may, however, show results per unit of topographic area considerably greater, or less, than those obtained from adjacent similar basins not subject to watershed leakage. A critical study of the underground water conditions may reveal evidence of watershed leakage sufficient to fully account for the apparent anomalous result of the gaugings.

### Conditions of Occurrence of Watershed Leakage

Streams or their tributaries which have no branches may for convenience be called first order streams, or tributaries, those which branch once, second order streams, and so on.

Nearly all first order streams are intermittent or evanescent in their head water reaches. The reason for this is illustrated by Fig. 1, in which c—a—b represents the stream profile, and d—g—b— the profile of the ground water horizon. The depth to ground water commonly increases with the height of the land. Streams near their sources, owing to their small eroding power, have not as a rule cut their channels deep enough to intercept the ground water horizon, and are therefore intermittent, flowing only after rains or when snow is melting.

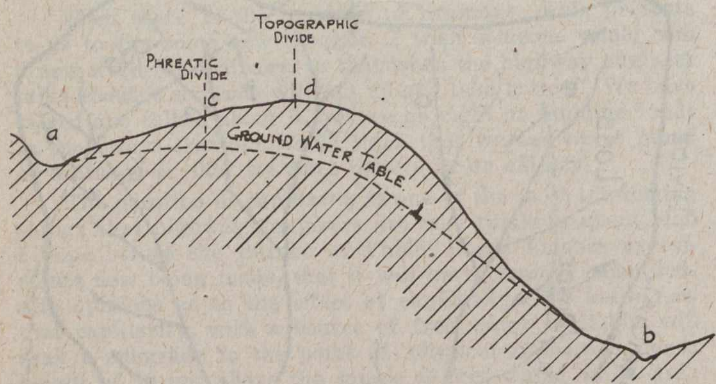


Fig. 3—Lateral Watershed Leakage Across a Permeable Divide

In Fig. 1 the stream shown would be intermittent above the point a, and perennial below this point. Infiltration through the soil on the area above a provides ground water which supplies the stream below a. The surface run-off of the stream above a is less than the total yield of its tributary area, the excess passing as underflow into the area below a.

Since the finger tips of the drainage net of a stream are mostly first order tributaries, subject to these conditions, it follows that there is usually a belt surrounding a drainage basin just within the watershed line (excepting in case of very impervious areas), from which the run-off occurs partly through the intermittent surface streams, and partly through the underflow of ground water to lower levels.

If the dividing ridge between two drainage basins is impermeable, there will be no watershed leakage. Watershed leakage in general only occurs where there is a continuous ground water horizon under both drainage basins or portions of drainage basins affected.

In general, the flatter the dividing ridge and the more sparse and infrequent the streams, the greater as a rule is the likelihood of watershed leakage. In large flat permeable areas the topographic and underground water divides will frequently cross and recross. The run-off relations for the headwater ramifications of the river system may thus be rendered very complex, there being inversion to one and diversion from another such tributary. Taken over the whole of a large area the local effects will often be largely neutralized.

Such conditions are illustrated by Fig. 2, in which the solid line indicates the topographic, and the dotted line the phreatic or underground water divide. In this case, taking the basin as a whole, the surficial and underground drainage areas are about equal. Some of their individual tributaries have their yield increased, as c and d, while the yield of others, as a, b and e, is greatly decreased, by watershed leakage.

The ratio of the area to the perimeter of a drainage basin increases in proportion to the area. Watershed leakage from a large basin usually occurs around the perimeter, so that the effect of watershed leakage on a given perventage of the periphery of a large drainage basin is less, relative to the total yield of the basin, than in the case of a small drainage basin. The likelihood of the occurrence of opposite effects, tending to neutralize one another, is always greater in the case of large than in the case of small areas. As a result of these conditions, the occurrence of watershed leakage in a sufficient degree to materially affect the accuracy of estimates of run-off is more probable in the case of small than of large drainage basins.

A condition necessary for the occurrence of watershed leakage is the existence of an outlet for ground water at a level lower than that of the stream draining the basin from which the water is derived. If the divide between two adjacent drainage basins is not impervious, and the stream on one side has cut to a lower level than the other, the lower stream may receive watershed leakage from the higher basin. Such leakage may occur either through sand and gravel, or through non-impervious rock, such as sandstone or limestone, under suitable conditions. Figs. 3 and 4 illustrate this.

In Fig. 3 the streams a and b are parallel, and the figure shows a cross-section of their valleys, and of the ridge between them. While the form of ground water table is generally similar to that of the overlying soil, under the conditions shown, the ground water divide would generally be to the left of the topographic divide, and if the soil were permeable, the stream b would receive the ground water from a strip c—d, the surface run-off from which is tributary to the stream a. In this case it is assumed that there are deep permeable deposits above the rock. These conditions may be reversed, as shown in Fig. 4, by the existence of impervious rock with suitable dip.

In Fig. 4, if the rock were horizontal, or the deposits of permeable materials were of great depth, the conditions would be similar to those in Fig. 3. In the presence of impervious rock dipping towards the upper stream, the ground water divide is thrown over to the right, and stream a receives the ground water flow from a strip c—d of area, the surface run-off from which is tributary to the lower stream.

Fig. 5 illustrates further the occurrence of watershed leakage due to permeable rock strata of suitable dip. Fig. 5 shows conditions existing relative to Schoharie creek, the basin of which is crossed by cavernous limestone of the Helderberg formation. This limestone outcrops in the Helderberg escarpment at a level lower than that at which the creek crosses it. The existence of these conditions, in conjunction with the notably small summer yield of the stream, suggests the possibility of watershed leakage.

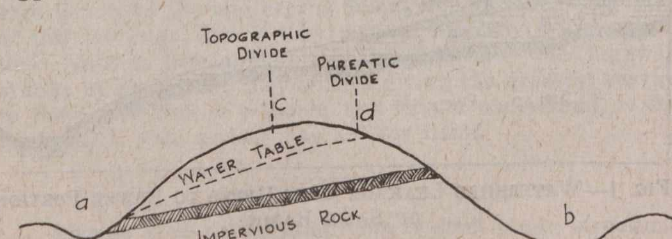


Fig. 4—Lateral Watershed Leakage Induced by Dip of Impervious Rock

Conditions under which small direct tributaries of large streams may lose ground water by underflow are illustrated by Fig. 6. The area directly tributary to the large stream, between the smaller streams, is the triangle a—b—c, but the ground water from a considerably larger area enters the main stream directly, reducing the yield of the tributaries. This condition is likely to occur around a lake margin, or on a broad valley plain, filled with alluvial deposits.

An impervious rock divide at the surface will, of course, prevent watershed leakage between adjacent basins, and if