STREAM FLOW AND GROUND WATER PROTECTION FORESTS¹

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IN PREPARING this paper it was found difficult to maintain the broad viewpoint necessary for a general discussion of the subject. A limited experience has formed a poor base from which to get a good perspective. There has been a tendency to dismiss opinions and conclusions that do not conform to the writer's, and it has been hard to keep in mind that these opinions and conclusions reflect the different experience which formed them. It has been a struggle all the way to keep imagination turned away from familiar scenes and to try to picture the very different sets of conditions which exist over the many watersheds of the earth.

This struggle accentuated a confusion developed from trying to note and appraise all variables in the problem. To bring some order to this confusion a hypothetical drainage basin was imagined, which could be made large or small, as required, whose shape was elastic and which could be taken instantly and set down under any set of climatic conditions desired. It was imagined that this was to be managed, and since in this case as in all others management involves the two functions of policy-making and administration, it was imagined that the policy-making body in solemn deliberation—keeping in mind the principle of the greatest good for the greatest number—had laid down the various uses to which the forests of this watershed were to be devoted and the weight to be given to each use in carrying out the policy. Into this set-up an imaginary individual was projected whose task it was to manage the forests in conformity with this overall policy. By following the considerations which this individual would have to keep in mind in developing a plan of management for changing locale and drainage basin characteristics, it was possible to get an orderly picture of the factors involved and how they are affected by changing circumstances.

In order that our authority can have a logical basis for planning he must have a clear understanding of the relation of forest cover to stream flow and ground water levels. In the process of arriving at this understanding he will find that there are differences of opinion. Probably the most widely held view, and one for which there is considerable substantiation, is that severe removal of forest cover is followed by an increase in the frequency and severity of damaging floods and a reduction of the ground water table. That this frequently is the result is shown by the Grand River Valley and by the report on the Ganaraska Drainage Basin. On the other hand, the writer seems to recall reading somewhere that the United States Army Engineers had records of the run-off from a drainage basin for over 100 years;

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that in that time the basin had been transformed from a forest area to cultivated land; and that records showed no discernible change in the character or quantity of run-off. And it is also recalled that in ground water measurements in France it was found that the ground water level was depressed beneath a plantation area, which would seem to indicate that plantation was less effective in feeding ground waters than open fields. To complete the picture there is the most informative study known to the writer—the Wagon Wheel Gap experiments of the United States Forest Service.

This latter experiment was so carefully conducted and so fully reported that it is worth while discussing it in some detail. It was an effort to discover the effect of removing modest forest cover from a watershed on the run-off from that watershed. For the purpose two contiguous drainage basins, as similar in all characteristics as could be found, were selected. Careful measurements of run-off and all variables which seemed pertinent were recorded for an eight year period. At the end of this time it was believed that sufficient data had been collected for the two watersheds to allow a reasonable estimate of the run-off from one, under natural cover conditions, from the data recorded on the other. One basin was then completely denuded of its cover and the measurements continued for another seven years. The difference between the run-off from the denuded basin as estimated from the data for the one left under cover, and that which actually occurred, was taken as the change caused by stripping the area of its forest.

The results were quite conclusive. There was a much higher peak to the spring flood and the flood was earlier and of shorter duration. There was also a small increase in run-off at all times of the year except for a short period at the recession of the spring flood.

Now it was previously said that the opinion most generally held is that removal of forest cover will result in a decrease in the low water flow. The Wagon Wheel Gap experiment contradicts this opinion. But the authors of this report are careful to point out the influence which local conditions had on the result. The experiment should not be taken as showing that the majority is wrong, but that circumstances alter cases. Indeed the experiment serves to emphasize that there are three main factors which determine what degree of influence a change in forest cover will exert on the run-off of a drainage basin. These three factors are: soil characteristics, climate, and topography. It is frequently stated that forest cover is the only factor capable of manipulation. This is true, but manipulation can only be undertaken successfully if the influence of the other factors be appreciated.

Soils differ in their texture, of course, and so in their permeability and water-holding capacities. At one extreme is the open, gravelly type, passing water readily, and capable of holding by capillarity and absorption relatively small quantities. At the other extreme is the fine-grained, heavy clay, for all practical purposes impermeable except in the root zone, but with a large holding capacity. In between there are all gradations and mixtures, complicated by stratification in various degrees.

As was demonstrated at Wagon Wheel Gap forest cover of even a moderate kind tends to reduce the total volume of run-off and will reduce it at all seasons of the year. The result there was traced directly to the character of the soil and the geology of the watersheds. Each watershed was, in effect, a basin of impervious bed rock filled with pervious open-textured material, which absorbed practically all the precipitation which fell upon it. It did this in spite of having slopes averaging 25 per cent. The inference is that soils of this type are admirably suited to perform the function of storage and slow release which forest cover is capable of exercising and, except for the flood times, do not need the assistance of the forest. For maximum run-off from this type of soil the minimum vegetative cover consistent with soil stability is needed. If flood control has to be taken into consideration the minimum amount of cover required to give satisfactory regulation will yield the most run-off.

Clay soils, and clay loam soils as well, present an entirely different picture. These soils are highly impermeable except in the zone where the roots have created a vertical permeability. This root zone is capable of absorbing water with considerable readiness, but because of the nature of the subsoil very little of this water will ever be contributed to the ground water supply or appear as run-off. All run-off will be from the surface and the regulation effect will be provided by the slower melting of winter snows, and by the sponge effect of the accumulation of moss and litter on the forest floor. While maximum quantity of run-off, as on the gravelly soils, would still be gained by a bare condition, it could only be achieved at the cost of serious erosion and flashy stream flow characteristics. From the point of view of stream protection it would seem advisable to maintain the heaviest cover possible over soils of these types.

It is with the intermediate soil types that manipulation of forest cover can be most effective. The open-textured soils exercise their function of storage naturally and do not need assistance. The close-textured soils cannot be made to store ground water usefully. The intermediate soils can be made to store water and feed stream flow by springs and seepage, if the time of contact is long enough. And this time of contact can be provided by maintaining suitable forest cover. Referring to the Wagon Wheel Gap experiment the report emphasizes that the normal ratio of high to low water flow, with moderate protective cover, was only twelve to one. It is pointed out that this low ratio (for a small watershed) was an indication of the ability of the watershed to exercise its storage function. And it is suggested that this ratio—the ratio of normal high to normal low water flow—with moderate protective cover, is an indication of the liability of the drainage basin to fail to exercise that function to the fullest possible extent if the cover is removed. It is further suggested that when the ratio is twenty-five to one, or greater, it is likely that the low water flow would be reduced by removal of the cover. It seems likely that this twenty-five to one ratio is too explicit, and that the

critical ratio should be estimated in the light of the size of the drainage basin. However, there is no doubt but that the ratio gives a quantitative indication of the value of forest cover as a watershed protection.

Considerable elaboration of these remarks could be made by taking into account the effect of climate; particularly the amount, intensity and seasonal distribution of precipitation and the seasonal range in temperature. However, the effect of these climatic factors seems fairly apparent. Soils, for instance, which in a relatively dry climate not subject to intense storms would be classed as absorptive in a more humid region would be classed as intermediate. And the difference between a heavy winter precipitation as a steady rainfall and the quick melting of a winter's accumulation of snowfall is easily imagined. It does not seem necessary to consider the climatic factors in detail. Still less does it seem necessary to elaborate on the effect of topography and drainage basin size and aspect.

There is perhaps one more factor that needs to be taken into account—that is the effect of cover type on the run-off. E. G. Dunford and C. H. Niederhof report this factor in the *Journal of Forestry*. They measured the amount of precipitation reaching the ground and so available for run-off under lodgepole pine cover, aspen cover, and on open grassland. Since erosion was not a problem and the primary consideration was water yield they rated aspen as to the most effective cover. Both they and the experimenters at Wagon Wheel Gap estimated that summer rainfall was not effective in providing run-off, the snow melt being the main source of that. And they found that the interception, and subsequent evaporation of the snow, was much greater for a coniferous stand than for a hardwood stand. It seems likely that climatic factors would play a part here, and that it would be unwise to expect these results to apply to all areas.

Assuming that we have read our hypothetical manager's mind correctly, and that his thinking has been sound, we can sum up the information about the area under his charge which he should have in order to work the watershed protection aspects into his plan of management. He should know first the annual precipitation and its seasonal distribution; second, the run-off characteristics of the draining streams; and last, he should learn as much as possible of the topography and the soil types with which he will be dealing. The rainfall and run-off can be measured directly. It does not seem practical to make an extensive soil survey. Fortunately, however, the forest itself will give him most of the information he needs. His timber type maps studied in conjunction with the climate will indicate what kinds of soils are involved.