbage) is available during good seasons, the saltbush is taken by sheep only in the way of a browse and is not consistently grazed. The high salt content makes it comparatively unpalatable.

In time of drought, it is the only plant available by virtue of its extreme drought resistance. Sheep will keep healthy, grow good wool, and even lamb on an exclusive diet of saltbush, though it may be difficult, if not impossible, to fatten stock on it. A chemical analysis reveals that it differs considerably from most plants in that its protein and salt content are high, whilst the respirable carbohydrates and crude fibre are exceptionally low. Thus if stock were grazed entirely on saltbush, it would be found that the addition of feed supplying roughage is necessary. As it is, this roughage is supplied by the presence of grasses and annuals which are found throughout most of the pasture. The high percentage of protein makes the saltbush a relatively rich pasture. The saltbush is not palatable to rabbits, which may, however, kill young seedlings by nibbling through the stem.

DROUGHT RESISTANCE.

The perennial saltbush is noted for its drought resistance, and it is this factor which makes it a plant of considerable importance in arid Australia. Its drought resistance can be attributed to a number of factors. Under the climatic conditions of arid Australia, the incidence of rainfall is very erratic and generally infrequent. Coupled with the low and unreliable rainfall there is a very high evaporation rate. To survive under such conditions plants must have some means of adapting themselves to the conditions. Professor J. G. Wood of Adelaide University has shown that the perennial saltbush together with some other members of the Family Chenopodiaceae, are able to absorb water through the leaves. Other drought-resisting plants lose water through their leaves. Examination of the leaves of *Atriplex* species has shown that they contain abnormally high concentrations of soluble salts in comparison with other species, with the result that the cells within the leaves have a particularly high osmotic pressure, which enables them to absorb water from a very humid atmosphere, from light falls of rain, and dew. In addition to the above property, the structure of the leaf is such that it is able to assist in the absorption of water. The leaves of most plants have a very thick coating of wax over the leaf surface which serves to prevent excessive loss of moisture from the leaves. It also prevents any absorption of water. The leaves of saltbush, on the other hand, are covered with very fine hairs, which enables the leaves to absorb moisture from the atmosphere. During periods of low humidity the hairs lose their moisture and collapse, and so form a protective covering which prevents the escape of water from the leaf tissues.

Returning to a consideration of climatic conditions, it is considered that a fall of rain of less than 25 points would not be effective in dry times to plants relying on their root systems as a means of obtaining moisture. Although the evaporation in such areas is very high, there is such a wide fluctuation in daily temperatures that, even during the hot summer months, the air at some time of the day is almost saturated with moisture. Thus by reason of their high salt content and particular structure the leaves are able to take advantage of moisture from light showers, dew and high humidity, which would not be available to it were the plant to depend solely on its root system.

Other factors which assist its drought resistance are the tenacity with which the leaves hold their water, by reason of high water-holding capacity of the chemical compounds stored in the leaves, and the very low water requirement of the plant. Even with its low water requirement it is capable of producing greater amounts of forage than plants with a high water requirement. Thus the perennial saltbush will continue to produce feed under conditions dry enough to kill most plants.

In addition to the structure of the leaves, the shallow root system contributes to the plant's drought resistance in that it produces feeding roots immediately following good rains. If severe drought continues for a long period the plant is capable of shedding its wilted leaves and, finally, the typical black sticks so often seen during droughts result; the plants are not dead but merely in a condition by which they can minimise water loss. It is possible that this shedding of leaves is accompanied by a sealing of the tissues, as occurs in annually deciduous plants. When the bushes are stripped of their leaves by stock, instead of being allowed to defoliate naturally, some degree of "bleeding" is bound to result and the plants will not be in a condition to withstand a prolonged drought. Regeneration in good seasons is effected by the growth of new shoots from the base of the stems.

REACTION TO GRAZING.

The first effect of grazing the saltbush pasture is the removal of the sticks of the dead bushes. This is brought about by the trampling of the stock. The next effect is the result of pruning and a marked improvement is seen in the vigor of the bush due to the constant removal of the terminal buds with the consequent development of lateral shoots so that the result is a more compact and vigorous bush. Ungrazed country exhibits sparse and twiggy bushes. Thus, it would seem, and experience has shown, that heavy grazing is beneficial to the mature saltbush. However, sheep are selective grazers and the seedlings of the bush rank high in selection. From this it can be seen that heavy intermittent grazing would appear to be the most beneficial form of treatment of the pasture, with periods free from stocking to enable seedlings to become established. Experiments carried out on the Koonamore Vegetation Reserve have shown that "light grazing of saltbush is more harmful to the vigor of the community than heavy stocking or no stocking at all."

Heavy stocking must not be confused with overstocking which is the primary cause of degeneration.

According to Wood, three stages of degeneration as a result of overstocking can be distinguished:—

(1) The bush is killed but the dead sticks are not removed.

(2) The bush is removed but the soil is still held by comparatively short-lived perennial plants.

(3) There is a total removal of all plant cover, so that the soil drifts, and the bare subsoil is exposed.

Generally, overstocking leads to the removal of the palatable species and the consequent introduction of relatively unpalatable species such as poverty bush and roly-poly (*Bassia* sp.). Further overstocking results in the obliteration of all perennial plants, or alternatively the baring of the soil and the formation of a scald. Thus judicious grazing becomes increasingly important in conjunction with "spelling," which, to be of any use, must not be confined to periods of drought or a period during which no effective rain may have fallen.

REGENERATION.

Successful seeding (and approaching death acts as a stimulus to seeding) and the survival of resultant seedlings are the vital factors in the perpetuation of a stand of saltbush. A cool wet season is optimum for germination, the optimum temperature being in the vicinity of 60 deg. Fahr., lower temperatures decreasing the rate of germination. Experiments have shown that a soil saturation of something in the nature of

Fig. 5.—Young plants of perennial saltbush regenerating from seed on the Mundi Mundi plain, December, 1949.

60 per cent. is the optimum. At a lower moisture content, the water-absorbing capacity of the spongy tissue of the bracts seriously competes with that of the seeds. Thus after a good rain, it is expected that a good germination will result, but it has been noted that such a germination does not occur after summer rain. It has been found that high temperatures inhibit germination, and thus high temperatures following summer rains are responsible for a considerable amount of damage to the seed reserves in the soil.

It is not certain that saltbushes which have been defoliated, and appear as "black sticks" during a drought, are capable of regeneration from the base. However, it is possible that this is so, though it is quite certain that young seedlings grow from around the base of the bush due to the favourable conditions brought about by this seed bed. It is possible that both these forms of regeneration are correct.

Regeneration on a scalded surface is considered rare unless aided by mechanical means, that is, the disturbing of the hard scald surface so that seed and water may be held. The light, winged fruit of the *Atriplex* sp. cannot remain stationary on the bare windswept surface but it is possible that here the *Bassia* spp. and their litter play a twofold role in the regeneration of saltbush. Firstly, they prevent soil drift and secondly, they hold mechanically the seed of saltbush and it is not uncommon to see pure stands of *Bassia* spp. with young seedlings of perennial saltbush throughout.

CONCLUSION.

The preservation of the perennial saltbush is a problem for the grazier—for should it die out then he shall bear the loss, but if it should flourish then he will reap the benefit of his good management. The preservation of existing stands and the encouragement of newly regenerating stands is essential. Unwise management, either through ignorance or otherwise, has in the past led to the destruction of millions of acres of good saltbush country, with consequent substantial reduction in the productive capacity of the pastures, not only through the degeneration of the pastures but also through the loss of the valuable topsoil upon which the grazier depends. If the productive capacity of the western plain is to be maintained at anything like its present level, the vegetation, whether saltbush, grass or scrub, must be protected and encouraged. At the first signs of degeneration, the pasture should be spelled and so preserve a national asset.

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WATER CONSERVATION ON THE INDIVIDUAL FARM

BY

D. L. LAMY, H.D.A., Officer-in-charge.

THIS subject of water conservation popularly envisages those great feats of engineering by which man has, in many parts of the globe, harnessed rivers to provide stored water for irrigation, for electricity generation, and more recently for flood control. In New South Wales it has been particularly exemplified by Burrinjuck Dam which has made possible the highly productive Murrumidgee Irrigation Areas over a hundred miles to the west. Similarly the Hume Dam has resulted in the growth of Irrigation settlements all along the Murray.

Considerable development of irrigation projects has taken place since the turn of the century, but it is generally recognised that if Australia is to increase its population, the necessary agricultural expansion will make more and more demands on water resources. Water may eventually prove to be the limiting factor in Australian development.

By comparison with many other well watered countries where rainfall is ample and reliable, and rivers are large and numerous, or where snow-melts result in strong flows during the warmer periods of the year, Australia, with its low variable rainfall, is extremely limited insofar as its water resources are concerned.

In New South Wales our dependence on irrigation is emphasised when we consider that 45 per cent. of the State has a growing season of 0-4 months with a further 19 per cent. of 5-8 months only. While the rapid deterioration of catchments by erosion has, until comparatively recently, not been recognised, it is inseparably bound up with the treatment our land receives.

HYDROLOGY.

Falling rain coming in contact with the land either enters the soil or runs off. That part which enters the soil may be partly retained, where it is evaporated directly or through plants, while the remainder gradually passes down into lower horizons to emerge perhaps months later in the form of springs and seepage thereby maintaining stream flow. On the other hand, run-off may develop into a most destructive force, being responsible for the removal of valuable soil, the siltation of dams and streams and the primary cause of floods.

It appears perfectly logical then that reduction of run-off and the encouragement of water to soak into the soil is of major importance to the individual landholder as well as to the nation as a whole, and if full development of our water resources is to be attained it is essential that recognition be given to the soil as the great natural reservoir. A further point to be recognised is that virtually every farm regardless of location or size forms a part of some reservoir or stream catchment so that all landholders have a vital part to play in the conservation of water resources. This article is intended to outline the precautions which they can take to the benefit of themselves, their neighbours, and the State.

INCREASING INFILTRATION.

The most important factor in conserving rainfall relates to the ability of the soil to take in water as it falls. Soil which is well protected with vigorous vegetation is in an ideal condition to absorb moisture. Vegetation improves the soil structure upon which infiltration is largely dependent. With

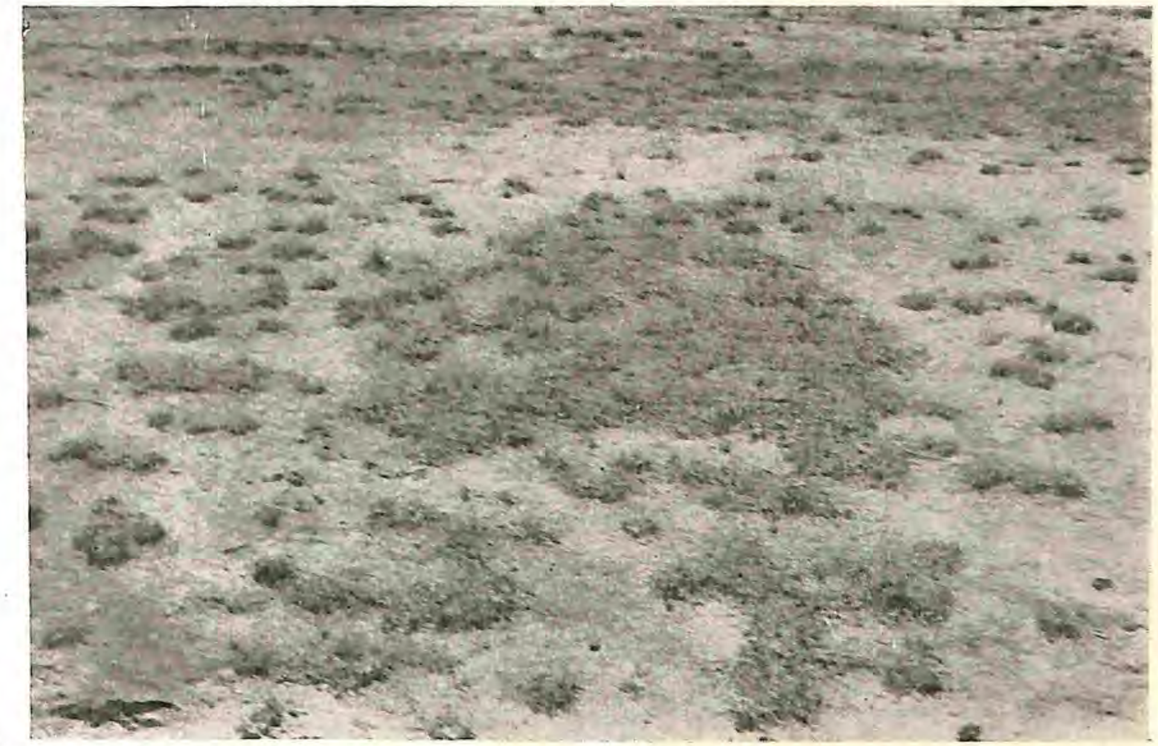

Fig. 1.—Excessive run-off from this poorly protected soil has resulted in the formation of the gully shown in *Fig.* 2.

soils of good structure and adequate humus, infiltration is at a maximum and so is water storage.

Vigorous vegetation, then, provides the key to water and erosion problems and all conservation practices aim directly or indirectly at promoting such growth; for example, vigorous pasture and overgrazing hardly go hand in hand; vigorous growth can only take place where the soil is able to absorb an optimum amount of water; taking an example of a mechanical control, a pasture furrow not only ponds water for use by vegetation but also retains valuable topsoil by reducing run-off velocities.

Even on agricultural land pasture is an essential. It is being more and more realised that if the fertility of arable areas is to be maintained rotations to include pasture must be adopted. In many parts of the wheat belt the deterioration of soil structure, following the loss of organic matter, has resulted in serious loss of soil by erosion and a consequent reduction in yields. In 1950 wheat sown in the Riverina resulted in many cases of poor crops associated with such vigorous skeleton weed growth that harvesting was not only difficult but also uneconomic. On the other hand, crops grown in clover ley rotations or on old lucerne stands dominated the skeleton weed and yielded well.

LAND USE.

With vegetation then as the ever-recurring theme of land protection it becomes necessary to devise land use programmes incorporating those types of vegetation most suited to the climatic and physical characteristics of each area. Timber and permanent pasture will always remain the best forms of land use in some areas, particularly where the country is too steep for cultivation; on the more gentle slopes, pasture-crop rotations will be adopted in widely varying forms. The pasture will be responsible for fertility maintenance and improvement while the cropping will promote sward rejuvenation.

CONTROL OF RUN-OFF.

While soil conservation practice aims at encouraging a maximum of absorption of water by the soil, it is not always possible to completely prevent run-off. At Wagga Soil Conservation Station a 300-acre catchment, exceptionally eroded during the years prior to 1946, was of necessity treated with contour furrows and banks with the aim of improving vegetative cover as well as altering the slopes characteristic of the land, so that the amount and velocity of run-off would be reduced to a minimum. As a result the catchment has not contributed any water to the 6,000 yard dam at its lower extremity for over three years, although rainfall was each year above average. The dam has, however, been kept full by collecting run-off from 34 acres of adjacent roads and denuded stock reserve. At the same time it is possible that there will be times when this 300-acre catchment will lose some rainfall as run-off, but provision has been made for such occasions by ensuring that the run-off will be controlled.

Run-off, where properly controlled, can serve useful purposes. In fact, in this State the watering of stock is widely effected by a system which encourages run-off and there does exist in the minds of many farmers an unwarranted fear that conservation of water in the soil jeopardises the proper functioning of farm water supplies. It can be safely said, however, that balanced conservation design with safe provision for water-supply catchments is possible and much to be preferred to a system of indiscriminate run-off with all its attendant evils.

RUN-OFF INVESTIGATIONS.

To control and utilise run-off from agricultural and grazing areas, it is necessary to find out how much run-off takes place and how fast it flows. Run-off is affected by both rainfall characteristics and watershed characteristics and until recently difficulties were experienced in developing equipment and instruments capable of dealing with the

Fig. 2.—A severe gully on an overgrazed stock reserve adjacent to Wagga Research Station.

Fig. 3.—Regenerated hillsides on the Wagga Station result in protected soil, minimum run-off and increased carrying capacity.

complicated process of run-off measurement. The Soil Conservation Service of New South Wales has now developed weirs and flumes, fitted with suitable water stage recorders, capable of accurate stream flow measurement. These are being installed on catchments particularly where it is possible to institute comparative studies of land usage. The information which these investigations yield is of particular value.

The Service has for several years now been investigating run-off under plot conditions, and in Volume 5, No. 1, of this Journal, the writer drew attention to excessive run-off and soil loss which occurred during abnormally severe storms experienced during the summer of 1947-1948. It will be recalled that from 1st December, 1947, to 15th February, 1948, 13.11 inches of rain were recorded which resulted in the following losses.

Treatment.	Run-off Percentage of Rain.	Soil Loss lbs./acre.
Wheat stubble ...	51	10,790
Fallow	42	22,323
Pasture	25	438

Now it is of interest to compare these results with the wet year of 1950 during the first eleven months of which 29.33 inches of rain were recorded:—

Treatment.	Run-off Percentage of Rain.	Soil Loss lbs./acre.
Fallow-Wheat ...	7.8	602.0
Pasture	0.47	7.7

While the 1950 rainfall was more than double that of the 1947-1948 summer, losses were slight, due in the main to the

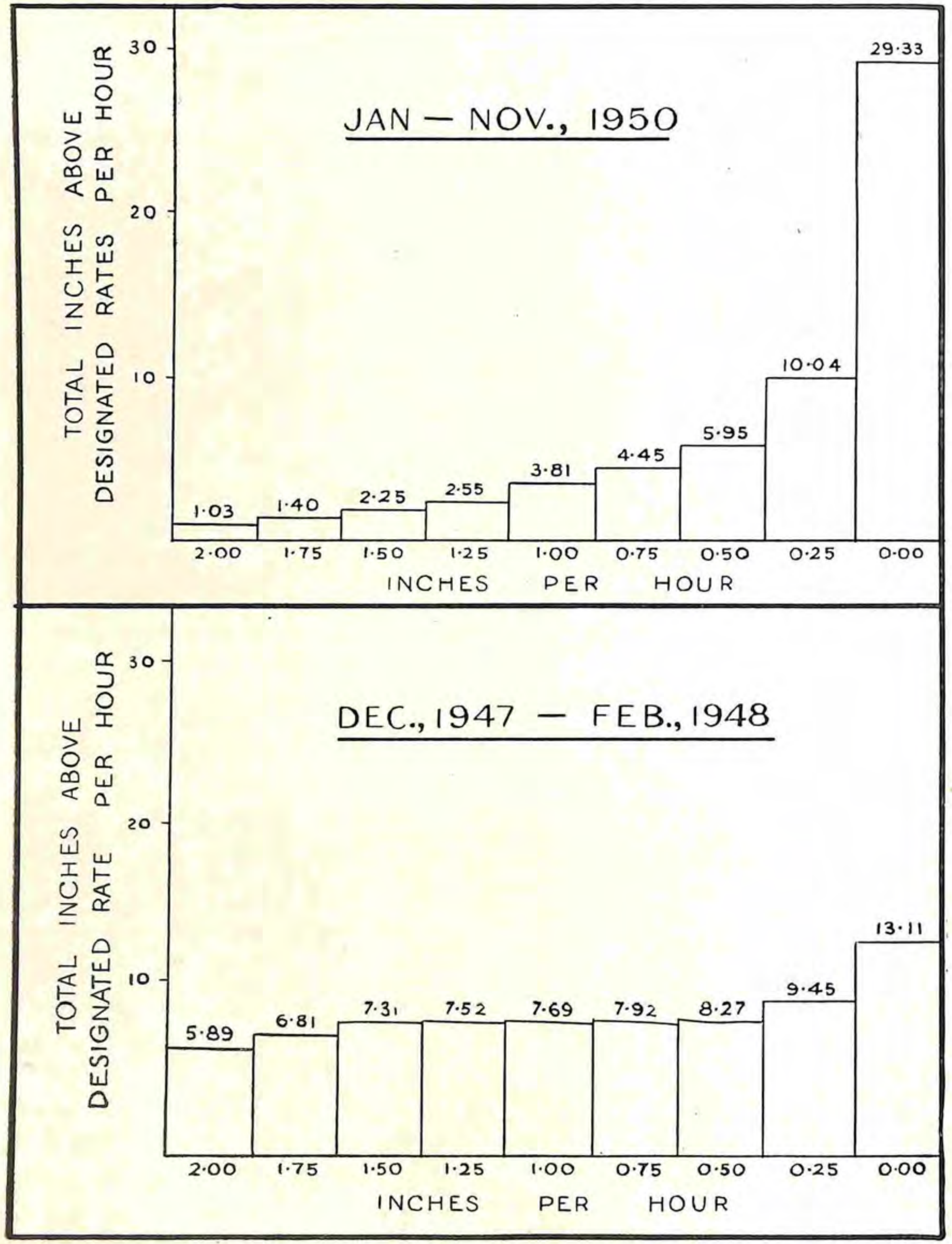

Fig. 4.—Histogram of relative rainfall intensities, Wagga Wagga Research Station.

entirely different characteristics of the rain (Fig. 4). While the high summer intensities were absent in the 1950 rains, their recurrence is unpredictable, so that vigilance is necessary at all times to ensure that the land is prepared for emergencies.

Although the 1950 run-off results, recorded under good farming practices, were slight, it is interesting to compare them with maximum flow recordings made on a 600-acre catchment close to Wagga. This catchment is badly deteriorated as seen in Figs. 1 and 2, and while discharges were relatively high with every fall of rain throughout the year, a peak was reached on 14th November when a maximum discharge in excess of 208 cusecs, resulted from a rain of 1 inch, most of which fell at low intensities.

CONCLUSION.

Records of water losses under Australian conditions are very few but the Soil Conservation Service is steadily amassing information on surface run-off and its related factors and the more adequate this information becomes the better position we will be in to define more precise measures to ensure maximum infiltration on the individual farms, where water conservation really begins.

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THE EROSION CONTROL PROGRAMME IN THE UPPER GLENBAWN CATCHMENT AREA

BY

D. D. H. Godfrey, H.D.A., Resident Soil Conservationist.

A DESCRIPTION of the topography, climate, land use and erosion in the Glenbawn Catchment Area was given by Secombe in this Journal, Vol. 4, No. 2, 1948. In this article a study is made of wise land usage and mechanical soil conservation measures now being practised.

WISE LAND USAGE.

There are thousands of acres within this catchment area of 500 square miles on which it is impossible to utilise mechanical measures of erosion control. A survey has shown that 482 square miles have slopes in excess of 20 per cent. and whilst mechanical measures can be utilised on slopes up to 35 per cent., the only possible method of stabilising the steeper slopes is the adoption of land usage measures designed to increase the vegetative cover, these include:—

1. *Wise stocking*: There are many acres that have been, and unfortunately still are being, injudiciously stocked. Deterioration resulting from this practice has been stressed time and again by this Service. There are also many areas which are being used for grazing by sheep when they are more suited for the less selective grazing by cattle.

Many landholders have realised the serious results to be expected from injudicious stocking and have limited their stock numbers whilst others are changing from sheep to cattle with good results.

2. *Rabbit control*: Damage caused by rabbits is, of course, closely allied but worse than that caused by injudicious stocking. The more rabbits an area is running the fewer stock can be safely carried on that area. It has been demonstrated by many landholders that, over a period, the rabbit can be controlled.

3. *Timber conservation and regeneration*: There are many areas which never supported very dense stands of natural timber; at the same time, there are also many areas of excessive slopes on which too much of the natural timber has been killed. In some cases this practice has been very hard to follow, as the slopes cleared are too steep even for reasonable grazing and the timber obtained from them very inferior. In other cases the timber has been removed for building purposes or killed for grazing. Whatever the reason the results have been tragic. The excessive run-off from these slopes adversely affects the lower, and one-time stable, slopes and flats, and erosional debris from these areas is contributing heavily to the siltation of the Hunter River.

The selective killing or removing of some of the trees is often necessary and even desirable and sometimes more grass will result and a better close

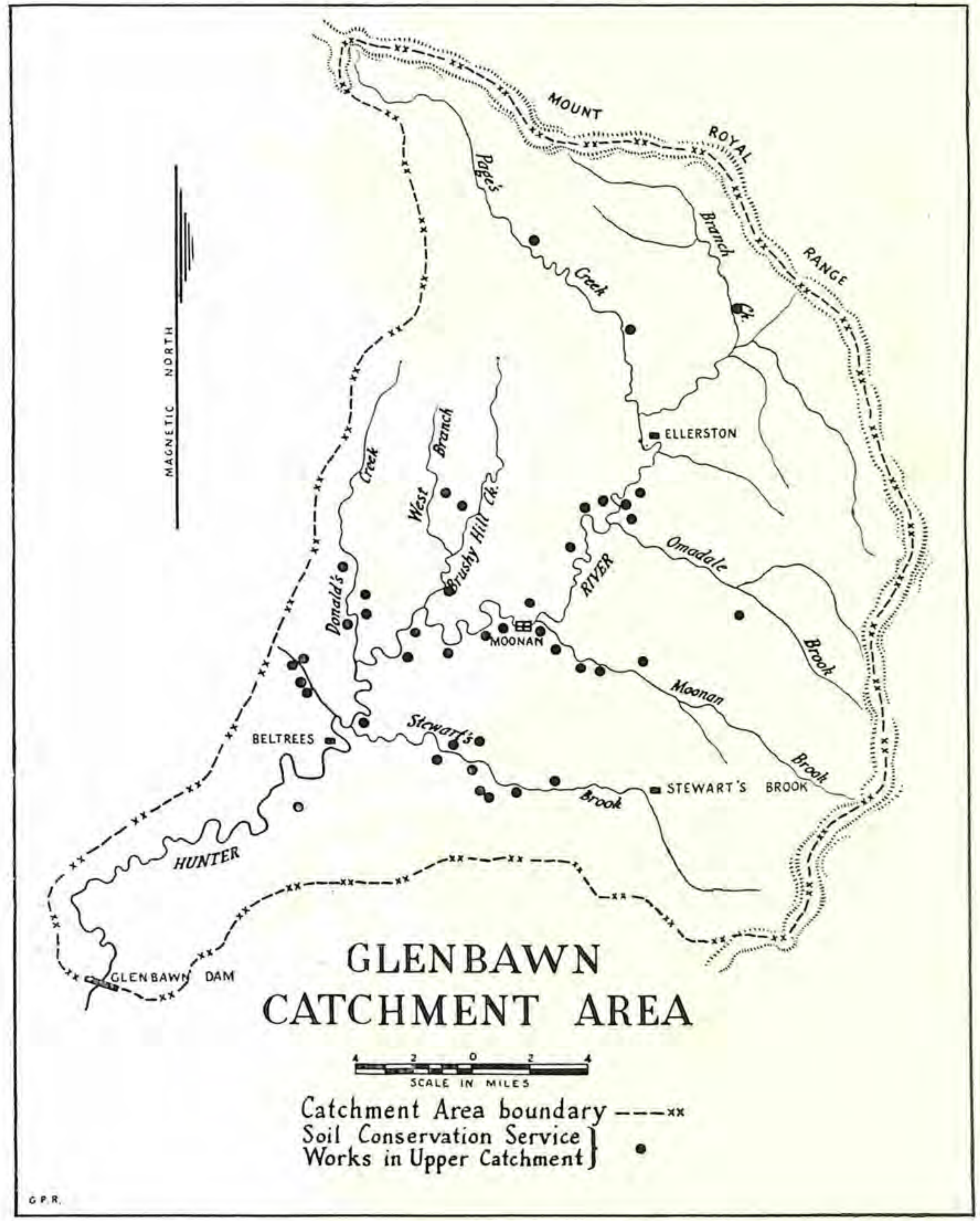

Fig. 1.

ground cover will be obtained. Unfortunately, however, the indiscriminate grazier has an additional flock of hungry sheep, or mob of cattle, waiting to eat the extra grass, and so the necessary protection offered to the soil by the individual tree has been lost; the protection given by the new grass cover is non-existent, and in a very short time the topsoil is moving downhill, gullies form and the clearing practice results in a drop in production rather than a rise, and incalculable damage is done to lower and better lands; flood peaks, river bank erosion and harbour siltation are all magnified many times.

This unwise destruction of timber at the headwaters of the Hunter is still proceeding and represents a menace to the Valley. The only safe land usage for mountainous catchment area lands is virgin timber.

MECHANICAL MEASURES.

Apart from the above, there are mechanical measures being carried out to assist in erosion control. It is stressed that these measures only assist in the control of soil erosion and are useless without the adoption of wise land use practices by the landholder. Remedial measures in the form of an altered land-use programme and care of ground cover will, in many grazing areas retard soil erosion considerably; mechanical measures such as pasture furrows, diversion banks, gully stabilisation, silt traps, etc., accelerate the rate of regeneration and assist nature to correct the man-made damage the soil has suffered.

There is very little cultivation land in the upper catchment and so the use of graded banks and waterways is limited. In some areas efforts have been made to cultivate land having too steep a slope with disastrous results. Fortunately the idea of turning this "too steep" cultivation into improved pasture is spreading and excellent results are being obtained.

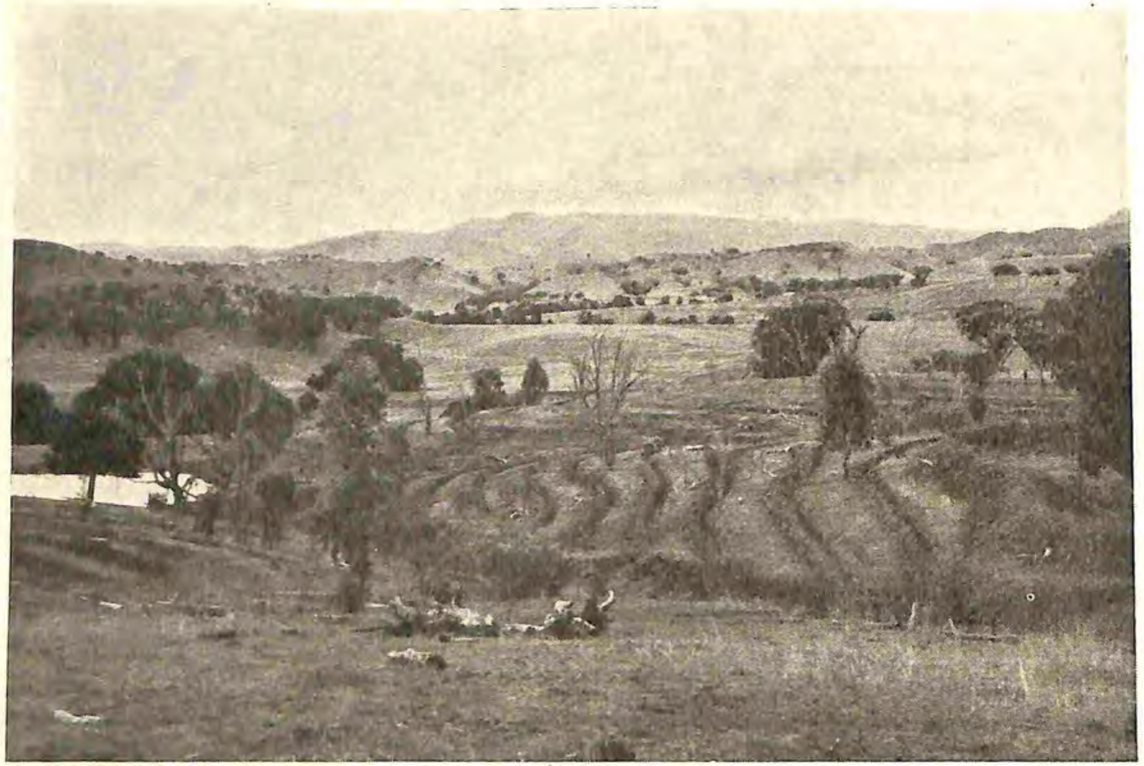

Fig. 2.—A Glenbawn minor demonstration.

Fig. 3.—Severe gully erosion on road and stock route south of Moonan.

The mechanical measures adopted all have the object of holding up excessive run-off and allowing this more time to soak into the soil and so become available to plants. The surplus that cannot be absorbed can be conveyed along gradual flow lines at a speed which will not cause the soil to erode. To this end use is made of silt traps, pasture furrows, absorption banks, diversion banks, graded banks and grassed waterways.

It is necessary that all new works be sown and fertiliser applied. Sowing has been carried out with seed made up from mixtures, including some of the following species:—Lucerne, rye-corn, Rhodes grass, liverseed grass, Wimmera rye, perennial rye, subterranean clover and ball clover. Kikuyu grass is especially valuable in some situations. The application of superphosphate in these upper areas of the catchment has proved very beneficial and in special circumstances sulphate of ammonia has been used to advantage also.

Assistance is provided to landholders in this area on the following basis:—

Demonstrations. — Mechanical works are undertaken by the Soil Conservation Service with the full co-operation of the landholder who contributes labour, fencing material, use of any plant or equipment at his disposal, seed, fertiliser and adopts a wise land use programme.

These works are carried out on areas of land that are either visible from roads or stock routes or well-known to other landholders, the object being to show the landholders what can be done and the results that can be expected from soil conservation works.

Demonstrations have been completed on six properties in the area. The size of the demonstrations averaged approximately 350 acres.

In addition, a further three demonstrations are now being undertaken. These demonstrations are primarily educational in function and introduce proven soil conservation measures into each section of the catchment.

Glenbawn Minor Demonstrations.—These comprise small works carried out with the object of initiating catchment area landholders into their own soil conservation programmes. They are extended in size by the landholder hiring the Service's plant and operators. At the end of December, 1950, 22 of these minor demonstrations had been completed in the Catchment area.

A further nine of these minor demonstrations are now being carried out.

Plant Hire Scheme.—This is a scheme whereby the landholder can hire, at a very moderate rate, plant or plant and operators to undertake soil conservation work which he is unable to carry out with his own equipment.

The plant available includes crawler tractors of from 35 to 90 draw-bar horsepower, fitted with dozer units, grader terracers, grader ditchers, rippers and road ploughs, together with the necessary operators.

All design and layout is done by Service staff free of charge to the landholder.

Many landholders have shown their satisfaction with regard to this scheme by applying for a second and third plant hire.

All funds expended on soil conservation works are a deduction for income tax purposes and work undertaken under the plant hire scheme falls within this definition.

General Assistance.—General advice on soil erosion problems is always available from the S.C.S. staff. On application to the District Soil Conservationist inspections of properties will be made and the landholder has the opportunity of discussing his erosion problems in the field with experienced officers who will explain what can and should be done and indicate what assistance this Service can give.

Fig. 4.—Severe sheet and gully erosion.

Fig. 5.—Portion of a Demonstration Area.

In addition, if any landholder desires to undertake soil conservation works with his own plant and labour, arrangements will be made to assist him with any designs necessary and to have the work checked and inspected as it progresses, if desired.

Several landholders in the Catchment have taken advantage of this service.

Plant in Use.—At the present time there are three tractors with bulldozer equipment attached, and the necessary subsidiary equipment, in daily use in this upper section of Glenbawn Catchment.

GENERAL.

A Kikuyu sod nursery has been established near the junction of Stewarts Brook and the Hunter River. This grass has been found extremely valuable for the treatment of overfalls in gullies, danger spots in dam and bank outlets, etc.

Many examples of work carried out and advocated by the Service are available for inspection by interested persons throughout the area. Considerable progress has been made in the last three years in the objective of interesting all landholders within the catchment in undertaking necessary soil conservation measures to preserve their properties and mitigate the silt menace in this upper section of the Hunter River.

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SOME OBSERVATIONS ON CREEK AND RIVER BANK EROSION IN THE MANILLA DISTRICT

by

L. J. Durham, B.Sc.Agr., Soil
Conservationist.

THE purpose of this article is to set out the effects and to attempt to outline the causes of stream bank erosion in this area, over the past twelve months.

Whilst the severity of the erosion is not to be compared with that of the Hunter River valley for example, sufficient evidence of the advance of this form of erosion, during the period mentioned, is available to cause concern to those engaged in soil conservation work in connection with the mitigation of siltation in the Namoi River.

Unlike the Hunter River valley and many others, large expanses of fertile river and creek flats are not a feature of the upper Namoi River and its many tributaries within Keepit Catchment Area. Early recognition of the damage in the past, and possible damage in the future, in relation to the limited lengths of alluvium, will help safeguard valuable land and materially enhance the life of Keepit storage.

THE CYCLE OF EVENTS.

In order to demonstrate the siltation potential from erosion of this nature and to outline the many difficulties associated with its treatment, let us examine the effect of individual gully activity.

In the first processes of gully formation, which can be called primary erosion for the purposes of this article, lateral concentration of water is usually responsible for it arriving at a point where it is subject to a drop in level. As a result of this over-fall, the head of the gully is enlarged and undermined, with a consequent eating-back of the gully in the direction of flow of the water. The second stage in the process is reached when a gully, once started, begins to scour at a rate dependent on the volume of water reaching it, and carry large volumes of silt to lower areas and streams. Except in odd cases erosion is usually confined to one to several major gullies in one paddock with the intermediate areas relatively stable, except for possible sheeting, and from which water concentrates to further the activity of the gullies.

The third stage is reached with concentration of all water from the gullies into the main drainage line for the catchment, be it a small or large creek or finally a river carrying the whole of the run-off from the total catchment area.

It will be appreciated that mitigation of the first two stages by wise land usage and mechanical measures involves the infiltration into the soil or reduction of erosive velocity of local and therefore limited quantities of water and it is this form of work which is at present being undertaken extensively throughout Keepit Catchment Area.

Once having entered the third stage, however, entirely different methods of control have to be utilised on individual eroded areas to obtain the desired effect. Upon the incidence of general heavy rains over most of a large catchment area, the volume of water to be carried by the main drainage of a local catchment or the total catchment is likely to be huge.

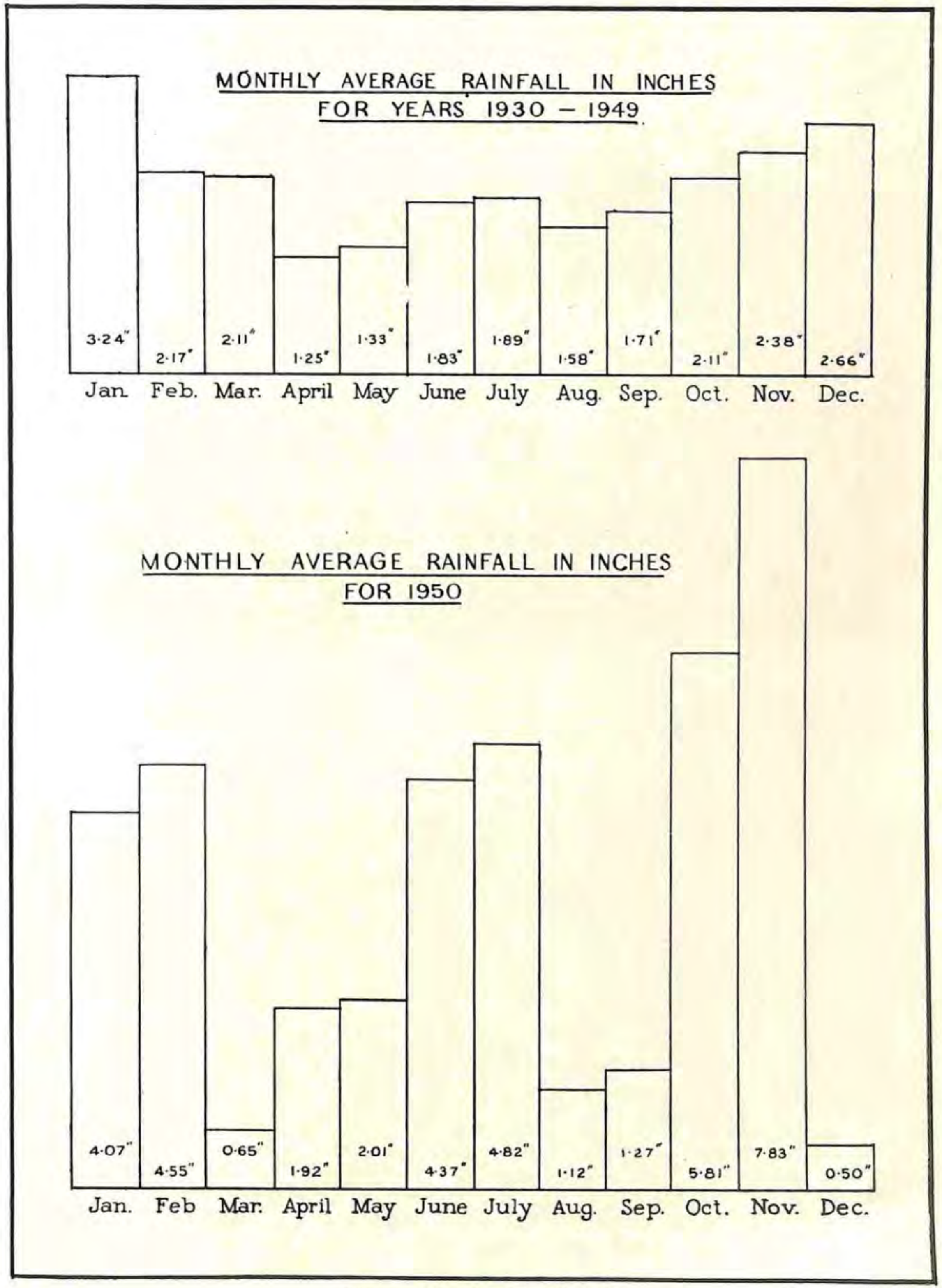

Fig. 1.—Manilla Rainfall Station.

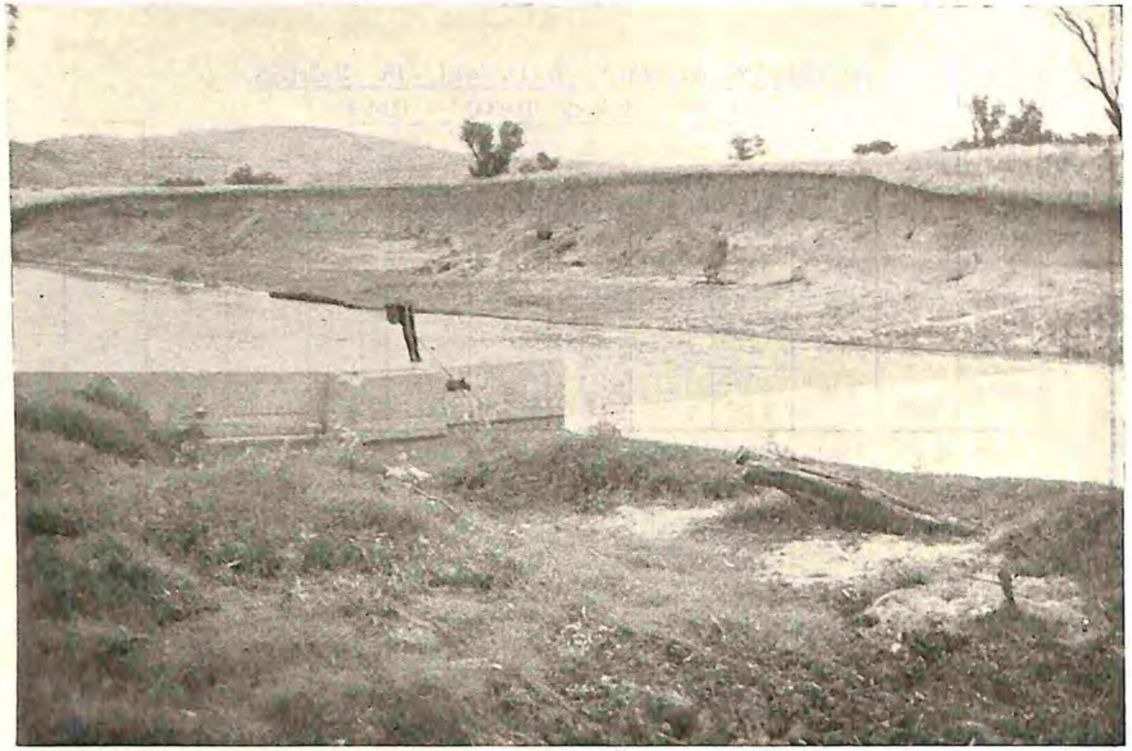

Fig. 2.—General view of the eroded river bank of the Namoi River adjacent to the Manilla weir.

Occurrences of this nature were many in number during 1950 in Keepit Catchment Area. Even though soil conservation works have been installed progressively for periods of up to three years in the lower regions of the catchment around Manilla and Barraba, much of this area and large tracts of country in the tablelands still require effective soil conservation treatment and contribute large volumes of surface run-off to the Namoi River system.

To quote one rainfall example, records for one property in the Glen Morrison area in the head regions of the catchment for 1950, are as follows:

STATION "BENDEE" GLEN MORRISON.—YEAR 1950.

Month.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Rain points	544	540	195	675	302	1,639	722	401	225	917	769	161	7,090

These figures indicate the volume of water likely to enter the upper reaches of the Namoi River from areas not yet subjected to soil conservation control measures. One heartening feature to be mentioned is the relatively light silt load carried from the tableland areas, but it is the volume of water which more concerns us at the moment.

CONTRIBUTING CAUSES TO THE EROSION.

For any one area these are likely to vary and to be many in number. So far as the problem exists in the Manilla district, soil type and the influence of excessive rainfall over the past twelve months have been responsible.

Soil Type.

Generally speaking, the main soil type found in most areas around Manilla is the deep, red to red-brown self-mulching soil, of a highly erodible nature.

These soils in general are of a very deep nature. Often reaching 20-30 feet in depth, they are particularly noted for the sloughing

Fig. 3.—An extension of the area shown in *Fig.* 2, 150 yards downstream from the weir.

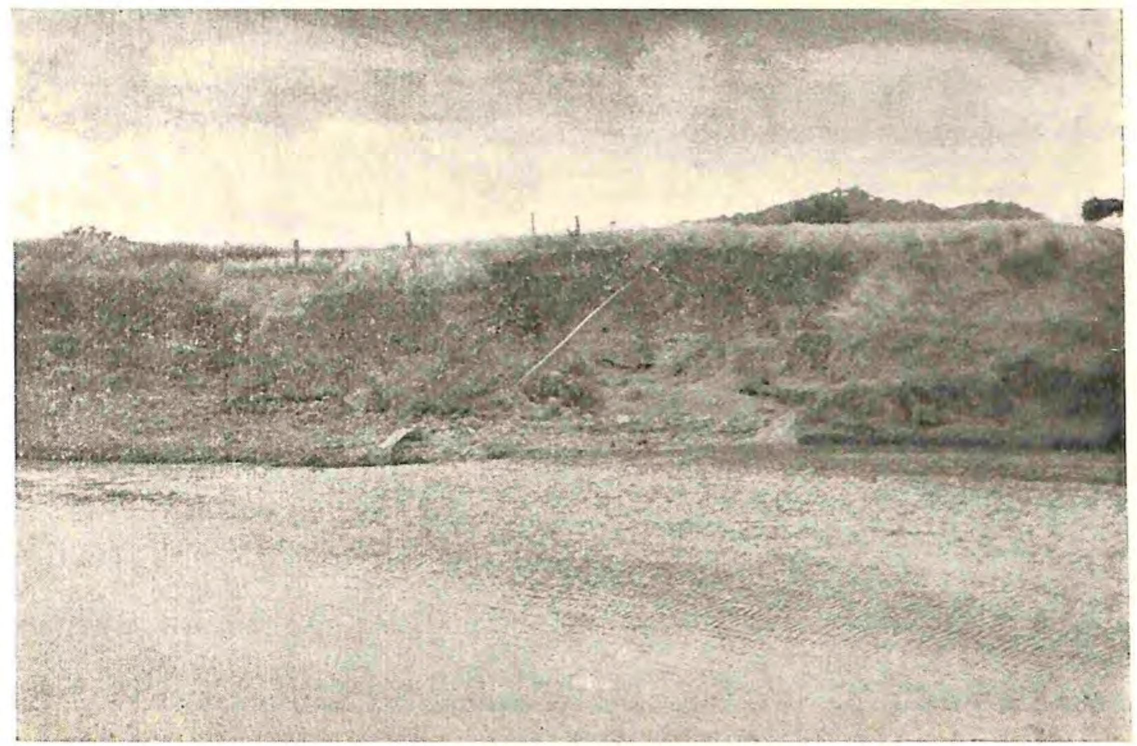

Fig. 4.—Further recent erosion 500 yards below the weir adjacent to the racecourse.

effect in gully sides, by which process many tons of soil may be lost in one place at one time.

Because of this characteristic, it is not surprising to find gullies in the area which have enlarged to depths and widths of 20 feet or more in the space of ten years or less.

It is not hard to imagine, therefore, the effect of large volumes of water during flood flows upon unstable sections of creek and river bank.

Influence of Rainfall.

During 1950, and particularly the latter six months, as shown above, very heavy rains were recorded on many occasions throughout Keepit Catchment Area.

To appreciate the unusual rainfall experienced during 1950, monthly falls are shown in histogram form, on the same scale as monthly averages at Manilla P.O., for the twenty years period 1930-49 (Fig. 1). Other stations throughout the catchment area show the same result. The station "Bendee," mentioned earlier, for a thirty-one year period 1917-47, had an annual average of 38.11 inches. The yearly total for 1950 was almost double this figure, being 70.90 inches. As a result, several minor and three major floodings occurred in the Manilla and Namoi Rivers.

The most serious of these occurred on 22nd and 23rd July, 1950, when the Namoi River at Keepit Dam site reached a maximum height of 34 feet 8 inches. Two later floodings occurred on 22nd and 25th November, 1950, when heights recorded at Keepit Dam site were 25 feet 6 inches and 27 feet 6 inches respectively.

Damage resulting from these floods, whilst not of significance compared with that in many other areas for the same period, does tell a story when translated in figures for siltation.

Fig. 5 —A change in the course of Hall's Creek at high flow brought about the damage to the banks shown in the background.

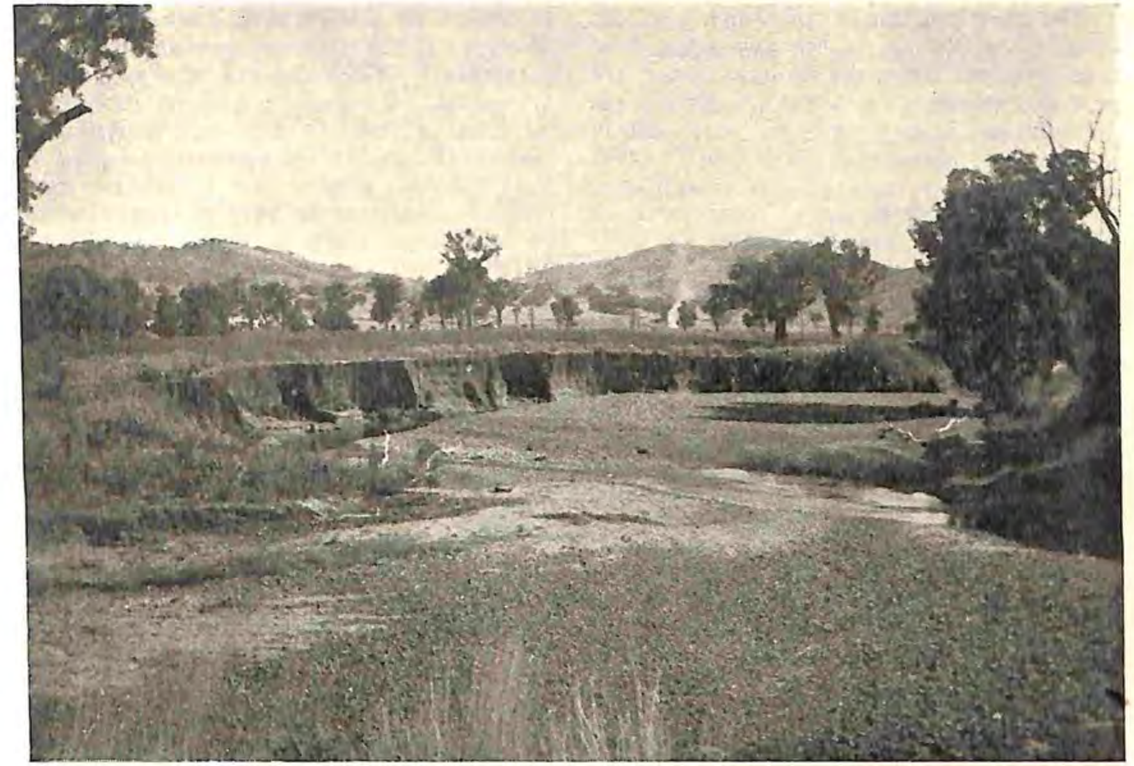

Fig. 6.—Huge quantities of soil were lost from this section of Hall's Creek adjacent to its junction with the Namoi River.

A siltation figure of approximately 0.5 per cent. from the Namoi River just below its junction with the Manilla River, at a flow in the vicinity of 40,000 cusecs on 22nd July, 1950, represents 20,000 tons of silt per hour moving down the river.

There is little visual evidence of extensive sheet erosion during the past twelve months owing to the prolific cover over the area following three or four favourable seasons. In addition, it is the considered opinion of officers constantly engaged on the Manilla lands that the contribution to siltation by sheeting during this period was small and that practically all silt carried by the Namoi River was the direct result of gully activity, creek and river bank erosion.

DAMAGE NEAR MANILLA.

By far the most serious case of river bank erosion exists on the Namoi River immediately below the weir from which Manilla town water supply is drawn.

Tremendous quantities of soil have been removed over the last twelve months with the result that this section of the river bank has now become completely unstable.

Observations show that this area of erosion originally began with the over-fall of water from a small swamp some two or three chains back from the weir wall.

Following the processes outlined above it was not long before quite a sizeable cut-back occurred in the rather steep and fairly high bank. Being a well-grassed bank it remained in much the same condition until early last year, when heavy rains and periodic flooding occurred. Excessive rains caused further cutting-back at the over-fall into the river and whirlpool effect during flood flows rapidly undermined the bank and enlarged the damaged area.

At the present time the damaged area extends for a distance of about 150 yards from the weir wall and back from the edge of the water at low levels, for a distance of some 40 yards.

The exact amount of soil which has been removed would run into many thousands of tons, but apart from the present damage the potential source of silt to the storage is high. In addition, having increased in extent in such a short period it is likely that the area may become a menace to the weir wall since it has encroached to within 10-15 yards of the wall, at its easternmost point.

Another serious area of bank erosion exists some 500 yards below the spot just mentioned and is doing much to menace a fence line on the Racecourse and a pipeline drawing water from the river.

Several other serious examples are to be seen in close proximity to Manilla along Wongo Creek, Hall's Creek, Yarramanbully Creek and the Manilla and Namoi Rivers.

Wongo Creek has been particularly menaced by this form of erosion owing to the many high intensity storms received in that area, with resultant flash run-off over large areas. More exact measures are being used to combat the erosion and siltation hazard in Wongo Creek catchment, than in other local catchments. With the aid of several large silt dams, of which two have been constructed to date, in conjunction with the usual soil conservation measures adopted on the catchment area lands it is hoped to considerably lengthen the time of concentration of run-off in the many branches of Wongo Creek.

CONCLUSION.

It is certain that considerable quantities of soil will continue to be lost from the banks of Wongo Creek and the many other creeks before soil conservation programmes for individual catchments can be completed.

The hazard of creek and river bank erosion, in the stabilisation of the eroding lands of Keepit Catchment area and the diminution of siltation of the Keepit storage, is one which may assume increasing importance if further rainfall years of the nature of 1950 occur.

KIKUYU IN THE EROSION CONTROL PROGRAMME

by

K. G. Secombe, H.D.A., Resident Soil Conservationist.

In recent times, frequent references have been made to Kikuyu grass (*Pennisetum clandestinum*), some in favour of it, and some much against it. However, in this article it is not intended to join in any of these controversies, but to present some facts in the light of recent experiences in the Hunter Valley.

Firstly, however, I must remind readers that this article has soil conservation as its primary purpose. Consequently, what is written here does not necessarily apply to lawns, gardens, etc., from the owners of which most of the criticism of this grass arises. It is agreed that Kikuyu can be difficult to eradicate from cultivation areas.

Fig. 1.—A farm dam spillway ten weeks after strip sodding with Kikuyu grass. This spillway has carried a twelve inch overflow for several hours safely.

EARLY HISTORY.

There are several opinions as to the exact details of Kikuyu's introduction into Australia, but all agree that it was about 1919-1920. The country of origin is also variously quoted as Kenya and the Belgian Congo, in Africa, both of which are situated on the Equator. The seed initially procured was planted in the Botanic Gardens, Sydney, and from there, cuttings were sent to Hawkesbury Agricultural College, Richmond. Trials at these centres were very encouraging and distribution of cuttings (or stolons) to various localities was made.

CLIMATE AND SOILS.

This grass has proved itself very adaptable in respect of both soil and climatic requirements. However, maximum development is achieved on sandy and red loamy soils—poorest results being on stiff clays. Higher rainfalls or moist locations assist in gaining optimum results, but then again this grass is considered drought tolerant, and grows quite well in many areas where rainfall is little in excess of 20 inches per annum.

Basically, Kikuyu is a spring and summer grower, but in areas where frosts are not excessively severe, some growth is made in winter. Consequently it can safely be stated that Kikuyu produces more fodder in winter than does paspalum.

FOOD VALUE.

As an indication of the fodder value of Kikuyu, the following table sets out comparative figures of this and other common fodders:—

TABLE 1.*

	Kikuyu, 2 months growth.	Oats, Feeding off stage.	Phalaris tuberosa.	Perennial Rye.
Moisture per cent.	81·25	82·00	75·00	75·20
Ash	2·40	2·00	3·00	2·60
Ether Extract ...	·47	·50	·60	·70
Crude fibre ...	5·98	3·20	4·00	7·10
Carbohydrates ...	5·89	9·40	10·60	11.50
Crude protein ...	4·01	2·90	6.20	2·90

* After Whittet, J. N., N.S.W. Department of Agriculture pamphlet—Kikuyu grass. Hallsworth, E. G. Unpublished data.

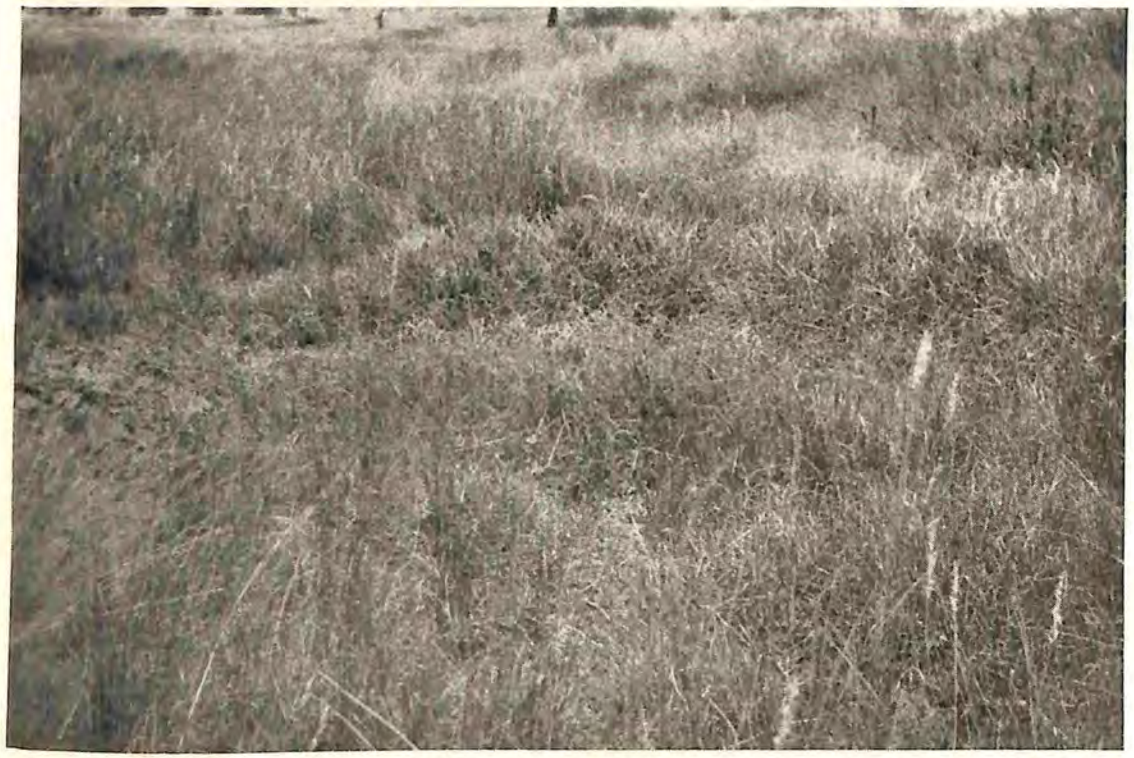

Fig. 2.—A former gully overfall, now Kikuyu sodded. This forms the inlet for the dam shown in *Fig.* 1.

Fig. 3.—Runners from an area of strip sodding in a waterway.

THE ROLE OF KIKUYU IN SOIL CONSERVATION.

Having established the value of this grass as a fodder plant, I propose to go one step further and illustrate the most important role that this grass is playing in soil conservation.

Those familiar with soil conservation activities will be aware of such structures as graded banks, diversion banks, silt traps, grassed waterways, etc. In the construction of each of these measures there is a place for Kikuyu.

The critical point in all mechanically constructed soil conservation measures is the outlet. It is at this point that the maximum amount of water flows, and often at the maximum velocity.

In many cases the most satisfactory method of stabilisation of these critical points is by use of Kikuyu sod. Although the area thus treated is small, the benefit resulting is reflected over a far greater area and this type of treatment is an insurance against damage to mechanical structures. It would be short-sighted policy to risk possible failure of a valuable asset for the sake of a small additional outlay. A few square yards of sod at a critical point could often prevent a spillway from scouring out, thereby involving either costly repairs to, or total loss of, a farm dam.

In view of the rapid rate of growth, and the stolon-forming habit of Kikuyu, strip sodding can often be employed where complete sodding is impracticable for various reasons. In normal seasons if strips are placed 3 feet apart in spring, the runners from one strip will usually join those of its neighbour within 4 to 5 weeks, and within three months a complete cover can be anticipated.

GULLY RECLAMATION.

Here is another instance where Kikuyu can be used to maximum advantage. There are various ways in which this grass can be employed in this work:—

(*a*) The planting of sprigs or sods at intervals along gully floors. As moisture is usually present in such places, rapid growth can be anticipated. This growth catches silt in times of "run-off-producing" rains, then grows up through the silt, thus binding it and raising the floor of the gully.

(*b*) Where it is practicable or convenient to fill gullies or at least to shape the sides to a reasonable batter (and this is seldom to be recommended unless the run-off from the catchment has been controlled), Kikuyu can then be utilised to give quick growth and consequential protection against further scouring to the depth of the original gully.

(*c*) Overfall erosion is both frequent and serious. Because of the characteristic habit of "eating back," the magnitude of the soil loss is very considerable. Spectacular results have been achieved in stabilising overfalls in the Hunter Valley by the judicious use of Kikuyu sod.

In these circumstances the overfall is shaped as well as possible so as to give a uniform spilling effect. Naturally the flatter the gradient the better, but slopes of 1 : 1 have been successfully treated. If, after shaping, the whole disturbed area is sodded, there is little or no danger of any damage occurring in the event of run-off-producing rains. All Kikuyu areas illustrated have carried large volumes of water without damage. The most damage that can be anticipated is the dislodgment of a few sods, which can be easily replaced. If

Fig. 4.—An absorption bank outlet completely vegetated 3 months after strip sodding with Kikuyu.

Fig. 5.—Gully head stabilisation by Kikuyu grass.

desired, additional protection for new works can be gained by pegging down the sod with strips of old netting.

SUPPLIES OF KIKUYU.

Due to the fact that this grass rarely sets seed in Australia, all plantings must be from either sods or stolons. Little difficulty should be experienced in getting supplies of either. Many town folk are anxious to give away Kikuyu lawns on account of the rapid and vigorous growth, and sods from lawns are ideal for this type of work. The most convenient sized sods from a handling point of view are about 12 to 15 inches square and 4 inches thick. Sprigs or stolons can be of almost any size and should be buried for about ¾ of their length.

CONCLUSION.

This valuable grass warrants a wide usage in the erosion control programme, particularly in the central and northern areas of the State where warm temperatures and reasonable spring and summer rains may be expected. In such areas Kikuyu can be used with great advantage in the safe water disposal system as an adjunct and safeguard to mechanical soil conservation measures.

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SOIL CONSERVATION IN THE BARRABA DISTRICT

by

J. M. PATTERSON, H.D.A., Soil Conservationist.

DURING the last two years the operations of the Soil Conservation Service have been extended to that portion of the Keepit Catchment Area comprising the Barraba district (Fig. 1).

The Manilla River and numerous tributaries rise in this area and the district generally is of a mountainous nature, especially on the northern side; on the southern and western sides the country opens out into undulating and in some places fairly flat fertile valleys. Timber has been cleared extensively to allow growth of natural grasses, but in the northern section of the district large areas still remain under forest.

LAND USAGE.

Sheep grazing is the main occupation, fine woolled Merinos being the most popular breed, and it might be added that some of the best fine woolled fleeces in the State have been grown in this district. Beef cattle also play an important part in the pastoral programme and several fine cattle studs are located in the district. In recent years wheat growing has gained in popularity; the cultivation practice follows the usual pattern of summer cultivation and sowing in late autumn. Stubble burning is far too extensively practised, with the result that many of the wheat paddocks are showing signs of erosion and some are very seriously damaged. A contributing factor to this erosion is the prevalence of summer storms, four inches in an hour being not uncommon; storm rains strike wheat lands at about the time stubble is burnt, resulting in maximum run-off and soil loss. It is on these areas that most of the recent erosion control work has been carried out.

EROSION PREVALENCE.

The heavy silt loads carried by the Manilla River indicate the extent of erosion in the district, although during the last four favourable climatic years the erosion on the grazing lands is masked to some extent. The most serious erosion damage occurs on wheat paddocks and on the steeper grazing country. A practice which increases the erosion risk in this area is that of burning the tall coarse spring growing grasses after they have dried off, usually about Xmas or New Year, thus laying the steeper slopes open to damage from maximum run-off during severe summer storms.

WORKS UNDERTAKEN.

Two major demonstrations have been carried out, and minor demonstrations are being undertaken in this portion of Keepit catchment area, followed by erosion control work undertaken under the Service's Plant Hire Scheme. Up to the present time forty-one landholders are co-operating with the Service in this district.

MINOR DEMONSTRATION AND HIRE.

The first erosion control work undertaken in the Barraba District was on Mr. F. J. Bowman's property at Red Hill, where he was faced with a problem on one of his cultivation paddocks. This area had been cultivated for a number of years and advanced stages of erosion were evident; fertility had declined and numerous gullies dissected the area. Mr. Bowman proved to be an enthusiastic co-operator and the work has been most successful. The general pattern of work followed that used on most agricultural land, viz., graded banks discharging into a constructed waterway. An area of 80 acres was treated under one system of discharge and a further 75 acres adjacent treated under another. Run-off from adjacent hills was prevented from flowing onto the cultivation area by direction into the main waterway by diversion banks and dams (Fig. 2). The waterway containing banks were constructed with a dozer and the water carrying surface was levelled with a grader terracer.

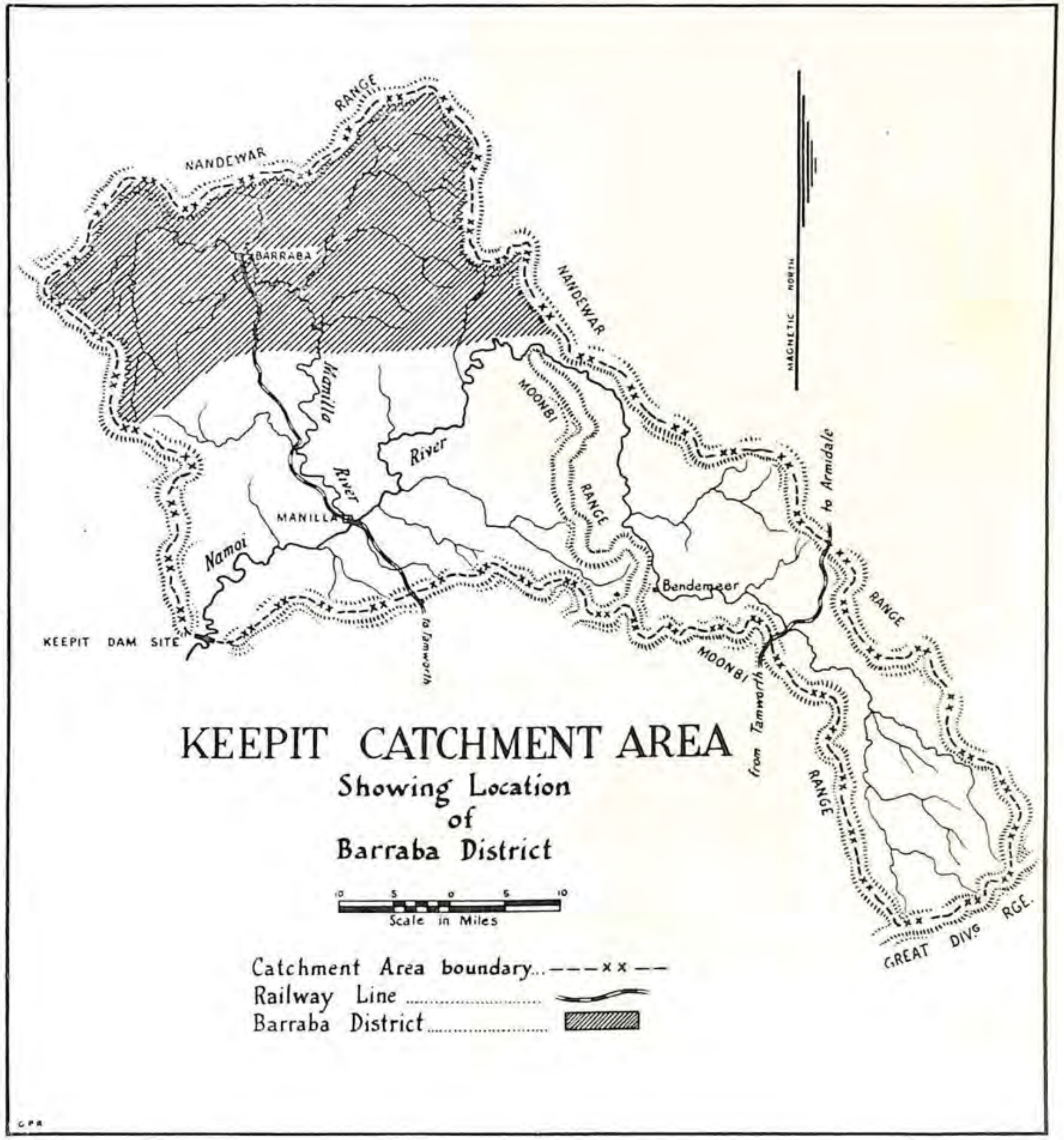

Fig. 1.

A grass mixture was sown on this surface containing per acre:—

	lb.
Liverseed	3
Rhodes grass	12
Paspalum	3
Sudan grass	5
Oats	10

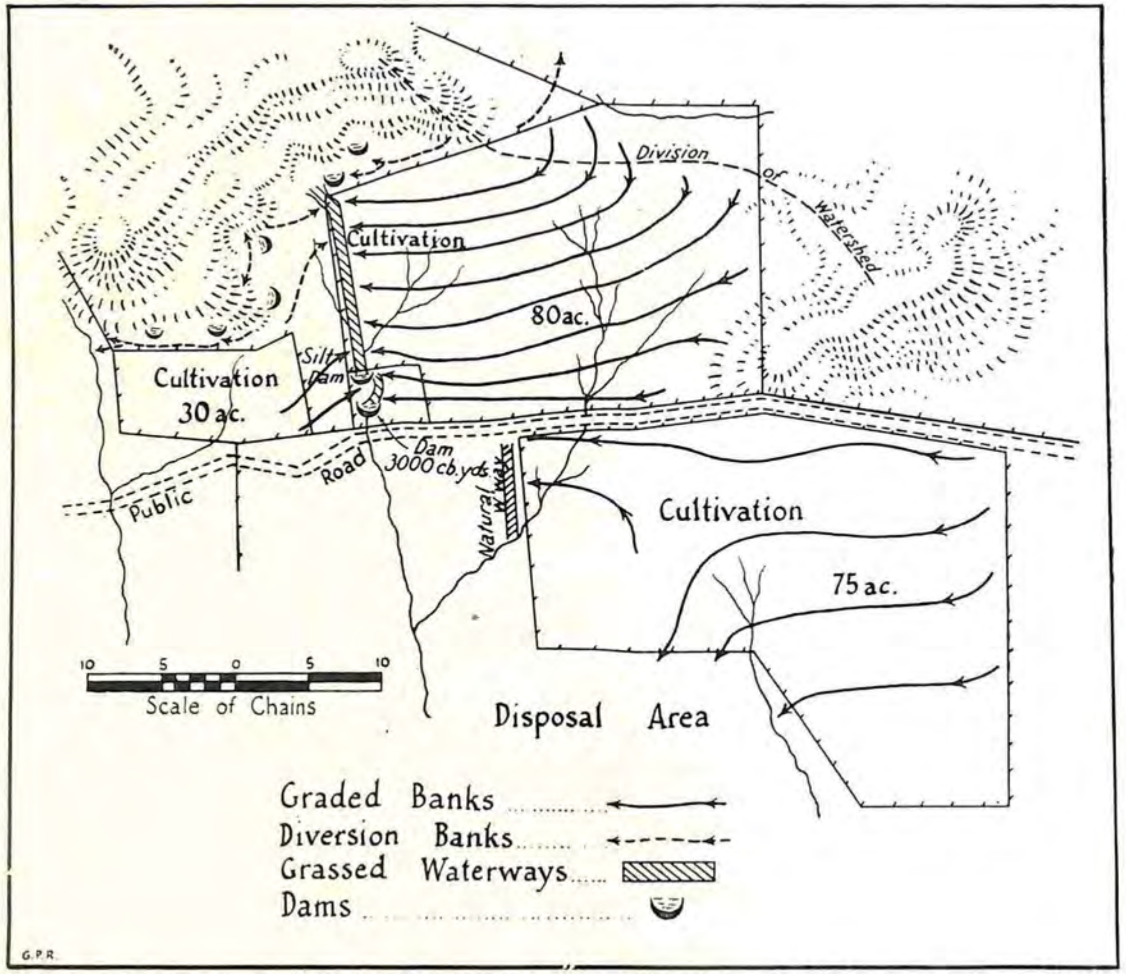

Fig. 2.—Red Hill Demonstration and Plant Hire work.

Sowing was carried out in early September and was preceded by a thorough working with a combine and light harrows, seed then being broadcast in front of the combine. A good germination was obtained and in the first season; all varieties of grasses sown were evident, but at the present time, eighteen months after sowing, the dominant grasses are Rhodes grass, paspalum, liverseed and couch. The natural couch grass growth is remarkable, the good seasons probably being responsible.

The graded banks flowing into the waterway were given a grade of 0.2 per cent. and were constructed with a dozer. The first two banks were constructed so that they were crossable with agricultural machinery, but the remaining banks were constructed with two pushes of the dozer and crossings for machinery were incorporated at either end.

The waterway discharges into a small dam of 500 cubic yards to act as a silt dam and

Fig. 3.—Graded banks and waterways on the Red Hill Minor Demonstration.

it, in turn, discharges into a much larger dam of 3,000 cubic yards, built across a natural depression which acts as a water storage dam and also protects the road below by reducing the rush of run-off experienced in severe storms. It might be added that the roadway below this area was practically impassable during wet weather but since work was carried out no trouble has been experienced.

A further 75 acres were treated below the road by constructing similar graded banks flowing into a natural waterway, the banks of which were pushed up from the outside and the natural grass cover utilised. Banks were also constructed emptying onto a well grassed gradual slope providing a safe disposal area. Since this work was completed it was thoroughly tested by a storm in which 5 inches were recorded in 3½ hours and all phases of work were satisfactory.

Mr. Bowman has since further extended the above work under the plant hire scheme and plans to render all his cultivation areas safe from erosion. In addition to the above mechanised erosion control work, Mr. Bowman has revised his cultural programme to include stubble mulching and rotations suitable to maintain soil stability and fertility.

MAJOR DEMONSTRATION.

The first Major Demonstration to be completed in the Barraba district was on the property of Messrs. G. E. Bowman & Sons, Tarpoly. Work followed the pattern outlined in Fig. 4, and was designed to protect valuable lucerne paddocks used at lambing and shearing time. These paddocks were showing severe erosion, both sheeting and deep gullies being evident. Here again damage was caused by run-off from very steep hillsides and diversion banks were used to direct run-off into safe disposal areas.

Natural waterways and shallow depressions were used to direct run-off into Tarpoly Creek and stock have been excluded

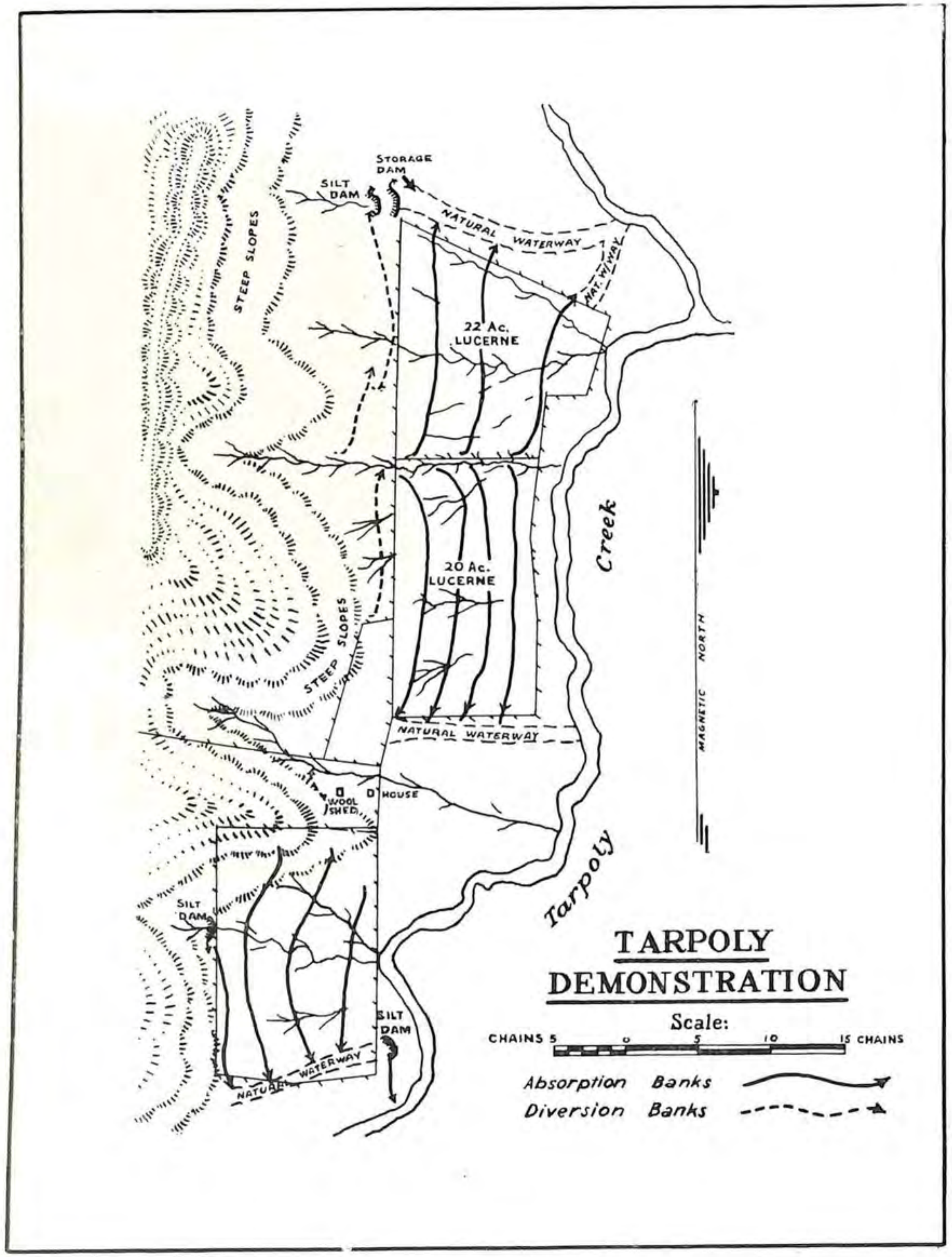

Fig. 4.

Fig. 5 —Silt dam and storage for water disposal on Tarpoly Demonstration.

from these discharge areas so that sufficient natural surface cover has developed to prevent damage from run-off during severe storms. The banks emptying into these waterways were constructed with no grade to obtain maximum absorption and irrigating effect on lucerne stands.

Silt and storage dams were constructed to perform the functions of catching silt and arresting the flow of run-off and also to provide water storage for dry seasons.

CONCLUSION.

Soil conservation has gained in popularity among Barraba landowners during the past two years in which the Service has been active in this district. So much is this the case that the number of landholders initiating soil conservation work have overtaxed the facilities of the Service immediately available. However, this is a good sign and by the mutual co-operative efforts of both parties a steady diminution in both the erosion of productive lands and the potential siltation of Keepit storage may be expected.

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