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# Natural laws of precipitation, great cycle, infiltration overland and groundwater runoff with a new formulas

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## Abstract

All the elements of water balance including precipitation are connected with soil. Some natural laws, which are a result of external (climate, relief) and internal (geological structure, thickness) natural factors, influence the leachate water to be transformed into surface outflow, infiltration, evaporation and subsurface runoff.

M. I. Ljovic has found dependencies between infiltration, evaporation and subsurface runoff. His method is a six component are. In this work, there has been connection established between infiltration in surface runoff and precipitation. This method for determining elements of water balance is a three component are and essentially is purely mathematics. On the graphics, values of the Ljovic's coefficients are linked with the new one in the graphics, from the three component method. The new formula tries to explain characteristics of natural laws of precipitation infiltration overland and groundwater runoff, in another way. The method can be applied on permeable and impermeable terrains. The results obtained mainly agree with the results obtained by the method of hydrograph analyzing.

## 1 Introduction

In Hydrology, water balance is determined by M. I. Ljovic's six component method:

$$P = S + U + E, \quad R = S + U, \quad W = P - S = U + E, \quad Ku = \frac{U}{W}, \quad Ke = 1 - Ku = \frac{E}{W},$$

where  $P$  is atmospheric precipitation,  $R$  is total runoff,  $S$  is overland runoff,  $U$  is groundwater runoff,  $E$  is evaporation,  $W$  is precipitation infiltration,  $Ku$  and  $Ke$  are the coefficients of the river recharge by groundwater and evaporation, showing which part of infiltrated precipitation belongs to groundwater runoff and evaporation. From one of the mentioned equations, we derived new coefficients:

$$W = P - S \Rightarrow W + S = P / : P \Rightarrow \frac{W}{P} + \frac{S}{P} = 1.$$

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The first coefficient,  $W/P$  is defined as the coefficient of precipitation infiltration  $K_w$ , which determines the part of precipitation infiltrated into the soil. The second,  $S/P$  is called coefficient of overland runoff  $K_s$ , which determines the part of precipitation belonging to the overland outflow. So, taking into consideration all coefficients, precipitation is, at first, spent into overland runoff and infiltration ( $K_s+K_w=1$ ) and then, infiltrated precipitation into evaporation and groundwater outflow ( $K_u+K_e=1$ ).

## 2 Determination of precipitation infiltration, overland and groundwater runoff

In hydrology, there are several methods for determination of precipitation infiltration, overland and groundwater runoff. None pretends to be exact. In this work, by use of mathematical laws, the following results are obtained.

After deriving the  $K_w$  and  $K_s$  coefficients, all the coefficients of the six component method ( $K_u$ ,  $K_s$ ,  $K_e$ ,  $K_w$ ) can be associated into a graphic of function shown in Fig. 1. In the graphic, distinguishing of precipitation into infiltration  $K_w$  and overland runoff  $K_s$  is presented. The coefficients are supplementing each other up to 1 (complementary). Then, spending to infiltrated precipitation into groundwater runoff  $K_u$  and evaporation  $K_e$  are presented. The same is valid for these two coefficients, as for the former (complementing to 1). The graphic shows complementarities of appropriate coefficients in any point of it, which can be seen from the mathematical expression ( $K_w+K_s=1$ ,  $K_u+K_e=1$ ). Several points from the Table 1, referring to steppe, hillea, South America and Russian Federation are included into the graphic. For them elements of water balance are determined by method of hydrograph analyzing, illustrated in Fig. 2. In this paper we tried to determine exactly precipitation infiltration  $W$ , overland  $S$  and groundwater outflow  $U$ , not only for impermeable terrains, but also for permeable terrains. Beside these two types of terrains, others are non existent. Impermeable terrains are ones where, with increase of infiltration in 0–1 range, continuously increases evaporation (0–1), and permeable terrains are the ones where, with an increase of infiltration (0–1), continuously increases groundwater runoff (0–1). In nature, the widest distribution has

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impermeable terrains. Permeable terrains, referring to intensively limestone gravel and other terrains with very intensive groundwater circulation, are rare.

## 2.1 Impermeable terrains

In this section we tried to give a connection between water balance coefficients from the three component and the six component methods. The coefficients from three component method are the following

$$R + E = P / : P \Rightarrow \frac{R}{P} + \frac{E}{P} = 1.$$

The coefficient of water discharge  $R/P$  shows which part of precipitation discharges, and  $E/P$  evaporation coefficient, which part of precipitation evaporates. The coefficients from six component method are the following

$$K_w = \frac{W}{P}, \quad K_s = \frac{S}{P}, \quad K_u = \frac{U}{W}, \quad K_e = \frac{E}{W}.$$

The connection between them is carried out in the following way

$$K_w K_e = \frac{W}{P} \cdot \frac{E}{W} = \frac{E}{P} \Rightarrow K_w K_e = \frac{E}{P}.$$

That means that multiplication of precipitation infiltration coefficient  $K_w$  with evaporation coefficient in relation to infiltration  $K_e$ , gives evaporation coefficient in relation to precipitation  $E/P$ . The last one,  $E/P$  originates from the three component method and it is known in every place where precipitation and river flow is measured. In that way, it is possible to determine  $K_w$  and  $K_e$  coefficients and on the basis of them, all other  $K_u$  and  $K_s$ . In that way, all other water balance elements ( $W$ ,  $S$ ,  $U$ ) could be determined, only by use of data on precipitation and evaporation.

In Figs. 3 and 4 are illustrated contours  $K_w K_e = E/P$  for 0–1 range. Zero and one are points and other values, curves of different length. The numerical value of the curves corresponds to the  $E/P$  value, which is the evaporation coefficient in relation to

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precipitation. For the sake of clearness and further presentation, watershed points from the Table 1, on the basis of their coefficients ( $K_w$ ,  $K_e$ ,  $K_u$ ,  $K_s$ ) and  $K_w K_e = E/P$  curves, are presented in the Fig. 5. Points of these terrains are located in appropriate  $K_w K_e$  curves. However, it is a question appearing now-if they have to be positioned just in that point? Namely, if they are even located in some other one, complementarily of the appropriate coefficients would be fulfilled and we would not be sure if the coefficients are correctly determined. In fact, the coefficient  $E/P$  should be found in a graphic within  $K_w K_e$  curve, being of the same value as the curve. In order to find the  $E/P$  coefficient within the graphic, let us divide  $K_w$  with  $K_e$

$$\frac{K_w}{K_e} = \frac{\frac{W}{P}}{\frac{E}{W}} = \frac{W^2}{PE}$$

Without the graphic, the water balance coefficients are determined according to the formula,  $\frac{W^2}{PE} = 1 \Rightarrow W^2 = PE \Rightarrow W = \sqrt{PE}$ .

Overland runoff  $S$  is obtained from the well known formula

$$P = W + S \Rightarrow S = P - W,$$

and groundwater runoff  $U$  from

$$W = E + U \Rightarrow U = W - E.$$

In every place where precipitation and river flow could be monitored, the precipitation infiltration, as well as overland and groundwater outflow, can be determined in the simplest, exact way. The exactness of the results depends on the accuracy of the determined precipitation and flow, in other words, evaporation.

## 2.2 Water permeable terrains

It has been already stated that permeable terrains are the ones where simultaneously with infiltration  $W$ , groundwater runoff  $U$  increases. That is shown by Fig. 6, where the

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$U/P$  curves have originated by multiplication of  $K_w$  (infiltration of precipitation) and  $K_u$  (recharge always by groundwater) coefficients.

$$K_w \cdot K_u = \frac{W}{P} \cdot \frac{U}{W} = \frac{U}{P}.$$

$U/P$  is the groundwater runoff coefficient, showing the part of precipitation belonging to subsurface outflow. It is the index of the catchments area permeability. With an increase of infiltration ability  $K_w$  in the 0–1 range it also increases in the same interval from 0 down left to 0 up-right. In permeable terrains, the point of the watershed is also in diagonal  $d_1$  because only in line, all water balance coefficients ( $K_w$ ,  $K_s$ ,  $K_u$ ,  $K_e$ ,  $U/P$ ,  $S/P+E/P$ ) are included in the 0–1 range. In the diagonal, a new  $S/P+E/P$  coefficient is occurred, extending from the watershed point to the end of the diagonal on graph to 0 up-right. It is called coefficient of total integral impermeability, consisting of  $S/P$  surface impermeability and  $E/P$  underground storage impermeability. Permeability+Impermeability=1, or

$$\frac{U}{P} + \frac{S}{P} + \frac{E}{P} = 1/P \Rightarrow U + S + E = P.$$

Precipitation is equal to a sum of overland (impermeability) and groundwater (permeability) runoff and evaporation (impermeability). From this, it can be concluded that it is a real index of  $E/P$  watershed storage, directing to internal impermeability. Hence,  $E/P$  is the coefficient of watershed storage. As the catchments area point is located in an intersection of  $d_1$  diagonal and  $K_w K_u$  curve in other words  $U/P$  (Fig. 7). The next question is, how to find it? The  $U/P$  coefficient is an unknown value. But, the  $K_w K_e$  curve is known that is  $E/P$ . In each point of the  $d_1$  is valid  $K_w + K_e = 1$ . From this

$$K_e = 1 - K_w, \quad K_w(1 - K_w) = \frac{E}{P} \Rightarrow K_w - K_w^2 = \frac{E}{P} \Rightarrow K_w^2 - K_w + \frac{E}{P} = 0.$$

Finally the last formula is the quadratic equation of coefficients of infiltration for permeable terrains and has two solutions, because the  $K_w K_e$  curve, intersects a diagonal  $d_1$

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in two points in the graphic. At the same time, the curve also intersects  $d_2$ , indicating impermeable terrains. That is the reason why it is necessary to examine the terrain and to determine if it is either impermeable or permeable. There are two possibilities ( $Kw_1$  and  $Kw_2$ ).

$$Kw_{1,2} = \frac{1 \pm \sqrt{1 - \frac{4E}{P}}}{2}$$

The first value is greater than 0.50 and shows high permeability, while the second is less. When the  $Kw$  infiltration coefficient is less than 0.50 a problem appears, because it is necessary to define if the terrain is permeable or impermeable. Note that  $KwKe$  ( $E/P$ ) curve also intersects the  $d_2$  diagonal, where impermeable terrains are distinguished. Now, let us see the graphic (Fig. 8a) showing groundwater outflow coefficients. For the same infiltration,  $Kw=0-0.50$  the coefficient in  $d_1$  (diagonal referring to permeable terrains) is less and in  $d_2$  (concerning impermeable terrains) is greater. At the same time, the evaporation coefficient (Fig. 8b) is greater in  $d_1$  (permeable terrains) and less in  $d_2$  (impermeable terrains). That phenomenon is connected to shallow soil layer (impermeable terrains) in mountain areas, protecting infiltrated precipitation against evaporation, during their percolation through more intensively developed fracture system beneath. Permeable terrains, on the other side, at an early stage of formation are rocky with a very few small fractures and without loose material, so precipitation is stopped within various impermeable recesses, evaporating lately. That is a case with compact limestone. According to graphic  $U/P$  and  $E/P$  (Fig. 8) became equal for  $Kw=0.50$ . In impermeable terrains, then was formed thicker soil layer, and in permeable fractures developed and widened, but without protective layer. With an increase of infiltration coefficient over 0.50 in diagonals, storage, that is permeability, becomes more visible. Finally, it can be concluded that the  $d_1$  diagonal, concerning permeable terrains, points of watersheds with  $Kw<0.50$  are characterized as impermeable, but they differ from storage ones in  $d_2$ , because they are without protective cover. These are denuded rocky areas, disposed to development. They are potential

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permeable terrains. They obtain permeability characteristics just for infiltration abilities greater than 0.50 still existing without protective soil cover, but with intensively developed fracture system. Such areas are unusual and can refer to smaller zones, even rock complexes with high frustrations. After the  $Kw_1$  and  $Kw_2$  infiltration coefficient determination, the next stage is the calculation of all other coefficients in graphic and in mathematical expression, as shown for impermeable terrains. As watershed points in permeable terrains are located in  $d_1$  diagonal of the graphic, then

$$Kw = Ku, \quad Ks = Ke.$$

Using the previous equality we will derive a new formula of precipitation infiltration for permeable terrains.

$$Kw = Ku \Rightarrow \frac{W}{P} = \frac{U}{W} / PW \Rightarrow W^2 = PU \quad (1)$$

### 3 Determination of natural laws

By mathematics many formulas have been derived, explaining a Hydrological Cycle. In the graphics the impermeable and permeable terrains are distinguished. The first are with the widest space distribution in the Earth's system.

#### 3.1 Impermeable terrains

$$W = \sqrt{PE} \Rightarrow PE = W^2 \Rightarrow E = \frac{W^2}{P} \vee P = \frac{W^2}{E}.$$

Precipitation infiltration is equal to the square root of precipitation and evaporation product. Evaporation is directly proportional to infiltration and indirectly proportional to precipitation. Precipitation is directly proportional to infiltration and indirectly proportional

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to evaporation. Part of precipitation infiltrating into the soil is equal to a the part of infiltrated precipitation which evaporate. That means, if 80% of precipitation is infiltrated within a soil, 80% of that quantity will evaporate.

$$K_w = K_e, \quad \text{or} \quad \frac{W}{P} = \frac{E}{W}.$$

- 5 The part of precipitation spending to overland runoff is equal to infiltrated precipitation spending to subsurface runoff. That means, if 30% of precipitation spends to overland runoff, the same percentage (30%) of infiltrated precipitation will spend to underground one.

$$K_s = K_u, \quad \text{or} \quad \frac{S}{P} = \frac{U}{W}.$$

- 10 Precipitation infiltration coefficient is equal to square root of evaporation coefficient in relation to precipitation. Equality shows that to one precipitation infiltration coefficient corresponds only one evaporation coefficient in relation to precipitation.

$$K_w = K_e, \quad \frac{W}{P} = \frac{E}{W} \Rightarrow \frac{W}{P} = \sqrt{\frac{E}{P}} \Rightarrow \frac{E}{W} = \sqrt{\frac{E}{P}}.$$

- 15 The evaporation coefficient in relation to infiltration is equal to the square root of evaporation coefficient in relation to precipitation. To one the evaporation coefficient in relation to precipitation corresponds just one evaporation coefficient in relation to infiltration. In the graphic (Fig. 9) are shown dependencies of water balance elements on infiltration in impermeable terrains.

### 3.2 Permeable terrains

- 20 In permeable terrains, infiltration coefficient has two solutions.

$$K_{w_{1,2}} = \frac{1 + \sqrt{1 - \frac{4E}{P}}}{2}.$$

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For such a type of terrains, the evaporation coefficient ( $E/P$ ) is less than 0.25. Infiltration coefficients greater than 0.25 belong to impermeable terrains. From Eq. (1) is.

$$U = \frac{W^2}{P} \Rightarrow PU \Rightarrow U = \frac{W^2}{P} \vee P = \frac{W^2}{U}.$$

5 Infiltration of precipitation is equal to square root of precipitation, underground runoff product. Groundwater runoff is directly proportional to the square of infiltration and indirectly proportional to precipitation. And at the end, precipitation is directly proportional to square of infiltration, and indirectly proportional to underground runoff. The part of precipitation infiltrating into permeable terrains is equal to the part of infiltrated precipitation spending to overland runoff. That means, if 70% of precipitation is infiltrated,  
10 70% of that quantity will spend to underground runoff.

$$K_w = K_u \quad \text{or} \quad \frac{W}{P} = \frac{U}{W}.$$

In permeable terrains, the part of precipitation spending to overland runoff is equal to the infiltrated precipitation spent to evaporation. If 20% of the precipitation spent to overland runoff, 20% of infiltrated precipitation would evaporate. Natural dependencies  
15 of water balance elements on infiltration characteristics for permeable terrains can be derived (Fig. 10). With an increase of infiltration characteristic within 0–1 range, parallel increases groundwater runoff  $U$  reaching 0.25 of its abilities for 0.50 of infiltration abilities, and after that suddenly increases and reaches maximum value 1 for infiltration characteristics, becoming equal to infiltration  $W$ . With an increase of infiltration characteristics, overland runoff  $S$  decrease to 0 with the same intensity as the previous increase. With infiltration characteristics to 0.50 total runoff  $R$  decreases slower, reaching then its maximum (75% of its possibilities) and then slowly increases, becoming equal to groundwater runoff for infiltration characteristics 1. Evaporation  $E$  with an  
20 increase of infiltration characteristics to 0.5 slowly increases, reaching maximum of its abilities (0.25), then slowly decreasing and disappearing for infiltration characteristic 1,  
25

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when all infiltration  $W$  spends to subsurface runoff. Comparing to the curves of natural dependencies of water balance elements on infiltration characteristics (Figs. 9 and 10), with Ljvovic's theoretical curves of water balance dependence on soil features (infiltration characteristics), insignificant disagreement of curves can be noticed, where with an increase of infiltration characteristic, increases impermeability, and that is only for their maximum values (Fig. 9). But, the second sketch of M. Ljvovic where an increase of infiltration and a decrease of impermeable characteristics is shown, giving similar, if not the same dependencies as those in the work (Fig. 10). In permeable terrains, with increase of infiltration characteristic in 0–1 range, in total flow, groundwater runoff continually increases, and the overland one continually decreases. They become equal for infiltration characteristics  $W/P=0.62$  (Fig. 1).

#### 4 Practical application of exploration results

In hydrological science, precipitation infiltration, overland and groundwater runoff was determined by different methods. This formulas make determination of all water balance elements (infiltration, overland and groundwater runoff) possible only according to precipitation and evaporation, and without analyzing the flow of hydrograph and its planimetry. In this paper will be presented one example of water balance elements estimate for impermeable and permeable terrains, where data on precipitation are evaporation are cited from examples for the continent of Africa. Africa ( $P=686$  mm,  $E=547$  mm)  $\Rightarrow \frac{E}{P}=0.797$ ,

$$Kw = \frac{W}{P} = \sqrt{\frac{E}{P}}, \quad \frac{W}{P} = \sqrt{0.797}, \quad \frac{W}{P} = 0.8927, \quad W = P \cdot 0.8927 \Rightarrow W = 612 \text{ mm}.$$

$$W = \sqrt{PE}, \quad W = \sqrt{687 \cdot 547}, \quad W = 612 \text{ mm}.$$

In the further procedure, the known formulas will be used

$$S = P - W = 686 - 612 \Rightarrow S = 74 \text{ mm},$$

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$$U = W - E \Rightarrow U = 612 - 547 \Rightarrow U = 65 \text{ mm}, \quad U + S = R \Rightarrow 65 + 74 = 139 \text{ mm}.$$

Note that, for Africa, by method of hydrograph analysis, it has been determined:  $W=595$ ,  $U=48$  and  $S=91$  mm. We can conclude that Africa belongs to impermeable terrains, because its evaporation coefficient ( $E/P$ ) is greater than 0.25, and for mountain near, ocean forest less than 0.25 (just 0.227), so we suppose that they are classified as permeable terrains. For terrains with evaporation coefficients ( $E/P$ ) less than 0.25, formulas either for impermeable, or for permeable terrains are used. In case of mentonied near oceanic forests, the formula for impermeable terrains will be used first, and than for permeabeable ones. The formula for impermeable terrains

$$W = \sqrt{PE}, \quad W = \sqrt{2200 \cdot 500} = 1049 \text{ mm}, \quad S = P - W = 1151 \text{ mm},$$

$$U = W - E = 549 \text{ mm}.$$

The following terrains are consired to be permeable

$$Kw_{1/2} = \frac{1 \pm \sqrt{1 - \frac{4E}{P}}}{2}, \quad Kw_{1/2} = \frac{1 \pm \sqrt{1 - 4 \cdot 0.227}}{2}, \quad Kw_1 = 0.652, \quad Kw = 0.348.$$

Just remember that two solutions are present, because the formula is a result of quadratic equation, and the curve  $KwKe=E/P$  in the graphic intersects  $d_1$  diagonal in two points. When it is established that terrain is really permeable, there is a possibility of choosing one of the two infiltration coefficients ( $Kw_1$  or  $Kw_2$ ). According to the first ( $Kw_1=0.652$ ),  $W=1434$  mm,  $S=766$  mm,  $U=934$  mm. According to the second ( $Kw_2=0.348$ ),  $W=757$  mm,  $S=1443$  mm,  $U=257$  mm. In the case of near oceanic monsoon woods, it is obviously not permeable, but impermeable terrains, previously worked out by the formula and which results are mainly in agreement with research by the hydrograph method. There, a comparison is shown in following way, see Table 2.

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## 4.1 Process of precipitation infiltration

The process of precipitation infiltration, overland and groundwater runoff develops through certain natural laws. The main factor in the process is the state of the soil (permeable, impermeable, wet, dry, frozen, etc.), determining its infiltration characteristic. In the  $W = \sqrt{PE}$ , through its members, all natural factors are contained, determining not only precipitation and evaporation, but also infiltration, overland and groundwater runoff. To carry out of categorization of some terrain as impermeable or permeable, longer period of precipitation and evaporation monitoring is necessary. Otherwise, depending on soil infiltration characteristics, during a year period, storage, impermeability and permeability is changing. The characteristics are even changing for individual precipitation, depending on their character. For example, for shower rains, soil is not able to infiltrate a greater quantity of precipitation, and it is practically impermeable. Formulas are applicable for all time periods, long standing, annual, monthly and for precipitation occurring once. To get completely correct results, it is necessary to determine exactly the quantity of precipitation and evaporation. For the monthly calculating of water balance, problem concerning evaporation appears, because during the winter period, precipitation like snow and ice are stopped within surface of a catchments area. Therefore, formulas can be applied only for running precipitation. For a several year period, the problem of evaporation as known is not existing. The formulas can be used for water balance calculating of catchments areas, states and continents. Formulas also refer to smaller terrains, rock complexes and other micro media.

## 5 Conclusions

In hydrological cycle, precipitation is, first of all, spent in overland runoff and infiltration. Part of infiltration precipitation spends to underground recharge of rivers, and another to evaporation. M. I. Ljovic has established dependencies between infiltrated precipitation  $W$  and groundwater runoff  $U$  and evaporation  $E$  through coefficients  $Ke = E/W$

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and  $K_u = U/W$ . In this work the relationships between precipitation  $P$  and overland runoff  $S$  and infiltration  $W$  were made, through coefficients  $K_s = S/P$  and  $K_w = W/P$ . In such a way complex dependencies among all water balance elements were made within a complete water circulation process. Multiplication  $K_w K_e$  in mathematical expression and in the graph, the dependencies among water balance elements from the six component and three component method were performed.

$$K_w K_e = \frac{W}{P} \cdot \frac{E}{W} = \frac{E}{P}.$$

By  $K_w K_u$  multiplication,  $U/P$  was obtained.

$$K_w K_u = \frac{W}{P} \cdot \frac{U}{W} = \frac{U}{P}.$$

On the basis of mathematical laws, great number of the formulas, discovers natural laws of hydrology. According the formulas, just on the basis of precipitation  $P$  and evaporation  $E$ , all other elements of water balance can be determined. Result obtained by formulas mainly agree with result obtained by hydrograph analyzing (Tables 3 and 4).

## Appendix A

### Mathematical background

$$ax^2 + bx + c = 0 \Rightarrow x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad (A1)$$

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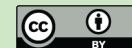
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**Table 1.** Water balance elements for Steppe, Hillea, South America and Russia.

Part of land	$P$	$R$	$E$	$W$	$S$	$U$	Ku	Ke	Kw	Ks	$E/P$
Steppe	500	50	450	460	40	10	0.02	0.98	0.92	0.08	0.90
Hillea	2000	1200	800	1400	600	600	0.43	0.57	0.70	0.30	0.40
South America	1648	583	1065	1275	373	210	0.20	0.80	0.77	0.23	0.65
Russia	500	198	300	348	152	46	0.13	0.87	0.70	0.30	0.60



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**Table 2.** Results for impermeable terrains obtained by hydrograph method and by formula.

Two methods	$W$ mm	$S$ mm	$U$ mm
Hydrograph method	1200	1000	700
By formula	1049	1151	549

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**Table 3.** Water balance of the river Velika Morava catchments area.

River	Method by Hydrograph $W$ mm	New method $W$ mm
Velika Morava Ljubicevki most	589	612
Velika Morava Varvarin	589	609
Juzna Morava Mojsinje	586	602
Juzna Morava Grdelica	552	567
Nisava Nis	571	573
Nisava Pirot	598	600
Toplica Doljevac	605	627
Vlasina Vlasotince	573	576
Zapadna Morava Jasika	629	647
Zapadna Morava Guljanski most	630	658
Moravica Arilje	667	662
Djetina Goroblje	648	670
Rasina Bivolje	548	585
Ibar Lapotnica Lakat	604	615
Ibar Raska	601	615
Sitnica Nedakovac	581	611

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**Table 4.** Balance estimate of fresh water for parts of the world.

Part of land	Method by Hydrograph $W$ mm	New method $W$ mm
Europe	524	552
Asia	509	561
Africa	595	612
North America	467	506
South America	1275	1324
Australia	564	612
Total land	630	671

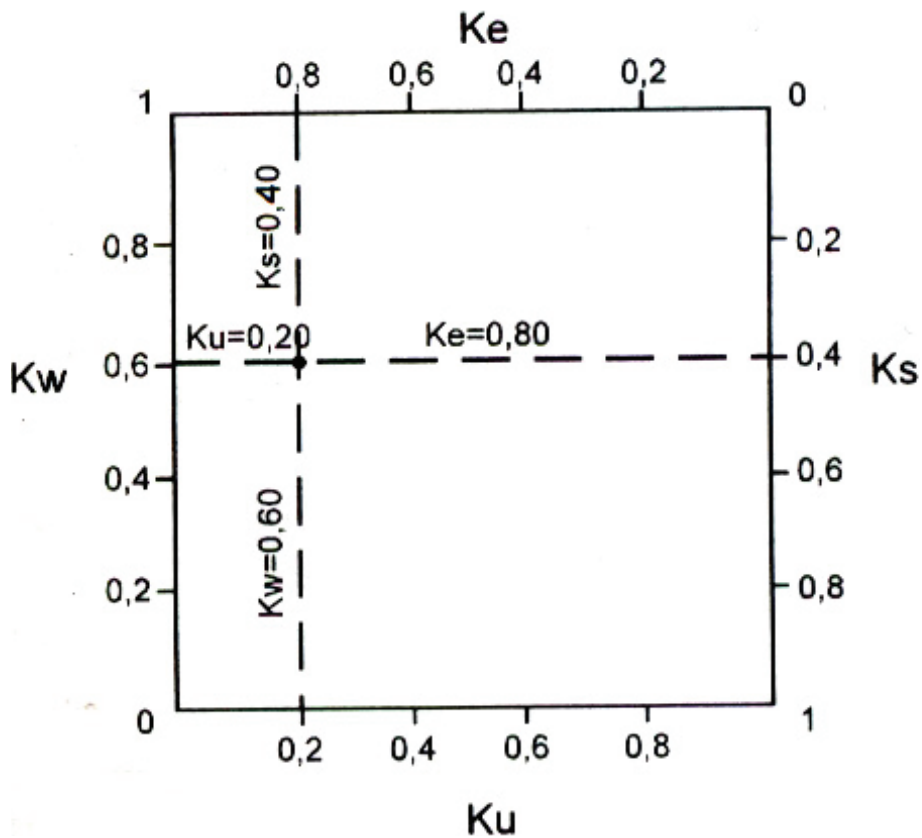


Fig. 1. Associating of all coefficients of six components method (Ku, Ke, Ks, Kw).

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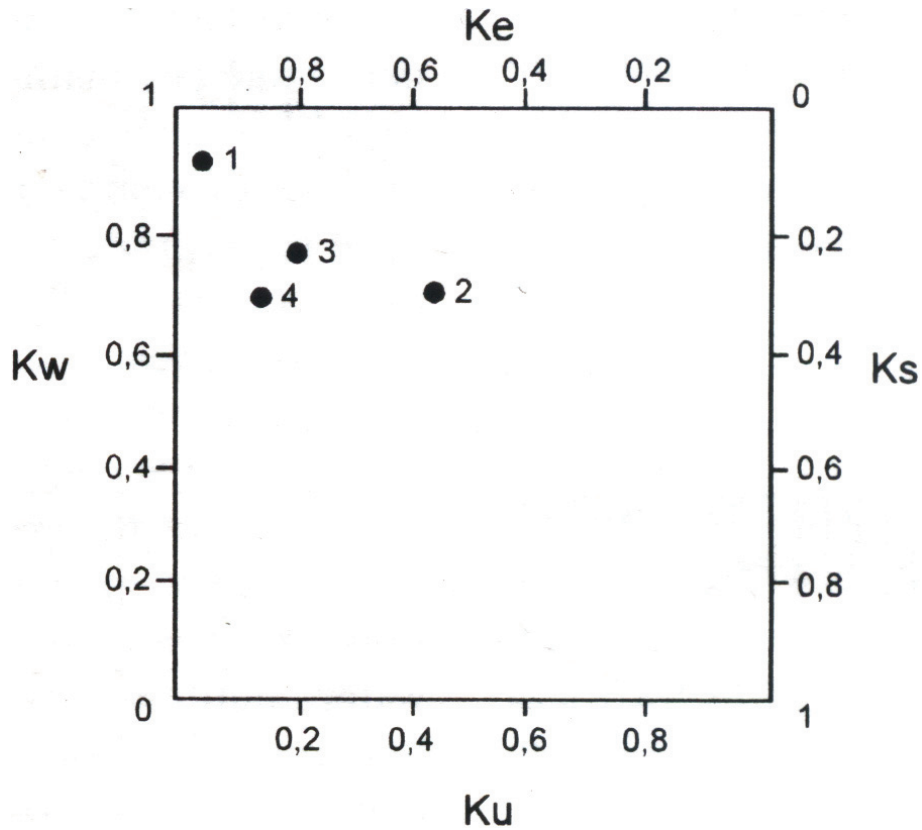
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**Fig. 2.** Elements of water balance from the Table 1, are determined by method of hydrograph analyzing.

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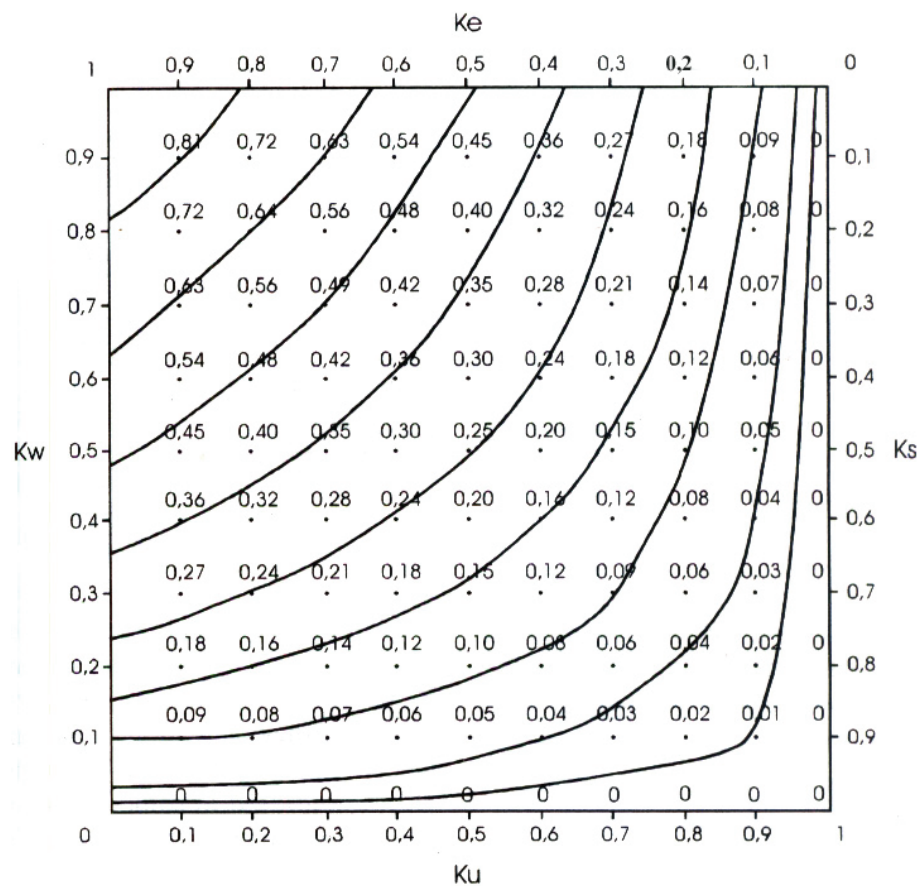
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**Fig. 3.** Multiplication  $K_w K_e$  and linking points with a same value, contours  $K_w K_e = E/P$ , for 0–1 range.

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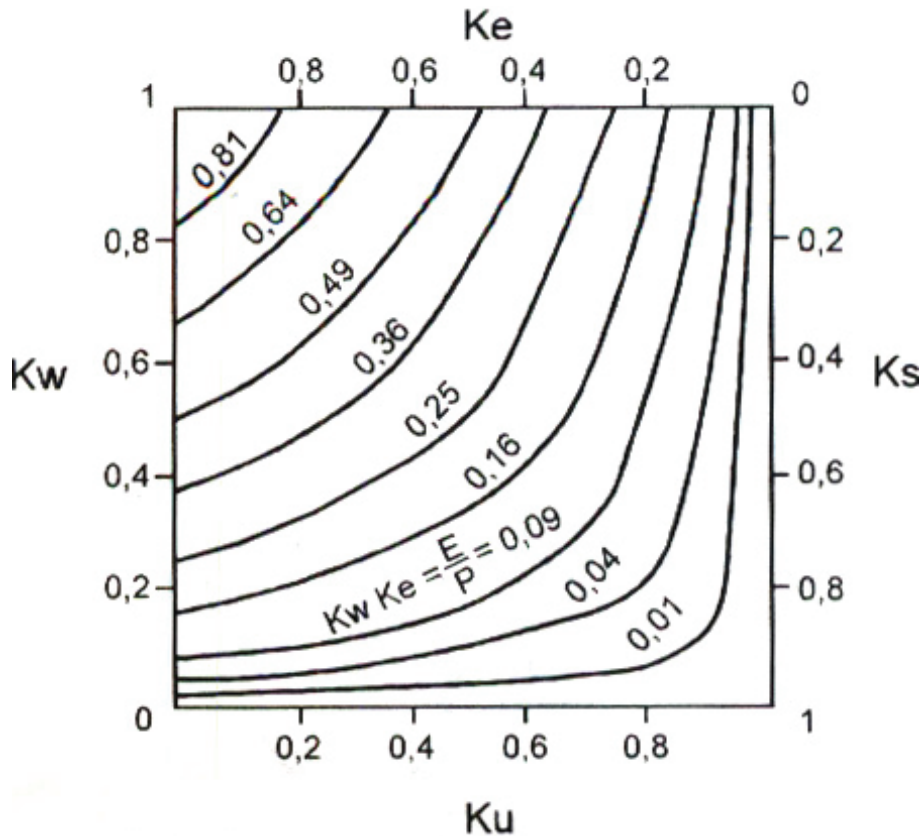
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**Fig. 4.** Multiplication  $K_w K_e$  and linking points with a same value, contours  $K_w K_e = E/P$ , for 0–1 range.

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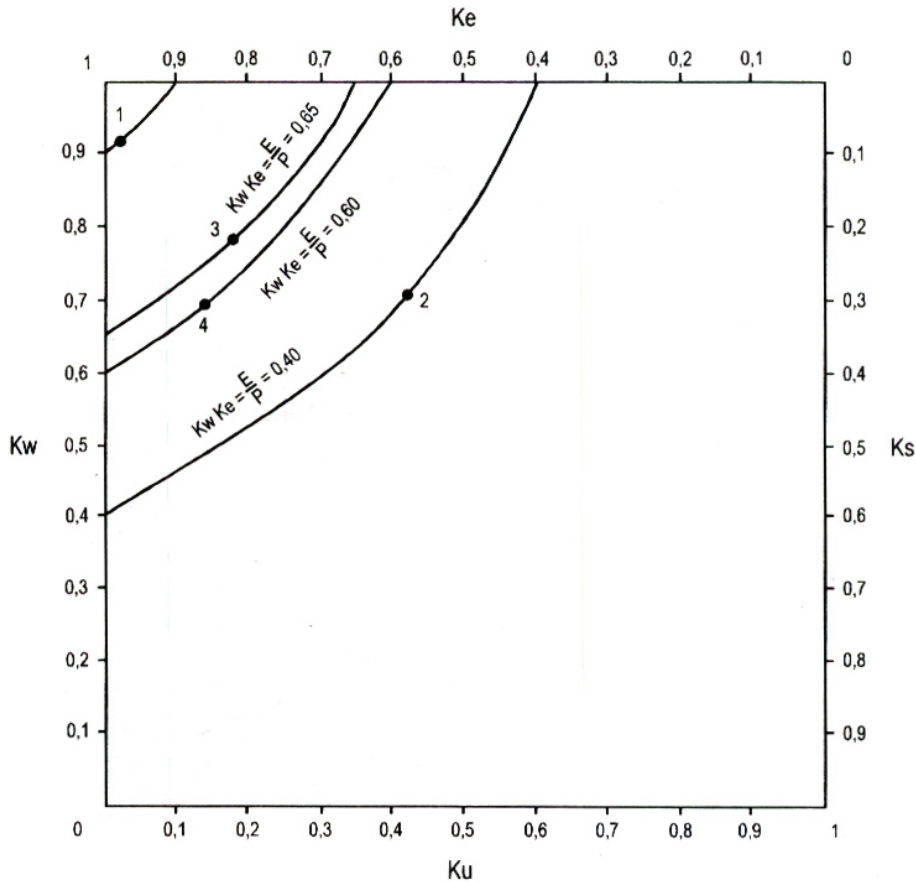
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**Fig. 5.** Presentation of the watershed points from the Table 1, on the basis of their coefficients ( $K_w$ ,  $K_e$ ,  $K_u$ ,  $K_s$ ) and  $K_w K_e = E/P$  curves.

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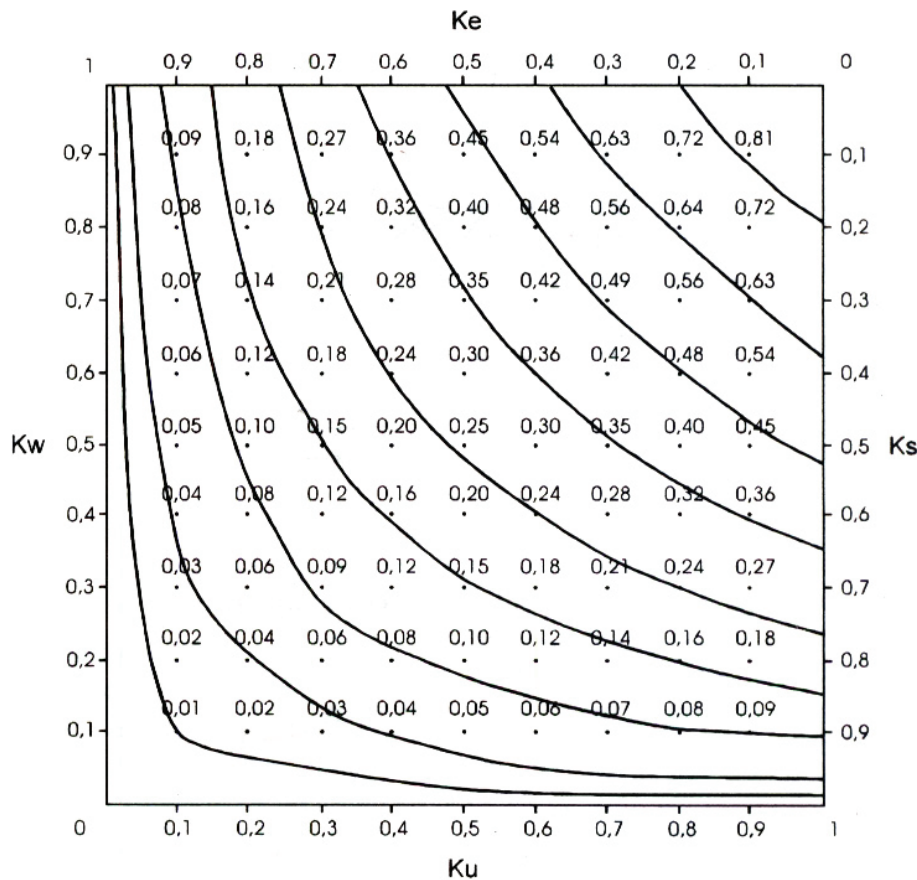
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**Fig. 6.** Multiplication  $KwKu$  and linking points with a same value, contours  $KwKu=U/P$  for 0–1 range.

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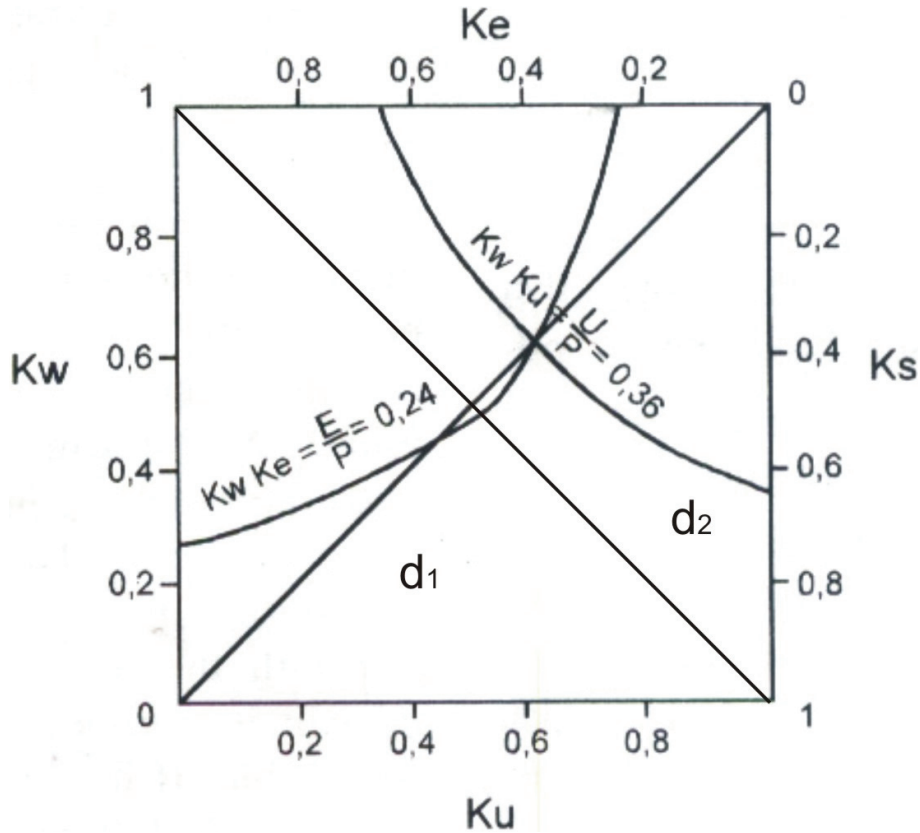


Fig. 7. In each point of the  $d_1$  diagonal, the following is valid:  $Kw+Ke=1$ .

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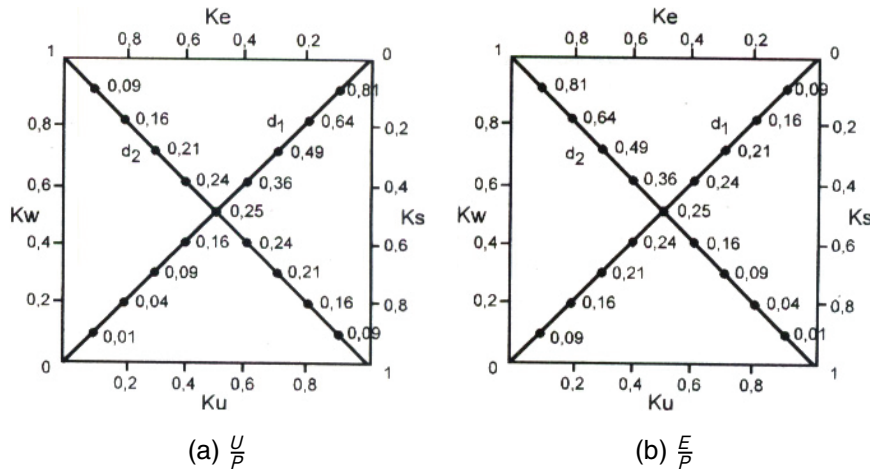


Fig. 8. Dependencies of water balance elements on infiltration in impermeable terrains.

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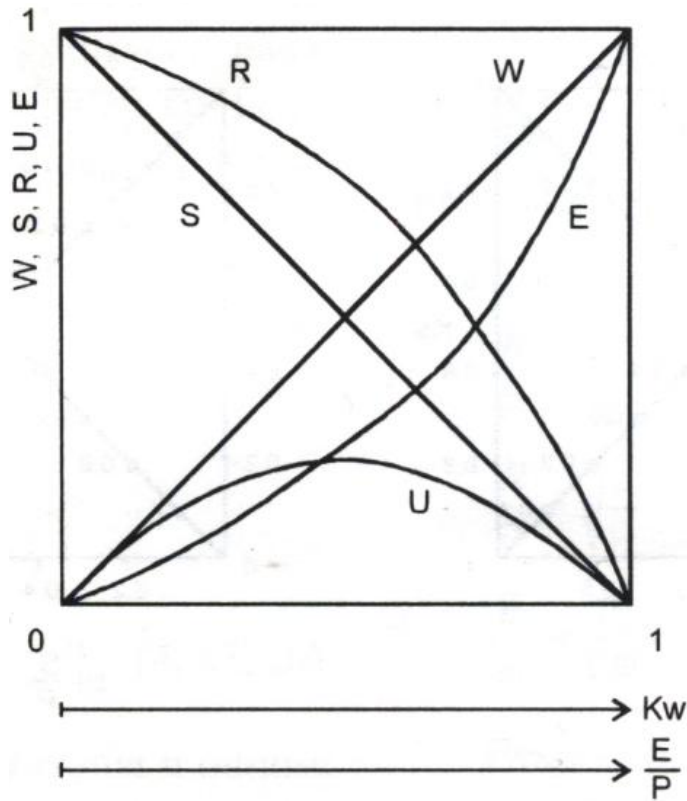
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**Fig. 9.** Coefficients  $W$ ,  $S$ ,  $R$ ,  $U$ ,  $E$  in impermeable terrains.

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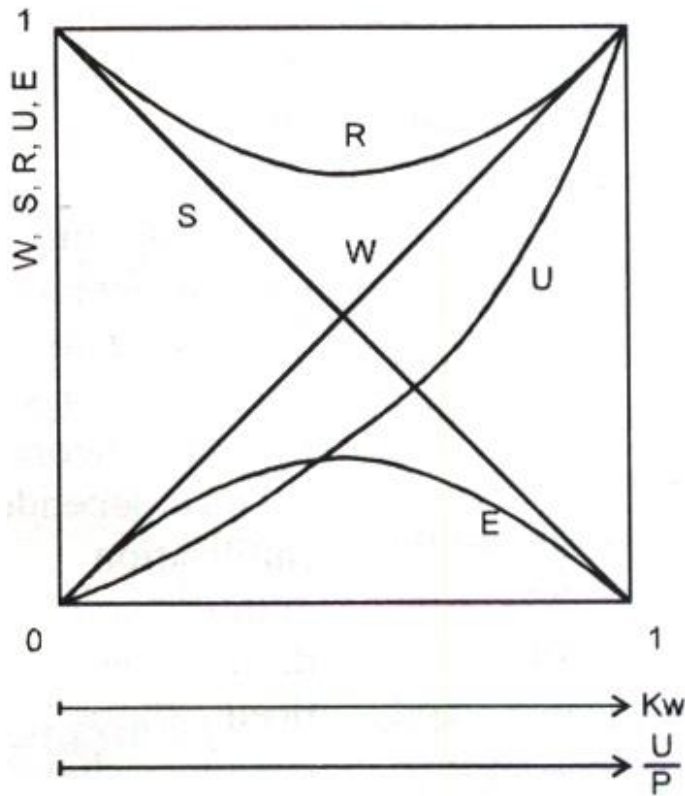


Fig. 10. Coefficients  $W, S, R, U, E$  in permeable terrains.

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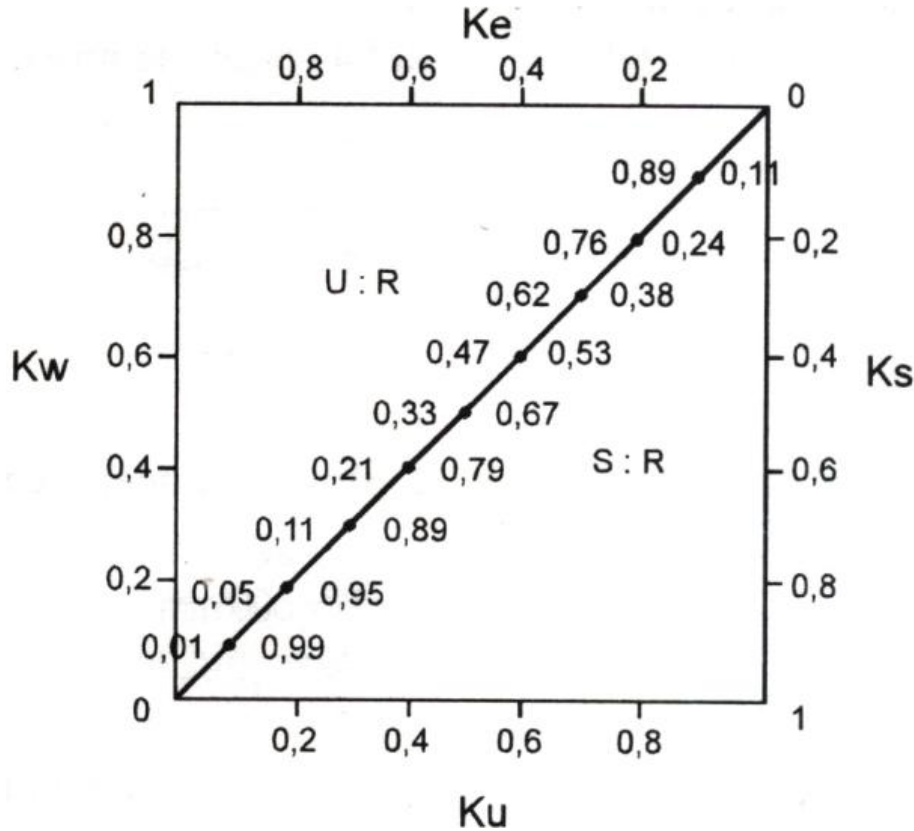
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**Fig. 11.** In permeable terrains, with increase of infiltration characteristics in total flow, ground-water runoff continually increases, and overland on continually decreases.

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