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Stream types and flood features on the north slope of the West Kunlun Mountains

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Abstract

Any change in water conditions of a stream depends largely on the source and its changes. When we plan to develop and use the water resources of a certain area, a thorough investigation of the source, water distribution and disastrous floods of the streams within a specific watershed in the past is urgently required. As long as the behavior and characteristics of the stream are understood, the stream runoff may be utilized. The streams on the north slope of the West Kunlun Mountains are vitally important to Hotan's economic development. Although the Hotan district is located in an arid warm temperate continental climate zone, streams originating from the West Kunlun Mountains irrigate vast stretches of farmland along their course and make life there easy and comfortable. Studies of stream behavior in the Hotan area are significant to farm–planning and water resource management.

1. Zonation of studied area

The Hotan area, from east of the Yarkant River divide to west of the Andi River the north slope of the West Kunlun Mountains, can be divided into several zones as follows:

1. The severely arid Pishan River watershed, including some rivers within Pishan County such as the Pishan River, Sangzhu River, Karsu River, Suleazi River, Besiqan River and Duwa River, which constitute 8.5% of the total surface water resources of the area, the total discharge being 0.75×10^9 m^3.

2. The severe lag flood zone of the Hotan River watershed including three counties (Hotan, Meyu and Luopu) and three rivers (Yurunkax River, Karakax River and Aqike River), having a surface discharge of 4.65×10^9 m^3 and taking 52.5% of the total discharge of the area.

3. A severely arid blown sand zone containing twenty–three streams in Cele County, Yutian County and Minfeng County. This area contains the Cele River, Qiaka River, Urukeshayi River, Nuer River, Shayiwake River and others. Surface water resources are 2.21×10^9 m^3, being 25% of the total discharge.

4. Inland zone of the Qiangtang Plateau in the western section of the north slope of the Kunlun Mountaina, mainly including the land within Hotan County. Surface water resources are 0.37×10^9 m^3 which takes 4.2% of the total discharge.

5. Inland zone of Qiangtang Plateau in the middle section of the north slope of the Kunlun Mountains, including some areas of Hotan County and Minfeng County, and the east and west sides of Keriya River. Surface water resources are 0.573×10^9 m^3, 6.5% of the total discharge.

Table 1 shows the hydrological characteristics of main streams in this area.

2. Stream types

2.1 Principle of classifying streams

Most of the hydrological stations are located in stream outlets so that the stations can measure the whole runoff of the streams. Where no hydrological station is available, the investigation data at the outlets are used. Recharge resources will be used as the main index of classification, and four types of

Table 1. Characteristics of main streams on the north slope of the West Kunlun Mountains.

Items \ Hydro-station	Unit	Pishan River	Song-zhu River	Duwa River	Kara-kax River	Yurun-kax River	Cele River	Nuer River	Keriya River	Niya River
Measuring time	year	28	27	8	30	30	28	24	30	8
Watershed area	km^2	2227	935	685	19983	14575	2032	420	7358	675
Mean discharge	m^3/s	10.1	8.36	1.47	69.7	72.3	393	5.46	22.6	6.23
Coefficient of variation	Cv	0.14	0.14	0.31	0.20	0.23	0.17	0.19	0.17	0.17
Annual runoff	billion m^3	3.449	2.625	0.465	22	22.8	1.24	1.708	7.115	1.99
Max. mean runoff	billion m^3	147	134	45.0	713	840	73.8	122	346	135
Max. annual runoff	billion m^3	235	192	146	1150	1460	147	230	780	181
Min. annual runoff	billion m^3	0.20	0.20	0.010	3.37	2.32	0	0.01	2.25	0
Measuring time for sand content	year	62–66	66–69	60–82	64–83	72–28	59–82	78–81	63–68	60–67
Mean sand content	kg/m^3	1.22			2.12	5.69	17.0	3.26	4.52	
Max. sand content	kg/m^3				401	202			128	
Occurring time	Yr. mo. day				78.6.1	78.7.10			68.8	
Sand transported annually	10000 ton				476.4	1190			326	
Percentage over a year from June–Aug.	%				82.8	95.5			91.3	
Erosive module	t/km^2				239	819			446	

streams are defined (Table 2): streams fed by ice and snow melt; streams fed by rainfall; streams fed by composite sources and streams fed by springs.

a. Streams fed by ice and snow melt

Most of the streams in this area belong to this type which originate from the higher Kunlun Mountains where glaciers and seasonal snow exist. The area covered by glaciers is 10–20% of the whole runoff–producing area. Because the amount of discharge depends on that of snow, and ice melt, a flood crest generally occurs in July and August. Snow and ice melt runoff is 60–70% of the total runoff; rainfall runoff in the summer is only 20–25% of the annual runoff. Consequently, the runoff in arid and high temperature years is greater than that in rainy years. Annual runoff is largely (60–75%) concentrated in the summer. The fluctuation of flood crest generally does not exceed twenty times the mean discharge over several years. The coefficient of variation C_v, which shows the year to year variability in annual runoff, ranges from 0.10 to 0.30. Stream belonging to this type are the Yurunkax River, Karakax River, Keriya River, Pishan River and Sangzhu River.

b. Streams fed by rainfall

This type of stream is characterized by small glacier–covered area at the stream source and little snow melt recharge in spring and fall. Summer precipitation supplies more than 75% of the stream flow. As there is no glacier to adjust the stream flow, streams disappear at some localities in arid years and in winter. Floods are concentrated in rainy summers and can have disastrous effects on farming and human life. We found in the flood investigation that the climate of Hotan area in the summer of 1987 was abnormal, air temperature was lower than that of previous years and intensity of precipitation was greater; as a result, disastrous floods occurred in small and medium streams recharged mainly by rainfall. Precipitation in July at Cele hydrological station, Urukeshayi Community, Yuqing Village and Qiaka Community set new records. Monthly rainfall at Badahan rainfall–gauging station was over 125 mm (Table 3), the maximum diurnal rainfall being 36.7 mm, which is greater than the mean annual rainfall over many years of Cele County. This heavy rain set new discharge records in Urukeshayi River, Qiaka River and Cele River; in particular the discharge of Urukeshayi River and Qiaka River reached twice the peak value in the past, damaging property and inundating a large area of farmland. This kind of water flood continues only a short time and its diurnal variation corresponds to that of the precipitation. Once the rainy season has passed, stream discharge decreases abruptly. Streams belonging to this type are the Suleazi River, Karsu River, Aqike River, Shakewake River, Yimamu River and Buzang River.

c. Streams fed by combined sources

Glaciers exist in this area, but the glacier melt water is limited. Snowfall is considerable in winter

Table 2. Types of rivers and hydrological features.

Type of river	Some main rivers	Ice-snow recharge (%)	Spring runoff (%)	Summer runoff (%)	Fall runoff (%)	Winter runoff (%)	Cv
Those fed by ice and snow melt	Yurunkax River Karakax River Keriya Pishan Sangzhu River	>30	10.6	66.7−80	10.6−14.6	2.5−7.0	0.14−0.23
Composite type	Duwa River Niya River Nuer River Jijigan River Andi River Yeyike River	>30	13−24	48−79	7.4−19	0.04−9.6	0.14−0.31
Those fed by precipitation	Urushayi River Qaha River Aqike River Shayiwake River	<20	13.4−23.4	54−72	11.2−12	2.4−11.0	0.31−0.62
Those fed by springs							

Table 3. Precipitation in some areas of Cele Country.

Name of hydrostation	Long. °E	Lat. °N	Mean precipitation (mm)	Alititude (m)	Precipitation of 1987 (mm)	Max. annual precipitation (mm)	1987			
							May	June	July	Aug.
Cele	80° 46′	36° 52′	35.1	1515	135.8	87.9	31.5	17.6	37.8	0.7
Badehanyi	80° 50′	36° 18′	148.8	2300	295.4	228.3	40.2	49.1	125.9	12.7
Nuer	80° 59′	36° 19′	151.3	2300	391.0	298.6	102.9	60.5	90.7	11.5

and fall, while rainfall in summer functions as an important recharge source. These streams possess small water−accumulating areas, and runoff−producing duration and intensity vary with the weather. Sometimes, rainfall flood and snow−melt flood occur one after another, but rainfall recharge often makes up over 60% of the total river discharge. The annual variation of discharge of this type of stream is great; discharge fluctuates greatly and the variation is complicated. Streams belonging to this type are the Duwa River, Nuer River, Niya River, Jijigan River, Andi River and Yeyike River. These streams have large discharge in summer and are partially recharged from glaciers and snow melt in winter and fall. The streams can hold water from year to year, but sometimes dry up.

d. Streams fed by springs

On account of special crustal structure, discharge of this kind of stream is stable year−round except in summer when rainfall and ice−snow melt create an obvious flood crest (peak), indicating constant recharge from ground water. Ice and snow meltwater in spring may be as much as 20−40% of the total discharge, and ground water may be over 40%. On the north slope of the West Kunlun Mountains exist some little streams which flow year−round and have stable runoff.

3. Analysis of Floods

Here some representative stream water floods are chosen to illustrate the formation and development of floods.

3.1 Lag flood of Hotan River watershed

This watershed contains two large tributaries. The Hotan watershed includes the Hotan River (including the Yurunkax River) and its tributary the Karakax River, which originates among lofty mountain peaks with snow year−round, flowing through oasis and farmland into desert. Most of the watershed reflects a desert landscape. The watershed is bounded by the Keriya River watershed on the east, by Karakunlun Mountains, Kunlun Mountains, Kashmir and Tibet on the south, and by the Yarkant River on the west. The Yarkant River is the largest river on the north－facing slope of the West Kunlun Mountains. The Yurunkax River meets the Karakax River, the biggest tributary in this area, at Kueshilashi in the northern Hotan area, and runs continuously from south to north through the Taklimakan Desert (the second largest desert in the world) and finally to the Tarim River. Its total length is 823 km and the altitude at the stream month is only 1010 m a.s.l. The water－accumulating area at the upper reach, at Tongguzilueke Hydrological Station, which is a river runoff controlling station, is 145,750 km^2. The whole watershed is divided into three parts —— mountainous part, hilly part and flat desert part. The mountainous part from stream source to Tongguzilueke is 98 km long, the mean inclination being 19.2%. Rocky river beds and river flood plain occur alternately. Many tributaries converge here, and river valleys are usually V－shaped. Downward cuttingly streams is also intense and makes rough topography. Hence, this is a water accumulating area of the river. The Karakax River is similar to the Yurunkax River, but its upper reach, i. e. the mountainous part, is overlain by glaciers. According to data provided by Lanzhou Institute of Glaciology and Geocryology the area of glaciers at the source of the Hotan River in the Kunlun Mountain area is 11,447 km^2. Runoff in the Hotan River watershed is controlled by relief, topography and climatic factors. As the Pamirs and Tian Shan form two natural protective screens on the west and north, respectively, cold air and water masses from middle Asia and Siberia are blocked. At the same time the Qinghai－Xizang Plateau and Kunlun Mountains on the south impede the southwest monsoon from the Indian Ocean; consequently, the Tarim Basin has low precipitation. Such climatic conditions, and geographical location make Hotan a warm temperate arid area within a continental climate zone. Although this watershed has some rainfall (Table 4), it is not enough for runoff to form because evaporation is much greater than precipitation. Hence, only the rainfall in the glacier area can generate runoff (overland flow), indicating that alpine snow and glacier melt are the most important recharge sources of this watershed. For example, in the Yurunkax River area, precipitation which contributes to runoff is 0.162×10^9 m^3, only 7% of the total river discharge. The discharge in winter is considered to be the base flow. It is found by means of hydrograph that the recharge from groundwater, which is 0.58×10^9 m^3, 25% of the total discharge, is greater than that from rainfall. Other discharge comes from glacier and snow melt, which is approximately 1.548×10^9 m^3, 60% of the total runoff. As a result, the flooding time and amount of floodwater correspond to glacier and snow melt, or to air temperature, heat balance and solar radiation. This kind of river is characterized by a lagging discharge peak and highly concentrated discharge in summer. If there exists continuous high air temperature, snow and ice melting is likely to create disastrous floods. Like the Yurunkax River, the Karakax River is characterized by a large amount of flood water, lag flood crest (peak) and obvious diurnal variation. The annual variation of the Yurunkax River is greater than that of the Karakax River. Table 1 shows that C_v (coefficient of runoff variation) of the Yurunkax River is 0. 23, while that of the Karakax River is 0.20, which indicates that the flood of the Yurunkax River is more severe than that of the Karakax River. The flood discharge of the two rivers varies greatly and has a similar annual variation. Floods of the two occur during high air temperature periods from July to August. According to stream gauging over a period of several years, the maximum flood discharge (flood peak) is from middle July to middle August.

Table 4. Precipitation on the north slope of Kunlun Mountains.

Locality	Altitude (m)	Mean value (mm)
Tawakule	1250	14.1
Hotian	1375	34.8
Tongguzilueke	1650	58.9
Aomixia	2700	245.0
Buya	2730	200.0
Karagutage	2750	195.2
Uruwati	1850	79.7

3.2 Keriya River

The mean river runoff is approximately 0.7115×10^9 m^3; $C_v = 0.17$. The river originates in high mountains over 5000 m a.s.l., fed by the melting of glaciers and snow on Wusitengtaqe and Lushitage Mountains. Glaciers in the Guliya area are more than 3000 km^2; runoff from them is over 60% of the total. Rivers discharge is a maximum in summer, when 66.7% of

Table 5. Distribution of mean annual runoff of some rivers.

Name of river	Spring runoff ($\times 10000m^3$)	Percentage over a year (%)	Summer runoff ($\times 10000m^3$)	Percentage over a year (%)	Fall runoff ($\times 10000m^3$)	Percentage over a year (%)	Winter runoff ($\times 10000m^3$)	Percentage over a year (%)	Mean annual runoff ($\times$million m^3)
Yurunkax	13135.7	5.7	185759.7	80.8	25143.4	10.9	5759.5	2.5	2298
Karakax	24394	10.9	161187.8	72.4	29338	13.0	7641.9	3.4	2226
Keriya	8356.5	11.7	47455.2	66.7	10387.8	14.6	4960.4	7.0	712
Pishan	4442.9	13.1	24267.2	71.4	4318.4	12.7	939.6	2.8	340
Sangzhu	3057.2	11.8	19391.6	74.8	2736.5	12.6	741.0	2.9	250
Note	Mar.—May		June—Aug.		Sept.—Nov.		Dec.—Feb.		

the annual discharge occurs (Table 5). The river, 530 km long, also has considerable annual variation. The flood peak (crest) generally occurs in September. Besides these features which the Hotan River shares, this river is featured by abrupt,short—lasting floods. It is believed that kind of abrupt flood is induced by the bursting of an ice dam. For instance, the flood crest discharge, on September 11, 1963 was 780 m^3/s, lasting more than ten hours, and on April 1, 1967 it was 135 m^3/s. The ice dam bursting may occur during the winter freezing period. This kind of flood threatens human life and property, and may inundate a large area of farmland and forest.

3.3 Intermittent streams fed by precipitation

These are small streams, but they cause severe flood disasters. The Qiaha River and Urusayi River within Cele County, for example, are located between the Yurunkax River and the Keriya River. They originate from the piedmont and form their own independent stream system, which has a small watershed area. The river beds are composed of gravel and sand, are broad and flat, and have a considerable amount of water seepage along their course. River discharge is fully controlled by the variation, duration and intensity of precipitation. The period from May to August, 1987, was raining, the precipitation reaching its maximum in late July (Table 3). Why can this arid area have such large rainfall? Because the orientation of the Kunlun Mountains makes a turn here, which makes it possible for the cold air mass to meet the warm air mass. This rainfall induced record floods on the two rivers on July 30; the disastrous floods inundated a large amount of crops and farmland as well as livestock and damaged many flood control works. This kind of flood also exists in other small streams. According to our investigation, in 1987, streams fed by ice and snow—melt were at their usual water level, but streams fed by rainfall had the highest water levels in history. Emphasis should be laid on the importance of floods of small streams originating from the piedmont.

As stated above, the various types of stream on the north slope of the West Kunlun Mountains are peculiar. Disastrous floods may occur in these streams. In order to solve the contradiction between water deficit and floods and to take effective measures to protect floods, we need to know the characteristics of recharge, runoff and discharge of rivers.