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HYDROLOGICAL STUDIES IN THE UPPER SNOWY CATCHMENT AREA WITH SPECIAL REFERENCE TO THE EFFECTS OF LAND UTILISATION.

BY

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INTRODUCTION.

THE Snowy Mountains of New South Wales form that portion of the Great Dividing Range between Forest Hill on the Victorian border and Bullock Hill near Kiandra. Forming the watersheds of the Snowy Catchment Area in the east and the Hume Catchment Area in the west, the Snowy Mountains are probably the most valuable natural water resource in Australia.

The most important part of the Snowy Catchment is the relatively small portion situated above Jindabyne, near the confluence of the Upper Snowy River and its two major northern and southern tributaries, the Eucumbene and Thredbo Rivers. In this paper, these three rivers, collectively, are termed the Upper Snowy River System and their combined catchments the Upper Snowy River Area (Fig. 1). This catchment may be sub-divided into four well defined environmental tracts: alpine, sub-alpine, montane and tableland.

The alpine tract extends from the tree line at approximately 6,000 feet to a maximum elevation of 7,328 feet at Mount Kosciusko. The average annual precipitation varies between approximately 70 and 90 inches, and the ground is snow covered for at least four months of the year continuously. Semi-permanent snow patches occur above 7 000 feet, which sometimes persist throughout the year. The climatic climax vegetation is tall alpine herbfield, and the associated soils are alpine humus soils and humified peats. Important physiographic and primary edaphic vegetation climaxes and soils also occur interspersed with the tall alpine herbfields. These include sod tussock grassland with silty bog soils, grey podsols, and alpine humus soils; short alpine herbfield (snow patch vegetation) with snow patch meadow soils; fen with fen peat and silty bog soils; valley bog and raised bog with valley bog peats and raised bog peats; fjældmark with lithosols and alpine humus soils; and heath with lithosols, grey podsols, and alpine humus soils. Of greatest significance in catchment area studies are those plant communities and soils determined primarily by ground water influences. The most important of these in the alpine tract of the Upper Snowy Catchment Area are certain of the sod tussock grasslands with silty bog soils and grey podsols; short alpine herbfield with snow patch meadow soils; fen with fen peat and silty bog soils; and valley bog and raised bog with valley bog peats and raised bog peats.

The sub-alpine tract, situated between approximately 5,000 and 6,000 feet, receives average annual precipitations from about 50 to 80 inches. This tract is snow covered continuously for one to four months of the year. The climatic climax vegetation is sub-alpine woodland and the associated soils are alpine humus soils and humified peats.

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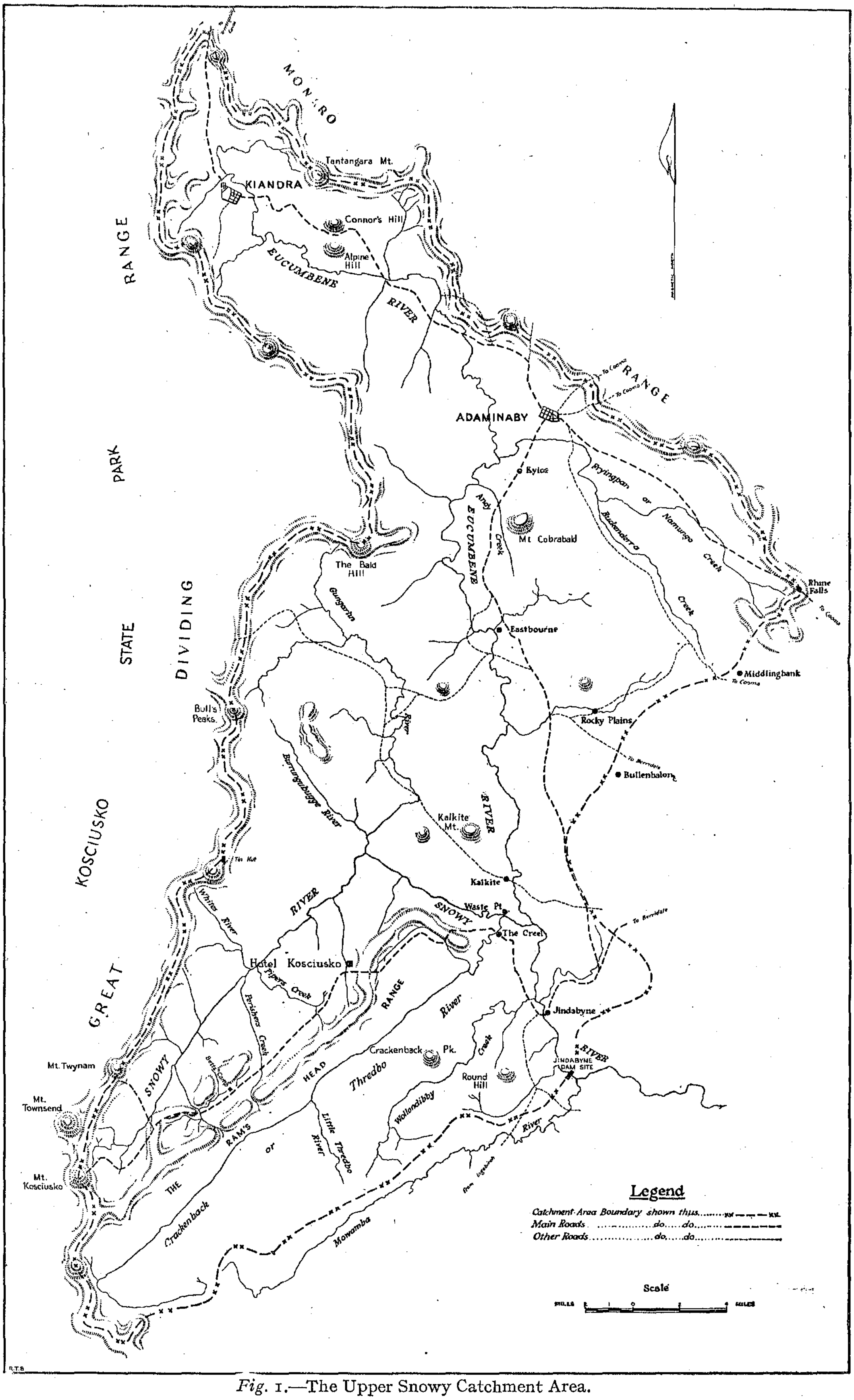


Fig. 1.—The Upper Snowy Catchment Area.

Except for fjældmark, and short alpine herbfield with snow patch meadow soils, the sub-alpine tract contains the same physiographic and primary edaphic vegetation and soil climaxes as the alpine tract.

The montane tract extends from about 3,000 to 5,000 feet. Average annual precipitations are relatively low, ranging from approximately 20 to 50 inches, and winter snowfalls do not usually persist for more than two to three weeks continuously. The climatic climax vegetation consists of wet and dry sclerophyll forests associated respectively with transitional alpine humus soils, brown podsolics, iron podsols, red loams, and lithosols; and with brown and grey-brown podsolics, brown earths, and lithosols. Associated physiographic and primary edaphic climaxes include wet tussock (meadow) grassland with meadow soils, silty bog soils, grey podsols, and brown earths; wet scrub with lithosols; wet mallee with lithosols, brown podsolics, and transitional alpine humus soils; and savannah woodland with brown and grey-brown podsolics, iron podsols, meadow soils, grey podsols, brown earths, and transitional alpine humus soils. The most important ground water plant communities and soils are wet tussock grassland with meadow soils, silty bog soils, and grey podsols. Localised fen and raised bog communities are occasionally encountered.

The tableland tract constitutes the least important portion of the Upper Snowy Catchment Area, fringing the montane tract below elevations of approximately 3,000 feet. Average annual precipitations vary from 20 to 30 inches, and winter snowfalls are usually light and non-persistent. The climatic climax vegetation is mainly savannah woodland with brown and grey-brown podsolics, iron podsols, meadow soils, grey podsols, and brown earths; but in areas of locally higher rainfall wet sclerophyll forest with brown podsolics and iron podsols may occur. Physiographic and primary edaphic climaxes include wet tussock grassland with meadow soils, silty bog soils, grey podsols, brown earths, and alluvial soils; wet scrub with lithosols; and dry sclerophyll forest with brown and grey-brown podsolics, brown earths, and lithosols. The most important ground water communities and soils are wet tussock grassland with meadow soils, silty bog soils, and grey podsols. Localised fen communities are occasionally encountered.

From the preceding discussion it is apparent that the alpine and sub-alpine tracts not only contribute most to the total flow of the Upper Snowy River System by virtue of their heavy precipitations and persistent snows, but also contain a larger proportion of ground water plant communities and soils which act as natural reservoirs for the storage and gradual discharge of water. For these reasons the alpine and sub-alpine tracts are the most important in relation to questions of catchment area efficiency and conservation. Comparatively small areas of the montane and tableland tracts are occupied by ground water soils and vegetation, and consequently the catchment area problems in these tracts are largely those of accelerated erosion and siltation.

The investigations outlined in this paper were undertaken to ascertain, firstly, the nature of the precipitation-riverflow relationships in the Upper Snowy Catchment Area, and, secondly, to what extent, if any, these relationships may have been modified by practices of land utilisation.

METHODS AND RESULTS.

1.—*Selection of River Flow and Precipitation Recording Stations.*

In studying the relationships between precipitation and river flow in a catchment area, the selection of representative recording stations is the first essential. In the Upper Snowy Catchment the only stations for which reliable data are available for a sufficiently long period of time are Kiandra in the sub-alpine tract for precipitation, and Jindabyne in the tableland tract for river flow. The distance by river between these stations is approximately 50 miles.

The paucity of recording stations is partly counter-balanced by the respective situations of Kiandra and Jindabyne. Detailed examination of precipitation data available for all stations in the Upper Snowy Catchment shows that not only is there a good correlation between precipitation at Kiandra and in the alpine, sub-alpine, and upper montane tracts as a whole, but that the lower montane and tableland tracts contribute comparatively so little to the total river flow of the Catchment that lack of precipitation recording stations in the latter tracts does not introduce serious sampling errors. The steepness of the precipitation gradient between the alpine and tableland tracts is illustrated in Fig. 2, in which the average annual precipitation decreases from approximately 90 inches at Mt. Kosciusko to less than 22 inches at Jindabyne within a distance of about 20 miles.

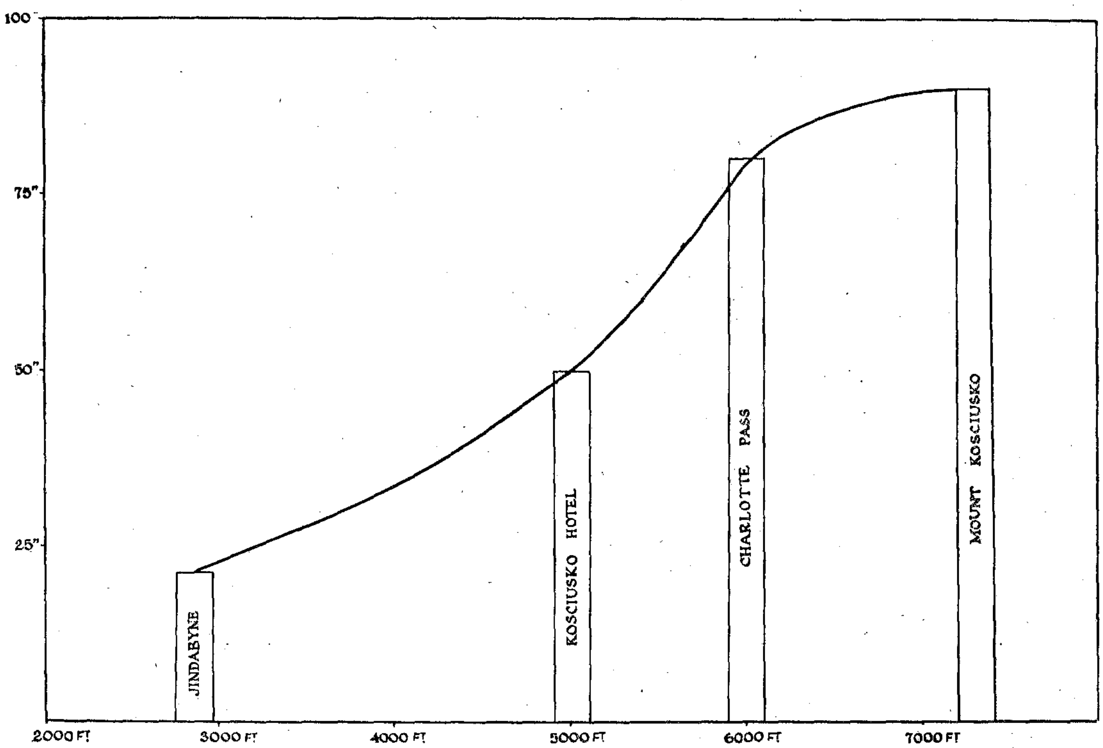


Fig. 2.—Precipitation Gradient, Snowy Mountains.

In view of the situation of Jindabyne just below the confluence of the Upper Snowy, Eucumbene, and Thredbo Rivers, the river flow data at this station also represents the resultant of conditions for the Upper Snowy River System. Where flow estimates are based on river height readings at a given point, changes in the shape of the river channel over a period of years may lead to erroneous conclusions concerning alterations in the volume of flow. Such changes in the shape of the river channel may occur quite rapidly if the river passes through unconsolidated sediments; but if it flows between well stabilised banks and over a stony or gravelly bed the rate of change, except, perhaps, over long periods, is not appreciable. Since the latter conditions obtain at the Snowy River at Jindabyne, alterations in the shape of the river channels do not constitute a significantly complicating factor in the present hydrological investigations.

2.—*Selection of Data.*

The nature of the relationships between river flow and precipitation in the Upper Snowy Catchment Area is complicated by the heavy winter snowfalls in the alpine and sub-alpine tracts, and by the consequently large volume of water suddenly released from melting snow during the spring thaw. The months of the year during which the effects of snowfall are least are November to April, inclusive, and only these months were considered in the present investigations.

Inspection of the data also revealed that small precipitations produced no appreciable variation in river flow, so that daily precipitations less than 20 points and their corresponding river flows were ignored. The elmination of data in this manner does not bias the statistical results.

The earliest and latest five-year periods for which complete daily precipitation and river flow data are available—1903-1907, and 1943-1947—were selected for analysis. Preliminary examination of Kiandra weather reports showed that during and prior to these two five-year periods, similar meteorological conditions were experienced.

Any changes in the river flow regime since 1907 might, therefore, be examined as evidence of changes in the Catchment Area itself.

At Kiandra and Jindabyne, respectively, 9.00 am. precipitation and river flow readings are taken. These daily readings provided the basis for the following statistical analyses.

3.—*Statistical Procedure and Results.*

Pilot analyses showed that river flow at Jindabyne on a given day was not affected significantly by precipitation measured at Kiandra more than four days previously. The following multiple regression equation was therefore adequate to study the precipitation-riverflow relationships for each period 1903-1907 and 1943-1947.

$$Y = a + b_1R_1 + b_2R_2 + b_3R_3 + b_4R_4,$$

where Y = change in river flow (as cubic feet per second) during a particular 24 hour period compared with river flow during the preceding 24–48 hours.

R_1 = precipitation (points of rain) during the same period of 24 hours.

R_2 = precipitation during the preceding 24–28 hours.

R_3 = precipitation during the preceding 48–72 hours.

R_4 = precipitation during the preceding 72–96 hours.

An Analysis of Variance was used to test the significance of total regression for each period (Table 1). In both periods the total regressions were highly significant ($P < 0{\cdot}01$).

TABLE 1.

Analyses of Variance for Periods 1903–1907 *and* 1943–1947.

Period.	Source of Variation.	Degrees of Freedom.	Sums of Squares.	Mean Square.	$F_{4,00}$
1903–1907	Regression ...	4	156,873,548	39,218,287	33.913*
	Residual ...	384	444,075,860	0,156,448	......
	Total ...	388	600,949,408	......	......
1943–1947	Regression ...	4	65,272,496	16,318,124	18.748*
	Residual ...	399	347,287,027	870,394	......
	Total ...	403	412,559,523	......	......

* Highly significant — $P < 0{\cdot}01$.

Having thus demonstrated the significance of total regression, the individual regression coefficients were then examined for significance by means of "t" tests with the following results. (Table 2.)

TABLE 2.

Significance of Individual Regression Coefficients for Periods 1903-1907 and 1943–1947.

Period 1903–1907.			Period 1943–1947.		
Regression Coeffieient.	t Value.	Probability.	Regression Coefficient.	t Value.	Probability.
$b_1 = +8{\cdot}191357$	$+8{\cdot}8231$	Less than 0·01*	$b_1 = +5{\cdot}127866$	$+6{\cdot}1148$	Less than 0·01*
$b_2 = -6{\cdot}980066$	$-7{\cdot}5387$	Less than 0·01*	$b_2 = -3{\cdot}918920$	$-4{\cdot}2271$	Less than 0·01*.
$b_3 = -0{\cdot}910318$	$-0{\cdot}9923$	Between 0·30 and 0·40.	$b_3 = -2{\cdot}960891$	$-3{\cdot}2173$	Less than 0·01*.
$b_4 = -0{\cdot}624521$	$-0{\cdot}6738$	Between 0·50 and 0·60.	$b_4 = -1{\cdot}012436$	$-1{\cdot}0874$	Between 0·20 and 0·30.

* Highly significant — P < 0·01.

The difference between corresponding regression coefficients for 1903-1907 and 1943-1947 were tested for significance. Since the variances of the individual regression coefficients in both periods are homogeneous, these tests of significance were made by obtaining the appropriate "t" values from the equations :—

$$t_1 = \frac{b_{1_A} - b_{1_B}}{\sqrt{s^2b_{1_A} - s^2b_{1_B}}} \quad \ldots \quad t_4 = \frac{b_{4_A} - b_{4_B}}{\sqrt{s^2b_{4_A} - s^2b_{4_B}}}$$

TABLE 3.

Significance of Differences between Corresponding Regression Coefficients for Periods 1903–1907 and 1943–1947.

Regression Coefficients.	t Value.	Probability.
b_{1_A} and b_{1_B}	$+2{\cdot}4486$	Between 0·01 and 0·02*.
b_{2_A} and b_{2_B}	$-2{\cdot}3362$	Between 0·01 and 0·02*.
b_{3_A} and b_{3_B}	$+1{\cdot}5781$	Between 0·10 and 0·20.
b_{4_A} and b_{4_B}	$+0{\cdot}2953$	Between 0·70 and 0·80.

* Significant—P between 0·01 and 0·05.

The statistical results tabulated in the previous pages may be summarised verbally as follows :—

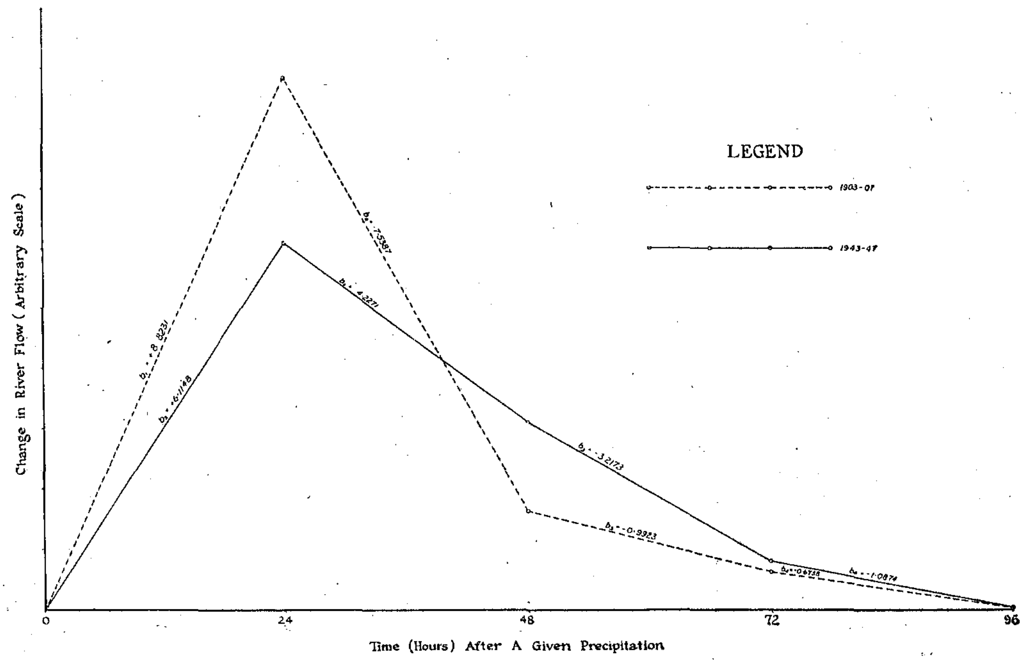
(a) During the snow-free months, November to April, for both periods 1903-1907 and 1943-1947, there was a highly significant positive regression of change in river flow at Jindabyne during a given 24-hour period on precipitation at Kiandra during the same 24 hours. The positive regression was significantly greater for 1903-1907 than for 1943-1947.

(b) For both periods there was a highly significant negative regression of change in river flow on precipitation during the preceding 24-48 hours. The negative regression was significantly greater for 1903-1907 than for 1943-1947.

(c) There was a highly significant negative regression of change in river flow on precipitation during the preceding 48-72 hours for 1943-1947, but not for 1903-1907. The difference between regressions, however, was not significant.

(d) For neither period was the negative regression significant of change in river flow on precipitation during the preceding 72-96 hours. The difference between regressions was not significant.

This summarised data is represented diagramatically on an empirical, comparative scale in Fig. 3.



EFFECT OF PRECIPITATION ON CHANGE IN RIVER FLOW DURING THE SUCCEEDING 96 HRS.

Fig. 3.

DISCUSSION OF STATISTICAL RESULTS.

The hydrological cycle in a catchment area may be summarised by the equation,

$$D = P - (I + T + E + S) + G,$$

where

- D = total discharge of water from catchment, derived from surface run-off and ground water.
- P = precipitation on catchment.
- I = precipitation lost by interception by leaf canopy and ground litter.
- T = precipitation lost by transpiration from vegetation.
- E = precipitation lost by evaporation from the surface soil.
- S = precipitation lost by deep seepage.
- G = ground water discharge.

The ratio between discharge as surface run-off and as ground water serves to characterise different types of catchment area. The majority of Australian catchments occur in forested areas where ground water plant communities and soils are of relatively minor importance. Under these conditions, surface run-off constitutes a far greater part of the total discharge. In the Upper Snowy Catchment and similar alpine--sub-alpine catchment areas, on the other hand, ground water soils and vegetation occupy a significant area of the total watershed, and contribute materially to the total discharge. The value and efficiency of a catchment area are enhanced by substantial ground water resources, since these resources both increase the storage capacity of the catchment and maintain river flow during periods of low precipitation. The statistical results of the river flow-precipitation analyses for the Upper Snowy Catchment Area indicate the importance of ground water both in relation to the general hydrology of the Catchment and to the changes which have occurred between 1903-1907 and 1943-1947.

Under completely natural conditions, the ground water plant communities and soils of the Upper Snowy Catchment Area would probably be almost completely saturated, and the ground cover of the more extensive non-ground water communities and soils dense and unbroken. Under these conditions, a given precipitation on reaching the ground would probably be discharged rapidly into the river system mainly as surface run-off. Little of this precipitation would be retained as ground water unless the same quantity of water already stored in the ground water soils and plant communities were released. That this river flow-precipitation regime probably obtained during 1903-1907 is indicated by the statistical results for this period. The highly significant positive relationship ($+b_1$) between change in river flow on a particular day (with regard to the previous day) and precipitation recorded during the same 24-hour period, indicates that most of the precipitation rapidly entered the rivers as surface run-off within 24 hours. The highly significant negative relationship ($-b_2$) between change in river flow and precipitation recorded 24-48 hours previously also shows that most of this precipitation had entered the river within the first 24 hours and that by 48 hours river flow was returning to normal. That river flow rose to a maximum within 24 hours after a given precipitation and fell to its base level within the next 24-48 hours is also shown by the lack of significant relationships ($-b_3$ and $-b_4$) between change in river flow and precipitations recorded 48-72 and 72-96 hours previously. (See Fig. 3.)

The statistical results for 1943-1947, however, indicate a different river flow-precipitation regime for this later period.

There is still a highly significant positive relationship ($+b_1$) between change in river flow on a particular day and precipitation during the same 24 hours, indicating that most of the precipitation still enters the rivers as surface run-off within 24 hours. The highly significant negative relationship ($-b_2$) between change in river flow and precipitation recorded 24-48 hours previously still obtains as in 1903-1907, but in addition the negative relationship ($-b_3$) between change in river flow and precipitation during the previous 48-72 hours is now highly significant. This shows that the effect of a given precipitation now persists for a longer time since the river flow no longer returns to normal within 48 hours as in 1903-1907, but is still decreasing significantly up to 72 hours. The non-significant negative relationship ($-b_4$) between change in river flow and precipitation 72-96 hours previously shows that after 72 hours no appreciable decrease in river flow occurs. (See Fig. 3.)

The tests of significance of the differences between corresponding regression coefficients in 1903-1907 and 1943-1947 also indicate that different hydrological conditions obtained in the Catchment during these periods. The significant differences between the regression coefficients (b_{1_A} and b_{1_B}) for change in river flow on precipitation during the same 24 hours, indicates that a given precipitation now causes river flow to increase less rapidly in 24 hours than in 1903-1907, presumably because less of this precipitation is now being discharged immediately as surface run-off. That a substantially greater part of this precipitation now enters the rivers after 24-48 hours than in 1903-1907, is shown by the significant difference between the regression coefficients (b_{2_A} and b_{2_B}) for change in river flow on precipitation during the preceding 24-48 hours. The differences between the corresponding regression coefficients in 1903-1907 and 1943-1947 (b_{3_A}; b_{4_A} and b_{4_B}) in respect of the 48-72-hour periods are not significant. (See Fig. 3.)

These differences between the river flow-precipitation relationships in 1903-1907 and 1943-1947 might be due either to changes in the condition of the Upper Snowy Catchment itself during the present century, or to the possibility that for one of the periods Kiandra may have been a much better estimator of average precipitation over the total Catchment than for the other period. While the latter alternative would seem to be supported by the smaller proportion of the variance accounted for by regression in the later period as compared with the earlier, and cannot be ruled out until further analyses for intervening periods have been undertaken; field evidence more strongly supports the former alternative that changes have occurred in the condition of the Catchment itself as suggested below.

The above-mentioned differences between the river flow-precipitation regimes of the two periods may be explained adequately in terms of the ratio of immediate surface run-off to ground water discharge, on the assumption that the effects of a given precipitation in increasing surface run-off will be virtually complete within 24 hours, while the effects on ground water discharge will be less rapid and persist for a longer period. That the ratio of immediate surface run-off to ground water discharge, with regard to a given precipitation, is now less than in 1903-1907, may be attributed to anthropeic changes in the ground water soils and plant communities of the Catchment. Field evidence is quite definite that these soils and communities have undergone widespread desiccation and humification during quite recent years (particularly since the severe fires of 1939) with the result that they are not only less water-saturated than previously, but also considerably lower in potential storage capacity. Whereas in 1903-1907 precipitations on undamaged and saturated ground water areas do not appear to have been absorbed appreciably but to have been discharged as surface run-off into the rivers within 24 hours, precipitations at the present time are now arrested temporarily, apparently because the partly desiccated ground water areas are no longer fully saturated. Furthermore, since their storage potential is also less because of accelerated peat humification, this arrested water cannot all be retained, and part of it discharges from the ground water soils or displaces some of the ground waters which have accumulated there previously. It would appear that the discharge of this temporarily arrested water is not complete within the 24 hours after a given precipitation, and the effects of the latter on river flow therefore persist longer at the present time than in 1903-1907. From the standpoint of the hydrological engineer, the greater lag between precipitation and run-off evident in the hydrograph for 1943-1947 would, at first sight, be preferable to the more immediate run-off in 1903-1907. This impression may be erroneous, however, for the following reasons. The hydrograph for 1943-1947 probably corresponds to an early transitional stage of damage to the ground water plant communities and soils. If this transitional stage were relatively stable—that is, if the hydrological changes in the Catchment Area occurred relatively early during the present century and little additional change occurred in more recent years—the long-term catchment efficiency of the Area would not be expected to undergo much additional deterioration. On the other hand, if this transitional stage represents a more recent condition of instability, there is a real danger that the present trend might continue to the stage where most of these soils and communities may be destroyed and accelerated erosion in non-ground water areas may also occur; finally resulting in the reduction of the water holding capacity of the Catchment Area to the extent that the hydrograph may become even steeper than in 1903-1907, with virtually no lag between precipitation and run-off. Although additional statistical analyses for intervening periods are needed to answer this question with certainty, the field evidence strongly suggests that the latter condition of instability is the one which now obtains in the Upper Snowy Catchment Area. A comparison of the areas under the two hydrographs, moreover, shows that approximately 10 per cent. less of a given precipitation reached the river in 1943-1947 than in 1903-1907. This loss of precipitation in 1943-1947 may be attributable mainly to the greater evaporation which would have occurred during the longer period of its temporary arrest by damaged ground water areas.

Since the incidence of the factors influencing the Upper Snowy Catchment Area in 1903-1907 and 1943-1947 appears to have been the same in most respects except the length of time under land use, a consideration of the nature and extent of the anthropeic changes in ground water areas of the Catchment is obviously necessary to an adequate understanding of the changes in hydrological conditions which appear to have occurred. These matters are discussed in the following section.

SIGNIFICANCE OF STATISTICAL RESULTS IN RELATION TO LAND USE.

Much of the Upper Snowy Catchment Area has been used for summer grazing of sheep and cattle for periods approaching 100 years; at first quite indiscriminately and during more recent years under the snow lease system.

Notwithstanding the undoubted value of the Upper Snowy Catchment Area for summer grazing, its importance as a watershed is so great that its future management to preserve its catchment efficiency appears a vital consideration for Australia.

As early as 1893, Helms (1893) predicted the disastrous consequences of fire in the Upper Snowy Catchment. More recently, Costin (1949, 1950), and the Joint Scientific Committee of the Linnean Society of N.S.W. and the Royal Zoological Society of N.S.W. (1946), have drawn attention to various aspects of catchment area deterioration. Detailed ecological work since 1946 has substantiated these findings and revealed more precisely the natuie, extent and recentness of the damage. The ground water vegetation and soils have suffered most, particularly the short alpine herbfields (snow patch communities) and snow patch meadow soils, the fens and fen peats, and the valley bogs and raised bogs and corresponding bog peats.

The short alpine herbfields and associated snow patch meadow soils are normally soft underfoot due to permanent saturation with snow water, and are thus most susceptible to the effects of trampling. This position is aggravated by the fact that certain palatable snow patch plants are eagerly sought after and selectively grazed by livestock. Excessive trampling has broken the naturally continuous herbaceous carpet of many snow patch areas resulting in accelerated nivation, water erosion, and desiccation.

The fens and fen peats have also suffered from grazing and burning. The dominant sedge, *Carex Gaudichaudiana* Kunth, is extremely palatable, with the result that the fens are overgrazed, irrespective of the overall stocking rate. This overgrazing has caused serious peat desiccation and humification accompanied at a later stage by the rapid removal of the desiccated peat by wind erosion. Once desiccated, peat becomes very light and difficult to re-wet, and is thus highly vulnerable to wind action. These conditions have been aggravated further by burning, and in extreme cases ignited fen peats have continued to smoulder throughout the summer months.

The bogs and bog peats of the Upper Snowy Catchment Area are characterised by the moss *Sphagnum cymbigolium* Ehrh. The present Australian environment in alpine and sub-alpine areas appears barely suitable for the active development of *Sphagnum* bogs and peats, which on the Australian continent may be considered relics of an earlier, moister climatic period. For this reason the bogs are most susceptible to any type of unfavourable human interference, and once damaged are in danger of progressive deterioration. Like the fens, the bogs are selectively grazed by livestock, and, owing to the soft character of the *Sphagnum* moss and underlying half-formed peat, are even more susceptible to damage by trampling. The bog surface is readily broken in this way, leading to accelerated drainage which, in turn, is followed by desiccation, humification and erosion of the peat. Severe fire damage of the same type as described for the fens has also occurred. Examination of many bog peat profiles throughout the Catchment has shown that a regional fall of several inches in the level of the water table has probably occurred since human occupation. Evidence for this conclusion is furnished by the presence of a podsolised horizon *within* the peat, and by the invasion of the bog communities by non-hygrophilous species. Neither of these processes operates in an undamaged fully saturated bog.

The deterioration of ground water soils and vegetation by accelerated desiccation, humification, and erosion is now widespread in the Upper Snowy Catchment Area, and if allowed to continue at the present rate, will probably lead to its pronounced drying out and a permanent reduction in its storage capacity. In relatively few areas, however, has this deterioration reached the stage of complete destruction, so that if remedial action is taken without delay, at least the present efficiency of the Catchment could be maintained.

Fire control throughout the catchment appears essential, and although restricted grazing is compatible with catchment area stabilisation in relatively dry areas not containing susceptible ground water soils and vegetation, these latter areas are especially liable to destruction by fire or stock or both.

The Upper Snowy Catchment Area is now being developed on a grand scale for water conservation and hydro-electric purposes. Constructional work in certain localities is being carried out at some cost to catchment area stability. In particular, road making operations have already destroyed numerous ground water plant communities and soils and initiated accelerated erosion in non-ground water areas. There is need for particular care in so locating these operations that the minimum reduction of catchment area efficiency results and this can be achieved by giving due consideration to the soils and vegetation of the areas concerned.

In a country such as Australia, where lack of adequate water resources is the most important natural limiting factor to production, the conservation of existing resources is a vital matter. This applies particularly to our limited alpine and sub-alpine catchments which, because of high average annual precipitations, persistent winter snowfields, and steep physiography, provide abundant and dependable supplies of water suitable for irrigation and also potentially valuable for hydro-electric purposes.

From the evidence which has so far been obtained, it is tentatively concluded that significant changes have occurred during comparatively recent years in the river flow-precipitation regime of the Upper Snowy Catchment Area, which may be attributable to anthropeic damage to the alpine and sub-alpine ground water communities and soils.

SUMMARY.

The river flow-precipitation relationships of the Upper Snowy Catchment Area during the six snow-free months November to April were examined statistically for two five-year periods 1903-1907 and 1943-1947.

The statistical results demonstrated for both periods a highly significant relationship between increased flow of the Snowy River at Jindabyne on a given day (relative to river flow during the previous day) and precipitation at Kiandra during the same 24 hours. This rapid increase in river flow is attributed to surface run-off. The increase in river flow after a given precipitation was followed by a sudden decline and return towards normal. This normal flow was re-attained within 24-48 hours in 1903-1907, and within 24-72 hours in 1943-1947.

There were significant differences between corresponding river flow-precipitation relationships in 1903-1907 and 1943-1947. Immediate surface run-off was significantly greater in 1903-1907, and virtually none of a given precipitation was arrested temporarily as ground water. By contrast, immediate surface run-off was significantly less in 1943-1947, probably due to the temporary arrest of part of the precipitation as ground water. This temporary arrest led to increased evaporation, with the result that approximately 10 per cent. less of a given precipitation reached the river in 1943-1947 than in 1903-1907.

These differences are associated with anthropeic changes in the ground water plant communities and soils during the last 50 years. It is suggested that in 1903-1907 these communities and soils were more nearly in their natural, undamaged, water-saturated condition, and consequently did not arrest or retain precipitations appreciably but discharged them immediately as surface run-off. By 1943-1947, however, the practices of grazing and burning had so damaged and desiccated these communities and soils, that precipitations were probably no longer discharged completely as immediate surface run-off but were partly arrested for a short time before being released as ground water.

The greater lag in 1943-1947 may be interpreted as a transitional stage associated with early damage to the ground water areas, which, if continued, may ultimately lead to a more rapid rate of run-off than in 1903-1907 and to reduction in the efficiency and storage capacity of the Upper Snowy Catchment Area.

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