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Regularities of Runoff Formation of Rivers Falling into the Kapshagai Reservoir

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The article deals with the runoffs of rivers falling into the Kapshagai Reservoir. By the conditions of the formation and the nature of interaction of water resources, the area under study is zoned into three areas: 1) the area of formation of water resources; 2) the area of alluvial cones and intense flow dispersion; 3) the area of groundwater discharge in the beds of numerous Karasu rivers. It also describes the special instrument studies of the relationship of the surface and ground waters in the selected rivers, and contains a developed technique of field study of the runoff changes along the length of watercourses in the presence of reaches of both loss of the surface flow and discharge of the groundwater flow. The instrumental gauging of the channel water cycles of rivers (CWC) was carried out under the supervision and with the direct participation of the author.

Key words: Watercourse, Runoff, Natural and geographical areas, River basins, Channel water cycle.

The considered territory on the left bank of the Kapshagai Reservoir (the northern slope of Trans-Ili Alatau) extends in the east-west direction for 150-180 km along the foot of the mountains, from the Shilik River in the east to the Shamalgan River in the west; and in the longitudinal direction, it extends for 50-70 km; the northern part is closed by the Kapshagai Reservoir; the total area is about 6,000 km^2. The mountain system itself belongs to the so-called zone of the runoff formation[1, 2, 3], where moisture condensation occurs, and one of the formed flows are the water resources of the northern slope of Trans-Ili Alatau (Fig. 1).

The piedmont plains researched in the article are a zone of draw-off (dispersion) of water resources coming from the mountain system, and are a territory that is well developed agriculturally. The area is favorable for agriculture in terms of both climate and soil[4, 5]. By the terms of formation and the nature of interaction of the water resources, the northern slope of Trans-Ili Alatau and the piedmont plains are divided into three zones (Fig. 1).

1. The area of water resources formation – the mountain slope composed of Paleozoic rocks and being the main area of the regional rivers nourishment.
2. The area of alluvial cones – the coalescing fan composed of fused alluvial cones and being an area of intense absorption of the prechannel flow of rivers, irrigation and meteoric waters.
3. The piedmont sloping plain, composed of fine-grained low permeable quaternary sediments is an area of groundwater discharge in the main rivers and in the Karasu rivers.

Conducting hydrometric measurements in these areas along the rivers allows defining the peculiarities of the relationship of ground and surface waters, identifying the areas of intensive groundwater discharge of the river flow

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underground loss (groundwater recharge). Also, the inventory of the channel of water cycle (CWC) is one of the methods of study and quantitative estimate of the water resources[6-7].

Field studies of the CWC included coordinated stream gauging at gauging stations located at sites selected in a certain way with account of the time of water travel. Such a method of field gauging stream operations is typically used to determine the value of groundwater recharge, i.e. discharge of groundwater into the river bed[8, 9] or the amount of runoff losses[10].

A prerequisite for the carrying out the field gauging stream operations on defining the changes in water resources along the length of watercourses is favorable weather conditions: rainless summer days and winter days without thaw[11-12]. Precipitation and snowmelt can provide additional surface discharge from the basin area of the river reach, which is not possible to take into account in field conditions.

In addition, the following factors are to be taken into account:

1. The distance between two nearest gauging stations should be such that the difference in water consumption (DQ) between them would be considerably greater than the water flow gauging error, i.e.:

$$\pm \Delta Q \geq 2.\ \delta_Q \text{ or } \delta_Q 0,5\ .\ |\Delta_Q| \quad ...(1)$$

2. Stream gauging of only two cross-sections within a small reach gives the value of changes in the runoff only for this reach, and as a rule, does not always characterize the entire watercourse.

As a result of the survey of the river basins in the studied area, we selected 10 reaches (five in the area of the surface runoff loss and five in the area of groundwater discharge), i.e. the pattern reaches of the Talgar, Turgen, Esik, and Shelek Rivers as shown in Figure 1. These reaches were selected under the condition that they must be representative for the remaining portion of each of the natural geographical area.

MATERIALS AND METHODS

When determining the flow losses in the unconsolidated sediments of alluvial cones, the watercourse has to be split in approximately equal portions as these losses are distributed unevenly along the length. For the area of the Karasu rivers originating in peripheral areas of the coalescing alluvial cones, it is necessary to carry out fully the water gauging in the first 3-5 km from the source, as in this initial segment, more intense discharge of the groundwater runoff to the river beds takes place, and then the process gradually slows down, ceasing completely in some places[13]. Thus, at dividing the river into the water cycle areas, we had to define, primarily, the areas of different discharge and, accordingly, identify the total number of cross-sections and their distribution along the length of watercourses.

The channel water cycle was prepared for water resources of the river reaches, by the conditions of formation of water resources. The equations of the channel water cycle were determined by the type of the river reach, for which the calculation was provided. Depending on the combination of natural and anthropogenic factors, the selected model river reaches were classified as:

- river reaches without a large alluvial plain and reservoirs with the water used for irrigation and other agricultural needs, for which the equation of the channel water cycle has the following form[14, 15, 16]:

$$Q_U + Q_{LI} - Q_D - Q_{WW} + Q_{RC} \pm Q_{WC} \pm Q_I \pm Q_A \pm Q_R = 0 \quad ...(2)$$

where Q_U, Q_d are, respectively, the water flows in the upper and lower cross-sections;
Q_{LI} – total consumption of local inflows;
Q_{WW} – total water withdrawal within the river reach;
Q_{RC} – total flow of surface irrigation returns;
Q_{WC} – consumption of channel storage taken with a minus sign when the water is accumulated in the reach, and with a plus sign when it is withdrawn;
Q_I – water consumption for ice formation with a minus sign at icing, and with a plus sign at ice melting;
Q_A – consumption of water exchange between the river and aquifers (with a plus sign when there is underground inflow, and with a minus sign at a loss of the surface runoff);
Q_R – the residual term of the equation of the channel water cycle, characterizing the residual balance due to calculation errors and incomplete account of the elements of the channel water cycle.

The analysis made by us showed that the equation of the channel water cycle for the two water cycle areas of the piedmont plains and the studied rivers near the left bank of the Kapshagai Reservoir will have the following form:

1. For the area of surface runoff losses in unconsolidated sediments of the alluvial cones:

$$S_S = Q_U + Q_{LI} - Q_D - Q_{WW} + Q_{RC} \quad ...(3)$$

where S_S is the absolute value of seepage losses.

2. For the area of groundwater discharge into the Karasu rivers:

$$S_{GD} = Q_D - Q_U + Q_{WW} - Q_{LI} - Q_{RC} \quad ...(4)$$

where S_{GD} is the absolute value of the groundwater discharge.

As the selected river reaches in the region have virtually no floodplains, the rivers' width is small, and gauging took place in the summer rainless periods and in winter periods without thaws, the values Q_{WC} and Q_I were neglected, as they were too small. Preliminary calculations showed that the proportion of these elements in the total cycle is 0.1-0.5% for the rivers falling into the Kapshagai Reservoir.

Reliability of the data on the water runoff in our environment determines the effectiveness of the channel water cycle calculation, since the consumption in the limiting cross-sections is usually much higher than the value of other elements. Therefore, the water consumption in the limiting cross-sections was found by the hydrometric method with a current meter and with account of the time of water travel.

The total local inflow was calculated by the formula:

$$Q_{LI} = Q_{LI}^1 + Q_{LI}^2 + ... + Q_{LI}^n = \sum_{i=1}^{n} Q_{LI}^i$$

where Q_{LI}^i are the measured water flows of individual tributaries.

The total diversion flow and discharge on the reach of the river was calculated by the formulas:

$$Q_{WW} = Q_{WW}^1 + Q_{WW}^2 + ... + Q_{WW}^n = \sum_{i=1}^{n} Q_{WW}^i$$

$$Q_{RC} = Q_{RC}^1 + Q_{RC}^2 + ... + Q_{RC}^n = \sum_{i=1}^{n} Q_{RC}^i$$

where the water flows Q_{WW} and Q_{RC} were measured simultaneously at water intakes and discharges using current meters.

The channel water cycle for the area of alluvial cones was calculated by the formula (3). For ease of analysis of the obtained materials and for comparing them with each other, it is advisable to use not the absolute values of the seepage losses, but the value of specific water loss per unit of the length of the river reach S_l ($m^3 / \sec \cdot km$) and the value of relative specific runoff losses – δ *% per* 1 *km:*

$$\delta\% = \frac{S_S \cdot 100\%}{Q_U \cdot l}$$

where, in addition to the previous designations, l is the length of the estimated reach of the river in km.

$$S_l = \frac{Q_D - Q_U + Q_{LI} + Q_{RC} - Q_{WW}}{l}$$

RESULTS

Area of alluvial cones and intensive flow dispersion

In 2013-2014, we made more than 80 measurements to determine the surface runoff seepage losses along the length of the Talgar Issyk, Turgen, and Shilik's river beds, and the linear diagrams of the respective model reaches are shown in Figure 2. In addition to these measurements, we analyzed and used measurements carried out by other organizations in the region[17, 18, 19]. During the hydrometric operations, all distances between the cross-sections were measured with measuring tapes. Locations of the cross-sections were selected with a view to ensuring the most favorable conditions for gauging.

On the Talgar River, 2 reaches were chosen. On the first reach, the upstream cross-section was combined with the Hydrometeorological Service gauging station (the Talgar River – the town of Talgar). The downstream cross-section is located at Talgarsky Waterworks. The gauging was performed from rigid bridges (Figure 2a). On the second reach (Figure 2b), the upstream cross-section is located down the river

Table 1. Calculation of the surface runoff losses on the model reaches (for 2013-2014)

Nos. of reaches	Q_U, m³/sec	Q_D, m³/sec	l km	S_S, m³/sec	S_S, %	$\delta\% = \frac{S_S \cdot 100\%}{Q_U \cdot l}$ % per 1 km
Alluvial cone of the Talgar River (the upper part)						
1.	2.11	1.03	2.2	1.08	51.2	23.3
1.	7.60	6.08	2.2	1.52	20.0	9.68
1.	12.1	9.30	2.2	2.8	23.1	10.5
1.	8.10	6.68	2.2	1.42	17.5	8.00
1.	14.1	10.7	2.2	3.40	24.1	11.0
1.	24.7	20.2	2.2	4.50	18.2	8.28
1.	24.0	19.6	2.2	4.40	18.3	8.33
1.	16.0	12.8	2.2	3.20	20.0	9.09
1.	4.00	2.60	2.2	1.40	35.0	15.9
1.	20.0	16.3	2.2	3.70	18.5	8.41
Average					24.6	11.25
Alluvial cone of the Talgar River (the lower part)						
2.	4.86	1.46	15	3.40	70.0	4.66
2.	5.36	1.67	15	3.68	68.8	4.58
2.	3.16	0.79	15	2.27	71.8	4.79
2.	3.38	1.10	15	2.28	67.4	4.49
2.	8.54	3.16	15	5.38	63.0	4.20
2.	5.11	1.36	15	3.75	73.4	4.90
2.	6.15	2.00	15	4.15	67.5	4.50
2.	2.28	0.36	15	1.92	84.2	5.61
2.	5.09	1.80	15	3.29	64.6	4.31
2.	10.5	4.08	15	6.42	61.1	4.08
2.	11.5	4.50	15	6.98	60.8	4.05
Average					67.1	4.47
Alluvial cone of the Issyk River						
3.	5.33	1.64	9.18	3.69	69.2	7.55
3.	1.39	0.11	9.18	1.28	92.1	10.0
3.	4.30	0.80	9.18	3.50	81.4	8.86
3.	2.50	0.42	9.18	2.08	68.4	9.06
3.	3.32	1.05	9.18	2.27	68.4	7.44
3.	5.34	1.62	9.18	3.72	69.7	7.59
3.	6.15	2.05	9.18	4.10	66.7	7.26
3.	7.70	2.54	9.18	5.16	67.0	7.30
Average					72.9	8.13
Alluvial cone of the Turgen River						
4.	13.1	11.5	2.5	1.50	11.4	4.58
4.	10.6	13.6	2.5	1.50	9.93	3.97
4.	10.4	9.30	2.5	1.10	10.6	4.23
4.	8.32	6.60	2.5	1.72	20.7	8.37
4.	4.35	3.00	2.5	1.35	31.0	12.4
4.	5.60	4.50	2.5	1.10	19.6	7.86
4.	3.62	1.40	2.5	2.22	61.3	24.5
4.	6.20	3.22	2.5	2.98	48.1	19.2
4.	8.61	6.60	2.5	2.01	23.3	9.34
4.	13.6	12.7	2.5	0.90	6.62	2.65
4.	16.0	14.7	2.5	1.30	8.12	3.25
Average					22.8	9.12

Alluvial cone of the Shilik River						
5.	56.0	53.0	21.2	3.0	5.36	0.25
5.	60.0	56.5	21.2	3.5	5.83	0.28
5.	61.19	58.0	21.2	3.9	6.30	0.30
5.	63.0	59.1	21.2	3.9	6.19	0.29
5.	65.0	61.0	21.2	4.0	6.15	0.29
5.	72.1	67.8	21.2	4.3	5.96	0.28
5.	75.0	70.0	21.2	5.0	6.67	0.31
5.	70.0	65.5	21.2	4.5	6.43	0.30
5.	83.0	77.0	21.2	6.0	7.23	0.34
5.	80.0	74.5	21.2	5.5	6.88	0.32
5.	86.7	81.0	21.2	5.7	6.57	0.31
5.	90.0	83.0	21.2	7.0	7.78	0.36
5.	92.0	85.5	21.2	6.5	7.06	0.33
5.	51.0	48.5	21.2	2.5	4.90	0.22
5.	50.0	47.5	21.2	2.5	5.00	0.24
5.	55.0	52.0	21.2	3.0	5.45	0.26
5.	45.0	42.5	21.2	2.5	5.55	0.26
5.	40.0	37.9	21.2	2.1	5.25	0.25
5.	35.0	33.2	21.2	1.8	5.14	0.24
5.	30.0	28.5	21.2	1.5	5.00	0.24
Average					6.04	0.28

Table 2. Calculation of the channel water cycle of rivers in the area of groundwater discharge (2013)

Numbers of reaches	Q_U, m3/sec	Q_D, m3/sec	l, km	$\frac{QLI}{l_D}$ m3/sec	$\frac{Q_{WW}}{l_D}$ m3/sec	Q_{AVW}	S_{GD}, l/sec.km	S_l in % per 1 km	$\delta\% = \frac{S_{GD} \cdot 100\%}{Q_{AVW} \cdot l}$
1. Reach of the Kashkan Talgar River									
6.5	0.200	0.231	2.15	-	-	0.22	0.03	14.42	6.69
20.5	0.341	0.385	2.15	-	-	0.36	0.04	20.47	5.64
5.6	0.401	0.449	2.15	-	-	0.43	0.05	22.33	5.25
22.6	0.177	0.247	2.15	-	-	0.21	0.07	32.56	15.36
5.7	0.103	0.287	2.15	-	-	0.20	0.18	85.58	43.89
21.7	1.490	1.972	2.15	-	-	1.73	0.48	224.19	12.95
6.8	0.116	0.222	2.15	-	-	0.17	0.11	49.30	29.17
	0.404	0.542	2.15			0.47	0.14	64.12	16.99
6.5	0.231	0.264	2.75			0.25	0.03	12.00	4.85
20.5	0.385	0.428	2.75	-	-	0.41	0.04	15.64	3.85
5.6	0.449	0.500	2.75	-	-	0.47	0.05	18.55	3.91
22.6	0.247	0.324	2.75			0.29	0.08	28.00	9.81
5.7	0.287	0.449	2.75			0.37	0.16	58.91	16.01
21.7	1.972	2.415	2.75	-	-	2.19	0.44	161.09	7.34
6.8	0.222	0.325	2.75	-	-	0.27	0.10	37.45	13.69
	0.542	0.672	2.75			0.61	0.13	47.38	8.49
6.5	0.264	0.284	4.50	-	-	0.27	0.02	4.44	1.62
20.5	0.428	0.448	4.50	-	-	0.44	0.02	4.44	1.01
5.6	0.500	0.540	4.50	-	-	0.52	0.04	8.89	1.71

22.6	0.324	0.384	4.50	-	-	0.35	0.06	13.33	3.77
5.7	0.449	0.539	4.50		-	0.49	0.09	20.00	4.05
21.7	2.415	2.625	4.50	-	-	2.52	0.21	46.67	1.85
6.8	0.325	0.405	4.50	-	-	0.37	0.08	17.78	4.87
	0.672	0.746	4.50			0.71	0.07	16.51	2.70
2. Reach of the Issyk-Karasu River									
15.5	0.245	0.274	1.52	-	-	0.260	0.029	19.08	7.35
15.6	0.110	0.201	1.52	-	-	0.156	0.091	59.87	38.50
16.7	0.940	0.987	1.52	-	-	0.964	0.047	30.92	3.21
15.8	3.739	3.747	1.52	-	-	3.743	0.008	5.26	0.14
12.9	1.190	1.217	1.52	-	-	1.204	0.027	17.76	1.48
	1.245	1.285	1.520			1.516	0.043	28.454	10.832
15.5	0.274	0.307	1.75	-	-	0.291	0.033	18.86	6.49
15.6	0.201	0.265	1.75	-	-	0.233	0.064	36.57	15.70
16.7	0.987	1.036	1.75	-	-	1.012	0.049	28.00	2.77
15.8	3.747	3.756	1.75	-	-	3.752	0.009	5.14	0.14
12.9	1.217	1.243	1.75	-	-	1.230	0.026	14.86	1.21
	1.285	1.321	1.750			1.303	0.036	20.686	5.260
15.7	0.005	0.004	4.7	-	-	0.005	-0.001	-0.21	-4.73
16.8	0.144	0.123	4.7	-	-	0.134	-0.021	-4.47	-3.35
	0.075	0.064	4.700			0.069	-0.011	-2.340	-4.038
15.7	0.004	0.001	5.8	-	-	0.003	-0.003	-0.52	-20.69
16.8	0.123	0.081	5.8	-	-	0.102	-0.042	-7.24	-7.10
	0.064	0.041	5.800			0.052	-0.023	-3.879	-13.895
4. Reach of the Kaskelen River									
15.5	4.940	5.437	4.5	-	0.15	5.114	0.347	77.11	1.51
15.6	5.110	5.761	4.5	-	0.16	5.356	0.491	109.11	2.04
15.7	5.190	5.818	4.5	-	0.2	5.404	0.428	95.11	1.76
15.8	6.739	7.357	4.5	-	0.31	6.893	0.308	68.44	0.99
15.9	5.245	6.034	4.5	-	0.35	5.465	0.439	97.56	1.79
	5.445	6.081	4.500			5.646	0.403	89.467	1.617
15.5	5.437	5.812	5	-	0.15	5.550	0.225	45.00	0.81
15.6	5.761	6.312	5	-	0.16	5.957	0.391	78.20	1.31
15.7	5.818	6.321	5	-	0.2	5.970	0.303	60.60	1.02
15.8	7.357	7.954	5	-	0.31	7.501	0.287	57.40	0.77
15.9	6.034	6.683	5	-	0.35	6.184	0.299	59.80	0.97
	6.081	6.616	5.000			6.232	0.301	60.200	0.974

beyond the Talgarsky Waterworks. The second and third cross-sections are located near the Kuljinskoye Highway.

At the Issyk River, we selected one reach (Fig.2c). The upstream cross-section was combined with the road bridge near the plant of the Issyk town, the downstream cross-section was at the bridge on the Kuljinskoye Highway.

On the Turgen River, we selected a reach of 2.5 km. The upstream cross-section was combined with a post of the Hydrometeorological Service (the Turgen River- the Tauturgen village) and the downstream cross-section was at the Turgen Waterworks (Fig.2d).

We also selected a 21-km reach on the Shilik River, the upstream cross-section of which was combined with a post of the Hydrometeorological Service (the Shilik River-the Malybay settlement) and the downstream cross-section was near the bridge on the Narynkol-

Table 3. Calculation of the channel water cycle of rivers in the area of groundwater discharge (2014)

Numbers of reaches	Q_U, m3/sec	Q_D, m3/sec	l, km	$\frac{QLI}{l_D}$ m3/sec	$\frac{Q_{WW}}{l_D}$ m3/sec	Q_{AVW}	S_{GD}, l/sec.km	S_l	$\delta\% = \frac{S_{GD}\cdot 100\%}{Q_{AVW}\cdot l}$ in % per 1 km
1. Reach of the Kashkan Talgar River									
7.5	0.211	0.239	2.15	-	-	0.23	0.03	13.02	5.79
19.5	0.345	0.385	2.15	-	-	0.37	0.04	18.60	5.10
4.6	0.425	0.459	2.15	-	-	0.44	0.03	15.81	3.58
23.6	0.177	0.247	2.15	-	-	0.21	0.07	32.56	15.36
4.7	0.159	0.324	2.15	-	-	0.24	0.17	76.74	31.78
22.7	2.124	2.642	2.15	-	-	2.38	0.52	240.93	10.11
	0.128	0.254	2.15	-	-	0.19	0.13	58.60	30.68
	0.510	0.650	2.15			0.58	0.14	65.18	14.63
7.5	0.239	0.281	2.75			0.26	0.04	15.27	5.87
19.5	0.385	0.430	2.75	-	-	0.41	0.05	16.36	4.02
4.6	0.459	0.506	2.75	-	-	0.48	0.05	17.09	3.54
23.6	0.247	0.366	2.75			0.31	0.12	43.27	14.12
4.7	0.324	0.532	2.75			0.43	0.21	75.64	17.67
22.7	2.642	3.102	2.75	-	-	2.87	0.46	167.27	5.82
5.8	0.254	0.374	2.75	-	-	0.31	0.12	43.64	13.90
	0.650	0.799	2.75			0.72	0.15	54.08	9.28
7.5	0.281	0.311	4.50	-	-	0.30	0.03	6.67	2.25
19.5	0.430	0.449	4.50	-	-	0.44	0.02	4.22	0.96
4.6	0.506	0.549	4.50	-	-	0.53	0.04	9.56	1.81
23.6	0.366	0.404	4.50	-	-	0.39	0.04	8.44	2.19
4.7	0.532	0.621	4.50		-	0.58	0.09	19.78	3.43
22.7	3.102	3.298	4.50	-	-	3.20	0.20	43.56	1.36
5.8	0.374	0.484	4.50	-	-	0.43	0.11	24.44	5.70
	0.799	0.874	4.50			0.84	0.08	16.67	2.53
2. Reach of the Issyk-Karasu River									
16.5	0.354	0.375	1.52	-	-	0.365	0.021	13.82	3.79
15.6	0.321	0.415	1.52	-	-	0.368	0.094	61.84	16.80
16.7	0.754	0.811	1.52	-	-	0.783	0.057	37.50	4.79
15.8	2.635	2.645	1.52	-	-	2.640	0.010	6.58	0.25
12.9	0.954	0.978	1.52	-	-	0.966	0.024	15.79	1.63
	1.004	1.045	1.520			1.024	0.041	27.105	5.454
15.5	0.375	0.411	1.75	-	-	0.393	0.036	20.57	5.23
15.6	0.415	0.482	1.75	-	-	0.449	0.067	38.29	8.54
14.7	0.811	0.852	1.75	-	-	0.832	0.041	23.43	2.82
15.8	2.645	2.655	1.75	-	-	2.650	0.010	5.71	0.22
13.9	0.978	1.008	1.75	-	-	0.993	0.030	17.14	1.73
	1.045	1.082	1.750			1.063	0.037	21.029	3.706
3. Reach of the Turgen River									
14.7	0.003	0.002	4.7	-	-	0.003	-0.001	-0.21	-8.51
15.8	0.098	0.076	4.7	-	-	0.087	-0.022	-4.68	-5.38
	0.051	0.039	4.700			0.045	-0.012	-2.447	-6.945
14.7	0.002	0.001	5.8	-	-	0.002	-0.001	-0.17	-11.49
15.8	0.076	0.032	5.8	-	-	0.054	-0.044	-7.59	-14.05
	0.039	0.017	5.800			0.028	-0.023	-3.879	-12.771
4. Reach of the Kaskelen River									
15.5	4.250	4.710	4.5	-	0.15	4.405	0.310	68.89	1.56
15.6	4.340	5.075	4.5	-	0.16	4.628	0.575	127.78	2.76
15.7	4.862	5.521	4.5	-	0.2	5.092	0.459	102.00	2.00
15.8	6.215	6.834	4.5	-	0.31	6.370	0.309	68.67	1.08
15.9	4.956	5.771	4.5	-	0.35	5.189	0.465	103.33	1.99
	4.925	5.582	4.500			5.136	0.424	94.133	1.880
15.5	4.710	5.075	5	-	0.15	4.818	0.215	43.00	0.89
15.6	5.075	5.642	5	-	0.16	5.279	0.407	81.40	1.54
15.7	5.521	6.012	5	-	0.2	5.667	0.291	58.20	1.03
15.8	6.834	7.424	5	-	0.31	6.974	0.280	56.00	0.80
15.9	5.771	6.418	5	-	0.35	5.920	0.297	59.40	1.00
	5.582	6.114	5.000			5.731	0.298	59.600	1.054

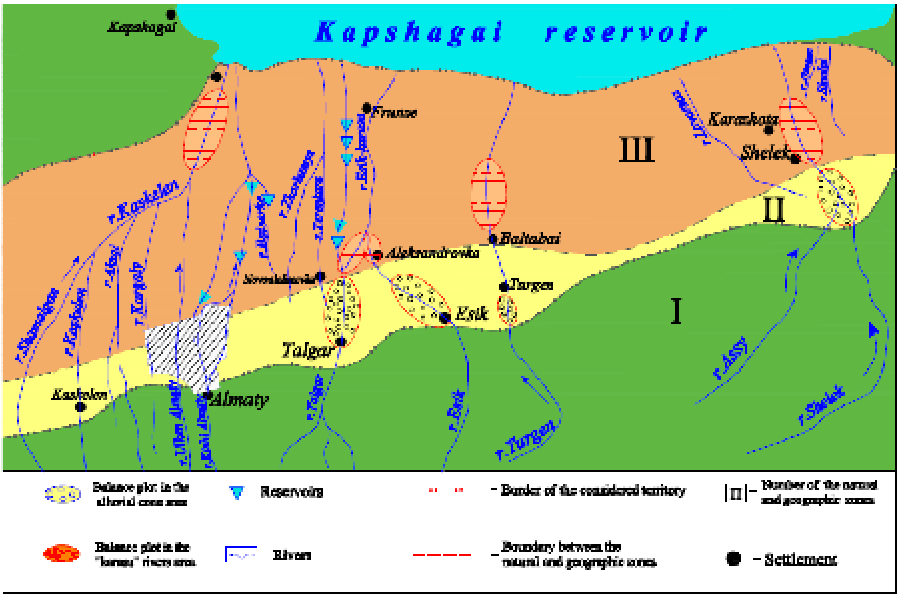


Fig. 1. The layout of the reaches of the piedmont plains of Trans-Ili Alatau

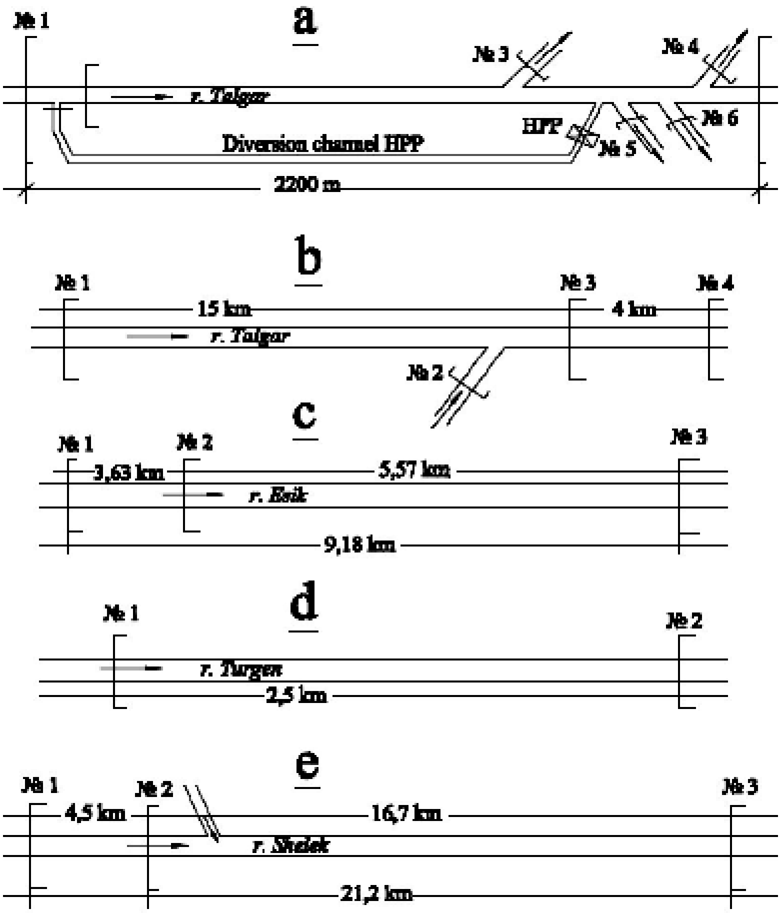


Fig. 2. Linear patterns of the river reaches for determining the seepage losses

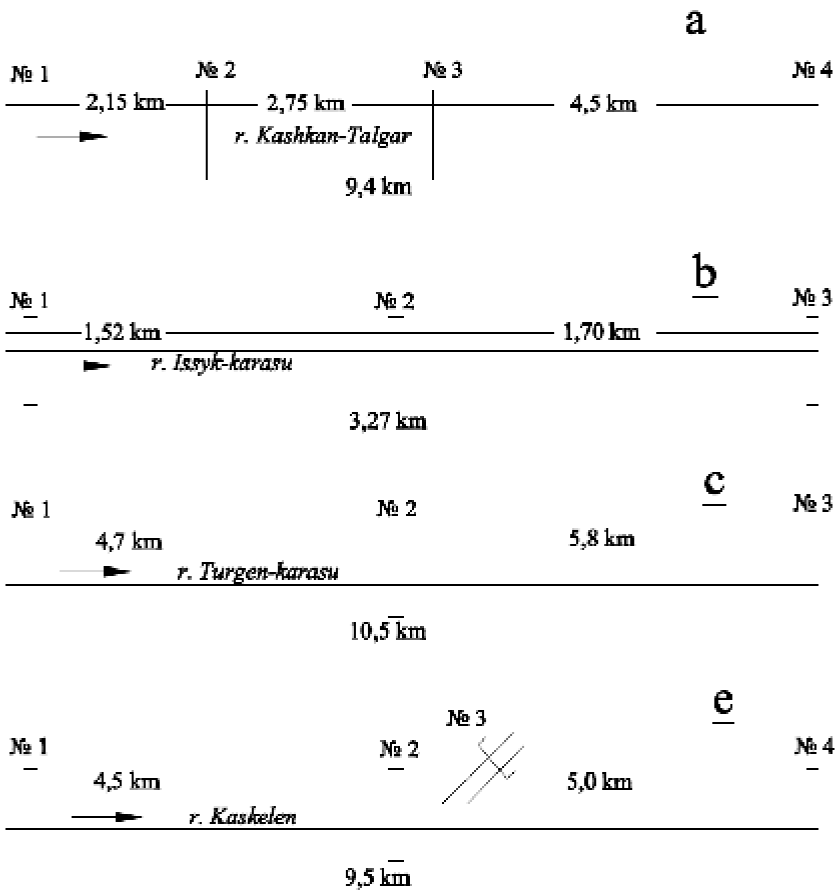
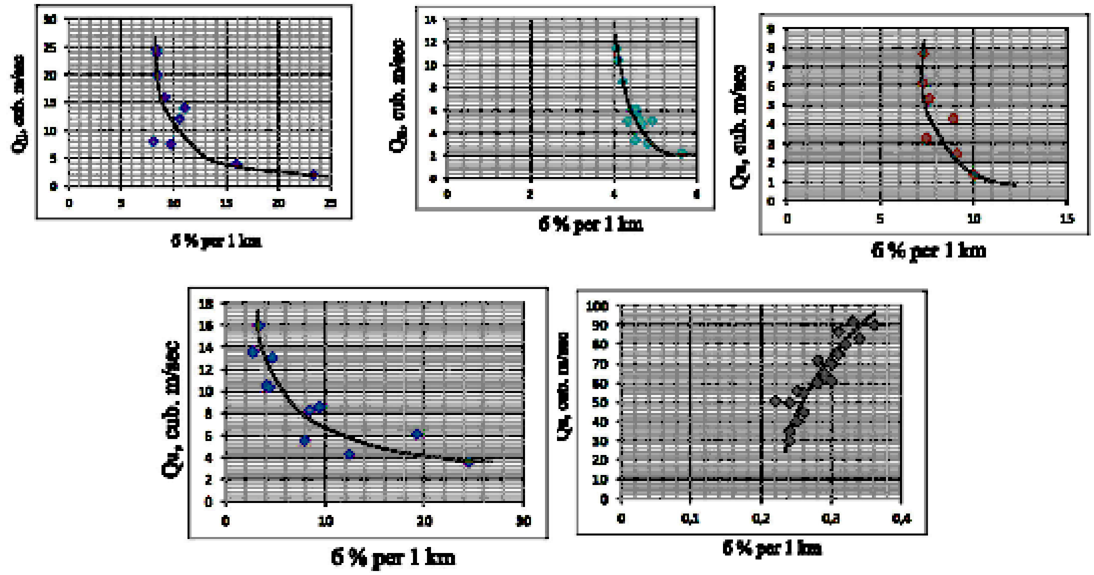


Fig. 3. Linear patterns of the reaches of rivers to determine the groundwater discharge



a - Talgar River (the upstream part); *b* - Talgar River (the downstream part); *c* - Issyk River; *d* - Turgen River; *e* - Shilik River.

Fig. 4. Dependency graphs δ% = *f* (Q_U)

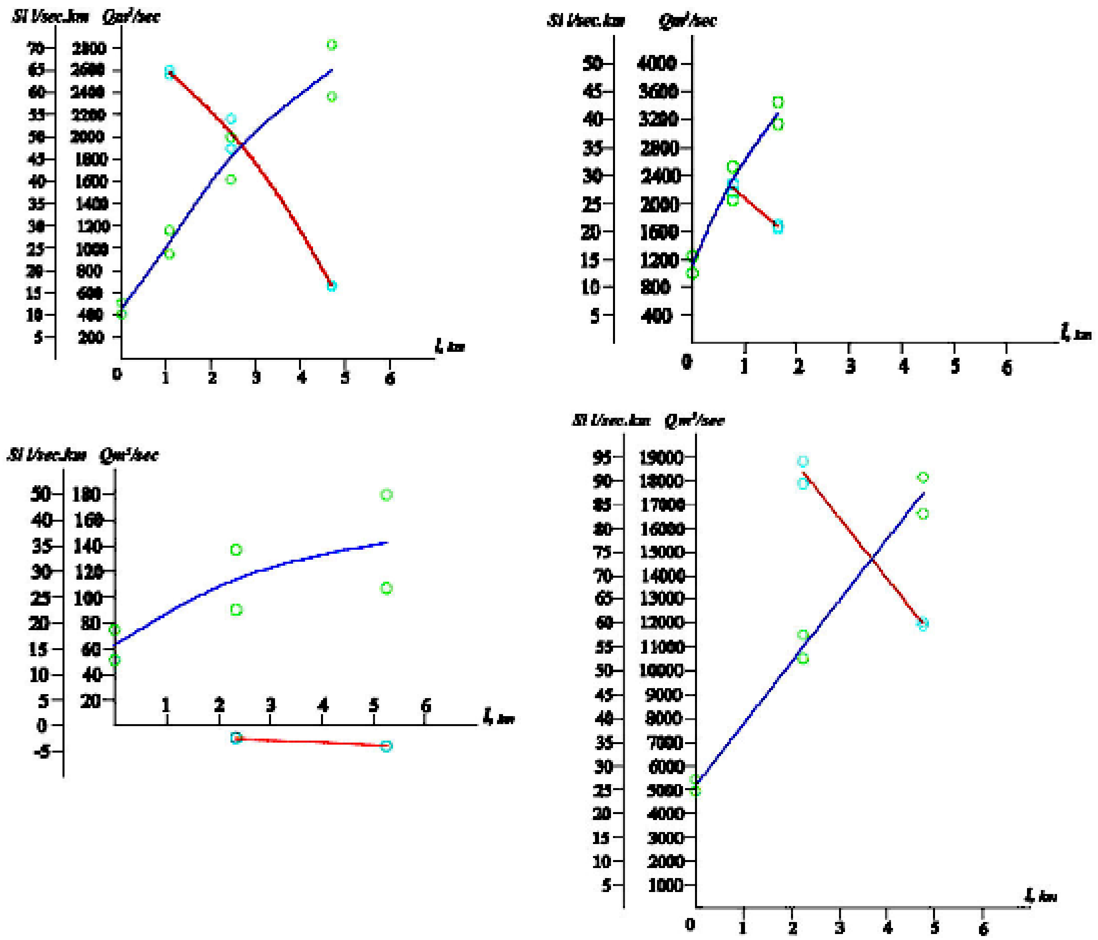


Fig. 5. The curves of the total and specific discharge along the rivers
a - Kashkan-Talgar River; *b* - Issyk-Karasu River; *c* - Turgen River; *d* - Kaskelen River.

Almaty Highway (Fig.2e).

All water discharge gauging was carried out with the current meters GR-99, GR-21M checked in the Hydrometeorological Service's Bureau of Verifications. Based on the obtained results, we compiled the channel water cycles of the model reaches of rivers. The calculation results are shown in Table 1.

When determining the runoff losses, we calculated their average unit values for each reach.

The area of groundwater discharge to the surface

The absolute values of groundwater discharge in the surveying seasons of 2013-2014 were determined using stream gauging, which were conducted on the above model reaches (Fig.1). Hydrographic and linear patterns of the balance reaches of the Kashkan Talgar, Issyk-Karasu, Turgen-Karasu, and Kaskelen rivers are shown in Figure 3.

Cross-section No.1 on the Kashkan Talgar River is located near the Oktyabrsky village down the artificial pond, from which water is pumped for irrigating. Cross-section No.2 is 2.15 km down the Cross-section No.1, near the bridge over the Kashkan Talgar River and Cross-section No.3 is 2.75 km down the Cross-section No.2 (the source of the Karatogan main channel). Cross-section No.4 is 4.5 km down the third cross-section, before the influx of the Kashkan Talgar River in the Issyk River (Fig. 1).

Cross-section No.1 on the Issyk-Karasu River is located 2.5 km down the influx of its right tributary – the Tashtykara River – opposite the Oktyabrsky melon field. Cross-section No.2 is located 1.52 km down the wash artificial dam. Cross-section No.3 is 1.75 km down the second cross-section, before the influx of the Kashkan Talgar River.

We provided balance gauging to determine the discharge of groundwater [20, 21, 22, 23] into the bed of the Kaskelen River on its lower reaches (Figure 3). Cross-section No.1 is located below the road bridge over the Kaskelen River on the Kapshagay-Almaty Highway. The second hydrometric cross-section is located 4.5 km down the first one near the railway bridge. Cross-section No.3 is combined with the cross-section with a cradle cableway at a distance of 5.0 km down the river from the second. The distances between the cross-sections were defined using rangefinders and topographic maps. Water discharge gauging was carried out with hydrometric current meters GR-99 and GR-2M from the bridge. The results of the balance calculations are provided in Tables 2 and 3.

DISCUSSION

Area of alluvial cones and intensive flow dispersion

Due to the fact that the losses vary depending on the flow rate in the upstream cross-section (Table 1), in order to evaluate them, we draw graphs of the correlation of specific relative water losses in the watercourse reach with the water flow in the upper control point (Figure 4a-e). The correlation has a hyperbolic shape, which is physically explainable, and can be used for approximate determination of the seepage losses along the length of each of the selected model reaches of the watercourse depending on the flow rate of water in the upstream cross-section. Based on these dependencies and knowing the size of the watercourse within the area of alluvial cones, we can determine the runoff losses value. The obtained data show, what model reach has the largest losses.

The area of groundwater discharge to the surface

The results of studies (Tables 2, 3, and Figure 5) showed that the greatest relative discharge is observed in the first few kilometers from the source of the Karasu rivers, and almost ceases by the end of the reach, except for the Kaskelen River basin. In the reaches of the Issyk-Karasu and Turgen Rivers, secondary seepage losses take place. In addition, the seasonal nature of the changes in the groundwater discharge is noted.

CONCLUSION

Area of alluvial cones and intensive flow dispersion

Figure 3 and Table 1 allow to conclude that the seepage loss of surface runoff has the following pattern:

1. runoff losses of the rivers in the western part of the region (Kaskelen, Talgar, Issyk) constitute 70-80% of the water flow in the upstream cross-section, i.e. at the exit of the rivers from the mountains;
2. runoff losses of the rivers in the eastern part of the region (Shilik, Turgen) are 9-15%, respectively.

Evaluation of the accuracy of flow measurement and calculation of channel water balance (Table 1) shows that the errors are within acceptable limits:

$$\Delta Q \geq 0{,}15 \cdot Q_B \text{ or } \delta_Q = \pm 0{,}5 - 10\%$$

i.e. at the assumed accuracy of the water flow measurement with a current meter.

The area of groundwater discharge to the surface

In the result of this calculation and analysis of the channel water cycle on the model reaches, we can draw the following conclusions:

1. Intensive groundwater discharge occurs within the first few kilometers from the Karasu source and then slows down.
2. The intensity of groundwater discharge from the wings to the middle of the piedmont plains sloping decreases, losing the runoff for seepage again in the basin of the Turgen River and on the right border of the basin of the Issyk-Karasu River adjacent to the left wing of the Turgen River basin.
3. Greatest intensity of groundwater discharge is shown by the Kaskelen River basin, where the intensity of discharge remains unchanged until confluence in the

Kapshagai Reservoir.

The above conclusions allow us to apply the observed regularities of the correlation of the surface and ground waters in the model reaches to the whole region under study.

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