Water balance analysis and water resources in the mountain area of Urumqui River Basin

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SYMPOSIUM 2 – ASPECTS QUANTITATIFS ET QUALITATIFS DU CYCLE DE L'EAU EN BASSINS INHOMOGÈNES

ASPECT QUANTITATIF DE LA VARIABILITÉ SPATIO-TEMPORELLE DES EAUX

WATER BALANCE ANALYSIS AND WATER RESOURCES IN THE MOUNTAIN AREA OF URUMQI RIVER BASIN

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ABSTRACT Urumqi River, which is situated in the inland arid region in Xinjiang, China, is an experimental basin to study runoff and water resources in northen slope of Tianshan Mountain, and it is also the main water supply source to Urumqi City, the Capital of Xinjiang Uygur Autonomous Region, therefore there is a very important social and economical value to study it. This paper tries to evaluate the total amount of water resources and its characteristics, to establish water balance equation and to analyze every parametric feature of water balance with the study on the precipitation, evaporation and runoff in the mountain area.

GENERAL SITUATION OF RIVER BASIN IN MOUNTAIN AREA

Urumqi River basin is in the Tianshan mountain at 86.75-87.93° E and 43.00-44.12° N, with direction from southwest to northeast then turning to north. The river length is 214.3 km and the total area is 4684 km², of which there is 1070 km² of the river basin in the mountain area. This paper mainly analyzes the characteristic of hydrology of the upper river from Yingxongqiao station which is situated at the mountain river mouth with a drainage area of 924 km² (Fig. 1).

The Urumqi river originates from the Tianger II Peak, central part of Eastern Tianshan Mountain, at the elevation of 4486 m. The elevation of Yingxongqiao Station is 1920 m and the average elevation in mountain area is 3005 m. In this area, the elevation of the average snowline is 3780 m, above it there are 124 glaciers, with an area of 38 km² which takes 4.1 % of the drainage area upstream of the Yingxongqiao Station.

FEATURE OF PRECIPITATION

Precipitation

According to the observed data from 1984 to 1987 in the basin, the average annual Precipitation of Urumqi River Basin in the Mt. area is 421.7 mm. Based on the study of Mr. Yang Daqin on the systematic error of observed precipitation in China, the correction has been made to the observed data of the precipitation by 30.9% increase for snowfall in high mountain area due to wind influence, by 13.5% increase for rainfall in middle mountain area due to wet lose of rain gauges and by 20.5% increase for rainfall in lower mountain area due to wind influence. The correction factor of observed Precipitation takes 1.15 for rainfall and 1.3 for snowfall.

The corrected value of average precipitation in Mt. area of Urumqi River is 526 mm, 25% more than the observed value.

The snow covered area in the basin and its seasonal translation

The snow covered area for each month is shown on Table 1.

The snow accumulated in Nov. and Dec. translates to snow melt runoff in next year, therefore the difference of the snowfall in these two months between this year and last year is the variation of basin snow cover ΔS.

EVAPORATION IN THE BASIN

In this basin there are observed records of evaporation only from water surface (by small size evaporation gauge, D = 20 cm).

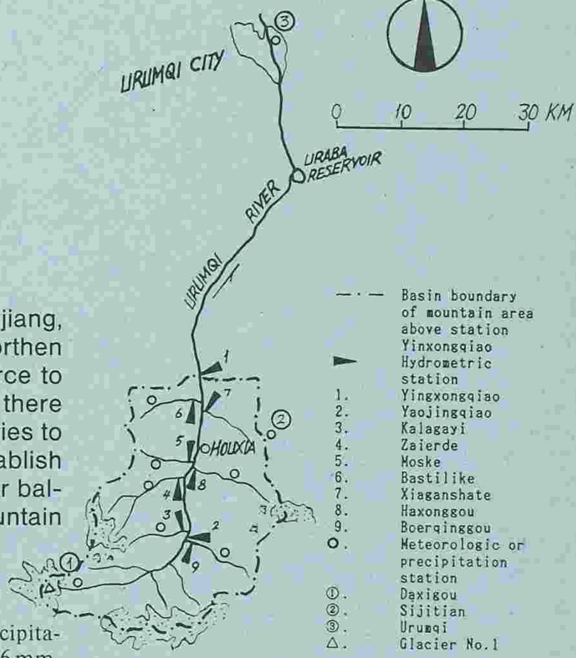


Fig. 1. – Map of mountain area of Urumqi River Basin.

The average annual evaporation is estimated at 521.8 mm after the correction to the observed data.

The calculating formula for land evaporation E advanced by Prof. Fu Baopu in Nanjing University of China is:

$$E = Eo\,(1 + P/Eo - (1 + (P/Eo)\,m)^{m-1}) \quad (1)$$

where P is preciPitation, Eo is evaporativity that can be replaced by evaporation from water surface. m is a feature parameter of underlying surface.

Table 1. – The snow covered area in each month.

	Jan	Feb	Mar	Apr	May	Jun
Snow covered area in the Mt. area (%)	100	100	100	72	45	20
Snow cover elevation (m a.s.l.)	>1650	>1650	>1650	>2400	>3100	>3600

	Jul	Aug	Sep	Oct	Nov	Dec
Snow covered area in the Mt. area (%)	11	11	35	87	100	100
Snow cover elevation (m a.s.l.)	>3800	>3800	>3300	>2300	>1650	>1650

Table 2. – Balance of glacial material in glaciers area of Urumqi Basin.

Year	P_G (mm)	R_G (mm)	E_G (mm)	ΔB (mm)
1984	500.6	434.9	148.7	-83.0
1985	369.1	842.4	138.7	-612.0
1986	506.9	952.0	169.9	-614.0
1987	541.0	535.7	203.3	-198.0
Average	479.4	691.3	164.9	-376.8

In the Daxigou station (3539 m a.s.l.) the land evaporation in 1986 is 288.3 mm calculated with this formula. The experimental station of Tianshan Mountain Glacier of the Chinese Academy of Sciences made the test of the land evaporation in high mountain area (3640 m a.s.l.) and estimated the land evaporation at 270.3 mm in this year, which is close to the result of this calculation. Therefore, the land evaporation calculated by this formula from 1984 to 1987 is 310.8, 274.6, 311.3 and 323.5 mm respectively and the average of the four years is 305.0 mm, which is close to the value of land evaporation 293.6 mm resulting from the basin water balance analysis.

RUNOFF CHARACTERISTICS

Glacier runoff in high mountain area
The glacier area in Urumqi river source is 38 km² and 4.1% of the basin area upstream of the Yingxongqiao Station. The experimental station of Tianshan glacier has observed the balance of glacial material at the Glacier No. 1 for many years.
The balance equation of glacial material is:

$$P_G = R_G + E_G + \Delta B \quad (2)$$

Where P_G and E_G are precipitation and evaporation on the glaciers area, R_G is glacier meltwater and ΔB is the difference the glacier fill and its consuming. See in Table 2.

Distribution of runoff in mountain area
Table 3 shows this distribution.
Among these branches, the runoff depth R are quite different from 69.7 to 375.7 mm and the runoff coefficients R/P are different too (0.15 to 0.61), that proves:

a) in the high mountain area precipitation is higher, then both runoff depth and runoff coefficient are larger. In the mid-mountain belt around Houxia. the precipitation and basin slope are less comparatively so both depth and coefficient of runoff are also smaller;
b) comparing right bank of river basin with the left, all of the runoff depths and coefficients in the left bank branches are larger than those in the right bank at the same height. e.g. the basin average elevations in Boerqing branch and Kalagayi branch are similar but the difference in runoff depth is 25.0%; both basin areas and average elevations in Haxonggou stream and Zaierde stream are very close, but the runoff depth of the former is 32.0% smaller than that of the later.

THE ANALYSIS FOR WATER BALANCE AND THE WATER RESOURCES IN MOUNTAIN AREA

Equation of water balance in mountain area
The equation of water balance in a year is the following:

$$P = R + E + Ug + \Delta V \quad (3)$$

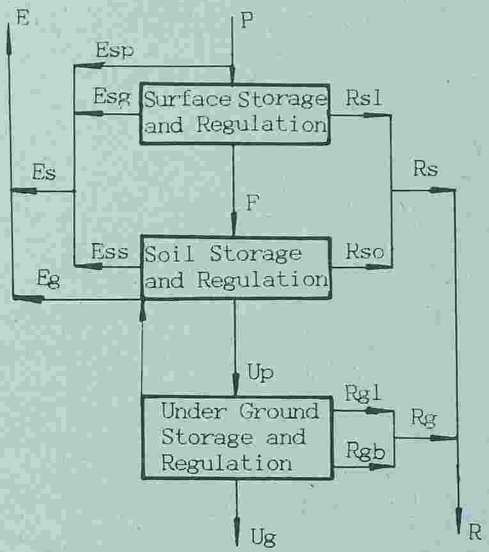
$$\Delta V = \Delta B + \Delta S + \Delta W \quad (4)$$

where ΔV is difference of basin water storages at the beginning and the end of year;

Table 3. – Water balance in the seven branches of Urumqi River and the main Stream upstream of the Yaojingqiao station.

Bank	No. and name of streams	A (km²)	P (mm)	E (mm)	R (mm)	ΔB (mm)	R/P
Left bank	2. Main streams above Yaojingqiao	237.0	555.1	274.6	318.4	-37.9	0.57
	3. Kalagayi	21.0	630.9	311.8	320.7	-1.6	0.51
	4. Zaierde	131.4	619.0	266.2	375.7	-22.9	0.61
	5. Moske	19.7	601.1	362.9	238.2	0.0	0.40
	6. Bastetilik	67.1	454.2	384.5	69.7	0.0	0.15
Right bank	7. Xiagansate	41.5	492.0	336.7	156.2	-0.9	0.32
	8. Haxonggou	112.9	556.8	307.1	255.9	-6.2	0.46
	9. Boerqing	72.8	531.0	311.0	239.0	-19.0	0.45

Note: The stream number and situation of branches is seen in Fig. 1.



P Precipitation
F Total infiltration
Up Seep into underground water
Ug Deep percolation
R Total runoff
Rs Surface runoff
Rsl Slope runoff
Rso Subsurface flow
Rg Groundwater runoff
Rgl Shallow groundwater
Rgb Base flow
E Total evapotranspiration
Es Land surface and soil evaporation
Esp Evaporation of plant interception
Esg Land evapotranspiration
Ess Soil evaporation
Eg Groundwater evaporation

Fig. 2. – The diagram of water balance.

ΔB is annual material balance of glacier; ΔS is difference between snow accumulations in the Nov. and Dec. in this year and last year; ΔW is difference of ground water storages at the beginning and the end of year. For the annual average value of water resources $\Delta V = 0$. then:

$$P = R + E + Ug \quad (5)$$

Water balance in the mountain area
Making the basin area upstream of the Yingxongqiao Station as an object of analysis, tabulates the observed data as Table 4: In this table, Ug, including submerge flow under river bed, is measured and calculated from lateral percolation in the foot-hill of the mountain area; ΔW is obtained by comparing the flow recession curve of hydrograph in this year with that in last year; E is calculated via Formula (5) with no observed data available.

Parameter analysis for water balance elements
Water balance formula (3) can be turned to:

$$P = Rsl + Rso + Rgl + Rgb + Ug + E + \Delta V \quad (6)$$

The total infiltration F is:

$$F = Rso + Rgl + Rgb + Ug + Eg + Ess \quad (7)$$

Where the Rsl, Rso, Rgl, Rgb are calculated by Mr Zhang Jienggang, Director of Runoff Experiment Station in Urumqi River. and the F are shown on Table 5.
Let coefficient of water yield in the basin $\alpha_1 = (R + Ug)/P$, that means this parameter expresses the total amount of surface water and ground water resources produced in the basin; coefficient $\alpha_2 = Rs/P$ is for surface runoff; coefficient $\alpha_3 = F/P$ is for soil

Table 4. – Water balance elements in mountain area of Urumqi River Basin (mm).

Year	P	R	Ug	E	ΔV	ΔB	ΔS	ΔW
1984	571.9	261.2	11.0	296.0	3.7	-3.4	7.3	-0.2
1985	426.2	219.2	9.3	235.8	-38.1	-25.1	-9.3	-3.7
1986	528.2	199.7	8.4	338.5	-18.4	-25.2	5.8	1.0
1987	577.8	265.9	11.2	304.2	-3.5	-8.1	0.9	3.7
Average	526.0	236.5	10.0	293.6	-14.1	-15.5	1.2	0.2

Table 5. – Water balance elements.

Year	R	Rsl	Rso	Rgl	Rgb	F
1984	261.2	156.4	22.2	42.2	40.4	332.8
1985	219.3	130.8	27.4	24.0	37.1	219.6
1986	199.7	111.8	25.7	38.0	24.2	345.2
1987	266.5	160.7	23.8	42.9	39.1	340.2
Average	236.7	139.9	24.8	36.8	35.2	322.0
%	100%	59.1%	10.5%	15.5%	14.9%	

Table 6. – The coefficients of water balance elements.

Year	α_1	α_2	α_3	α_4	α_5	α_6	α_7
1984	0.46	0.31	0.58	0.29	0.65	0.01	0.46
1985	0.54	0.37	0.63	0.26	0.64	-0.14	0.39
1986	0.39	0.26	0.65	0.20	0.72	-0.05	0.45
1987	0.48	0.32	0.59	0.27	0.66	-0.01	0.44
Average	0.47	0.31	0.61	0.25	0.67	-0.04	0.44

infiltration; coefficient $\alpha_4 = (Rg + Ug)/F$ is for ground water recharge; coefficient $\alpha_5 = (Ess + Eg)/F$ is for soil evaporation; coefficient $\alpha_6 = \Delta V/F$ is for the storage and regulation in the basin; coefficient $\alpha_7 = Rg/Rs$ is runoff stability factor, all of these coefficients is shown in Table 6.

The above coefficients indicate that:

a) α_1: 47% precipitation in mountain area can be turned into the utilizable water in down stream, so the basin water yield is quite high;

b) α_3: the total infiltration water makes up 61% which means the basin surface has quite strong absorbing power;

c) α_5: the surface evaporation takes 67% of total infiltration, which indicates most of infiltration water is lost by evaporation.

d) α_6: the coefficient of basin storage and regulation is very small only taking 4%, that shows the precipitation mainly forms runoff and is consumed to evaporation.

The total amount of water resources in mountain area

The total amount of water resources in mountain area W:

$$W = P - Es = R + Ug + Eg \qquad (8)$$

Owing to lack of observed information of Eg, let Eg = 0 temporarily and then:

$$W = R + Ug \qquad (9)$$

R, the average value of the annual runoff at Yingxongqiao Station from 1958-1987 in long observed series is 254 mm, Ug is taken to be 10 mm. Then total amount of water resources in mountain area of Urumqi River Basin W is 264 mm.

CONCLUSION

a) Located in the arid area in the centre of the Eurasia, the Urumqi river basin is characterised by a high average elevation (3005 m a.s.l.) of the basin with the basin slop facing to the west current in middle latitude. This results in a high annual precipitation (526 mm) and relatively abundant water resources (264 mm) in the basin.

b) Based on the observation of the glacial material balance in recent several years, the glacial material is in the state of deficiency (with ΔB taking minus value). In addition, the distribution of surface runoff is uneven in the whole basin. These should be taken into account in the plan of water resources development in the basin.

c) According to the analysis of the coefficients: α_1 α_3 α_5 α_6, the river basin can be featured with high water yield, strong soil absorbing and evaporative capacity and low water storage within a year. These characteristics can be considered as the representative for the study on the rivers in the north slop of the East Tianshan Mountain range.

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