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Proceedings of the CEReS International Symposium on Hydro-Environment in Asia

Edited by

Shizuo Shindo, Takashi Ishiyama and Changyuan Tang

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Preface

Based on scientific hydrological sciences and the advent of modern technology, this century has seen great progress in water resources research, which has undoubtedly contributed to the development of our society. Towards the 21st century, however, we are facing complex and difficult hydrological problems from the global to local scale and ultra-long to short time frames.

In order to provide scientists, engineers and concerned practitioners with an invaluable occasion to discuss environmental issues related to hydrology and water resources, especially in Asia, the CEReS International Symposium on Hydro-Environment in Asia will be held at the Chiba University, Japan, during 5-7 November 1997.

The proceedings includes 4 keynote presentations highlighting the main issues related to the frontiers of hydrology and water resource researches. Further 44 papers are published in the proceedings to deal with the following key topics:

1. Climate Change and Hydrology
2. Evaporation
3. Water Resources and Ecological Environment
4. GIS and Modeling
5. Water Resources and Water Quality
6. Lake, River Environment

I wish to congratulate all the members of editorial team for their efforts. I would like to thank the authors, who made our task easier by doing their best to follow the publishing instructions. It is very much my hope that the conference delegates and the readers in general, find the proceedings useful in addressing the problems posed in hydrology, water resources and environment.

Finally, I must sincerely acknowledge all persons who have participated in planning and supporting the symposium, without whose contributions both the event and this proceedings would not have been possible.

Koscak Maruyama

Koscak Maruyama, Ph. D.

President of Chiba University

25 October 1997

International Symposium on Hydro-Environment in Asia

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Keynote Papers

Global Warming Impact on Transferable Water from Yangtze River Basin to the North China Plain

Liu Changming

United Research Center for Water Problems, CAS, Beijing 100101, China; Shijiazhuang Institute of Agricultural Modernization, CAS, Shijiazhuang 050021, China

Abstract

Water will be transferred from Hanjiang river of the Yangtze River Basin to the North China Plain (NCP) for water supply. There are two planned large-scale long distance water transfer projects: the East Route, which could carry water from lower main course of the Yangtze (Changjiang) River to NCP, and the Middle route, which would divert water from the Hanjiang River, a major tributary of the Middle Yangtze to NCP, which is likely to be implemented in early 21st century. Both projected main canals are more than 1200km, passing through seven provinces and cities, and the annual total transferable water quantity would be more than 50 billion cubic meters. For the Middle Route, the calculated quantity of transferable water was based on hydrological records from the Hanjiang River. However it may not be assure under double carbon dioxide. It is well known that the Middle Route may be limited by transferable water from upper Hanjiang River. It is estimated that the regions along the main canal would become warm and dry and variability of water resources may increase. These would affect the syntonization/ asyntonization of water resources variations between the Yangtze River and the rivers with in NCP, and consequently would influence on the transferable water quantity and availability for water supply. The author addressed: first, to further study and to better understand such impact on available water, second, to quantitatively determine the magnitude of such impact, third, to adapt a model to evaluate such impact.

I. Introduction

The distribution of water resources in China is very uneven: water is more in south and less in north. The runoff in the Yangtze River basin plus the south regions of it makes up more than 80% of China's total with less than 40% arable land, while the runoff in the northern Huanghe, Huaihe and Haihe riverbasins, amounts to only 6.5% with almost 40% arable land. Also, influenced by the monsoon climate, the rainfall and runoff concentrate in the wet seasons with a great amplitude among years. Moreover, the water exploiting level is very high in the northern China, especially in the Hai riverbasin. In such case, the insufficiency of water resources in northern China has become a hindrance to socio-economic development.

The idea of South-to-North Water Transfer Project(SNWTP) was suggested firstly in the early 1950's and the survey work on SNWTP has been carried out for decades of years since late 1950's. Then the Yangtze River basin Planning Office (the predecessor of the Yangtze Riverbasin Water Resources Commission). Huanghe

Riverbasin Water Resources Commission, Huaihe Riverbasin Water Resources Commission, Chinese Academy of Sciences and Jiangsu, Anhui provinces have been involved in integrated survey of the canals and put forward preliminary designs of transferring water north ward from the upper reaches (West Route), the middle reaches (Middle Route), the lower reaches (East Route) of the Yangtze River.

II. Water Transfer Schemes

The SNWTP includes three routes to carry water from the Yangtze River to the North China (Figure 1). Each route has function in solving the water problems in the different areas, and they can be connected to form a large water resources system which covers most extent of north China. The West Route of SNWTP is planned to transfer water from the upper reaches of the Yangtze River to the upper stream of the Huanghe River to provide water for the Northwest China[1]. The transfer sites are at Liangye of the Tongtianhe River, Renqingling of the Yalongjiang River and Xieerga of the Zuzumuhe River, a tributary of the Daduhe River, having total watershed area of 168,000 km^2 with the annual average runoff of 22.1 billion m^3. The West Route is now at the feasibility study stage and still has a lot of problems to solve. Its implementation would be expected for remote future. Therefore, the author would like to brief only the routes into the NCP.

- Middle route of SNWTP

It is planned to transfer water from the middle reaches of the Yangtze River to Beijing, Tianjin and the western part of the North China Plain[1]. The water supplying area includes Hubei, Henan, Hebei, Beijing and Tianjin provinces and cities. The short-term engineering, simply named as "Yinhan", means a water diversion from the Hanjiang River, the longest tributary in the middle reaches of the Yangtze River. The long-term engineering, simply named as "Yinjiang", would carry water from the main course of the Yangtze River to the Danjiangkou Reservoir and then go northward because Yinhan can not afford enough water. The Yinhan water conveyance canal would begin at the Taocha water intake at the Danjiangkou Reservoir, then would go along the southern foot of the Funiushan Mountain, the pediment at the eastern foot of the Taihang Mountain and would terminate at the Yuyuantan Lake in Beijing. Water supplying to Tianjin City would construct second main canal starting at Xushui County of Hebei Province eastward through the Haihe Plain to the city.

- East Route

The East Route will transfer water from downstream Yangtze to the eastern part of NCP. The conveyance canal would be about 1,150 km long, along which the discharge capacity would be allocated by different sections. Because the elevation of the land along this route is low at both ends and high at the middle, water would have to be pumped through 15 stages with a total lift of 65m. Water will be transferred by gravity after crossing the Yellow River. Water would cross Huanghe through a tunnel to be constructed beneath its bed. This is because the flow of Huang he is so heavily

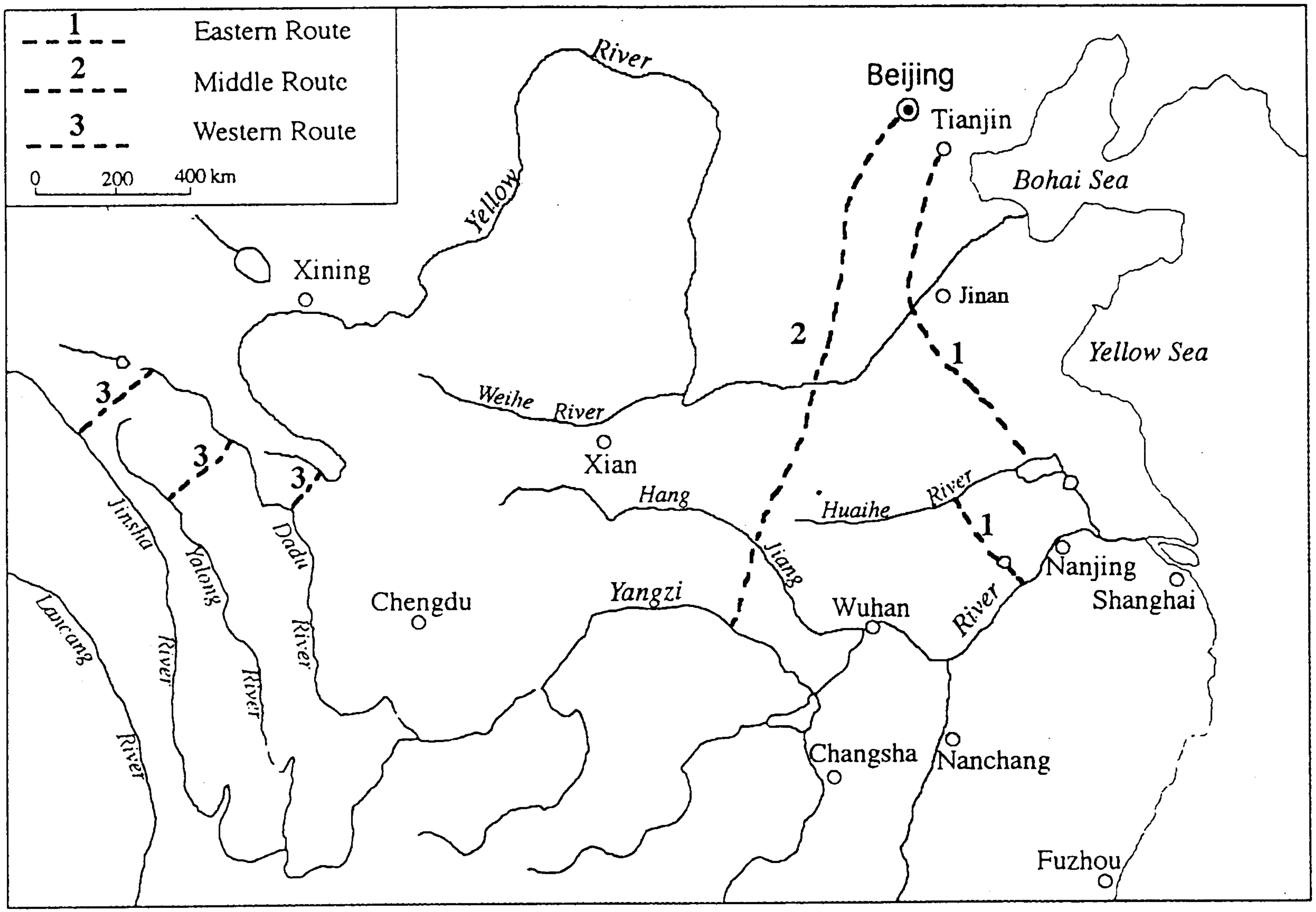

Figure 1. **Proposed Routes for South-to-North Water-Transfer Projects**

laden with silt, surface crossing is not advisable. The advantage of the East Route is the using Beijing-Hangzhou Grand Canal as the main canal, the engineering work will be much easier. The main disadvantage of the East Route is that since pumping is indispensable for the section south of the Huanghe, it will consume a large amount of electricity per annum, estimated at about 5 billion k Wh.

Considering future climate in 20-50 years[2], what will be impact of global warming on the SNWTP region? The answer of the question must be the important task for us.

III. Predication of Global Warming Influence on Annual Water Yield

On basis of water cycle, annual watershed water yield (R) depends on water balance components of precipitation (P) and evapotranspiration (E). The latter is in closed relation to temperature (T). There are several models for determination of E related to temperature.

1. C.W.Thomthwaite

$$E_0 = 1.6\,(10t / I)\,d \qquad (1)$$

where t is average monthly temperature, I and d are parameters respectively.

2. L. Turc developed E formula[3] based on water balance elements including annual temperature.

$$E = P / [0.9+P^2 / L^2]^{0.5} \qquad (2)$$

where $$L = 300+25T+0.05T^3 \qquad (3)$$

3. W.B.Laugbein[3]

$$E = P-10^{A1T+A2} \qquad (4)$$

where A_1, A_2 are parameters.

4. H.W.Fong

$$E = 38*10^{79T / 199+T}-271 \qquad (5)$$

Above models may be employed for determining an influence of temperature changes on evapotranspiration and through which the water yield can be predicted according to water balance equation[4]:

$$R = P-E \quad \text{(for annual water yield)} \qquad (6)$$

$$R = P-E+W \quad \text{(for monthly water yield)} \qquad (6a)$$

Considering adaptation to a regional scale, the model developed by L. Turc is advisable for the predication. The Turc's model for annual runoff as water yield was based on a study of data collected from 254 basins located worldwide. In order to make sure in applying Turc's model to the regions of the South-to-North Water Transfer Project (SNWTP) in China, we have conducted calibration study on its parameters. Assuming parameters involved in the formula (2) and (3) as a,b,c, and d, we get:

$$E = P / [d+P^2 / (a+bT+cT^3)^2]^{0.5} \qquad (7)$$

Where parameters a,b,c, calibrated by several subregions along the middle route of the planned SNWTP compared with other regions in China.

The major results from the calibration work show following points:

(1) the original parameters presented by Turc's model is likely good to filling data of the southern China, where precipitation is rich with a higher humidity (Table 1).

Tab.1 Tests of Turc's Model with Data Collected from Several Regions in China
(Parameters: a=300, b=25, c=0.05, d=0.9)

Location	Region	E(measured)	E'(estimated)	E'-E	E'-E/E(%)
Taiyuan	North	431.3	386.9	-44.4	-10.3
Hanjiang	Middle	550.0	575.4	25.4	4.6
Hainan	South	930.3	1040.7	110.4	11.9
Fuyu	Northeast	325	269.5	-55.5	-17.1
Talimu River	Northwest	76.0	87.5	11.5	16.6
Tengchong	Southwest	770.0	816.7	46.7	6.1

From Tab.1, We can see that the adaptation of the Turc Model is low in some regions including the SNWTP areas. Therefore, the original parameters of the Turc model must be fitted in accordance with measured data.

Tab.2 Results from Fitted Turc Model's Parameters

Location	Region	E(measured)	E'(estimated)	E'-E	E'-E/E(%)	Parameters
Taiyuan	North	431.3	441.4	10.1	2.3	a=-813.693 b=-229.279 c=-0.627
Hanjiang	Middle	550.0	488.1	-61.9	-11.2	a=30443.9 b=3096.182 c=-4.484
Hainan	South	930.0	888.9	-41.1	-4.4	a=37.407 b=40.528 c=0.0137

(2) The fitted parameters for the model present fairly good results. The relative error is obviously reduced in comparison with the original Turc's Model (Tab.2).

IV. Prediction and Hypothetical Scenarios

1. Predication

Using equation (2), (3), we obtain the derivatives

$$\partial E / \partial T = P^3(25+0.15T^2)\ [0.9+(P/L)^2]^{-1.5}L^{-3} \quad (8)$$

and

$$\partial E / \partial T = [0.9+(P/L)^2]^{-1.5} - P^2[0.9+(P/L)^2]^{-25}\ L^{-2} \quad (9)$$

Using modified parameters instead of parameters used by equation (2), (3), we get:

$$\partial E / \partial T = P^3(229.279-1.881T^2)\ [0.9+(P/L)^2]^{-1.5}L^{-3} \quad (10)$$

and

$$\partial E / \partial T = [0.9+(P/L)^2]^{-1.5} - P^2[0.9+(P/L)^2]^{-25}\ L^{-2} \quad (11)$$

Figure 1 shows the computed $\partial E/\partial T$ for the SNWTP area with mean annual temperature values from 10 °C to 16 °C.

2. Regional response of water yields to temperature rise

According to water balance equation, the water yield as runoff (R) in our case will be:

$$R = P - \{1 - [\ 0.9 + (P/L)^2]^{-0.5}\} \quad (12)$$

and we have

$$L = 300+25T+0.05T^3 \quad \text{(for south)} \quad (13)$$

$$L = -813.693+229.279T-0.627T^3 \quad \text{(for north)} \quad (14)$$

The formula(10) as well as (14) fitted with data satisfied for local area and can not use for extrapolation.

3. Scenarios

As above mentioned, the planned water transfer schemes are always subject to the transferable water from resource output areas. So we must conduct an analysis on the transferable quantity of water, which would be influenced by the global warming[5]. Unfortunately, we have no certain determination of temperature rise for local scale are as under different level of concentration of CO_2 and other greenhouse gases. According to the results obtained by GCMs model (NCAR), we employed hypothetical scenarios to deal with the possible change in the transferable water.

Figure 2 shows the hypothetical scenarios predicted for the SNWTP water exporting areas under different levels of changes in temperature and precipitation. From this figure we can see that under warm-dry scenarios, e.g. under annual temperature rise of

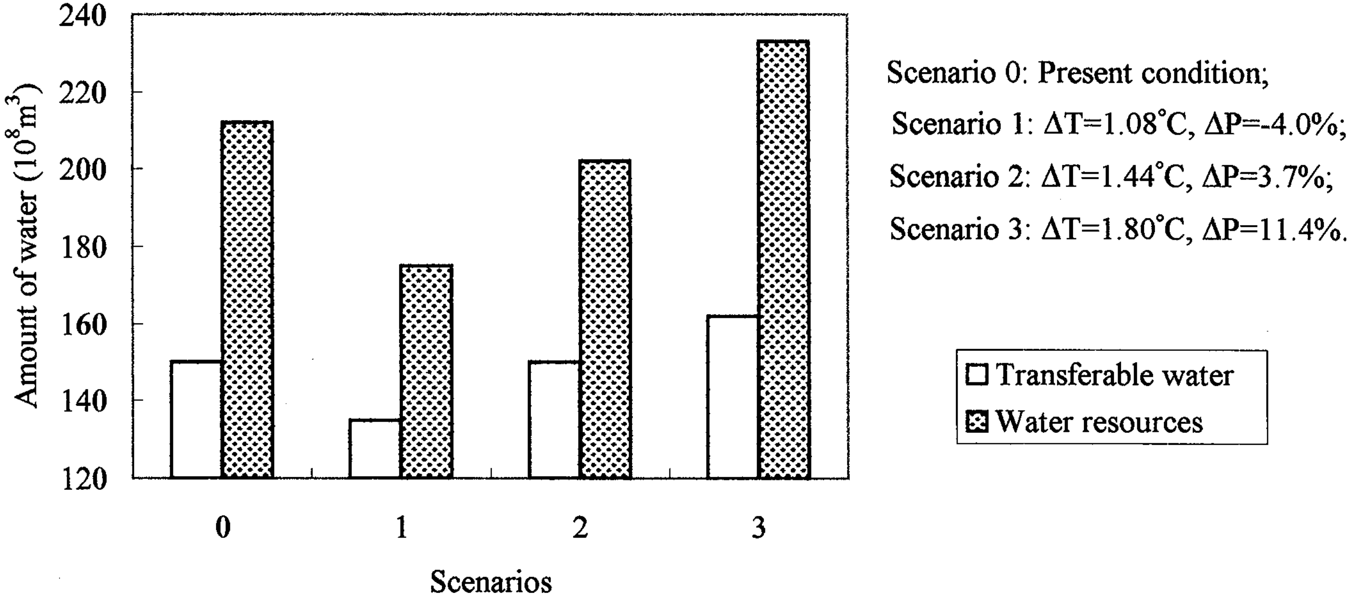

Figure 2. **Scenarios for Transferable Water from Exporting Region**

3°C and annual precipitation decrease of 20%, the transferable water of water exporting region would be reduced by about 60%. In such case, the operation work of SNWTP would be out of order.

V. Brief Conclusion

The SNWTP, particularly its Middle Route has had a problem in transferring quantity of water from exporting regions where the population density is high with many industrial areas. It's of great signifiicance in analyzing the influence of global warming on the transferable water quantity. The results of this study illustrate a serious situation to be happened under the conditions of temperature rise with warm-dry scenarios.

Acknowledgment

The author wishes to thank the support of National Natural Sciences Foundation.

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Paleohydrology of the lost Vedic Sarasvati River during the Indus Civilization

Isamu Kayane
Faculty of Modern Chinese Studies, Aichi University
Kariya 3－123, Ushiku, Ibaraki 300－12, Japan
Fax:＋81－298－73－8197

Abstract

Sarasvati is the most important river goddess in the Rig Veda, the oldest writings in the ancient India on hymns and legends composed during 1500 ～ 1000 BC. 'Saras' indicates water, 'vat' means rich in something(stream), and 'i' is a suffix for female nouns. The Sarasvati River was the most sacred river and goddess during the Harappan period (Indus Civilization) in the Punjab plain. Punjab means five waters(rivers) in Persian. According to the Rig Veda and the Mahabharata, a long magnificent Hindu epic composed during 200 BC ～ 400 AD, the Sarasvati River was ① a big river comparable to the Ganga and the Yamuna, ② one of five rivers in the Punjab plain, ③ a river different from the Satluj River, and ④ it flowed out from the Himalaya and reached to the sea.

The Sarasvati River flowing westward had disappeared in a period before the east－ward advance of the Aryans, who invaded into the Punjab plain from west and destroyed the native Dravidian. It have been told that the lost Sarasvati River had became an underground river and merges with the Ganga and the Yamuna at Arahabhad. Arahabhad have been an important place of pilgrimage and worshipped as 'triveni', the place where three rivers join.

Figure 1 is the chronological horizon of the main Indus cities dated by carbon 14 and relative dates. The Indus Civilization rose at Mohenjo－Daro in ca.2500 BC, then it spreaded eastward to the Punjab plain and southward to the coastal flatland within 300 years. A fact worth special mention in Fig.1 is the simultaneous fall of nuclear cities and Kalibangan in ca.1700 BC. The wet climate during the hypsithermal interval after the post－glacial warming had changed to a dry climate in the Indus valley in ca.1700 BC as shown in Fig.2 indicating estimated variations of the rainfall of Rajastan. It may be said that the Arians invaded into the Punjab plain in ca.1500BC, which was almost 200 years

after the fall of these cities.

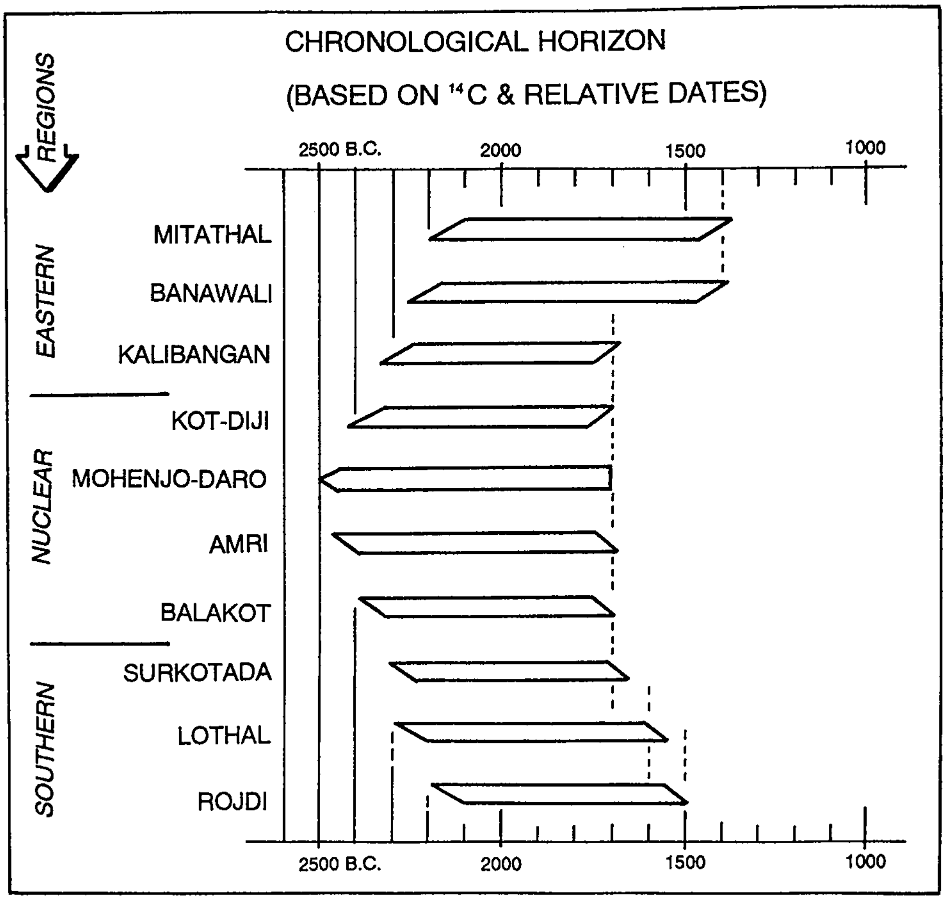

Fig.1 Chronological horizon of Indus cities(Khanna,1992)

Figure 3 shows present river systems in the Punjab plain and the Himalaya regions. Five rivers in the Punjab deciphered from the Rig Veda by the author are the Sarasvati, the Jelum, the Chenab, the Ravi and the Satluj. The author made a field work in the Punjab plain in 1997 to investigate the ancient river course of the lost Sarasvati River, which flowed out from the Himalaya and could reach to the sea. Present Saraswati River is a small tributary of the Ghagghar River(Fig.4) flowing out from the foreland hills of the Himalaya. It dries up near Sirsa though its river bed continues to the dry huge bed of the lost Sarasvati River. The Ghagghar River could not supply enough river water possible to reach the sea even under much wetter climatic condition.

Figure 4 shows the reconstructed ancient river course of the Sarasvati River based on available literatures and maps. Hakara, wahinda and nara in Fig.4 are the dried old river channels existing in the desert. Exact location of these old river channels are examined and confirmed on the scale of 1 to 200,000 topographical maps of India and Pakistan made in the former USSR. The Paleo–Sarasvati River shown by broken lines in Fig.4 had changed its course at near Rupnagar located at the foot of the foreland hills in ca.1700 BC. As a result, the Paleo–Sarasvati River had dried up resulted in collapse of Kalibangan and many other Indus cities along the Paleo–Sarasvati River in the Cholistan desert.

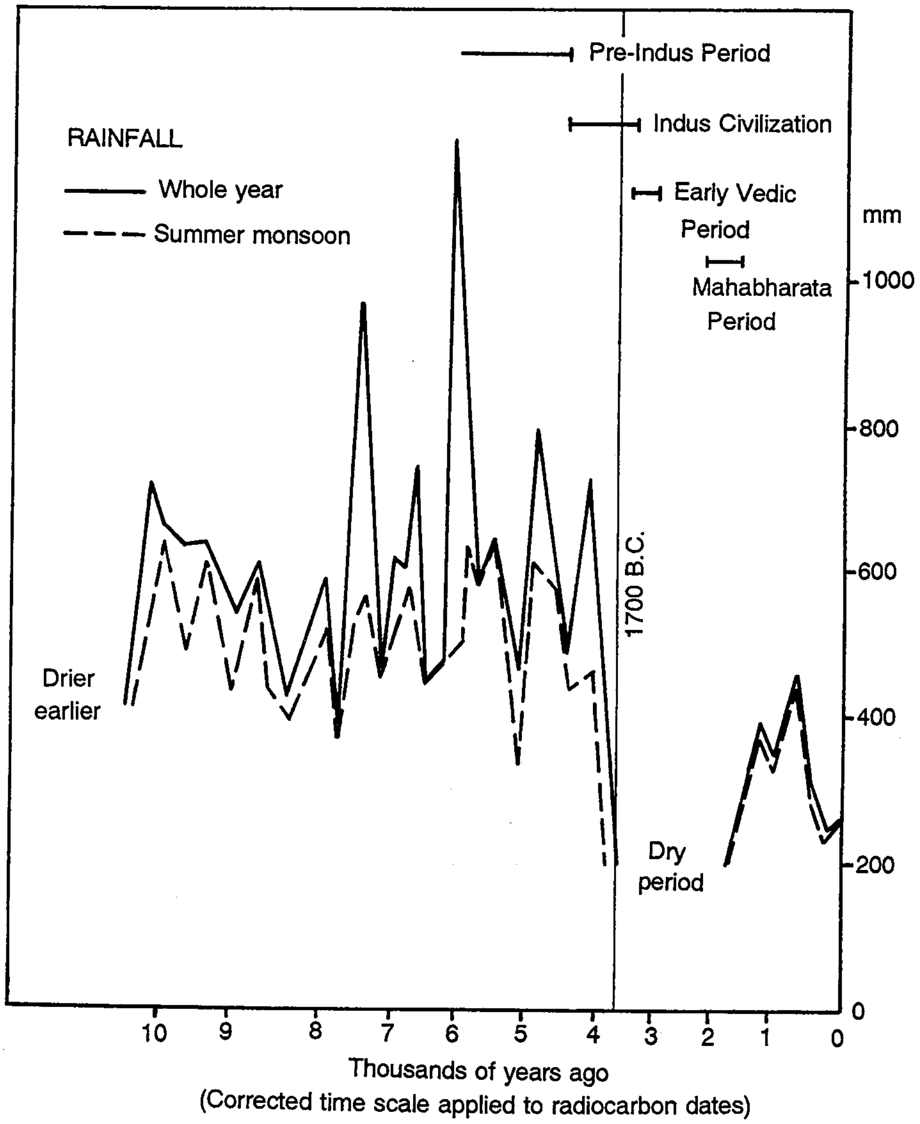

Fig.2 Estimated variations of the rainfall in Rajastan(Lamb,1982)

During the Indus Civilization the Beas River was the main river of the Satluj River. The discharge of the Satluj River had suddenly increased after joining of the Paleo–Sarasvati River in ca.1700 BC when its river course had changed to the present course of the Satluj River. The sudden increase in the discharge at Mohenjo–Daro after joining of the Paleo–Sarasvati River to the Indus river basin in ca.1700 BC might cause to increase flood frequency of the Indus River, which then might cause to destroy the water supply system of Mohenjo–Daro. On the other hand it is presumed that the Harappans had abandoned their city due to drought. The Ravi River should bave been more sensitive to drying of climate comparing to other four rivers in the Punjab plain because it has larger percentage of flat land and smaller percentage of mountain area.

The author would like to stress the importance of changes in palephydrological conditions as an intermediate factor relating the climate change with the collapse of the Indus Civilization.

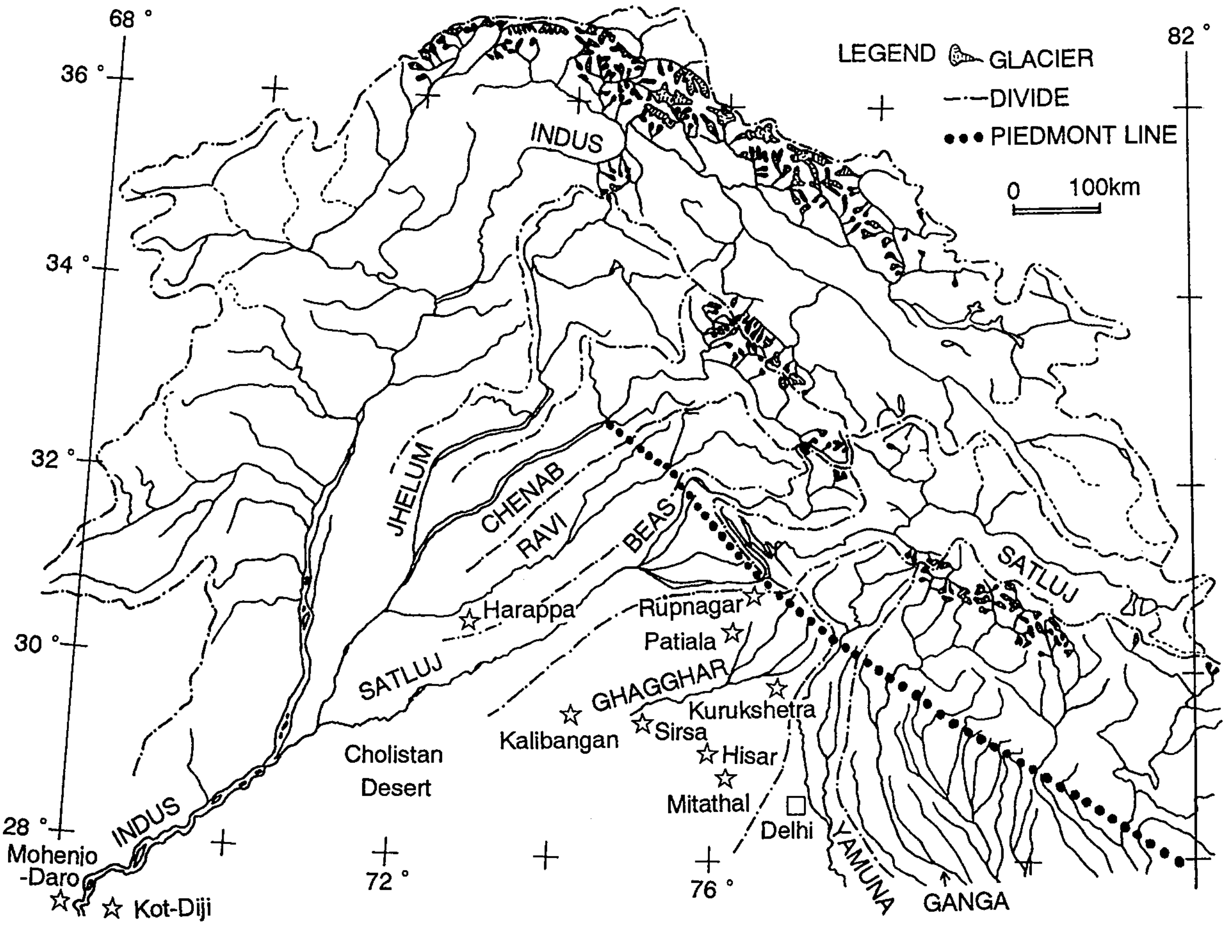

Fig.3 Present river system in the Punjab plain and Himalaya regions

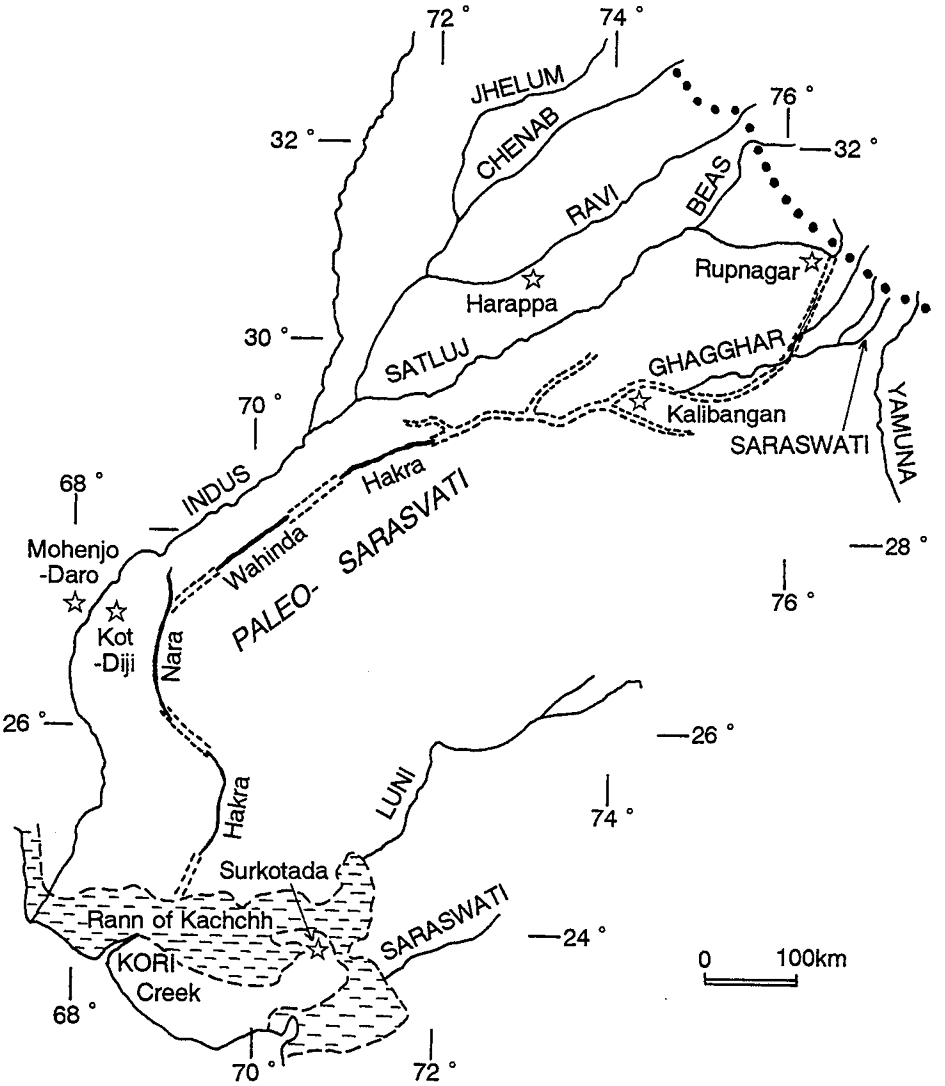

Fig.4 Reconstructed river course of the Paleo–Sarasvati River during the Indus Civilization

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Physical Environments of Brackish Lakes and Tidal Rivers
Putting Emphasis on Internal Oscillations

Setsuo Okuda(*)

* Faculty of Science, Okayama University of Science

Abstract

In brackish lakes and tidal rivers where a stable stratification with a sharp halocline usually exists, a characteristic aquatic environment often appears. One of serious environmental problems is an appearance of anoxic water mass in the lower layer at these water regions especially in summer because of weak vertical mixing and active dissolved oxygen consumption.

In such circumstances, internal oscillations frequently occur due to tide or/and wind and bring about an active movement of an anoxic water mass in the lower layer, and affects seriously the aquatic environment there.

Then I studied physical processes of the internal oscillations in Lake Nakaumi and The River Ohashi and found that the oscillations with a few meter amplitude frequently occur and propagate as internal Kelvin waves in the lake and the oscillations sometimes cause anoxic water intrusions through the Ohashi River into Lake Shinji.

1. Introduction

In Japan, there are many brackish lakes and tidal rivers where a stable stratification with upper fresh water and lower saline water causes a peculiar aquatic environment.

The aim of this presentation is to clarify the physical characteristics of brackish lakes and tidal rivers putting emphasis on internal oscillations and their effects on aquatic environments.

Our study field is a special estuarine region consisting of Lake Nakaumi, the Ohashi River and Lake Shinji, where the saline water from the Sea of Japan and fresh waters from many rivers inflowing into the lakes contact and mix under various meteorological and hydrological conditions. This water region is characterized by stable density stratification with a sharp halocline, except under extraordinary conditions such as very large flood or strong wind.

The stable stratification brings about weak vertical mixing between the upper fresh water and lower saline water and supresses the downward transport of dissolved oxygen. This often causes anoxic states in the lower saline layer, especially in summer when the oxygen consumption rate becomes very large owing to the active chemical and biological processes. This anoxic state in the lower layer controls the aquatic environment there, for example, it affects fishes and seriously impairs the growth of benthic organisms such as shells and seaweeds. The anoxic water mass does not stand still in the lower layer, but usually moves about corresponding to tides, river discharges and wind blowings.

Therefore, it is very important for us to investigate the occurrence and movement of the anoxic water mass in the estuarine regions to understand their effects on the aquatic environments both from the academic and practical points of view.

Then in collaboration with the fisheries experimental station of Shimane Prefecture, we investigated the changes in the distribution of anoxic water and the internal oscillation which strongly controls the occurrence and movement of the anoxic water mass in the brackish lake - Lake Nakaumi and the tidal river - the Ohashi River.

2. Observation Method

We observed the distributions of temperature(T), electric conductivity(EC) and dissolved oxygen concentration(DO) with multi-sensor instruments from a research vessel sailing around the regions as shown in Fig.1. The observation results show a stable stratification consisting of an upper layer with a smaller density in situ σ_t and a higher DO and a lower layer with a larger σ_t and a lower DO. The DO concentration in the lower layer becamed very low (nearly zero) during summer, inducing serious conditions for life forms in the lower and benthic layers.

Besides the above usual observation methods, we have developed a simple neutral buoy to directly measure the internal oscillation - a vertical movement of halocline where exists a sharp density gradient owing to a large difference of salinity between the upper and lower layers. The weight of the buoy could be adjusted using small metal ballast to make the apparent density of the buoy equal to that of the water in the halocline at the observation station. We set the buoy using a mooring system to follow the vertical movement of the halocline.

3. Results and discussion

We have repeated the field observations in our study regions several times during 1994 to 1996, but we will show only main results and briefly discuss them, selecting the most recent observation results about the distributions and movements of anoxic water in Lake Nakaumi and the intrusion of anoxic water into The Ohashi River.

3.1 The occurrence of an anoxic state in the lower layer of Lake Nakaumi

The occurrence of an anoxic state in the lower layer of Nakaumi during summer seasons has been well known from the observation results of the fisheries experiment station of Shimane Prefecture. The main causes are the bottom topography (a deep depression in Nakaumi), a stable stratification with a sharp halocline, and a large oxygen consumption rate in summer in the lower layer.

Besides the vertical distributions of DO concentrations, three dimensional distribution of DO and their temporal changes were obtained from a recent observation by a Kinki University Group (1997). This results illustrate that an anoxic water mass first appears in the southeastern region of the lake and expands toward the western region along the lake bottom. The saline water inflows from Nakaura waterway into Lake Nakaumi and spreads into a wide central basin along the lake bottom taking a form of density current, and after arriving at the western boundary - the exit of The Ohashi River, the water is entrained into the upper layer with a jet flow from the river and returns toward east through the upper layer.

It seems to take a long time (maybe about ten days and more by some estimation from numerical simulation and buoy tracing) for a water mass to pass through Lake Nakaumi inflowing upstream through the lower layer and outflowing downstream through the upper layer. During this long passage period, a small downward flux of oxygen from the upper layer and a large oxygen consumption rate in the lower layer promote the rapid decrease of DO concentrations in the lower layer.

3.2 Internal Oscillation

It is well known that a wind stress causes a set up of water surface and a drop of interface between two layers - halocline at the leeward side. Our simple estimation from the two layer model reveals that in Lake Nakaumi, a 7-8m/s wind along the east-west direction brings about a few centimeters set up of water surface and a few meters drop of the halocline level. Thus a daily change of wind due to sea and land breeze in summer with an ordinary speed of 7-8m/s may bring about internal oscillations with an amplitude of a few meters.

In shallow coasts with a small slope gradient of the order of 1/1000, a few meter rise of the halocline may cause a long horizontal creeping up of highly saline and anoxic water on a few kilometers. This means that an internal oscillation due to strong wind may have a serious effect on the biological life of coastal regions in brackish lakes.

Therefore, we investigated the internal oscillations in Lake Nakaumi about the occurrence conditions, amplitudes and periods, and propagating style of oscillatory waves. We set the neutral buoys at the fixed stations as shown in Fig. 1 and recorded the vertical movement of halocline and the results are compared with the hourly changes of vertical distributions of density in situ σ_t (=[ρ -1]×1000, ρ :density calculated from EC and T) and DO.

The result illustrates that the level of halocline measured from the neutral buoy record well agrees with the level of the layer with constant density σ_t =10.0 and with constant DO = 3.0 mg/l and so the height of halocline well corresponds to the upper boundary of the anoxic water mass with DO less than 3mg/l.

Fig.2 shows the time series change of wind vectors, water level and halocline level (internal oscillation) and it illustrates that water level changes caused with tide of amplitude about a few ten centimeters have some correlation with internal oscillation only at Pt. 3 near from the entrance of tidal wave, Nakaura waterway. Also it shows that the internal oscillations have an inverse phase between at Pt.1 and Pt.2 which are situated at western and eastern sides in the lake respectively. This means that the halocline level moves upward or downward corresponding to the windward or leeward side respectively as we can understand comparing the level motion with hourly change of wind direction in Fig.2(a).

Furthermore, we compared the phase differences of the internal oscillations between neibouring stations at Pt.4, 5 and 6 which are situated along a straight coastline at almost same water depth to investigate the propagating state of the internal osillation. The result is shown in Fig.3 which illustrates that an oscillatory wave was progressing with a consant propagation speed of 24 cm/s. This speed well coincides with the one calculated from the equation for the internal wave phase speed Ci which is expressed with the density difference between upper and lower layers, and each thickness of both layers.

Besides this observation result, the calculation of rotating propagation speed along the path Pt.1->2->3->1 reveals that the period of circulating propagation (about 24 hrs) is longer than that of inertial period (20.4hrs) and the period of internal Poincare wave (17hrs). From these facts, we considered that the internal oscillation in Lake Nakaumi propagates anticlockwisely as an internal Kelvin wave.

Finally we found that the internal oscillation is first caused mainly by wind stress at the lake surface, but the oscillatory motion propagate along the whole lake coast anticlockwisely and the vertical movement of halocline with a large amplitude occurrs in any point near the coast independently of wind direction which decided the initial direction of oscillating axis.

3. Creeping up of anoxic water into The River Ohashi

Frequently the saline and anoxic water mass creeps up into The River Ohasi and sometimes arrives at Lake Shinji and it gives some adverse effects on the environments in Lake Shinji .

Then it is necessary for us to investigate special conditions which may cause the intrusion of the anoxic water from Lake Nakaumi. We have carried out a field observation on the distribution of current, EC and DO along The River Ohashi by a boat sailing and on the internal oscillation with the neutral buoy at Pt.09 near the eastern mouth of the river simultaneouely. The observation by boat sailing had been repeated four times corresponding to various tidal phases.

Of course, anoxic water mass is rising up along the river bottom during ebb tide period, but the anoxic water with DO less than

3mg/l appears only under the halocline level in Lake Nakaumi during the rising up period of the level somewhat different from high tide period.

The horizontal distribution of DO along the bottom illustrates that DO values do not decrease rapidly toward upstream direction and this means that the oxygen consumption rate during the creeping stage through the river is not so large. Then the cause of the anoxic water intrusion into Lake Shinji seems to be a direct passing through of the anoxic water from Lake Nakaumi without a large oxygen consumption along the river course.

Conclusion

In conclusion, the following points were made clear about physical environments in the brackish lake and the tidal river which are characterized with stable stratification and a large internal oscillation.

1) Stable stratification and low circulation speed in Lake Nakaumi promote anoxic state in the lower layer.
2) Internal oscillations i.e. vertical movements of halocline in Lake Nakaumi are caused mainly by wind stress and partly by tidal action. Their large amplitude and rotating propagation style cause a large scale creeping up of anoxic water to the whole lake coast and into The River Ohashi.
3) Dissolved oxygen consumption rate during the passage of water mass through The River Ohashi from Lake Nakaumi to Lake Shinji is not so large and a main source of anoix water rising up into Lake Shinji is a direct inflow of anoxic water mass from Lake Nakaumi.
4) Countermeasures to prevent the spread of anoxic state in brackish lakes and tidal rivers should be planned on the basis of scientific studies on mechanism of occurrence and movement of anoxic water masses.

Acknowledgment

The main part of observation results in this paper is supplied from the joint field works between Okayama University of Science and fisheries experimental station of Shimane Prefecture, and the author gives his thanks to all members who supported the joint field works.

(a)

(b)

(c)

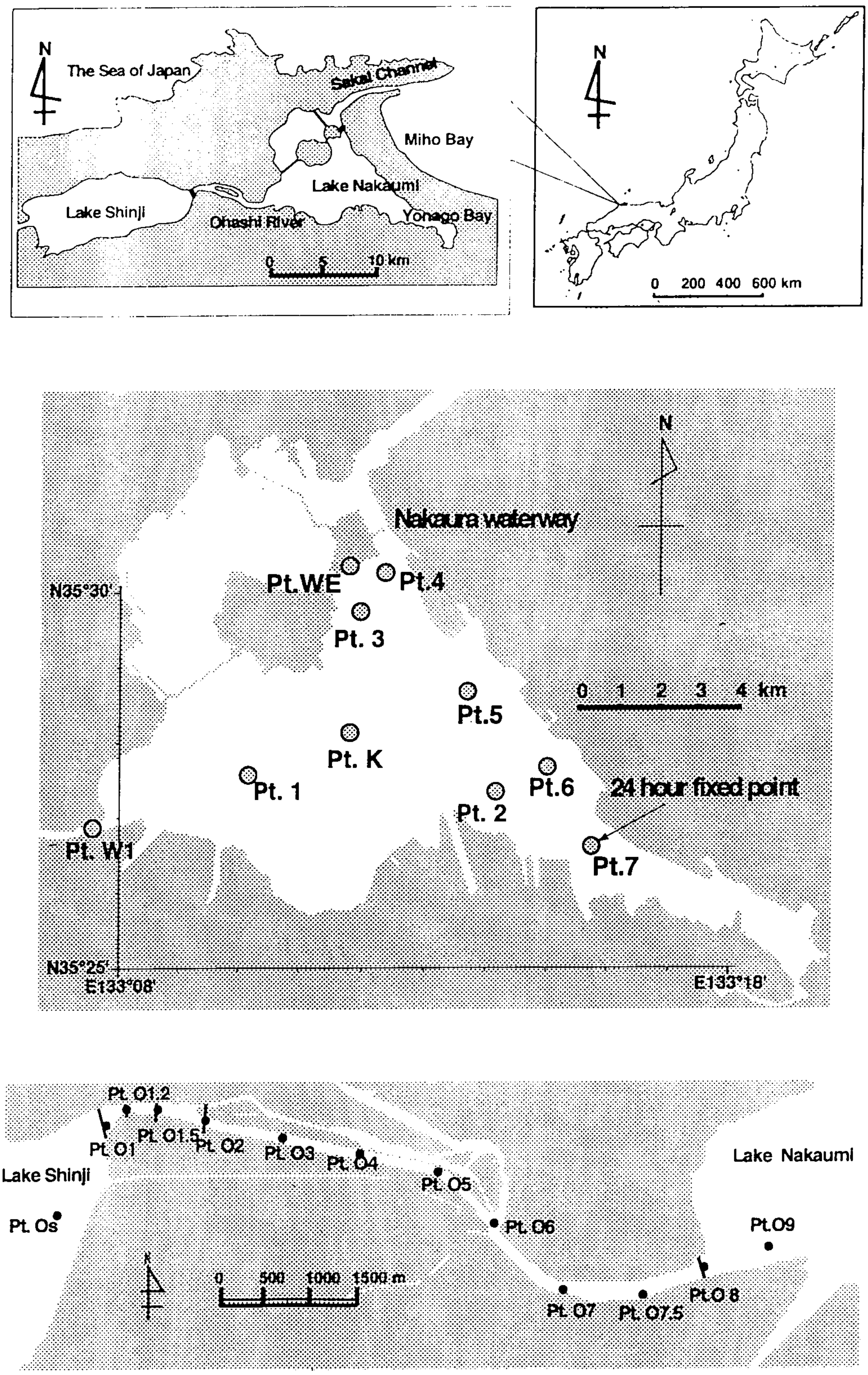

Fig. 1 Observation points in Lake Nakaumi and the Ohashi River

(a) Map of Lake Nakaumi and the Ohashi River

(b) Observation during 1995~1996 in Lake Nakaumi

(c) Observation from Aug. 27 to 28, 1996 along the Ohashi River

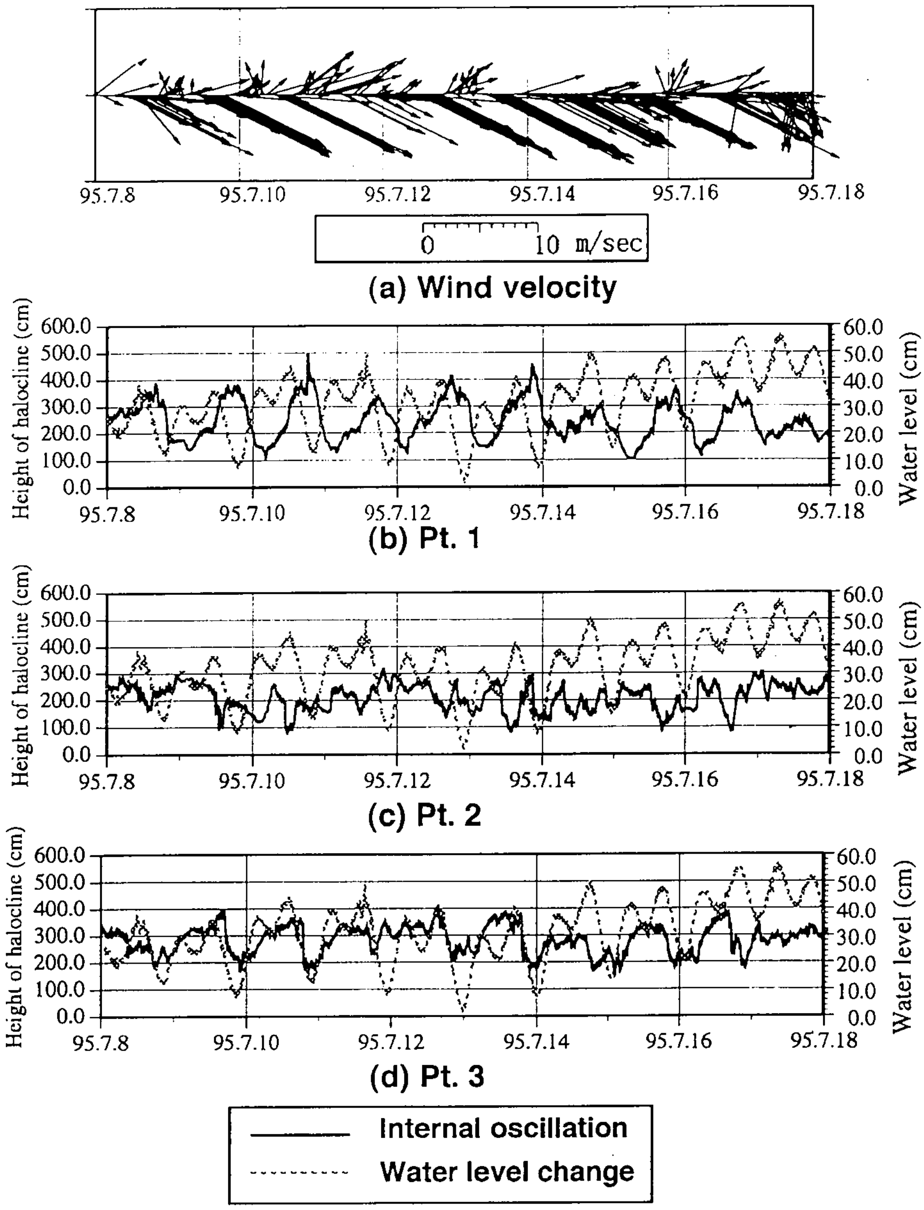

Fig.2 Temporal changes of wind velocity (a), and internal oscillations at Pt. 1 (b), Pt. 2 (c) and Pt. 3 (d) in Nakaumi from July 8 to 18, 1996 derived from the changes of the height of the halocline - the distance of the neutral buoy from the bottom

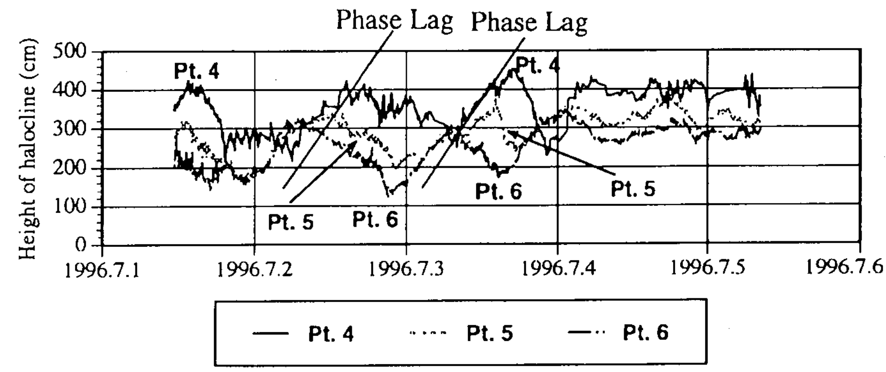

Fig.3 Phase lags of internal oscillations between neibouring stations Pt. 4, 5 and 6 along a straight line in Lake Nakaumi

Groundwater of the North China Plain

Fei Jin

Institute of Hydrogeology and Engineering Geology
China's Academy of Geological Sciences

Abstract

This paper briefly introduces basic hydrogeological conditions, recent result of its groundwater resource evaluation, all suggested measures to solve the water resource shortage problem. In order to make all necessary measures a reality, the most important problem is to strengthen infrastructure construction and capability construction.

1. Introduction

It is known to many people both at home and in abroad that the total water resource of the North China Plain is insufficient and its groundwater is under overexploitation. A lot of studies have been carried out in order to solve the water shortage problem. Generally speaking, as a fruitful result, such studies have promoted the progress of strengthening water saving measures, preventing water pollution, and limiting groundwater overexploitation. However, to thoroughly solve the water shortage problem and to reach the goal of rationally utilizing groundwater and effectively protecting the environment, is an extremely complicated and difficult system task, and needs long term tremendous efforts. On the basis of briefly introducing its basic hydrogeological conditions and some other problems, this author wishes to state his view on how to solve the problem of sustainable utilization groundwater resource as well as the whole water shortage problem.

2. Basic hydrogeological conditions

Speaking of North China Plain, there are two geographical concepts, the first one denotes the plain to the north of Huaihe river, the east of Taihang-Funiu-Dabie Mountains, the south of Yan Mountains, and the west of Bohai and Yellow Seas, the other concept denotes the part of above mentioned plain, located on the north of Yellow River. Because of its worse hydrogeological conditions and groundwater overexploitation, hydrogeologists usually use the later concept, and so does this paper. This plain has an area of about 260,000 km^2, a very dense population of about 70,000,000. Economically this plain is important for its relatively developed industrial and agricultural production, and of course its enormous population. Politically and culturally, this plain is significant due to its long history and the location of such important cities as the capital of China – Beijing, the other from the 4 municipalities under the direct jurisdiction of the central government – Tianjing, and the Hebei provincial capital – Shijiazhuang. The normal annual precipitation in the plain ranges coarse sand, fine sand, fine sand and silt, as well as silt. From west to east, the particles of quaternary aquifers become finer, and the thickness of individual aquifers decreases.

Aquifers at depths from 0 to 400 m can be divided into two groups. The first group is called shallow groundwater and ranges from 0 to 80 m deep. The second aquifer group is called deep confined groundwater, or simply deep groundwater. It ranges from 80 to 400 m in depth. (Depth of 400 m is taken as the lower line for dividing the two groups, but this is not a hydrogeological boundary, it only shows the maximal depth of most available hydrogeological data and the maximal exploitation depth. Again the depth of 80 m as the dividing line between the shallow and deep aquifer groups is an approximate or an average figure, for concrete places, it should be decided according to hydrogeological data).

In the piedmont area (area A, fig. 1) to the west and the north of the plain, the two groups of aquifers are taken as an hydraulically unified group. They are of coarse grain aquifers, well recharged, more permeable (transmissivities range from 100 to 2000 m^2/d), and have good water quality(bicarbonate type, TDS less than 1 g/l). The depth of water table or pressure head over there used to be 3 –5 m before 1950's, but now it is 10 – 30 m.

In the middle part of the plain (area B, fig. 1), the shallow fresh water aquifers are, primarily, fine sand, and, secondarily, fine - medium sand and silt - fine sand. The cumulative thickness of shallow fresh water aquifers is 5 to 30 m, and the hydrochemical types of water are bicarbonate, bicarbonate - sulphate, bicarbonate - chloride, and sulphate - chloride waters with TDS less than 2 g/l. The transmissivities are 50 - 300 m^2/d. In some places of the area B, the shallow groundwater is brackish water with TDS of 2 - 5 g/l and hydrochemical types of sulphate -chloride or chloride - sulphate waters (fig. 2). Deep groundwater over there is fresh water and distributed evenly throughout the area, its aquifers consist primarily of medium-fine and fine sands, generally with a cumulative thickness about 40 m and buried to a depth greater than 100m. In most places these deep aquifers have transmissivities from 100 to 500 m^2/d. The hydrochemical types of water are bicarbonate, bicarbonate-chloride, sulphate-chloride, chloride-sulphate waters with TDS less than 1g/l.

In the coast area (area C, fig. 1), the widely distributed shallow groundwater is salt water with TDS greater than 5 g/l(fig. 2), only in a few places are there isolated thin lenses of shallow fresh or brackish water. The deep groundwater in coastal area can be found at the depth greater than 150 m, and the aquifer's accumulative thickness is 50-70 m. the hydrochemical types of deep fresh water are bicarbonate-sulphate, bicarbonate-chloride, sulphate-chloride, or chloride-sulphate waters with TDS less than 1 g/l. In the river mouth area of the Yellow River, both shallow and deep aquifers contain only salt water (Fei, 1988; Zhu, 1990).

3. Groundwater resource evaluation results, overexploitation

From 1960 to 1991, many authors have carried out different kinds of groundwater resource evaluation studies. The latest large scale groundwater resource evaluation for the whole plain and its adjacent mountainous areas was accomplished jointly by this institute and relevant institutions from the Ministry of Water Conservancy in 1990 and published in 1991. The result of this evaluation was accepted unanimously by the Ministry of Geology and Mineral Resources and the Ministry of Water Conservancy as an official figure. According to the evaluation, the exploitable shallow fresh groundwater resource for the whole plain is 17,415,000,000 m^3/a, the exploitable deep confined fresh groundwater resource is 1,598,000,000 m^3/a, and the present average overexploitation rate of the deep confined fresh groundwater is about 1,500,000,000 m^3/a. The present exploitation rate of shallow fresh groundwater for the whole plain is about 16,000,000,000 m^3/a, i.e. slightly less than the exploitable resource. However such exploitation rate is not evenly distributed from place to place in the plain. In the piedmont area of the Taihang Mountains, especially in places surrounding the medium and bigger municipalities along the railway from Beijing to Guangzhou, the shallow fresh groundwater is being seriously overexploited, for example: in the central district of Beijing municipality, the shallow fresh groundwater is being overexploited by 200,000,000 to 300,000,000 m^3/a averagely, in the area from Shijiazhuang to Hangdan, the overexploitation rate is about 600,000,000 m^3/a. In the middle part of the plain, the exploitation rate of shallow fresh groundwater is approximately equal to the exploitable resource, and in its southern places close to the Yellow River, the shallow fresh groundwater is not exploited fully (Zhu, 1990).

The environmental problems caused by the overexploitation is as the following:

3.1 The water table or pressure head of groundwater in the piedmont areas of the Taihang Mountains is withdrawing seriously, for instance the maximum depth of groundwater table and pressure head in the central district of Beijing is over 30m, and that of Shijiazhuang is over 37m.

3.2 The long time overexploitation of deep confined groundwater in the middle part of the plain caused in landsubsidence in Tianjing, Changzhou, Dezhou etc., for example: the pressure head withdrawing rate of the deep confined fresh water in Tianjing is 0.9 - 2.1 m/a averagely, the landsubsidence rate is about 83 mm/a, and the total landsubsidence has reached 2.7m as the maximum.

4. Suggestions to solve the water shortage and groundwater overexploitation problems

To solve the groundwater overexploitation problem is an organic part of the whole solution of the water shortage problem. Starting from 1970, many learners have been studying on this problem and put forward a lot of suggestions (Liu,1989; Zhu, 1990; Cheng, 1996). To sum up, those suggestions are as the following:

4.1 Eastern line and middle line projects of diverting water from the south to the north. Eastern line project can provide 6.5 billion m^3/a of water for the middle and east parts of the plain. Middle line project can provide about 8 billion m^3/a of water for the piedmont area along the Taihang Mountains and the other parts of the plain (Xie, 1995). Naturally, it is significant for solving the water shortage problem of the plain, if such projects can be made a reality. At present time, the feasibility studies for those two line projects have accomplished, and the initial design stage work for the middle line project has started. However, there are so many technical and environmental problems that need to be considered carefully, and on the other hand, such projects require tremendous financial investment, therefore, most likely those projects will not be made a reality in near future.

4.2 Saving water and rational utilization of water. Such factors as the natural condition and dense population caused in the water shortage problem of the plain. In despite of whether the diverting water from the south to the north can be made a reality, the most essential and important measures to solve the water insufficiency problem are saving water all the time and every where.

4.3 Preventing pollution, protecting environment, protecting fresh water resource, that is already extremely valuable, against any kind of deterioration. Since 1980, along with the rapid development of economy, a lot of country-side and small town enterprises have build up, and due to their poor technical condition, they caused in serious pollution problems. At the same time, such publicly beneficial work as groundwater monitoring network has been weakened due to insufficient financial support. Starting from 1990, the work of preventing pollution has been strengthened by legislation and administrative measures, and many achievements have gained. However, it is still a big job and most existing environmental problems are still to be solved urgently, requiring much more efforts to strengthen the work.

4.4 The economy development allocation should be rational in accordance with local water availability. Industry and agriculture production of water saving type should be encouraged, and the high water consuming production should be restricted. Also, the municipality size and the inevitable citifying process should be controlled, and the city or town allocation planning should be made in accordance with water resource possibility.

4.5 Enhance the repeat utilization rate of water, encourage and develop waste water treatment and purification work. Encourage sea water purification work while it is feasible.

4.6 Realize conjunctive management of surface and ground waters. The piedmont area of Taihang Mountains should be constructed as a groundwater intensive exploitation and artificial recharge area in order to fully utilize the aquifer's natural water resource regulating ability as well as the excess water, during raining season and winter time, from all reservoirs and the middle line project of diverting water from the south to the north.

4.7 A big, well designed and managed draining system for the middle and east parts of the plain must be constructed in order to control the depth of shallow groundwater while irrigating and diverting water from the south to this area. The shallow fresh groundwater, even brackish water, should be used as much as possible together with the diverted surface water. The deep groundwater overexploitation situation should be eliminated as soon as possible, and while the condition permits, the artificial recharge to deep confined aquifers should be carried out, Deep groundwater system should be constructed and treated as an emergency water source for dry years.

4.8 In places where brackish shallow groundwater are distributed, special measures of draining brackish water and strengthening recharge with fresh water are wishful for the purpose to improve the environment and to increase regulatable water resource.

4.9 Strengthen the unified management of water resources. The existing institutional situation – multiple water management institutions, each acts on their own, difficult to adjust their activities, some time regard the department's benefit even higher than the country's, and so forth – must be solved properly. Present urgent task is to change the water management situation from a "rough" type into a scientific type so as to well control, well utilize, and well protect limited water resource (Cheng, 1996).

4.10 Strengthen the scientific research on water resource problems. To solve the water resource problem of the North China plain is a very complicated system problem. Although a lot of researches have been carried out during recent 30 years, there are much more studies that need to be done either from the view point of learning the natural conditions and rules or from the point of developing different technical measures as well as the way of their systematic and comprehensive application.

5. Essential barrier for solving the water resource problems

Above mentioned 10 suggestions are stated as a brief summing-up of the results from different studies. Obviously, all researches have promoted the progress of the water resource management work and many of those suggestions have been realized to different degree, improving the water shortage situation and the environment quite a lot. However, as a whole the water resource shortage problem is far from its reasonable solution. The reason for that is firstly because of the complexity of the problem itself, and on the other hand, the fact that the country can not afford to realize such tremendous engineering projects like diverting water from the south to the north sooner. All of those factors are understandable, but they are not the essential barrier. People can do much better than what it is now, if such barrier did not exist. Recently, many learners both at home or in abroad start discussing the utmost importance of paying enough attention to the capability and infrastructural constructions of most areas where the water problems are serious. In the author's view, right this is the essential barrier or weakness for the plain and many other areas in China. It is true that many contents of the capability and infrastructural constructions have already been put forward in the above mentioned suggestions under different terminology. But we must be clearly aware that the capability and infrastructural constructions as a whole is a system work and scientific study itself. Only if relevant scientists of different specialties, including social scientists and economists, would jointly work out a realistic program and consciously do their best efforts to promote the program and to strengthen and enhance the constructions, the existing difficult water problem of the plain would not be solved (Fei, 1996).

Capability construction includes: conversation between scientists and decision makers in order to exchange views and to enhance the awareness on how to deal with the given problem; public education for the purpose to enhance the public consciousness in saving water and protecting environment; education and training for water problem related personnel in order to enhance their working ability.

Infrastructure construction includes: institutional construction, what mentioned above in suggestion 10 is some of its major contents, what is more is: such institutions should be of management character, and be separated from running relevant enterprises, it should be given enough administrative power to solve water problems without any interference from any other authorities, and so forth; legal constructions in the context of water related and environment related legislation constructions, which has already started not long ago, yet needs to be much more strengthened; hardware constructions, which should be regarded as a long accumulative process and be perfected step by step, depending upon the available sources and technology.

Obviously, the groundwater overexploitation problem and as a more general problem – water resource management problem of the North China Plain is a very difficult problem not only due to its technical difficulties, but mainly due to the complexity of involvement of social, economical, technical, scientific, and even political components. However, it is believed that final finally this problem will be solved, if we could start paying much more attention to the capability and infrastructural constructions together with developing all other possible scientific and technical progress.

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1. Climate Change and Hydrology

Water Circulation Rates in Urumqi and Turfan Areas, Western China, from the Viewpoint of Tritium

Koichi Kitaoka(*), Seiji Horiuchi(**), Maki Watanabe(3*), Setsuo Okuda(4*), Guijin Mu(5*) and Hongfei Zhou (5*)

* Beppu Geothermal Research Laboratory, Faculty of Science, Kyoto University
Noguchibaru, Beppu, Oita 874, Japan
Fax: +81-977-22-0965, Email: kitaoka@bep.vgs.kyoto-u.ac.jp

** Department of GeoSystem Sciences, Nihon University
3-25-40 Sakurajosui, Setagaya-ku, Tokyo 156, Japan

3* Faculty of Letters and Education, Ochanomizu University
2-1-1 Otsuka, Bunkyo-ku, Tokyo 112, Japan

4* Faculty of Science, Okayama University of Science
1-1 Ridai-cho, Okayama 700, Japan

5* Xinjian Institute of Geography, Chinese Academy of Sciences
40 South Beijing Road, Urumqi, Xinjian 830011, China

Abstract

Tritium concentrations are used to trace water circulation in Urumqi and Turfan areas in Xinjian, western China. Tritium analyses were made for 77 samples of river waters, groundwaters, spring waters, lake waters and glacier ice collected in summers in 1992 and 1994. The tritium concentrations in the waters are in a wide range from 0 to 125 TU. Tritium levels in precipitation in the area are over ten times as high as those at Tokyo. Groundwaters and spring waters in the flat regions are mainly derived from river waters originating in glacier regions. River waters contain more than 50% melt glacier in summer. Circulating meteoric water part in river water has spent a mean time of about 15 years in groundwater systems in the mountain regions. River waters take several ten years to pass the underground to most springs and wells in the flat regions, though some waters from wells and springs with low tritium content are corresponded to old river water more than 40 years ago. Taking into consideration for tritium enrichment by evaporation in closed and semi-closed lakes, the ratios of groundwater flow into salt lakes to precipitation are relatively small as against those in fresh water lakes.

1. Introduction

Urumqi and Turfan basins are situated in Xinjian, western China, extending for over 500 km^2 with several closed salt lakes. The area is essentially flat and semi-arid, surrounded by the lofty Tianshan Mountains with perpetual snow and glacier. The chemical characteristics of river water, spring water and lake water in the area have been investigated by Watanabe et al. (1995). The main sources of groundwater in the flat regions may be derived from rivers originating in perpetual snow and glacier regions, as the annual precipitation in the flat regions is less than 100 mm.

Tritium is created naturally in the upper atmosphere by the interaction of nitrogen with cosmic radiation, and is transported into groundwater systems by meteoric water. The tritium concentration in precipitation in many part of the world rose after a series of thermonuclear detonation tests in the 1950's, and by 1963 had reached a peak concentration two orders of magnitude above the previous natural level. The relatively short half-life (12.43 y) makes this isotope a valuable tracer of water movements occurring over time spans of a century or less. The tritium content of groundwater can thus give useful information on the circulation of water. In some cases, it is a good indicator of the residence time of water in the groundwater system.

Tritium concentrations are used to trace water circulation in the area. Water samples were collected from rivers, wells, springs and lakes in summers in 1992 and 1994. In 1986, tritium concentrations in precipitations, glacier, rivers, springs and groundwaters in this area were measured by the Chinese Academy of Sciences (Shi and Cai, 1989). The data for various types of water in 1986 will be compared with the new data from the hydrological viewpoint in the present paper.

2. Sampling and results

Samples of river water, groundwater, spring water and lake water in the area were taken twice, from 14 to 16 July in 1992 and from 27 June to 16 July in 1994. A total of 77 water samples (20 samples in 1992 and 57 in 1994) were collected for tritium and chemical analyses. The locations of sampling points are shown with sample numbers (or symbols for samples of 1992) in Figure 1.

Tritium analyses were made using the method of liquid scintillation counting. The accuracy of this counting procedure is 0.5 TU for tritium concentration lower than about 5 TU. The term TU (tritium unit) denotes the number of tritium atoms per 10^{18} atoms of hydrogen.

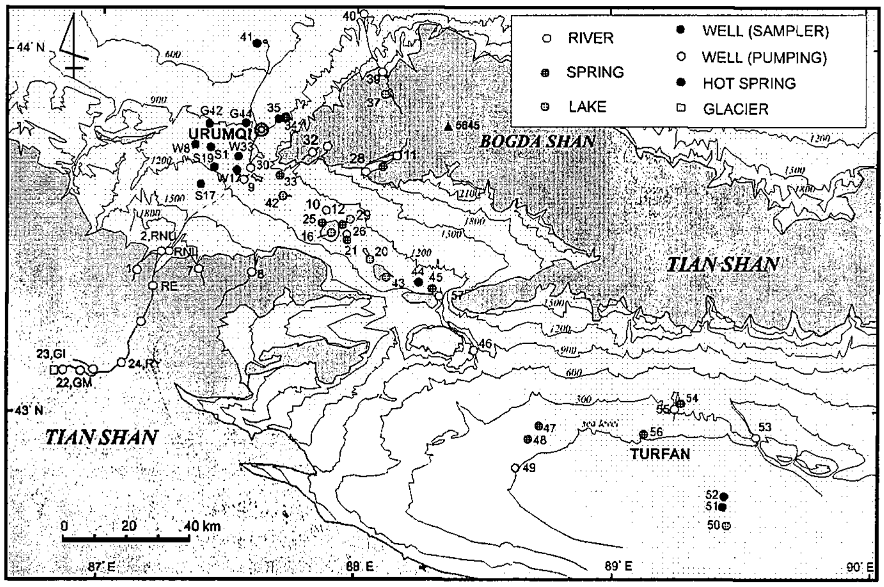


Fig. 1: Sampling points of river, spring, lake, well and glacier in Urumqi and Turfan areas in 1992 and 1994

The tritium concentrations in waters fall into a wide range of 0 to 125 TU. It is noted that the tritium concentration of Urumqi River water at the source point (at the glacier end: GM in Fig. 1) is nearly the same as those in the middle stream of the river (RY, RE and RNL), although the tritium concentration in glacier ice (GI) is very low. The tritium concentrations in Urumqi River water have a tendency to increase with distance toward downstream, and seem to decrease gradually with time during these eight years as a whole.

Most spring waters were relatively in low tritium concentration compared with river waters. Tritium concentrations in lake waters are worthy of note to be similar to those of river waters, although most lakes in the area are closed or semi-closed and salty. It is conspicuous that a series of great tritium concentration over 100 TU occurred in many groundwaters collected from wells in Urumqi City in 1992, though very low tritium contents were in some groundwaters around there. A big spring (No.45), located near the water divide between Urumqi and Turfan basins, discharged also high tritium waters in 1994.

3. Estimation of tritium concentration in precipitation in the area

Interpretation of tritium concentrations measured in natural waters requires an estimation of the natural variation of tritium concentration in precipitation in the area. IAEA World Survey Network Stations monitor tritium concentration in monthly precipitation at many points in Eurasia. Monitoring at Tokyo started in 1961 by IAEA, and from 1980 onward, has been made for monthly precipitation at Chiba just near Tokyo by National Institute of Radiological Sciences.

There are correlations in the annual means among stations in the Northern Hemisphere. Then the annual means of tritium concentration at Tokyo before 1960 can be estimated by using Ottawa record. Even at a station with a short observation period, the annual means in precipitation at the station for other periods can be estimated using a regression line obtained by a correlation with those at Tokyo.

The distribution of annual mean of tritium concentration in precipitation in Eurasia obtained in this manner is shown in Figure 2. Number indicated in the Figure denotes a factor to be multiplied by the annual mean at Tokyo. The factor will be represented by a symbol M. At Urumqi, the measured values of tritium concentration for 4 precipitations in 1986 by Shi and Cai (1989) were 105.7, 56.5, 108.0 and 84.2 TU, whose average corresponds to a factor M of 12.5 as against the annual mean of 1986 at Tokyo. Although the period and number of precipitation data measured at Urumqi are not sufficient at all to take correlation with those at Tokyo, the factor is the only instance. The value of this factor is not inconsistent with the general distribution in the central part of Eurasia.

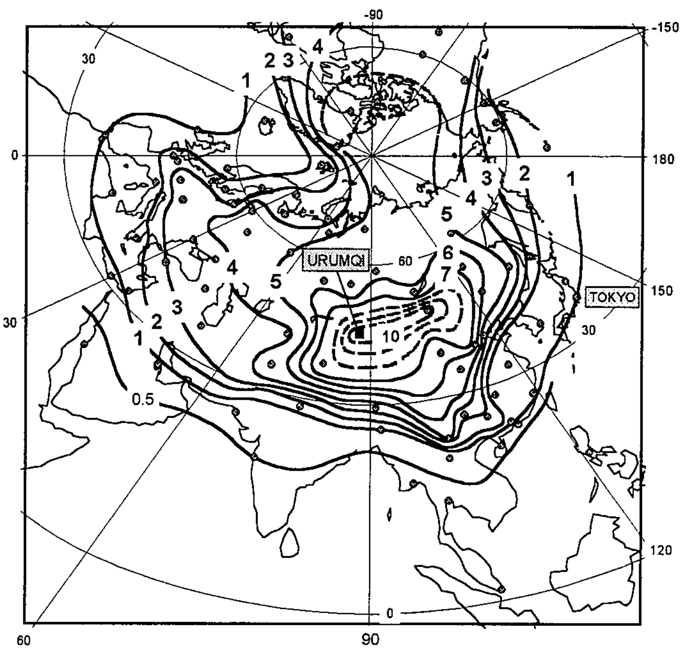


Fig. 2: Distribution of annual mean tritium concentration in precipitation in Eurasia. Figure denotes a factor (M) to be multiplied by the annual mean at Tokyo. That is, M=1 at Tokyo.

4. Effect of evaporation to tritium concentration in lake water

A lake water sample collected from Ayding Lake (No. 50 in Fig. 1) in 1994 was in great tritium concentration (47.9 TU). The site for collecting the water sample was in the muddy swamp. Water sampled was saturated with salt in puddle. Groundwaters from wells (No.51 and 52) near the sampling point of the lake were in low tritium concentration (0.0 TU and 2.7 TU, respectively). Tritium in the lake water from the swamp seems to be enriched by evaporation of recent precipitations.

According to Craig and Gordon model (Gonfiantini, 1986), the isotopic fractionation factor is composed of an equilibrium separation factor between liquid and vapor at the surface, and a kinetic factor transporting vapor from the surface to the atmosphere. The relative vapor pressure of HTO to H_2O is 0.90 to 0.92 in a temperature range of 20 to 40 °C (Jacobs, 1968). As the equilibrium separation factor, which is the reciprocal of the relative vapor pressure, that is, 1.086 to 1.111, a value of 1.099 will be used. The kinetic factor, which is approximated to be proportional to the square root of the ratio of diffusion coefficients of H_2O to HTO in air, is estimated to be 1.016, if the relative humidity in the atmosphere is approximated to be zero because of the arid condition. After all, the fractionation factor α of tritium at the lake surface is estimated to be 1.116.

A water balance in a steady state for lakes with no inflow river can be expressed as:

$$\frac{dV}{dt} = Q_P + Q_G - Q_E = 0 \qquad (1)$$

where Q_P, Q_G and Q_E are precipitation, recharge rate by groundwater and evaporation rate. V is the water volume of lake, and t is time. If the water in a shallow lake is assumed to mix rapidly, the mass balance will be expressed as:

$$\frac{d(CV)}{dt} = C_P Q_P + C_G Q_G - C_E Q_E - \lambda(CV) \qquad (2)$$

where C is the tritium concentration in lake water, and λ is the radioactive decay constant of tritium (0.0558 y^{-1}). The total flow rate Q passing through the lake is equal to the evaporation rate Q_E for a closed lake. We will introduce here a parameter β defined as: $\beta = Q_P/Q$. The mean residence time of water (turnover time of water) in the lake can be defined as T=V/Q. By combining (1) and (2) equations, we get the differential equation for $C(t)$:

$$\frac{dC}{dt}+\left(\lambda+\frac{1}{\alpha T}\right)\cdot C=\frac{1}{T}\cdot\left[\beta\cdot C_P(t)+(1-\beta)\cdot C_G(t)\right] \tag{3}$$

where α is the fractionation factor: $\alpha = C/C_E$. The integration of equation (3) is

$$C(t)=\int_0^{\infty}\left[\beta\cdot C_P(t-\tau)+(1-\beta)\cdot C_G(t-\tau)\right]\cdot\frac{1}{T}\cdot\exp\left[-\left(\lambda+\frac{1}{\alpha T}\right)\tau\right]\cdot d\tau \tag{4}$$

For the Ayding Lake (No.50, in Fig. 1), the tritium concentration in groundwater C_G could be zero for the reason mentioned above. The residence time T of lake water might be less than a few years at longest in such the swamp condition. At first, we will estimate the lower limit of tritium concentration in precipitation by applying the above model to the data of lake water under the extreme condition of $\beta = 1$ (i.e., zero contribution of groundwater). As a result, we can confirm that the M–value must be greater than about 10 to satisfy the tritium data. A factor M of 12.5 obtained by averaging the precipitation data at Urumqi in 1986 is not inconsistent with this result. Although the number of precipitation data in this area are very limited, we will use reluctantly the factor M of 12.5 in this paper.

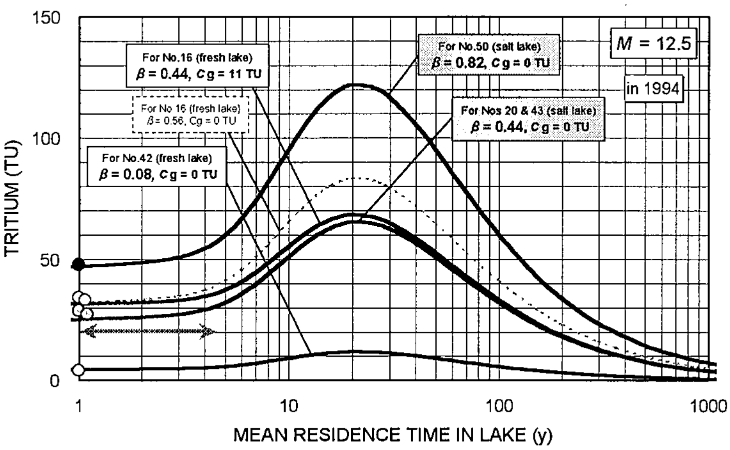


Fig. 3: Calculated relationships between tritium concentration in lake water influenced by evaporation and mean residence time of water in lake in 1994.

If the M-value of 12.5 is adopted as the input C_P (assuming $C_G = 0$), the best fit of β value for the Ayding Lake data is 0.82 (Fig. 3). For a small lake (No.42 in Fig. 1) whose water is fresh with low tritium concentration, small β value of 0.08 is estimated. For the salt lakes (No. 20 and 43 in Fig. 1) in the Urumqi basin, the estimated β-values are both about 0.44 (Fig. 3).

By the way, for the fresh water lake (Chaiwopu Lake: No.16 in Fig. 1), tritium concentrations in spring waters and groundwaters near the lake are relatively high (from 8.0 to 13.1 TU). If the tritium concentration of recharge groundwater is assumed to be 11 TU during these recent several years (the mean residence time may be less than 5 years), β of 0.44 is estimated (Fig. 3. As a reference shown by a dotted curve, if zero tritium content in the inflow groundwater is supposed, β-value is to be 0.56.). However, the β-value estimated on the lakes of No.16 and 20 should be recognized to be an upper limit, because these lakes are not closed completely (a little surface discharges from the lakes were observed in 1994 summer). As a whole, it seems that the ratio of direct precipitation to the total recharge of lake has a tendency to increase with salt concentration of lake water (Table 1).

Table 1: Tritium and chloride contents of lake waters, and the estimated ratios β of precipitation to total flow rates passing the lakes. Lakes of No.16 and 20 are not closed completely.

No.	Tritium (TU)	Cl (ppm)	β	Name of lake
42	4.2	45.6	0.08	Hongwei Lake
16	34.3	202.0	< 0.44	Chaiwopu Lake
20	28.9	3,700	< 0.44	Small Salt Lake
43	27.5	115,000	0.44	Large Salt Lake
50	47.9	100,000	0.82	Ayding Lake

5. Tritium concentration in river water

5.1 Modeling of tritium concentration in discharge water

To interpret the measured tritium concentrations in river waters, there is a need for model describing water behavior in the drainage region with respect to meteoric water infiltrated from the surface. The tritium-versus-depth profile (if obtained) in the unsaturated and saturated zones will reflect the time history of tritium concentration in the precipitation and the recharge rates. The infiltrating water is supposed to pass fast the unsaturated media because of its poor porosity.

For transport of tritium in a groundwater body, we will define the concentration C as the concentration averaged over the thickness of the aquifer along a cross-section. A discharge point, such as a spring or a pumped well, can be regarded as a singular point at which various streamlines originating in the related recharge area are concentrated in a steady state. The average tritium concentration of groundwater $C(t, x)$ at the horizontal distance x in the flow direction at time t can be expressed as (Kitaoka, 1988):

$$\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}=-\left(\lambda+\frac{1}{T}\right)C+\frac{C_R(t)\cdot r(t)}{T} \qquad (5)$$

where u is the pore water velocity averaged over the section, $C_R(t)$ is the tritium concentration in recharge water and $r(t)$ is the weighting factor for the recharge amount at time t. The parameter T is defined as: $T=nH/\varepsilon$, where n is the effective porosity, H is the thickness of groundwater and ε is the recharge rate per unit area. When the start of time t is put sufficiently long before the concerned point in time, the solution of the above differential equation does not depend on the initial value of concentration C and the pore water velocity u as long as T is uniform in the flow direction. The final solution is as follows:

$$C(t)=\int_0^\infty C_R(t-\tau)\cdot r(t-\tau)\cdot\frac{1}{T}\cdot\exp\left[-\left(\lambda+\frac{1}{T}\right)\tau\right]\cdot d\tau \qquad (6)$$

Tritium concentration $C(t)$, averaged over a cross-section of the aquifer, can be approximated by an exponential distribution of residence times of water in the aquifer. From the theory, it can be seen that the average tritium concentration $C(t)$ does not depend on the horizontal position if T is uniform. The mean residence time T is represented by the water volume nH stored in a column of unit area divided by the recharge rate ε per unit area. This is the same definition as so-called "turnover time" of a well-mixed reservoir system, because it denotes the ratio of the whole water volume V in an aquifer to the volume rate Q of water passing through the aquifer.

In order to apply the model, it will be assumed that the annual recharge amount to the groundwater system in the recharge region is constant every year. We will use the annual mean tritium concentrations of precipitation for $C_R(t)$, putting $r(t)=1$.

5.2 Output of the model

Figure 4 shows the calculated output curves using the exponential model, assuming instantaneous recharge of precipitation (as M = 12.5) to groundwater systems. All the tritium data fall into a range of outputs from the exponential model. Solid squares, which denote Urumqi River, show to be corresponded "apparently" to the residence time of 150 to 200 y. Most river waters fall into a range between 50 y and 300 y. These apparent

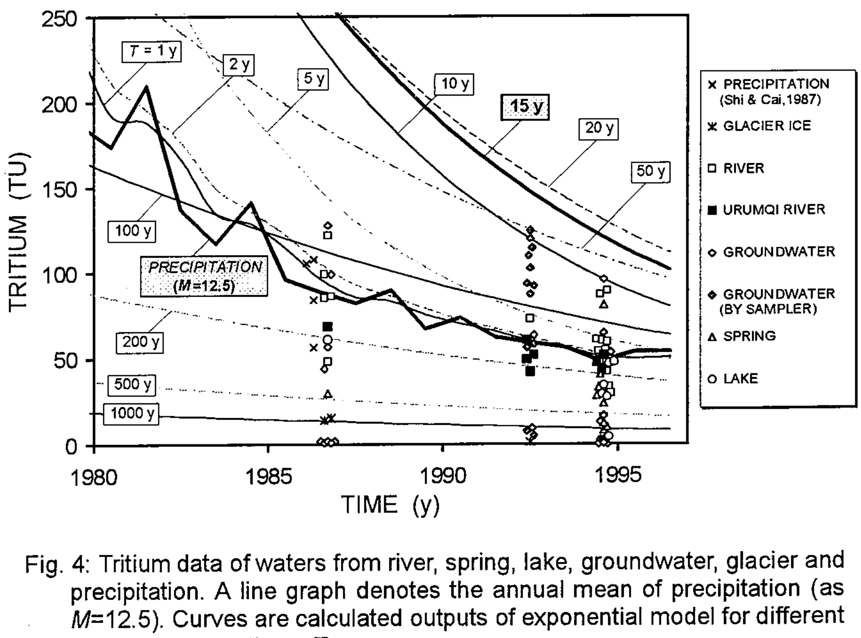


Fig. 4: Tritium data of waters from river, spring, lake, groundwater, glacier and precipitation. A line graph denotes the annual mean of precipitation (as M=12.5). Curves are calculated outputs of exponential model for different mean residence times T.

residence times of water seem too long.

5.3 Runoff of melt glacier

The high-water season of rivers in the area is in high-air-temperature periods. This suggests that the river waters in summer contain melt snow and ice from mountain areas. The melt glacier may be tritium-free water precipitated a great while ago. It will be assumed that river water can be separated into two parts: discharges from circulating water including melt from newly deposited snow, and discharges from melt glacier originated from very old precipitations. Here, we will call the former as meteoric water and the latter as glacier ice, for the convenience of simplicity.

If the tritium content of glacier ice is assumed to be zero, and that of precipitation is prescribed as $M = 12.5$, we can estimate the proportion of meteoric water to river water for the measured tritium data of river water by using the exponential model. That is, the proportions of meteoric water to river water can be estimated by dividing the measured tritium concentration by the output concentration of the exponential model due to the direct input of the prescribed precipitation for various residence times at the concerned time of data. In Figure 5, the calculated proportions of meteoric water to river water are shown by thin curves (solid, dotted and broken curves) for 8 tritium data of Urumqi River water collected in 1986, 1992, and 1994.

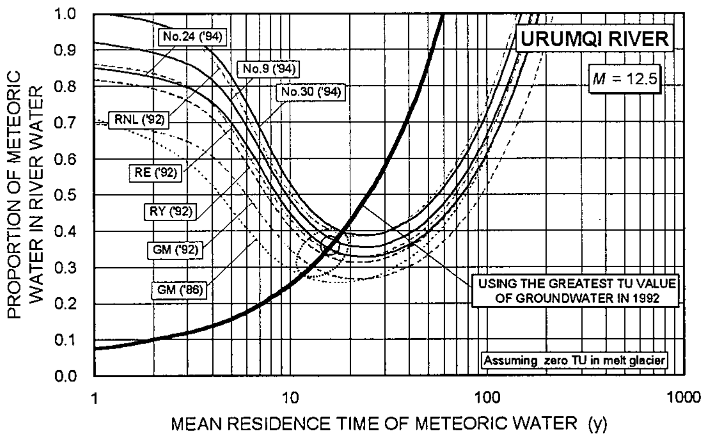


Fig. 5: Meteoric water proportion to river water versus mean residence time calculated by using exponential model and measured data for Urumqi River water. Also shown a bold curve by using the greatest TU value of groundwater in a well in 1992. These calculations are based on the assumption of no tritium content in melt glacier.

On the other hand, the groundwaters from wells in Urumqi City in 1992 were in high tritium concentration, as mentioned above. The main source of the groundwaters is considered to be river water from the Urumqi River, because the infiltration from the ground surface in the flat region must not be predominant in the arid environment, even though irrigation canals are dispersed in the flat region. It is likely that such the groundwaters in high concentration were derived from Urumqi River when the river water had been in high tritium levels in the past. We will assume here that the highest concentration (124.8 TU in 1992) of the groundwaters corresponded to the highest concentration of the river water in the past. Using this highest concentration of groundwater, we can estimate the proportion of meteoric water to the water for various residence times of meteoric water. A bold curve in Figure 5 indicates the proportion of meteoric water to river water with respect to this highest concentration of groundwater in 1992.

Thus, we can obtain the relations between the meteoric water contribution to river water and the mean residence time of meteoric water, in two different ways. Using Figure 5, the meteoric water proportions to river water could be obtained to satisfy both the relations estimated by the two independent ways. As the result, the mean residence times of meteoric water increase from about 11 to 18 y with the proportion of meteoric water to river water from 0.27 to 0.4. The meteoric water proportions seem to have a tendency to increase with distance toward downstream from the original point at glacier end. Using the tritium data in the middle stream, the proportion of meteoric water to river water is about 0.35 (i.e., 0.65 proportion of melt glacier to river water), and the mean residence time of the meteoric water part is about 15 y, as indicated in Figure 5.

The mean residence time of 15 y for meteoric water inferred from the tritium concentrations in Urumqi River water may reflect hydrologic states over a wide area of the recharge regions including perpetual snow and glacier regions. Let's suppose a tentative hydrologic condition such as the annual recharge (ε) of 400 mm per unit area to the groundwater systems in the recharge regions. Then, the mean residence time of 15 y (T) corresponds to a water volume of 6 m per unit area ($nH= \varepsilon T$, a height of water column). The water volume for the groundwater flow system could correspond to a vertical range of 300 m to 3,000 m, if the effective porosity (n) in the rock formations is assumed to be in a range of 0.02 to 0.002 in the mountain region. Even such the rough calculation does not seem to provide so unrealistic vertical range of groundwater flow for the lofty Tianshan Mountains.

6. Contribution of melt glacier to river water

A thin solid curve in Figure 6 is the output of meteoric water with 15 y mean residence time. A bold curve in the Figure denotes the estimate for the discharge with 0.35 proportion of 15 y meteoric water to river water. This bold curve is calculated for the Urumqi River water in summer. The data of the river water collected in summers are plotted by solid squares.

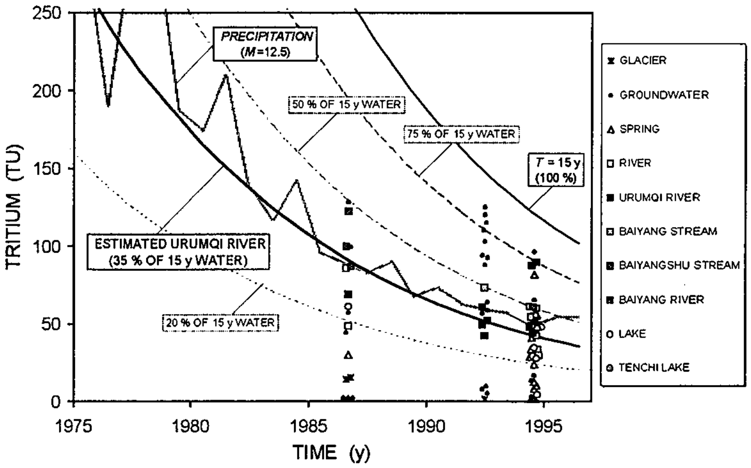
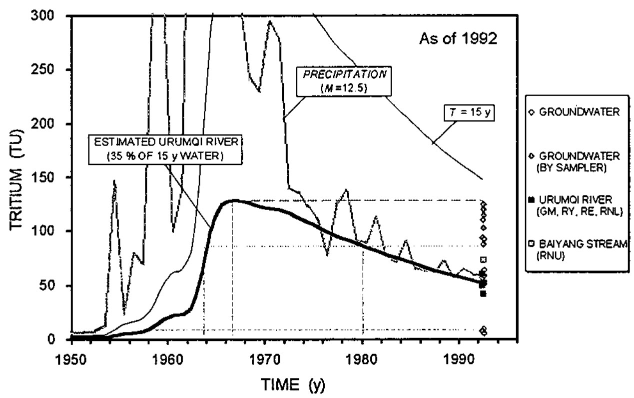


Fig. 6: Variations of tritium concentrations estimated for river waters. Plots are tritium data for various types of water. A thin solid curve represents the output of meteoric water from a system of 15 y mean residence time due to direct input of precipitation. A thick curve is the estimate for Urumqi River assuming to contain 65 % melt glacier of no tritium. Dotted and broken curves are 20, 50, 75 % content of 15 y meteoric water.

On the other hand, Sangong River (No. 37, 39 and 40 in Fig. 1), which also originates in glacier regions in the lofty Bogda Shan, are in similar tritium values as those of the Urumqi River. Tenchi Lake (No. 37) located in the upper-reach of the river shows the same value of tritium concentration to the river water in the lower-reach. Both the mean residence time of meteoric water and the proportion of meteoric water to river water for Sangong River are similar to those for Urumqi River.



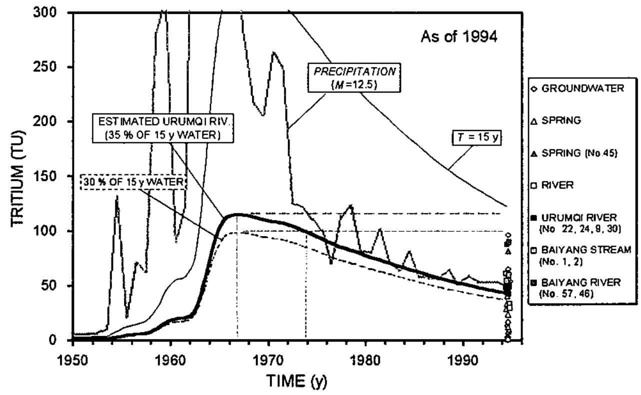


Fig. 7 and 8: Tritium concentrations as of 1992 and 1994, respectively. Plots are measured data in 1992 and 1994, respectively. Thin curve is the output of meteoric water from a system of 15 y residence time. Bold curve is the estimate for Urumqi River water assuming to contain 65 % melt glacier of no tritium.

Bold curves in Figure 7 and 8 show the variation of tritium concentration of river water calculated under the meteoric water proportion of 0.35 to river water. All the TU values of precipitations and calculated curves are converted as of 1992 and 1994, respectively, by radioactive decay, to be compared with data. The data of Urumqi River are shown by solid squares.

The highest TU value (96.2 TU) in 1994, which was of groundwater from a well (No. 49) located in western part of Turfan basin, could correspond to the peak of the estimate calculated under 0.3 proportion of meteoric water to recharge water, as shown in Figure 8. The proportion of meteoric water is similar to that of Urumqi River. The relatively high tritium concentrations in 1994 for the spring water (81.4 TU) of No. 45 and the river waters (89.4 TU and 87.2 TU at No. 46 and 57, respectively) originated from this spring correspond apparently to a high meteoric water proportion of about 0.7 (Fig. 6), as the spring water may be supplied by underground stream from the Bogda Shan Mountains. If the river water in the upper reach contains 15 y meteoric water and its proportion to river water is similar to that of Urumqi River, the river water must have taken about 15 to 30 y to pass the underground to the spring (Fig. 8).

Most river waters contain meteoric water in a proportion range of 0.2 to 0.5 (Fig. 6). For rivers originating in relatively small altitudes in mountains (compared with Urumqi River) such as Baiyang stream (No. 1, 2) and Baiyangshu stream (No. 11, 28), it is noticed that the proportions of meteoric water to river are relatively large as compared with that of Urumqi River. This may suggest the difference of relative contribution of melt glacier to river waters. In these circumstances, tritium contents in river waters in the area are substantially influenced by melt glacier, and may depend on the areal proportion of glacier in the upper part of the drainage basin.

The travel time of the underground stream water from the end of river to an observation point, such as a well or a spring, can be estimated by using Figure 7 or Figure 8. Tritium concentrations of most spring waters are corresponded to around 30 y of age, though some of spring waters are corresponded to about 10 y, or more than 30 y. Most groundwaters of relatively high tritium content may have traveled under the ground for a range of 12 to 28 y. Groundwaters in very low tritium concentration are corresponded to the river water more than 40 years ago. The main source of underground water in the foothills and the flat regions can thus be considered to be river water, and to contain predominantly melt glacier in summer.

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Preliminary Research on the Response of Regimen to Climate Changes in Tibet Plateau

Liu Tianchou (*) and Zhao Chunian (**)

* Tibet Survey Bureau of Hydrology and Water Resource, Lhasa, China
** National Natural Science Foundation of China, Beijing, China

Abstract:

This article talks about the long- term series of temperature, precipitation, lakes, and river runoff according to observation materials. The results show: the temperature increases and the increasing range in winter (October-March) is more than in Summer (June- September) ; the water level of inland lakes descends; the precipitation and river runoff change according to regions and they usually decrease in both northwest of Tibet and inside Tibet.

Keywords: Tibet Plateau, temperature, water level of lakes, runoff

1. The Besic Characteristic of Hydrology

Tibet Plateau, with an area of about 1,200,000km^2 and an average elevation of over 4,500m, is the main part of Qingzang Plateau, many important rivers such as the Yangtze River, Nujiang River, Salween River, Lancang River-Mekong River, Yarlung Zangbo River -Brahmaputra River, Indian River and Irrawaddy River all originate from or pass Tibet(Fig.1).

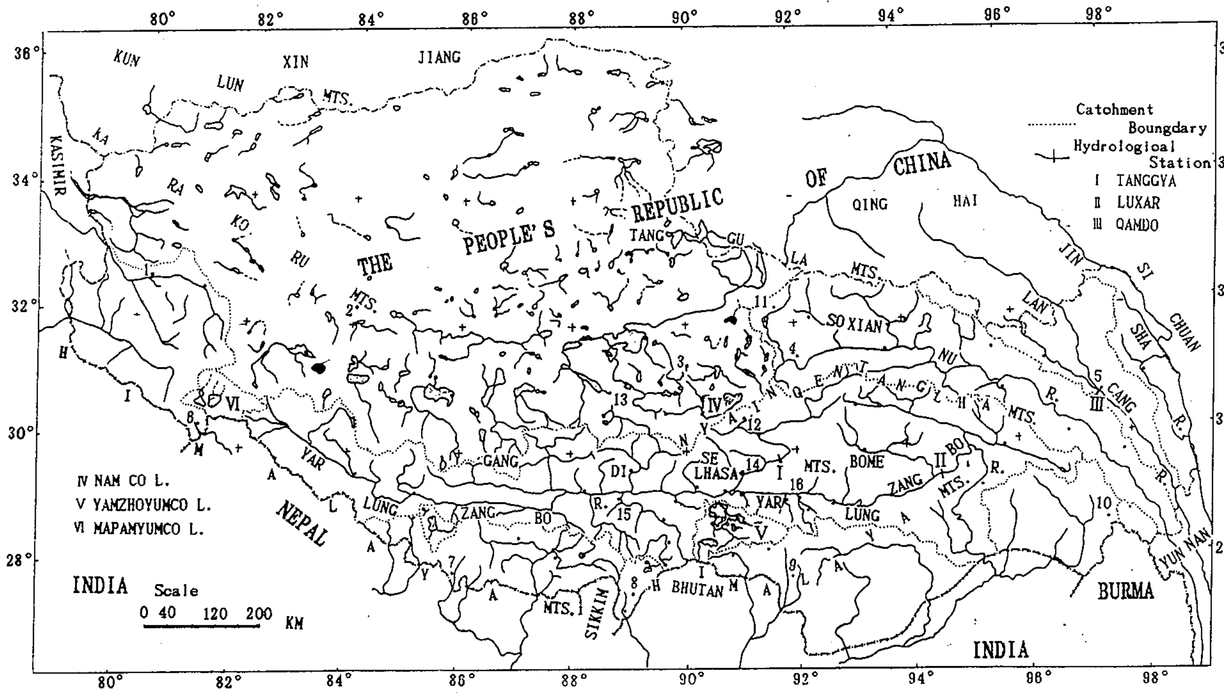

Fig. 1 The Water System in Tibet Plateau

There are more than 20 rivers with drainage area of more than 10, 000km^2 within the boundaries, including the longest one-Yarlung Zangbo River, which is 2,229km's long. It's estimated that the river runoff in Tibet Plateau is 448.2 billion m^3, The waterpower resource reserves in terms of cheory are morn than 0.2 billion kilowatt, and a hundred million kilowatt with able to open up the resources, which is one of the most plentiful province in the water reseurces and waterpower reseurces in the whole country.

The lakes on Tibet Plateau scatter all over like stars in the sky or men on a chessboard, whose area is about 1/3 of the total lake areas in China, among which there are seven lakes,each has an area of more than 500km ^{2}, and three lakes each has an area of more than 1,000km^2. Namco lake, with an area of 1,960km^2, has the highest elevation in the world. 98 percent of the lakes are inland lakes, while the outflow lakes are dotted over the outflow rivers in south Tibet and southeast Tibet and the areas are very small. Most of the inland lakes are saltwater lake. in a few freshwater lakes of the plateau, Mapam Yumco lake, with an elevation of 4,588m,is the second big freshwater lake in China.

Glacier in Tibet is 46. 7 % of the total glacier area in China. Nyainqentangcha Mountains is the concentrated distribution region of the marine glacier in China. 1,500 million m^3 glacier melts per year. The famous Qiaqing Glacier, has a length of 35 km and an area of 151.1 km^2. The continental glacier is mainly concentrated in Karakoru Mountains and the north of the Himalayas.The Rongpu Glacier, situated in the north of Mount Qomolangma, is the longest glacier of the region, which has a length of 22.2 km and an area of 86.9 km^2. The water resource of Tibetan glacier is 60% of the total in China and is the main supply to lakes and rivers. The temperature change has direct affect on the melt and growth of glaciers.

2. The Temperature and the Hydrologic Situation of Lakes, Glacier and Rivers

2.1 Temperature Change

Recently, many researches on the temperature of Tibet have been carried on. Dr. Yao, Tandong points out:"Tibet Plateau has an obvious tendency of getting warmer in recent decades.The temperature increases not only obviously higher than other areas, but also than it was. Guliya icecap is the most serious."(Yao)

We agree with Mr. Yao's opinion and further more we have done more research on space-time Change.

Temperature is not only a very important factor of climate, but also a main index that reflects the material balance of glacier.

According to observing temperature data at about 30 stations, 10 - year running average temperature was calculated at the typical stations selected(Table 1).

Table 1. Table for Timely Average Temperature Divergence of Typical Stations

District	Station		T Divergence(℃)		District	Station		T Divergence(℃)	
	No.	Name	ΔT_1	ΔT_2		No.	Name	ΔT_1	ΔT_2
From west to east along the line of 32° north latitude	1	Shiquanhe	-0.2	0.3	From north to south along the line of 91° 、89° east longitude	11	Amdo	0.4	0.1
	2	Gerze		-0.1		12	Damxung	0.6	0.2
	3	Pangkog	0.4	0.4		13	Xainza	0.4	0.2
	4	Nagqu	0.7	0.3		14	Lhasa	0.5	0.3
	5	Qamdo	0.1	0.1		15	Xigaze	0.3	0.2
From north-west to south-east along Himalayas	1	Shiquanhe	-0.2	0.3		16	Zetang	0.1	0.5
	6	Burang		-0.1		8	Pagri	0.5	-0.1
	7	Nylam	0.1	-0.1					
	8	Pagri	0.5	-0.1					
	9	Conag	0.2	0.0					
	10	Zayu	0.3	0.0					

Table 1 shows that not only from west to east, or from north to south in the Plateau,but also along the foot of the Himalayas,the temperature has a increasing tendency. The range of temperature increase differs with the place. The increasing range per year is between 0.5℃ and 1.0℃ in the hinterlands of plateau, while in the south edge areas of Tibet Plateau along the Himalayas,the increasing range of temperature is lower than that in hinterlands. The temperature was almost not change from 1970 to 1980, some areas decreased.

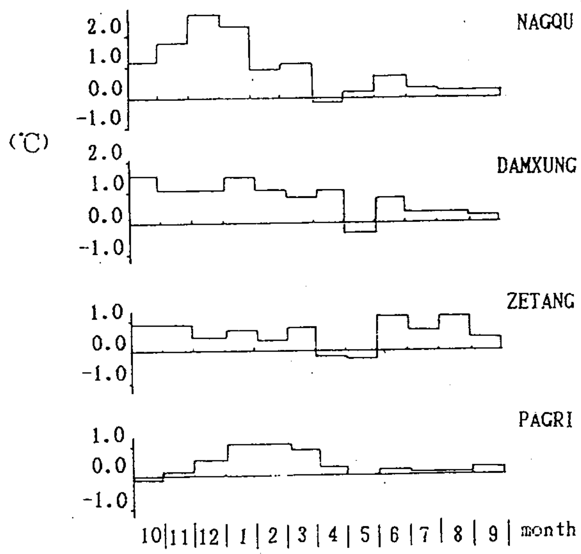

Fig. 2 Monthly Average Temperature Change in the Typical Stations

The increasing range of temperature is different in every month of a year (Figure 2) . The temperature increases mainly from Oct. to the winter (March) of the next year.For example: the average temperature per year in Naqqu increases 1.0℃ while in winter the temperature increases 1.7℃, it increases 0.8℃ and 1.2℃ in Damxung, The increasing range of tempe rature from June to September in summer is less than in winter. In the increasing process of tem perature in summer the highest temperature occurs in June which makes the melting speed of glaciers to accelerates. Wang.LinglLan points out that "The temperature change in summer has much effect on the increasing or decreasing of zero balance line of glaciers." The Yarlung River, a tributary of the Yarloug Zangbo River,which the source the YilarXangbo Glacier was collapsed in 1995. It was caused by the temperature rapid increases from the middle ten days May to the middle ten days June. It is also found that the average increasing range of temperature per year and per season is different with the distribution of regions. The range is showing an increases tendency from south to north in Tibef.The average increasing range of temperature per year is 0.4℃ in south Pagri, it increases 0. 6 ℃ in winter and less than 1.0℃ in DamXung, but it increases gradually to north, in Nagqu, the temperature increasas to 1.7℃. (Table 1. Figure 2.)

2.2 The Change of Precipitation

All kinds of water supplies in Tibet come from rain fall.The water vapor mainly comes from the warm airflow of the Bay of Bangal of Indian Ocean, which goes to the north and enters hinterlands of plateau by the obstruction of the Himalayas and loses very quickly. Gradient Regions of precipitation form from southeast to northwest and from south to north in plateau. The change of precipitation per year is very small and the distribution is very uneven.Most areas can be divided into dry and wet seasons. The precipitation from June to September each year is 70- 80 % of the precipitation of the whole year, especially in the middle of the Plateau the precipitation is over 90% .

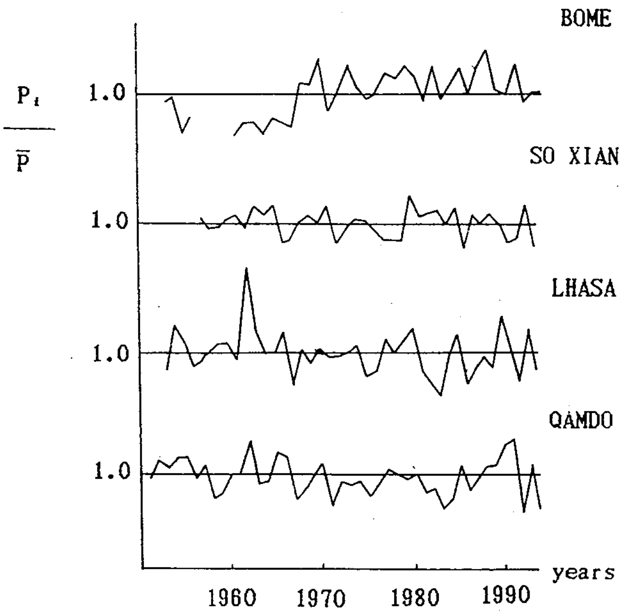

Fig. 3 The Process Line of Yearly Precipitation in the Typical Stations.

In figure 3, the vertical coordinate is designated by $P_i/\overline{P}$,P_i is the yearly precipitation, $\overline{P}$ is the average yearly precipitation of several years. To the southeast of Tibet east to Bome there is a small change in precipitation per year and the variation coefficient of yearly precipitation Cv is below 0.20. The precipitation in the 1960' was below the yearly average, while the precipitation from 70's to 80's increased to above average yearly amount.It seems that there was a little increasing tendency of precipitation; the variation coefficient Cv to the northeastern Tibet along, Sog Xian, is between 0. 20 and 0. 25. The precipitation has been fluctuating around the average of many years since 1950's. The limterlands of the plateau, Lhasa and Qamdo,the variation coefficient Cv is around 0.30. The yearly precipitation were larger than the average in most years before 1970,while after 1970 the precipitation of almost all the years at those stations was below the average.The precipitaion has been reduced by 3-5% in the recent 40 years. In the northwest of Tibet, precipitation in Shiquanhe is below 200mm and in hinterlands the precipitation is even less than 50mm. The variation coefficient is larger than 0.35. However,this factor was above average in 1970′s and below average after 1980′s.The precipitation has been reduced by 5% in recent 30 years.

2.3 Hydrologic Situation of Rivers

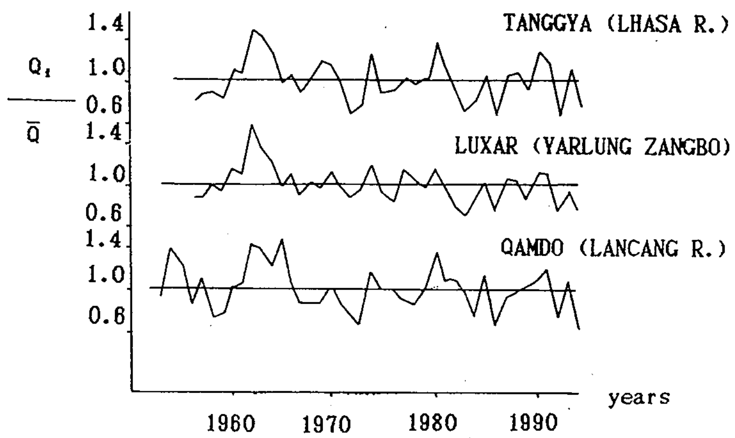

Fig. 4 **Flow Amount Process Line of Typical Station in Drainage Area**

This article only gives three control stations as an example, including the NuXiar Station in the middle reaches of Yarlung Zangbo River, the chomdo Station in the upper reaches of Lancang River and the Tanggya Station in the lower reaches of Lhasa River. In Fig4. the vertical coordinate flow amount process line is selected as $Qi/\overline{Q}$,Qi is the yearly runoff and $\overline{Q}$ is the yearly average runoff of many years. In order to show the change process of runoff has a decreasing tendency in receut 40 years, it reduced by 3-5% .

There are a lot of reasons which can cause the reduction of river flow amount,among which the climate changes and the human activities are the directest reasons. The drainage areas of the river stations from Fig 4. alomst be situated in the hinterlands of plateau, and the proportion of glacier areas make up quite small in the whole drainage areas. This is one region which the rising of temperature and the reduction of preciption.

The temperation increases and the melting speed of glaciers accelerates caused increasing the river runoff amount far less than the river runoff amount which the temperature increases,the evaporate increases and the condition of give and flow together in the surface is not good caused reducing. First, the reduction of precipition is the main reason, which cause the reduction of river ruaoff . Secoud, the increasing of irrigate water in farmland and pastureland also is a factor not to be ignored.

The Nyang Chu River is one of five tributaries of the YarlungZangbo River. On account of the increasing of irrigate water is the JiangZi, which catchment area is 6,200 km^2 Since 1980's, it happened to cut off the flow intermittently between April to May. The yearly runoff reduced by 20% . Some river sources and small tributaries even more like this.

2.4 The Change of Water Levels of Lakes

The outflow lakes of Tibet Plateau are mainly river's flow-in-and - out lakes, the water levels of lakes change with the water level of Rivers. The change of water levels of some moraine lakes is mainly influenced by the melt of ice and snow:When temperature increases, the melting speed of glaciers accelerates and more melting water flows into these lakes so that the water levels of lakes go up.

Inland lakes are sensitive to the climate change.This article puts much emphasis on the preliminary analysis of water level change of Yamzho Yumco, which is the biggest inland lake in the south of Tibet Plateau.

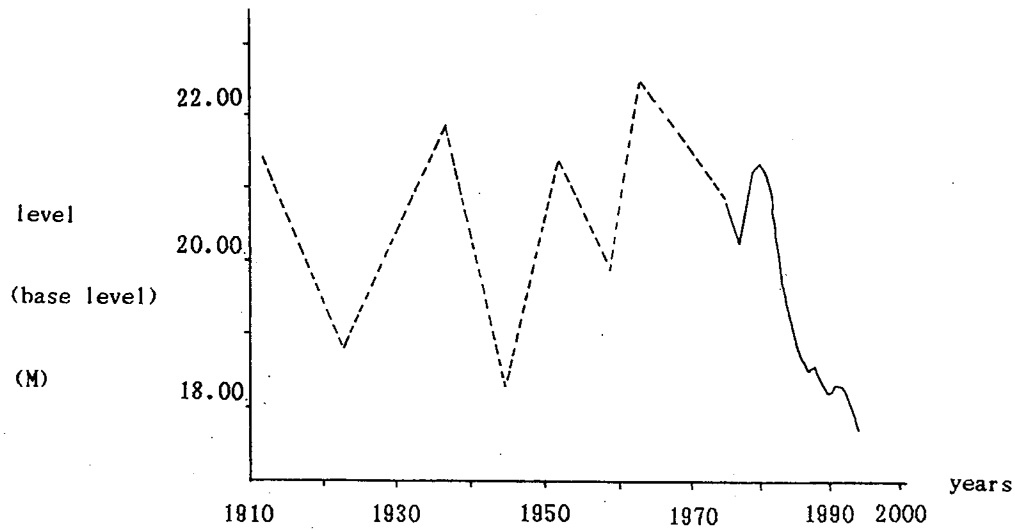

Fig.5 Water Level Process Line of Yamzho Yumco L.

Yamzho Yumco has a drainage area of 6,100km^2, a lake area of 631km^2 and a lake face elevation of 4,438m above the sea level.The precipitation of the drainage area is about 350mm and the average evaporation is 1,250mm. The yearly average temperature is 3.6℃. According to hydrologic record since 1974 and historical hydrologic survey, in recent 100 years the water level change alternates between rising period and falling period, but the whole tendency is descending, especially after 1970's because temperature increases and precipitation reduced, there was not enough water to flow into this lake; while with the influence of human activities from 1980's to 1990's (mainly caused by using lake water to irrigate the farm and pasture land), this problem became more serious. For example, CarLungXung Qu and GarMaLin Qu, which flow into Yamzho Yumco. CarLungXung Qu is the melting of snow and ice (the proportion of glacier areas make up 20% in the whole drainage areas); the yearly runoff charge is stable and the coefficient of modulus of the yearly runoff is 1.56; has no obvious change from the middle of 1970's to the middle of 1990's. The temperature increases, the melting speed of glaciers accelerates and the supply of river runoff increases to make up the decreasing of precipition. Garmalin Qu is no the melting of snow and ice and the influence of human astivities, which the coefficient of modulus of the yearly runoff is 7.72. The cause of draw water from the upper and middle reaches of the drainage to irrigate the pasture land has obvious increase in 1990's, the irrigation seasons (between April to June) per year happened to cut off the flow since 1991. When the Yamzho Yumco has the year of plenty of water in 1995, but Garmalin Qu still has cut off the flow for more than two monthes and the yearly runoff was below the 50% of normal amount.

Most of the inland lakes in plateau are in the period of declination; some which have plenty of water supply (such as the melting of snow and ice) such as Pomo Yumco and saltwater lakes, geren co、 Lanlang co all Mapam、 Yum co、Bangong co has no obvious change in water level.

3. Remarks and Conclusions

3. 1 The average temperature of Tibet Plateau increases and the increasing range of temperature in winter (Oct.-March) is more than that in Summer (June-September); the increasing amplitude increases from South to North.

3.2 In recent 40 years, the precipitation change increased in different regions in Tibet Plateau has been unbalanced. The precipitation in southeast of Tibet has an increasing tendency and has no obvious change in northeast of Tibet, while it has a decreasing tendency in northwest and center of Tibet Plateau and reduces by 3-5% of the yearly average amount.

3.3 The levels of many inland lakes are descending and the water area is shrinking.The water level of Yamzho Yumco has a descending tendency because of the reduction of precipitation and the influence of human activities.

3.4 The getting warm of climate has changed the environment of the whole world. Almost all the glacier flood and glacier mud- rock flow often occur in Tibet Plateau , which indicates the environmental effects caused by the increasing temperature . Restricted by the observation data and especially lack of long - term field observations, the understanding of this theme is quite preliminary, and needs to be carried on in the future.

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Existing Glaciers, Water resource and Climatic Environment Change in the Area of China Himalaya

Qin Dahe

(Lanzhou Institute of Glacialogy and Geocryology and the Bureau of Science and Technology for Resources and Environment,
Chinese Academy of Science)

Abstract

Himalayas, the huge mountain chains with 2400km long from east to west, is a great center of existing glaciation in lower latitudes of the earth, with about 50 high peaks in the height of over 7000m (a.s.l) and 10 peaks over 8000m(a.s.l). It is a natural barrier to stackle the humid air masses from the south Asian monsoon. Therefore, the scale of existing glaciers in the south slope is bigger than that in the north. For example, the equilibrium line of Kongbu Glacier in the north slope of Qomulongma reach to 5800-6000m a.s.l while down to 5500-5600m a.s.l in the south slope. The total area of existing glaciers in the whole mountain chains is about 3000Ckm^2 but only 11055km^2 in China territory and mainly scattered on the several high peaks. In the 5000km^2 Qomulongma, scattering 4 Peaks over 8000m a.s.l and 38 peaks over 7000m a.s.l, the total glacial area is about 1600km^2 by the calculated in 1:100,000 topography published in UK in 1951, of which 772.32km^2 is scattered in the north slope, 685km^2 in the south slope, and 100km^2 in the west part of Qomulongma area.

Glacial meltwater is important part of water resource in West China. The total runoff discharge of glacial meltwater in China can reach to 560 x 10^{8}m^3/a. Water storage of glaciers in Qomulongma area is up to 1326.02 x 10^{9}m^3. The special character of glacial meltwater runoff changes is depending on the climate changes. In the rain-rich years, temperature in mountainous region is lower and limits glacial melt, which is resulted in the smaller contribution of glacial meltwater runoff to rivers. On the contrary, contribution of glacial meltwater runoff to river is lager and the discharge of river runoff is increase. Changes of glacial water resource directly reflect the cases of climate fluctuation. In general, changes of most glaciers in Himalayas showed the retreat trend in the last ten decades, reflecting the global climate warming. Meanwhile some different cases also existed in different areas. The end of Rounbu Glacier on the north slope of Qomulongma located on the same position from 20's to 70's of this century. But thickness of the glaciers was thinning clearly. In the period of megathermal(6000-3000 a.B.P), mean annual temperature was 2°C higher than present, and the end of Rounbu glacier was 700m higher than present.

Sensitivity of Forest Growth Rate to Temperature and Precipitation Change in Taihang Mountains

[1]Yonghui Yang, [2]Jianwen Zhai, and [1]Zhiping Wang

[1]*Shijiazhuang Institute of Agricultural Modernization of the Chinese Academy of Sciences, Shijiazhuang, 050021, P.R.China.*
[2]*Department of Forestry in Hebei Province, Shijiazhuang, 050051, P.R.China.*

Abstract

An attempt was made to assess the effect of increase in mean annual temperature and precipitation on forest growth rate. By analyzing data from 77 meteorological stations and 721 forest sample plots in different faces of Taihang Mountain, it was approved, through regression, that there was a good relationship between temperature and forest growing stock in the whole Taihang Mountain. And furthermore, the effect of temperature on forest growing stock in different faces represented by Shanxi Province in the northwest slope of the whole Taihang Mountain, which run from southwest to northeast, and Hebei Province in the southeast face was analyzed. The result suggested that, in Shanxi Province, 1°C of temperature increase could result in 3.8 m^3 decrease in forest growing stock. But in Hebei Province, 1°C of temperature increase could result in 6.88 to 8.68 m^3/ha of decrease in forest growing stock for 23 year's old forest averagely. The relationship between precipitation and forest growing stock was not very certain since the unevenly distribution of rainfall in this region.

Key Words Temperature, Precipitation, Forest Growing Stock, Taihang Mountain.

1. Introduction

Temperature is one of the most important components for forest. The variation of Taihang Mountain, which span an area of 6° in north latitude and about 2500 m in elevation, creates a big difference in temperature. According to the meteorological records from 77 meteorological stations in Taihang Mountain, temperature varies from -4.1 °C in Wutai of Shanxi Province to 14.9 °C in Jiaozuo of Henan Province. This could result in a big difference in forest growth rate. But throughout 50's study after the establishment of the People's Republic of China, hardly has any study been done on this aspect. In forest, change in elevation was considered as an important factor for site classification but not temperature directly[2]. The temperature difference created by latitude change was ignored. Actually, according to site classification in 1989, Taihang mountain was treated as four different regions for afforestation such as mountains in Hebei, Mountains in Shanxi, Mountains in North part of Taihang Mountains, which refers to area with elevation more than 1500m, and Mountains in South part, which refers to area in Henan Province. These regions were mainly distinguished by administrative territory and change in elevation. Inside of each type, although temperature changes about 5°C from south to north, and temperature decreases about 3 to 4°C, sites were classified by face of slope, soil thickness, microtopography, and elevation. No temperature factor was considered.
Throughout the world, the relationship between temperature and biomass was widely discussed. A world recognized map[1] describes the generally relationship between temperature and

precipitation and vegetation type change. John Grace(1988)[3] studied the effect of temperature on plant productivity and pointed out that temperature is a very critical factor for the productivity of plants in England where temperature was a limited factor for the growth of plants. It was concluded that when temperature increase 1°C, the productivity could increase by 10%. Yang(1997) demonstrated a 1.5 to 1.9 times increase in biomass after transfer plant cores down to 800 m which result in a temperature difference of 5°C in north in England. The condition in Taihang Mountain is quiet different in climatic factors to the con dition in England. It is well known that the vegetation type in Taihang Mountain is mainly limited by the low precipitation and drought condition. Therefore, it is no doubt the increase in temperature will raise the evapotranspiration and results in a more serious drought condition which will act on the growth rate of trees. As Taihang Mountain already located at the transition zone of sparse forest, shrub, and grassland in terms of the generally relationship between temperature, precipitation and vegetation distribution in that map[1]. Therefore it is interesting to find out how big the effect of temperature increase on forest growth rate will be? This can also reflect the trend of forest under global warming.

2. Variation of Temperature and Rainfall in Taihang Mountain

The relationship between temperature and elevation has been well recognized. Generally, when elevation raise 100 meter, temperature will decrease 0.4-0.7°C. But the relationship between temperature and elevation has been hardly studied. In Taihang Mountain, the relationship between precipitation and elevation has been noticed that when elevation increase precipitation will increase, when elevation reach a certain level, precipitation will start to drop. An attempt was made to testify the correlation between these two climatic factors with latitude and elevation by collecting data from 77 meteorological stations all over the Taihang Mountain from 34°42′ to 39°59′ north latitude. The correlation between latitude and elevation and temperature was expressed by the following equation:

$$T=15.4-0.62\times(L-34.7)-0.52\times(H/100) \quad r^2=0.91 \quad n=74 \qquad (1)$$

Where, T=average annual temperature, L=degree of north latitude, H=elevation in meter.
The correlation of precipitation with latitude and elevation did not show any significant relationship. Therefore, it was hard to predict any precipitation change by means of elevation change.

3. Variation of forest growth rate and in relation to temperature and precipitation change.

In order to develop the relationship between temperature, precipitation and forest growth rate. Data from 721 sample plots from Shanxi Province, Hebei Province and Beijing was analyzed.

3.1 Relationship between temperature, precipitation and forest growing stock in Taihang Mountain.

Firstly, data of forest investigation including 721 sample plots from Shanxi Province, Hebei Province, and Beijing was collected and collated. Base on the location and elevation of sample plots, temperature in different sample plots was calculated according to equation 1 and meteorological data from nearby meteorological station. Since there was not any relationship between elevation and precipitation, precipitation from nearby meteorological stations was recognized as the precipitation of the sample plots. Next, straightforward linear regression between temperature and growing stock was established to estimate the effect of temperature on growing stock. But just as what was concluded by Leith(1972)[5] in trying to regress the relationship of productivity and temperature, accurate field measurements of net primary productivity were notoriously difficult to achieve because sampling problems. The R squared was only 0.23 which suggested exactly no correlation between temperature and growing stock. This was very reasonable since many factors such as face of slopes, location such as valley, slope, soil thickness, precipitation, age of new planted forest, could result in big or small influence on growing stock. In order to decrease the influence of different factors on growing stock of different sample plots, data with different temperature was divided into different groups to achieve an average result to compromise the variation caused by different factors. Since the sample plots in different groups were not evenly distributed, sampling data listed in Table 1 were grouped by every 2°C of temperature change.

Table 1. Forest investigation data grouped by different temperature intervals.

temperature interval °C	growing stock (m^3)	average height of tree(m)	average WHD (cm)	precipi-tation (mm)	age (a)	direction of slope*	soil thickness (cm)	sampling number
0-1.9	80.25	8.63	11.08	436	23.3	5.79	48	61
2-3.9	67.12	7.73	9.44	527	18.8	5.56	49	32
4-5.9	96.2	7.89	12.38	586	23.6	4.59	60	38
6-7.9	48.6	5.97	9.43	618	24.4	4.30	60	133
8-9.9	44.48	6.78	9.08	588	22.1	4.30	51	244
10-11.9	39.67	6.27	8.86	582	24.3	4.63	48	167
12-13.9	34.02	6.59	7.06	534	15.5	2.32	50	18

*In this investigation, direction of slopes was divided by 8. 1 direction means southeast(SE), 2 means south and other direction follow that way. 8 means NE. So the average of 8 directions is 4.5. If the number of average direction is lower than 4.5, there will be more sample plots in south direction otherwise there will be more sample plots in north face.

On basis of table 1, the correlation between temperature, precipitation, direction of slopes and forest growing stock was established. The best correlation lineal was expressed in the following way:

$$V=104.02+P\times0.066-T\times6.62-D\times7.88 \qquad r^2=0.72 \qquad (1)$$

Where, V=growing stock, P=precipitation, T=temperature, D=direction of slopes.

The above equation suggested that for every 1°C of change in mean annual temperature, forest growing stock would decrease 6.62 m^3, if precipitation raise 100mm, forest growing stock would increase 6.6 m^3. This model illustrated the relationship between temperature, precipitation and forest growing stock in the special region with an annual precipitation varying from 500 to 600 and mean air temperature spanning from 0 to 13°C. However, the coefficient of precipitation may not be the truth, as 500mm of precipitation is right the transition area of sparse forest to shrub and grassland, even little change in precipitation may caused a big difference in vegetation type.

Generally speaking, there is a significant difference between the condition of Shanxi, which represents the northwest slope of the whole Taihang mountain, which run from southwest to northeast, and the condition of Hebei, Henan and Beijing, which located in the southeast slope of the whole Taihang Mountain. In Shanxi, slope is generally in northwest direction and gentle, and soil thickness is generally evenly distributed. In Hebei, slope is generally in southwest direction and steep, and the soil thickness is very variable. Therefore, it is necessary to look at the relationship between two climatic factors, temperature and precipitation, and forest growing stock in different condition.

3.2 The relationship between temperature, precipitation and forest growing stock in southeast slope of Taihang Mountain.

The data of 273 sample plots from Hebei Province and Beijing, which are very near each other and represent the southeast slope of Taihang Mountain, was collected and collated by means of the same analysis method as in 3.1. Compared to the whole Taihang mountain, temperature in the east slope change only from 6°C to 13°C. By dividing temperate data into different groups, table 2 is obtained.

Table 2. Forest investigation data grouped by different temperature intervals in east slope of Taihang Mountain.

temperature interval °C	growing stock (m^3)	precipi-tation (mm)	age (a)	direction of slope	soil thickness (cm)	sampling number
6-6.9	67.98	557	22.4	4.2	73.7	23
7-7.9	50.28	542	21.8	3.9	59.5	34
8-8.9	45.41	553	23.7	4.4	49.3	26
9-9.9	44.1	572	24.8	4.1	45.1	75
10-10.9	36.52	570	22.1	4.3	47.6	58
11-11.9	32.85	595	24.3	4.2	41.4	37
12-12.9	18.39	568	23.5	4.6	38.3	19

The best correlation between temperature, precipitation and forest growing stock was expressed as the following equation:

$$V=107.5-T\times 6.88 \qquad r^2=0.94 \qquad (2)$$

$$V=-74.5+P\times 0.30-T\times 8.68+St\times 0.26 \qquad r^2=0.99 \qquad (3)$$

From this two equations, it is obvious that the correlation between temperature, precipitation and growing stock is strongly related. When temperature increase 1°C, forest growing stock decrease 6.88 to 8.68 m^3/ha, for 23 year's forest averagely, which is roughly about 10%. And for every 100mm increase in precipitation, growing stock increase 32 m^3/ha for averagely 23 year's forest, which is about 41%. These equation suggest 500 to 600mm of precipitation is very critical for forest when temperature varying from 6 to 13°C. But equation 3 may not correctly reflect the relationship between soil thickness and forest growing stock. The effect of soil thickness could be higher as in Taihang Mountain soil thickness always limited the growth of tree especially when soil thickness is less than 30cm. It is suspected that the relationship between soil thickness and forest growing stock may be offset by the strong correlation between temperature and growing stock.

3.2 The relationship between temperature, precipitation and forest growing stock in northwest slope of the whole Taihang Mountain.

Compared to the result from Hebei, the result from Shanxi province was not so ideal. The averaged data of different temperature interval was listed in table 3.

Table 3. Forest investigation data grouped by different temperature intervals in northwest slope of Taihang Mountain in Shanxi Province.

temperature interval °C	growing stock (m^3)	precipi-tation (mm)	age (a)	direction of slope	soil thicknes s (cm)	sampling number
2-2.99	67.18	534.9	18.0	5.8	53	19
3-3.99	52.21	502.3	20.1	5.6	44	12
5-5.99	95.52	551.6	22.5	3.4	55	24
6-6.99	50.96	645.0	23.9	4.4	47	49
7-7.99	46.06	630.0	23.0	4.8	49	54
8-8.99	40.23	616.3	20.4	4.6	51	87
9-9.99	50.00	589.2	22.4	4.7	53	26
10-10.99	50.91	539.5	19.9	5.0	54	28
11-11.99	58.82	566.4	19.6	5.6	53	8

From above table, two regression models were obtained:

$$V=-149.5-T\times3.8+St\times3.6+A\times2.2 \qquad r^2=0.64 \qquad (4)$$

and

$$V=-170.6-P\times0.19-T\times2.9+St\times5.21+A\times5.20 \qquad r^2=0.79 \qquad (5)$$

Where, A=forest age.

From these two equations, it is clear that there is a negative relationship between temperature and forest growing stock. But the relationship between precipitation and forest growing stock is strongly against the natural law for the distribution of vegetation in this region. This could be caused by the unevenly distributed precipitation as precipitation always varies from place to place even in a small area. Also the negative relationship between precipitation and forest growing stock in equation 5 offset the negative effect of temperature on forest growing stock. In fact, the impact of temperature on forest growing stock should be higher. So, equation 4 can be a better equation to express the relationship between temperature and forest growing stocks in northwest slope of the whole Taihang Mountain.

4. Discussion

Using difference in temperature caused by elevation and latitude change to study the effect of global warming was suggested IPCC(1992) and many other scientist. Using this methodology, Yang(1997) studied the effect of global warming on the biomass in upland grassland and suggested that a 1.5 to 1.9 times of increase in biomass could happen if temperature increase $5^{O}C$ in the growing season in England. The prediction of the variation of precipitation is always a difficult problem such as the prediction of precipitation by GCMs for a certain region. Although, from geological point of view, Taihang Mountains is a relative small region, precipitation also changes a lot from area to area. So there is not any relationship between elevation and latitude. The prediction of the influence of precipitation on forest growing rate is also difficulty as different equation has different result.

Although different models have different coefficience for temperature, the trend is very obvious.

An increase in temperature increase will no doubt result in an decrease in forest growing stock though the decrease rate may change from 3.8 in Shanxi Province to 8.68 in Hebei Province. The author believe this is reasonable, as in Shanxi Province, soil condition is generally better(not very stony as in Hebei Province) and, from large geographical point of view, slopes in Shanxi province is in northwest direction and is in southeast direction in Hebei Province. Temperature may produce a lower influence on forest growing stock in north face of the mountain and in better soil condition where soil can hold more soil in reason season for the dry season[6].

Acknowledgment

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2. Evaporation

Evaporation

—— A Most Elusive Hydrologic-Cycle Matter ——

Yasushi Nakayama (*)

* Igarashi Survey and Design Office Co.,Ltd.

No.18, Yoshinochô 4-chôme, Minami-ku,
Yokohama 232 Japan, Fax: +81-45-251-9678

Abstract

This paper deals with pan evaporation, the waters evaporation and wide-area evapotranspiration. Pan evaporatioin is observed with an evaporimeter. The waters mean reservoir, river, lake, ocean, etc. The higher surfacial waters get in temperature, the more water runs off into evaporation. Wide-area evapotranspiration will keep constant in spite of yearly precipitation or rainfall.

1. Preface

Balance equation of water circulation consists of some terms. One of them is evaporation, which is often dealt with an unknown term. As concerns this theme, the writer will present pan evaporation, the waters one and wide-area evapotranspiration in this order. Scattering from sea level to about 13,000 meters high, the precipitable water may be estimated only 25 millimeters in thickness. But, the actual storage for rainfall will be by far less than this thickness.

2. Pan Evaporation

Two types of pan have been used up to this day. One is 20cm in diameter and 10cm in depth; the other is 120cm and 25cm. The latter is predominant since 1966. An evaporimeter of small type at every observatory was abolished in 1965, and evaporimeters with large pans remain only 14 sites today. An appendix protector is prevention works for birds neither to drink nor to bathe themselves in water.

Initial adjustment of an evaporimeter-S (-L) is watering the pan 20mm (200 mm) deep. It is observed after 24 hours again. This is a daily evaporation.

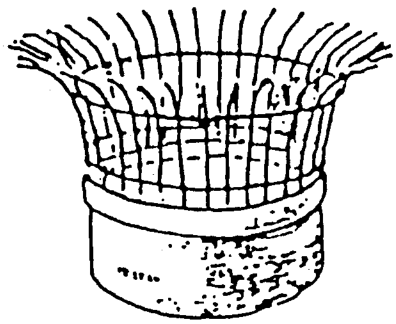

Fig.1 An Evaporimeter-S of Those Days

Table 1 Five-day Pan Evaporation at Utsunomiya 1965, mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	7.4	11.4	13.2	20.3	13.3	11.9	16.0	21.1	21.1	20.2	11.9	6.6
	6.2	10.1	15.3	19.0	14.2	22.5	12.1	23.4	6.6	13.0	8.3	7.1
	8.5	11.0	17.9	15.2	20.1	15.5	9.2	25.9	14.1	14.3	10.5	5.5
	9.7	9.2	9.4	16.3	19.2	9.2	14.1	20.0	20.4	11.0	9.2	7.1
	8.8	14.8	13.8	13.1	21.9	18.7	10.1	15.9	13.2	11.9	7.7	7.4
	10.7	9.9	24.7	10.6	9.9	14.8	25.9	32.3	14.0	12.1	5.4	6.6
TL	51.3	66.4	94.3	94.5	98.6	92.6	87.4	138.6	89.4	82.5	53.0	40.3
/D	1.65	2.37	3.04	3.15	3.18	3.09	2.82	4.47	2.98	2.66	1.77	1.30

By courtesy of the Meteorological Agency
Grand total: 988.9
Daily evaporation: 2.71

3. The Waters Evaporation

Many kinds of the equation have been recently advocated. One of them is shown below:

$$E = (A + BW)(e_w - e_a)$$

where, E: pan evaporation, W: the velocity of the wind,
e_w: saturated vapor pressure,
e_a: air vapor pressure, A, B: constant

A case study of the Towada Lake was published in "Handbook of Rural Engineering, 5th ed, p.848, 1989". This lake lies in Towada caldera. A caldera has usually a deep, flat bottom. No freeze is seen here because the waters are hundreds meters in depth.

Table 2 Calculation of the Waters Evaporation at "X" Reservoir

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
(1) pan evap, mm	51	66	94	95	99	93	87	139
(2) air temp, °C	1.4	2.4	5.7	11.6	16.4	20.0	23.6	24.9
(3) $e_w(2)$, Pa								
(4) humidity, %								
(5) moisture, Pa								
(6) interf t, °C	1.4	2.4	5.7	11.6	16.4	20.0	23.6	24.9
(7) $e_w(6)$, Pa								
(7)-(5)								
(3)-(5)								
(8) waters e, mm	51	66	94	95	99	93	87	139

Another study will be presented in this paper. Roughly speaking, superficial waters temperature of the "X" reservoir resembles air temperature at Utsunomiya except October and November. Thin ice plates cover partly the reservoir early morning in the winter.

Table 3 Water Vapor Pressure, Pa

Temp, °C	0	1	2	3	4	5	6	7	8	9
0	611	657	705	757	813	872	935	1001	1072	1148
10	1227	1312	1402	1497	1598	1705	1818	1937	2064	2197
20	2338	2487	2644	2810	2984	3168	3362	3566	3781	4007
100	101300									

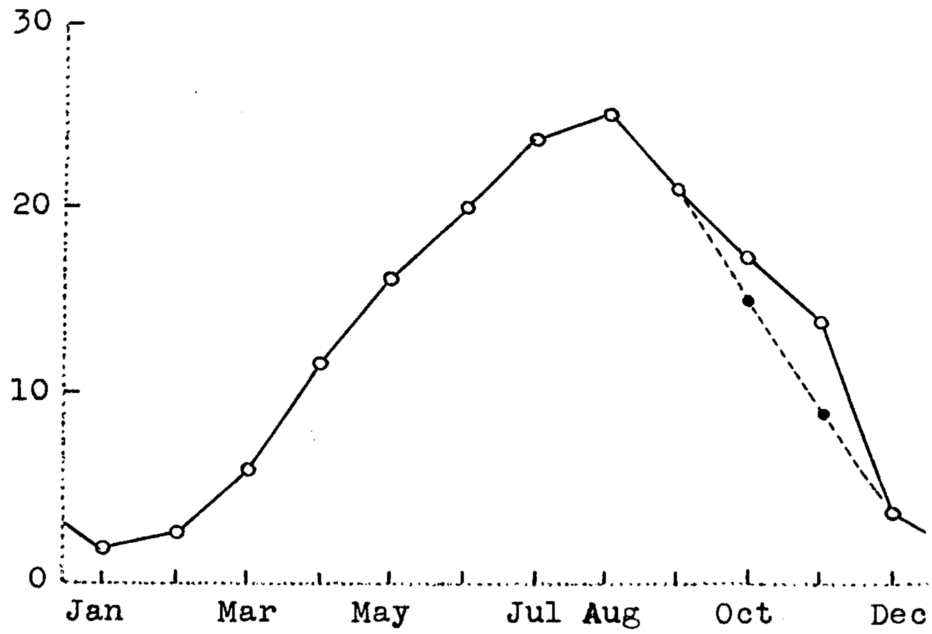

Fig.2 Interfacial Temperature, °C
o waters temperature
• air temperature

Sep	Oct	Nov	Dec	Remarks
89	83	53	40	Utsunomiya 1965 (Meteorological Agency)
20.9	15.1	9.3	3.9	Utsunomiya '51-'80 (Chr sci tables)
	1716	1171		Table 3
	77	73		Utsunomiya '51-'80 (Chr sci tables)
	1321	855		(3)x(4)
20.9	17.3	13.9	3.9	
	1975	1588		Table 3
	654	733		
	395	316		
89	137	123	40	(1)((7)-(5))/((3)-(5))
				Sum of (1): 989 mm
				Sum of (8): 1,113 mm

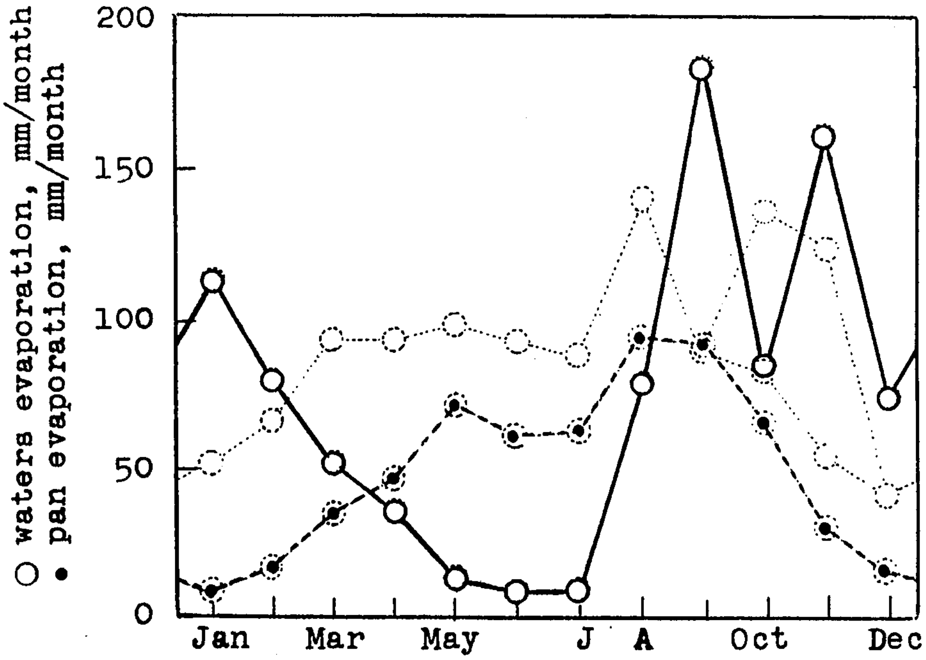

Fig.3 Evaporation at the Towada Lake

area: 61.0 km^2
depth max: 327 m
pan evap: 590 mm/yr
waters evap: 847 mm/yr

(Japanese Society of Irrigation, Drainage and Reclamation Engineering, 1989)

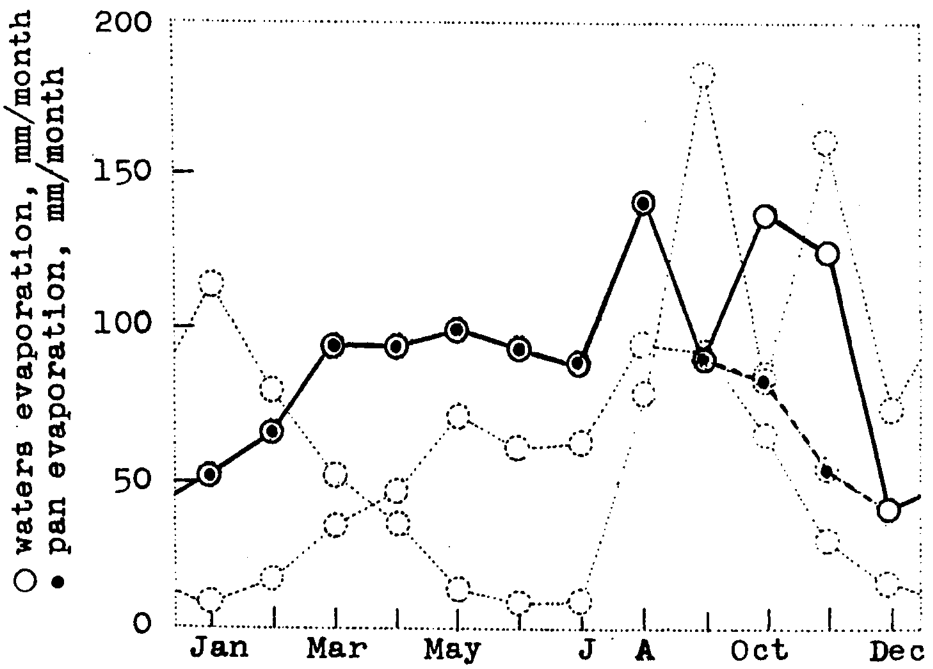

Fig.4 Evaporation at the "X" Reservoir

area: 0.2 km^2
depth max: 10 m
pan evap: 989 mm/yr
waters evap: 1,113 mm/yr

◌ for a comparison between two cases

4. Explanatory Hypotheses
4.1 Light carrying Heat

Heat is transferred by conduction, convection and radiation. We can see the black waters on an infrared photography; almost all heat rays or near infrared rays run into the waters without reflection, and vary into heat.

Table 4 Light through the Waters

Light		Travel range, m
Near infrared rays or heat rays		4
Visible rays	red	20
	orange	
	yellow	
	green	80 or more
	blue	
	indigo	
	violet	
Ultraviolet ray		

4.2 Temperature Distribution in the Waters

In summer, heat is generated in epilimnion. In fall, the other way, it is carried upward by convection. Because water gets the maximum density at 4°C, very cold water remains, in midwinter, on the surface with ice. This phenomenon is seen, especially, at the shallow waters.

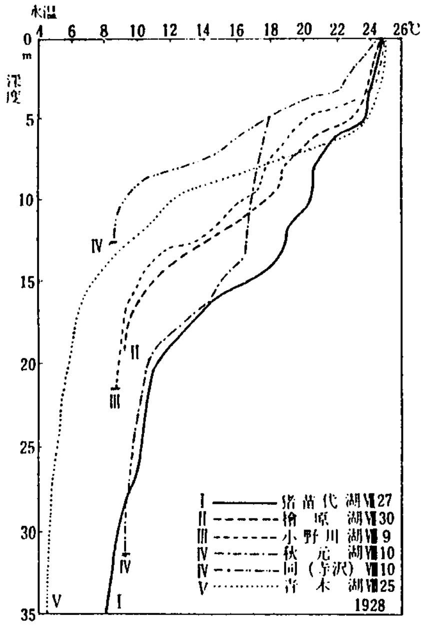

Fig.5 Vertical Distribution of Water Temperature (Horie, 1964)

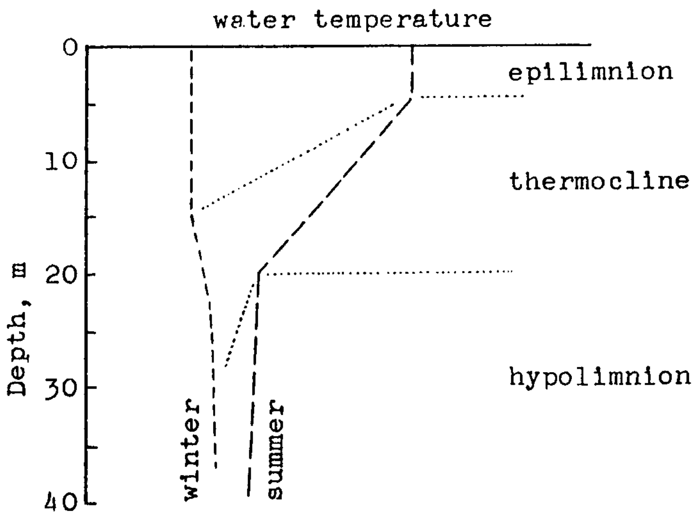

Fig.6 Explanatory Chart of Metalimnion in Summer and Winter

A deep lake, such as Towada Lake, is not frozen even in cold regions.

5. Wide-area Evapotranspiration

The administration on water resources belongs to the National Land Agency. In the white paper or official government report, they estimate water resources as follows. Table 5 is induced from wide-area evapotranspiration, which is shown in parentheses. The word of "wide-area" means forest, field, paddy field, garden, town, river, lake, etc. Even if precipitation vary considerably, wide-area evapotranspiration will remain nearly the same.

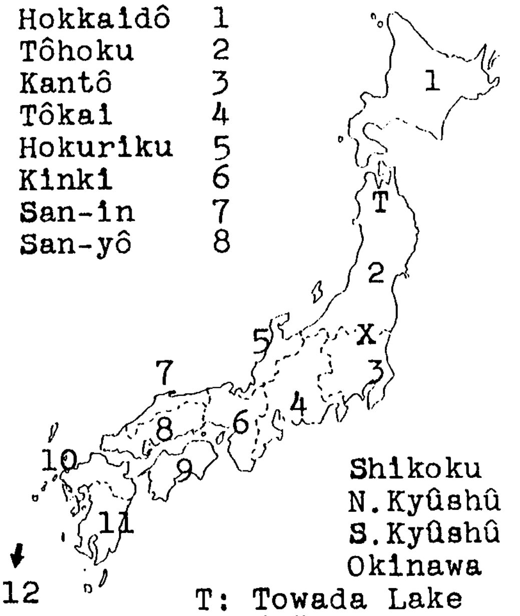

Fig.7 Index Map

Table 5 Water Resources Storage

	1/10 droughty year			Normal year		
	Precipitation, mm/yr	Evapotranspiration, mm/yr	Water resources, million m^3	Precipitation, mm/yr	Evapotranspiration, mm/yr	Water resources, million m^3
Hokkaidô	955	(474)	40,200	1,185	(473)	59,500
Tôhoku	1,370	(560)	64,400	1,669	(560)	88,200
Kantô	1,227	(543)	25,200	1,530	(542)	36,400
Tôkai	1,763	(522)	53,200	2,151	(523)	69,800
Hokuriku	2,132	(724)	17,800	2,612	(729)	23,800
Kinki	1,480	(663)	22,300	1,876	(663)	33,100
San-in	1,557	(668)	9,000	1,978	(664)	13,300
San-yô	1,351	(659)	15,000	1,710	(658)	22,800
Shikoku	1,688	(726)	18,100	2,145	(731)	26,600
N.Kyûshû	1,499	(849)	11,600	1,938	(846)	19,500
S.Kyûshû	1,854	(809)	25,400	2,425	(808)	39,300
Okinawa	1,495	(963)	1,200	2,135	(981)	2,600
Total	1,401	(598)	303,400	1,749	(597)	434,900

6. Today's Topics —— El Niño Event

If rising of about 2°C of surfacial sea temperature appear in the eastern Pacific ocean, off Equador and Peru, it will bring cool summer with heavy stomy rain and warm winter to Japan, which lies about 15,000 kilometers far from Equador or Peru. This is an el niño event, and such a combination of cause and result is called "teleconnection". El niño and la niña are an antonym each other. El niño carries a poor catch of anchovy, sort of sardine; la niña causes a long drought in the west of the United States and China, and a flood in Bangladesh.

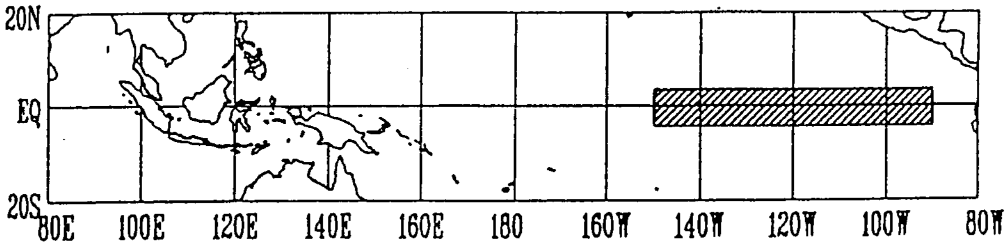

Fig.8 El Niño Monitoring Area
from 4°N to 4°S
from 150°W to 90°W

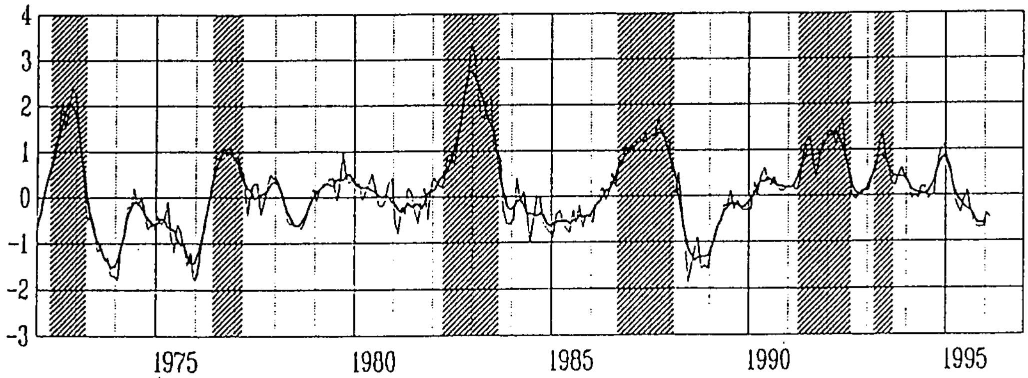

Fig.9 Superficial Sea Temperature Deviation with El Niño Period Shaded
By courtesy of Meteorological Agency, M.A.

February 1996

February 1995

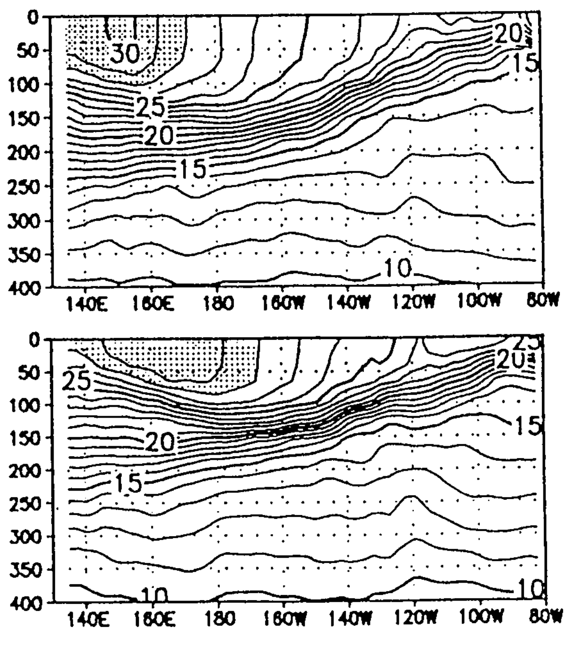

Fig.10 Thermal Profile (M.A.)

7. Conclusions

The writer would like to sum up all the results in brief and to show them below.

	Tôhoku Towada L.	Kantô "X" reservoir
Precipitation, mm/yr	1,669	1,530
Pan evaporation, mm/yr	590 (100)	989 (100)
Waters evaporation, mm/yr	847 (144)	1,113 (113)
Wide-area evapotranspiration, mm/yr	560 (95)	542 (55)

If we take up the following matrix or a hydrological balance sheet, we shall be able to deduce that "w_{11} and w_{21}" equals "w_{12} and w_{22}" and that w_{12} is constant. El niño varies w_{22} or "w_{11} and w_{21}".

$$\begin{array}{lcc} & \text{precipitation} & \text{evaporation} \\ \text{Land} & \left(\begin{matrix} w_{11} \\ w_{21} \end{matrix}\right. & \left.\begin{matrix} w_{12} \\ w_{22} \end{matrix}\right) \\ \text{Ocean} & & \end{array}$$

Acknowledgment

The writer deeply appreciates a lot of data and informations on the "X" reservoir by courtesy of Nippon Giken Inc.

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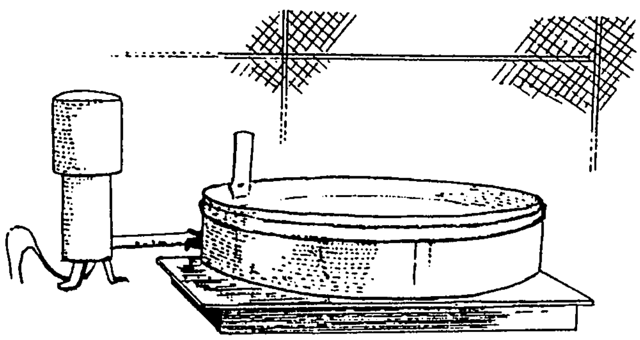
An Evaporimeter-L of Today, since 1966

This type shows pan evaporation 0.5 - 0.9 times as much as that of an evaporimeter-S monthly, and 0.8 times yearly. Because of a large heat capacity, the facilities indicate several hours behind a pyrheliometer.



Comparative study of water balance in Asia between Kuo and PAS Schemes simulated by the JMA89 Model

Kimpei Ichiyanagi *, Masaru Chiba *, Masato Sugi **, Ken-ichi Kuma*** and Nobuo Sato****

* National Research Institute for Earth Science and Disaster Prevention, Science and Technology Agency, Japan
3-1 Tennodai, Tsukuba, Ibaraki 305, Japan
Fax: +81-298-1622, Email: kimpei@ess.bosai.go.jp, chiba@ess.bosai.go.jp

** Climate Research Department, Meteorological Research Institute, Japan

*** Numerical Prediction Division, Japan Meteorological Agency, Japan

**** Office of Meteorological Satellite Planning, Japan Meteorological Agency, Japan

Abstract

The result of ten year integrations of the JMA89 global model with Kuo scheme and Prognostic Arakawa-Shubert scheme (PAS) were compared. In global, basinwide water balance simulated by PAS scheme was more realistic than that of Kuo scheme, but river runoff of both Kuo and PAS schemes were overestimated than observation. Land surface hydrology in Asia between Kuo and PAS schemes was compared in detail. The results showed that deep convection scheme take large influences to land surface hydrology not only precipitation pattern, but also evapotranspiration through cloud and solar radiation processes.

1 Introduction

Atmospheric general circulation models (AGCM) is a useful tool for studying land-atmosphere-biosphere interactions and for predicting global climatic changes. Typically, AGCM with a land surface hydrology parametrization including the biospheric model have developed such as the biosphere atmosphere transfer scheme (BATS) of Dickinson et al. (1986) and the simple biosphere (SiB) model of Sellers et al. (1986). A primary goal of these parametrizations is to produce realistic surface water balances, those components are precipitation, evapotranspiration, soil moisture storage, and river runoff. However, the observed data available to validate hydrological results of AGCM are lacking.

In particular, river runoff is represented to the water balance of large scale drainage basin, and excellent methods to check the reliability of the global water budget simulated by AGCM long term integrations. The contribution of global runoff has been discussed in several papers. Russell and Miller (1990) was compared model generated river runoff with observations in major rivers, and showed quantitatively well corresponding between them. Sausen et al. (1994) was also compared in 33 major rivers, and it was largely affected by model's precipitation and parametrizations of land surface hydrology. Oki et al. (1995) was estimated water balance in a specific river basin not only for land surface but also for atmospheric vapor flux convergence.

In similar to these former studies, Ichiyanagi et al. (1997) was also compared river runoff between two different deep convective schemes in AGCM. And, it made clear that water balance in major river basins simulated by PAS scheme represented more realistic features than that of Kuo scheme. The purpose of this paper is to compare of water balance not only for river runoff, but also for other hydrological components between these two convection schemes. In particular, effect of deep convective schemes to water cycle in Asia was discussed.

2 Model Description and Observation Data Sets

The AGCM used for the present study is derived from Japan Meteorological Agency for operational weather forecasting model (JMA89). This model is a global primitive equation model using a spectral transform methods, with a triangular wave truncation at wavenumber 42 and 21 vertical levels (T42L21). The horizontal resolution is approximately 2.8 degrees in both latitude and longitude. For the parametrization of land surface processes, SiB model described in Sato et al. (1989) was used. A level-2 closure model for vertical diffusion is used (Mellor and Yamada, 1974). For deep convection, modified Kuo (1974) and Prognostic Arakawa-Shubert (PAS) schemes have been employed. The AGCM with each scheme was integrated for 10 years from January 1, 1979 with observed SST data which is used for the Atmospheric Model Intercomparison Project (AMIP). The 10 years integration output from 1979 to 1988 was averaged in each month and summed up to annual mean value.

River runoff observed at gauging station is provided from the Global Runoff Data Centre (GRDC, 1992; 1996). Long term mean values are calculated from these data by averaging over the available data period in each station. The continental land mass was manually devised into river basins using published world maps. Precipitation observed at gauging station is used Monthly Station Precipitation Data provided from NOAA Baseline Climatological Data Sets. All gauging station data in specific river basin was simply averaged for each month.

3 Results and Discussion

3.1 Water balance in major river basin

The annual mean values of precipitation and river runoff simulated by AGCM have been summarized in each river basin, and compared with observations in Figure 1.

We can see the good correlation between model simulation and observation in precipitation. In specially, precipitation simulated by PAS scheme is surprisingly good (Fig.1a). There are also good correlation between river runoff simulated by PAS scheme and observation data (Fig.1b). But river runoff simulated by Kuo scheme is not so. The results of these comparison show that water balance simulated by PAS scheme is more realistic than that of Kuo scheme in global. Generally, simulated river runoff is overestimated for most of the river basins than observation in both Kuo and PAS schemes, but differences between model simulation and observation are widely spread among each river basins.

3.2 Distributions in Asia

Simulated differences more than 100 mm/year between Kuo and PAS schemes in convective precipitation, large scale precipitation, transpiration and interception, evaporation from bare soil, soil moisture in both surface and root zones and river runoff fields are shown in Figure 2.

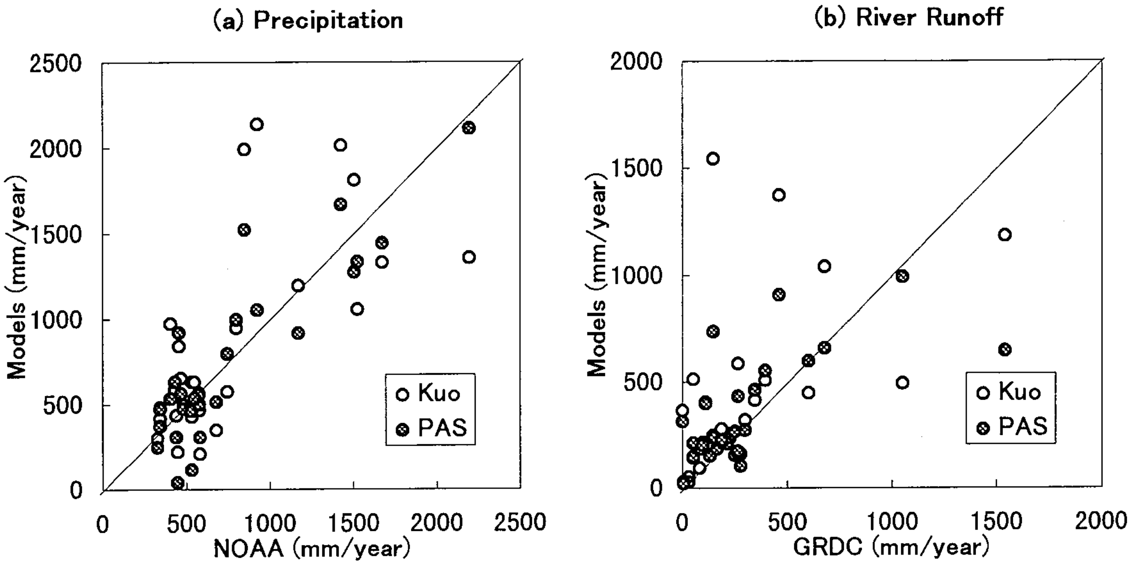


Figure 1. Comparison between AGCM simulations and observation.

The differences between Kuo and PAS schemes are clearly appearing in both convective precipitation and large scale precipitation fields (Fig.2a,b). Over ocean, convective precipitation simulated by PAS scheme is larger, but large scale precipitation simulated by Kuo scheme is larger. Over land, both convective and large scale precipitation simulated by Kuo scheme are larger than those of PAS scheme. Only in East India, Indochina Peninsula and Tibetan Plateau, convective precipitation simulated by PAS scheme is larger. Distribution of transpiration and interception field is similar to that of evaporation from bare soil field (Fig.2c,d). Evaporation simulated by Kuo scheme is larger in China and West India, and in Tibetan Plateau that by PAS scheme is larger, respectively. Soil moisture simulated by Kuo is larger in Tropical Region (Fig.2e). Distribution of river runoff field is similar to that of convective precipitation field (Fig.2f), except in Tibetan Plateau where river runoff simulated by Kuo scheme is larger than convective precipitation.

There are three areas where characteristics of anomaly fields are different in Figure 2. First one is an area where Kuo > PAS in both convective and large scale precipitation fields (e.g. West India and China). Corresponding to precipitation fields, transpiration and interception, evaporation from bare soil, soil moisture and river runoff fields are all Kuo > PAS. Second one is an area where Kuo < PAS in convective precipitation field (e.g. East India and Indochina Peninsula). Both transpiration and interception field and evaporation from bare soil field are Kuo equal to PAS. And, river runoff field is almost same to precipitation fields. These two patterns show good correlation between precipitation and river runoff. Third one is an area where Kuo < PAS in convective precipitation field, and Kuo > PAS in large scale precipitation field (e.g. Tibetan Plateau). Both transpiration and interception field and evaporation from bare soil field are Kuo < PAS, and also same to convective precipitation field. But, soil moisture and river runoff fields are Kuo > PAS, and also same to large scale precipitation field. Third area is more complex to understand formation processes of this relations than those for former two areas.

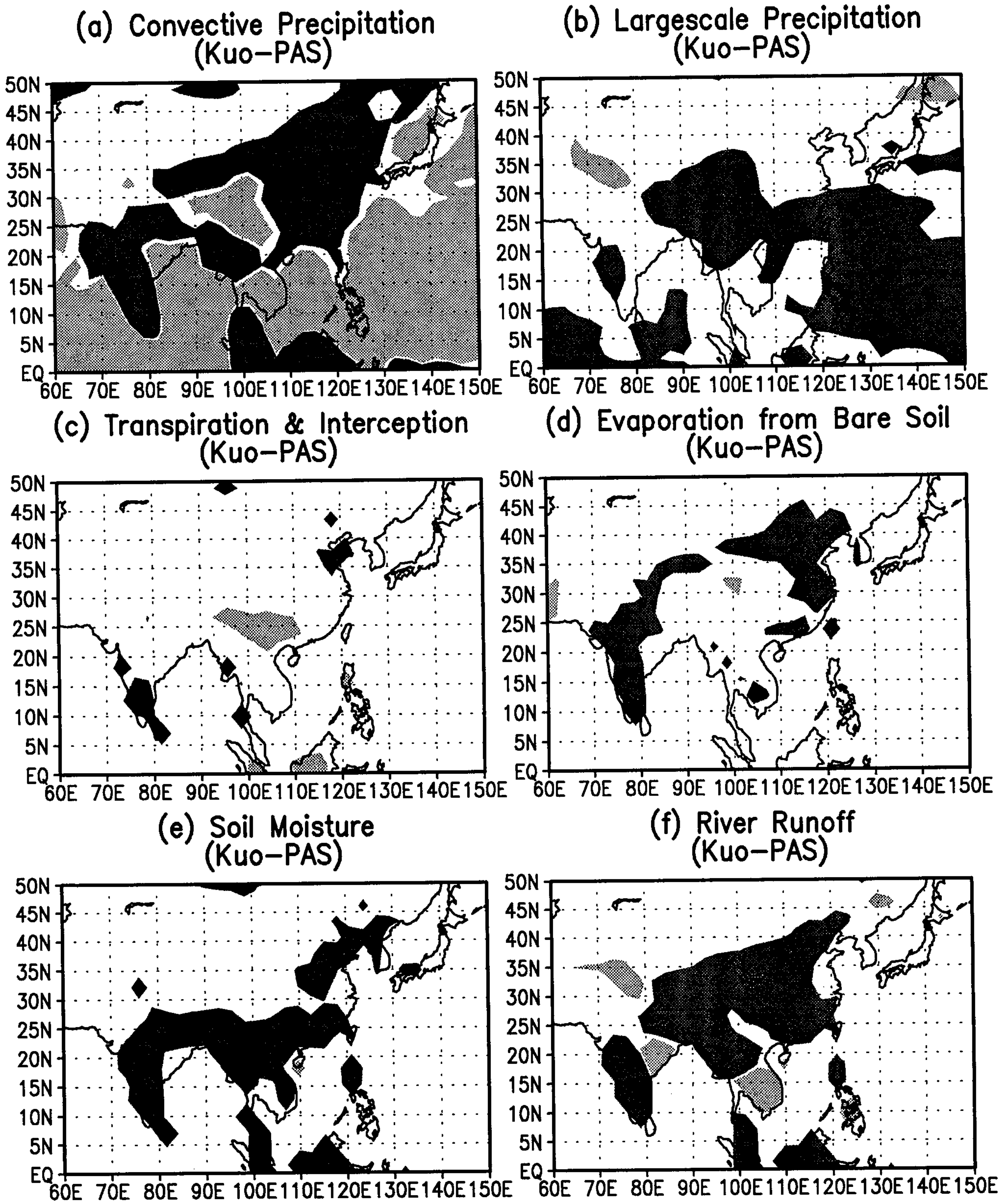


Figure 2. Distributions of differences between Kuo and PAS schemes more than 100 mm/year. Deep and shallow shadings show Kuo > PAS and Kuo < PAS, respectively.

3.3 Seasonal variation

To make clear the influence of deep convection scheme to land surface hydrology, seasonal variations of precipitation, river runoff, downward solar radiation on three regions were shown in Figure 3.

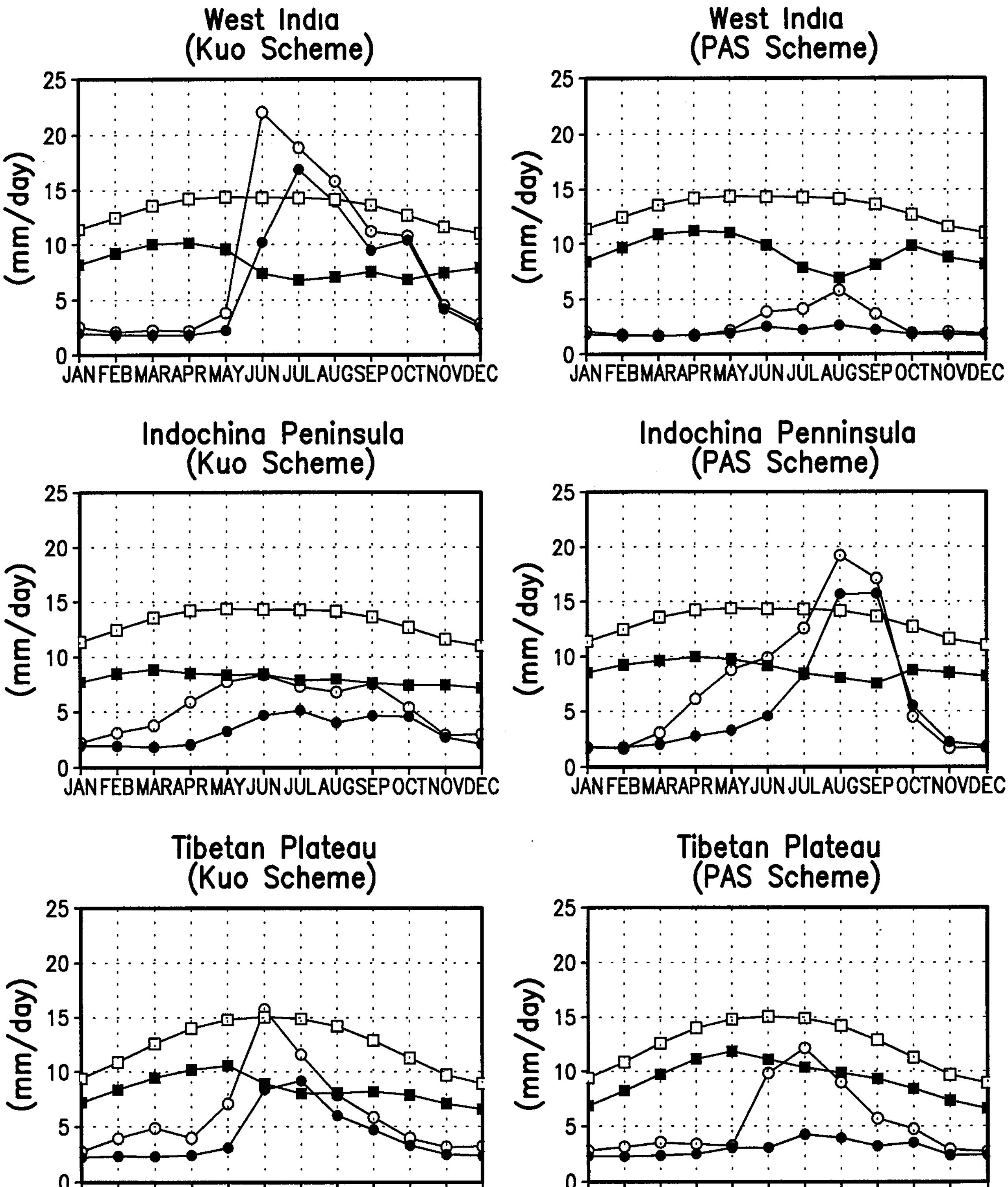


Figure 3. Seasonal variations of land surface hydrology and solar radiation in three regions. Open and solid circles show precipitation and river runoff, and open and solid squares show downward solar radiation on top and bottom of atmosphere, respectively.

Seasonal variation of precipitation simulated by Kuo scheme in West India is clearly showed summer monsoon peak (Fig.3a). But, that of PAS scheme is too small (Fig.3b). In contrast, precipitation simulated by Kuo scheme is too small, and that of PAS scheme is large in Indochina Peninsula (Fig.3c,d). In Tibetan Plateau, precipitation is not different between two schemes, but river runoff simulated by PAS scheme is much smaller than that of Kuo scheme during summer (Fig.3e,f). Difference of downward solar radiation between top and bottom of atmosphere simulated by PAS scheme is much smaller than that of Kuo scheme. It pointed out that solar radiation on land surface is larger, and evapotranspiration is also larger. Therefore, most part of precipitation is evaporated on land surface, thus river runoff becomes smaller in PAS scheme. Above all, deep convective scheme takes much influence to land surface hydrology, not only precipitation input but also evapotranspiration output through cloud and solar radiation processes.

4 Conclusions

Basinwide water balance and regional distributions of surface hydrology in Asia simulated by the JMA89 Model with both Kuo and PAS schemes were compared. The results was summarized as follows: Basinwide water balance in specific river basin simulated by PAS scheme is good corresponding to observations. Deep convection scheme takes much influences to basinwide land surface hydrology, not only by precipitation input but also by evapotranspiration output through cloud and solar radiation processes.

Acknowledgments

The authors thanks to the Global Runoff Data Centre and NOAA for providing observed river runoff and precipitation data, respectively. The GRDC data sets used here is from the Mushiake Laboratory in the Institute of Industrial Science, University of Tokyo.

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Behavior of Water Vapor in the Surface Boundary Layer in Desert Areas

Tetsuo Kobayashi and Hideyuki Nagai

Faculty of Agriculture, Kyushu University
6-10-1 Hakozaki, Higasi-ku, Fukuoka 812-81, Japan
Fax: +81-92-642-2804, E-mail: kobayasi@agr.kyushu-u.ac.jp

Abstract

Observations of boundary-air-layer processes made in the daytime in desert areas show that the behavior of water vapor in the surface boundary layer is considerably different from that in moist areas; that is,

(a) latent heat flux is negative (downward);
(b) constant-flux layer of water vapor is not detected;
(c) mixing ratio of water vapor increases with height on fine days;
(d) counter-gradient flow of water vapor occurs.

These phenomena are shown to be resulted from the following processes.

(1) Hot, dry soil surfaces produce dry air or gradients of water vapor density by thermal diffusion.

(2) The gradients of water vapor density made at the surface are transported upward by micro-convection cells arising from the large difference in temperature between the surface and the air immediately above it.

1. Introduction

Air flows over changing surface conditions show that an internal boundary layer (IBL) develops over the new surface, growing in height with downwind distance. It is supposed, in general, that the lowest 10 % or the surface boundary layer has been achieved in equilibrium with the new surface and is often called the equilibrium layer or the constant-flux layer.

There are two kinds of IBLs, active IBL and non-active or passive IBL. The former develops over surface changes, smooth to rough, cold to hot, and dry to wet, while the latter is formed over changes, rough to smooth, hot to cold, and wet to dry. However, the data on the non-active IBL have scarcely been obtained so far. Especially, there is no evidence for supporting the formation of IBL for humidity when air flows from moist areas to dry areas. In other words, it is not clear to us what occurs when cool moist air conditioned in oases for example flows into deserts.

This paper reviews the behavior of water vapor observed recently in arid regions and describes a model constructed to explain the behavior of water vapor over dry soil surfaces.

2. Boundary-air-layer processes of humidity

Recently, many observations of boundary-air-layer processes in arid regions have been made and "peculiar" phenomena have been found. Wang and Mitsuta (1990) showed that the flux of latent heat or of water vapor over a gobi desert in the HEIFE (Sino-Japanese Cooporational Program on Atmosphere-Land Surface Processes in Heihe River Basin) area was negative (downward) in most of the daytime. Harazono et al. (1992) observed also humidity inversions or increases in humidity with increasing height over a sand dune in Hulunbuir sandy land, China, during the day. However, these observations do not mean that water vapor moves into the ground, because its gradient immediately below the surface in the dry surface layer (DSL) points downward; that is, soil water moves upward just beneath the surface (Kobayashi et al., 1993).

Hu et al. (1993) made observations of the profile of specific humidity in the 0.25 to 16 m surface air layer over a sand surface at the HEIFE desert station and found that there often existed a minimum value of specific humidity near the ground in the daytime, which seems to mean that the water vapor flux is not constant with height but even changes its vertical direction in the surface air layer. Teshima and Kobayashi (1997) took observations of boundary-air-layer processes in Kokosiri ranges of the Qinghai-Xizang plateau, China, and showed that the constant-flux layer of water vapor disappeared as the soil surface dried and unstable conditions prevailed in the air layer just above the surface. Tamagawa (1996) analyzed the data on wind, temperature and humidity obtained at the HEIFE desert station, and concluded that the Monin-Obukhov hypothesis was not supported.

Nagai et al. (1997) showed that monthly mean mixing ratio of water vapor on fine days at the HEIFE desert station increased with increasing height below 20 m throughout year, which means that humidity inversions always occur in the surface boundary layer at this station. Kobayashi and Nagai (1995) confirmed at the same station that evaporation was occurring under these humidity-inversion conditions, which means that water vapor was transported against its density gradient.

No explanation for these phenomena has not been offered till now.

3. Humidity inversion across the soil surface

Figure 1 shows the vertical profiles of water vapor density obtained at about 1500 JST on fine days in a 3 m by 3 m dune sand field at Kyushu University, Fukuoka, Japan (Kobayashi et al., 1996). The water vapor density in DSL where water moves only in the vapor phase was estimated from the soil temperature and moisture content assuming the vapor to be in equilibrium uniquely with the liquid in the same pore. The DSL thickness was in the range of 1.5 cm to 4 cm. Humidity in the air was measured with an Assmann ventilated psychrometer. The vertical profiles took a jump discontinuity at the hot, dry soil surface and increased from under to above the surface; that is, the humidity inversion developed across the soil surface.

Humidity inversion across the surface were measured also with HUMICAP humidity sensors (VAISALA). The sensors were covered with a metal filter of 1.2 cm diameter and installed at depths of 0.6 cm, 2.6 cm and 10 cm, and at a height of 2.6 cm in the same sand field that was covered with a vinyl house to keep dry conditions, natural ventilation of the air being allowed through openings in the wall. Thus, the top of the sensor at 0.6 cm deep was just exposed to the air, and it was dusted with sand. Figure 2 shows the diurnal variation of water vapor density on fine day (June 26, 1994), the DSL thickness being about 4.5 cm in the daytime (Kobayashi et al., 1996). The difference in temperature between the soil surface and the air in the vinyl house amounted to about 15 °C. The water vapor density at 0.6 cm deep was often smaller than that at 2.6 cm high during the period 1100 JST and 1500 JST when the soil surface temperature was much higher than the air temperature immediately above the surface.

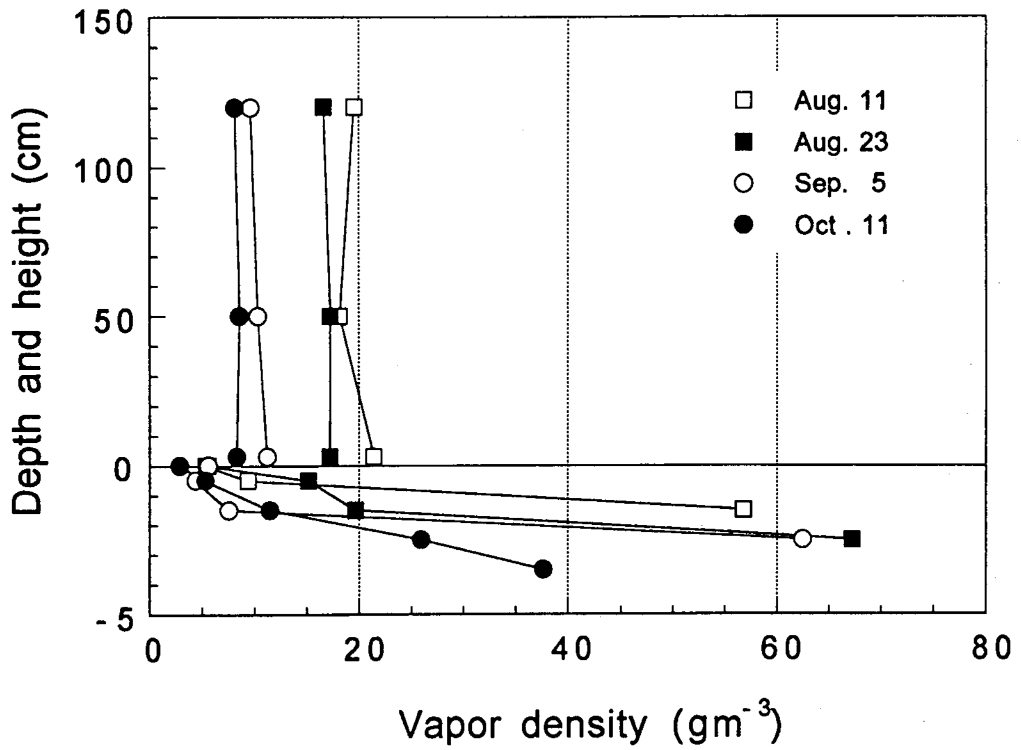

Fig. 1. Vertical profiles of water vapor density measured at about 1500 JST on fine days in a dune sand field at Kyushu University, Fukuoka, Japan in 1993.

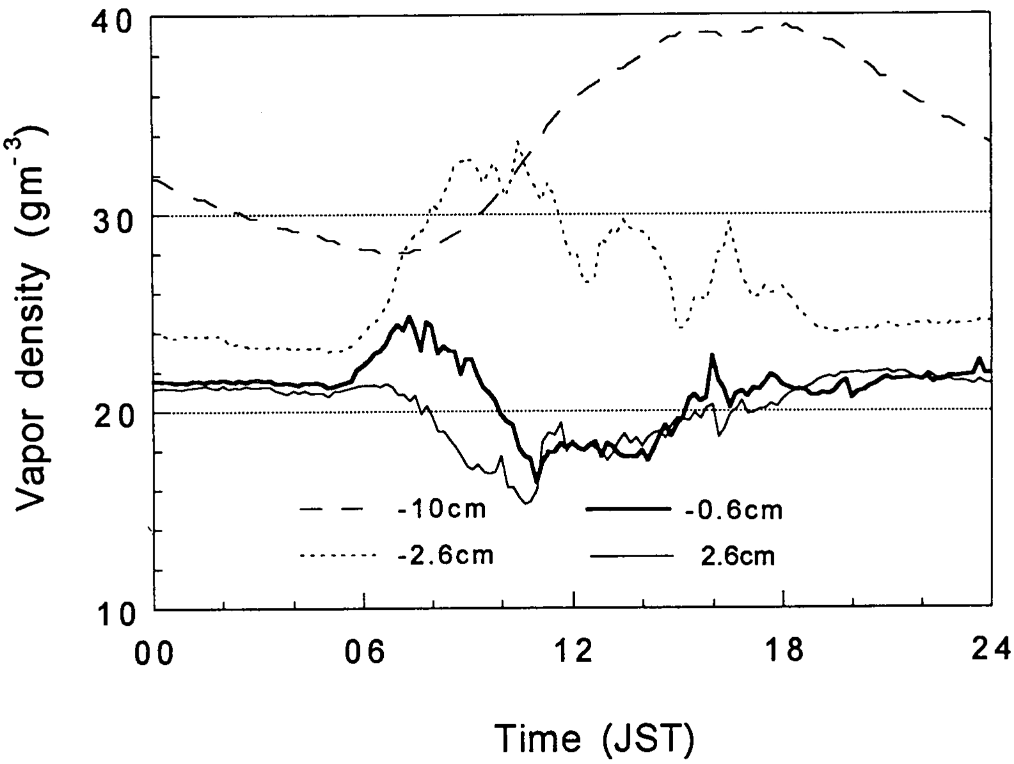

Fig.2. Diurnal variations of water vapor density measured with HUMICAP sensors in the same field as in Fig.1 at a height of 2.6 cm and at depths of 0.6 cm, 2.6 cm and 10 cm on June 26, 1994.

4. Production of dry air

The humidity inversion seems to be related to another peculiar phenomenon which is also seen in Fig.2. After the sunrise at about 0150 JST, the water vapor density near the surface increased owing to the temperature rise. However, it started decreasing drastically at about 0700 JST at 0.6 cm deep and 2.6 cm high, and also at 2.6 cm deep delayed in time about one hour.

The minimum density at 2.6 cm high was below 17.0 gm^{-3}, while the daily mean and minimum values of water vapor density observed at Fukuoka Meteorological Observatory about five kilometers away from the sand field was 20.5 gm^{-3} and 19.7 gm^{-3}, respectively. These results mean that the small sand field with a dry surface layer in vinyl plastic house with openings in the wall produced dry air during the day and this process was activated suddenly in the morning when the surface temperature exceeded a critical value.

If hot, dry soil surfaces make dry air, the discontinuity at the surface in the vertical profile of water vapor density, or the humidity inversion across the surface can be explained in the same way as in the case of temperature discontinuity at the surface in which sensible heat generated there plays an essential role.

5. Mechanism for producing dry air

Dry air can be made by separating water vapor from moist air. There are two processes by which water vapor can be removed from moist air, condensation and thermal diffusion. Although the former is very common, the latter may be unfamiliar to us.

A flow of matter caused by a temperature gradient in a fluid mixture is called thermal diffusion (de Groot and Mazur, 1984). If moist air, which is a mixture of dry air and water vapor, is kept under a strong temperature gradient, water vapor moves toward regions with lower temperatures. As a result, since the air in regions with higher temperatures becomes dry, thermal diffusion makes dry air with leaving moist air as a by-product. Thus, it may be more relevant to say that thermal diffusion produces the gradient of water vapor density in the air.

Kobayashi et al. (1997) discussed this subject and concluded that temperature gradients in close proximity to soil particles forming the ground surface can be large enough to develop humidity inversions across dry, soil surfaces.

6. A micro-convection model

A model that describes the way the gradient of water vapor density is transported upward is presented in Fig.3 (Kobayashi et al., 1997). The stippled area shows dry air made at hot, dry soil surfaces. The dry air made at the surface is mixed with moist air above and below, part of which is the by-product of thermal diffusion, resulting the convergence of water vapor toward the surface. Thus, if only mixing by eddy diffusion or forced convection were in action, the dry air could not efficiently be transported upward. Consequently, free convection which occurs as a result of the density gradients should be responsible for the transport.

A convection cell consists of the core where the updraft is fast and the environment where the downdraft is slow. The hot, dry air made just above the ground surface is easily entrained into the cell. However, if it is made and trapped in soil pores being opened to the atmosphere, the mass movement of hot, dry air may be complicated, because hot air is small in density and is laid under cool heavier air; that is, unstable conditions prevail there. This phenomenon can be solved as a problem of the Kelvin-Helmholtz instability (Kobayashi et al., 1997).

The results obtained are as follows:

The instability develops when (a) the difference in temperature between the two gases, hot and cool, is large, (b) the surface wind is strong, (c) soil pores are large, and (d) the wave number of disturbances is large; that is, the size of convection cell is small.

From these results, we can imagine that lots of small convection cells develop here and there, and hot, dry air is sent up from the surface through the thin core like a jet (micro convection jet, MCJ). In the wide environment rather moist air moves downward and part of it taken into the soil pores, and under strong temperature gradients the dry air layer is reformed there. It is essential to realize that MCJs send up not only dry air but also gradients of water vapor density or humidity inversions produced at the surface, which means that the air masses moving up from the surface are rather small parcels composed of two kinds of gases, dry air in the lower part and moist air in the upper part (Fig.3).

One type of experimental evidence in support of this model is also seen in Fig.2. The phenomenon that water vapor density near the dry surface started decreasing suddenly in the morning can be explained on the basis of this model; that is, the instability near the surface develops with a rise in the surface temperature and when a critical state is reached MCJs burst and dry air confined within the thin, dry air layer spreads to the surroundings. Nagai et al. (1997) showed another example of such a phenomenon in which a sudden increase in the surface wind speed caused a sudden decrease in water vapor density in DSL as well as in the surface boundary layer, which suggests that the strong wind triggers the burst of MCJ as is expected from the result (b) shown above.

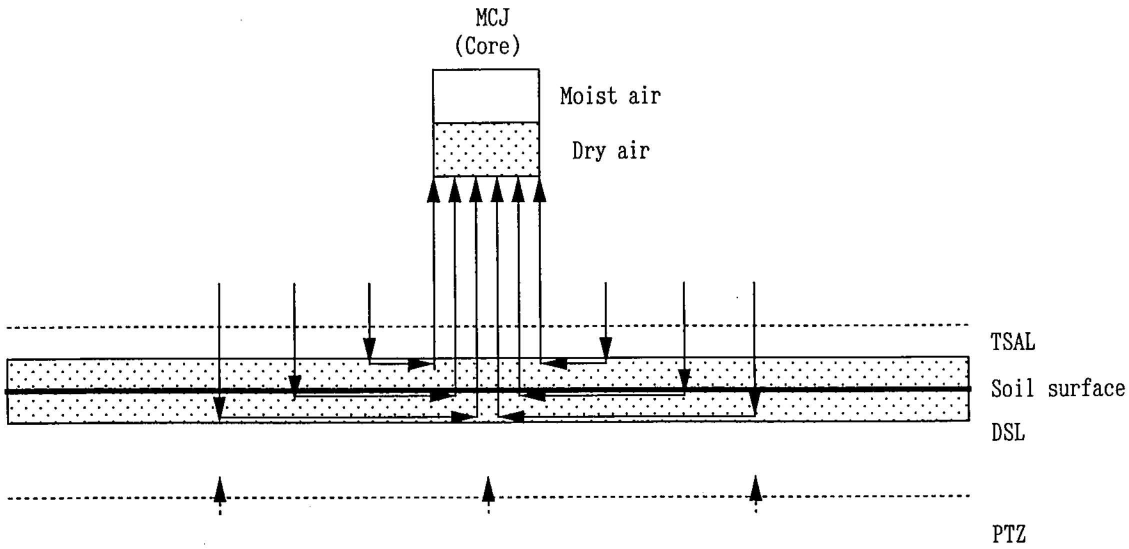

Fig.3. Schematic representation of a micro-convection model that describes the way dry air and humidity inversions made at the surface are transported up into the surface boundary layer.

7. Cause and effect of water vapor advection over deserts

Even if air masses conditioned in moist regions flow into areas with dry surfaces in the daytime, the humidity at the surface is scarcely influenced by them, because thermal diffusion arising from temperature gradients resists the flow of water vapor driven by its density gradient in TSAL and it is determined by the moisture conditions in the uppermost soil layers and the soil surface temperature (He and Kobayashi, 1997). Thus, the air masses do not easily adjust to dry soil surfaces, which means that advective effects of water vapor generated in moist-surface areas (e.g., oases) will not be eliminated for a long distance over dry-surface areas (e.g., deserts) (Kobayashi et al., 1993) . This may be the main reason why the formation of IBL for humidity has not been confirmed when air flows from moist areas to dry areas. On the contrary, since humidity just above the surface is increased by the advection and hence humidity inversions across the surface are strengthened, the humidity inversion in the surface boundary layer will be strengthened as well.

8. Concluding remarks

In desert areas, in the daytime when the surface temperature is much higher than the air temperature, humidity at the surface is smaller than that in the surface boundary layer. However, water vapor is transported against its density gradient by MCJs, which means that there is another driving force for the water vapor transport besides the gradient of water vapor density; that is, the temperature gradient. Therefore, the rate of evaporation from hot, dry soil surfaces can not be expressed by the Ohm's analogy or the bulk aerodynamic formulations, because these techniques are explicitly based on the assumption that the process is isothermal. Consequently, it may be said that the rate of evaporation from hot, dry soil surfaces can not be estimated by observing boundary-air-layer processes. He and Kobayashi (1997) proposed to use a bulk formulation of the water vapor transport in DSL where the temperature gradient is tens to hundreds times less than in TSAL and its effects can be neglected (Kobayashi, 1993).

In desert areas, soil surfaces are usually dry and hence high temperatures are developed in the daytime. Thus, we come to a conclusion of great interest that deserts produce dry air. It may be said that dry air makes deserts and deserts themselves make dry air, which means that deserts have another self-induction effect in addition to that suggested by Charney (1975).

When moist air flows into desert areas, water vapor may be absorbed by dry soil surfaces in the nighttime. However, in the daytime, it keeps flowing over hot, dry surfaces for a long distance and humidity inversions will be developed in the surface boundary layer. The humidity structure in the surface boundary layer in desert areas is very complicated and further study is needed to clarify the details of the behavior of water vapor there.

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SOME FEATURE OF EVAPORARION FROM THE GROUND SUFACE OF TIBETAN PLATEAU

ZHANG Yinsheng*, H. Yabuki**, YAO Tandong*, PU Jianchen*, and T. Ohata***

*Lanzhou Institute of Glaciology and Geocryology, CAS, Lanzhou 730000, China
**Institute of Hydrospheric-Atmospheric Sciences, Nagoya University, Nagoya 464-01,Japan
***School of Environmental Sciences, The University of Shiga Prefecture, Hikone 522,Japan

Abstract

The processes of evaporation on the ground in Dongkemadi River Basin near the Tanggula Pass were observed with weighting-lysimeter method from May to September 1993, and some preliminary results were got. Evaporation mainly occurred from May to September and the daily mean soil evaporation in July is higher than in other months; there is a nice linear relationship between the soil evaporation and water evaporation which observed in 20 cm evaporation pan; the soil evaporation is much influenced by ground surface water content; that varied not only with the change of the water content, but also with water content self; the evaporation processes are influenced by topography through changing climatic parameters and the conditions of supplying water on the ground surface, as evaporation process is stronger in the fine days, the soil evaporation at the top is higher than at the bottom for a slope; the daily process of soil evaporation for different ground surface conditions is quite different. Comparing to the west of the Plateau, the soil evaporation in the center of Tibetan Plateau is few. The annual soil evaporation is estimated to be about 300 mm.

Key words: Tibetan Plateau, Soil evaporation, saturated soil evaporation, water evaporation

Evaporation, as a unitary parameter relating water cycle process with energy exchange process, plays an important role in environment change. An observation on evaporation was systematically carried out in Dongkemadi River Basin near the Tanggula Pass in the center of the Tibetan Plateau from May to September 1993. The items of the observation are soil evaporation, water evaporation, saturated soil evaporation and water content in soil on the ground surface. Based on the analysis on the observation, some features of evaporation processes in the studied region are presented in this paper.

1 OBSERVATION AND RESULTS

The observation site (BC) is located in the Dongkemadi River Basin $(33^{0}02'N, 90^{0}02'E, 5070m.a.s.l.)$. The ground surface is smooth and wild, formed with glaciation and covered by a single grass not longer than 3-5 cm. The Dongkemadi Glacier lies in the headwater of the river, and bare rock appears nearby. According to the observation in automatic weather station, the annual mean air temperature is $-6.0\,^{0}C$ with an annual range of 24.9 K, the monthly mean air temperature is over 0° C from June to Sep.; the annual mean relative humidity is 65% and the precipitation is mainly occurred from June to Aug.; the annual mean wind speed is 3.6 m/s, with an irregularly prevailing wind direction; the extreme maximum solar radiation occurs in May; the surface soil is wet with men water content of 46% from May to Sep..

Weighting-lysimeter method was used in this observation. A natural soil lump is isolated in a pan and is weighted regularly. The soil evaporation can be obtained by following formula:

$$E = \Delta W / S + P_r \qquad (1)$$

where: E is evaporation; ΔW is weight difference of the soil lump; S is the area of the pan and P_r is precipitation measured on the ground surface.

A nature soil lump, 20 cm in diameter and 17 cm in highs, was put into a pan, which was stetted in the soil and let it's surface with the same high as surrounding soil. The lump was weighted and replaced by a new one at 20:00 everyday. To obtain the saturated soil evaporation, take another pan with soil, and which should be keep in saturated state. In addition, water surface evaporation was measured with the same size pan. To study the effect of topography on evaporation process, soil lysimeter were seated on the top and middle of an hill near BC with a heights of 300m. Observation was also taken with 2 hour interval to get the daily process of soil evaporation and saturate evaporation on different ground surface. The soil evaporation and water content also monitored along altitude from BC to the glacier's timinus. The monthly mean evaporation in the period from May to Sep. 1993 are show in Table1.

Table 1 The daily means evaporation and water content of surface in Dongkemadi River basin from May to Sep., 1993

Months	*Soil evaporation (mm)*	*Saturated soil evaporation (mm)*	*Water evaporation (mm)*	*Water content of surface soil (%)*
May	0.8	2.5	4.3	43
Jun.	2.1	3.3	4.9	40
Jul.	2.7	3.4	4.6	52
Aug.	2.5	3.6	4.1	45
Sep.	1.8	3.0	2.9	47
Mean	2.0	3.2	4.2	46

2. FEATURE OF EVAPORATION PROCESS

The evaporation processes on a ground surface are control by its environmental characteristics such as climatic parameters and ground surface conditions. Therefore, evaporation relates well with water evaporation, water content of soil and topographic factors.

2.1 *The relationship between soil evaporation and water evaporation*

Generally, the observed water evaporation is obtain by the pan with20 cm of diameter. The observed value is higher than real one and keeps a linear relation (Zhang, 1992). Anyway, the observed value of water evaporation is a good parameter to indicate the possibility of soil evaporation. The relationship between daily soil evaporation (E) and daily water evaporation (E_w) on BC shown in Figure 1 can be express as:

$$E = 0.726E_w - 0.20 \qquad (mm/d) \qquad (2)$$

with correlation coefficient of 0.853.

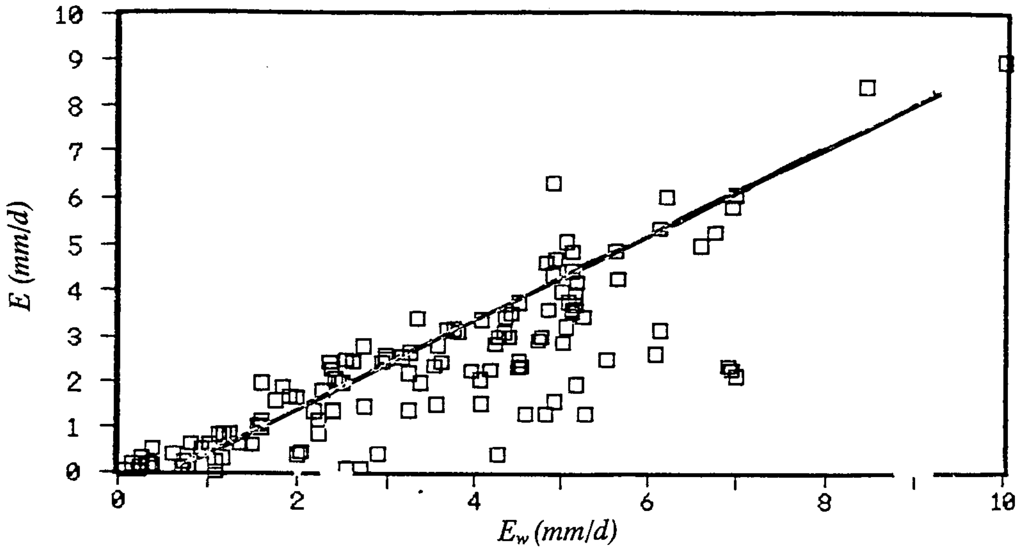

Figure 1. The relationship between daily soil evaporation (E) and water evaporation (E_w)

2.2 The relationship between soil evaporation and water content

The possibility of water supply in soil is an important parameter to govern soil evaporation. There would be a relationship between soil and water content (Brutsaert, 1982). The relationship between daily soil evaporation and surface water content in the observed point is shown in Figure 2. The following equation is obtained by correlation analysis:

$$E = (W/23.8)^{1.646} \qquad (mm/d) \qquad (3)$$

with a correlation coefficient of 0.835. The derivative form of Equation (3) is:

$$\frac{dE}{dW} = 0.246W^{0.646} \qquad (4)$$

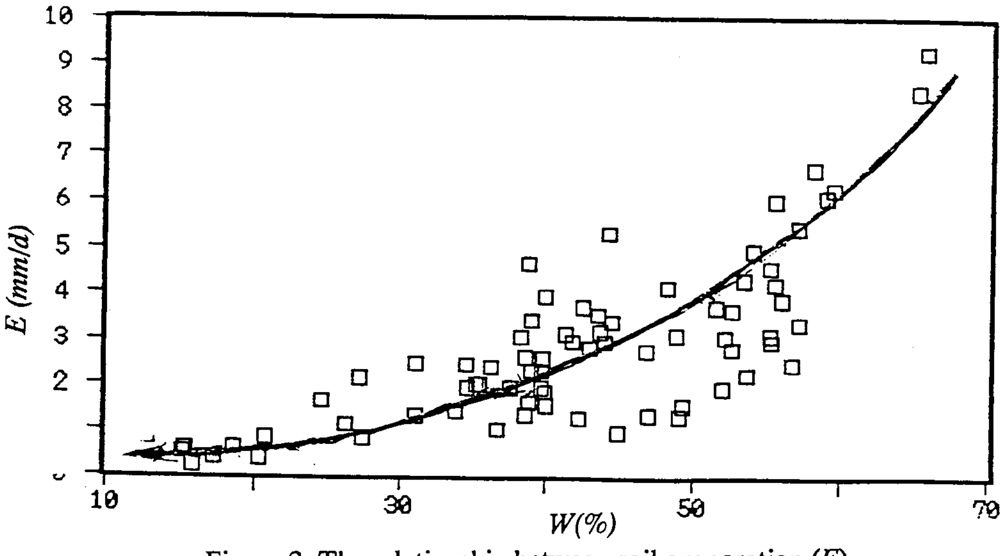

Figure 2. The relationship between soil evaporation (E) and water content of soil (W)

Equation (4) means that the soil evaporation depends nit only on change of water content but also on water content itself. For instance, at water content of 50%, soil evaporation would vary 1.1 mm in response to 10% water content change; at water content of 80%, it would 1.5 mm in response to the same water content change.

2.3 *The influence of topography on evaporation*

Through changes climatic parameter and surface condition topography changes evaporation condition. At the top of a hill, the stronger wind and higher vapor transfer general results in more evaporation. However, it is possible that fewer possibility of maintaining water and lower water content of soil. The daily evaporation values for different parts of a hill in BC are shown in Figure 3.

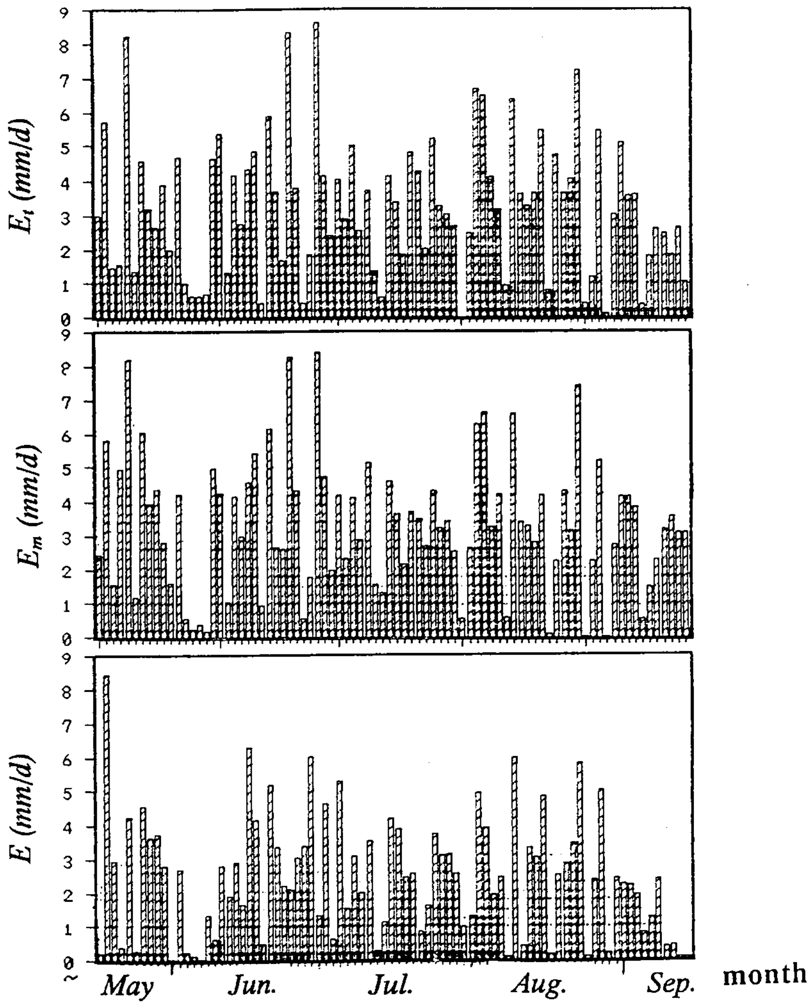

Figure 3. Daily soil evaporation at the top (E_t) (a), at the middle (E_m) (b) and at the bottom (E) (c) of a hill

The difference of evaporation among the three points was fewer and the mean difference was within 0.3 mm in June, when lower water content appeared on the ground surface, 38% on an average. From July to September, the evaporation difference among these points got larger in accordance with increase in surface water content of soil, reaching 1.0 mm or more. From Correlation analysis we have:

$$E = 0.540E_t + 0.664 \qquad (mm/d) \qquad (5)$$

$$E = 0.541E_m + 0.695 \qquad (mm/d) \qquad (6)$$

Where E_t, E_m and E are daily evaporation at the top, at the middle and at the bottom of a hill respectively. It can be seen from Equations (5) and (6) that the daily evaporation at the bottom was higher than that at other two points as evaporation less than 1.4 mm. Most of these cases occur bad weather.

2.4 *The daily process of evaporation*

Hourly observation of daily process of evaporation was carried out in a few day both in BC and D105. D105 point is 5 km far from BC and with more dry surface condition. The difference of surface water content of soil is 19-25%. The daily processes of soil evaporation and saturated soil evaporation in BC and D105 on 27 May, 28 May, 22June, 23 June and 7 July are shown in Figure 4 respectively.

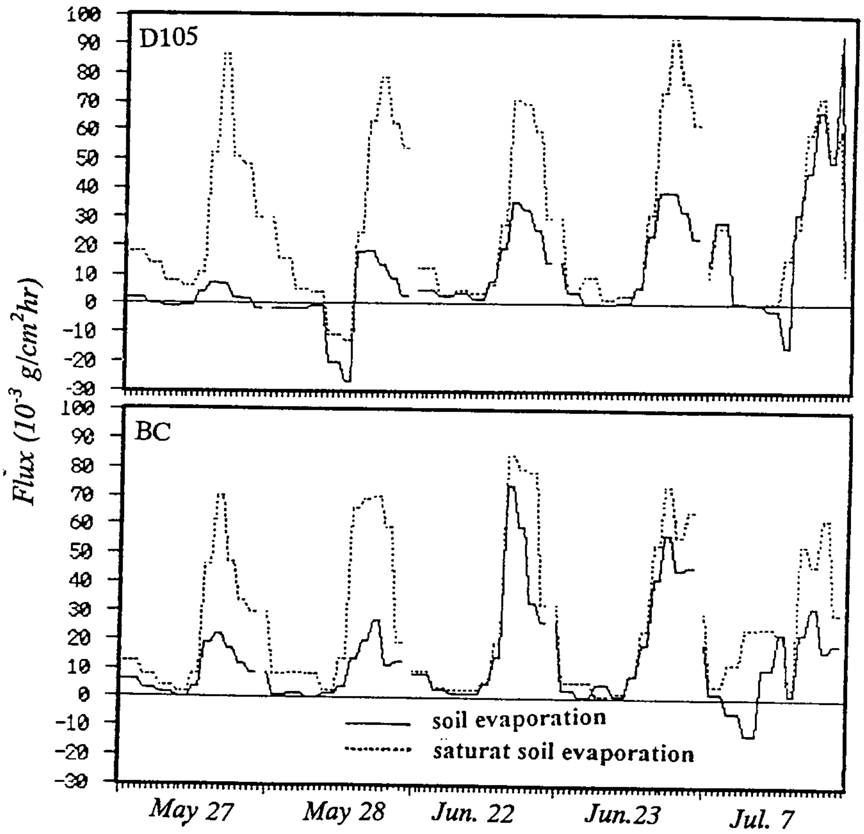

Figure 4. The daily processes of evaporation in BC (a) and in D105 (b)

The observing days were in good weather expect for 7 July when local weather system appeared. The difference between saturated soil evaporation in the two points was within 10^{-3} g/cm^2, and higher saturated soil evaporation occurred in D105 where the surface was drier; but higher soil evaporation occurred in BC due to higher water content. Anyway, both soil evaporation and saturated soil evaporation in the two points varied in the same phase, evaporation processes mainly occurred from 12:00 to 20:00 and the maximum occurred around 15:00. On 7 July, when a local weather system pass, the evaporation process was disturbed and soil evaporation and saturated soil evaporation became quite similar in D105. That was due to fewer vapors in the atmosphere above the dry ground surface, causing higher evaporation in the case of good water supply. Both soil evaporation and saturated soil evaporation were fewer in May, which would be due to fewer melting and fewer water supply in soil. Observation reveals that there is a large difference between soil evaporation and saturated soil evaporation in daytime and little one in night.

3. DISCUSSION

The Tibetan Plateau, an exceptional ground surface in the world, has a special climatic seasonal variation due to Plateau monsoon. Moist season occurs in warm season, this is more obvious in the studied region. According Zhang (1984), the moist-warm season in this region begins from the end of May and ends at the beginning of Sep.. This is verified by our observation in 1993. In the moist-warm season, good water supply condition due to more precipitation together with surface soil thawing makes evaporation intensive. In the dry-cold season, there are very few evaporation for the dry and frozen ground surface, and sometimes condensation became considerable. From the observation and discussion above, the annual evaporation is estimated to be 314 mm, among them 25 mm in May, 63 mm in June, 84 mm in July and 64 mm in Sep..

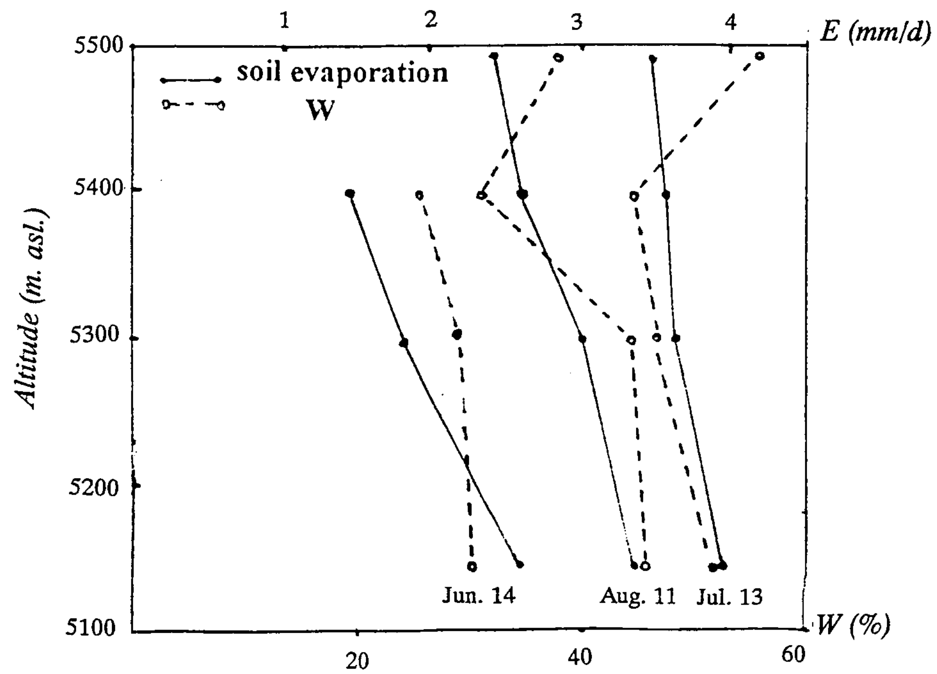

Figure 5. The variations of soil evaporation (E) and water content (W) with altitude

There are complex topography and large relative altitude difference in the Plateau. The variations of soil evaporation and water content of soil with altitude on 14 June, 13 July and 11 Aug. are shown in Figure 5. Below 5400 m.a.s.l., both soil evaporation and water content of soil decrease with altitude; over 5400 m.a.s.l., water content increase but soil evaporation decrease with altitude for lower temperature. Therefore, influence of climatic and surface conditions on evaporation is based on the observation in the basin. Certainly on the top of a mountain evaporation would sharply decrease for the bare rock and few water contents.

The geographical condition is variegated in the Tibetan Plateau for its broadness, so is the evaporation process. A comparison of ground surface evaporation between Dongkemadi River basin in Tanggula Pass and Urumuqi River basin in Tianshan Mountains is shown in Table 2. Soil evaporation and water content of soil are higher in the intermediate zone of Urumuqi River basin; of course the air temperature is higher, $-5.6\,^{0}C$ of annual mean, but wind speed, as an important factor controlling evaporation, is lower. It is worthy to mention that fewer water evaporation occurs in Urumuqi River basin, which should attribute to observation. The water evaporation pan was seated at 70 cm height above the surface in Urumuqi River basin and that in Dongkemadi River Basin was seated on Ground surface. So, the precipitation collection ratio was different, resulting in different error in water evaporation observation.

Table 2. Comparison of monthly evaporation between Dongkemadi River basin in the Tanggula Pass and in Urumuqi River basin in the Tianshan Mountains

Region	**altitude (m.asl.)**	**Month**	**Water content of surface soil (%)**	**Soil evaporation (mm)**	**Water evaporation (mm)**	**observed period**
		May	43	25	129	
		June	40	63	138	
Tanggula Mts	5070	July	52	84	133	1993
		Aug.	45	78	127	
		Sep.	52	64	87	
		yearly		313		
		May			99	1986
Tianshan		June	60	81	104	
Mts	3549	July	63	100	140	
		Aug.	55	71	117	
		Sep.			96	

Generally, it is thought that evaporation is weak in the center of the Tibetan Plateau for its high altitude and cold climate, however, it is not fewer than that in the intermediate zone of the Tianshan Mountains.

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Some Misconceptions on the Penman-Monteith Input Parameters for Crop Water Requirement Calculation

Jiemin Wang * ‡ and W.G.M. Bastiaanssen**

*Lanzhou Institute of Plateau Atmospheric Physics, CAS, Lanzhou, Gansu 730000, China
**Winand Staring Centre for Integrated Land, Soil and Water Research, Wageningen, The Netherlands

Abstract

The most recent guidelines on crop water requirement calculations are based on the Penman-Monteith equation (PM), using a minimum resistance to evapotranspiration. The use of PM demands specific knowledge of crop and meteorological parameters. Effects of the treatment of these parameters and the user's knowledge of the potential evapotranspiration calculations are demonstrated for a spring wheat crop at field scale. The errors could be substantially high if improper meteorological and crop parameters were adopted. Verification was carried out against state-of-the-art measurement techniques applied in the Heihe River Basin project (HEIFE) in Northwest China.

1. Introduction

The Penman-Monteith equation (PM) is a common tool in calculation of the surface latent heat flux. The use of PM has been recommended by the FAO (Smith, 1991) and is gradually becoming a more common element in decisions about the allocation and distribution of irrigation water. Information on potential evapotranspiration is also vital for monitoring the operational irrigation scheme.
A large irrigation scheme is a conglomerate of various small fields, each with its own local characteristics and conditions: wet/dry, green/bare, rough/smooth, homogeneous/heterogeneous crop stand, warm/cold, saline/non-saline, sheltered/unsheltered, etc. As a consequence, the near-surface micro-meteorological conditions vary from field to field and generalized meteorological and crop parameters can hardly be derived. Calculation of potential evapotranspiration is thus always a compromise between data demands and data availability. In the absence of sufficient meteorological input data, one has to rely on a very limited range of input parameters obtained from the nearest meteorological station, even though the station may be far away. Crop data are usually taken from standardized tables such as those provided by Doorenbos and Pruitt (1977). The errors introduced by using different crop and meteorological data have so far been marginally understood, because measurements of actual crop water consumption at field scale are difficult to conduct.
The well-known Penman-Monteith equation is written:

$$\lambda E^{PM} = \frac{\Delta(R_n - G) + \rho_a C_p(e_s - e_a)/r_{ah}}{\Delta + \gamma(1 - r_s/r_{ah})} \tag{1}$$

where λE^{PM} is the latent heat flux according to PM, Δ is the slope of the saturated vapor pressure, R_n is the net radiation, G is the soil heat flux, ρ_a is the moist air density, c_p is the air specific heat at con-

‡ Present: Invited Researcher, Center for Environmental Remote Sensing, Chiba University
1-33 Yayoi-cho, Inage-ku, Chiba 263, Japan. E-mail: jmwang@rsirc.cr.chiba-u.ac.jp

stant pressure, e_s and e_a are atmospheric saturated and actual vapor pressure respectively, r_{ah} is the aerodynamic resistance to heat and vapor transfer, γ is the psychrometric constant and r_s is the bulk resistance to evapotranspiration. The time scale for PM typically ranges from a few minutes to one hour. The 24 hour evapotranspiration value, ET, can be obtained with the aid of time integration:

$$ET = \int_0^{24} \left(\frac{\lambda E^{PM}}{\lambda \rho_w} \right) dt \tag{2}$$

If land surface comprises a full canopy, the bulk resistance r_s is affected by soil moisture, Photosynthetically Active Radiation, vapor pressure deficit, temperature and leaf water potential etc. When r_s is lower than a crop-dependent threshold r^{min}, potential evapotranspiration can be calculated.

Eq.(1) requires the input of meteorological and crop data, such as the net radiation R_n (or incoming solar radiation $K^{\downarrow}$); air temperature T_a, relative humidity RH and wind speed u; the surface albedo r_0; surface emissivity ε; surface roughness length for momentum (z_{0m}) and heat transport (z_{0h}); the displacement height d and the leaf area index (LAI), etc. Some parameters are directly used however, most of them are used to derive more explicit parameters by physical (micrometeorological) laws or empirical formulas.

Hydrologists and irrigation engineers like to use 'crop factor' in their models. For the i_{th} crop, crop factor $k_{c,i}$ can, for example, be defined as

$$k_{c,i} = \frac{ET_i^{pot}}{ET^{ref}} \tag{3}$$

where the upscript 'pot' and 'ref' refer to respectively the potential ET, and the ET for clipped grass (Allen et al., 1995), with approximately h=12cm, r_0=0.23, z_{0m}=0.12h, z_{0h}=0.01z_{0m}, d=0.67h, LAI=2.85, and r_s^{min}=200/LAI (sm^{-1}). Values of k_c-factors have been provided by various sources (e.g. Doorenbos and Pruitt, 1977).

2. Some critical notes

i) Physical-mathematical constraint

The derivation of PM relies on the linearization of the saturated vapor pressure at the evaporation front. Such parameterization is only physically feasible if the temperature difference between surface and air, (T_0-T_a), is low (e.g. <5K). In fact, PM was firstly derived for open water surface where (T_0-T_a) is small anyway. The evaluation of the equilibrium surface temperature of Eq.(1), T_0^{PM}, would be necessary, because the surface available energy

$$R_n - G = H^{PM} + \lambda E^{PM} \tag{4}$$

is basically related with it. T_0^{PM} can be obtained by

$$T_0^{PM} = H^{PM} \frac{r_{ah}}{\rho c_p} + T_a \tag{5}$$

ii) Meteorological data constraint

Micrometeorological measurements should meet also the condition of referring to an wet environment (well supplied with water). For practical reasons, this essential rule is not always complied with. Meteorological stations are often situated at the edge of towns, with no facilities to irrigate the surface underneath the observation instruments. Besides, Eq.(1) needs to be solved at small time increments, followed by a time integration to obtain ET^{pot} for 24 hours. In the absence of hourly records, Eq.(1) has to be applied with time integrated values for all parameters, for instance, with 24 hour representative values. For most cases, this is mathematically incorrect.

iii) Crop factors

A great deal of confusion attends the definition and application of crop factors. k_c is sometimes also used to obtain actual evapotranspiration (i.e. $r_s > r_s^{min}$), so it should be smaller than that defined in Eq.(3). Another concern is that the definition of the reference crop; Some other crops, e.g. alfalfa instead of clipped grass, has also been used, which accompanied by new k_c-tables. This is more difficult for hydrological modellers and irrigation engineers to choose.

Besides, the canopies of irrigated crops are not always closed. Especially in the emergence and transplantation development stages, bare soil pockets can form a significant proportion of the total crop acreage. Soil evaporation may form a significant part of the total evaporation losses. The standard k_c values do not provide any information on this condition.

3. Surface energy balance study in HEIFE BOP

A sophisticated and comprehensive database on land surface-atmospheric interaction, particularly surface energy and water balance, has been established during HEIFE, a Sino-Japanese cooperative program executed in the Heihe River Basin, Northwest China, 1990-1993. The land surface processes in the irrigated areas of Linze and Zhangye were carefully studied (Wang and Mitsuta, 1992; Wang et al., 1993). Profiles of air temperature, humidity, and wind speed were continuously measured at four 20m towers over a period of several years, while the all-component radiation balance was also the subject of continuous monitoring. During some intensive observation periods (IOPs), including the specific Biometeorologocal Observation Period (BOP) in a spring wheat growing season, 1992, turbulent heat fluxes were measured by means of eddy correlation devices and the Bowen-ratio surface energy balance method. Weighing lysimeters were used to assess daily variations of evapotranspiration. Stomatal conductance was measured, as well as single leaf transpiration rates. Soil moisture and water table depths were recorded automatically. These data are valuable for testing the reliability of PM calculations of potential evapotranspiration.

The data collected in the 2nd Biometeorological Intensive Observation Period (BIOP2), June 3 to 13, 1992, were selected to study the surface energy balance of irrigated areas. The spring wheat field was located in the central area of Zhangye oasis (approximately 15km by 20km in size), with a crop height of 65cm at the start of BIOP2, rising to 75 cm at the end; It was in the heading stage. Two different sites in the field were equipped with sonic anemometers and infrared hygrometers to measure the turbulent fluxes by eddy correlation technique. Fig.1 shows the layout of the experiment site.

There was ample water supply during BIOP2, soil water content permanently exceeded 0.25 cm^3cm^{-3}. It is assumed that the observation field fulfill the typical conditions where actual evapotranspiration can be fairly nominated as a site where potential evapotranspiration is maintained ($r_s = r_s^{min}$). This was also verified with single leaf stomatal resistance measured by Li-cor 1600 system. Fig.2 shows the stomatal resistance (averaged between 10 a.m. and 4 p.m.) during BIOP2. The mean value was 201 sm-1, but minimum values of 50 to 120 sm-1 were frequently recorded particularly after the irrigation day. The measured evapotranspiration rate in table 1 may be used as potential evapotranspiration rates; The data set is to be used in testing λE^{PM} predictions for wet land surfaces with a variety of input parameters.

The cumulative potential evapotranspiration results of the two sites (C and J) in the common six days were identical (24.3mm), confirming the high level of accuracy of the eddy correlation measurements.

Net radiation data were added to provide a better picture of the complete surface energy balance.

Table 1. Daily average heat and ET fluxes measured at two sites using eddy correlation method in Zhangye station during BIOP2. The observed daily averages of net radiation were also presented.

Date	Site C					Site J				
	λE (Wm^2)	ET (mm d^{-1})	H (Wm^2)	Rn (Wm^2)	Λ (-)	λE (Wm^2)	ET (mm d^{-1})	H (Wm^2)	Rn (Wm^2)	Λ (-)
June 3	149	5.3	15	-	0.91	131	4.6	12	208	0.91
June 4	156	5.6	-27	190	1.21	163	5.7	-32	168	1.25
June 5	61	2.1	-7	105	1.14	-	-	-	-	-
June 6	206	7.3	9	205	0.96	-	-	-	225	-
June 7	160	5.7	15	207	0.91	-	-	-	224	-
June 8	155	5.5	14	203	0.92	-	-	-	236	-
June 9	134	4.7	-13	174	1.11	129	4.2	-11	195	1.09
June 10	68	2.4	-27	72	1.66	78	2.7	-18	100	1.31
June 11	97	3.4	11	170	0.90	101	3.6	8	207	0.93
June 12	83	2.9	2	139	0.98	99	3.5	5	154	0.95
June 13	-	-	-	206	-	134	4.8	3	229	0.98
Average	127	4.5	-1	167	1.00*	119	4.2	-5	195	1.06

The evaporative fraction Λ was defined from:

$$\Lambda = \frac{\lambda E}{\lambda E + H} \tag{6}$$

with an average of 1.0 to 1.06, revealing that the net available energy in the irrigated field, Rn-G, was hardly exceeded by evapotranspiration and the development of sensible heat flux was compressed. Λ seems to be a simple and safe upper boundary to check λE^{PM} calculations.

The potential ET was also measured by lysimeters. The results showed a 20% higher value than in Table 1, because of their small size (d=2m) and the surrounding of bare soil. Most research on crop water requirement is based on lysimeter measurements, this may represent a serious shortcoming of the relevant validation studies. Physically, the turbulent flux measurements reflect a much larger area. The data of BIOP2 can also provide the evaluation of other important parameters such as daily surface albedo r_0 (0.188) and emissivity ε (0.965, from H and surface longwave radiation). Roughness parameters can be calculated with similarity formulas:

$$\frac{u}{u_*} = \frac{1}{k}\ln\left(\frac{z-d}{z_{0m}}\right) \tag{7}$$

$$\frac{T_0 - T_a}{H} = \frac{\rho c_p u_*}{k}\ln\left(\frac{z-d}{z_{oh}}\right) \tag{8}$$

For d=0.4m, approximately z_{0m}=0.129 and z_{0h}=0.135, with a ratio around one. This was also noticed by Wang et al. (1997) on the basis of latent heat flux measurements in association with vertical humidity gradients. The popular rule of z_{0m}/z_{0h}=10 is thus not necessarily correct for irrigated crops.

4. Application of the Penman-Monteith equation

Several categories of users are using PM based on their background, data accessibility, and specific objectives. Some results are quite different because of misunderstanding and improper parameterization. To distinguish the parameterization scheme more precisely, we set more categories for analysis: 1) Micrometeorologists, who are aware of the PM with a better physical basis, personally collected the field data at flux sites, understand how each parameter has been measured and have full access to the most sophisticated database; 2) plant physiologists, who realize the diurnal cycle of evaporative behavior of site-specific crop parameters. Some of them can access full data sets; Others (we put them as category 3) uses estimated results, for example, to calculate net radiation by using solar radiation and other routine data of the meteorological stations. 4) Hydrologists, who are not interested in time scale less than one day but have specialized in spatial variations; Local crop parameters are essential to obtain adequate results; 5) Agronomists, who may take some guidelines and use relevant formula to retrieve crop parameters; 6) Irrigation engineers, who favor crop factors as well as other guidelines; 7) Some agriculture engineers, who may just take the meteorological data from the nearest met-station and follow the 'guidelines'.

Calculations have been done by using the ways which the respective category users are most possibly using. The results, e.g. cumulative λE^{pot} for the 11 days of BIOP2, obtained by different categories are shown in Fig.3. The errors in the cumulative evaporation fraction are shown in Fig.4.

Estimations from the most professional users (category 1) are quite well, which implies that the physical-mathematical formulation of PM is appropriate. However, a 54% error was found for June 10, probably resulted from larger stomatal and bulk resistance of this specific day. The error of the results from category 2 and 3 are a little larger than category 1, but it is encouraging to show that the downward short wave radiation can be used to assess energy balance instead of Rn measurements. λE^{pot} estimation from category 4 seems successful however, from Fig.4, it is deceptive. The results of category 5 is similar; Some errors, e.g. in the estimation of Rn, are quite large, but compensated with some others in a unpredictable way. The errors of category 7 may exceed 100% in some days. This clearly shows that the performance of PM relies heavily on representative meteorological data. Particularly, arid zones are characterized by sparse vegetation, micrometeorological data must reflect this actual condition.

5. Conclusions

A basic and simple case study demonstrated that the potential attractiveness of PM greatly depends on the skills of the user. Complex physics should be seriously considered. Some typical meteorological and crop parameters used in PM responds continuously to ambient factors and shows a distinct diurnal variation, which should be aware in the evaluation of daily evapotranspiration.

Acknowledgment

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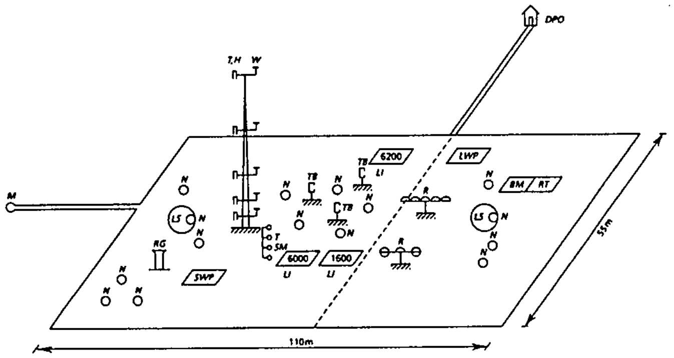


Figure 1. Instruments used at the comprehensive experimental site during BIOP2, Zhangye, June 1992. T,H,W = Profile tower, R = radiation, TB = eddy correlation, N = neutron probe, LI = Li-cor, LS = lysimeter .

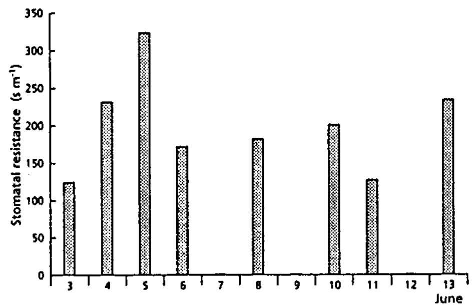


Figure 2. Single leaf stomatal resistance measurements on spring wheat during BIOP2.

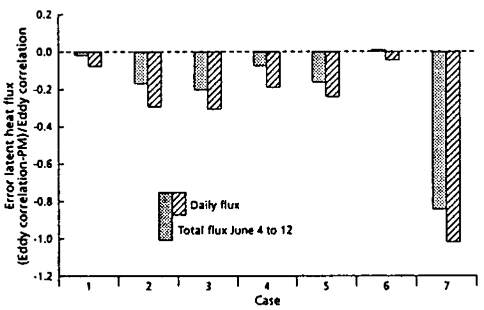


Figure 3. Errors in the eleven-day cumulative latent heat flux and average daily error estimated by the Penman-Monteith equation for the 7 categories defined in the text.

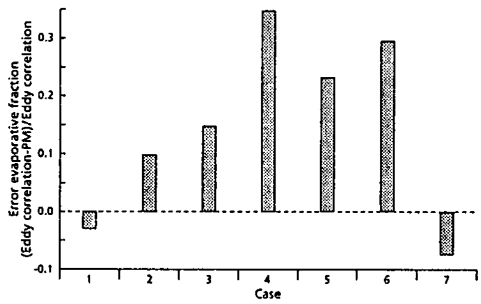


Figure 4. Errors in the eleven-day cumulative evaporative fraction estimated by the Penman-Monteith equation for the 7 categories.

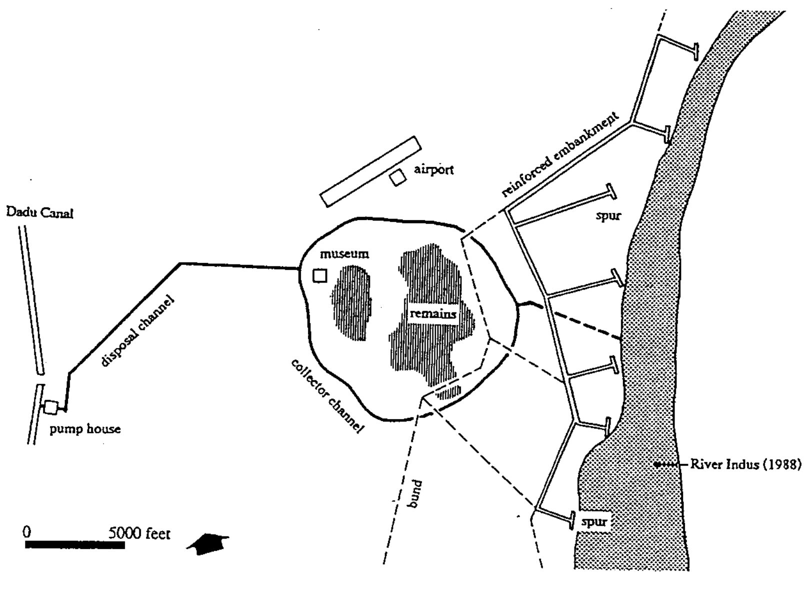
3. Water Resources and Ecological Environment

A Preliminary Study on the Stability of Ecosystem and Landscaping for the Site of Moenjodaro and the Vicinity, Pakistan

Sadatoshi Tabata
Center for Environmental Remote Sensing, Chiba University
1-33 Yayoi-cho Inage-ku Chiba 263 Japan
Fax:+81-422-37-5337

Abstract

The content of this paper is dedicated to a preliminary analysis and evaluation of fundamental conditions necessary to prepare a comprehensive landscape planning scheme for the site of Moenjodaro and the vicinity which require the most urgent and complete proposal because of its primary value as a cultural asset. It is discussed that a comprehensive landscape planning coordinated with the agricultural land use in the area should be prepared upon the completion of initial tasks to safeguard the remains against immediate threats of destruction. In particular, amount of the water resource generated by the ground water control program was estimated and several conditions of possible agricultural development and land reclamation in the area utilizing those byproducts were discussed. Also, a group of specific plant species suitable for landscaping and plantation of the site to protect the remains against wind erosion and prepare a appropriate environment for the tourism purposes was identified. However, it became clear at present that a set of technical information needed to prepare a realistic scheme has been in critical deficiency.



Location of the Remains and Other Related Features in the Area

Introduction

Even after the independence of the nation, the site of Moenjodaro, Harappa, and other historical remains of the ancient cities of Indus Civilization in Pakistan had not been given satisfactory treatments for preservation due mostly to political and economical reasons of developing countries. In response to the critical conditions of those remains, The United Nations Educational, Scientific and Cultural Organization (UNESCO) had took an initiative for promoting the preservation of the sites in the first quarter of 1960s. Those endeavors have shown a certain degree of success and several prominent sites are safeguarded from immediate threats of structural damage. For the next phase of the environmental development, it is required to extend the conservation task for larger scale of the site as well as promoting landscape planning and economical development to revitalize the local communities. The contents of this paper is dedicated to a preliminary analysis and evaluation of fundamental conditions necessary to establish a comprehensive landscape planning scheme for the site of Moenjodaro and the vicinity which require the most urgent and complete proposal because of its primary value as a cultural asset blessed by the entire world.

The study begins with overviewing the process of the preservation tasks in the past which is followed by setting up objectives of the landscape planning. A detailed analysis and evaluation will be provided for two important factors closely related to land use of the site and the vicinity : control of ground water level for desalinization of the structural remains; examination of the existing vegetation and plant species suitable for landscaping within the site and the surrounding area. The primary source of information is several reports prepared by Pakistan government and UNESCO, and the minutes of the proceedings at the International Consultive Committee for the Preservation of Moenjodaro. Also, hearing surveys were conducted on the site of Moenjodaro and the local communities as well as at the Authority for the Preservation of Moenjodaro in Karachi.

Process of the Conservation Tasks in the Past

During the colonial period between the discovery of the site in 1922 and the end of World War II, excavation of the site was conducted mostly by British archaeologists such as J. Marshall and E. Mackey. Upon the independence of the nation in 1947, the jurisdiction of the site was transferred to the Department of Archaeology, Government of Pakistan. It was reported that some structural damages by salinization was found at that time and minor repairs and washing by fresh water were repeated several times.

Sukkur Barrage, the largest irrigation dam in the Indus valley, was constructed 120 km upstream from the site of Moenjodaro in 1933. It enabled the middle basin of the Indus valley be irrigated for agricultural development and rice cultivation prevailed in the surrounding agricultural communities. It activated the rise of ground water table which deteriorated the structural damage of the remnant through salinization. Also, the full operation of Sukkur Barrage influenced the stream pattern of the River Indus and its main course shifted further west to the right bank near the site which made the flooding of the river one of the major threat of physical damage.

In 1960, recognizing the urgency of the safeguarding of the remains against damage, the government of Pakistan asked UNESCO for technical and financial assistance. UNESCO responded immediately with dispatching groups of specialists in archaeology and conservation technology for next several years and, in 1972, established the first version of a masterplan for the preservation of Moenjodaro as a joint effort with Pakistan Government. In the following year, "International Symposium on the purpose of discussing the contents of the master plan as well as promoting the UNESCO's preservation fund which aimed at US$5,000,000. Also, an international conciliative committee of the specialist was organized to support the activities of the preservation project to be executed following the master plan and a part of the actual project was initiated in 1981. After several times of revision, the master plan was officially approved by UNESCO in 1978. The following is the major tasks for the preservation and actual proposals to be executed.

(1) Ground water control

The level of ground water reached immediately under the structural remains when the project was initiated. The part of the brick foundation decomposed in a submerged condition and it made further excavation practically impossible. Also, salinized water rises through capillary action in a sedimentary layer of the soils underneath and it enhances decomposition of the bricks in the lower part of the remains by salinization effects. For a countermeasure, it was proposed to lower the ground water level by excavating a number of tube well in the form that encircles the remains and pumping up the ground water. The extracted water will be utilized for irrigation of agricultural land in the area immediately downstream of the site. The details in the agricultural development will be discussed later.

(2) Preservation of structural remains

Since most of the remains had been abandoned for a long period of time, its substantial part became structurally unstable through weathering. In order to prevent physical collapse of the remains, it was required to reinforce the structure and prepare a proper surface drainage system on the site. Decomposition of the bricks through salinization would be prevented by salinized ground water, coating the entire remains with saline resistant materials, and removing salinized soils from the site.

(3) Flood control of the River Indus

The site of Moenjodaro is located 1 km west of the right bank of the River Indus. It seemed necessary to reinforce the existing bunds as well as changing the course of main stream further east from the right bank, so that the immediate threat of flooding would be minimized. Among other technical proposals are reinforcing the embankment with heaps of rocks along the site and constructing 7 T-shape spurs which run out to the main stream at right angle.

(4) Revegetation and landscaping of the site and the surroundings

It is considered that some portion of weathering of the remains would be cause by air bone saline carried with sand particles coming from outside of the site. As a countermeasure development of green belts encircling the site would be effective for protecting the remains against strong wind and sand. Also, it is proposed to restore an imaginary landscape of the Indus Civilization for tourism purpose and to alleviate visual impact of ground structures and facilities by revegetation and its planting design.

In order that those major proposals of the masterplan are executed effectively on the schedule, four subcommittees were organized within the International Consultive Committee and technical assistance has been provided.

Among four major proposal, the priority has been given to the ground water control on the site and the flood control of the River Indus which have ultimate urgency. Installation of the tube wells and construction of disposal channels which executed in two stages were completed in 1985. On the other hand, reinforcement of the bunds along the river bank and construction of the spurs started in 1985 and two spurs and embankment are left to be completed as of November,1990. Also, repairs and partial restoration of the remains have been executed continuously since 1981 and temporary treatments were completed for the most of excavated remains.

The landscape planning of the site and the vicinity, the main topic of this paper, is categorized into the task of plantation and landscaping of the site. In comparison with other three categories of the preservation tasks, it has been given a low priority and suspended until 1988 because it was not a matter of urgency and the investigation of unexcavated remains has not yet been completed. In the meanwhile, discussions on plant species suitable for the plantation and landscaping were repeated, but not concluded in a list of selected species. However, at this moment of time when the preservation tasks directly related to the protection of the remains, although uncompleted, have been initiated and proved certain degree of success, it is considered that the tasks of plantation and landscaping would be activated and specific proposals would be put forward.

It has been argued repeatedly in the consultive committee that the tasks of plantation and landscaping should be extended into a regional scale including a proposal of land use in the surrounding local communities. The masterplan advocates the agricultural development of the area through irrigation of ground water disposed from the tube wells and changing of cropping patterns. Also, multi-purpose plantation and afforestation for desalinization of the land have widely been practiced in the region. Therefore, coordination with agricultural land use in regional scale must be retained to create productive conditions and it is an ultimate objective of the landscape planning which propose a land use masterplan in the surrounding region of the site. The following discussions are focused on the ground water control, vegetation and suitable plant species which form substantial part of conditions related to the landscape planning.

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Chronological Record of the Events Related to the Preservation of Moenjodaro

Year	Excavation and Preservation Task	UNESCO and Others
1922	Discovery of remains by R.D.Banerji Excavation by J. Marshall continued through 1936	
1931	Publication of "Moenjodaro and the Indus Civilization"	
1933		Competion of Sukkur Barrage
1938	Publication of "Further Excavation of Moenjodaro"	
1940 - 48	Desalinization tasks of remains	
1947		Independence of Pakistan
1960	Requesting UNESCO's assistance	
1961		Site visit by E. Warner of the British Museum
1964	Excavation by University of Pennsilvania	1st research group headed by H.D.Plenderleith Open of Moenjodaro International Airport
1966		2nd research group headed by S.J.Van Kregten
1967	Renovation of Moenjodaro Museum	
1968		3rd research group headed by M.Wheeler
1972	"Masterplan for the Preservation of Moenjodaro"	4th research group headed by Z.Iskander
1973	International Symposium for the Preservation of Moenjodaro	Flood of River Indus
1974	Establishing Authority of the Preservation of Moenjodaro Installing experimental tube wells Establishing research laboratory on the site	Foundation of UNESCO fund
1976	Founding International Consultive Committee	Flood of River Indus
1978	Symposium on Plant Community and Landscaping	Approval of preservation masterplan
1980		Approval of preservation taskforce
1981	Initiating preservation task	
1982	Completing disposal channel	
1983	Installing tube wells (1st stage)	
1984		"Tokyo Appeal " by Prince Mikasa of Japan
1985	Installing tube wells (2nd stage) Initiating flood control project	
1986	Completing spurs and embankment (1st stage)	
1987	Completing spurs and embankment (2nd stage)	
1988	Completing spurs and embankment (3rd stage) Revising masterplan	
1989	Completing spurs and embankment (4th stage)	
1990	Completing spurs and embankment (5th stage)	

AGRICULTURAL DEVELOPMENT AND ITS INFLUENCE ON WATER RESOURCES IN WATER DEFICIENT SALINIZED REGION, CHINA

Tian Kuixiang

Shijiazhuang institute of agricultural modernization, CAS,China 050021

Environmental problems such as water shortage and waterlogging and ecological problems, are the most serious problems human face.

1. Agricultural Background of Huang-Huai-Hai plain in China

Huang-Huai-Hai plain, so called three river plain in Japan, including 316 counties from 5 provinces and 2 cities, covering an area of 350,000 km^2 with 18 million hectare of arable land occupied by 200 million people, is the greatest plain and the most important agricultural region in China. It produces 20% of grain, 57% of cotton, 17% of oil and 14% of meat for the whole China.

According to the statistics, the increase of Chinese grain production during the last 40 years is showed in table 1:

TAb. 1 Analysis of increase of food supply in China (billion kg)

stage	one	Two	three	four	five	
Lasting period	1949-58	1959-78	1979-84	1985-93	1994-2000	true yield
(years)	9	20	6	9	7	in 1993
3 provinces in Northeast China	6.65	14.02	13.09	11.70	12.5	5.99
7 provinces in North China	18.09	31.5	20.7	29.47	15.0	125.66
5 provinces in northwest China	4.96	6.94	4.42	6.77	5.0	29.92
5 provinces in southwest China	13.29	18.71	12.67	5.23	5.0	76.28
10 provinces in southeast China	27.65	52.65	43.40	-3.99	12.5	164.75
total increase	70.63	123.82	94.28	49.18	50.0	456.48
average yearly increase	7.85	6.19	15.71	5.46	7.14	
total national yield	200	304.75	407.3	456.45	506.45	
yield per unit(kg/hm^2)	1642.5	2527.5	3607.5	4132.5	4590	
t/ha	1.6	2.5	3.6	4.1	4.6	

From 1949 to 1993, the national grains production increased by 343.28 billion kg, which was 3 times of that in 1949. Grain production from 5 provinces and 2 cities in Huang-Huai-Hai region increased by 99.76 billion kg, which made up 29% of the total national increase, and mainly on plains areas.

2. Comprehensive control of drought, waterlogging, alkalization, and salinization and change in water and soil condition in Haihe plain

In order to improve grain yield, aside from development in sciences ar d technology and in society, an important way is to optimally utilize natural resources. The improvement of yield depends on the utilization of water resources. Generally, yield increase results from a higher input of water. This results in another problem, since Haihe plain is already lack of fresh water.

Climate in Haihe watershed is mild. Although the precipitation varies from 400 to 600 mm, the difference between different years is very big. The unevenly distributed precipitation, which is generally illustrated by 70 to 80% of rainfall taking place in the period from July to august, and 40 mm to 60 mm of rainfall and sometimes no rainfall in more than one hundred days period in spring, always results in dry spring and waterlogging summer. Thus, flooding always results in the upward move of salt from ground water and furthermore causes salinization and alkalization problem. Just as described by farms, soil surface in spring is white and covered by water in summer.

To increase crop yield, the cycling of drought and waterlogging needs changing. A best way to do so is to make use of irrigation system. Thus, during the last 40 years, a comprehensive control method for drought, flood, alkalization and salinization is summarized. This method includes constructing reservoirs in upper streams, draining salty water by digging rivers and digging wells for irrigation. Up to now, reservoirs in upper stream in mountainous areas hold a big amount of runoff and rivers in low land drain a big amount of water directly to the sea, thus the waterlogging problem is basically solved. By developing agricultural irrigation system, drought in spring is offset, meanwhile the ground water table drops. Thus the possibility of secondary salinization is decreased. At the present, 60% of field can be irrigated. Crop yield is improved greatly.

Many ways can result in the increase of crop yield. But the use of ground water is very critical. Generally, to produce every one kilogram of grain, one cubic meter of water is needed. Therefore, to improve grains yield, the uptaking of ground water must be increased. This has result in over- exploitation of ground water. For example, in east part of Haihe plain, the recharge of ground water is 60,000-80,000 $m^3/km^2\ a^{-1}$, but the water discharge is about 120,000 $m^3/km^2\ a^{-1}$, which creates a overdrafting of 20,000-60,000 m^3/km^2a^{-1}. In west part where near the mountain, the overdrafting of ground water is about 100,000 $m^3/km^2\ a^{-1}$. That means yield increase is contributed from the over utilization of ground water. Then, water deficiency results in a drier soil condition and desertification, local hot stove and worsen climate. Under the premise of settling the exigent food problem which is closely related to human beings, the cycle is getting more and more serious.

3. Water shortage is the critical barrier of agricultural development and soil

improvement

The present situation of water resources in Haihe watershed can be described as follows:

- Depletion of surface water.

From the mid-1970s, after the transformation of rivers in Haihe plain, boat transportation disappeared and all rivers dried up except the upper stream of Baiyangdian lake. Even in rain season, there is hardly any river with water flow.

- Limitation in transferable water.

During the history, a certain amount of water could be transferred from Yellow river to Haihe plain through big Canal. But since the increased utilization of water in Yellow River, the water transfer was broke off in 1980. In 1993, with the government interference through the negotiation of different provinces, 10 billion m^3 of water was transferred from Yellow river to Hebei during the period from November to February next year. But in recent years, since, in spring, Yellow river always dried out, available water for transferring was very limited.

- Dropping of ground water table.

The exploitation of ground water results in dropping of ground water table. In the low plain areas, the density of deep wells is 0.3 wells/km^2. Ground water table drops in a speed of one meter per year to present 35-55m. Shallow ground water table in east is now 3-8m below the ground, and 20-28 m in piedmont plain. Most natural lakes such as Ningjinbo and Daluze dry up.

- Decreasing of soil water content.

As the precipitation distributes unevenly and ground water table drops, soil water can't be recharged, especially in spring season when crops request water. Usually, soil in top 40-50 cm is very dry or nearly exhausted. Even after rain or irrigation, soil water in the top layer still can't be raised up totally which result in a drought situation similar to losse platue in Northwest part of China.

- Salinization problems.

  In large scale, since the dropping of ground water table, saline soil and alkali soil areas are shrinking, However, in some special parts, the decrease of runoff results in an accumulation of salt in soil. According to the estimation by Shi Yuanchun, salt accumulation in soil can be 2788.5 kg/ha.a. According to the experiment from some certain sites, an increase of 0.01% in soil salt content can averagely result in an decrease in winter wheat yield by 187.5kg/ha. In addition, the serious shortage of fresh water stabilizes soil salt content.

So, the shortage of fresh water is the greatest barrier to crops yield increase and soil improvement.

4. Water saving and water transfer

Is there no way to settle the present agricultural problems? The answer is no. To protect ecological environment and increase agricultural production to meet the food request of increased population, water saving technologies and water transfer projects are taken into effect in China. Water saving technologies are intended to improve water use efficiency. In fact, water saving technologies in Haihe plain have a great potential which can be suggested through the comparison of WUE in different regions in Haihe plain, as listed in table 2.

Tab.2 Comparing water use efficiency in different areas in Haihe Plain

Areas	piedmont areas	west part of Heilonggang	east part of Heilonggang	coastal plain
biomass(g/m^2)	1350	492	407	222
WUE*(g/m^2mm)	1.59	0.87	0.71	0.40
grain production (g/m^2)	542	175	144	60
WUE for grain (g/m^2mm)	0.64	0.31	0.25	0.11

* WUE: Water use efficiency.

Water saving agriculture is an effective way to increase grains' yield and WUE. It can be developed through the application of high efficient irrigation system, plastic film covering, proper fertilizer addition and good varieties.

To utilize land resources and solar energy effectively, transferring water across watershed is also a measurement to develop agriculture. Now, water from Yellow river is been transferring into Hebei province. But because of the high content of sands in Yellow river during flood season (200-300kg/m^3, even to 600kg/m^3), water can only be transferred after the flooding period when several provinces along Yellow River also need water for agricultural purposes. Thus, water supply from Yellow River to Haihe river plain is only 1.5-2.0 billion m^3/a which is far from the request. In 1997, resulted from the overdrafting of water from Yellow river, Yellow River was dried out from February to June. Thus, available water for water transferring is very limited. The project to transfer water from Yangtze river to Beijing, Tianjin and Hebei Province may need several decades of time and a huge investment to be implemented.

5. The effect of South-to-north water transfer on climate and soil environment

Transferring water across watershed is a way to settle the problem of water shortage in north China. But it may also causes many ecological problems.

- Transferring water in winter for spring utilization needs to store a lot of water in ditches and reservoirs. This way can easily result in ground water table rise up and secondary soil salinization.
- Storing water in large scale could change the local climate especially in rainy seasons, a contradiction of draining and storing water could happen.

All above problems are very important aspects for attentions. At the present, Dalangdian reservoir has been constructed to store water transferred from Yellow River to Hebei Province. Fortunately, this reservoir is very near to our Nanpi Experimental Station. This provides us a basic opportunity to study the effect of South-to-North water transfer on environment.

Changes in the Hydrological Environment and Land Degradation in the Tarim Basin

Hiroki TAKAMURA★ and Muhtar QONG

★Department of Geography, Faculty of Letters, Rissho University. 4-2-16 Osaki, Shinagawa-ku, Tokyo 141, Japan. Fax: +03-5487-3353, E-mail: hiroki@ris.ac.jp

I Introduction

The Tarim Basin is located in the central part of Eurasian Continent and is a typical inland basin, with an area of 530,000 km^2 in the extreme arid zone. Around the basin there are huge mountains such as the Kunlun mountains to the south; the Tianshan Mountains to the north and the Pamir Plateau to the west. The central part of the Tarim Basin is occupied by the Taklimakan Desert, extending ca. 1,500 km from west to east and ca. 600 km north to south with an area of 338,000 km^2.

Several large rivers and groundwater were formed due to the development of alluvial fans at the foots of surrounding mountains in the Tarim Basin. The Tarim River system is a main river system in the Tarim Basin. The Yarkant River in the west and the Khotan River in the southwest and the Keriya River in the south once reached the Tarim River in ancient times, but now only the flood water can flowed into the Tarim River. At present, the length of rivers in the desert changes greatly year by year with the fluctuation in the amount of discharge. For example, in 1991, the Keriya River reached as far as 200 km from the Keriya oasis to the lower reaches in Daryaboyi, but in 1992, the river discharge disappeared at the point ca. 130 km away from the Keriya oasis.

In fact, the hydrological environment is changing continuously in the Tarim Basin, precipitation, river water and ground water were not equivalent to evaporation loss from the land surface, lower reaches of rivers and some lake surface.

The present study is intending to:
To synthesize patterns, processes and the relationship between the changes in hydrological environment and land degradation currently taken place in the Tarim Basin.

II Hydrological Environment

1. Air temperature

The average air temperature in the surrounding areas of the Taklimakan Desert ranges from -9℃ in January to 25℃ in July. It is extremely hot in summer, generally in July and ground surface temperature sometimes exceed 60℃. In contrast, it is extremely cold in winter. Therefore, the annual range of air temperature in the Taklimakan Desert is very large. For instance, at Khotan station the annual mean air temperature is 12.2℃、and the mean air temperature is 25.6℃ in July, and that is -5.4℃ in January. The daily range of air temperature is very apparent and generally 12.5℃ at Khotan. Especially during autumn, the daily range of air temperature is largest. Recently, air temperatures in and around the Taklimakan Desert has been rising obviously in all stations in winter. The mean surface air temperature has risen about 3.0° C with a range from 2.0 to 9.0℃ since 1951 and the risen rate reaches 0.05-0.21℃/year in winter(Fig. 1)

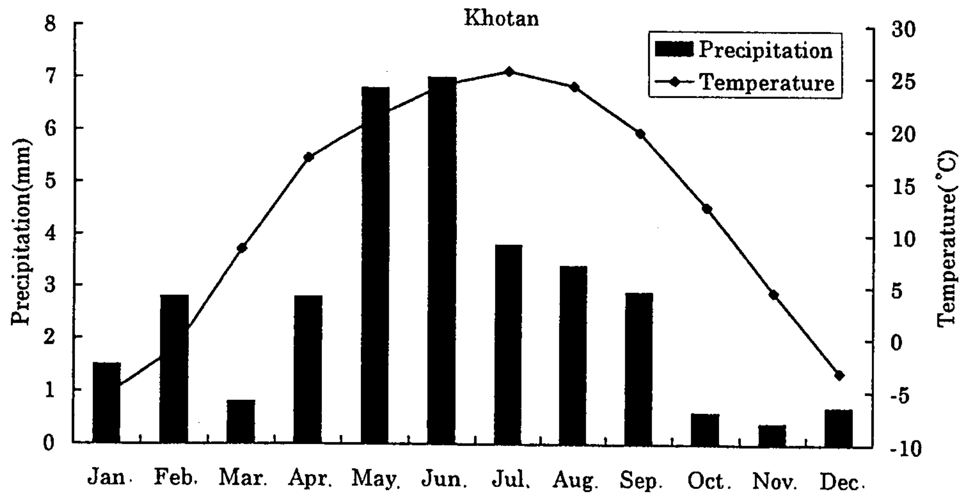

Fig. 1 Monthly average precipitation and temperature at Khotan(1959-1979)

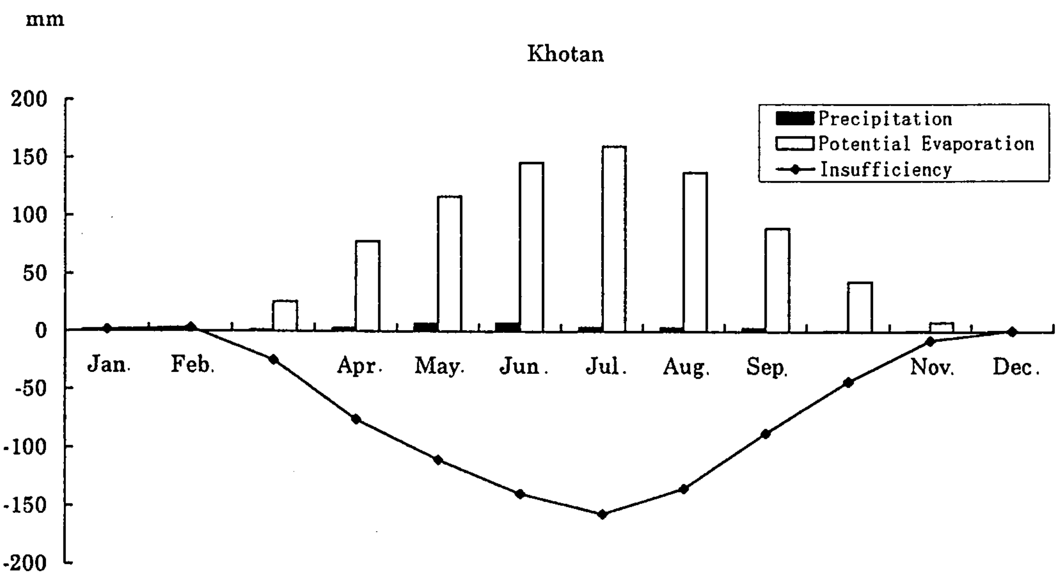

Fig.2 Monthly average precipitation, potential evaporation and water deficit at Khotan(1959-1979)

2. Precipitation

In the Tarim Basin the annual mean precipitation, which is concentrated from June to September is reduced gradually from the west to the east. The southern and the eastern areas are extremely arid, the annual mean precipitation is only 0 to 50 mm (Cheng, 1992). The precipitation of central part of desert is unknown, because of there is no meteorological station. The mean annual precipitation of Turpan is 17 mm, and the other oases located in the marginal region of the Taklimakan Desert are ranging from 20 to 70 mm.

Recently, there are some changes in the amount of precipitation in the Tarim Basin. For example, summer precipitation seems to be increasing at Qarkilik in the southeastern part of the Tarim Basin since 1950s. The annual precipitation's were 16.2 mm in the 1950s, 18.0 mm in the 1970s and 40.0 mm in the 1980s, respectively (Yin *et al.*, 1992).

3. Evapotranspiration

Because of the existence of the Tianshan Mountains the air with water vapor cannot reach the Tarim Basin, which located in the leeside of the Tianshan Mountain Ranges. However, there is a track of moisture transportation from the Indian Ocean along some river valleys and the moisture can arrive at the south edge of the Tarim Basin sometimes in summer.

However moisture holding air flows in and around the Tarim Basin are weaker in summer and stronger in winter. Accordingly, in the desert area not only precipitation is largely limited, but also annual evaporation (potential evaporation) is very high. It is over 2000 mm most of the stations in the Tarim Basin. For example, the annual potential evapotranspiration is 2602 mm (recorded in the local meteorological station) at Khotan.

But, according to our calculations by using Thornthwaite method the potential evapotranspiration from the surface are very large and strong in and around Taklimakan Desert. Data of the five meteorological stations (located around Taklimakan Desert) for the years 1959-1979 are shown in OHP. The annual potential evapotranspiration is 787.8mm and the water deficit is –735.7mm (the annual precipitation is 52.1mm) at Kashgar. In the southern part of the Taklimakan Desert, the potential evapotranspiration is higher than the other places. For example, The annual potential evapotranspiration is 804.3mm and the water deficit is –770.8mm(the annual precipitation is 33.5mm, 1250-1300m a.s.l) at Khotan(Fig. 2).

4. Humidity

The annual mean relative air humidity is lower in summer and higher in autumn and winter. For example, the mean annual relative air humidity is 42% at Khotan, but the seasonal variation of relative humidity is very large, and it changes with the change of temperature between day and night. The relative air humidity is higher when the temperature falls down; it is ca. 50% from November to February.

5. Water Resources

The discharge of rivers entering into the Tarim Basin depends mostly on the melting of snow and ice of surrounding high mountains .The river discharge is mainly concentrated to the spring and summer seasons, and it accounts for 60-70% of annual discharge. Sometimes floods occurs during the snow-melt season. But, the annual discharge is relatively stable and it makes up the main part of the water resources and plays an important role in maintaining the ecological environment in the Basin. The Aksu, Yarkant and Khotan Rivers join at near Aral and formed the Tarim River. The Tarim River is located at the foreland plain of the Tianshan Mountains. The annual discharge of the river is composed of 72.0% from the Aksu River, 22.5% from the Khotan River and 5.5% from the Yarkant River, respectively (Wang, 1991).

There are many lakes, in and around the Basin. In the plain area, there are Bagrash Lake, Ayding Lake and Shekar Lake. These lakes are the important surface water resources, especially fresh water lakes can be used as irrigation water for agriculture.

There are a large amount of groundwater resources in the aquifer of the Basin(available groundwater resources ca. $1.3616*10^{10}m^3$). In the piedmont fan areas, where shallow groundwater is rich and many springs are concentrated. Water leakage plays an adjustment and supply role in abstracting groundwater along the rivers. For example, the annual discharge of the Keriya River is $7.06\times10^8m^3$, and 56% of discharge $4.0\times10^8m^3$, water is used as irrigation water for agriculture and the remained $3.0\times10^8m^3$ water still leaking into the ground and recharge the groundwater per year (Soil and Land Resources in the Taklimakan Desert, 1994).

III Land Degradation

The Tarim Basin is one of the regions affected by land degradation: degradation of its lands resulting from the changes of hydrological environment and human activities.

1. Sandy Desertification

In the Tarim Basin, ca. 857,000 ha (Wang, 1996) of lands have been desertified by wind erosion during the last century (Zhu, 1987). Especially, in the bank region of the Tarim River 38,000 ha of land have been desertified because the water supply from river runoff had been cut off. This occupies 61% of the total area of alluvial plain of Tarim River.

Along the lower reaches of the Tarim and the Konqi Rivers desertified lands account for ca. 66% of the total area, including 49% of latent and weakly desertified lands and 51% of severely decertified lands (Xi and Zhou, 1983).

2. Vegetation Degradation

At least 285,000 ha of *Populus euphratica* woodlands were destroyed since 1958 not only in the lower reaches but also in the middle reaches of the Tarim River (Fan, 1984). The result was that 32% of woodland disappeared and 10% of woodland was devaluated in the Tarim Basin (Wang, 1996).

3. Soil Salinization

In the Taklimakan Desert, salt accumulation is very conspicuous along the river course because of intensive evaporation (2,000-2,500 mm/year) and low precipitation (0-80 mm/year). The area affected by salinization 5,857,100 ha (Li, 1984), mainly distributed in the Tarim Basin.

4. Land Aridization

In addition to the above major desertified land types, there is another important environmental degradation resulting from careless management of water resources. This is a common problem in many canal irrigation areas in the Tarim Basin.

1) Due to the agricultural development on a large scale many reservoirs were constructed. As the result the some changes of distribution pattern in water system occurred.

2) There was enough runoff so that a large lake, the Lop Nur Lake with more than 535,000 ha, was formed at the end of the Tarim River system. In 1921, the Tarim River changed its river course and flowed to the old Lop Nur Lake, and the lake area with more than 200,000 ha was formed. But, in 1970s water supply to the lower reaches has decreased. As the result the famous Lop Nur Lake was disappeared in 1972, and groundwater level in the lower reaches of the Tarim River, lowered from 3-5 m in the 1950s to 8-10 in the 1980s (Zhu *et al.*, 1988; Zhu and Wang, 1996).

3) River water was fresh with the mineral concentration of lower than 1 g/l (Okada *et al.*, 1995) in the past. But now, the river water is fresh (the mineral concentration lower than 1 g/l) only in 3 months, and brackish (1-3g/l) in 3 months and salt water (more than 3g/l) in 6 months (Zhu *et al.*, 1988). In addition, the mineral concentration of the lake water increased continuously.

IV Discussion and Conclusion

According to our investigation, environmental changes due to the changes of hydrological environment have resulted from following reasons:

1. Evapotranspiration

Evapotranspiration is used for vegetated surface. The annual evapotranspiration is different in and around oases in the Tarim Basin. According to our calculations the annual precipitation is about 25-100mm, annual evapotranspiration is about 100mm at Khotan station. So that, in situations where this annual precipitation is completely evaporate and to create intense water deficit. Thus the potential evapotranspiration will reached to above 500mm in the oases, in some desert area the potential evapotranspiration will reached 1000mm. The oases, which located in the southern part of the Tarim Basin, located between 25mm and 100mm isohyet. Many oases in the northern part of the Tarim Basin are located between 25mm-200mm isohyet and 100mm-200mm isogram of annual evapotranspiration, therefore, higher temperatures may still lead to a general increase in evapotranspiration. As the result the precipitation will evaporate completely, especially in the warmer seasons. In general this will lead to insufficiency of water in the areas. For example, many oases located between 1mm and 5mm isogram of mean annual river runoff, and the oases, which located in the west and north part of the Tarim Basin, located between 1mm and 5mm isogram of mean annual river runoff. Because of there is no enough rainfall in the central part of the desert, the deficit of river water (runoff) reached to about 1000mm per year. River runoff and runoff coefficients trend to be higher in the surrounding mountain areas(Fig. 3).

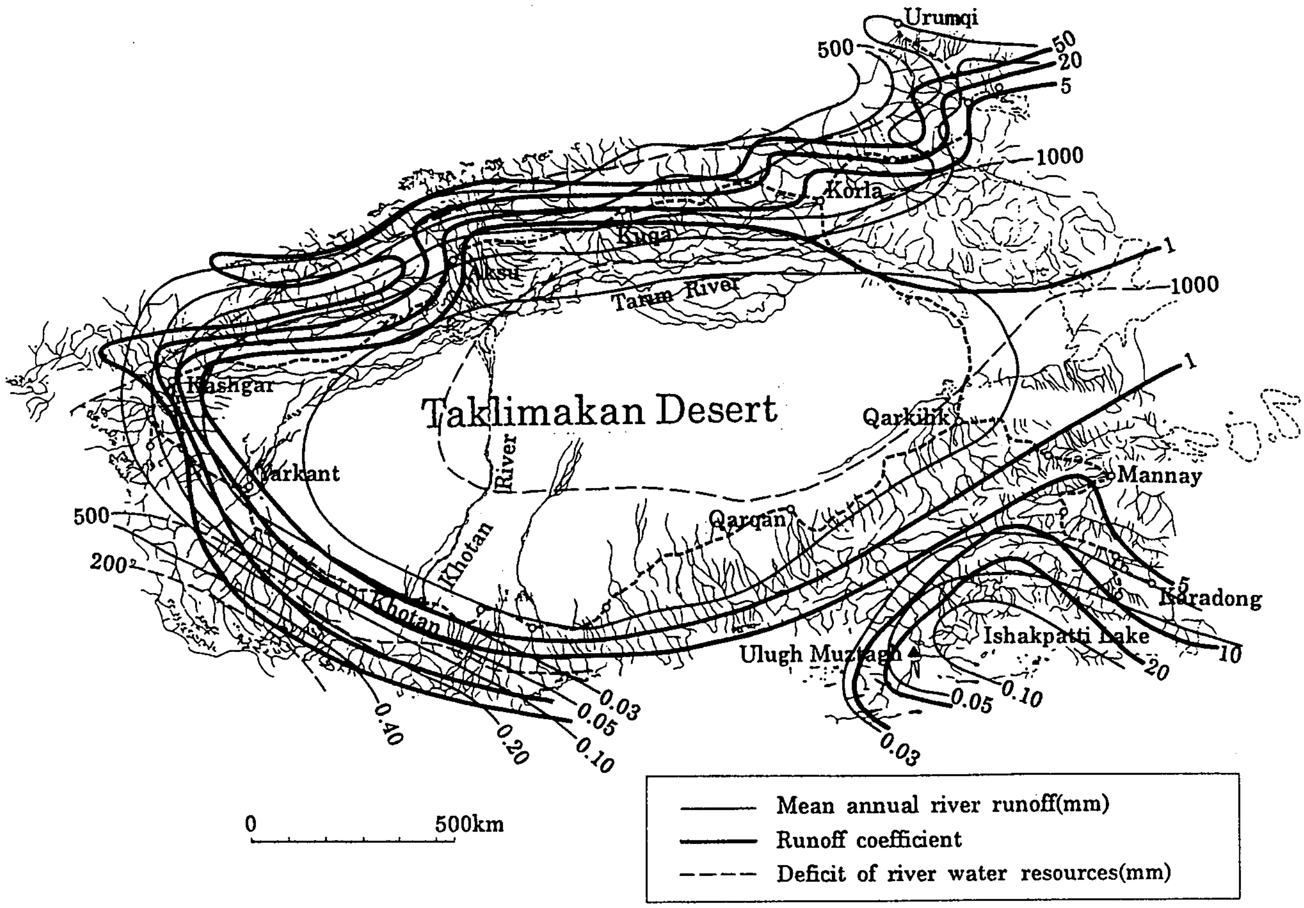

Fig. 3 Distribution of the mean annual river runoff, runoff coefficient and deficit of river water resources in the Tarim Basin

2. Water Resources Management

1) The river water which flowed to the lower reaches reduced sharply. The irrigated farmland, which was distributed on the lower reaches of the many inland rivers, was abandoned because of shortage of water supply. So that, the land degradation in the lower reaches of river is caused by the misuse of inland river water in the upper and middle reaches in the Tarim Basin.

2) The groundwater level lowered 4-6m between 1959 and 1979 in the Argan District located in the lower reaches of the Tarim River. All of those prove the land degradation in the form of land aridization. From the results of the field investigation from 1993 to 1995, in the middle reaches of the Tarim River there are many old dried river courses on the both sides of the present river courses with 80-100 km width.

Due to the changes in water supply, especially lowering of the groundwater level, *Populus euphratica* woodlands were greatly degenerated and former landscape of natural woodlands was turned into the landscape of withered woodlands or bare sandy surface(Fig. 4).

3. Soil Salinization

1) In the Tarim Basin, land salinization is a result of the large amount of water infiltration from the rivers and irrigation canals to the surrounding areas. Especially, the water seepage from the canals are so serious and 2,565 million m^3 of river water have been recharged to groundwater per year (Lei, 1995). The utilization coefficient of canals is only from 0.4 to 0.45 on the average, although a great amount of irrigation water supplied to the farmlands.

2) It is very clear that, especially in an arid area, water leakage around a dam has brought about disadvantageous influence on surrounding areas due to the rising of groundwater level, resulting in severe soil salinization.

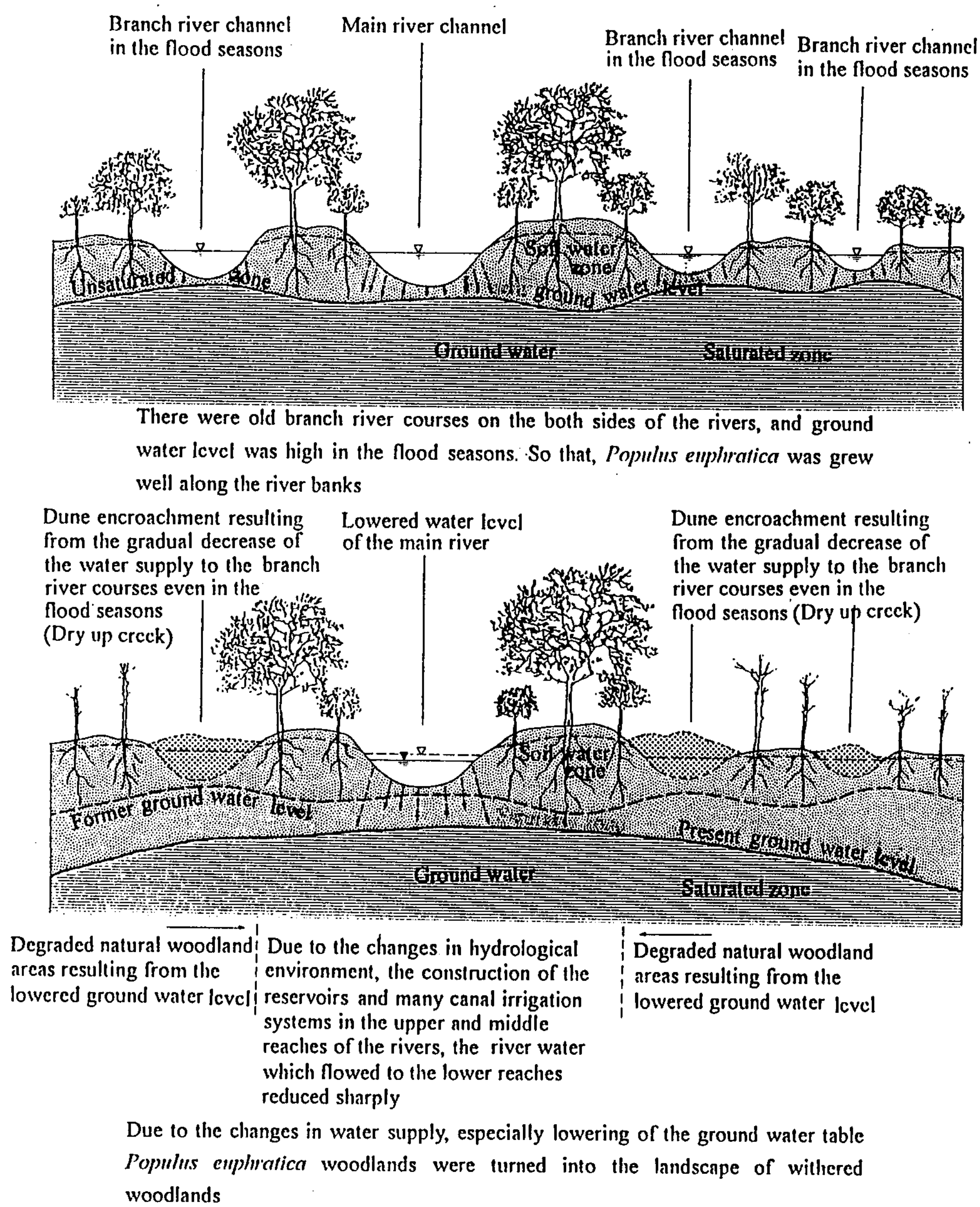

Fig. 4 Land degradation along the Tarim River resulting from the lowering of the ground water level

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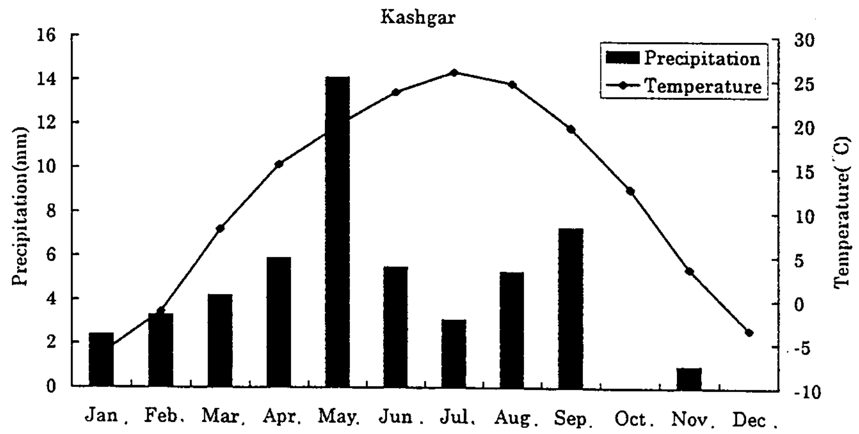

Fig.5 Monthly average precipitation and temperature at Kashgar(1959-1979)

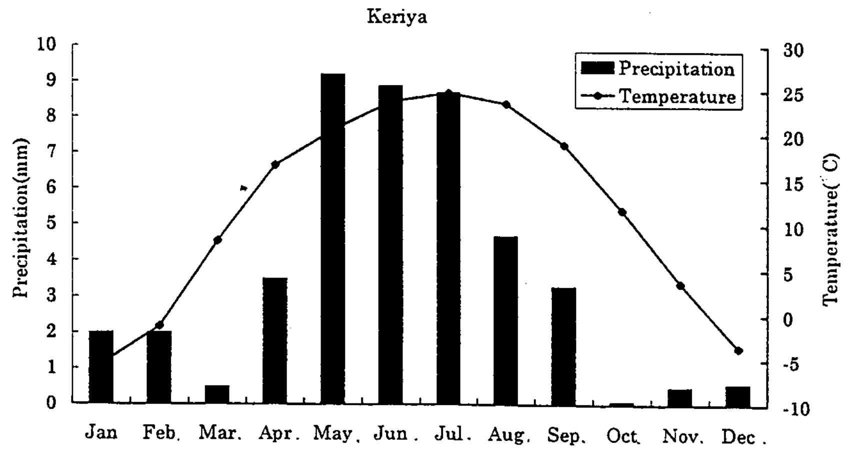

Fig. Monthly average precipitation and temperature at Keriya(1959-1979)

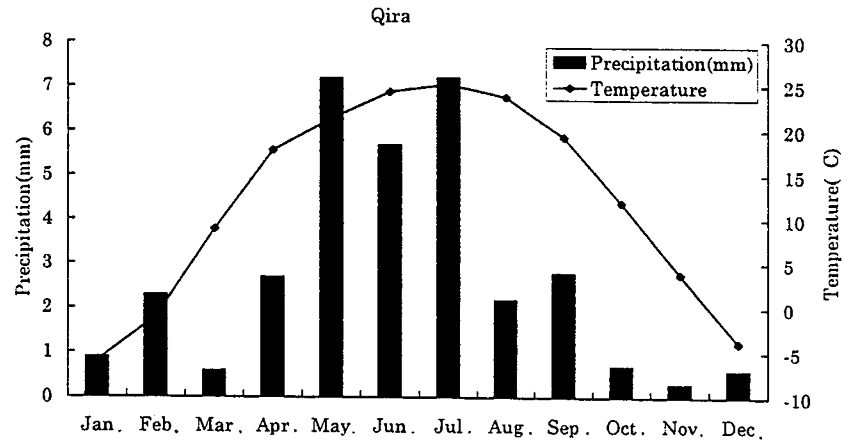

Fig.4 Monthly average precipitation and temperature at Qira(1959-1979)

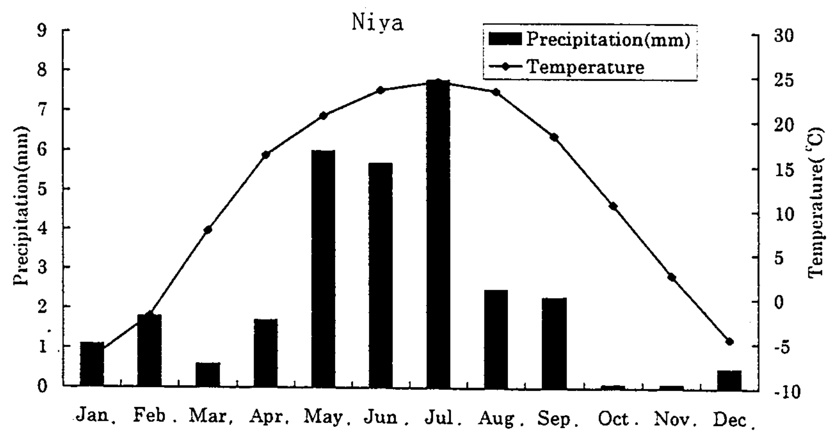

Fig.5 Monthly average precipitation and temperature at Niya(1959-1979)

Appendix Data 1(H. Takamura and Q. Muhtar)

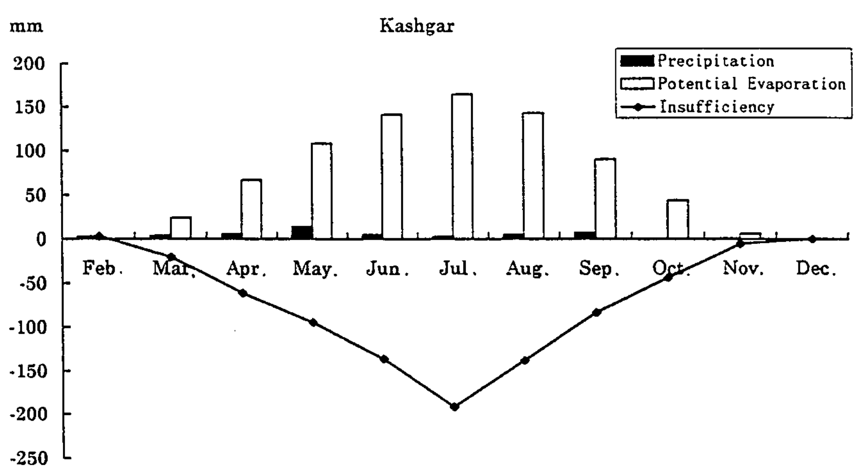

Fig.9 Monthly average precipitation, potential evaporation and water insufficiency at Kashgar(1959-1979)

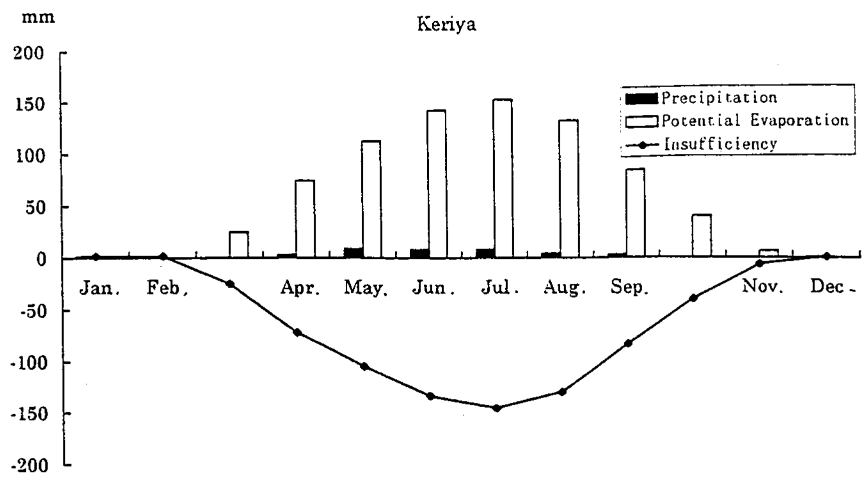

Fig.11 Monthly average precipitation, potential evaporation and water insufficiency at Keriya(1959-1979)

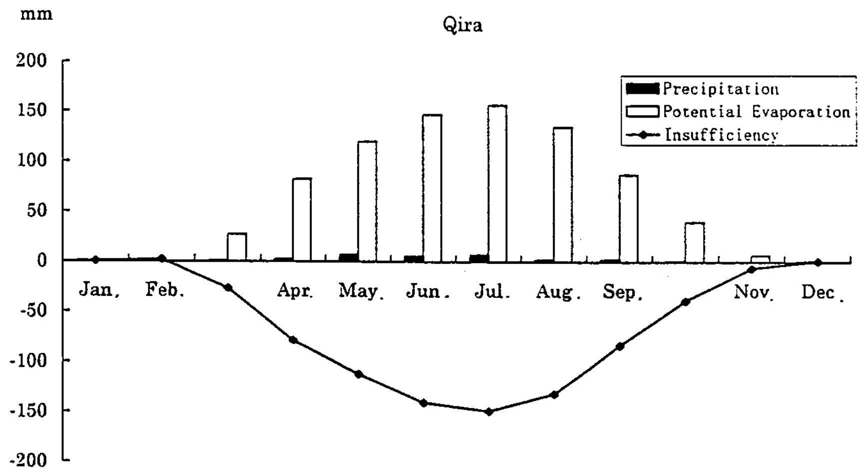

Fig.10 Monthly average precipitation, potential evaporation and water insufficiency at Qira(1959-1979)

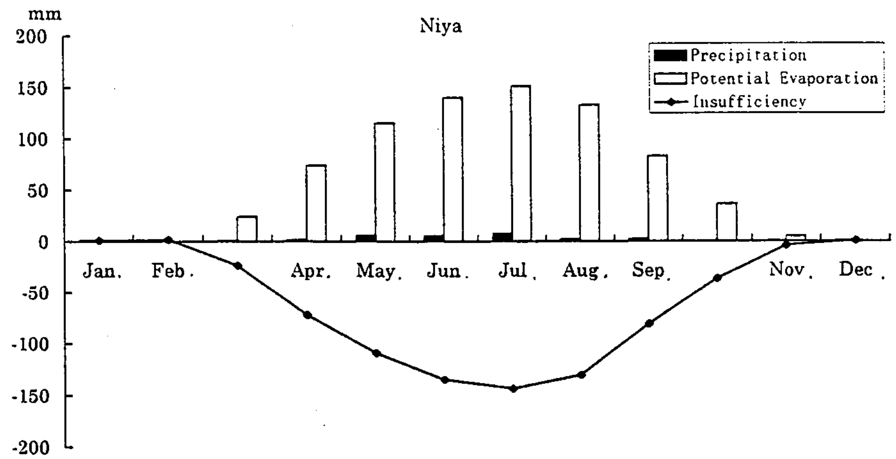

Fig.12 Monthly average precipitation, potential evaporation and water insufficiency at Niya(1959-1979)

Appendix Data 2(H. Takamura and Q. Muhtar)

Sustainable Management of Freshwater Resources: Research, Capacity Building, and the Role of the UNU

Juha I. Uitto (*) and Iwao Kobori (*)

* Academic Division, The United Nations University
53-70, Jingumae 5-chome, Shibuya-ku, Tokyo 150, Japan
Fax: +81-3-3499-2828, Email: uitto@hq.unu.edu, kobori@hq.unu.edu

Abstract

There are indications that freshwater will become the critical resource for development as we move into the new century. Availability of good quality freshwater is essential for all aspects of human endeavour, including food production, health, industrial and urban development, as well as for ecosystem needs. Yet, water problems have received little attention in recent years, as compared with other environmental issues, such as climate change. Earlier this year, the United Nations convened a Special Session of the General Assembly to assess progress five years after the Earth Summit. The Special Session affirmed the need to focus the actions of the international community around sustainable development of freshwater resources. As part of the UN system, the United Nations University carries out research, training and capacity building, and dissemination on pressing global problems. The University's programme considers water resources as central in the strive for sustainable development.

1. Background

Freshwater is an increasingly scarce resource and a global-scale freshwater crisis is looming larger by the day. Demand for freshwater is growing rapidly. The dramatic population growth during the present century alone has stood for much of the increase, but the situation has been exacerbated by the rapidly rising per capita consumption of water due to economic development, industrialization and urbanization. This trend is likely to continue into the future with economic development in the developing countries. Agriculture is the main user of freshwater resources (Postel, 1993).

Availability of clean freshwater will in the near future become the most important limiting factor for food production and development in general in many parts of the world. The United Nations has estimated that by the year 2025 two-thirds of the world population may live in areas where they are subjected to moderate to high water stress if the current trends in water consumption growth continue (UN, 1997).

Serious improvements in the efficiency of water use and water management will, thus, be absolutely essential. This will need to combine technological improvements, new technologies, policy means, and economic tools. Notably, it will also mean improved cooperation between the various sectors (public, private, industrial, agricultural), as well as international and regional cooperation.

As recognized during the UN General Assembly Special Session Rio+5 held in June 1997, water crisis is likely to be one of the most important resource management issues during the early part of the 21st century. This paper focuses on the actions of the United Nations University (UNU) in response to this challenge.

2. The Role of UNU

The United Nations University (UNU), as an autonomous academic organization under the United Nations umbrella, contributes to the goals of sustainable development set by the UN through research, advanced training, and dissemination of knowledge. Environment and resource management issues have featured centrally in UNU's programme since its inception more than twenty years ago.

Water management, with integrated basin management as the overriding principle, is one of the main entry points to the University's present programme. The programme approaches integrated basin management from three particular angles: governance, capacity building, and management tools. The present programme is geared so as to contribute to the work of the United Nations ACC Sub-Committee on Water and, especially, the Commission on Sustainable Development 1998 session which will consider "freshwater" as the sectoral theme and "transfer of technology/capacity building/education/science" as cross-sectoral themes for in-depth consideration.

2.1 Hydropolitics

The project on Integrated Management of River Basins aims to identify the issues in disputes concerning water resources and alternative scenarios that could lead to the solution of complex problems related to the shared resources. The project is also intended to contribute to a comprehensive and objective environmental management setting for the sustainable development of international freshwater bodies, in support of the Convention on the Law of the Non-navigational Uses of International Watercourses adopted by the UN General Assembly earlier this year. It needs, nevertheless, be kept in mind that international agreements, although important, are not sufficient for solving problems related to sustainable resource management. Actions on national level, as well as international cooperation, are essential (Uitto, 1997)

Implemented by the UNU Headquarters, the project will build upon the considerable earlier work in the areas of governance, policy formulation and development of new scientific tools for efficient water management in national and international river basins. This earlier work has focused on a number geographical regions where it is seen that freshwater is the limiting factor for development and disputes are emerging around shared water resources.

An obvious example is the Middle East where freshwater has figured centrally in the peace process. In 1993, UNU and its partner the International Water Resources Association (IWRA) convened the Middle East Water Forum, which sought to find ways for utilizing the limited water resources available in the region and to harness them for sustainable development (Biswas, 1994). The innovative mode of operation was to bring together high level professionals and decision makers from the region and international experts to analyze the problems and to identify solutions that would be technically and economically feasible, environmentally sound, and socially and politically acceptable (Murakami, 1995; Wolf, 1995). The Forum considered three main international river basins in the region, the Nile, Jordan and Euphrates-Tigris. It is claimed that the Forum made a concrete contribution to the Middle East peace process by providing alternative solutions to the complex problems that were considered outside of the political sphere (Murakami et al., 1995).

Following the successful implementation of the Middle East Water Forum, UNU organized meeting focusing on the Aral, Caspian and Dead Seas (Kobori and Glantz, forthcoming), and an Asian Water Forum which initiated work on three major river basins in Asia, Mekong, Salween and the Ganges-Brahmaputra (Biswas and Hashimoto, 1996; Paoletto and Uitto, 1996).

It is planned to build upon this work within the framework of the UNU Environment Area programme. The programme will contribute towards a detailed assessment of the state of freshwater resources at national and regional levels. Focused workshops will centre on sustainable development of specific river basins, inter-comparative studies of basin management (including legal and institutional aspects), and economic instruments for efficient water management. A Forum on the Ganges River Basin is planned for early 1998. It is felt that this will be opportune as the two main riparians, Bangladesh and India, have recently signed an agreement concerning sharing the water resources. The Forum will also include the third riparian, Nepal.

2.2 Capacity Building

The UNU also engages in capacity building with specific emphasis on the needs of the developing countries. The International Network on Water, Environment and Health (UNU/INWEH) was established to bring together academic, governmental and industrial partners with the UN system and NGOs for a major capacity building effort. Located in Canada, UNU/INWEH started operations in early 1997. The focus of the work will be in capacity building projects in Africa, Latin America and the Middle East. The core staff of UNU/INWEH is very small, as the projects will be implemented through international networks and cooperating centres to be established in the regions concerned.

Similarly, the UNU project on Environmental Monitoring and Analysis in the East Asian Region provides an example of public and private sector cooperation for improved environmental management on a regional scale. Basic environmental data forms the basis of our understanding of the environment. Accurate data leads to accurate decision- and policy-making on issues related to environment and development. Calibrating analytical methodologies throughout the East Asian Region has proved a serious challenge. The unavailability of reliable basic environmental data for the region has presented an equally difficult challenge. Intercalibration leads to the ability to compare the state of environment on a regional and global basis, generating data that can serve as the basis for decision-making.

The project consists of two closely related sub-projects. The sub-project on Environmental Monitoring and Analysis in the East Asian Region seeks to generate reliable data, undertake unique knowledge and technology transfer to the participating laboratories, and develop studies to strengthen environmental governance in the region. The objectives are to undertake monitoring and analysis of land-based sources of pollution in the East Asian region; capacity building through 'training the trainers' to promote the intercalibration of analytical methodologies and quality assurance/quality control (QA/QC) practices; to promote access to information, sustained exchange of information and effective dissemination of results; and to interpret data for policy options, providing impetus for accurate decision-making by key actors. The project covers the following countries and territories: China, Indonesia, Japan, Republic of Korea, Malaysia, Singapore, Thailand and Vietnam

The Asia-Pacific Mussel Watch sub-project forms the Asia-Pacific phases of the International Mussel Watch Programme. It aims at coastal pollution monitoring utilizing sentinel bivalves, and capacity building in national laboratories in selected Asian countries in India, Indonesia, Malaysia, Philippines, Taiwan and Vietnam.

2.3 Dissemination

Apart from applied policy-oriented research and capacity building, the third pillar of UNU's work is dissemination. The University utilizes a broad range of dissemination means, including the Internet and other modern information technology tools.

The UNU Global Environment Forum series commenced in 1991 with the support of a major private sector company is intended to highlight pressing global environmental problems and to disseminate state-of-the-art research to a broader audience. In recent years the forums have covered issues related to water resources in arid environments and in urban centres (Uitto and Schneider, 1997).

The United Nations University Press has also recently initiated a series on Water Resources Management and Policy, which will publish books by leading international authorities on topics related to the theme of the series.

3. Conclusions

The international community must rise to the multiple challenges posed by the need to provide socially, economically and environmentally sustainable development to the multitude of humankind. The United Nations system must play a central role in promoting these ideals, in initiating and coordinating needed actions, and in prompting nations to agree to and act on them.

Progress in the five years since the Earth Summit was assessed at the United Nations General Assembly Special Session in June 1997. The results are a mixed bag and much remains to be done and the implementation of the recommendations of the Agenda 21 need to be strengthened. The United Nations University as part of the UN system contributes to this work through focused, policy-oriented research, capacity building in particular in the developing countries, and dissemination with the aim of providing a solid knowledge base on which policies for moving towards sustainable development can be formulated.

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GLACIER LAKE OUTBURST FLOODS AND DEBRIS FLOW DISASTERS IN TIBETAN PLATEAU

DING YONGJIAN
Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences, 730000 Lanzhou, China

ABSTRACT

End moraine dammed lake and glacier dammed lake outburst floods(EMDLOFs and GDLOFs) are the most important disasters related glacier in China. The former happen mainly in Tibet, and the latter occur principally in the Xinjiang Province. Great EMDLOFs have been reported 19 times since 1935, and recorded GDLOFs are now 30 since 1956. EMDLOFs are closely associated with ice avalanches, and 81 % of all failures of the dams occur during July to August when ice avalanches occur frequently. GDLOFs often occur in years of the highest air temperature, and 63.3 % of all failures are between August and September when the storage capacity of the glacier lake reaches maximum. Whether the end moraine dammed lakes are of potential danger depends on the flow of the glacier that feeds the lake and the vertical distance between the terminus of the glacier and the level of the lake.

INTRODUCTION

Glacier lakes of various sizes and shapes are widely distributed in the alpine regions of Tibetan plateau where the present glaciers are situated. Catastrophic outbursts from glacier lakes, produced by various causes, occur frequently in these regions. Most of them have been ignored as they happened in untraversed regions. However, the known catastrophic outburst from glacier lakes, as well as meltwater floods and debris flows, have caused severe damage with respect to life and property, farmland, water conservancy, communications, transportation, etc. (Ding, 1992). With the development of communication and transportation, farming and animal husbandry in the west of China, the disasters which are brought about by glacier lake outburst floods and debris flows have seriously affected life and property and economic reconstruction of these regions. Therefore, it is important and urgent to understand the distribution of the dangerous glacier lakes and in order to study the causes of their bursts and to promote preventive measures. Hence, catastrophic outburst from glacier lakes have been brought to the attention of scientists, and various types of outburst disasters have been reported and studied during the past decades (Hewitt, 1982; Lu and Li, 1986; Liu and Sharmal, 1988; Xu, 1987; Xu and Feng, 1988, 1989; Zhang and Zhou, 1990; Ding and Liu, 1992).

DISASTERS FROM THE BURST GLACIER LAKES

Up to the present, outburst from lakes dammed by end moraines happened most frequently in the middle section of the Himalayas (Table 1). Twenty one outburst from lakes dammed by end moraines have been investigated since 1935. For example, catastrophic outburst from glacier lakes in the Himalayas in 1954 inundated hundreds of residential areas, including the cities Xigaze, Gyangze and Yadong and a number of farmlands, water conservancy and traffic facilities. After the Damenhai glacier lake burst in Gongbogyernde county in 1964, the outburst flood rushed down with the speed of 10 m/s from 5120 m a.s.l., headed direct to the mouth of a channel at about 3400 m a.s.l. and lashed at the side of the Niyang River. The outburst debris flow piled up a dam in the valley of the Niyang River, 20 m high, 850 m long and 150 wide at the top, which obstructed the Niyang River for about 10 hours. The flood destroyed the Sichaun-Xizang highway, cut off the traffic for 20 days, inundated most of four pasturelands, and washed away a lot of trees on both sides of the gully. In 1981 the Zhongzangbo glacier lake burst and debris flow in the Nyalam county smashed the highway in arrange of 50 km between the outlet of Zongzangbo gully and the Sun Kosi Power Station in Nepal. In 1982 the Jinco glacier lake burst flood submerged eight villages and a large number of fields, and more than 1600 livestock were killed. In 1984 the Erkuran glacier lake of the Gez river basin burst and outburst flood and debris flow blocked the Gez river and damaged the China-Pakistan highway and a bridge.

Table 1 History of outbursts from lakes dammed by end moraines (Ding and Liu, 1992; Xu and Feng, 1989;)

Lakes	Longitude	Latitude	M / D / Y	F/D	Cause	Maintains/River-systems
Zhanlonba			1902	F/D		Nyainqentanglha/Yiongzhangb R.
Taraco	86°07'54"	28° 17'29"	8 / 28 / 35	D	IA	Himalayas/Poiqu River
Qubixiama	85° 02'24"	27° 42'30"	6 / 10 / 40	F	IA	Himalayas/Upper Kangma R.
Xingguolonba			1950	F		Nyainqentanglha/Niyang R.
Sangwang	90° 40'00"	28° 24'54"	7 / 16 / 54	F	IA	Himalayas/Upper Nyangqu R.
Hailuogou	102° 00'00"	29° 32'00"	7 / ? / 55	D		Hengdaun/Upper Yalong R.
			7 / ? / 66	D		
			8 / 30 / 76	D		
Zhangzangbo	85° 51'25"	28° 10'38"	7 / ? / 64	D		Himalayas/Poiqu R.
			7 / 11 / 81	D		
Guangxieco	96° 34'	29° 25'	7 / ? / 64	D		Nyainqentanglha/Niyang R.
Longda	85° 00'25"	28° 24'46"	8 / 25 / 64	F/D	IA	Himalayas/Trisuli R.
Gelhaipu	87° 48'31"	27° 57'50"	9 / 21 / 64	D	IA	Himalayas/Pumqu R.
Damenhai	93° 09'15"	29° 56'20"	9 / 26 / 64	D	IA	Nyainqentanglha/Niyang R.
Ayaco	86° 29'33"	28° 20'49"	8 / 15 / 65	D	IA	Himalayas/Pumqu R.
			8 / 17 / 69	D	IA	
			8 / 18 / 70	D	IA	
Bugyai	94° 48'36"	31° 46'20"	7 / 23 / 72	F		Nyainqentanglha/Nujiang R.
Zari	90° 48'30"	28° 22'50"	6 / 24 / 81	F/D	IA	Himalayas/Pumqu R.
Zirema	86° 03'54"	28° 04'36"	7 / 11 / 81	F/D	IA	Himalayas/Poiqu R.
Jinco	87° 38'29"	28° 11'39"	8 / 27 / 82	D	IA	Himalayas/Pumqu R.
Gule	94° 30'00"	29° 30'00"	7 / 15 / 88	D	IA	Nyainqentanglha/Berongzhongbu

M/D/Y=Month/Day/Year, F/D=Flood/Debris flow, IA=Ice avalanche into the lake.

TYPES AND DISTRIBUTION OF THE BURST GLACIER LAKES

Two types of potentially dangerous glacier lakes are known in China. One is an end moraine and the other is the lake dammed by glacier. Outbursts form lakes dammed by end moraines occur in the Himalayas, the Middle and eastern of Nyainqentanglha mountains and the sections of Hengdaun mountains (Figure 1). The dams of the end-moraine lakes are made up of various terminal moraines that formed since the Little Ice Age, of which the youngest moraine lakes, which are close to the present glaciers, are the most dangerous.

Outburst from glacier-dammed lakes are mainly scattered over the Karakorum mountains, the Pamir and the west of the Tien Shan in the west of China. The famous glacier-dammed lakes, the Taramkangri Lake and Kyagar Lake, are situated at the upper reaches of the Yarkand river in the Shaksgam valley. The Taramkangri and Kyagar Glaciers, both located on the north slopes of the Karakorum, extended down to the Shaksgam valley and have dammed up two lakes, 5 km apart (Table 2). These two glacier lakes have burst repeatedly, as recorded at Kaqung hydrological station at the outlet of the Yarkand river since 1954. Up to now, more than 30 outbursts from glacier-dammed lakes have been

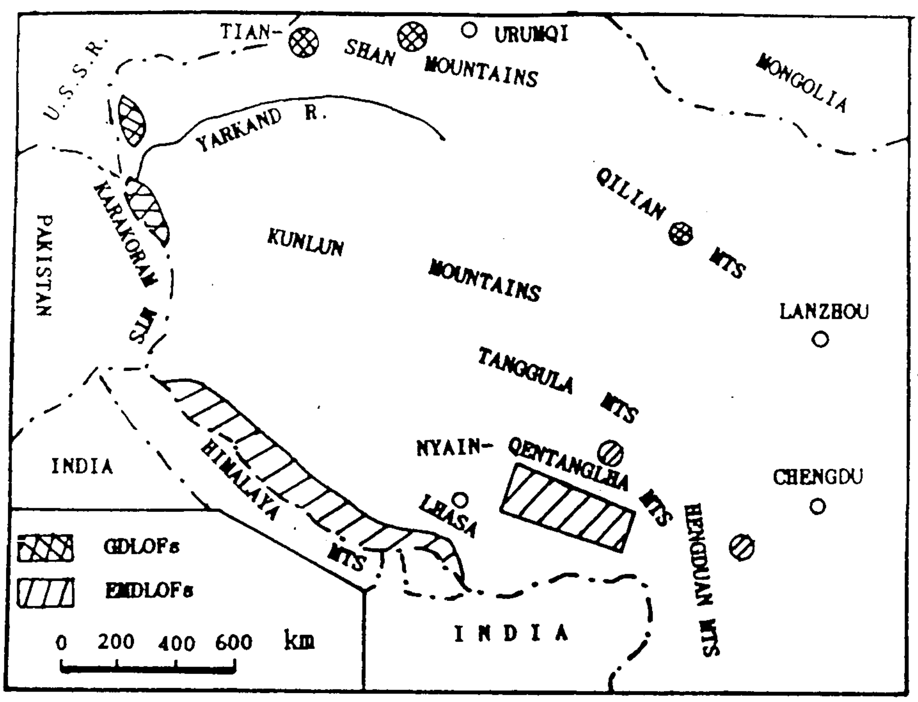

Figure 1 Distribution of floods from glacier-dammed lakes (GDLOFs) and floods from lakes dammed by end moraines (EMDLOFs).

Table 2. Data for Taramkangri and Kyagar Lakes (Zhang and Zhou, 1990)

Lake	Altitude m a.s.l.	Length km	Width m	Volume $10^8 m^3$	Maximum depth m	Length of Barrier Km
Kyagar	4836	4.93	398	0.60	85	1.5 1976-1987
	4900	9.48	638	3.15	155	Postglacial Maximum
Taramkangri	4650	5.25	500	0.96	70	3.8 1976-1987
	4672	7.41	610	1.92	90	Postglacial Maximum

recorded since 1956, of which there have been 20 times in the Yarkand River, the Karakorum, six in the Kunmalike River, Tien Shan mountains, three in the Sikeshu River, Tien Shan mountains, two in the Gez River, the Pamir and one in the Qilian mountains.

Glacier lakes liable to outbursts are distributed mainly over the mountainous border regions of QinghaiXizang Plateau where there are frequent neotectonic movements and high altitude. The highest concentration of outbursts from lakes dammed by end moraines is found in the Middle Himalayas around the Mount Everest. The region where outbursts from glacier-dammed lakes occur frequently is in the Karakorum where the second highest peak in the world, Mount Qogir, is located. Similar lakes in China are mostly situated between 4500 and 5200 m a.s.l. Their areas are under 3 km^2 for the largest ones and only 0.01 km^2 for the smallest ones.

INVESTIGATIONS OF OUTBURSTS FROM GLACIER-DAMMED LAKES

The mechanism of an outburst is complicated, but the external factors that trigger it are obvious. When a glacier lake can store water, its level will rise with increasing glacier ablation. Consequently, outbursts from glacier-dammed lakes often occur in years of the highest air temperature (Figure 2). The volume of most of outbursts is between 1000 and 3000 m^3s^{-1}. The reason why four of the floods reached peaks between 5000 and 6000 m^3s^{-1} is because two ice-dammed lakes, Taramkangri and Kyagar, burst at the same time. Three of the four largest floods in the Yarkand River, and all floods in the Kunmalike River, happened between August 20 and September 30, which is over a month later than the maximum ablation period in July. Failure of the dam happens mostly between August 20 and September 30 when the storage capacity of the glacier lakes reaches a maximum (Table 3). It might be postulated that the catastrophic outbursts from glacier-dammed lakes can be predicted on the basis of weather forecasts, when satellite images show that the lakes have reached their maximum area.

In general, the ice dams are not frozen to their bed, water from the lake does not flow over the dam, and the lake drains through subglacial channel. After the outburst, the dam forms again.

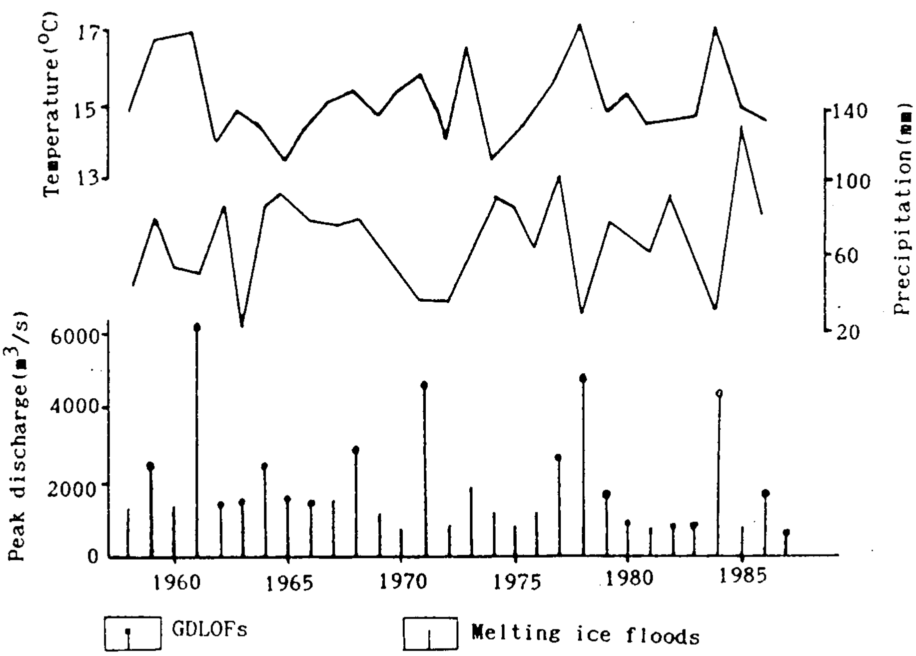

Figure 2 Peak discharge of glacier outbursts of the Yarkand River at kaqun station, mean air temperature in Summer and annual precipitation at Tashikurgan station (3090) m a.s.l). GDLOFs are floods from glacier-dammed lakes.

Table 3. Timing of outbursts from glacier-dammed lakes and outbursts from lakes dammed by end moraines (Ding and Liu, 1992)

Date	Outbursts from glacier-dammed lakes		Outbursts from lakes Dammed by end moraines	
	Number	%	Number	%
July to 20 August	7	23.3	13	61.9
20 August to 30 September	14	46.7	6	28.6
after 30 September	7	23.3	0	0
before 1 July	2	6.7	2	9.5
total	30	100	21	100
July	2	6.7	10	47.6
August	11	36.7	7	33.4
September	8	26.6	2	9.5
others	9	30.0	2	9.5
total	30	100	21	100

POTENTIALLY DANGEROUS END MORAINE DAMMED LAKES

An end-moraine dam is different from a marginal glacier dam. The latter is composed of ice which easily melts and cracks, but the former is composed of till of various sizes and is normally much more stable than the ice dam. An inventory of existing glacier lakes of the Pumqu and Poiqu Rivers in Himalayas have been made by a Sino-Nepalese expedition investigating glacier lake outburst in Himalayas in 1988 (Table 4). Only 3.7 % of the total number of the glacier lakes and 7.2 % of the end moraine-dammed lakes are dumping glacier lakes.

Table 4. Glacier lake inventory in the Poiqu and Pumqu basins (Liu and Sharmal, 1988)

Type of lake	Lakes number	Lakes % of total	Lakes area km^2	Lakes % of total	Lakes Volume km^3	Lakes % of total	Mean area km^2	Mean volume km^3	Mean depth m
Cirque	86	31.6	6.56	11.7	0.066	4.4	0.076	0.77	10
Trough valley	47	17.3	12.47	22.2	0.312	20.7	0.265	6.63	25
end moraine-dammed	139	51.2	37.09	66.1	1.124	74.9	0.267	8.09	30
total	272		56.11		1.501				

The following morphological features characterize the dangerous end-moraine dams: it has closed lake basin, a height of dam over 80 m, a ratio of dam height to the top width less than 0.6, an angle of slope of the outside of the dam of about 23^0 and a water depth at dam over one-third of its height (Xu and Feng, 1989). Further, the dam contains ice core that may reduce their stability. However, a static pressure maintained by the lake is still not high enough to burst the dam without an additional external action being exerted. The investigated outbursts from lakes dammed by end moraines were all induced by ice avalanches that came from the glaciers feeding the lakes. In each case, an ice avalanche dropped suddenly into the lake and swift and violent waves traveled down the lake, creating breaches in the dam. Because an ice avalanche is associated closely with melting of ice, the periods of maximum ablation also are those of frequent ice avalanches. Hence, 81.0 % of all failures of the dams occur during the hottest months of July and August (Table 3).

Whether or not the end moraine-dammed lakes are dangerous depends on the flow of the glacier that feeds the lake. In an advancing glacier, the glacier tongue is so steep that many cracks develop and ice avalanches are easily produced. Ice avalanches falling into the lake will create waves of huge surging pressure to the dam wall. On the other hand, when a glacier extends down into the lake along a gentle slope, ice sliding into the lake creates small pressures to the dam wall. The areas of the glaciers above the end-moraine lakes are usually between 1.5 and 5.5 km^2 and the glaciers are between 1 and 4 km long. The glacier tongue is generally located in a steep depression or a valley, with the lower part in an extended state, so that cracks tend to form. Thus, it is important to understand recent development and morphological features of the glacier to determine whether an end moraine-dammed lake is of potential danger. Table 5 shows some typical end moraine-dammed lakes in the middle Himalayas of China. It can be seen that the potentially dangerous lakes have a larger lake area and smaller glacier area, a shorter distance from the glacier terminus to the lake and a steeper angle of slope to the glacier tongue than the stable, not dangerous lakes.

Table 5. Comparison of dangerous and stable moraine-dammed lakes in Himalayas (Ding and Liu, 1992)

	Lake			Glacier			
	altitude m a.s.l.	area km^2	Distance to glacier M	terminus elevation m a.s.l.	Length km	area km^2	average slope %
Dangerous:							
Jinco	5350	0.550	0	5350	3.8	3.24	34.4
Coxar	5420	0.660	0	5440	2.8	3.43	23.6
Ahamachimaico	5470	0.565	0	5200	3.8	1.66	15.7
Paquco	5300	0.506	0	5320	4.0	5.40	17.8
Stable:							
Dongyico	4980	0.04	600	5800	3.1	5.25	18.5
Zonbuxan No.13	5320	0.198	0	5360	12.5	24.39	7.2
Kada No. 13	5570	0.191	300	5460	8.0	14.49	11.0
Zongbuxan No.2	5670	0.072	300	5750	5.0	4.96	5.1

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Water shortage and its environmental impacts

Chen Jianyao

(Institute of Geography, Chinese Academy of Sciences
Beijing 100101, P.R.China, Email: chenjy@iog.ac.cn)

1. The analyses of water shortage

The false presumption that China has plenty of water resources may occur due to the summer flooding of many regions in 1996, and this can only be explained clearly as the result of high temporal and spatial variation of precipitation. The annual average water resource of China is about $28124\text{x}10^8$ m^3, but the amount per capita is only $2400m^3$[1], ranking in the 109th position among 149 countries according to statistical data of United Nation[1]. Thus, China, as a whole, has to face unavoidably with the water shortage problem, especially in some areas and/or in a certain period. In case of city, more than 300 cities among total 600 cities have experience the water shortage. Consequently, how to define water shortage, identify the area with such problem and assess its possible impacts on environment is becoming a more and more interesting subject among scientists and relevant organizations.

Generally, water shortage may be viewed as the occurrence of deficit in terms of water supply and water demand. Even though the water resources for supply may in the long term be stable and sustainable with regard to water circulation, water quantity available for human consumption does decline due to the deterioration of water quality. On the other hand, Chinese economy has grown about 10% annually in recent years, and the population has not yet reach its peak and about $1500\text{x}10^4$ newly-born babies each year join in our family, both of these two factors require more water demand. Hence, the situation of water shortage tends to become more and more serious, which will remain in the foreseeable future.

Water shortage can also be evaluated by energy index: R/LP, where R is net radiation, L is latent heat and P is precipitation. This index is actually the ratio of potential evaporation E to precipitation, and R/L is the maximum potential evaporation. In order to subdue the effects of geomorphology, soil and et. on runoff, the amount of runoff Rs may be discounted from precipitation to obtain soil moisture influx SMI=P-Rs, and new index Ni can be defined as R/[L(P-Rs)]=R/[L*SMI]=E/SMI, which can then be used to locate the water shortage area(Liu and Du, 1985). If Ni of a given area is more than 1, this area may potentially have the problem of water shortage. This index is rather important in agriculture and regionalization.

Another index Cv, variation coefficient of annual runoff can be used to assess the water shortage, even though in an indirect way. The lower the value of Cv, the less fluctuation of runoff, and normally the more runoff and precipitation. In case of river discharge, Cv is about 0.12-0.15 for Changjiang river, 0.45 for Yellow river, 0.55-0.65 for Huaihe river and 0.60-0.75 for Haihe river. Cv for plains, basins and huge desert in north-western China is usually more than 0.8. One may defend that Cv is responding not only to the

[1] Lu Yongjian, Chinese Science News, Jan. 13, 1997

runoff itself, but also to the shape, size and other factors of the catchment, but the huge difference in annual average discharge does show the concurrence with Cv. The annual average discharge of Changjiang river is 9800×10^8 m^3, 560×10^8 m^3 for Yellow river, 530×10^8 m^3 for Huaihe river and only 283×10^8 m^3 for Hailuanhe river(Zuo and Xu, 1985).

One apparent characteristic of water resources in China is its uneven distribution in time, thus resulting in seasonal water shortage. In the eastern part of China, most of rainfall precipitates in the summer, with little in the winter due to monsoon climate. The higher the latitude, the more the percentage of summer rainfall to the total yearly rainfall. Hence, the main crop, wheat, has to face with serious water shortage in the spring, when the rainfall accounts for less than 15% of yearly rainfall in Huang-Huai-Hai Plain, but wheat consumes normally more than 80% (from reviving, heading to ripping) of total water needed (Chen, 1996). Coincided with the dry and hot wind prevailing in the Plain at this time, the potential evaporation from March to June could be high as 300-400mm, which is about 3-4 times that of the precipitation of the same period. Total days, when the Yellow river runs out of water, has increased in recent years and caused many eco environmental problems in the low reach.

The issue of global climate change has become a common topic in the world and been closely related to water resources. One of conclusions of the project undertaken by Ye Duzheng[2] is that the temperature in North China in the year of 2030, compared with the current situation, is expected to raise at about 1.0-1.5°C in the winter and 0.5-0.8 °C in the summer, and the precipitation will remain more or less the same in the winter but increase 1-2% in the summer. The discharge in main rivers of North China, such as Haihe river and Luanhe river will decrease 3-6% due to the mixed effect of temperature and rainfall, and the runoff to Miyun Reservoir decline 2.4×10^8 m^3.

Therefore, the water shortage problem rises as the consequence of not only natural factors but also social and economic aspects, and the reasons could possibly be summarized as follows:

- uneven distribution of rainfall in time and space
- the expansion of population and swift growth of economy
- the pollution of water resources
- low level of water re-use rate and poor water resource management
  and possibly
- the consequence of global green-house effect and climate change

2. The impacts of water shortage on environment

As a result of natural, social and economic factors, the water shortage has feedback to all above factors and it could be an important element that constrains the sustainable development of economy and eco-environmental system. Because of this complex feedback, it is not easy to assess the impacts of water shortage on environment. Nonetheless, the impacts could basically be divided into two categories: direct and indirect, even though the boundary may not be clearly defined.

2.1 Direct impacts

[2] Li Bin, Chinese Science News, Dec. 2, 1996

Serving as one considerable component of entire eco-environmental system, water resources play a very important role in keeping the whole system sustainable. The water shortage, such as the diminishing of water body, does decline the environmental quality and disable the creature, which previously lives on it, to survive any longer. Taking Tarim river as an example, the extensive reclamation of farmland in upper stream and the water diversion to the irrigated area radically reduce the water to the low stream, resulting in the disappearance of Lop Nur. The low reach after Tikanlik was out of water after 1970, and thus its length was shorten about 200km. The environmental impacts of water shortage in this case can be judged as follows: (1) The extended dying of forest along the river bank, and the reduced capability against strong wind. (2) The degradation of range land. (3) The increasing potential in disaster of the gust of wind and sand, and the enlargement in desert. (4) The abandonment of farmland, and even having difficulty for local people in access to drinking water(Chen, 1993).

If the water shortage takes place in the coastal area of East China, where the economy has grown quickly in recent years and more and more water supply is needed, ground water will have risked of depletion and one serious environmental problem will arise: sea water intrusion. The survey in Laizhou city of Shandong Province has indicated that the area with ground water level lower than sea level has increases from 14.3 km^2 in 1979 to 262.05 km^2 in 1989(Fig.1), with average spread speed of about 25 km^2/year and the lowest ground water level of -16.74 m. Among the area of 262.05 km^2 in 1989, there are about 212.44 km^2, in which the content of CL^- of ground water is more than 300 mg/l and not suitable for irrigation (Yin, 1992). Most of these lands have to be relinquished without irrigation.

In order to cope with water shortage problem, many cities, especially in North China, have resort to groundwater, which unfortunately needs much more time than surface water in the process of circulation and can not be easily recovered if the aquifer suffers long excessive exploitation. If the aquifer could not be recharged and were left depleted, the problem of land subsidence would inevitably come up, such as the case in Tianjin city. The survey in Kaifeng city has showed that the area of depression(with groundwater depth more than 10 m) and the depth of groundwater in the center of it has reached 31.4 km^2 and 18.9 m in 1989, while only 2.2 km^2 and 12.1 m respectively in 1976[3]. The area and grade of land subsidence has closely related to the area and depth of groundwater depression.

The less water in the channel, the less power in transporting sediment, and the more sediment yield in the river bed. The relation of flow velocity(v) and the weight of transported sediment(W) could be expressed by Eley's law: $W=Av^6$, which means that a little change in the velocity will bring about large amount of variation in transported sediment. In the low reach of Yellow river, it is estimated that 40 m^3 of water is needed to transport 1 ton of sediment during flooding season, while 100 m^3 of water needed to transport the same amount of sediment during non-flooding season(Ye, 1994). Continuous addition of yield to Yellow river bed has caused many troubles, the most serious one could be the possible disastrous breaking up of the bank due to high altitude of the river bed in case of big flooding.

[3] Shu longcang, Utilization of Water Resources and Environmental effects in Kaifeng City

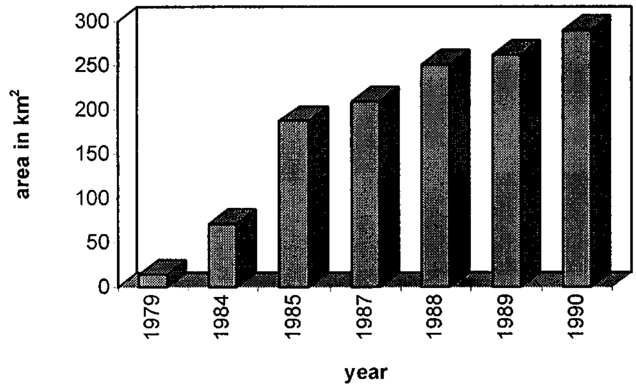

Figure 1 The development of area with groundwater level lower than sea level in Laizhou city(revised after Yin, 1992)

The water shortage has great effects on the mass and energy balance of water circulation. Generally, there are five components in the process of circulation, i.e., atmospheric water(P), surface water(R), plant water(V), soil water(S), groundwater(G), and there are possible ten combinations and interfaces between each two waters(Liu, 1993). SPAC(soil-plant-atmospheric continuum) initiated by J.R. Philip is actually the concept in dealing with the combination of P, V and S. The water shortage has impacts on all these components and the related hydrological process, in which: Precipitation = Runoff + Evapotranspiration.

The reduction of precipitation normally means the reduction in runoff and actual evapotranspiration, though potential evapotranspiration may increase, which will in turn effect precipitation and cause less and less rainfall. Even though this may not explain the formation of desert, it does indicate the hydrological process taking place there. Therefore, water shortage itself may cause the reduction of water resources, no matter how this seems to be puzzling, and probably this could be the most interesting impacts of shortage on environment. Water shortage is normally the result of many factors as mentioned in the former section, and its impacts on the mass and energy balance of water circulation and other environmental elements are very complex. The frame work of Fig.2 is the simplification of these complicated relations.

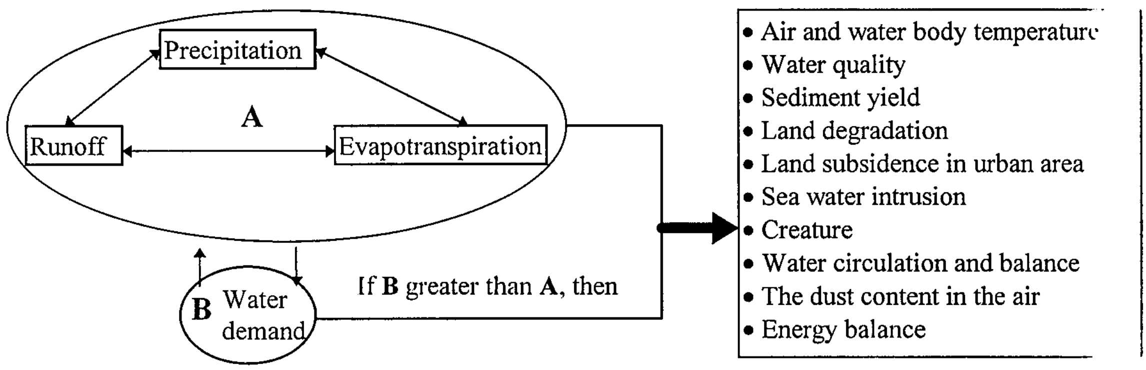

Figure 2 The context of water shortage and its environmental impacts

2.2 Indirect impacts

Many measures have been taken by human beings to cope with water shortage problem, such as building the reservoir and dam, transferring water from one area to another. The number of reservoir built in China up to 1989 is 82848, which accommodated total volume of 4617.31×10^8 m^3 .*[4] The east route of water transfer project is supposed to divert 1000 m^3/sec from south to north. All these efforts have definitely influenced the eco-environmental system. This has once been and will continue to be a disputable issue such as the case for the Three Gorges Project.

Another measure that people are taking and will have effects on environment is the enhancement of water management, which has been practiced in many cities of China. Water reuse rate is quite high in some cities, such as Tsingdao and Dalian. The present of water shortage may remind water users of its precious value and modify their ways in using water. Environmental quality will surely benefit from all of these practices

Most of waste water from factories has been discharged into the river without or with simple physical treatment due to insufficient fund and/or other reasons. Then, the less water used may mean the less polluted water to the river, and this also may do good to environment.

One measure called rainwater catchment system, i.e. to collect rainwater from impermeable pavement such as house roof and street, has played quite important role in the arid and semi-arid area of China, where annual average rainfall is about 400 mm. One program named "121" has been carried out in Gansu Province, in which every family develops 1 mu (one-fifteenth hec.) of impermeable area and collects rainwater water in two underground cells to irrigate 1 mu of crop field and supply domestic water use. One may argue that this measure will have great effects on runoff of the catchment and the other environmental aspects, and may not be suitable for extensive use. Actually, considering the size of impermeable area to the whole catchment, this measure may have only minor effects on the concerned aspects.

Because there are so many measures to reduce water shortage and its impacts as to sea water desalination, rainwater catchement system and even the proposal of drawing iceberg to coastal cities that it is hard to define fully the indirect impacts of water shortage on environment. Every measure may have its own impacts.

3. Policies to water shortage and its environmental impacts

The water shortage may break the mass and energy balance of the entire eco-environmental system, and a new balance needs to be reconstructed. The policies made help to ensure this reconstruction do less harm to the environment and human beings and people make the maximum profit from sustainable development of society, economy , natural resources and environment.

Therefore, the policies must concentrate on the sustainable development of limited water resources and the protection of vulnerable environment. Basically, there are two approaches in dealing with water shortage and its environmental impacts: to have new sources for water supply and to improve water management, and the latter should have the priority to the former one. The policies relevant to the impacts of water shortage on environment, either direct or indirect, are proposed as following:

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*[4] Yearly book of water conservation of China, 1990

- To educate human habitants on the earth to be aware of the importance of sustainable development of water resources and related environmental issues
- To encourage the use of technology to save water in both industry and agriculture.
- To take strict measures, such as increasing the price, to control the waste of water
- To set up laws to ensure the rational distribution of water resources
- To build rainwater catchment system in the arid and/or semi-arid region
- To constrain the expansion of population and industry in the area of poor water resources
- To make use of insurance policy to reduce the harm due to water shortage

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A Magnificent Plan on Reclaiming the Great Northwest China - the Tentative Preliminary Study on the Transfer of Water and Power from South to North in the Western Part of China

Chen Chuanyou
CISNAR, P. O. Box 9717, Beijing, P.R. China, 100101

Abstract:

There are abundant land, Mineral and energy resources in the Great Northwest China. However, the ecological environment there is also fragile. Lack of water is the key problem affecting the local economic development.

The six provinces and autonomous regions in the Great Northwest China have a total area of 4.2 million km^2 and a population no more than 100 million. There is a boundless stretch of land where the arable land amounts to several million hectares with enormous potential of agricultural production as long as water is supplied. This potential should present the only functional way to alleviate the grain and meat shortage in China and the over-dense population in the eastern part of China in the 21st century.

Coal, petroleum, natural gas and nonferrous metal resources in the Great Northwest China occupy a decisive position in China. The proved reserves of coal is 160 billion ton which is 160 times the annual coal output of whole China. According to the cooperative survey with U.S. by means of seismic exploration and analysis, the reserve of natural gas is expected to be 300 billion m^3, and the proved reserve of potassium, magnesium, sodium and barium salt ore ranks first in China. If the problem of water shortage can be solved, the Great Northwest China will become the bases of energy, raw materials, heavy chemical industry, petrol-chemical industry and salt chemical industry in China. Petroleum will possibly become the major product for export and earn large amount of foreign currency for China.

There exist drought, water deficit and fragile ecological environment in the Great Northwest China. If proper policy of land reclamation is not adopted, the sustainable development in that region is impossible and, as a result, the development in the eastern part of China should be affected greatly.

The Yaluzangbu River in Tibet is rich in water resources and hydropower, awaiting to be exploited for water and electricity supply to turn the water resources superiority into enormous economic, social and environmental benefits.

The Yaluzangbu River basin has an area of 240 000 km^2 with an annual runoff of 140 billion m^3, 2.5 times that of the Yellow River while its hydropower potential accounts for 20 percent that of the whole China. The well-known great U-turn of the watercourse from Pai to Medog in the lower reach of the Yaluzangbu River is characterized by very steep gradient and highly concentrated fall. It will form a 2250 m water head for hydropower generation if a 16 km straight tunnel is built between Pai and Bobang in Medog county. With the regulating reservoir built below Pai, it is possible to construct a super hydropower station with an installed capacity of 30 000 MW, the largest hydropower station in the world and almost twice that of the Three Gorge Hydropower Station. While the Great U-turn Hydropower Station can provide tremendous, low-cost electrical power, part of the electricity can also be used to pump water for the purpose of water transfer from south to the north in the western part of China.

For the long-term consideration, the advantage of the ample water resources in Yaluzangbu River should be taken to make up the disadvantage of water deficit in the Great Northwest China. This is an important strategy of optimizing the use of natural resources of the country. And also it is the only way for the economic development in the Great Northwest China.

The tentative plan for water transfer is conceived as following: A total amount of 30 - 40 billion m^3 water is pumped from the middle reach of the Yaluzangbu River and the upper reach of the Nu, Lancang and Jinsha rivers respectively onto the Tibet Plateau, and then flows gravitationally through the east part of the Tibet Plateau into the Zaling and Eling lakes located in the source area of the Yellow River with an elevation of 4500 m. Lying on such a high elevation, these two lakes can supply water westward to Caidam and Tarim basins in addition to the recharge of the Yellow River. Furthermore, a few huge hydropower stations can be built by making use of the fall along the course of water transfer with a total installed capacity of 14 000 MW. If this plan is realized, It will bring water and electric power as well as environmental improvement to the Great Northwest China.

It is convinced that The water and power transfer in the Tibet Plateau will give great benefits and will not create any harms to neighboring countries. The lower reach of Yaluzangbu River runs through the mountain valleys where population is sparse, and there is no problem of resettlement for the project. After the Yaluzangbu River flows into India, its name is known as Bromapura River which goes to the Indian Ocean via Bangladesh. It is known that the India and Bangladesh often encounter severe floods owing to their heavy rainfalls, threatening the lives and properties of local people. If the Great U-turn Hydropower Station is constructed, floods in this two countries will be reduced significantly, and on the other hand, more water can be provided during the dry season. It is believed that this project will also bring great benefits to the economic development in these two countries upon its implementation.

The Ecological Features And Significance of Hydrology in Arid Inland River Basin of China

Wang Genxu and Cheng Guodon
(Lanzhou Institute of Glaciology & Geocryology, CAS, Lanzhou, 730000)

Abstract: In arid inland river basin of China, the hydrological state has close relation ship with the ecological environment. They are not only depended on each other but influenced and interacted with each other, however the hydrological ecology functions and significance are varied in different region of upper middle and lower reacher. In order to promote rational utilization of the limited water resources and a steady increase of the economy, we should fully understand this functions and significance and set up the study method of ecological hydrology.

Key Words: Inland river Hydrology Arid Ecological system

INTRODUCTION

The arid inland river basins of China are located in the centre of Eurasian continent. They have the same vertical section–originating from high mountains, flowing through middle and low mountains, utilizing and turnover between surface and ground water in the alluvial plain , and finally being disappeared in the desert. The vertical section is also the basic hydrological feature of inland river and there are same vertical seciton of vegetation too (Tang, 1992; Cheng, 1993). Influenced by climatic, geological and geomorphological conditions, the water system build and reform the constituents and status of the ecological environment in inland river basins under phase change and material transition in different existing form and taking part in physical, chemical and biological processes by the way of dissaving and carrying other materials (Li Baoqin, and others 1990).

For a longe time, the hydrological state has been studied only by hydrological method in inland river of China. Due to focusing on utilizing water resources for artificial oasis development, the ecological system is deteriorated with phenomena of soil salinization and desertification after reclamation. Thanks to the deterioration of ecological environment in some exploited inland river, more and more hydrologists and ecologists gradually recognize the close relationship between hydrological factors and ecological changes at present time, and have put forward a lot of viewpoints and knowledge about hydrological ecology or ecological hydrology (Tang and Qu, 1992; Cheng, 1992). Degradation of the ecological environmont in arid inland river basin has become a matter of concern in the last few decades as several of its ill–effects have become increasingly evident, and steps have been and are being taken to tackle this problem both by Government and voluntary agencies, such as ecologists and geographists (Li, 1990; Cheng, 1993). In this paper, depending on our field investigation and research in three years and those work acheived by prestudy, we analyse the ecological features and significance of hydrology and their relationship in different regions of an inland river basin in order to bring out that it is necessary to set up the study method of ecological hydrology in this place.

THE ECOLOGICAL SIGNIFICANCE OF HYDROLOGICAL FACTORS IN MOUNTAIN REGION

The rainfall and evaporation in an inland river basin vary gradiuently with space, especially with elevation.(Table 1).

Table 1 Variations of rainfall and evaporation with elevation in some inland river basins

Elevation (m)	>4000		4000—3000		3000—2000		2000—1000		<1000	
Item / River basin	Rain.	Evap.	Rain.	Evap.	Rain.	Evap.	Rain.	Evap.	Rain.	Evap.
Heihe	600—700	<700	400	1000—1400	200	1640	150—80	2000—2500	80—40	>3000
Shi yang	520—800	<800	410—520	1200—1500	360	1760	160—110	2600	100—110	3000—3200
Urumqi	>700	<820	470—600	920	310—500	1100—1500	400	1200—2000	<150	>2000

In general, rainfall is within the range of 300— 800mm at upper mountain regions, while only 30— 60mm in desert plain of lower reaches, the evaporation flux decreases progressively from over 3000mm at lower reaches to below 700mm at upper reachers in high mountain land. Concentrating in mountain regions, rainfall contributes to the formation of not only large glacier and snowcover, but main runoff distributed area—takes form of about 676 rivers. The hydrological state as mentioned above results in the vertical landscape zones of vegetaion that is of the main vegetation ecological characteristics of an inland river basin(Fig.1).

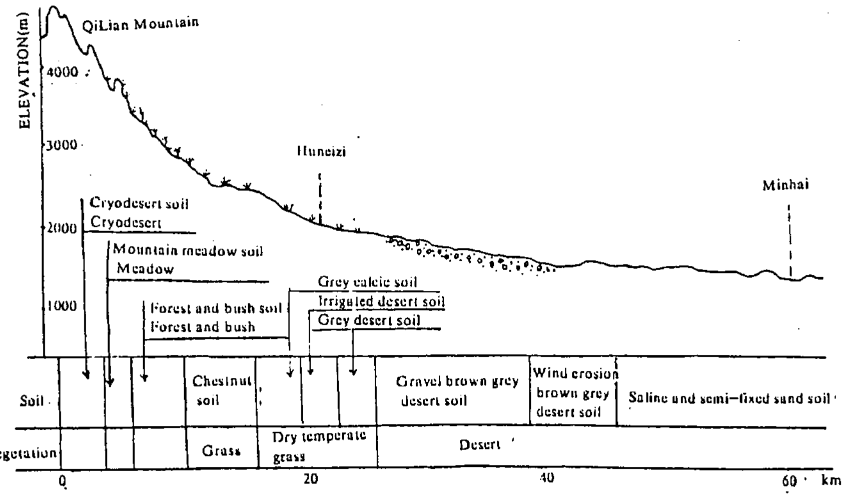

Fig 1. The vertical landscape zones of vegetation and soil in inland river basin

In Fig.1 the forest and bush zones are generally referred to as water resource conserved region. The zone and other florizones formed by hydrological system, on the contrary, influence the hydrological state in mountain land and alluvial plain, which is expressed as follow:

- Forest and grass may change the annual distribution of runoff. Blocking and holding rainstorm, the flora forest, bush and grass regulate the runoff intensity, and change the flood discharge and its emerging time (table 2), so that the runoff discharge during dry season can be maintained to a certain extent (Cheng, 1992; Fu, 1989).
- Reduce the sand content of river. There are lots of factors that influence the sand content of river, such as climate, geological factors, the materials of river bed and the extent of vegetation coverage, and so on. Among above factors, the vegetation is the most important factor. Taking Qilian moutains as an example, the sand content of Shulei river basin (in the western Qilian mountains) is about 1.5—5.0 kg / m^3, in Heihe river basin it is about 1.0kg / m^3, but it is only 0.5kg / m^3 in Shiyang river basin (in the eastern Qilian mountains), such pattern closely relates to that the extent of vegetation coverage reduces from the east to west of Qilian mountains (Tang, and others, 1992).
- Having advantage to the transformation of rainfall into groundwater. The forest and bush of grass zones become one of the main feed regions of ground water. Table 2 shows the water permeability of varied vegetation covering types.

Table 2 The permeability of different vegetation covering condition (mm / min)

type of vegetation covering	bryophyte	dead branchs and fallen leaves	the surface soil covered with grass	bare soil
permeability (mm / mim)	81–159	15–22	8–12	0.39–1.4

The bryophyte and dead branches and fallen leave layers are of the most advantageous conditions for water transformation. Because their permeability is larger than the local rainstorm intensity, leading to no runoff on these layers, and the transtormation of most of the rainfall into ground water. The runoff is supplied by spring water in the district.

But in the dry grasslands and desert grasslands of mountain districts, the runoff of surface lands is intensively concentrated in deep river valley, ground water is excreted into river, and the sand content of river is increased with the greater flow velosity, the rainfall become poor with the elevation lowering (Table 1). This hydrological state formes the dry and desert ecological system, and inversely, this poor ecological environment is unable to conserve water and land resources.

THE RELATIONSHIP BETWEEN HYDROLOGICAL FACTORS AND ECOLOGICAL EVIRONMENT IN ALLUVIAL PLAIN

Out from mountain mouth, the inland river flow into the arid middle and lower reacher. Because of rain fall < 150mm in this region the rain has no influence on runoff. In China, there are about 560 inland rivers their average annual runoff are only $0.15 \times 10^8 m^3$or less, the length of the basins short and no relationship between each other (Cheng, 1992). Most of these rivers are transformed into man made canals from mountain mouth now, and forme a lot of spotted irrigating oases. There are only a few rivers which could run through the alluvial plains and flow into terminal lakes or be faded into the desert.

In the upper alluvial fan, the river valley narrow, the river bank high and cliffy, the surface water is concentrated in the deep river and ground water level has an average depth of 150— 300m. This hydrological state bring out the arid or hyper–arid ecological system–from temperate grasslands to desert grasslands (Fig 1.). The dominant types of vegetation include Sympegmaregelii, Salsoha abrotanoides, Reaumuria soongorica and Stipa krylovii, etc. They are mainly temperate desert vegetation. In the district, the dominant soil types are Gray desert soil, Gray calcic soil and Gray–brown desert soil. The organic matter and nitrogen content of the soils are very low, generally the organic matter content $<0.9\%$ and the total nitrogen $<7\%$. But salinization of soil was occured only at middle or deep layer. So that reclamation of the region must be depended on man–made irrigating system. After reclamation, if there are perfect irrigation, this kind of land could become one of the best oases in an inland river besin without salinization. If irrigation being not ensured abundantly, the reclamation can seriouly destroy the frail ecological environment of the place.

In the middle and lower parts of an alluvial fan and silt plain where the irrigation was highly developed, the hydrological state can be characterized by the folowing:

- The river bed has low slope of less than 5‰, and shifting water courses, branches, and curves. The river courses have been distributed in area about 400—3000m. The shifting river course with more and more deposits make the river a very complicated water net. Because of the wide and shallow sections of the river course, water runs everywhere and lakes are formed in the hollow areas during flood period. There are many abandoned river course with various dunes in this region.
- Ground water level is generally less than 5.0m. In most places ground water flow out to surface in spring especially, and formes many mash swamps and spring water courses. The ground water here feed the river during dry season or low water level period.
- Due to the large–scale exploitation of surface water, the river hydrological state has been controlled by man. Instead of carring water to the lower reaches, the flood discharge is being made from some reservoirs in great extent. In most of inland rivers, the flood discharge may be zero when the flood runoff in this region is below some certain volume. For example, in the Yarkant River, the deadline runoff is about $11.5 \times 10^8 m^3$; in the Heihe River, it is $14.0 \times 10^8 m^3$; in Shiyang River and Urumqi River, it is as much as one occurred in 30 or 50 years.
- Surface water and ground water are exchanged frequently, and interact with each

other. The transformation processes of waters can be described as: water permeated from river bed, irrigation cannels and irrigating fields ➤ ground water ➤ overflow to surface as spring to surface water ➤ irrigating return or exploited for irrigation and permeating into ground water again. In Shiyang River, the first transforming water is about 53.31% of total runoff in upper alluvial fan, the second transforming water is 68.79% of runoff in lower basin, and third transforming water about 48.77% of total lower basin runoff. In Heihe River, they are about 64.26% 、 86.10% and 21.32% respectively. This complex and large drscharge transfomation makes the available water resources increased.

This hydrological characteristics make it possible here to develope large–scale man–made oases, so that the irrigating agriculture in this region is the most flourishing of whole river basin which integrated over 70% irrigating area and about 80% industries and population. Besides the highly developed agriculture, the ecological system appears manifold. There are diverse vegetation: Xerophyte、 Salt phyte、 Helophyte and Hydrophyte, etc., with than 200 types of vegetation distributed in this region.

The cultivated soil brought out from the Gray desert soil and Gray–brown desert soil, but the content of organic matter and total nitrogen are higher (could reach at 2.5% and 0.1% respectively), so its ecological function is prior to the parent material soils. But there is another ecological characteristic in this place–secondary salinization of soil which is the most serious ecological problem in the middle and lower reaches of the inland river. About 10— 21% total cultivated soil has been salinized (Table 3), and it is increased yearly. Thesecondary salinization of soil is one of three primary ecological variations after large–scale reclamation in this region. The others are concluded as follow as:

Table 3 Secondary salinization in some inland river basin

River	Salinized soil area(km^2)	ration to total land(%)	cultivated Salisoil (km^2)	ratio to total cultivated soil(%)
Shiyang	2049.81	4.98	295.37	11.54
Heihe	1584.21	2.27	256.73	10.75
Shule	4713.64	4.57	273.21	21.7
Urumqi	796.80	5.65	275.02	19.24

① The variantion of river course and flood discharge result from human activities make many dry river courses abandoned with various sand dunes.The vegetations grew along the abandoned river course are declined. This two factors accelorate the desertification of inner oases.

② The development of man made oasis depends upon the destruction of the natural ecological system. The large–scale reclamation make the Helophyte and Hydrophyte vegetation declined or died out. The natural ecological system has been replaced by man–made agricutrual system. Simultaneously, the change of hydrological state results in the deterioration of the ecological environment in lower reaches.

THE FEATURES OF HYDROLOGICAL ECOLOGY IN THE RIVER DISAPPEARED REGION.

Inland rivers in the lower reacher flow usually into terminal lakes or disappeared in the desert. There are only belt oases surrounded by desert, so the ecological environment is very frail in this region, the hydrological state has been controlled by human activities, espeially the large–scale exploitation of water resources in middle reaches. Flood discharge and annual distrbuting regulation are re–formed by human activities: The high runoff appears during Nov.～Mar, and the runoff fed mainly by ground water is very little and almost cut off during Apr～Oct. except for large discharge flood. The annual runoff in this place have lost its natural meaning. In ancient years, rivers and lakes were joined together in this place. There were abundant water resources. A large qutantity of forest and grass have once grown in the region, together with all kinds of livestock. Loulan, Heicheng, etc, those well–known ancient cities, were located here. But in the 30'S and 40'S of this century especially in the last 30 years, the ecological enviromnent of lower reaches in almost all inland rivers have been seriously destroyed becase of human activities. The areas of oases turn to be smaller and smaller, the surrounding desert in some sections has been joined together, and the terminal lakes were reduced or disappeared.

In this region, the ecological features are fully decided by the hydrological state. The hydrological variations inevitably lead to the change of ecological environment. The characteristics of ecological system formed by hydrological variation can be conclued as follow:

(1) Water quality are becoming worse with the runoff cutoff (Table 4). From Table 4, we can see that the quality of surface water and shallow ground water in these regions are worser than that in alluvial apron. Because of cut down of runoff, the strong evaporation enrich the mineralization of water, and the variation of water quality generally tends to be worse yearly.

Table 4 The variation of water quality in terminal region

Water type	Alluvial apron		Terminal region of river basin	
	Mineralization g/L	water chemical type	mineralization g/L	water chemical type
Surface water	<0.80	HCo_3–Ca–Mg	3.0–78	So_4–Cl–Na–Mg
Shallow ground water	0.1–0.7	HCo_3–Ca–Mg	5.0–16.0	So_4–Cl–Na–Mg Cl–$S0_4$–Na–Mg

(2) Salinization and desertification of soil become more and more serious in this region. Along with the groundwater level droped with poor quality caused by the decrease of water resources, the soil tends to be salinized seriously . The salinizing processes can be

showed as: the meadow or boggy soil $\to$light salinized meadow soil $\to$intermediate salinized meadow soil $\to$heavy salinized meadow soil $\to$meadow saline soil $\to$Saline soil. Such process can be seen in all the lower reaches of inland river basins. With soil salinization, a large cultivating area have been abandoned. In the lower reach of Shiyang River, the abandoned area reaches up to 1.3×10^4ha. The salt content of soil 10cm below surface is more than 7.9%.

Due to the change of hydrological state, the vegetation declines and grassland degenerates, the fine grains and nutrients in the land are blown off as a result of wind erosion. The final result is the formation of all kinds of dunes, this is the one reason contributing to land desertification. The second reason for land desertification has something to do with the change of river courses, there are many abandoned dry river beds and with the declination of vegetation and lots of sand dunes are formed. From 1950'S to the present, the desertified area has increased to an area 391×10^3ha in Tarim River, 4.99×10^4ha in Shiyang River and 35.09×10^4ha in Heihe River. There are about 50% of the total available cultivated land under desertification or tends be desertified.

(3) Vegetation is serously degraded or destroyed. The vegetation ecological system in the river terminal region can be classified into: the arbor with typical plants of Diversifolia Schronk and Narrow-leaved Oleaster, the bush dominented by Tamaxix Ramosissima and Haloxylon Ammoderdron, the meadow with main plants of Chennopodiaceae and Leguminosae, etc. The change of hydrological state directly lead to the declination of the vegetation ecological system. In Tarim river, the area of the Diversifolia Schronk wood declined by 56.9% in 20 years from 1958 to 1978; In Eijina disitrict of Heihe river, the area of the Divesifolia schronk and Narrow-leaved Oleaster decreased by 5.76×10^4ha in 22 years between 1958 and 1980. In all inland river basins, the meadow vegetation has been seriously destroyed in the lower reaches. Originally, there were plenty of meadow vegetation: Phragmites australis+Splendid achnatherum+Leymus secalinus, but now, which have been or tends to be replaced by arid temperate vegetation.

CONCLUSION AND DISCUSSION

(1) In water conserved region of high mountain in inland rivers, the ecological vegetation and hydrological state are depended on each other and influenced and interacted with each other. Abundant rainfall and large runoff in this place form the lush vegetation, especially the rich and varied forest and meadow or bush belt. Conversely, the forest and bush vegetations obviously conserve water resources and influence the hydrological state–river discharge, sand content and runoff distribution, etc. The reclamation and lumbering or over herding in these regions result in the change of hydrological state and soil erosion.

(2) In alluvial plain, the abundant water resources and convenient utilized condition with good water quality construct the high beneficial and efficient irrigating agriculture.

The large–scale reclamation in middle reaches promote the sustainably developed oases but with the hydrological state heavily changed and natural ecological system seriously destroyed. Because of human activities, some factors such as flood discharge and its distribution, river courses and water quality, etc. have been changed seriously in middle and lower reaches, which results in the degradation of vegetation and declination of ecological system. The area of salinization and desertification are rapidly expanded yearly in lower reachers. In these places, a certain hydrological state formes a corresponding ecological environment, especially certain flora communities and their ecological features. Any hydrological change inevitably leads to the change of the ecological environment.

(3) In order to alleviate the change of the ecological environment, it is necessary to promote rational utilization of the limited water resources and develop water conserved vegetation. Therefore, we should have a correct understanding and evaluation of the ecological characteristics of the hydrology in arid inland river basins. Approaches to the hydrological state or ecological characteristics separately is of no significance in the area. We should fully understand the functions of the water resources in order to efficiently combine the preservation of the ecological balance and economic development. Becouse of the relationship of dependence, influence and interaction with each other between hydrological state and ecological enrivonment discussed above, we should establish an integrated research method for ecological hydrology in the inland river, to make overall plans and take all the factors into consideration and to put the limited water resources to a rational use in a comprehensive way.

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IMPACTS OF HUMAN ACTIVITIES ON WATER CYCLE IN NORTH CHINA

LI Lijuan
(Institute of Geography, Chinese Academy of Sciences, Beijing 100101, P.R.China)

I. Introduction

North China, with total area 272,000 km^2, covers Hebei Provinces and 2 metropolis--Beijing and Tianjin City, and the part of Henan and Shandong Province to the north of the Yellow River. Most of this region, which is situated in the semi-humid, semi-arid continental monsoon climate temperate zone, gets an annual precipitation of 500~600 mm, more than 70~80% of annual precipitation and 90% of runoff are concentrated in flood season(June to August). Whereas, the environmental conditions of the area are fragile, with flood, drought, salinization and soil erosion. Its river network contains the entire Haihe River Basin including eight river systems, that is, the Nanyun River, Ziya River, Daqing River, Yongding River, Chaobai River, Beiyun River, Jiyun River and Luanhe River, and the flood raining river courses of the Tuhai River, Majia River and Heilonggang-Yundong River etc.. The Yellow River, with its small tributaries along the Yellow River, lie in the south boundary of the region.

II. Level of Water resources development

The perennial average amount of total water resources are 38.61 billion m^3, including 22.95 billion m^3 of surface water, 25.41 billion m^3 of ground water and 9.75 billion m^3 of their duplication. A great of water conservancy projects have been built since the 1950s. By the end of 1984, thirty large reservoirs with a total storing capacity of 24.03 billion m^3 had been built in Haihe River Basin, 83% of river area and more than 70% of runoff were controlled by these reservoirs. More than 883,000 pumped wells and several large diversion projects, such as water diversion from the Luanhe River to Tianjin and Tangshan City, from the Qinglong River to Qinhuangdao City, from the Yellow River to Tianjin, have been built. The water projects have enhanced the level of water resources development in the area, they build up the local resistance to drought, flood, salinization and soil erosion.

The overall level of water resources development in the area is over 80%, the highest in China(the average level is 20% in China). The level of water resources development in the area was over 60% for surface, and over 100% for ground water. The local water projects make great contribution to resolving the water consuming problem of local industry and agriculture as well as urban and rural daily life. However, the area becomes one of the main water deficient areas as the local water requirement increases so rapidly with the economic development and population growth that it already surpasses the local water supply capability. According to an analysis of current water supply demand in North China, the shortage of water resources is as much as 2.9~10.9 billion m^3/a now. The over-exploitation of water resources along with water pollution leads to a series of environmental problems.

III. The main impacts on water cycle by water development in North China

Water development and utilization, human activities effected directly on water cycle, have resulted in natural water cycle changing in the quantity relationship between key elements and their motion direction. And the water quality is simultaneously getting worse. Due to the intensive exploitation of water resource by the deficiency of water resource in North China, key elements of water balance changed, runoff volume reduced, evaporation increased, vertical movement of moisture was strengthened, water cycle pattern transformed from open system into regionally closed system; Meanwhile, due to the incompetent water purification system in comparison with the wastewater discharge, water bodies pollution goes bad to worse. Furthermore, some water bodies become unusable. The reduction in amount of runoff, both surface and under ground, and the pollution of water bodies have caused a series of environmental problems.

1. The impacts on the key elements of water cycle and water balance

Through the exploitation and utilization of water resources since the late 1950s, great changes of water cycle process and water balance has taken place. It shows in the follow three aspects: runoff amount reduction, sediment and salt accumulation.

1.1 Runoff amount reduction

The rapid reduction of water discharge in the lower reaches, attributed to many reservoirs built in the upper reaches, decreases the relevant water discharge emptying into sea. For example, the rivers in this area dried up so long that some rivers flowed only a few days during a year. In term of the reduction of annual water discharge entering into Hebei Province from 1980 to 1985, the water discharge was 31.3% of 9.98 billion m^3/a which was the inpouring water annual in the 1950s. Besides the reduction of the inpouring water amount, the local produced water discharge decreased rapidly. The average local-produced water discharge declined from 23.32 billion m^3/a in the 1950s to 7.71 billion m^3/a in the 1980s, that is, the latter is 33% of the former.

The over-exploitation and utilization water resources caused the discharge flowing into the sea--a component of water cycle--decrease rapidly. The discharge flowing into the sea was 1.46 billion m^3/a in North China in the early 1980s, in contrast, 24.185 billion m^3/a in the 1950s. Meanwhile, the percentage of the water discharge flowing into sea in comparison with annual runoff amount dropped from 64.5% in the 1950s to 10.3% in the 1980s. This rapid reduction, not only transformed the water cycle process from an open system into a closed system, but also affects the regularities of sediment and salt transport in North China.

In short, the reduction of runoff amount aggravates the relationship between water resource supply and demand in North China. Meanwhile, it causes river course to dry up, sediment and salt accumulation.

1.2 Sediment accumulation

North China has 288,000 km^2 of mountain area, with sand yield at a perennial average of 594 million t/a and erosion intensity at an average of 2,062 $t/km^2 \cdot a$. Sand yield in the area is shown in detail as follow: sand yields of the Yellow River , which is at perennial average of 341 million t/a, pours into the Yellow River except for that 10 percent of the sand yields piles up in the reservoirs; that of the Haihe River Basin is at a perennial average of 253 million t/a. Reservoirs and river courses are silted up by sediment from the mountain area. Annual sedimentation in 17 large reservoirs in Hebei Province is estimated to be as much as 38 million tons, and in the Guanting Reservoir 22 million tons. The whole sedimentation is about 80 million tons in consideration of enormous medium-and small sized reservoirs in the area. Besides, the projects of diversion from the Yellow River bring a good number of sand to the plain, next to the lower reaches of the Yellow River. Sedimentation in the irrigation area by diversion from the Yellow River increases with the increment of water discharge diverted from the Yellow River year by year. For example, the inpouring sand in Shandong Province went up from an average of 68 million t/a in the 1970s to 90 million t/a in the 1980s. Around 65 million tons of sand deposited in irrigation ditches and escape canals causes wind-blow sand hazard in the area near ditch source and weakens flood drainage. Therefore, sediment accumulation becomes the main environmental problem in the irrigation area by diversion from the Yellow River.

About 125 million tons of the sediment entered the plain and accumulated there, another 128 million tons was carried away by the water discharge flowing into the sea as stream load. However, sediment accumulation in the plain increase as the water discharge flowing into sea declines year after year. As a result, river courses are badly silted up. For example, in the part of the Hutuo River from Raoyang to Anping with an area of 62.5 km^2, 15 million tons of sand has collected from the late 1950s to the early 1980s; the river course from Gaocheng to Wuji lifted at an average of 2 m, and 5.6 million tons of sand has piled up there; net sediment accumulation in the Ziya New River course reaches 5.69 million tons during the period of 1967~1985, and the length of sedimentation was 39.5 km. Sediment accumulation weakened the main flood drainage in the Hebei Plain by 48~91 percent.

1.3 Salt accumulation

Salt has been piling up in this area, due to the intensive development and utilization of water resources, the rapid reduction of runoff flowing into sea and the consumption of water diverted from the Yellow River. Annual salt accumulation is estimated to be at an average of 2 million tons in the plain and reservoirs in North China. Qingbei and Fuhu in the Hebei Plain are in a state of salt collecting all the time. As a result, salt concentration of the rivers is liable to increase. The irrigation area by diversion from the Yellow River is in the same state as the Hebei Plain. In Shandong Province, 2.4 million t/a inpouring salt along with 1 million t/a less salt discharge leads to 1.4 million t/a salt accumulation. Salt accumulation may cause soil salinization in the plain, especially in the irrigation area by diversion from the Yellow River. Soil salinization will take place at any time unless the rise of ground water stage is carefully controlled.

2. The Environmental impacts Caused By the Over-Exploitation of Ground Water

A lot of wells have been dug in North China since 1970. The over-exploitation of ground water is wide-spread, because the climate has been much more arid than before in 1980's and the utilization ratio of ground water was as high as over 100%. According to the statistical data, the accumulation of ground water over-exploitation is over 40 billion m^3 in North China (30 billion in the Hebei Plain). The over-exploitation of ground water will cause ground water table dropped continuously and ground water drying up, and will form regional cone of depression and bring about land subsidence, sea water intrusion, drinking water fluorosis and other problems. The most harmful among them are land subsidence and fluorosis.

2.1 Regional Depression Cone of Ground Water

The over-exploitation of shallow and deep ground water has formed regional cone of depression. Most centers of the cones are located right beneath cities, industrial and mineral regions. Moreover, large-scale depression cone of deep ground water was created in the areas where deep ground water is the sources irrigation water. According to the statistical data, in North China, the shallow ground water has dropped 10~20 m, the cone area covered 20,000 km^2, water table in the center of cone region has dropped 20~40 m. In the eastern part of the North Plain, the cone of deep ground water covered 22,000 km^2, water table dropped at a rate of 3~5 m/a; Tianjin, Cangzhou and Hengshui are the worst among them. There is compound cone of deep ground water like Ji-Zao-Heng cone in the central of the North China Plain. The lowest water table of Cangzhou cone was 90.2m below the surface, and the Ji-Zao-Heng cone 71.3 m in the center in 1994.

The formation of depression cone of ground water damages pumped wells, reduces the water yield of the wells, dries up spring, as a result, water supply from ground water is shorter than before.

Moreover, since ground water table are much deeper than before(deeper than 10 m), much precipitation infiltrated into the soil, that resulted in runoff coefficient reduction. For example, runoff was produced in Hebei Plain in 1960's when annual precipitation was more than 250 mm. Whereas it occurred when annual precipitation was more than 500 mm in 1980's. Only 3.5 mm runoff was produced in case of 832 mm annual precipitation in 1988. And it made soil desalinization in west part of Hebei Province because of much more water infiltration into soil.

On the other hand, evaporation from phreatic water was getting much less as ground water table was getting deeper.

2.2 Land Subsidence

Land subsidence is consequently caused by water release of densely pressured strata and over-exploitation of ground water. Land subsidence brought about by densely pressured clay cannot be resumed even if the water stage rises to the original level.

Land subsidence in North China mainly took place in Beijing, Tianjin, Cangzhou and Hengshui. In Beijing, the strongest subsidence runs to 0.59 m, and subsidence covers more than 600 km^2. The total area of land subsided in Tianjin, Cangzhou and Hengshui was 440,000 km^2. Land subsidence occurred all over Tianjin City, the strongest subsidence of ground runs to 2.59 m, and over an area of 10 km^2 subsided more than 2 m, the surface of Shanghai Avenue in the Tanggu District. Tianjin is now below sea level. The surface of Cangzhou and Hengshui cone has subsided 1.52 m by 1994.

2.3 Sea Water Intrusion

Sea water intrusion is a phenomenon that sea water intrudes into aquifer by way of surface and underground passages and salifys fresh water. Sea water and fresh water in littoral zone has an interface which is next to the coastline. Over-exploitation of ground water moves the interface into inland and causes Cl^- concentration of ground water to exceed 300 mg/L. After sea water had intruded water source in Qinhuangdao City, the water supply plant was damaged, water exploitation decreased. Sea water intrusion also took place in Cangzhou.

2.4 Endemic Fluorsis

Because surface water and shallow ground water dried up in Cangzhou in recent years, deep high-fluoride ground water (F^- concentration is higher than 1 mg/L) was exploited as drinking water supply, which brings about endemic fluorosis and does harm to the human health. Therefore, endemic fluorosis becomes the main environmental problem there.

Generally, deep ground water in the eastern part of North China, has a high concentration of fluoride. In Cangzhou, the F^- concentration of the third aquifer runs to as high as 7 mg/L, and high fluoride area covers 26,000 km^2. According to the statistical data, in Heilonggang of Hebei Province, there were 1.1 million fluorosis patients (1.04 million dental fluorosis and 0.56 million skeletal fluorosis) in 1987, 417,000 patients more than that in 1984. The prevalence of endemic fluorosis in the affected area is greatly correlated with the fluoride content of drinking water and the duration that people drink the fluoride water. Patients crippled by fluorosis become a serious social problem.

3. Water Quality Pollution

On the one hand, the reduction of water amount weakens the diluting and self purification capability of water body to make water pollution even worse; on the other hand, pollution makes clean water unusable and decreases the amount of water available.

The pollution sources of surface water in North China are mainly the urban and industrial point sources. More than 3 billion m^3 of waste water in the area have been discharged into the river system, in which 77% of it is from industry, and the rest from domestic sewage. While 80% of it is directly discharged into river networks or infiltrated on land without any treatment, causing severe water quality pollution. The main pollutants are organic matter, nitride and phenol. According to the data of the evaluation on river water quality in North China in end of 1980, 84% of the water course could not meet the 1~3 class of surface water quality standard, 55% could only be used for irrigation and 29% was polluted so badly that water is unusable.

In term of regional distribution, in the badly polluted area water supply is remarkably deficient. Water pollution aggravates the local complexion. Ground water pollution begins to appear in North China and is being aggravated. It is brought about by urban and field surface discharge, and is more severe in urban industrial area than in any other places.

In Beijing and its near suburbs, the ground water hardness and nitrates content of the ground water keep increasing. The region where ground water hardness exceeds the standard has an area of 254 km^2, and nitrates pollution spreads over 200 km^2. The area where all the indices of $SO_2^{=}$, Cl^- and water hardness of ground water are up to their standards covers only 25% of Tianjin which has an area of 200 km^2. In Hebei Province, there are many districts where some index exceed the standards of drinking water including water hardness and COD.

IV. Discussion and Conclusions

Human activities have a great impacts on natural water cycle, that are:

1. reduction of runoff and river discharge into the sea, that resulted in rivers and lakes dry up in most time of a year.
2. reduction runoff coefficient and increase infiltration.
3. increase evaporation from soil, whereas decrease evaporation form phreatic water.
4. Water quality has been worse heavily, and water pollution spread both for surface and ground.
5. Over-exploitation of water resources has resulted in many environmental problems.

As mentioned above, over-exploitation of water resources have changed natural water cycle process and resulted in many environmental problems. So it is not a good way for sustainable water resources development both for surface and ground water. The highest level of water development should below 50% at a whole, and for surface water it should lower than 30% to keep enough water for the environment, while for ground water it must be lower than 80% to avoid emergence of ground water depression cone and related problems such as land subsidence, sea water intrusion et. al. The best way to meet increasing water demands of human activities is to rise efficiency of water resources use through application of high technology in industrial, agricultural and domestic water consumption, such as water recycle. Meanwhile reduce waste water discharge through treatment and recycle technology.

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Formation and Sustainable Utilization of Water Resources in the Hexi Area of China

Kang Ersi
(Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences, Lanzhou 730000, China)

Abstract

In the Hexi area of northwest China, along with the increase of altitude, precipitation increases, air temperature and evaporation decrease. The mountainous watersheds receive much more precipitation, and possess lower temperature and lower evaporation rate as compared with the low land area, and therefore are the runoff generation area. The runoff is consumed and scattering at the low land area. In the mountainous watersheds, both the high mountain zone and the mountain vegetation zone are important to contribute the runoff generation. From east to west of the area, the runoff depth decreases and the contribution of glacier melt water to runoff increases. Both the mountainous watersheds and the low land area in front of the mountains show an increase of air temperature and precipitation. The runoff reduction in the low land area can be attributed mostly to the human activities. The yearly runoff and runoff in the summer months from the mountainous watersheds are well coorelated to the mountain precipitation. The monthly runoff of April, May, September and October is well possitively correlated to air temperature, but sometimes negatively correlated to precipitation. Therefore, during those months of spring and autumn, snow melt runoff contribute most of the river runoff. In the exploitation and utilization of water resources, in addition to the further construction of the water conservancy facilities and carrying out the water transferring engineering over the drainage basins, the emphasis shoule be put on how to manage and efficiently use the limited water resources, to make the most of the social, economical and ecological benefit of water resources.

1. Introduction

Hexi area of northwest China is located to the west of the Yellow River drainage basin, including Hexi Corridor from Ushao mountain ridge at the east to the border between Gansu Province and the Xinjiang Uygur Autonomous Region, the Qilian mountains at the south and the Beishan mountains at the north. The area ranges from latitude 37°17'N to 42°48'N and longitude 93°23'E to 104°12'E, covering about 27×10^4 km^2 with the population of 415×10^4(Chen et al., 1992). The area consists of three inland river basins: Shulehe River at the west, Heihe River in the middle and Shiyanhe River at the east. The inland river basins can be divided into four altitude zones: high mountain ice, snow and permafrost zone, mountain vegetation zone, oases zone and desert sone. The former two zones constitute the montainous watersheds which are the generation area of water resources, while the latter two zones constitute the low land area where water resources are consumed and runoff is scattering and disappearing. The Hexi area is situated at the inland area of Eurasia, far from the oceans. The water vapour currents come mainly from the summer south-east monsoon from the Pacific Ocean and the summer south-west monsoon from the Indian Ocean(Zhou, 1983; Sun, 1977-1978), next from the wester air current(Yang, 1992a). In winter, it is extremly cold and dry because of the dominent cotrol over the area by the Mongolia and Siberia High. Therefore, the Hexi area is dry in climate and short of water resources. Based on the data measured at the meteorological stations and hydrometric stations distributed in the area, this paper is intended to discuss the formation characteristics of water resources, the relationship between mountainous runoff and climotological elements, and the problems facing the sustainable utinization of water resources in the area.

2. Formation of water resources

The spatial distribution of annual air temperature and precipitation shows that, in this area, precipitation is more and air temperature is higher at the east part than those at the west part, while precipitation is more and air temperature is lower at the mountainous area than those at the low land area in front of the mountains(Yang, 1992b). Fig. 1 shows significant altitude dependency of annual air temperature, precipitation and pan evaporation measured at the standard meteorological stations distributed in the area. Along with the increase of altitude, precipitation increases, air temperature and evaporation decrease. As the regional characteristics, precipitation is closely related to altitude(Fig. 1), and the gradient is 18mm/100m. This indicates that the topographical lifting mechanisms play a very important role in the formation of precipitation in this area. This can be expained by the facts, that the Qilian mountains strech from southeast to northwest, facing actually northeast. The controlling low presure system over the Qilian mountains and the subtropical high moving west during summer make the air current carrying water vapour from southeast move towards west(Yang, 1992a). Therefore, the lifting mechanisms are built up by the interaction between the air current, elevation and slope orientation of the Qilian mountains. The precipitation is mostly concentrated during the summer season in a year(Yang, 1991), therefore, the annual precipitation shows obvious altitude dependency. Because of the elevation influence of the Qilian mountains, the altitude gradient of air temperature is -0.5°C/100m, and that of pan evaporation is -60mm/100m.

The lowest altitude of the mountainous watersheds of the Qilian mountains in this area ranges from about 1950m at the east to 2700m at the west(Chen et al.,1992). Fig.1 indicates that the mountainous watersheds receive much more precipitation, and possess lower temperature and lower evaporation rate, and therefore are the runoff generation area.

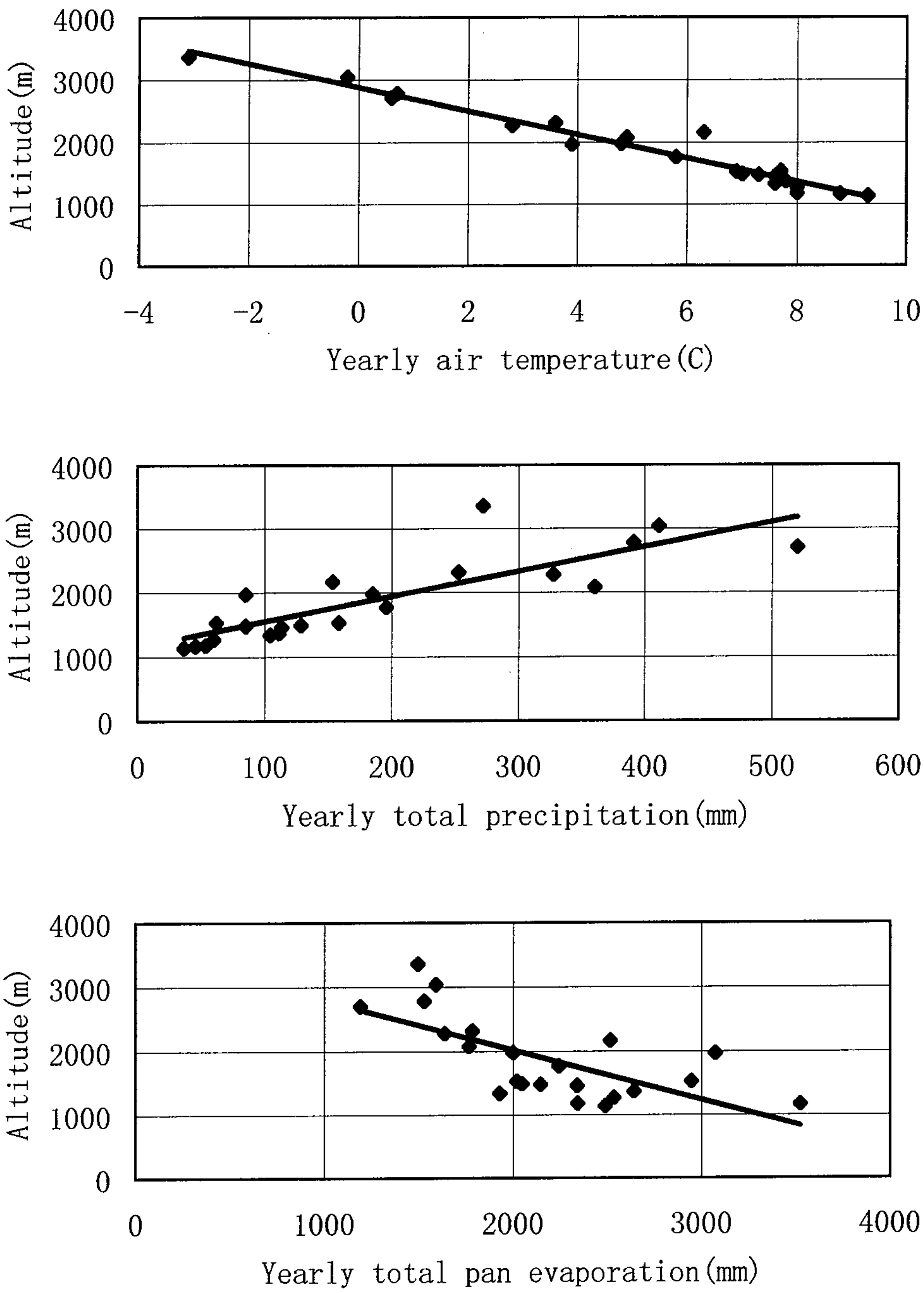

Fig. 1 Altitude dependency of yearly mean air temperature, total precipitation and pan evaporation in the Hexi area (averaged values at the standard meteorological stations during 1950s to 1980s)

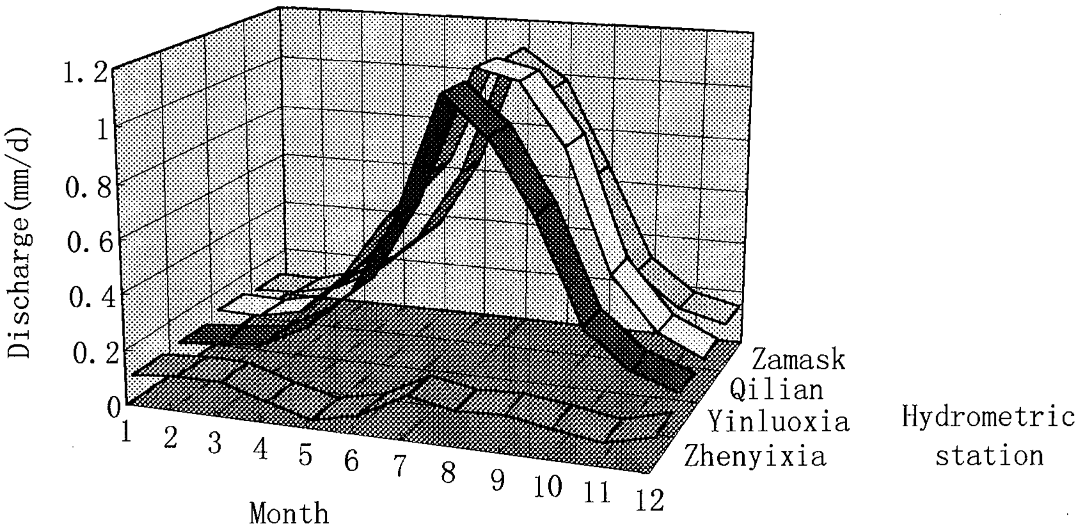

Fig. 2 Mean monthly runoff distribution at the hydrometric stations of Heihe River

Station	Altitude(m)	Catchment area(km^2)
Zhenyixia	1995	35634
Yinluoxia	1674	10009
Qilian	2590	2452
Zamask	2635	4589

Fig. 2 shows the mean monthly discharge at the hydrometric stations of four sub basins of the Heihe River basin, which is situated in Qinghai, Gansu and Inner Mongolia, covering 13×10^4km^2. It originates in the Qilian mountains and flows through the Hexi Corridor of Gansu province and enter into the western part of Inner Mongolia Plateau(Gao et al., 1990). The hydrometric stations Yinluoxia, Qilian and Zamask control the three mountainous watersheds of the north flank of the Qilian mountains, which represente the runoff generation area of the mountains. The Zhenyixia hydrometric station is located at north side of the Hexi Corridor, at the north Beishan mountains, which is much lower than the Qilian mountains. The catchment area controlled by the Zhenyixia station consists of the mountainous part in the Qilian mountains and the low land part of the Hexi Corridor. Therefore, runoff at the Zhenyixia station representes the surplus of the mountain runoff after utinization of water resources in the Hexi corridor, and is much smaller than the runoff at the other three hydrometric stations. Fig. 2 indicates that runoff is generated from the mountainous watershed and consumed at the low land Hexi corridor area. Runoff from the mountains is mostly concentrated during the months from May to Septembe, and the largest runoff occurs during the summer months from June to August. The three mountainous watersheds can be divided into the high mountain ice, snow and permafrost zone and mountain vegetation zone by the altitude line 3600m(Gao et al., 1991). The high mountain zone accounts for 55%, 40% and 83% in the hydrometric basins of Yinlouxia, Qilian and Zamask respectively. The hydrographs of the three mountainous watersheds show the similar characteristics. The monthly runoff distribution is the same, and the runoff generation is also close to each other. At the high mountain zone, the runoff coefficient is large because of the more precipitation, less evaporation, and the existance of glaciers and permafrost(Yang, 1991). At the mountain vegetation zone, the water restrainting forests have strong ability to conserve water, and therefore to promote the runoff generation (Che et al., 1996). Therefore, both the high mountain zone and the mountain vegitation zone are important to contribute the runoff generation.

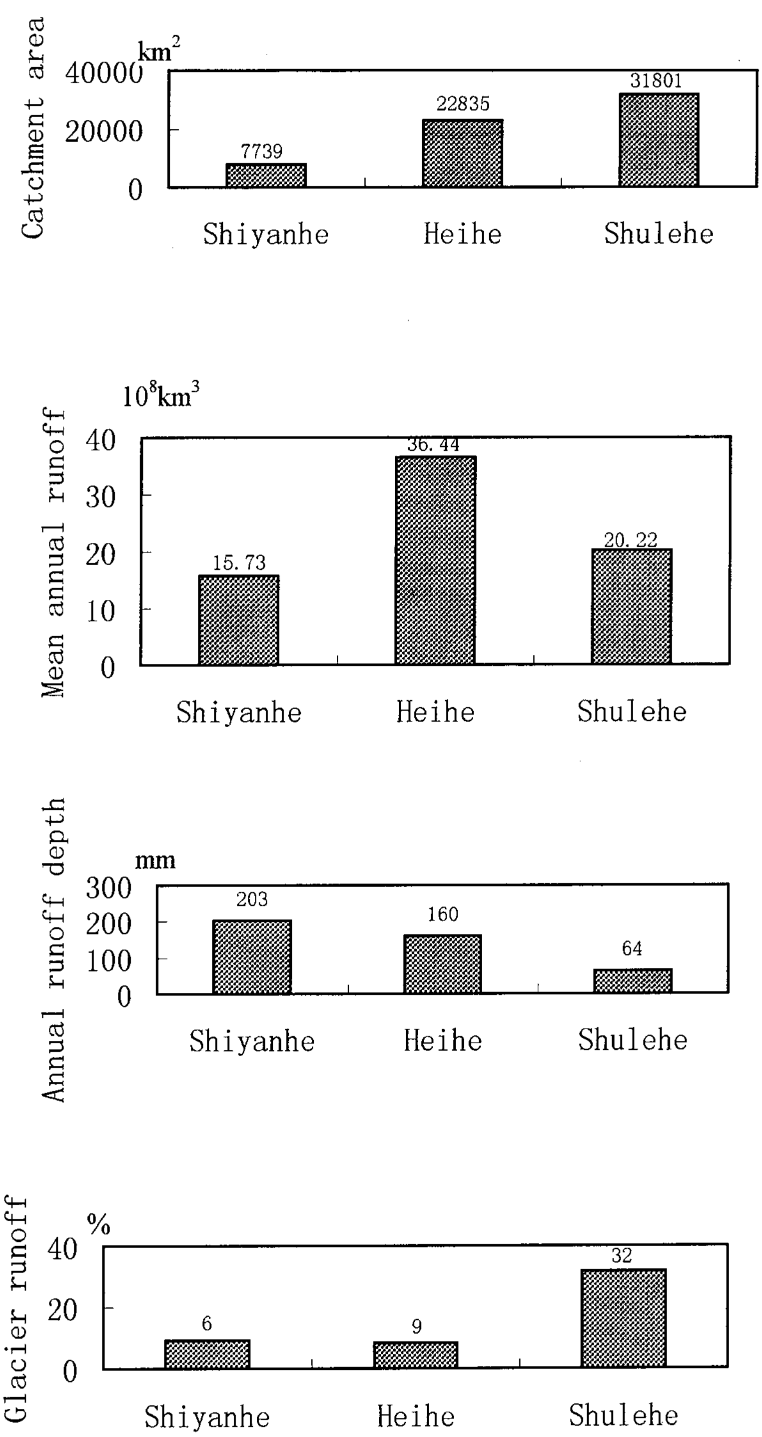

Fig.3 Runoff generation characteristics of the mountainous watersheds in the inland river basins of Shiyanhe, Heihe and Shulehe in the Hexi area

Fig. 3 shows some regioal characteristics of runoff generation in the mountainous watersheds of the Hexi area. From east to west, the catchment area of the three mountainous basin increase, and the Shulehe is the largest. The runoff depth decreases from east to west, and the Shiyanhe is the largest. The contribution of glacier melt water to runoff increases from east to west, and the Shulehe has the largest glacier runoff proportion which plays an important role in the runoff geration and regulation. The runoff volume is determined by the catchment area and runoff depth, and the Heihe in the middle has the largest. These characteristics are controlled by distribution of air temperature and precipitation in the Hexi area, in addition to the influence of topograph.

3. Relationship between runoff and climatological elements

Fig. 4 shows the trends of runoff at the hydrometric stations Zhenyixia, Yinluoxia, Qilian and Zamask, and of precipitation and air temperature at the meteorological station Zhangye(in the Hexi Corridor) and Qilian(near the Qilian hydrometric station) in the Heihe River basin. With reference to the response of regional hydrology to global warming, the Heihe River basin controlled by the Zhenyixia station is taken as an example in the present study. During the time series shown in Fig. 4, both the mountainous watersheds and the low land area in front of the mountains show an increase of air temperature and precipitation. From 1957 to 1993, the annual air temperature and precipitation increased by 0.36°C and 27mm at the Zhangye meteorological station in the low land area, and by 0.41°C and 19mm at the Qilian meteorological station in the mountains respectively. When the annual runoff increases at the mountainous watersheds, it decreases at the Zhengyixia station. From 1954 to 1994, the runoff at the Yinlouxia station increased by $0.48\times10^8m^3$, that at the Zhengyixia station decreased by $2.75\times10^8m^3$. Therefore, the utilization of water resources in the low land area by human activities reduces the runoff a lot.

Table 1 and 2 show the relationship between runoff and climotological elements at the hydrological and meteorological stations of the mountainous watersheds in the heihe River basin by their correlation coefficients both yearly and monthly from April to October. The yearly runoff from the mountainous watersheds are well coorelated to the mountain precipitation, this indicates that the runoff is formed in the mountains and precipitation is the main contribution to the runoff generation. The monthly runoff of April, May, September and October is well possitively correlated to air temperature, but sometimes negatively correlated to precipitation. Therefore, during those months of spring and autumn, snow melt runoff contribute most of the river runoff. During the summer months from June to August, all the monthly runoff are well possitively correlated to precipitation, which dominently contributes the runoff generation during these months. When temperature is possitively correlated to runoff, ice and snow meltwater contributes the runoff generation. The negative correlation of air temperature to runoff can be explained by that, sometimes air temperature is negatively correlated to precipitation in the mountains, and air temperature is also an indicator of evaporation loss.

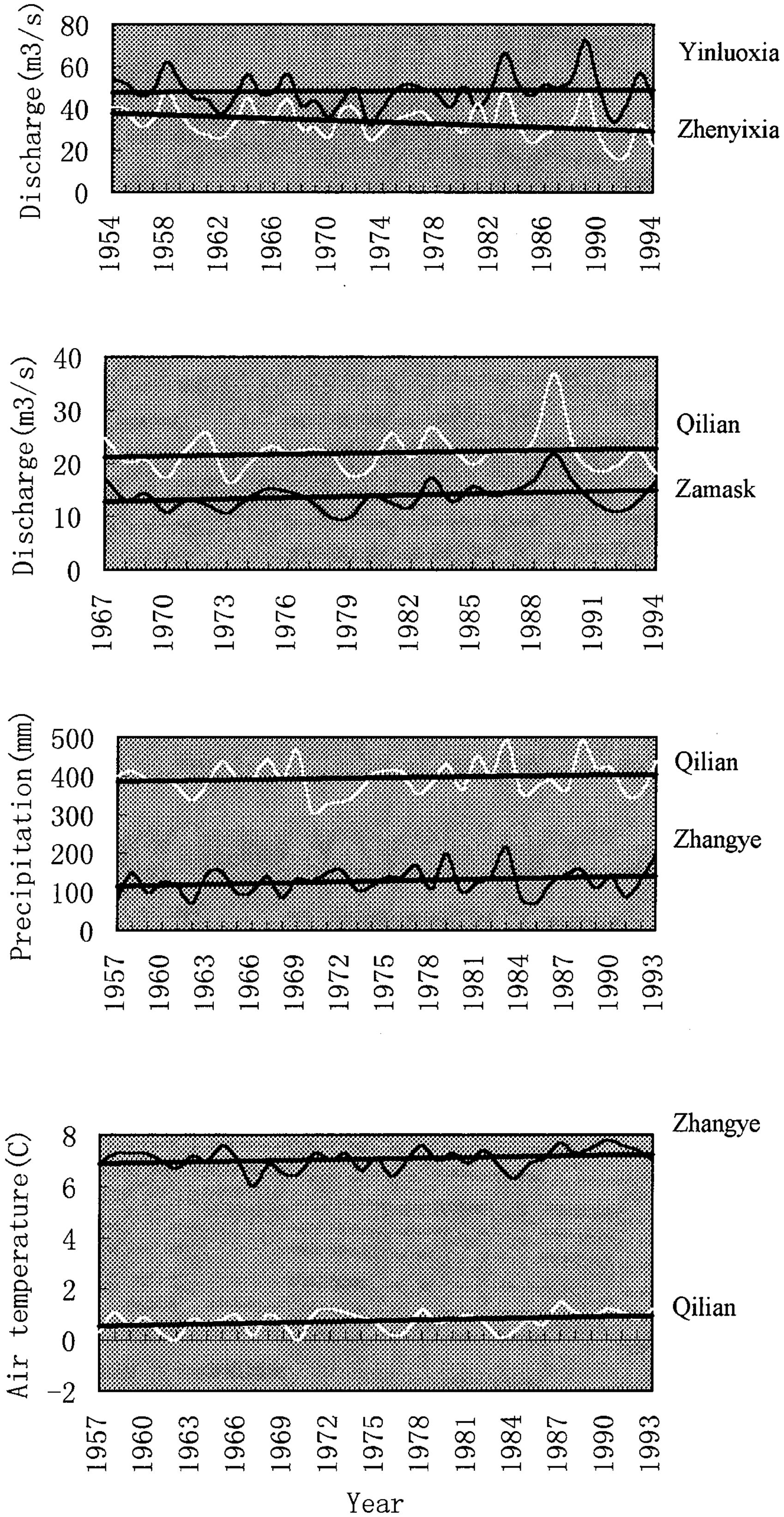

Fig. 4 Changes of runoff, air temperature and precipitation of the Heihe River basin

Table 1 The relationship between runoff, air temperature and precipitation*
(Time series are from 1957 to 1993)

Discharge (m^3/s)	Correlation coefficient							
	TZ(°C)	PZ(mm)	TQ(°C)	PQ(mm)	TY(°C)	PY(mm)	TT(°C)	PT(mm)
QY	0.0063	0.3767	-0.0717	0.5232	-0.1114	0.6295	-0.0756	0.4778
QQ	-0.0207	0.0288	-0.0948	0.4778	-0.2490	0.5458	-0.0635	0.2479
QZ	0.0756	0.2186	0.0615	0.4265	-0.0113	0.6917	0.0004	0.5173
QY4	0.2179	-0.0090	0.2744	0.1006	0.2536	0.1083	0.2293	-0.0385
QY5	0.3743	0.4903	0.2061	0.5390	0.3262	0.6205	0.1837	0.3780
QY6	-0.2507	0.5863	-0.1845	0.5856	0.1082	0.6913	-0.0927	0.5665
QY7	-0.2413	0.3063	-0.2968	0.5032	-0.0706	0.4742	-0.1100	0.2452
QY8	-0.4429	0.5882	-0.1849	0.6443	0.0579	0.6121	-0.0649	0.1360
QY9	0.0739	0.4095	0.0281	0.5460	0.2328	0.6852	0.1827	0.5817
QY10	0.4128	-0.1888	0.4471	0.2724	0.5059	0.2743	0.4859	0.2005

* QY4 to QY10 are monthly discharge in April to October, other symbles are annual values.

Table 2 Explalation of symbles in Table 1

Station	Altitude (m)	Latitude	Longitude	Discharge	Air temperature	Precipitation
Yinlouxia hydrological	1674	38°48'N	100°11'E	QY		
Qilian hydrological	2590	38°12'N	100°14'E	QQ		
Zamask hydrological	2635	38°14'N	99°59'E	QZ		
Zhangye meteorological	1484	38°56'N	100°26'E		TZ	PZ
Qilian meteorological	2787	38°11'N	100°15'E		TQ	PQ
Yeniugou meteorological	3180	38°25'N	99°35'E		TY	PY
Tuone meteorological	3361	38°49'N	98°25'E		TT	PT

4. Sustainable utilization of water resources

China is short of water resources, while in the Hexi area, it is averaged only 1590m^3 per person, accounting for 59% of the national level. In terms of the per mu(0.0667 hectares) water resources accounting in the hexi area, it is only 33% of the natioanl level. Therefore, Hexi area is dry and considerably short of water resources. On the other hand, the distribution of water resources is quite uneven for the three inland river basins (Fig. 4). Most of the population of the hexi area is concentrated in the Shiyanhe basin and Heihe basin, where the shortage of water resources is especially serious and the problems facing the exploitation and utilization of water resources are critical.

The utilization ratio of water resources is quite different for the three river basins, 86% for Shiyanhe, 47% for Shulehe and 37% for Heihe. As a whole, the utilization ratio of water resources is low in the area. Because of the lagging behind irrigation technique, generally flood irrigation, the utilization ratio of irrigation water is also low. As a result, the economic benefit of water resources is low. The grain production per cubic metre of water is 0.44kg for Shiyanhe basin, 0.25kg for Heihe basin and 0.17kg for Shulehe basin (Chen et al., 1992).

Although water resources are dynamic and regenerated, their amount is limited, therefore there have to be a limitation for the exploitation and utilization of water resources. At present, the channel water is too much at the upper and middle reaches of the inland rivers, and the ground water is over-extracted. The inland rivers originate from the Qilian mountains, and finaly run into the lnland lakes at their termini. Historically, the lakes had relatively large area and water volume. Because of the increase of the channel water at the upper and middle reaches, the runoff into the lakes is reduced and the water balance of the lakes is largely changed, causing the east and west Juyian lakes at the down reaches of Heihe and the Hala lake at the down reaches of Shulehe to be dried-up and withered, and the lakes at the down reaches of Shiyanhe to have completely disappered. In addition, the runoff at the down reaches of the three inland rivers is all reducing year by year, increasing the contradiction of water resources utilization between upper-middle and down reaches. For example, the runoff at the down reaches of Shiyanhe had reduced the total runoff volume by $3.7\times10^8 m^3$ from 1950's to the beginning of 1980's, and that of Shulehe had reduced by 24% of the runoff from the beginnig of 1960's to the beginnijng of 1980's. The runoff stopping days increase from 50 days of 1950's to 80 days of 1970's. As a result, the ground water levels are descending. From the end of 1950's and the beginning of 1960's to 1980's, the ground water levels in the plain area of the Hexi area dropped generally by 3 to 5m. Especially serious is the drop of ground water levels in the Shiyanhe basin. At the south of the Wuwei basin of Shiyanhe, the ground water levels dropped generally by 10 to 20m from 1959 to 1977. The mineralization degree is then increasing and the water quality is deteriorated.

In the inland river basins of the Hexi area, the human economic activities are concentrated in the oases zone in front of the mountains, where the ecology and environment are very fragile. As soon as the exploitation and utilization of water resources cause the reduction of the water maitaining the ecological balance, the dezertification and salinisation of oases will occur. For example, in the Minqin oasis region of Shiyanhe basin, there was a large area of meadow-marsh soil and meadow soil during the 1950's, which have become desert soil because of the drop of ground water levels and soil drying. The more and more gathering of salt in soil makes the soil solted, causing the reduction of vegetation, then the bare soil becomes desert. For example, the caltivated land of 10×10^4 mu and more at the north Minqin oasis was abadoned, and the landscape of wind corrosion and sand cover is occuring. In the Heihe basin, the over-channeled water at the upper and middle reaches has caused a reduction of the natural sacsaou forests from 1700×10^4 mu to 300×10^4 mu in the oasis range $3\times10^4 km^2$ at the down reaches in the Alashan region of Inner Mongolia, where 60% of the wells are short of water, and the reduction rate of the bank diversiform-leaved polar forests is 2600 hectares per year, causing the especially large sand storm during 1993 to 1995.

In the exploitation and utilization of water resources, in addition to the further construction of the water conservancy facilities and carrying out the water transferring engineering over the drainage basins, the emphasis shoule be put on how to manage and efficiently use the limited water resources, to make the most of the social, ecolomical and ecological benefit of water resources. Therefore, an intensive study should be carried out on the regional response of water resources to global warming and human activities, to work out the scientific decision making for the maintenance of good cycle of ecology and environment, to achieve the sustainable utilization of water resources and the sustainable development of regional economy.

5. Conclusion

The Hexi area of northwest China is dry in climate and short of water resources. The water resources in the area are generated in the montainous watersheds, while they are consumed and runoff is scattering and disappearing in the low land area in front of the mountains. With reference to the response of regional hydrology to global warming, both the mountainous watersheds and the low land area in front of the mountains show an increase of air temperature and precipitation. When the annual runoff increases at the mountainous watersheds, it decreases at the low land area. Therefore, the utilization of water resources in the low land area by human activities seems to influence the changes of runoff a lot. Although water resources are dynamic and regenerated, their amount is limited, therefore there have to be a limitation for the exploitation and utilization of water resources. The upper, middle and down reaches of an inland river basin are related to each other and restricted by each other, forming an inland river system as a whole. It includes a system of water resources and a system of ecology and environment. Therefore, in the exploitation and utilization of water resources, both the protection of water resources and the protection of ecology and environment should be seriously taken into account.

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Sustainable developement countermeasure of water resources in Gansu Province

Feng Qi Cheng Guodong
Lanzhou Institute of Glaciology and Cryopedology, Chinese
Academy of Sciences, Lanzhou *730000*)

Abstract There are some problems which exist in water resource in Gansu province, suchas shortage of wvater resources, uneven distribution of water resources, deterioration of water environment, serious waste of water resources . And the contractary is more apparent in recent years in development and utilization of water resources with the economic increasing, which serious affects the economic sustainable development of Gansu Province. Thus the article gives out the countermeasures for water resources exploitation in the future as follows: strengthening management, enhancing science and technological level in the utilization of water resources, rational allocation, optimization of water resources environment, increasing invest ment in water conservancy projects for sustainable use of water resources.

Key word Gansu Province water resources sustainable use of water resources

Water resources in Gansu Province is not only valuable natural resources, but also important environment factor due to little precipitation and dry climate. On one hand enormous volume of water has been developed with the development of Cansu's economic construction, on the other hand much water channelled was wasted due to unreasonable exploitation and utilization. In response to the imporant problems of environment and development of 21th century, we generalize the research result of water resources, analyse today's problems of water resource development and finally put forward some countermeasures to solve the water crisis.

1 Current situation water resources

1.1 Transformable water resources

Water resources exist in the forms of glaciers, precipitation, rivers, lakes (reservoirs), ground water and soil water, Annual transformable water resources can be divided into precipitation, runoff, shallow ground water recharged by other water resources.

Precipitation. Precipitation is the basic origin of other water resources , which not only decides the water condition of Gansu Province, but also affects the recharge water amount of rivers, ground water and snowfall on apline glaciers. Gansu is located more than 1000km away from the oceans ,thus resulting in a higher precipitation in mountainous areas and a lower precipitation in plain areas. Hexi Corridor of Gansu have a precipitation ranging from 100~250 mm, while Ejin Banner have a precipitation less than 50 mm.

The total precipitation in Gansu Province is $36\times10^9 m^3$, corresponding to a thickness of 132 mm . However about half of precipitation falls on mountains and only a little falls on plains. The actual precipitation reaching to surface is only 32% of total precipitation in accordance with the data calculated by Gansu Meterological Bureau.

Runoff. Runoff in Gansu Province comes from precipitation and thawed glaciers, but runoff can't be directly used unless they flow into channels or form spring water and transform into surface runoff.

Total amount of runoff is about $71.02\times10^8 m^3$, corresponding to a thichness of 25.8mm. And the total runoff of the three biggest inland river Heihe River, Shiyang River and Shule River is $66.3\times10^8 m^3$, accounting for 94.5% of the total runoff. So it can besaid that inland rivers runoff is the main water resources.

Shallow ground water resources supplied by natural water source. Ground water recharged by natural water is a very important part of the region's water resources. According to the measurement of the seepage ratio of channel system in farmlands and analysing the amount of seepage water of channel system and farmlands in piedmont plains as well as calculating the precipitation and considering flood and storm into piedmont plains, the total ground runoff is $10.11\times10^8 m^3$, comprehensive ground water supplied amount is $49.80\times10^8 m^3$, and the natural supplied amount is $16.82\times10^8 m^3$.

Total water resources. Surface water resources consist of Alpline precipitation and thawed glaciers, it is calculated in accordance with the runoff flowing out of mountains. Naturnal ground water resources comes from precipitation infiltrated into piedmont plans from lateral direction and surface water seepages. Therefore total water resources is about $75.36\times10^8 m^3$, this is the transformable water sources in Gansu Province, and a part of Huanghe river water flow from Hekouzhen into middle section of the river, others water resources have been developed.

1.2 Future water resources

Future water resources include Alpine glaciers, deep ground water, desert ground water, they are difficult to develop due to its geographical situation and long peroid of transformation.

Alpline glaciers. Alpline glaciers and firm is a particular form of water resources and thawed glaciers has important singnificance to 5~9 month's river water which affects the distribution of annual runoff and the concentralization degree of the river water. Generally, alpline glaciers stores much precipitation in cold-wet years, then gives out the water in arid-warm years to distribute interyears water resources. Therefore alpline glaciers not only provide much water resources to Gansu, but also forms a stable and efficient condition for water resources development in plains. The total runoff of glaciers is $23.4\times10^8m^3$, and the total area is $875.81km^2$ which can supplies $6.44\times10^8m^3$ of thawed water to rivers, accounting for 11.95% of total runoff.

Aquifers and artesian in piedment plains. Sediments of piedment plains in Gansu is much thick. The ground hydrological types includes aquifers and artesian in piedmont plains and Hexi corridor formed about 1-6 artesian with a water head of 1-5 m. between 50-300 m depth, the salt content of groundwater is 1-3g/L and the discharge is 2-3L/s.

Ground water lake and lowland water . Some basin in Gansu is almost covered by desert, with a precipitation ranging from 50~100 mm which can infiliterate and form fresh water lens in thin dried sand layer. It is estimated that ground water recharged by precipitation is about $1.2\times10^8m^3$ and a large amount of water are stored in 100~200 m deep aquifers under sand dunes.

2 Problems

2.1 Shortage of water resources

Water resources in Gansu Province is $75.36\times10^8m^3$. Annual mean water resources, pre mu of arable land and per person in Gansu is 24.6%, 34.3%, 61.5% of that of the country's average level, and is 21%, 24%, 15% of that of the world's average level. The per person occupying water resource in Shiyang River is 32.8% of that of the country's and 6.9% of the world's; the per mu share water resource is 39.4% of that of the country' and 18.8% of the world's.

The future trends of water resource changes. Precipitation in most Gansu Province is below 400mm, while evaporation is over 1000mm. Because of global climate changes and human being influences ,the climate of Gansu Province is trending to become dries . From 20 century on,air temperature has risen and evaporation has increased with the warming climate ,60's— 80's air-temperature of Gansu increased 0.28℃ whichbrings about obvious changes of water resouces. With the future warming climate ,the air-temperature of arid northweast will increase about 1℃ by 2030 and prcipitation will become uncertain. In future water exploitation will greatly increse due to production development ,the contration of glaciers, and lakes as well as the disappearance of solid water in alpline regions leads to the unstablity of river water.

Prodiction of water demand and supply. The total water shortage in Gansu will be about $6.13 \times 10^8 m^3$ by the year of 2000 in terms of predication, which will greatly influences to agricultural production of the region.

Table 1

2.2 **uneven distribution of water resources**

Regional distribution. Both shortage and uneven distribution of water resources increases the conflicts of water resources, supply and demand.

Water resources in north and west of Gansu Province is more than that in south and east. Shiyanghe river basin owns least water resources in three rivers basins of Hexi corridor .

Seasonal distribution. Arid in spring, flooding in summer, water shortage in autumn and waterless in winter are the characteristics in Gansu . Because of Pacific ocean and Indian ocean monsoon influence ,Pecipitation in Gansu is mainly constrated in summer. Natural channeled water of Hexi corridor is 19～31% ofits total from April to June which is about 35～45% of annual water demand and inflow discharge is insuffient to meet the demand of irrigation farmland ,and thus result in large areas corp outputof reduction. According to statisticed data drought affected farmland occupies about 30% of its total farmland area due to delayed irrigation and nonirrigation. Water shortage seriously influences and limits ecological enviornmental improvement and the sustainable development of society and economy.

2.3 Unreasonable explositation and utilization of water resource

Serious waste of water resources. Water resources in Gansu is both short and misused. Most of rivers adopt traditional multichannel irrigation method, therefore much water is wasted, and much of water resources in plain reserviors near middle section of river and the region with high ground water level are lost by evaporation. ① Rural area. Large irrigation norm and heavy irrigation are common which leads to great loss of water resources. Present water-saving technique is of tranditional method and its area is limited. Water utilization factor is very low and utilization coefficient of canal system is 0.3~0.45 or so. In Siyang River basin, the channeled water factor is 73% and utilization factor is 41%, so half of water is wasted; the channeled water factor of Heihe River is 65% and net utilization factor is 31%, about 2/3 water is wasted. If the water utilization factor can be increased, it will save much more water resources for the lower section of rivers. ② Cities. Per capita water consumpation of Jingchang city and Lanzhoui city is respectively 200kg/d, 185kg/d and the standard of water utilization is low. So the water utilization factor should be increased at once. ③ Industries. Water waste in industries is widespread. The water consumpation of comprehensive ten-thounsand yuan RMB output value is very high in Gansu, for instences, Lanzhou and Jingchang city respectively accounts for $370m^3$ and $470m^3$, which is higher than that of Qingdao of $67m^3$.

Deterioration of water environment. Deterioration of water environment manifested in the land desertification, soil salinization and water pollution ① Land desertification area and potential desertified lands in Gansu is about 2.7% and 1.3% of China's total desertified land area, which is invading in natural oases. The Land desertification area expanded about $51km^2$ and the ground water table decrease to , reach 5 m in Yueyang irrigntion region due to misuse of water resources and the low utilization ratio from 1969—1979. The land desertification area of Mingqi oasis expanded about 2.13×10^4ha., the speed of sand dune movement is 8—10m a year.

②Soil salinization. Soil salinization of Gansu covers an area of $1.16\times10^6km^2$, accounts for 34.35% of Hexi corridor total salinized area. About 50% farmland was salinized in different degree, and 70% famland appeares soil salinization or heavy soil alkalization. So the production output decreases about 30% of total production output when the salt content increase only two times.

③ Water pollution。Due to irrigation backwater and industrial water polluted effluent ,surface and ground water are serious contaminated. The salt content of ground water reached 17g/l, about 76 thousand people and 124 thousand cattles have no fresh water to drink and 37×10^4 km^2 of farmland is abandoned ,for about $450\times10^7m^3$ of ground water was exploited in Mingqin oasis. Endemic sickness ,keshan diseasse and knschi-beck disease in Qinyang of Gansu due to drinking high humic acid water and low selenium water .

3 Countermeasures

In order to rational exploitation and utilization of water resources it need to enhance management level, increase investment in water projects for sustainable use of water resources.

3.1 Enhancing management level

Water management in Gansu Province is much backward and still practices the mean water use method which was used in Qing Dynastry. In views of regions, Gansu river source comes prom Qinghai and some down river relates with Inner Mongolia ; in views of departments, water conservancy,forestry,industry, environmetnal protection,urban institutions respectively exercise management of agricultural water,forestry water,grassland water,industrial and mining water,urban water,and there is no a scientific management system of water resources. Hence there is an urgent need to change the managemental system and set up new managemental organization to unify water management, coordinate water use ,keep eyes on users to strictly abide by water law, unify exploitation and allocate water sources whthin a river basin as soon as possible. Only by doing so ,the problems of water resources development can be solved and ensure the rational and efficient use of water resources.

3.2 Strengnthening science and technology in water development.

It is a complicated system of rational and efficient developement of water resources, therefore utilization and expoitation of water resources must rely on sciences and technology,in combination with water management,typical demonstration,personnel training,and popularization of advanced and practial techniques.

Strengathen science and technology in water development includes rational allocation, effecient utilization and optimizing water environment.

(1) Rational allocation

① The principle" determination the development scale of farm and, population and water resources according to the actual amount of water resources" should be abided by in utilization and exploitation of water resources, after knowing the amount of water resources .

② Viewed the surface and ground water as a whole ecological system, scientific management must be done to handle the relations of upper, middle and lower reaches of river; the relations of agriculture, forestry, husbandry animal, ecology, industry, mining and city; and the relations of surface and ground water in order to obtain a best social, ecological and economic benefits.

③ Correctly handle with the relation between water saving and allocation of water resources. According to actual situation of Gansu saving water is main task and rational allocation of water relies on saving water. In the views of developmint in the future ,it is necessary to realize the interbasin water-transferring project based on feasibility study.

④ Study on multi-purpose panning and management of water resources within a basin

(2)Efficient utilization of water resources

Gansu province must constructs efficient and economical water environments including those in agriculture ,forestry, animal husbandry, industry and mining, and ecology. The effcient and economical development of water resources should be carried out through propaganda, technical renvation and personnel training.

(3) Optimizating water resources enviornment

Ecological enviornment in Gansu is fragile and the development of water resources, has a decisive influence on it, therefore the principle of optimizating environment must be carried out in development of water resources in order to coordinate ecological and economic benefits.

3.3 **Increasing investment**

Investment is the key to development of water resources.

The potentiality of land resources in Gansu Province is so great that it will become future main production region of chinese agriculture, and water conservancy is blood of agriculture, so the state should preferentially invest in the water conservancy construction .

Saving water and diverting water to some extend is the basic way for water resources development in Gansu Province.

3.4 **Sustainable utilization.**

The aim of rational utilization and exploitation of water resources in Gansu Province is to ensure the sustainable use of water resources . So the following three principles must be abided by namely, protecting drinkable ground water and land productivity, protecting biodiversity and avoiding excessively developing of fresh water resources.

The problems of water resource in Gansu Province is an obstacle for the development of land and mineral resources. In order to do well in the development, shorten the gap between east and west China , raise people's living standard, it is very important to make an in-depth study on the sustainabe development and optimum organization of water resources.

table 1 The shortage of water resources in future ($1\times10^8m^3$)

	industry	agriculture	ferestry and grassland	Population and animal	city	others
total demand 81.49	2.10	72.30	6.00	0.94	0.10	0.05
Total supply 75.36	surface runoff			ground water		
	51.36			24.00		
shortage	6.13					

4. GIS and Modeling

Simulation and Model of Interflow on Hillslope of Forest Catchment

Tiefan Pei, Jingzhong Li and Zhanqing Hao

Institute of Applied Ecology, Chinese Academy of Sciences,

No. 72 Wenhua Road , Shenyang , P.R. China

ABSTRACT

Interflow processes on hillslope of broad-leaved Korean pine forest in catchment of Erdaobai river, which is the source of Songhua river, was simulated in Forest Hydrological Modeling Laboratory of Changbai Mountain Forest Ecosystem Research Station, Chinese Academy of Sciences. Saturated conductivity and effective porosity of soil on hillslope of broad-leaved Korean pine forest were measured, and submodels of saturated conductivity and effective porosity were established with depth from surface separately. substituting those submodels into Sloan's storage-discharge model and according to the adjusted model, the processes of interflow were simulated. After comparing the simulation results predicted by our model,exponential model(Robinson,1996), Sloan's model separately with observed results, the predicting precision of the adjusted storage-discharge model to interflow processes on hillslope of forest catchment was presented.

INTRODUCTION

Interflow is slow and steady, its current velosity is about 0.2m/h. Interflow plays a very important role in changing rainstorm-runoff processes on forest catchment, flatting-top and prolonging the runoff time, reducing the flood disaster, increasing the use efficiency of water resources. Interflow on hillslope of forest catchment is an important link of water cycling in ecosystem in which watershed is as a unit. Studying its transformation mechanism and hydrological processes, setting up and perfecting the model will not only enrich the theory of experimental forest hydrology, but also provide the basis for hydrological analysis and calculation of forest catchment, design, management and building of water conservation forest.

Interflow model developed in the whole world until now can be divided into 3 types roughly: finite element model or finite differential model based on the Richards equation, kinematic wave model and storage -discharge model based on the kinematic wave and kinematic assumptions separately. Precision of finite element or finite differential model is little bit high, but calculation is very complicated. So it is not suitable for forecasting rapidly and is difficult to expand to the whole catchment. Kinematic wave model is only fit for $\lambda<0.75$ ($\lambda=4i\cos\alpha/k_s\sin^2\alpha$), so its application is limited. Sloan put forward (Sloan and Moore,1984) storage-discharge model in 1983 . Sloan and Moore (1984) applied finite element model, kinematic wave model and storage -discharge model in forest catchment, and compared the forecasting results. It shows that storage-discharge model has higher precision, low cast, and was possible to link to be a better catchment model. Beven et al (1982b) believe that saturated conductivity k_s and effective porosity θ_s-θ_r are two important physical parameters when interflow was simulated , and both of them decrease with the depth. However,Sloan treated k_s and θ_s-θ_r as constants when he simulated interflow on hillslope of forest catchment with storage-discharge model. When Robinson and Sivapalan (1996) simulated interflow with storage-discharge model on hillslope of forest catchment, they supposed that saturated conductivity decreased exponentially with the depth. Based on this, it is possible to form a saturated zone in the soil under the rainfall intensity, then this zone will develop up and down, and finally formed a water discharge at the outlet section of hillslope. Unfortunately they did not consider this flow, therefore, they were not able to simulate the interflow processes of catchment realistically. This paper try to do some improvement.

METHOD

Using forest catchment of Erdaobai river, which is the source of Songhua river, as the background, the interflow on hillslope of broad-leaved Korean pine forest was simulated in Forest Hydrological Modeling Laboratory. Firstly, one of plot which has the same area as underlying model trough and is typical of this kind of forest, was selected, semi-decomposed and non-decomposed litters covered on the forest floor were collected for later use. All the soil were sampled according to different layers. First layer is loam soil, then albic soil and loess, total depth of soil samples is 1m. During the soil sampling, all the roots in soil were collected. After the samples, which include litter, root and different layer of soil, were taken into the laboratory, we began to simulate the forest soil characteristics in the underling model trough. Loess was put into the bottom of trough firstly, then compacted the soil until relative error of the bulk density between field soil and simulated soil is within 5%. The albic soil and loam soil were simulated in the same way. The depth of every layer is 33.3cm, and with total depth of 1m. Since most of the root distributed in up-layer of the soil, root were put into the soil at random, some of the thick roots were taken out. After all the soil layer simulation were finished, the litters were put on the surface according to the order in forest floor. Rainfall was controlled by the rainfall system. 3 different rainfall events were simulated .event 1: intensity is 0.52mm/min and precipitation is 156.0mm, event 2: intensity is 1.2mm/min and precipitation is 216.0mm, event 3: intensity is 1.9mm/min and precipitation is 342.0mm. During the rainfall, the processes of surface runoff and interflow were observed at the outlet section of the underlying model trough. Flow was measured by V-trough measuring meter in the measuring system which was controlled by computer control system.

At the hillslope of typical broad-leaved Korean pine forest, 1-2 of sampling point in upper, middle and lower slope position was arranged. In each sampling point, soil samples were taken in different soil depth at 0cm,20cm, 40cm, 60cm, 80cm and 100cm . And their saturated conductivity and effective porosity were measured. Effective porosity is : $\omega(z)=\theta_s-\theta_r$, θ_s is saturated volumetric moisture of soil sample, θ_r is residual volumetric moisture of soil sample. Taking average of saturated conductivity measured in the same depth, regressioning all of the conductivity measured in different depth with the corresponding soil depth, we establish the saturated conductivity submodel. Effective porosity submodel can be developed in the same way. Taking the soil samples from the underlying model trough in different depth, measuring their saturated conductivity and effective porosity, then substituting the measurement results into the two corresponding models, the parameters of soil in the trough were determined. Firstly, substituting the saturated conductivity submodel and effective porosity submodel, both of them use the parameters measured by experiment, into storage-discharge model, then interflow processes under different rainfall conditions were simulated . Secondly, saturated conductivity and effective porosity are taken as a constant, this means they are no change with the soil depth , simulating the interflow processes of different layer on computer under 3 diffferent rainfall condition described as above. Last, supposed that saturated conductivity decreased exponentially with the soil depth, interflow processes were simulated in the same way. Comparing the interflow processes observed by experiment with three simulated interflow processes on computer. We can estimate the precision of them separately.

ANALYSIS AND RESULTS

The idealed hillslope segment has an impermeable boundary or bed, of slope α , length L, and a soil profile of constant thickness D(as is show in Figure 1). Then, the balance of water, per unit width, can be written as:

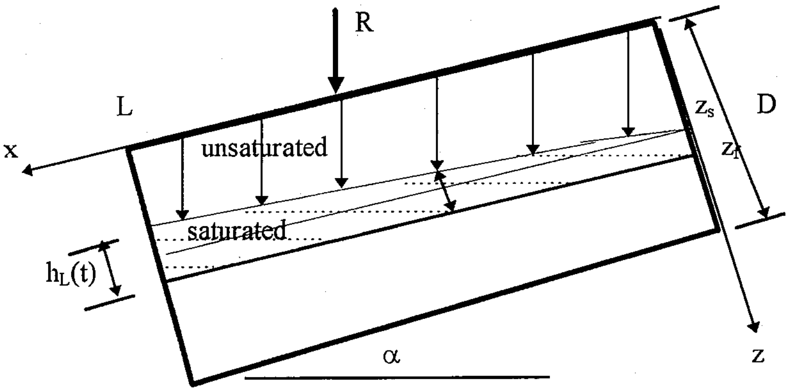

Figure 1　The idealed hillslope

$$\frac{dv}{dt}=i(t)-Q(t) \qquad (1)$$

where v is the drainable volume of water in the saturated zone, i(t) is the rate of water input from the unsaturated zone to the saturated zone, t is time, Q(t) is the discharge from the hillslope. The equation of unsaturated conductivity can be written as equation : (Brooks-Corey,1984)

$$K(\theta,z)= K_s(z)\left(\frac{\theta-\theta_r}{\omega(z)}\right)^N \qquad (2)$$

where $k(\theta,z)$, $k_s(z)$ are unsaturated conductivity and saturated conductivity at depth z separately, θ_s, θ_r,θ are the saturated volumetric water content, residual volumetric water content and volumetric water content separately. N is a pore size distribution index, $\omega(z)(=\theta_s-\theta_r)$ is effective porosity.

Beven(1982) had pointed out that both saturated conductivity and effective porosity tend to decrease with depth into the soil profile. and we had get the equation by experiment at fileld in forest catchment as:

$$\begin{cases} k_s(z)=k_o-f_1\ln(z) & (3a) \\ \omega(z)=\omega_0-f_2\ln(z) & (3b) \end{cases}$$

where k_0, $k_s(z)$ is the saturated conductivity at surface of soil profile and at depth z Separately; z is the depth from surface, ω_o is the effective porosity at surface of soil profile, f_1, f_2, are parameters, and the unit of z is cm.

We can suppose that the soil is isotropic, then both k_0 and ω_0 do not change on the direction paralleled with the surface of soil profile. The piston displacement model (Beven, 1982) assumed that a sharp piston-like wetting (or drying) front develops at the surface during a rainfall event and moves down vertically through the soil profile. It is further assumed that the maximum water content of the piston-like wetting front adjusts itself to the percolation rate R(R is rainfall rate), and the water content above the wetting front become steady. Then using Darcy's law and kinematic assumption in the unsaturated zone above the wetting front we can write :

$$\theta(R,z)=\theta r+\left(\frac{R}{Ko-f_1\ln z}\right)^{1/N}(\omega_0-f_2\ln z) \qquad (4)$$

where $\theta(R,z)$ is the volumetric water content at depth z and under rainfall rate R.

We assume that the water content in soil before rainfall has reached residual water content θ_r, then, using the continuity equation for the unsaturated zone above wetting front we can write the rate of wetting front development in unsaturated zone as :

$$\frac{dz_f}{dt}=\frac{R}{\theta(R,z_f)-\theta_r}\cos\alpha \tag{5}$$

Because the saturated conductivity decreases with depth, under rainfall rate R a saturated zone forms probably at depth z_s, and it will became thicker gradually. The delay time is the time which wetting front reaches the depth z_s from surface of soil, and it depends on the nature of soil and rainfall rate. When the wetting front just reaches the depth z_s, the saturated zone begins to form. So, at the depth z_s we can write :

$$K_s(z_s)=R \tag{6}$$

then, the depth Z_s can be given as :

$$z_s=\begin{cases}0 & R\geqslant K_0\\ e^{\frac{k_0-R}{f_1}} & k_0>R>k_0-f_1\ln D\\ D & R\leqslant K_0-f_1\ln D\end{cases} \tag{7}$$

by integrating equation (5) from 0 to z_s we can write the delay time as :

$$t_d=\frac{1}{R\cos\alpha}\int_0^{Z_s}\left[\theta(R,z)-\theta_r\right]dz \tag{8}$$

When the rainfall rate R is less than the surface saturated conductivity, the percolation rate of water is affected mainly by rainfall rate, but when the rainfall rate is greater than the surface saturated conductivity, the percolation rate of water is affected by both the rainfall rate and the surface saturated conductivity, so the rate of water input from unsaturated zone to saturated zone can be written as

$$i(t)=\begin{cases}L*I & t\le t_r+t_d\\ 0 & t>t_r+t_d\end{cases} \tag{9}$$

where t_r is rainfall time. and I is given as

$$I=\begin{cases}R\cos\alpha & R\le k_0\\ (2.5k_0+R)\cos\alpha/3.5 & R>k_0\end{cases} \tag{10}$$

After the saturated zone had formed, we assumed that the rate of wetting front development can be written as

$$\frac{dz_f}{dt}=\frac{I}{\theta_s(z_f)-\theta_r}\qquad z_f<D \tag{11}$$

and after the wetting front reaches the impermeable bed, we must have

$$\frac{dz_f}{dt}=0\quad z_f=D \tag{12}$$

by integrating equation (11) between $[z_s,D]$we can write out:

$$t_u=t_d+\frac{1}{I}[(\omega_0+f_2)D-f_2D\ln D-(\omega_0+f_2)z_S+f_2z_S\ln z_S] \tag{13}$$

then, after the saturated zone formed, the relationship between the depth of wetting front and time can be given as

$$\begin{cases} t = t_d + \dfrac{1}{I}\left[(\omega_0 + f_2)z_f - f_2 z_f \ln z_f - (\omega_0 + f_2)z_s + f_2 z_s \ln z_s\right] & t < t_u \\ z_f = D \qquad \dfrac{dz_f}{dt} = 0 & t \geq t_u \end{cases} \tag{14}$$

where z_f is the depth of wetting front.

Since the kinematic storage model assumes that the water table has a constant slope between the upslope and downslope boundaries of the sloping soil mass, and that the hydraulic gradient equals the slope of the impermeable bed (as is show in figure 1), we have

$$\begin{aligned} V &= \frac{1}{2}L\int_{z_f-h_L}^{z_f} \omega(z)dz \\ &= \frac{1}{2}L\omega_0 h_L - \frac{1}{2}Lf_2\left[z_f \ln z_f - (z_f - h_L)\ln(z_f - h_L) - h_L\right] \qquad z_f > h_l \end{aligned} \tag{15}$$

where h_L is the saturated thickness normal to the hillslope at the outlet

and

$$\begin{aligned} Q &= \int_{z_f-h_l}^{z_f} k_s \sin\alpha \, dz \\ &= k_0 h_L \sin\alpha - f_1 \sin\alpha\left[z_f \ln z_f - \left(z_f - h_L\right)\ln\left(z_f - h_L\right) - h_L\right] \qquad z_f > h_l \end{aligned} \tag{16}$$

when the saturated zone rises so that the water table intersects the soil surface ($z_f - h_L \leqslant 0$), (15) and (16) must be modified separately as :

$$\begin{aligned} V &= \frac{1}{2}(L + L_s)\int_0^{z_f} \omega(z)dz \\ &= \frac{1}{2}(L + L_s)\left[\omega_0 z_f - f_2 z_f \ln(z_f - 1)\right] \qquad z_f \leq h_l \end{aligned} \tag{17}$$

and

$$\begin{aligned} Q &= \sin\alpha\int_0^{z_f} k_s dz + IL_s \\ &= \sin\alpha\left[k_0 z_f - f_1 z_f(\ln z_f - 1)\right] + IL_s \qquad z_f \leq h_l \end{aligned} \tag{18}$$

where L_s is the saturated slope length

then, by substituting (9) ,(15) or (17), (16) or (18) into (1) we have:

1. $Q(t) = 0 \qquad t \leq t_d$ (19a)
2. when $t_d < t \leq t_r + t_d$

$$\begin{aligned} \frac{dh_L}{dt} &= \frac{f_2}{\omega_0 - f_2\ln(z_f - h_L)}\left[\ln z_f - \ln(z_f - h_L)\right]\frac{dz_f}{dt} - \frac{2(K_0 + f_1)\sin\alpha}{L\omega_0 - Lf_2\ln(z_f - h_L)}h_L \\ &+ \frac{2f_1\sin\alpha}{L\omega_0 - Lf_2\ln(z_f - h_L)}\left[z_f\ln z_f - (z_f - h_L)\ln(z_f - h_L)\right] \\ &+ \frac{2I}{\omega_0 - f_2\ln(z_f - h_L)} \qquad z_f > h_L \end{aligned} \tag{19b}$$

or

$$\frac{dL_s}{dt} = -\frac{2I + (\omega_0 - f_2\ln z_f)\dfrac{dz_f}{dt}}{\omega_0 z_f - f_2 z_f \ln z_f + f_2 z_f}L_s$$

$$
+\frac{2IL-2\sin\alpha\left[K_o z_f - f_1 z_f(\ln z_f - 1)\right] - L(\omega_0 - f_2\ln z_f)\dfrac{dz_f}{dt}}{\omega_0 z_f - f_2 z_f \ln z_f + f_2 z_f} \quad z_f \le h_L \qquad (19c)
$$

3. when $t>t_r+t_d$

$$
\frac{dh_L}{dt} = \frac{f_2}{\omega_0 - f_2\ln(z_f - h_L)}\left[\ln z_f - \ln(z_f - h_L)\right]\frac{dz_f}{dt} - \frac{2(K_0+f_1)\sin\alpha}{L\omega_0 - Lf_2\ln(z_f - h_L)}h_L
$$
$$
+\frac{2f_1\sin\alpha}{L\omega_0 - Lf_2\ln(z_f-h_L)}\left[z_f\ln z_f - (z_f - h_L)\ln(z_f - h_L)\right] \quad z_f > h_L \qquad (19d)
$$

or

$$
\frac{dL_s}{dt} = -\frac{2\,I + (\omega_0 - f_2\ln z_f)\dfrac{dz_f}{dt}}{\omega_0 z_f - f_2 z_f\ln z_f + f_2 z_f}L_s
$$
$$
-\frac{2\sin\alpha\left[K_o z_f - f_1 z_f(\ln z_f - 1)\right] + L(\omega_0 - f_2\ln z_f)\dfrac{dz_f}{dt}}{\omega_0 z_f - f_2 z_f\ln z_f + f_2 z_f} \quad z_f \le h_L \qquad (19e)
$$

By joining (19), (11), (14) we can obtain the values of h_L or L_s of any time, and by substituting h_L or L_S into (16) or (18) separately we can obtain the discharge from the hillslope Q(t)

Geometric and hydrogeological parameters of the underlying model trough used in these simulation are as: B(width of the underlying model trough) =280cm, D=100cm, L=500cm, α=3°, k_0=0.02cm/min, f_1=0.003cm/min, ω_0=0.16, f_2=0.2, and N=3.0 . We compared the solutions of our model, Sloan's model and J.S.Robinson's model with observed values for rainfall event 1, event2, event 3(as show in figure 2-4 and table 1-3). The results of comparison show that our model yields excellent results at simulating total value of interflow, peak time, peak flow and delay time.

DISCUSSION

In this paper we have presented a simple, approximate model of interflow for an idealized, representative hillslope for forest catchment. This model is based on the balance of water, Darcy's law and kinematic assumption. In its present form the analysis includes these condition that the saturated zone is formed at some depth between surface and bottom of soil profile, or at the surface of soil, or at the bottom of soil, which depends on the rainfall rate and the nature of soil, and the analysis includes the effect of the unsaturated zone during both wetting and drainage. It can be used to simulate the subsurface response for a general, simple rainfall event, and it can yield a good result at predicting the total volume of interflow, peak time, delay time and peak flow. But, for some big storms (such as event 1), it is not accurate at predicting the value of peak flow. In addition, its disadvantage is that it cannot predict the duration of interflow accurately, and the rising hydrograph and falling hydrograph predicted by this model is steeper than observed results. The reason is probably that the assumption of a piston-like drying front and wetting front is used in the analysis, but the assumption is clearly not a good one [Beven, 1982].

table 1 Comparison of event1

results	Dur.(min)	D.T(min)	T.V(m^3)	P.T.V	P.T(min)	P.F(l/min)	P.P
our model	606	0	0.92	70%	180	374.08	64%
Sloan's model	640	3	0.41	57%	180	157.89	78%
Robinson's model	620	12	0.94	68%	192	307.67	66%
observed value	1600	0	0.71	100%	180	240.92	100%

Table 2. Comparison of rainfall event2

results	Dur.(min)	D.T(min)	T.V(m^3)	P.T.V	P.T(min)	P.F(l/min)	P.P
our model	606	0	0.45	98%	180	150.83	94%
Sloan's model	640	3	0.26	60%	180	100.51	63%
Robinson's model	620	21	0.6	66%	201	189.84	83%
observed value	2100	0	0.44	100%	180	161.11	100%

Table 3. Comparison of rainfall event3

results	Dur.(min)	D.T(min)	T.V(m^3)	P.T.V	P.T(min)	P.F(l/min)	P.P
our model	1050	0	0.48	88%	300	107.6	96%
Sloan's model	1050	5	0.34	62%	300	77.01	70%
Robinson's model	1200	40	0.43	79%	340	84.87	76%
observed value	2300	0	0.54	100%	300	112.03	100%

Where Dur. is duration, D.T is delay time, T.V is total volume, P.T.V is precision of total volume ,P.T is peak time, P.F is peak flow, P.P is precision of peak flow.

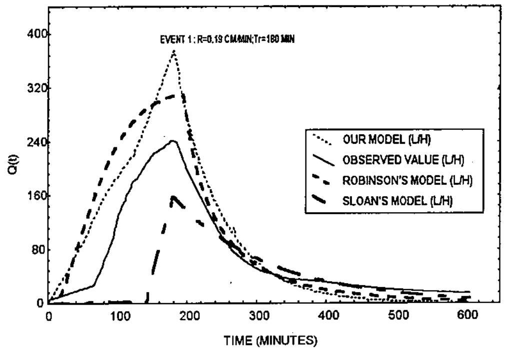

Figure 2 Hydrograph of interflow of rainfall event 1

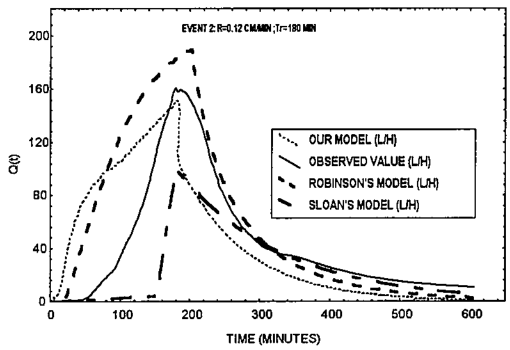

Figure 3 Hydrograph of interflow of rainfall event 2

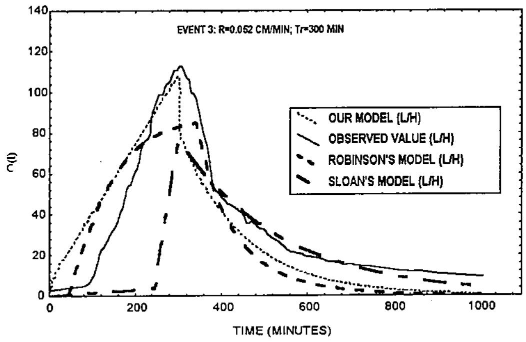

Figure 4 Hydrograph of interflow of rainfall event 3

CONCLUSION

According to the simulation of interflow on hillslope in forest catchment of Changbai Mountain we can conclude that:

1. The saturated conductivity decreases logarithmically with depth into the soil profile in forest catchment.

2. The effective porosity decreases logarithmically with depth into the soil profile in forest catchment.
3. The total volume of interflow increases with rainfall at the same rainfall rate, and decrease with rainfall rate at the same rainfall in forest catchment.
4. The delay time of interflow decreases with rainfall rate when the rainfall rate is less than the surface saturated conductivity of soil mass, and is 0 when the rainfall rate is greater than the surface saturated conductivity of soil mass.

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A GIS-aided Analysis of Winter Discharge in The Shirakami-sanchi

Yoshihiko Sano (*),Kiyotaka Sakaida(*),Hajime Makita(**) and Yukio Torikata
*Institute Geography,Graduate School of Science,Tohoku University
Aramaki-aza-aoba Aoba-ku Sendai 980-77 Japan
Fax:+81-22-217-6648 ,Email:sano@geo.dges.tohoku.ac.jp

** College of Liberal Arts,Hirosaki University

1. Introduction

Precipitation tends to increases in proportion to height, there exist heavy rain zone at the height of 1000 to 1500 meter in Japan (Yoshino, 1986). However it is difficult, especially during winter, to obtain the precipitation data (snowfall, snow depth, etc.) in mountainous regions, because there are a few of observatory in mountain and almost of them close down in winter. This study aims at estimating snow accumulation in mountainous areas using LANDSAT images covering the catchment areas and discharge data at dam site stations in the period of snow melting. The GIS-aided analysis is applied for the study of water budget in mountainous regions.

2. Study area, data and analysis technique

There are three small-scale catchment areas, Meya, Subari and Hayakuchi, in the Shirakami-sanchi, northeastern Japan (Fig.1). The primary data used in this study are two LANDSAT data sets, 28 April and 14 May in 1988. Each coordinates of LANDSAT data is transformed into UTM by GIS. The serious analysis of remotely-sensed data is the geometric correction of imagery. With corrected imagery, two data sets can be compared with a heigher degree of accuracy, using topographical map with a scale of 1 to 25000 in this study. Geometric correction using ERDAS involves a regression analysis of the relation between the master data and the uncorrected image. To develop this statistical model, we must establish corresponding points between the two sets of data. These points are referred to as ground control points (GCP), we used the dam site, the dam-lake and the river for GCP. Snow cover area is calculated from the classification results of pixel data (band 1, 2 and 3 composite). Difference in compare snow cover area between April and May shows the area of snow melt in the period.

The discharge measured at the dam site stations is obtained from the annual report of management of multipurpose dams. It is the amount of water supplied from the dam-catchment to the dam-lake. The discharge relates to temperature in early spring, and alternately precipitation since May (Fig.2). This results indicates that the discharge before April is due to snow melting in dam-catchment (Sakaida et al., 1995).

The volume of snow melting is estimated from the difference between the discharge and the areal precipitation, therefore the depth of snow melting can be calculated from the volume of snow melting and the area of snow cover.

Overlaying a LANDSAT data scene and the contour map which is converted to grid data using GIS, we investigate the relation between snow cover and topography.

ERDAS (raster GIS) and ARC/INFO (vector GIS) are applied as analyzing tools.

3. Conclusion and problems

The altitude of snow line is obtained using the LANDSAT data overlaid on the contour map in GIS (Table.1). Two LANDSAT data scenes in the period of lingering snow show the more snow accumulation on north or east side of slope than south or west side.

The melting-snow volume estimated from the two LANDSAT data is equivalent to the discharge of the duration at the dam sites (Table.2). The melting-snow depth in the period of sixteen days is estimated 55 to 100 centimeter, when the density of accumulated snow is about a half of water. The result demonstrates the possibility of estimating the volume of snow accumulation and snow melting in mountainous regions where direct record is hardly obtainable. However, the following problems are left for further investigation. Problem of mixel data : Pixels of LANDSAT data contains various surface conditions, for example, one pixel within a radius of 90 meters has information of snow, vegetation, etc. and they are mixed. It may induce an error of snow cover area calculation. Limitation in LANDSAT data resolution : Resolution relates to the problem of mixel. Increasing resolution will give more satisfactory result. Moreover, dense ground-truth in mountainous regions on climatology and hydrology are necessary to improve the accuracy of melting snow volume estimation.

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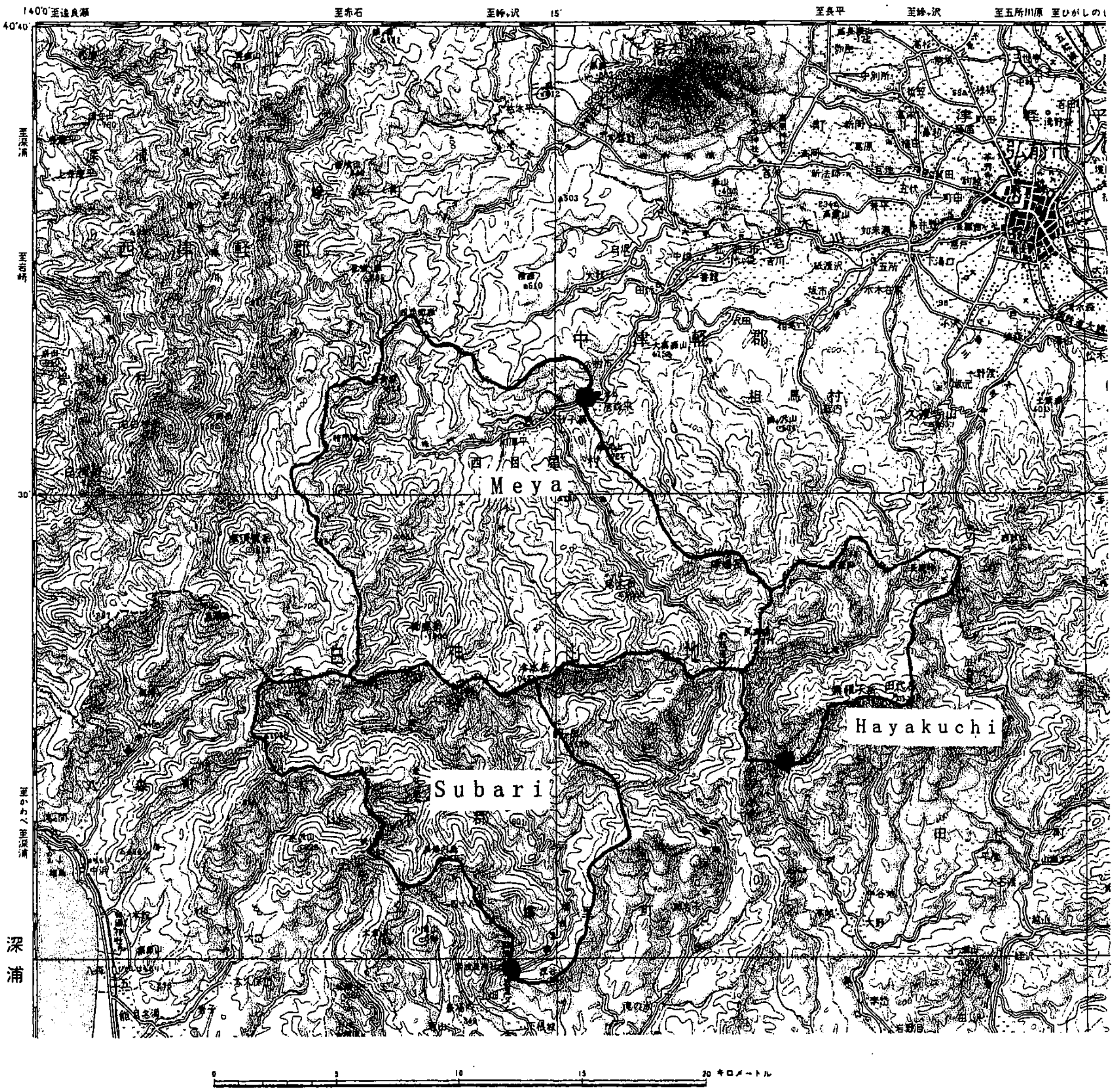
Table 1 Altitude of snow lines for each direction of slopes

	28 April	14 May
Mt.Aoshika (1000m)	E:600m W:600-800m	E:800m W:800m
Mt.Happou (885m)	E:500-600m W:600-700m	E:800m W:800m
Mt.Ohusu (881m)	N:400-500m S:600-700m	N:600m S:800m
Mt.Tashiro (1178m)	N:600m S:600-700m	N:800m S:1000m
Forest of Benten (1083m)	NE:400-600m SW:600-700m	NE:800-900m SW:900m
Forest of Shiritaka (977m)	NW:700m SE:600-700m	NW:---- SE:800-900m



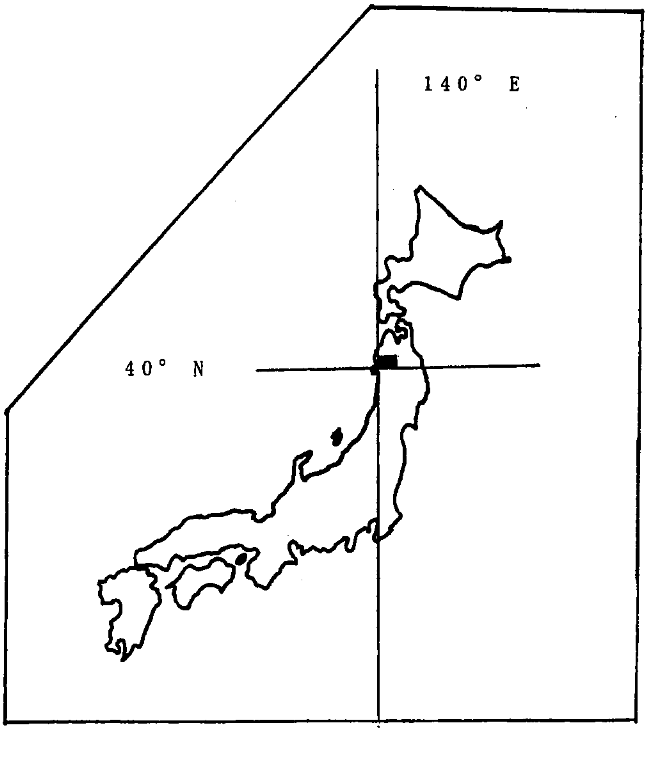


Fig.1 Study area

● dam site

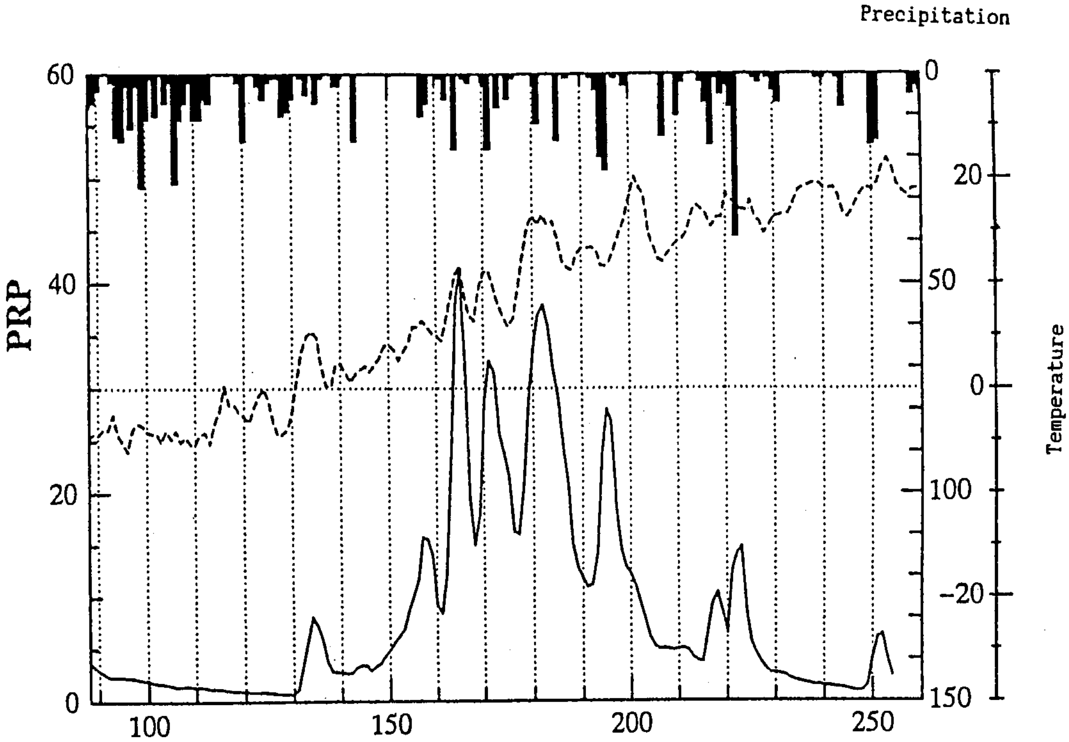


Fig.2 Seasonal changes of discharge, temperature, precipitation at subari dam site station in 1988

Table 2 Areal change snow cover and discharge for each dam-catchment

	Meya	Subari	Hyaguchi
Catchment area Sa(km2)	171.5	100	48.5
Area of snow cover 1 S1(km2)	105.2	51.9	31.6
Area of snow cover 2 S2(km2)	17.9	4.9	2.5
Area of melting of snow Sd=S1-S2	87.3	47	29.1
Amount of discharge D(km3)	0.0608	0.0341	0.0133
Precipitation P(mm)	77	97	95
D/Sa (mm)	355	341	274
Volume of snow melting (km3) M=D-PSa	0.0476	0.0244	0.0087
Depth of snow melting (mm) M/S1	452	470	275

snow cover 1 --- 28 April snow cover 2 --- 14 May

GIS for Sustaining Water Resource in Heihe Catchment

Li Xin, Cheng Guodong and Ding Yongjian
Lanzhou Institute of Glaciology and Geocryology
Chinese Academy of sciences, Lanzhou 730000, P. R. China
E-mail: wdcdgg@ns.lzb.ac.cn

Abstract Water resource is the key factor to influence the social and environmental develop in arid and semi-arid regions. A water resource information system had been established in Heihe Catchment for managing, planning water resource, and helping to build up a spatial decision-making system and models for regional sustainable development. In setting up the information system, a detailed design had been worked out in order to extend the system to a wider region such as Hexi Corridor. Meanwhile, some new methods were used such as Open Database Connectivity (ODBC) and Object-oriented analysis. They were used for developing water resource models, designing a GIS-DSS-model interface and integrating the system.

Key Words Water resource, Sustainable development, Geographic Information system, Model, Decision Support System

1 Introduction

Heihe is one of the most important rivers in the arid and semi-region of Northwest China. It is located in Hexi Corridor, Gansu Province. The catchment is approximately 130,000 Km^2, including the landscapes of ice and snow, grassland, forest, oasis and Gobi. Because of the abundant land resources, solar energy and a long-period history of cultivation, the Heihe Catchment has been built as a most productive supplier of grain and vegetable in Northwest China. On the other hand because of the lack of water resource, further regional economical and social development has encountered a great obstacle and the eco-system in the lower valley of Heihe Catchment has heavily deteriorated. Water resource has become the most restrictive factor in the sustainable development of this region (Cheng, 1996).

In recent years, sustainable development has become a worldwide concern. In order to sustainablly manage the quantity and quality of the water resource in Heihe Catchment, the Chinese Science Council has set up a project for "Researches on Water Resources Allocation and Utilization and Coordinated Growth of Community, Economy and Ecosystem in Heihe River Catchment, Hexi Corridor, Northwest China". In the project, Geographic Information System (GIS) and Decision-Making System (DSS) are the key support technologies.

Undoubtedly, GIS is one of the most powerful tools for water resource managing, planning and decision-making (Baumgartner, 1996; Rodda, 1997). GIS has been wildly used in the research of water research during the past decades, and has been tested to has the following advantages:

1. The precondition of water resource management and scientific decision making is to obtain the fundamental information first. GIS can provide the spatial information such as terrain, landtype and hydro-geology, non-spatial information such as meteorological and hydrological data, and expert suggestions.
2. Spatial variability is an inherent nature of water resources. GIS-aided spatial models describe the water resource in a catchment as a suite of processes, comprising river flow, under-ground water resource, evaporation, and their relations with natural and social background. Thus, GIS can take into account the full diversity of conditions.
3. GIS is used to develop spatial decision support systems (SDSS), which has been tested to be benefit for describing and resolving non-structed problems. Integrating GIS and SDSS for water resource management has became an up-to-date tendency in recent years (Bishr, 1995; Fedra, 1996; Jamieson, 1996; Watson, 1996).
4. GIS bridges the gap for Water resource specialist researches and the users, making mathematic models more accessible to users, interpreting those poorly structed problems more directly and displaying the information and results more comprehensively.

A detailed design of the water resource information system of the Heihe Catchment (HeiheGIS) had been worked out, and the system is establishing in the Lanzhou Institute of Glaciology and Geocryology (LIGG), CAS. It can provide integrated information and spatial analysis tools for the administrators, decision-makers and researchers of this region. By a opening data policy, HeiheGIS will be extended to a more wildly user group in future, providing the information for them to simulate the present usage and plan the future exploration of water resource in Heihe Catchment. In this paper, the authors will pay attentions to the design of HeiheGIS and the GIS-DSS-model Interface.

2 Conceptual Design of HeiheGIS

2.1 System Architecture

HeiheGIS, had been designed to integrate the capabilities of GIS, database management system, water resource modelling together, and designed to have a complete and compatible standard, so that it can be extended to a more detailed system, or extended to a more wildly area such as the whole Hexi corridor. The main components of the HeiheGIS are showed by

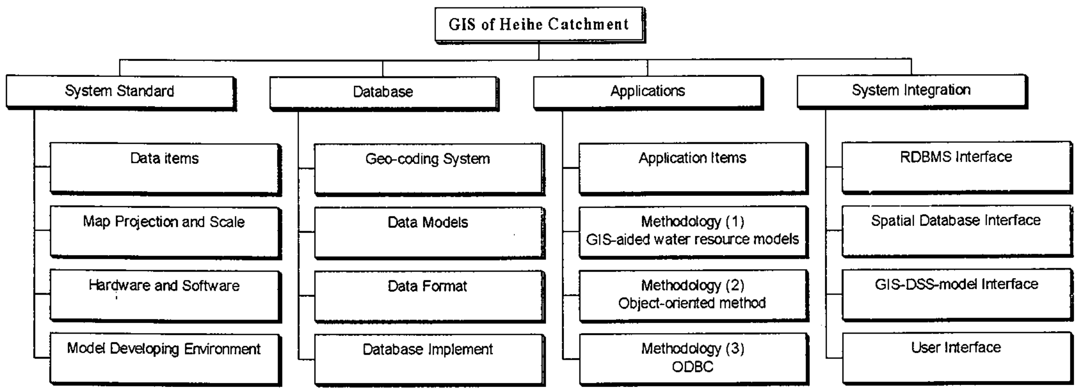


Fig. 1 Architecture of the Water Resource Information System of Heihe Catchment

figure 1.

2.2 System Standard and Configuration

2.2.1 Data Items

Five types of data are included in HeiheGIS for both spatial and non-spatial data. There are:

1. Regional background, including administrate boundaries, basin boundaries, digital elevation data, geology and the locations of meteorological and hydrological stations.
2. Population, including both urban and rural population.
3. Resources, including meteorological resources such as radiation, air temperature, precipitation and evaporation, land resources such as soil type and land use, water resources such as ground, under-ground water resource and main hydraulic buildings, biologic resources such as frost and grassland.
4. Economy, including global economic, rural economic and urban economic.
5. Eco-system, including environmental index, environmental pollution and environmental deterioration.

Also, some remote sensing data such as NOAA AVHRR and TM data are used to get some quantitative information such as surface temperature and surface moisture. These data are important parameters in water resource and hydrological models, and can be integrated with gridded GIS easily because of their raster data structure.

2.2.2 Map Projection and Scales

The map projection, Transverse Mactor was chosen in HeiheGIS because it was adopted for Chinese topographic maps, so that different data can overlay with digital elevation model (DEM). The central median is 99°N for Heihe Catchment.

For a meso-scale water resource study, a map scale of 1:250,000 will be suitable, and the grid size is a third-level 1/16 grid suggested by Chinese National GIS Standard, the grid size is 10″ in latitudinal orientation and 15″ in longitudinal orientation, rectangular grid size is 500×500m. The reasons why two types of grid exist together is, rectangular grid is always compatible with remote sensing data, and easy for topographic analysis; latitudinal and longitudinal grid is always used for modelling and compatible with climatic models such as general circulation models (GEM).

2.2.3 Hardware and Software

UNIX workstation is more powerful for GIS analysis and graphic processing. However, the user-group of HeiheGIS is not well equipped, they prefer desktop PCs. Therefore, UNIX based workstation is only used in the server end to take the advantages of UNIX based ARC/INFO. The client ends are based on desktop PCs.

The main GIS software used in HeiheGIS is ARC/INFO. It is the most powerful and popular GIS software in the world. The ARC/INFO for UNIX is based on both vector and grid data format, and its GRID module had involved many functions for water resource and hydrological applications, these characteristics make ARC/INFO very convenient for developing water resource models. Another ESRI's leading product ArcView is also used in HeiheGIS, but mainly on the client ends. The most merits of ArcView are that it is compatible with the data format in ARC/INFO very well, and it has a Windows style user interface, so it is easy for users to be skilled with it. For model developers, a GIS software based on grid data format, IDRISI, is also available, it can provide powerful functions for spatial decision-making.

2.2.4 Model Developing Environment

Some application models can be developed by a simple and efficient way, for example, developed directly by GIS-based macro languages such as ArcView Avenue, ARC/INFO SML or AML. These applications need not to be integrated in the water resource information system and DSS; they are used for particular calculation or simulation to provide intermediate data. These kinds of applications are always restricted by the capabilities of the macro language in particular GIS software.

Another types of models are impotent components of the water resource information system and DSS of Heihe Catchment, for example, the regional economic model and the multi-objective decision-making models. These kinds of models must be developed by high language and by using right developing strategies, so that they can have high efficiency and easy to be integrated. These models are developed by using Object-oriented languages like C++ and JAVA. In developing models, standard C++ is used unless there need a class library (for instance, class for ODBC); the suggested class library will be Microsoft Foundation Class (MFC).

3 Database

The hybrid database architecture of ARC/INFO was used in HeiheGIS for database management. That means the spatial data and non-spatial data are storage separately, spatial data are managed by file access and non-spatial data are managed by RDBMS (relational database management system). However, both spatial data and non-spatial data are used for model developing, and they can be joined by geo-code to make spatial analysis.

3.1 Geo-coding System

The data in GIS has complex spatial, temporal and attributive characteristics, therefore, geo-codes are required for classifying and describing each geographic feature. Geo-coding is the foundation for GIS to identify the geographic object, to express their logical relation and to refer to the attribute information in RDBMS.

The geo-code for HeiheGIS is a nine-digital code. Among it, the former four digital is called high-level code; it is coded by a hierarchy manner. That means, the geographic data in HeiheGIS can be classified from higher levers to lower levels, and they are divided into three classes. The first digital expresses the five main components that include background information, population, resources, economy and eco-system. The second digital expresses the sub-classes that make up the fist class; for example, regional background can be divided into boundaries, transportation, topography and geology. The third and forth digital express more detailed information.

The lower level geo-code has five digital. It can be hierarchy code (for example, land use can be classified into more detailed categories) or an ordinal code (for example, the geo-code of the locations of meteorological stations).

3.2 Data Model and Data Format

More and more water resource models have been developed by using a gridded GIS (Doe, 1996; Polarski, 1997). The HeiheGIS goes along the same way. Although all the spatial data in HeiheGIS are stored in both vector and grid data models, only the grid data model are used for model developing because models based on gridded maps provide a simple and flexible way of modelling water resource and hydrological processes at the catchment scale. Other merits of grid data model are its compatibility with remote sensing data, and its fuzzy boundaries. The latter merit avoids of the misleading precise of the vector data model.

Moreover, many water resource models operate on RDBMS as before. In HeiheGIS, with the association between spatial data and their attribute, model results can be display by map more directly. In addition, all disperse data can be converted to gridded maps by a series of interpolation methods such as Tessian polygon, trend surface and Kriging interpolation.

The data formats adopted in HeiheGIS are ARC/INFO Coverage for vector data and IDRISI Image, ARC/INFO ASCII GRID or USGS DEM for grid data.

4 Using HeiheGIS for Model Developing

The major purposes of HeiheGIS is help to solve the problems on water allocation, to find out some ways for restraining ecological deterioration, and to provide the decision-makers with plans on economic development. To achieve these targets, four models need to be developed. They are:

1. Models for the water resources bearing capacity and water allocation among industrial, agricultural and ecological sectors.
2. Models for evaluation on current situation of the ecological environment and prediction of its evolution trends.
3. Models for regional sustainable economic development.
4. Models for multi objective decision-making.

Not all the models need to be brought into the GIS domain. Traditional water resource models used relational database. However, GIS can produce some important parameters for these kinds of models (for example, the area and percentage of different land types). New generation water resource models used spatial data directly; they are named spatial model or distributed model. For developing these models, two new software technologies are applied in HeiheGIS; they are ODBC (open database connectivity) and object-oriented analysis.

4.1 ODBC method

Traditional water resource models used relational database for data input and output. In these models, managing database is always a troublesome problem because of the database independence. That means different models are based on different data format, which can be

ASCII text, oracle, excel, or dbase. This situation makes it very difficult for developing, modifying and integrating the water resource models. Once the data format changed, the program must be rewritten and recompiled. Another problem is old compute language like Fortran can not manage relational database directly, so the models need to be developed by a mixed programming technology or the database need to be translated into a special format. In addition, the users have to be skilled with database management.

ODBC is the way to resolve the above two problems. Firstly□ODBC is a concordant developing interface, it uses SQL (Sequence Query Language) for database management. That means the water resource models can be dependent from the database. No matter what kind of database used, the source code of the model will be same. Once the data format changed, the only thing need to do is to change an ODBC driver if the database is supported by ODBC. Programs need not to be rewritten and recompiled. On the other hand, almost all the popular developing environments have included the ODBC in them, such as Visual C++, Delphi, and Visual Basic. Therefore, the database can be managed by high language directly. This makes database management very easily and model development very efficiently. Because ODBC focused on the relational data model rather than data format, it makes the model developers pay more attentions to how to organize their data other than how to store their data in a material format.

4.2 Object-oriented Analysis

The object-oriented method can overstep the barriers between modelling of environmental systems and GIS (Livingstone, 1994). It offers a good opportunity to represent concepts in both real world system and computer systems. In HeiheGIS, Object-oriented method is used to translate the real phenomena of water resource into computer language and to integrate water resource models with gridded GIS. The following concepts are applied in model developing.

1. Class and object. An abstract base class for gridded GIS, CGridGIS had been defined. It can be constructed by the most common gridded files such as IDRISI Image and ARC/INFO ASCII GRID. Moreover, it owned member functions and operators for basic operations of gridded map.
2. Encapsulation. Because the models encapsulate data and methods together, they run on their own data rather than outside parameters. This is one of the powerful features of object-oriented design. It makes modules can be tested individually outside the realm of the large models.
3. Inheritance. The water resource models can inherit from CGridGIS and be naturally brought into gridded GIS. In addition, models can be organized into a hierarchy, so the descendant of a class in the hierarchy inherits all the characteristics of its parent classes and has some additional properties.
4. Polymorphism. It provides modelling flexibility. New models can override some member functions and operators of their super-class to get new properties.

5 Development of a GIS-DSS-Model Interface

Original, GIS serves as input and output for water resource models. Transforming the GIS data into the format required by the models can be extremely time-consuming and boring. Likewise, displaying the model output in a GIS form is equally difficult. Each model may has some of its own separate input files, at the final integration stage, all input requirements from those different models are derived from GIS.

During the last few years, research has focused on how to integrate GIS with DSS and water resource models more seamlessly. One method is to develop DSS and models in the GIS framework, for example, by using a GIS develop toolkit, such as the macro language AML in ARC/INFO. This method can make GIS, DSS and water resource models integrated very well. However, GIS software usually provides very limited functions for decision-making and water resource modelling, and macro languages are not powerful for scientific computation. Therefore, building such an integrated water resource information system is not effective, not flexible and not user-friendly. Another method is to integrate GIS, DSS and models through a common interface. For the non-spatial data, ODBC can be used to support a SQL based querying. For the spatial data, as there has not a standard data-access method like SQL, data files must be used for data access. However, by using CGridGIS, the base-class for gridded GIS, the spatial data-access, memory allocation and basic GIS analysis will be easy to proceed. If this object-oriented method is used well, a seamlessly integrated water resource information system can be established. In the system, both spatial data and non-spatial data need not to be transferred to another format, DSS and water resource models can use data directly from GIS, and the results can also be used directly by GIS for visualization. The structure of the integrated information system can be presented as the following figure.

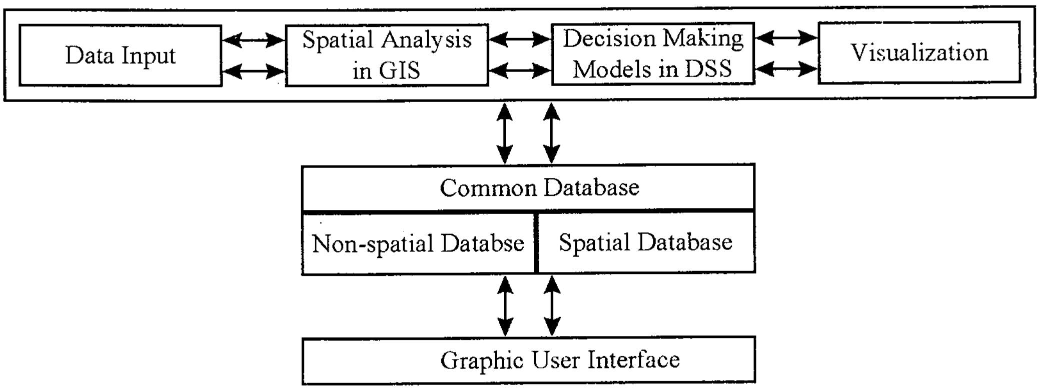


Fig. 2 Integration of GIS, DSS and water resource models

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A GIS-aided Analysis of Occurrence of Regolith Slides on Segmented Hillslopes around Sendai, Northeastern Japan

Debasree CHATTERJEE, Yoshihiko SANO, Yuzuru ISODA,
and Toshikazu TAMURA
Institute of Geography, Graduate School of Science, Tohoku University, Sendai 980-77, Japan
Fax +81-22-217-6648, E-mail debasree@geo.dges.tohoku.ac.jp

Introduction

Any hillslope profile extending from crest to adjacent valley bottom is divided into several segments by breaks of slope. On most hillslope profiles in the Japanese Island, the lower convex break of slope, which separates the upper and lower segments, is remarked as the uppermost boundary of the zone in which recent regolith slides occurred frequently. Concentration of recent slides on the lower segment is interpreted from the both view-points of present-day hydrogeomorphic processes and of historical development of hillslopes in changing morphoclimatic condition since at least the Last Glacial period (e.g., Moriya, 1972; Hatano, 1974; Tamura, 1981, 1987; Hatano and Oyagi, 1988).

Many regolith slides induced by the heavy rain in 1986 in the Tomiya Hills, north of Sendai, presented a good example of concentration of slides on the lower segments (Miyagi and Tamura, 1987). On the other hand, the rain-induced slides in 1994 in the Takadate Hills, south of Sendai, showed a more frequent occurrence of slides on the upper segments (Chatterjee et al., 1995, 1996). A comparative study of the two slide events is expected to provide a fruitful knowledge of slide occurrence and related hydroenvironment on segmented hillslopes in the humid temperate zone. Intensive analysis of slide distribution requires an accurate information on areal frequency of slide occurrence. This study intends to apply GIS technique to obtain the frequency of surface slides per unit area on each segment which has an irregular form.

Method

A distribution map of regolith slides in association with slope breaks were prepared using large-scale topographic maps (scale 1:5000, 1: 10,000) and aerial photographs (scale 1:5000, 1: 10,000) taken immediately after the two sliding events. Breaks of slope were first recognized on large-scale aerial photographs and traced on the large-scale topographic maps. Then the position of slide heads was plotted on the map. It was followed by verification by reconnaissance field survey for the final preparation of the base map. The final base maps were digitized through GIS using the ARC/INFO software. The certain aim to use a GIS technique is to build a digital database for further analysis.

A digital map database consists of two types of information: spatial and descriptive. Spatial information represents three types of geographic features: point features (viz. a landslide scar), line features (viz. a river), and area features (viz. a drainage basin), and those describe the spatial relation between them. GIS has the ability to link the spatial and descriptive data and maintains the spatial relation between the map features. In ARC/INFO, ARC handles the features and INFO component handles the feature description in tabular form. For the restricted digitizing space base maps were divided into several parts and digitized. A base map contains two sets of information: area of slope segments and distribution of surface slides. Each set of geographic information is called a layer. Each layer in ARC/INFO is called a coverage. Then the digitized coverages were edited through ARCEDIT and a unique numerical identifier was assigned to each feature for each coverage, and stored in the data file that are called feature attribute tables.

For the spatial analysis of the database, all coverage of the database were registered to a common coordinate system. Then common ID numbers were decided for the tics of all coverages. Thus a master file was created with common tic number to obtain properly registered coordinates for all coverages. Then the coordinates of the coverage and also the coordinates of the master tic file were converted into real-world coordinates. All the conversions were performed inside the INFO file that includes the conversion of each x, y coordinates into centimeter scale, and then into the map scale. Because of the large areal extent of the study area, each map was divided into few parts during digitizing, and they were later jointed to the coverage. The edgematching was performed to get the data linked by the fuzzy matching. Then the joined coverage was transformed into the master tic file and derived the final form of the coverage. The coverage attribute tables of the two coverages, slope segments and surface slides, were overlain to obtain the tabular data for geographic analysis, which was performed using identity inside the INFO data file.

Results

Fig.1 shows a schematic diagram of a segmented hillslope. The result shows that frequency of surface slides is 0.92 per square kilometer on the upper segments in the Takadate Hills, while 0.08 on the lower segments (Fig.2). In the Tomiya Hills frequency of slides is 0.87 per square kilometer on the lower segments and 0.13 on the upper segments (Fig.2). The total area of the Takadate Hills is 1.5 times greater than that of the Tomiya Hills. The areal ratio of the upper segments and the lower segments of the Takadate Hills are 8.06 km^2 and 3.0 km^2, respectively (Fig.2). In the Tomiya Hills the areal ratio of the upper segments is 3.9 km^2, while the lower segments is 3.2 km^2 (Fig.2). The two data sets, area of slope segments and distribution of surface slides in respective slope zones, were overlain using GIS that were compiled in the final coverages of the Takadate Hills and the Tomiya Hills.

The density of surface slides was calculated from numbers of surface slides in an individual slope segment dividing by the area of that slope segment. The total density of slides is 3.5 times higher in the Tomiya Hills than that of the Takadate Hills. The density of surface slides is 91 per square kilometer on the upper segments, whereas 21 on the lower segments in the Takadate Hills (Fig.2). In the case of the Tomiya density of surface slides is 504 per square kilometer on the lower segments and 59 on the upper segments (Fig.2). Therefore, the distinct contrastive trend in the topographic occurrence of regolith slides in the two hills calls for further investigation of hydrogeomorphic processes on hillslopes.

Consideration

Change in soil-water transitivity on a slope profile, which is affected by the beak of slope, seems to affect the position of slide heads. The headscarp migrates upslope in the history of hillslope development. It is resulted in the evolution of segmented hillsides. Preliminary analysis of infiltration and regolith characteristics on different positions at failured and non-failured sites in the two hills indicate that the upper part of the upper slope segments in the Takadate Hills have very high concentration of fine soils, which seems to have inherited from the weathering of bedrock; volcanic and pyroclastic rocks of the Miocene likely resulted in significant break in soil-water permeability in the surface above and below the upper convex break during the extraordinary heavy rainfall in 1994. On the other hand, in the Tomiya Hills composed of Miocene sandstone, relatively higher accumulation of regolith with higher concentration of fine soils at the lower positions of hillslopes may have created critical pore water pressure according to the usual law of subsurface water movement and upward migration of saturation point due to watertable rise on the lower segments at the time of heavy rain.

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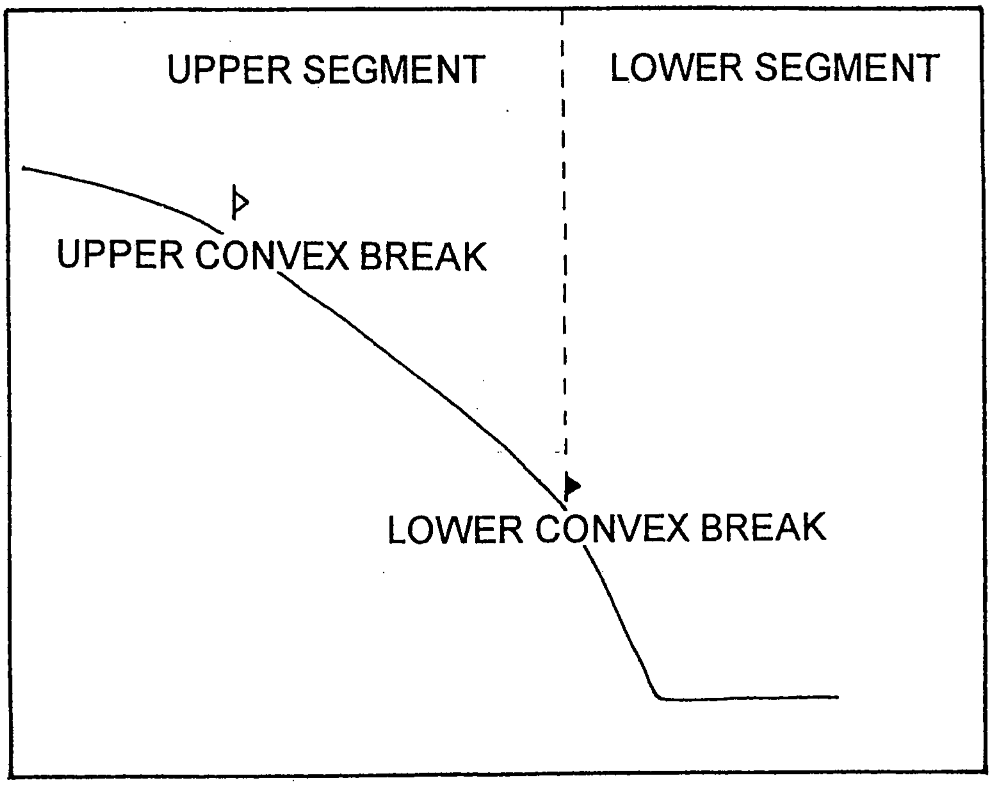

Fig.1 A Schematic Diagram of a Segmented Hillslope.

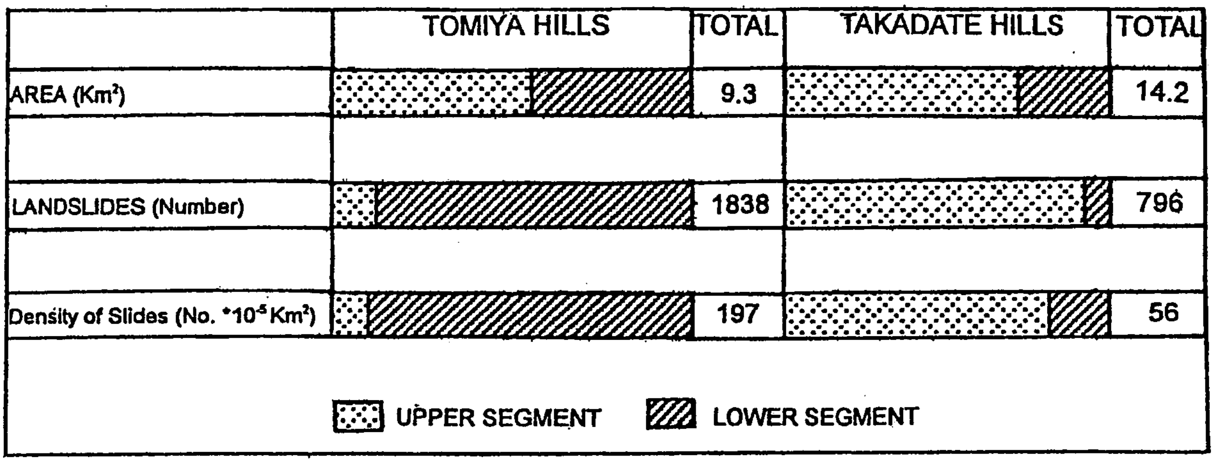

Fig.2 Area of Slope Segments, Number of Landslides, and Density of slides on Upper and Lower Segments in the Tomiya and the Takadate Hills.

Effects of Groundwater Flow and Surface Temperature Warming on Subsurface Temperature Field in the Nobi Plain, Central Japan.

Youhei Uchida and Yasuo Sakura

Department of Sciences, Faculty of Earth Science, Chiba University
1-33 Yayoi-cho Inage-ku Chiba 263 Japan
Email : uchida@earth.s.chiba-u.ac.jp
ysakura@earth.s.chiba-u.ac.jp

Abstract.

In the Nobi Plain, temperature profiles were measured in 41 observation wells in 1993 and 1994. There are many temperature inversions in the vertical temperature profiles of recharge area. In the Nobi Plain, annual mean surface temperature increases about 2℃ during last 100 years, and it is assumed that this surface warming causes subsurface temperature inversions. A three-dimensional numerical model of heat transfer in the Nobi Plain is used to investigate the influence of surface temperature warming outside the discharge area, where inversions are evident in the measured temperature profiles. Simulated results show that subsurface temperature inversions are formed in recharge area at depth between 50m-130m below sea level, because subsurface temperature has been cooled with the advective heat transfer by the downward groundwater flow from the surface. On the other hand, shallow subsurface temperatures in the center part of the plain have been heated more by upward regional groundwater flow than by the effect of surface warming, so that temperature inversions are not observed.

1. Introduction

In the Nobi Plain, temperature profiles were measured in 41 observation wells in 1993 and 1994. There are many temperature inversions in vertical temperature profiles of the recharge area. In the Nobi Plain, annual mean surface temperature increases about 2℃ during last 100 years, and it is assumed that this surface warming causes subsurface temperature inversions. The effects of past climatic changes on the subsurface temperatures have been recognized for a long time [Lane, 1923 and Birch, 1948]. The most recent major climatic change, the rapid warming of 1880 - 1940 A.D., has caused a temperature inversion in many parts of North America, Europe and Australia, at a depth of 50 to 100 m [Cermak, 1971 and Jossep, 1990]. There are several studies dealing individually with the effect of groundwater flow and surface warming on the subsurface thermal regime but there are few studies including both effects e.g., [Kukkonen and Clauser, 1994]. The purpose of this study is to evaluate the effects of groundwater flow and surface temperature warming on subsurface temperature field in the Nobi Plain using field observation and three-dimensional numerical model.

2. Study Area Description

The Nobi Plain is about 1300 km^2 in area. To the west it is adjacent to an alluvial fan at the foot of the Yoro mountains (Figure 1). River terraces near the Owari hills lie to the east, and Paleozoic basement rock crops out in mountains to the north. The Ise Bay borders the plain to the south. Nobi Plain is a sedimentary basin tilted westward and is composed of sand, gravel, sandy-clay and clay deposited during the Pliocene and Pleistocene. The main aquifers are three layers of gravel which are composed of river bed gravel deposited during glacial advances. Confining layers are composed of sandy-clay and clay deposited during inter-glacial stages.

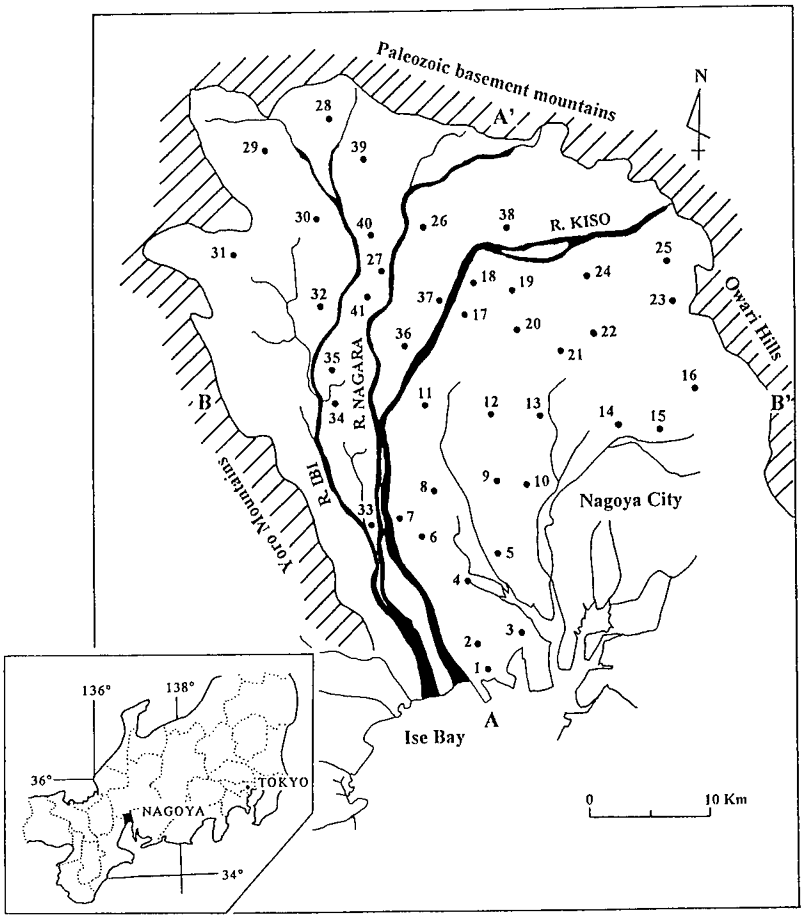

Figure 1. Study area and observation wells.

A large amount of groundwater was used for industry and agriculture in the Nobi Plain from the 1950's to the 1970's, causing declines in head and land subsidence. In 1973, daily pumping peaked at 3.8 million m^3 . When control of withdrawal began in 1972, heads recovered and subsidence was gradually reduced . In the Nobi Plain, annual mean surface temperature increases about 2℃ during last 100 years. Annual mean surface temperature has raised from 14℃ to 16℃ in the north part of the plain, and from 14.5℃ to 16.5℃ in the south part of the plain around Nagoya, respectively.

3. Field Observations

Figure 2 shows the vertical distribution of hydraulic heads in a cross section A-A' in Figure 1. Figure 2 shows the effects of pumping on regional groundwater flow. The effects of pumping are evident at 100 m to 200 m below the surface in the central part of the plain, where many supply wells are concentrated and a cone of depression still exists. In this area, the lowest hydraulic head is about -7m and groundwater flows toward the cone of depression. The regional groundwater flow system is recharged in the northern part of the plain and discharges toward Ise Bay.

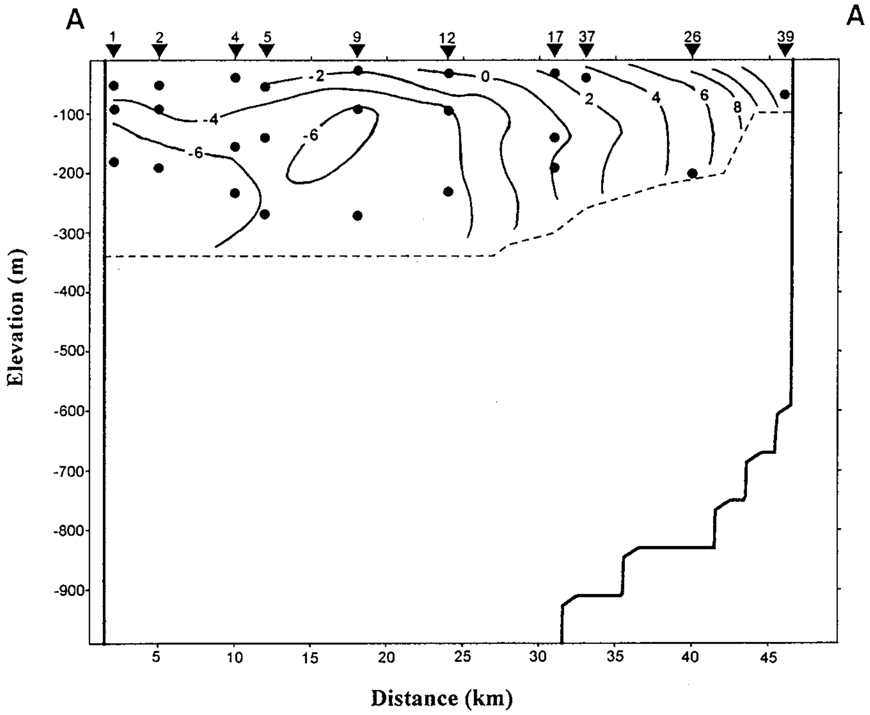

Figure 2. Vertical distribution of hydraulic heads in a cross section along A-A'

Figure 3 shows the vertical distribution of subsurface temperature in the same cross section as Figure 2. In this figures, we used the annual stable temperature below the isothermal layer. In general, the effect of seasonal fluctuations of surface temperature extends to a few tens of meters. We defined the isothermal layer at the depth where the influence of surface temperature change is almost not recognized or the subsurface temperature fluctuation is less than 0.1℃. The average geothermal gradient in the absence of groundwater flow in Japan is about 0.03℃/m. It is clear that there is a marked difference in the subsurface thermal distribution from north to south in Figure 3. In the south, subsurface temperature and temperature gradient are high because of upward groundwater flow in the discharge area. While in the north, subsurface temperature and gradient are relatively low because of downward flow in the recharge area, moreover, the isothermal lines of 15 ℃ and 17 ℃ are formed temperature inversion that is manifested as a minimum temperature or inverse temperature gradient in the subsurface shallow layer.

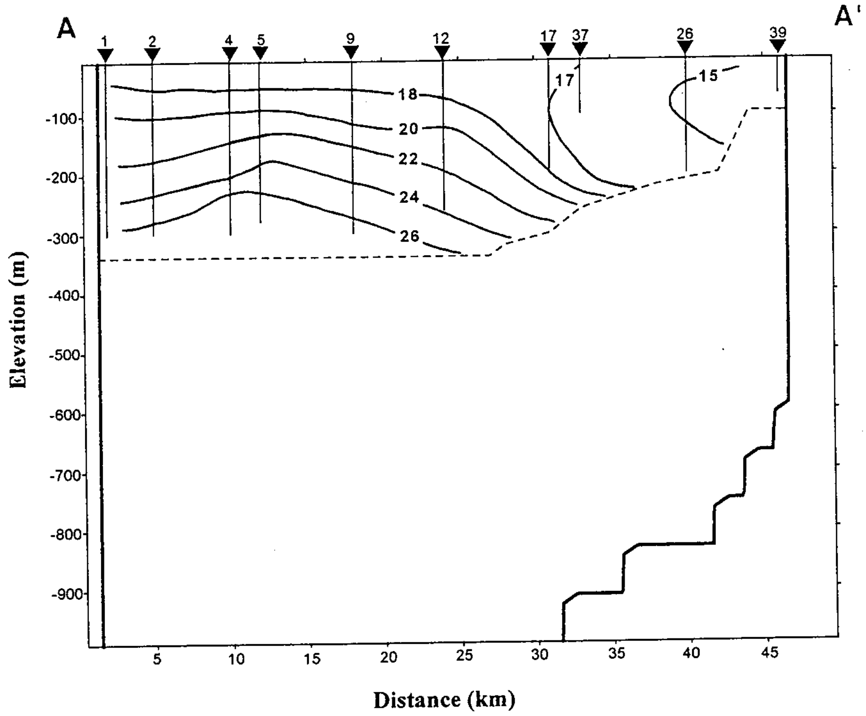

Figure 3. Vertical distribution of subsurface temperature in a cross section along A-A'

4. Simulation Model

We carried out numerical simulations using a three-dimensional model with groundwater flow and heat transfer in the Nobi Plain to investigate the influence of surface temperature warming. As for groundwater flow model, the amount of pumping is estimated from the published data by municipality. As for heat transfer model, surface temperature is assumed to be increasing linearly at a rate of 0.02℃/year from 14℃.

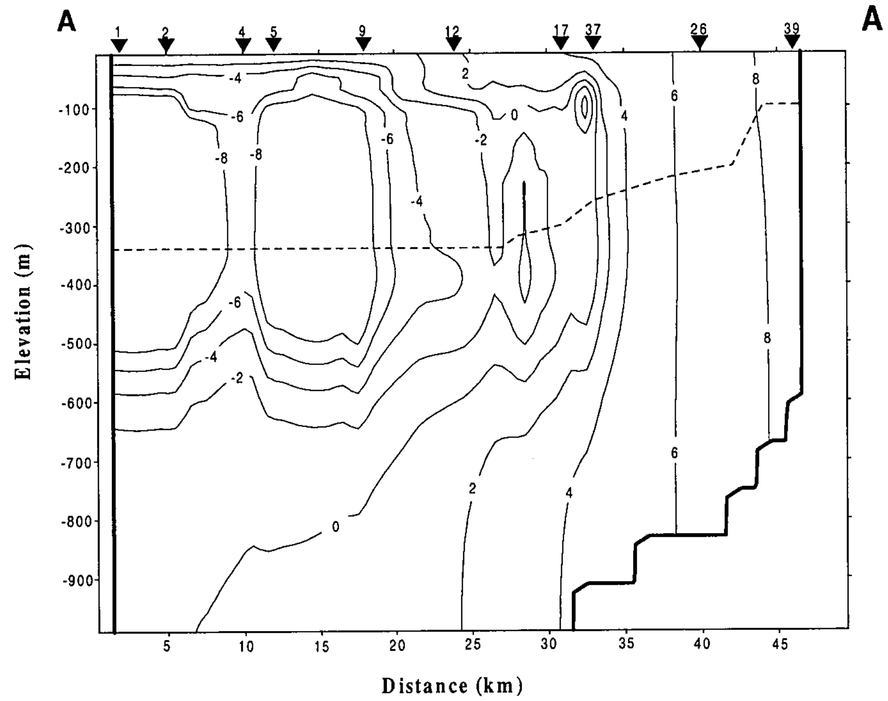

Figure 4. Simulated vertical distribution of hydraulic heads in a cross section along A-A' in 1990.

Figure 4 shows the simulated vertical distribution of hydraulic head in a cross section along A-A' in 1990. There area many pumping wells in the center part of the plain, therefore, induced recharge owing to pumping occur from wells 1 to wells 37. Figure 5 shows the simulated vertical distribution of subsurface temperature in a cross section along A-A' in 1990. As a result of simulation, subsurface temperatures in shallow layer are affected by changes of surface temperature and pumping. In the recharge area, we can simulate temperature inversions anywhere at the depth between 50m - 130m below the sea level, because subsurface temperature has been cooled with the advective heat transfer by the downward groundwater flow from the surface. On the other hand, in the discharge area, we cannot recognize temperature inversions because subsurface temperature has been heated more by regional groundwater flow than by the effect of surface warming or the depth of inversion has been shifted within the surface layer of 30m by the upward groundwater flow, where seasonal fluctuation of subsurface temperature conceals the inversion.

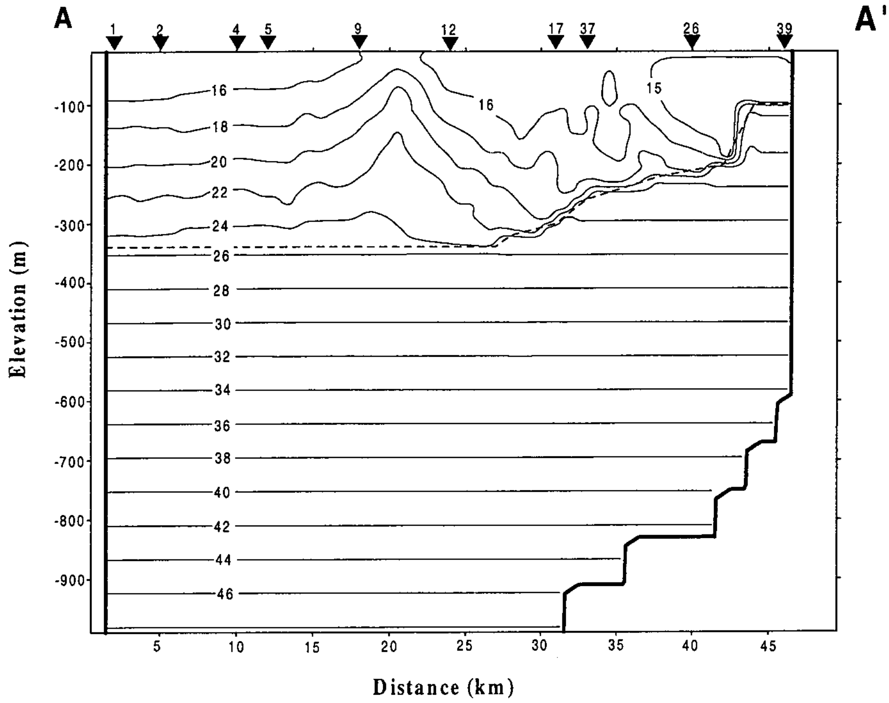

Figure 5. Simulated vertical distribution of subsurface temperature in a cross section along A-A' in 1990.

5. Conclusions

In this paper, we have presented a three-dimensional data set consisting of head and temperature measurements in 41 observation wells finished at depth up to 300 meters below sea level in the Nobi Plain. The subsurface thermal regime were analyzed by the field data and compared with the simulation result of mathematical modles. The conclusions are summarized as follows:

(1) As a result of simulation which include the effect of surface temperature warming, subsurface temperatures in shallow layer are affected by changes of surface temperature and pumping. In the recharge area, we can simulate temperature inversions anywhere at the depth between 50m - 130m below the sea level, because subsurface temperature has been cooled with the advective heat transfer by the downward groundwater flow from the surface.

(2) In the discharge area, we cannot recognize temperature inversions because subsurface temperature has been heated more by regional groundwater flow than by the effect of surface warming or the depth of inversion has been shifted within the surface layer of 30m by the upward groundwater flow, where seasonal fluctuation of subsurface temperature conceals the inversion.

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The Study on Environmental Aquatic Chemistry and Dynamic Model

Ye Changming, Professor, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, 100085, China

The earth environment is composed of atomsphere, hydrsphere, pedosphere, lithesphere and biosphere. The hydrosphere is the most active one among the spheres, and interacts on other spheres. In hydrological cycles, water interacts continuously with substances and induces the weathering, soil corrosion and formation of soils and sediments. The chemical action plays an important role in environmental processes. Thus the study of environmental aquatic chemistry and its mathematical models must be attached great importance to in understanding the water environmental processes.

Conception of Environmental Aquatic Chemistry

Environmental aquatic chemistry is a subject to study the contribution and cycles of chemicals in water environment. For traditional environmental aquatic chemistry, the chemical processes are generally inclusive of sorption-desorption, precipitation-solution, acid-base reaction, hydrolysis, redox reaction and complex reaction in waters. Besides the processes mentioned above, wohever, modern environmental aquatic chemistry should consider the effects of biological and hydrological processes on the chemical reactions(1-2). Therefore, modern environmental aquatic chemistry should study the chemicals-biota-wter-air system in which the waters(including suspended and bottom sediments) can be treated as a carrier of chemicals and biota in water environment. The interfaces include air-water, water-sediment and water-biota ones(Fig.1), namely the multimedia environmental interface.

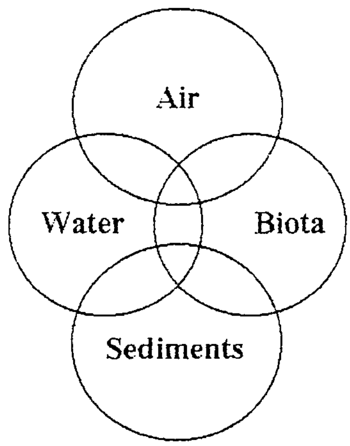

Fig. 1 Interface of air-water-biota-sediments system

The surface chemistry on solid-water interface has studied greatly in both conception and experiment in recent years, especially the study on sorption-desorption process of interaction of solid(including the botom sediments) sueface with solute in water has developed in depth(3-5). The behaviour of chemicals on air-water interface have attracted onc's attention and were studied extensively. For examle. the two-film model of volatilization of chemicals from water and the water surface microlayer adsorption and concentration of chemicals are the important research results of air-water interface behaviour of chemicals(6-9).

One of the important contains of water-biota interface behaviour is the aquatic ecotoxicology which is the science devoted to the study of the production of harmful effects by substances entering the natural waters; an essential part of aquatic ecology is the assessment of movment of potentially toxic substances through water environment and through aquatic food webs.

Water Environmental Mathematical Models

As the mechanism research of chemical reaction in water environment, over the last decade many significant transport and transformation processes such as diffusion, sorption, chemical degradation and biodegradation, and their dynamics were described in detail. Mathematical models in the mechanism research has proven to be a powerful tool for understanding the complex structure and dynamics of water environment and ecosystems(10), especially the fate of chemicals in aquatic ecosystems(11-14). For the results of joint action of chemical, biological and hydrological processes, the fate of pollutants and eutrophication of waters are major targets simulated and predicted by the models. At the present, the aquatic environmental models in common use mainly are:

- chemical thermodynamic models;
- chemical dynamic models;
- nutrient cycles models in lake and reservoir;
- dissolved oxygen and BOD models;
- food chain models for chemicals transport in waters, and
- the multimedia environmental models

As a specific example of multimedia environmental models of chemicals, we have studied the sediments/chemicals interaction dynamic model(SCDM) of water in this paper.

The SCDM-- As a Case Study

The particles involed in the study are suspended solids, solid sediments and alga in waters. In the past studies on transport and fate of organic pollutants, the particle sorption-desorption or chemical degradation and biodegradation were considered only, and alga were not treated as a particle. Here on the basis of the research of sorption, hydrolysis, biodegradtion and algae accumulation in waters, the dynamic model on interaction between water particles and trace organic chemicals was presented to simulate the concentration distribution of dimethyl phthalate(DMP) in the different environmental media of a reservoir.

The reservoir can be treated as a complete mixed system in which the distribution of pollutants are approximately considered to be a homogeneous with steady state equilibrium condition, so that the free concentration of pollutants can be computed using sorption equilibrium constants. The prototype of the SCDM is shown in Fig. 2.

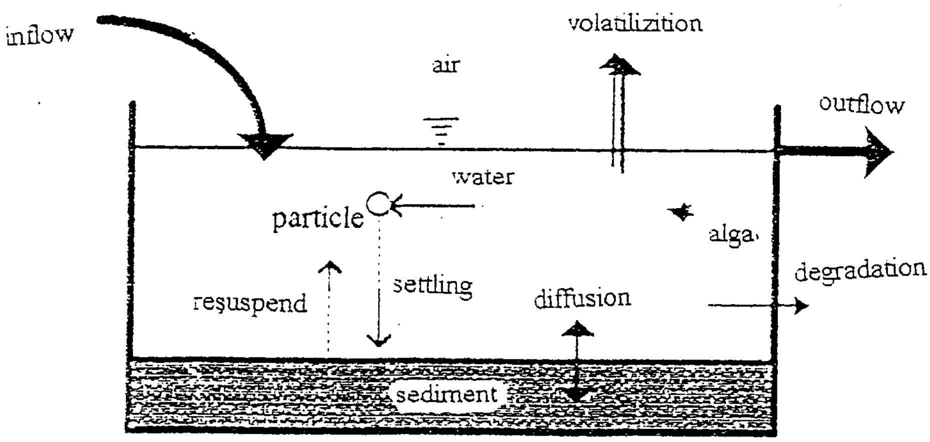

Fig 2. The schematic diagram of prototype of SCDM

On the basis of mass continuety principle of fluid, the mathematical model for simulating the change of transport and fate of the trace organic chemicals with time can be written as following equation:

$$\frac{dC_T}{dt} = \frac{W}{V} - \frac{Q}{V} C_t - (V_s - V_r) - (\Sigma K_i C) - K_1 C \qquad (1)$$

where C_T is the concentration of chemicals in water with particles, g/m^3; t is the time, d; W is mass rate of entering of chemicals into water, g/d; V is the volume of water, m^3; Q is the volume rate of water through environmental compartment, m^3/d; V_s is the rate constant of particle settling, d^{-1}; V_r is the rate constant of sediment resuspended, d^{-1}; C_p is the concentration of sorbed chemicals on particles, g/m^3; K_i is the ith semi-first order reaction rate constant of chemicals, d^{-1}; K_1 is the accumulation factor of alga, d^{-1}; C is the concentration of dissolved chemicals in water, g/m^3.

If K_p is the linear sorption partition coefficient of chemicals between particles and water; M is the concentration of suspended solids; N is the concentration of alga; C_A is the accumulation concentration of chemicals on laga, then the C, C_p and C_A can be expressed as follows:

$$C = \frac{C_T}{1 + K_p M + K_1 N} \qquad (2)$$

$$C_p = \frac{K_p M C_T}{1 + K_p M + K_1 N} \qquad (3)$$

$$C_A = \frac{K_1 M C_T}{1 + K_p M + K_1 N} \qquad (4)$$

The eq.2 qnd eq.3 were substituted into eq.1 to yeild

$$\frac{dC_T}{dt} = \frac{W}{V} - \left(\frac{Q}{V} + \frac{(V_s - V_r)K_P M}{1 + K_p M + K_1 N} + \frac{(\Sigma K_i) + K_1}{1 + K_p M + K_1 N}\right) \qquad (5)$$

the analytical solution of eq.5 is

$$C_T = C_{T0} \exp(-bt) + (C_{T,ino}/n)(\exp(-mt) - \exp(-bt)) \qquad (6)$$

where C_{T0} is the initial total input concentration of chemicals, g/m^3; m is rate constantof exponential decay of loadings, d^{-1}; C_{T0} is the total concentration of chemicals in water with particles when t=0, g/m^3;

$$b = \frac{Q}{V} + \frac{(Vs - Vr)K_p M}{1 + K_p M + K_1 N} + \frac{(\Sigma K_i) + K_1}{1 + K_p M + K_1 N} \qquad (7)$$

$$n = (b - m)\frac{V}{Q} \qquad (8)$$

For a reservoir, $V=2\times10^8 m^3$, $Q=1000m^3/d$, W=10kg/d, $C_{t0}=2\times10^{-5}mg/L$, $m=4\times10^{-4}d^{-1}$, The parameters used in model calculation were given in table 1(15). At first, allthe data were substituted in to eq.6 to calculate the total concentration of DMP , then the eq.2, eq.3 and eq.4 were used to calculate the C, Cp and C_A respectively(Fig.3). The concentration and mass percentage of DMP in each phase was given by table 2 which shows the DMP mainly distributed in alga, then in mineral solid particles.

Table 1. DMP parameters used in the model

chemicals	Kp	M (mg/L)	N (mg/L)	ΣKi (d^{-1})	K1 (d^{-1})
DMP	0.08	20	10	0.4	80

Table 2. Concentration and mass percentage of DMP in each phase (%)

	disolved in water	sorbed on alga	sorbed on particles
concentration	0.125	99.67	0.199
mass	0.01	99.59	0.4

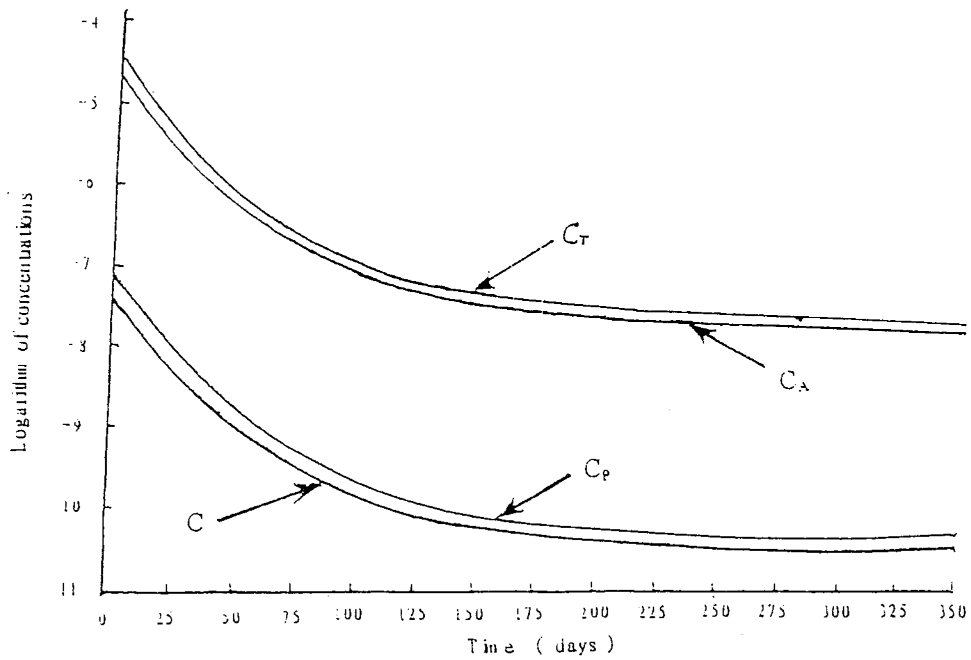

Fig. 3 Variation of concentration logarithm value of DMP in each phase with time

Conclusion

This study shows that the modern environmental aquatic chemistry is different with traditional one and mainly devoted the study of chemicals-water-biota-air system. The concentration distribution of DMP in water-particles-alga system can be calculated using the SCDM. The calculated results show the concentration of DMP in alga is greater than in mineral particles, and higher than in water.

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Sediment Mitigation Planning using Numerical Simulation for Bai-shi Reservoir in China

Shu Takahashi, Kumar K. Janakiriman, Lal Samarakoon, Minoru Sugiyama, and Kazuo Nakagawa
Nippon Koei Co., Ltd., Research & Development Center,
2304 Takasaki, Kukizaki, Japan

Abstract

Effective sediment control is required for the Bai-shi dam on the Dai-Ling-He River in China. The bottom outlets have been designed to discharge the sediment from the reservoir during floods using the two alternative gate operation methods: (a) venting density current and (b) drawdown-flushing. Using venting density current rule, the high concentration sediment can be discharged through the bottom outlets. Using drawdown-flushing rule, riverine flow runs on the reservoir bed and can flush out the sediment from the reservoir. This study presents numerical simulations using a two-dimensional mudflow model and a quasi-three dimensional flow and sediment transport model to predict the behavior of the sediment in the reservoir under the different gate operation rules.

1. Introduction

The Dai-Ling-He River originates from the western hills in Liaoing province f China and flow into the Gulf of Liaodong (Fig 1). The total length and catchment area is 435km and 23,500km^2, respectively. The population of the Dai-Ling-He River Basin has increased to four million with the growth of agriculture and industry. To meet the increasing water demand for irrigation, municipal, and industry and to meet the need for flood control, the Bai-shi dam was planned. Bai-shi dam has been projected to supply a total of 7 x10^8 m^3/year to the down stream areas (Department of water resources of Liaoing province, 1993). The Bai-shi dam site is located at around 20km downstream of the confluence point of the Dai-Ling-He River and the Mong-Nie-He River. The dam is of concrete gravitational type with dimensions, 514m long and 50.3m high (Fig. 2). The full and effective storage capacities of the reservoir will be 16x10^8 m^3 and 10x10^{6}m^3 respectively, at the beginning of the operation. However, the Dai-Ling-He River transports a large volume of suspended sediment, which is produced by heavy soil erosion during floods. The annual sediment transport of 23x10^6 ton has been observed at the Bai-shi dam site. Furthermore, the large floods contribute nearly 50% of the total sediment flows.

The sediment is predominately silt. Without control methods, the sedimentation will quickly reduce the effective storage of the reservoir. To prolong the life span of the dam, twelve bottom outlets were designed at the dam. Two alternative gate-operation rules are planned during the floods, namely:

(a) *Venting density current method:* The sediment inflow can be released as a density current through the bottom outlets(Fan and Morris, 1992).
(b) *Draw-down flushing method:* The reservoir should be drawn down a priori so that some previously deposited sediment can be scored and the flood with large sediment concentration can be flushed through the bottom sluices(Fan and Morris 1992, and Chang et. al 1996). This operation may be used when a large scale of flood occurs.

The objectives of this study are: 1) to estimate the sediment volume discharged from the bottom outlets using numerical simulation models and 2) to investigate the effective gate-operation rule which effectively discharge the reservoir sediment. This study is part of the feasibility study undertaken by Japan International Cooperation Agency (JICA).

In addition, the extensively eroded area in the basin was identified using remote sensing technology. The river sediment and the land cover change in the basin that could have influenced surface erosion were investigated. Time-series analysis was also made to detect trends and shifts in the hydrologic records of daily-suspended load and daily discharge.

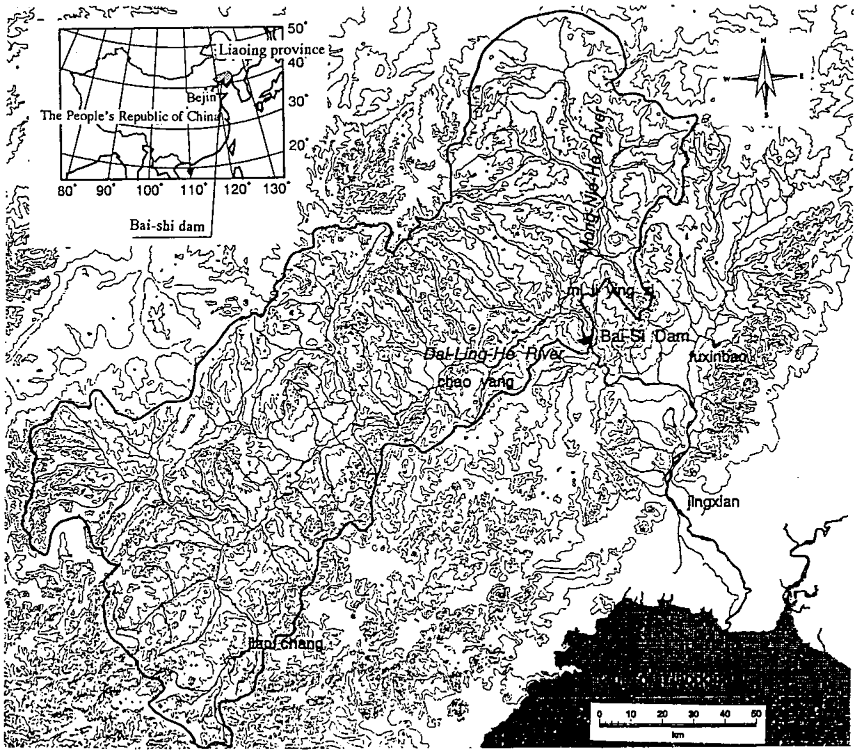

Fig.1 Location of the study area

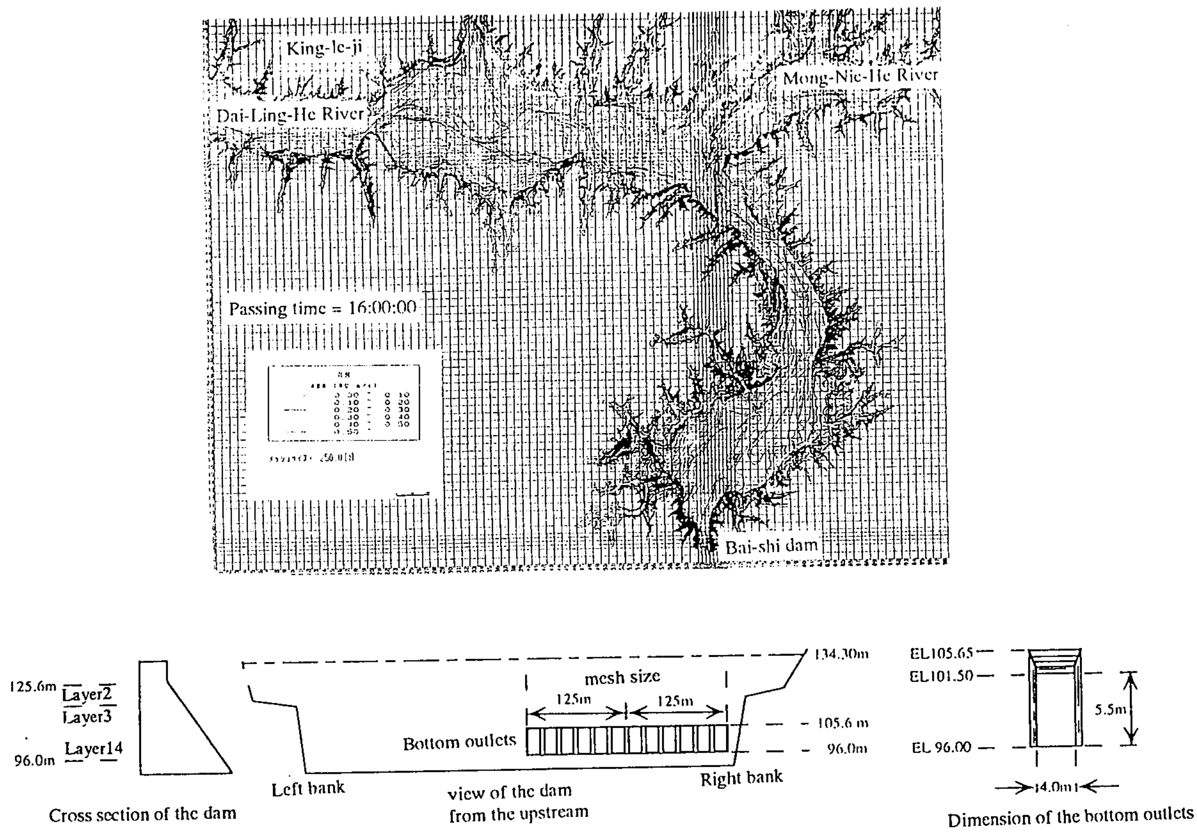

Fig. 2 Plan view of the Bai-shi resevoir and the modelling of the dam

2. Venting density current through the bottom outlets

To estimate the sediment volume vented from the bottom outlets while retaining the high water level in the reservoir, the time series of the sediment concentration profile at the dam was obtained by considering the following processes:

(1) Advection of suspended sediment due to the flow
(2) Diffusion of suspended sediment due to the difference of density in the flow
(3) Falling rate of suspended sediment and
(4) Pick-up rate of deposited sediment due to the bed share stress of the flow.

Because the sediment particle is small (d_{50}=0.02mm) and the flow in the reservoir may vary due to the complex geometry of the reservoir, a quasi-three dimensional flow and sediment transport model was applied for this simulation.

2.1 Flow and sediment transport equations in a multi system

The quasi-three dimensional flow and sediment transport model uses a multi level system. In the multi-level system, water body is split into some layers in depth, and the flow is simulated in a two-dimensional manner for each layer. The momentum and material in a vertical direction are exchanged between the layers and thereby the flow and sediment transport are simulated in a three-dimensional manner. Assuming the pressure is hydrostatic, governing equations for flow and suspended sediment can be written as follows:

Continuity equation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

Momentum equation

$$\frac{\partial u}{\partial t}+\frac{\partial (uu)}{\partial x}+\frac{\partial (uv)}{\partial y}+\frac{\partial (uw)}{\partial z}$$
$$=fv-\frac{1}{\rho}\frac{\partial P}{\partial x}+\frac{1}{\rho}\left(\frac{\partial \tau_{xx}}{\partial x}+\frac{\partial \tau_{yx}}{\partial y}+\frac{\partial \tau_{zx}}{\partial z}\right)$$

$$\frac{\partial v}{\partial t}+\frac{\partial (uv)}{\partial x}+\frac{\partial (vv)}{\partial y}+\frac{\partial (vw)}{\partial z}$$
$$=-fu-\frac{1}{\rho}\frac{\partial P}{\partial x}+\frac{1}{\rho}\left(\frac{\partial \tau_{xy}}{\partial x}+\frac{\partial \tau_{yy}}{\partial y}+\frac{\partial \tau_{zy}}{\partial z}\right)$$

$$\frac{\partial P}{\partial z}=-\rho g$$

Where x, y, z are coordinate directions; u, v, and w are velocities in x, y, and z directions; f = coefficient for Coriolis effect; g = gravitational acceleration; P = pressure, τ = shear stress.

Advection and diffusion equation of suspended sediment

$$\frac{\partial C}{\partial t}+\frac{\partial (Cu)}{\partial x}+\frac{\partial (Cv)}{\partial y}+\frac{\partial (Cw)}{\partial z}$$
$$=\frac{\partial}{\partial x}(D_x\frac{\partial C}{\partial x})+\frac{\partial}{\partial y}(D_y\frac{\partial C}{\partial y})+\frac{\partial}{\partial z}(D_z\frac{\partial C}{\partial z})-w_o\frac{\partial C}{\partial z}+q_{su}$$

Advection and diffusion equation of temperature

$$\frac{\partial T}{\partial t}+\frac{\partial (Tu)}{\partial x}+\frac{\partial (Tv)}{\partial y}+\frac{\partial (Tw)}{\partial z}$$
$$=\frac{\partial}{\partial x}(E_x\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(E_y\frac{\partial T}{\partial y})+\frac{\partial}{\partial z}(E_z\frac{\partial T}{\partial z})$$

Where C = volumetric concentration of suspended sediment; T = temperature; D_x, D_y, D_z, E_x, E_y, and E_z are diffusion coefficients in x, y, and z directions, respectively; w_o = falling velocity of suspended sediment; q_{su}= pick up rate of deposited sediment.

The model was solved using finite difference method. The above governing equations were integrated in depth and then were discretized in an explicit form. A pick up rate of deposited sediment, q_{su}, was estimated using Ashida and Michiue's formula (Ashida and Michiue,1978). The density of the flow was described as a function of temperature and suspended sediment. The mean grain size of suspended sediment (d_{50}) is 0.0214mm on average and its falling velocity was estimated as 0.0407cm/s using Rubey's formula. The shape of the reservoir affects on the simulation results. According to the master plan, the sediment accumulation in the reservoir after 30 years should be controlled to 3.0×10^8 m^3. Therefore, the shape of the reservoir was estimated with 1.5×10^8 m^3 of sediment accumulation using Empirical Area Reduction method for the subsequent simulations.

2.2 Results

(1) Behavior of suspended load in the reservoir during flood time

The simulation was done for three major floods over the last 38 years -a 50 year return period food (July of 1962), a 20 year return period flood (August of 1969), and a 10~20 year return period flood (August of 1984). The simulation results are summarized as follows:

Flow in the upstream of the dam

Because the reservoir widely curves in the upstream portion and is located at the confluence point of Dai-Ling-He River and Mong-Nie-He River, the flood force are diminished in magnitude. Furthermore, the flow rotates in the wide portion of the upstream of the dam. Therefore the flow heading towards the dam becomes significantly weak.

Concentration of suspended sediment in the upstream of the dam

According to the flow in the reservoir, most of suspended sediment does not reach the dam, meaning the concentration of suspended sediment at the dam is low. The density current also seems to dissipate before reaching the dam.

Scour and deposition of reservoir sediment

Since a large amount of suspended sediment flows into the reservoir and accumulates before reaching the dam, the deposition surpasses the scour in the entire reservoir. The deposition is especially significant in the upstream of the confluence point, in the downstream wide portion of King-re-ji, and in the wide upstream portion of the dam.

(2) Effective operation rules for the bottom outlets

In general, the sediment concentration peak follows the flood peak when a large flood flows into the reservoir. Therefore, more reservoir sediment can be discharged through the bottom outlets by releasing more water after the flood peak. To analyze its effect, the model was run for the two different strategies. In strategy-1, the water level of the reservoir after the flood peak was regulated at the limited water level during the flood season, 125.6m. In strategy-2, the water level can be drawdown by 2.0 m below the limited water level.

Figure 3 (a) and (b) show the hydrographs of inflow (Q_{in}), outflow (Q_{out}), simulated water levels and simulated sediment concentrations near the bottom outlets during 1969 flood, for Strategies 1 and 2. Under these flood control strategies, outflow (Q_{out}) was reduced once from 5,000m^3/s to 2,500m^3/s when the reservoir water level reached 1.3m above the limited water level (125.6m). The flood peak appeared after 16 hours and reached 10,000m^3/s, whereas the sediment concentration peak appears roughly 20 hours after the flood peak and increases between 4,000 ~ 6,000 ppm. Table 1 summarizes total inflow and outflow of discharge, of sediment, the ratio of total sediment inflow to the total sediment outflow (R_s), and the water released to discharge a unit volume of sediment (Q_{req}). The R_s of strategy-2 for 1984 flood was 19.2% and the highest of all. In conclusion, strategy-2 seems slightly more effective in discharging reservoir sediment than strategy-1 but it always results in releasing 1x$10^8 m^3$ of unused water to the downstream. Therefore, strategy-2 does not seem to have greater advantages over strategy-1.

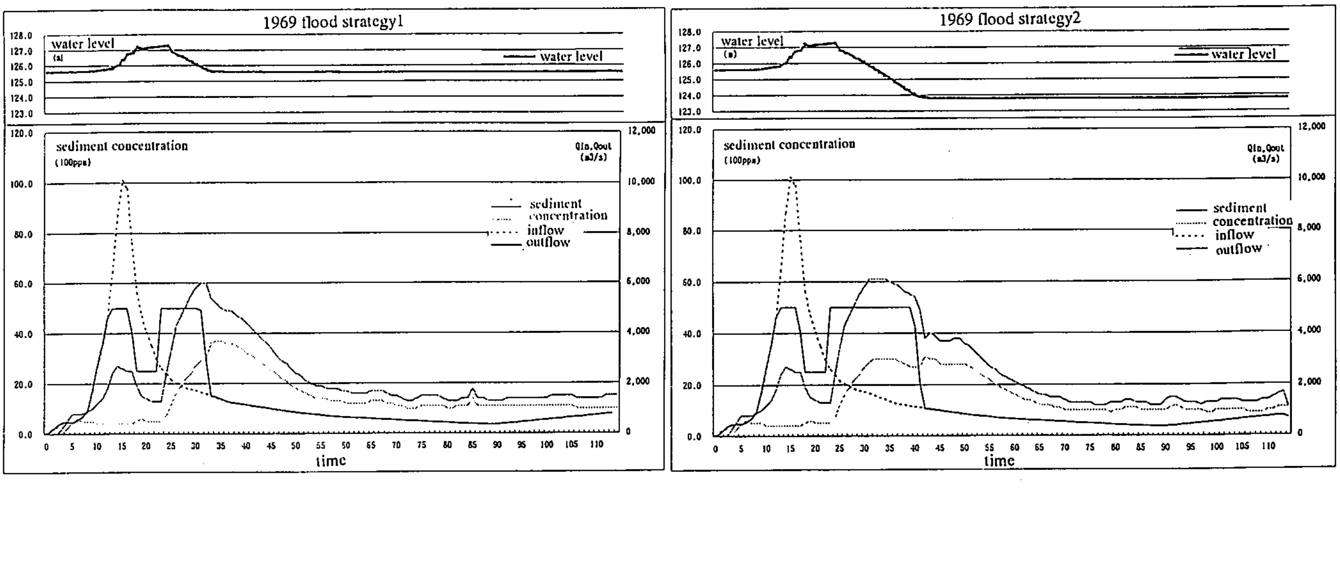

Fig. 3 Hydrographs and simulated results for the alternative operations of the bottom outlets.

Table-1 Summary of simulation for 1969 flood

Strategy-1

Floods	*Discharge ($x10^6m^3$)*			*Sediment ($x10^6m^3$)*			R_s (%)	Q_{req}
	In	Out	In-Out	In	Out	In-Out		
1962	1,292	1,317	-25	32.2	3.9	28.3	12.2	$338m^3$
1969	559	564	-5	7.2	0.8	6.4	11.0	$705m^3$
1984	666	664	2	8.3	1.3	7.0	15.8	$511m^3$

Strategy-2

Floods	*Discharge ($x10^6m^3$)*			*Sediment ($x10^6m^3$)*			R_s (%)	Q_{req}
	In	Out	In-Out	In	Out	In-Out		
1962	1,292	1,409	-117	32.2	4.1	28.1	12.8	$344m^3$
1969	559	679	-120	7.2	1.1	6.0	15.7	$617m^3$
1984	666	788	-122	8.3	1.6	6.7	19.2	$493m^3$

3. Draw-down flushing method

When draw-down flushing rule is used during floods, the reservoir will be fully drawn down a priori so that riverine flow runs down on the dry bed, score previously deposited sediment, and flush out them through the bottom outlets of the dam. A two-dimensional mudflow model was applied to simulate the behavior of reservoir sediment under this operation rule. The draw-down requirement makes this method unattractive for large reservoir, such as this, because of the difficulty in forecasting floods ahead. However, we assume this method may be implemented in future since sedimentation may progressively diminish the capacity of the reservoir.

3.1 Two-dimensional mud flow model

In the two-dimensional mudflow model, the depth average flow was calculated by applying a two dimensional shallow water flow equation, while the bed variation was calculated using continuity equation for bed load transport.

The two dimensional continuity and momentum equations, which was formulated by integrating the governing equations between the bottom and a depth, z, can be described as follows:

$$\frac{\partial q_x}{\partial t} + \beta_x \frac{\partial u q_x}{\partial x} + \beta_y \frac{\partial v q_x}{\partial y} = -gh\frac{\partial H}{\partial x} - \frac{\tau_x}{\rho} \qquad \frac{\partial q_y}{\partial t} + \beta_x \frac{\partial u q_y}{\partial x} + \beta_y \frac{\partial v q_y}{\partial y} = -gh\frac{\partial H}{\partial y} - \frac{\tau_y}{\rho}$$

Where q_x , q_y = x and y components of discharge per unit width; β_x, β_y = x, y components of momentum adjustment factor (=1.0), u, v = x and y components of the depth-averaged flow velocities; h = water depth; H = water level (ground elevation + water depth); τ_x and τ_y = x, y components of shear stress. Assuming that the bed shear stresses are described by the local depth-averaged flow velocities, τ_x and τ_y in the momentum equations can be written using Manning's mean velocity equations as

$$\frac{\tau_x}{\rho} = \frac{gn^2 u\sqrt{u^2+v^2}}{h^{1/3}} \qquad \frac{\tau_y}{\rho} = \frac{gn^2 v\sqrt{u^2+v^2}}{h^{1/3}}$$

Where g = gravitational acceleration; n = Manning's roughness coefficient.

A continuity equation of flow can be described as:

$$\frac{\partial h}{\partial t}+\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}=0$$

<u>Sediment Transport Equation</u>

Continuity equation of sediment can be described as:

$$c_* \frac{\partial z_b}{\partial t}+\frac{\partial q_{Bx}}{\partial x}+\frac{\partial q_{By}}{\partial y}=0 \qquad q_{Bx}=\frac{u}{\sqrt{u^2+v^2}}q_B \qquad q_{Bx}=\frac{v}{\sqrt{u^2+v^2}}q_B$$

Where t = time; c* = sediment concentration of bed material load; q_{Bx}, q_{By} = x and y components of bed-load transport rate per unit width, q_B = bed-load transport rate per unit width.

Because the flow contains a large volume of suspended sediment, Brown's formula stated below was adopted.

$$q_B = \Phi_B \sqrt{sgd^3}$$

Where Φ= dimensionless sediment discharge,; q_B= sediment discharge per unit width; τ*= dimensionless bottom shear stress (=u* /sgd; s=σ/ρ-1,u*=friction velocity; s= specific gravity of sediment in water; σ/ρ=specific gravity of sediment = 2.65);τ^*_c= critical dimensionless bottom shear stress(=0.05).

The entire reservoir is discretized using a finite difference cell using a grid size of 200 m. The above flow and sediment transport equations in the cells were solved explicitly using the leap-frog method.

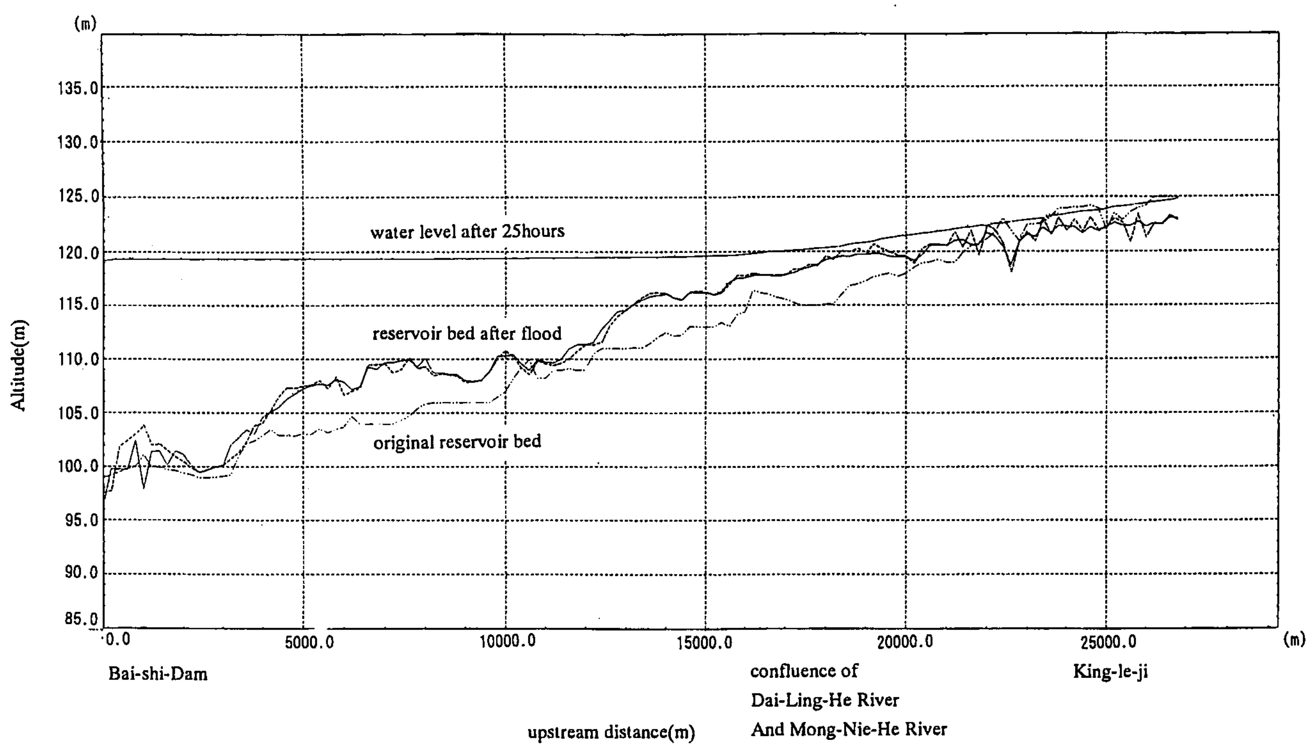

Fig. 4 Longitudinal profile of the reservoir bed

3.2 Simulation for 1969 flood

The simulation under the draw-down flushing method was made for 1969 flood, by assuming the reservoir was fully drawn down a priori from the limited water level, and flood flows into the empty reservoir. In addition, the bottom outlets were assumed to be fully open during the flood.

The total released sediment was 1.8×10^6 m^3. The ratio of the release to the total sediment inflow (7.25×10^6 m^3) was 25%. Figure 4 shows the longitudinal reservoir bed change and the simulated water level after 16 hours, respectively. Since the volume of released water, Q_{out}, was limited by the capacity of the bottom outlets, the flow was not like in a river. The water level raised high and was almost horizontal up to 15km upstream of dam. Thus, thc velocity and the bottom shear stress decreased significantly even near the dam. Consequently the longitudinal erosion did not proceed to the dam especially where the width was wide in range. Only the sediment near the dam was flushed out.

4. Conclusions

Main objective of this study was to investigate how much reservoir sediment operating the bottom outlets during floods can discharge. The two operation methods: (a) venting density current and (b) draw-down flushing were tested using and a two dimensional mudflow model and a quasi-three dimensional flow and suspended sediment simulation model.

The conclusions are:

(a) Because of the reservoir's geometric complexity and the size of the bottom sluice gates, the volume of reservoir sediment discharged by venting current density method varied from 10% to 20%, while that for draw-down flushing method was 25%. This suggests there exists a need for sedimentation mitigation measures upstream of the reservoir.

(b) The simulation models presented here should be calibrated using the field data observed after actual reservoir operations start. This is required because the models presented here have the following weakness:

- The quasi-three dimensional flow and sediment transport model does not contain the appropriate formula describing a pick up rate of sediment with such a small grain size (d_{50}=0.002mm). Ashida and Michiue's formula, appropriate for a bigger size, was applied to the model instead.
- Brown's formula can appropriately describe the sediment transport when the water level of the reservoir is relatively low. However, the sediment is transported in advection and diffusion manner when the water-level in the reservoir becomes high, Thus the advection and diffusion formula should be added to the present two-dimensional mudflow model to precisely describe the sediment transport.

5. References

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5. Water Resources and Water Quality

Chemical and Isotopic Characterization of Inland Waters around Desert Area in Xinjiang, NW China

Sadayo YABUKI*, Akihiko OKADA*, Qing CHANG**, Yoshikazu INOUE***, Akira UEDA****, and Zi-Li FAN*****

* Division of Surface Characterization, The Institute of Physical and Chemical Research
2-1 Hirosawa, Wako, Saitama, 351-01 Japan
Fax: +81-48-462-4654, Email : syabuki@postman.riken.go.jp
** Department of Environmental Science, Kumamoto University
2-39-1 Kurokami, Kumamoto, 860 Japan
***Division of Environmental Health, National Institute of Radiological Sciences
4-9-1 Anagawa, Inage, Chiba, 263 Japan
**** Mitsubishi Materials Corporation
1-297 Kitabukuro, Ohmiya, Saitama, 330 Japan
***** Xinjiang Institute of Biology, Pedology and Desert Research, Chinese Academy of Sciences
South Beijing Road 40, Urumqi, Xinjiang, China

Abstract

For seeking the origin of water and the hydrologic cycle, we investigated the major ion concentration of inland waters in and around desert area in Xinjiang, NW China. Concentrations of a short-lived radioactive isotope, tritium, two stable isotope species, oxygen-18 and deuterium (D), and isotopic compositions of strontium are also measured. The chemical and isotopic composition of the waters from these areas have regional characteristics which mean that the geological feature of their water-head and drainage areas control the chemistry of inland waters.

Hydrogen and oxygen isotope compositions show that river waters are not directly recharged by rain water, but by glacier and/or frozen ground melt, therefore the seasonal variation of isotopic compositions is not so conspicuous as that of precipitation. The results of tritium concentration of waters also suggest that glacier and/or frozen ground melt are important source of water flow of the basins in Xinjiang.

Introduction

The desert area in Xinjiang is mostly located in inland basins such as Tarim Basin, Zhungar Basin and Turpan Basin. Annual precipitation rate at desert area is small, therefore precipitation and glacier discharge at the surrounding mountain areas are major water sources for the basins. Surface flows, as well as subsurface ones from mountain ranges, irrigate oases distributing around the desert periphery, and go underground in the desert area.

Geochemical studies of water give important information for a better understanding of the influence of geological and climatic condition to a hydrologic system. From 1990 to 1994 we investigated the desert area in Xinjiang, NW China and collected inland water samples, including river waters, lake waters, ground waters (Okada and Yabuki, 1991; Okada et al., 1992, 1994a, 1994b, 1995). In this paper we review the results of major ion chemistry of inland waters under arid condition. Isotopic compositions of strontium, concentration of a short-lived radioactive isotope, tritium and two stable isotope species, oxygen-18 and deuterium (D) of the water samples, are also reported and discussed (Yabuki et al., 1993; Yabuki et al., 1996a; Yabuki et al., 1996b).

Geographical features of investigated areas

1. Tarim Basin is the largest enclosed interior basin in China, surrounded by world-famous high altitude ranges, Tianshan, Pamir, Kunlun and Arjin Mountains. Some of the peaks reach higher than 7000 m above sea level. Only the northeast of the basin is opened and leads to the Hexi Corridor, Gansu Province, but no river comes out from the basin. Taklimakan Desert, the largest sand desert in

China, occupies most part of the Basin. Annual precipitation at the central desert area is less than 10 mm and around desert periphery is 60 to 80 mm and evaporation rate is 2000 to 3000. The basin slopes from southwest to northeast to the lowest point, Lop Nur. Rivers from surrounding mountain ranges, such as Akesu River, Kashigar River, Yercheng River, Hetian River and Keliya River, finally join to Tarim River, the largest river in Tarim Basin which runs from the west to the east. Tarim river as well as Kongque River at eastern part and Cherchen River at the south-eastern part becomes underground stream toward the lowest point, Lop Nur.

2. Zhungar Basin in northern Xinjiang is surrounded by Tianshan and Altay Mountains. The center of the basin is occypied by Gurbantenggut Desert, the second largest sand desert in China. The basin is opened toward the north-west, and moist currents come from this direction. Therefore the climate of Zhungar Basin is relatively moderate comparing with other desert areas in Xinjiang. The annual precipitation amounts to 200 mm at the northern foot of Tianshan Mountains and 100 mm even in the desert area.

3. Turpan Basin constitutes an intermontane basin found within the eastern Tianshan Mountain Ranges. The north of the basin is flanked by Mt. Bogeda with 5445 m height. Huoyanshan Mountains at the northern part of the basin divide the basin into two parts. The lowest area of the basin is Aidinghu Lake which located southern part of the basin with -154 m below sea level.
Turpan Basin is known as one of the most dried and high-temperature region in China, with less than 20 mm of annual precipitation and 3000 mm evaporation. The melted snow and glacier water at the mountain region and precipitation rushed out from the outlet of the mountain valley, then disappear into desert, therefore, it formed the aquifers that rich in dynamic storage of ground water.

Samples

Water samples including river waters, ground waters, soil waters and lake waters are collected by the field investigations executed every year in October from 1990 to 1994. Sampling location maps are shown in Fig. 1. As sampling area covers wide range, we divide sampling areas as follows:
1. Northern and eastern parts of Tarim Basin: Including Akesu, Kuche, Luntai and Kuerla and Yuli, Tieganlike and Alagan. The area is consist of fluvial fans and alluvial-fluvial plains of southern foot of Tianshan Mountains, river basins of Tarim River, Kongque River and Bositenghu Lake.
2. Southern part of Tarim Basin: Northern foot of Arjin mountains and Kunlun Mountains, Ruoqiang, Qiemo, Minfeng, Yutian and Hetian, including river basin of Cherchen River, Keliya River and Hetian River.
3. Western and south-western parts of Tarim Basin: So called Kashigar Delta between South Tianshan Mountains and West Kunlun Mountains, including Yerchen River and Kashigar River basins.
4. Pamir: The Pamir Plateau, located in the western part of Tarim Basin, is 4000 m hight on average. Some peaks are higher than 7000 m above sea level.
5. South-western part of Zhungar Basin
6. Turpan Basin

Analysis

1. Temperature, pH and electric conductivity of the samples are measured at sampling sites with portable pH and SC meters. HCO_3 and CO_3 content are determined by titration.
Major cations, K, Na, Ca and Mg and Strontium concentration are determined by inductively coupled plasma spectrometer (Japan Jarrell-Ash, ICAP-575 II). Anions such as Cl, SO_4 and NO_3 are measured using ion chromatography (Shimadzu, HIC-6A). \
2. Tritium concentration: The measurements of tritium concentration are carried out using liquid scintillation counter (Packard, TRI-CARB 2260). Detection limit is 0.2Bq/L (50ml water, 2000 minutes).

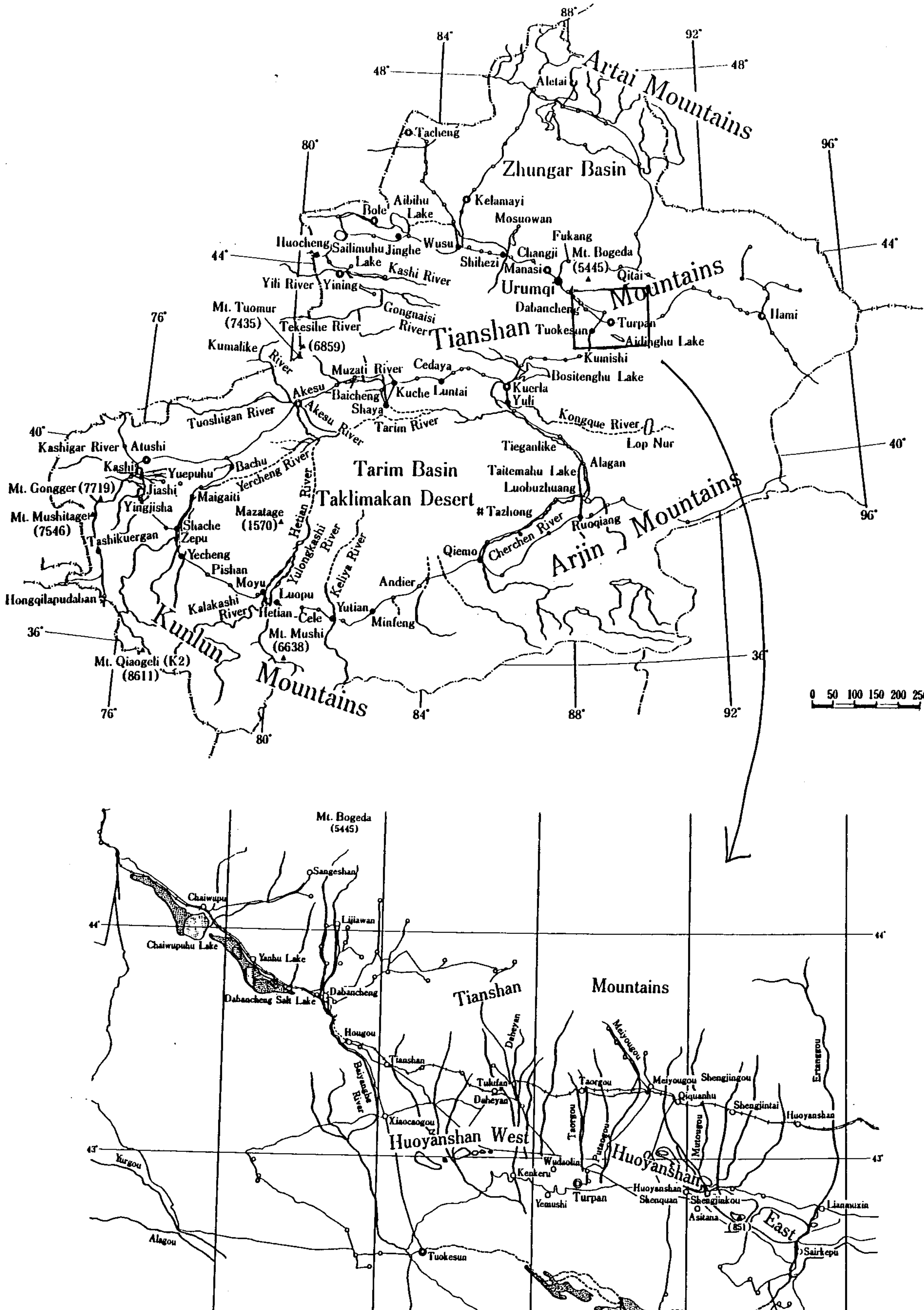


Fig. 1 Maps of Xinjiang (upper) and Turpan Basin (lower) showing the sampling locations

3. Hydrogen and oxygen isotopes: For measurements of deuterium and oxygen isotope composition, water samples are decomposed into hydrogen and oxygen gases. Hydrogen gas can be collected by water-metal zinc reaction at 420 °C for 6 hours. In the case of oxygen, isotope exchange between water and carbon dioxide is used. Prepared gas samples are analyzed by Niel type double inlet mass spectrometer (Finigan Mat Delta-E). Measured values are expressed as δ value, permil deviation from a reference, defined by the following formula.

$\delta = 10^3 (R - R_0) / R_0$ (‰)

Here R and R_0 are isotope ratios of the sample and the standard, respectively.

4. Strontium isotopic composition: Filtered water samples are directly passed through a cation exchange resin (AG 50W-X8 Resin, Bio-Rad) column in HCl media to separate strontium from other major elements. The isotopic composition of Sr was determined by using a thermal ionization mass spectrometer (VG Elemental VG54).

Results and discussion

1. Chemical types of inland waters

According to Piper (1944), chemical type of water can be plotted on tri-linear diagram as the function of major cation (Ca-Mg-(Na+K)) and major anion (HCO_3-Cl-SO_4) concentration as shown on Fig.2. Piper diagram is useful to discuss the environmental condition and chemical characteristics of water samples. Water belongs to the area I is (Ca-HCO_3) type, river water and shallow ground water belong to this category. Area II is Na-HCO_3 type, fresh ground waters usually show this type. Area III is Ca-SO_4 or Mg-SO_4 type of the waters under special geological environment. Waters belong to Type IV, Na-SO_4 and Na-Cl type is saline water.

Fig.2A Waters from Zhungar Basin, and Akesu River belong to Ca-HCO_3 type while Tarim River belong to Na-Cl type. The results suggest that Tarim River is strongly affected by saline soil of river drainage. Bositenghu Lake and Kongque River show Na-SO_4, but waters from lower reaches-desert area show Na-Cl type.

Fig. 2B Waters from southern part of Tarim Basin belong to Na-Cl type, not only desert area but also ground waters and river waters of Kunlun Mountain area. It is suggested that salt layer in Kunlun Mountains provide Na and Cl ions to water systems . Waters from Pamir belong to Ca-HCO_3 type.

Fig. 2C and 2D. In Turpan Basin, most of water comes from Bogeda Mountains. Waters belong to Tianshan Mountains show Ca-HCO_3 at upper reaches and after they passed Huoyanshan Mountains they change their chemical type to Na-SO_4 because of sodium sulfate enriched layer in Huoyanshan Mountains. Waters from desert area show Na-Cl type. Karez is a method to exploit and utilize the ground water in arid region. Through the subsurface tunnels, the groundwater could flow out itself to the ground surface. Karez water from Wudaolin shows Na- Ca-HCO_3 type, same as spring waters at the foot of Huoyanshan Mountains, while the well waters show $NaSO_4$ type, which shows Karez keep their water quality better than teh well water.

2. Correlation between major soluble ions

(Na+K)-Cl: Most of river waters in Xinjiang, concentration ratios of (Na+K)/Cl are more than unity. This means that sulfate and carbonate ions also contribute to valance with sodium and potassium ions. Especially in Turpan Basin, sodium ion is provided as Na_2SO_4 that widely spread at the central area of the basin. Correspond to excess (Na+K)/Cl ratio of river waters of lower reaches from Turpan Basin, (Ca+Mg)/SO_4 ratios at lower reaches show less than unity, and other waters of lower reaches are equal unity, which suggest, that the river waters are strongly affected drainage soil salt characteristics. While, at upper reaches, cation concentrations exceed Cl and sulfate concentration. The results suggest that at the upper reaches, sodium, potassium, calcium and magnesium are derived not only from evaporites but also from carbonate or silicate rocks. At the upper reaches in Turpan Basin, (Ca+Mg)/HCO_3 ratio is nearly equal to unity, which suggest that main sources of these ions are carbonate rocks.

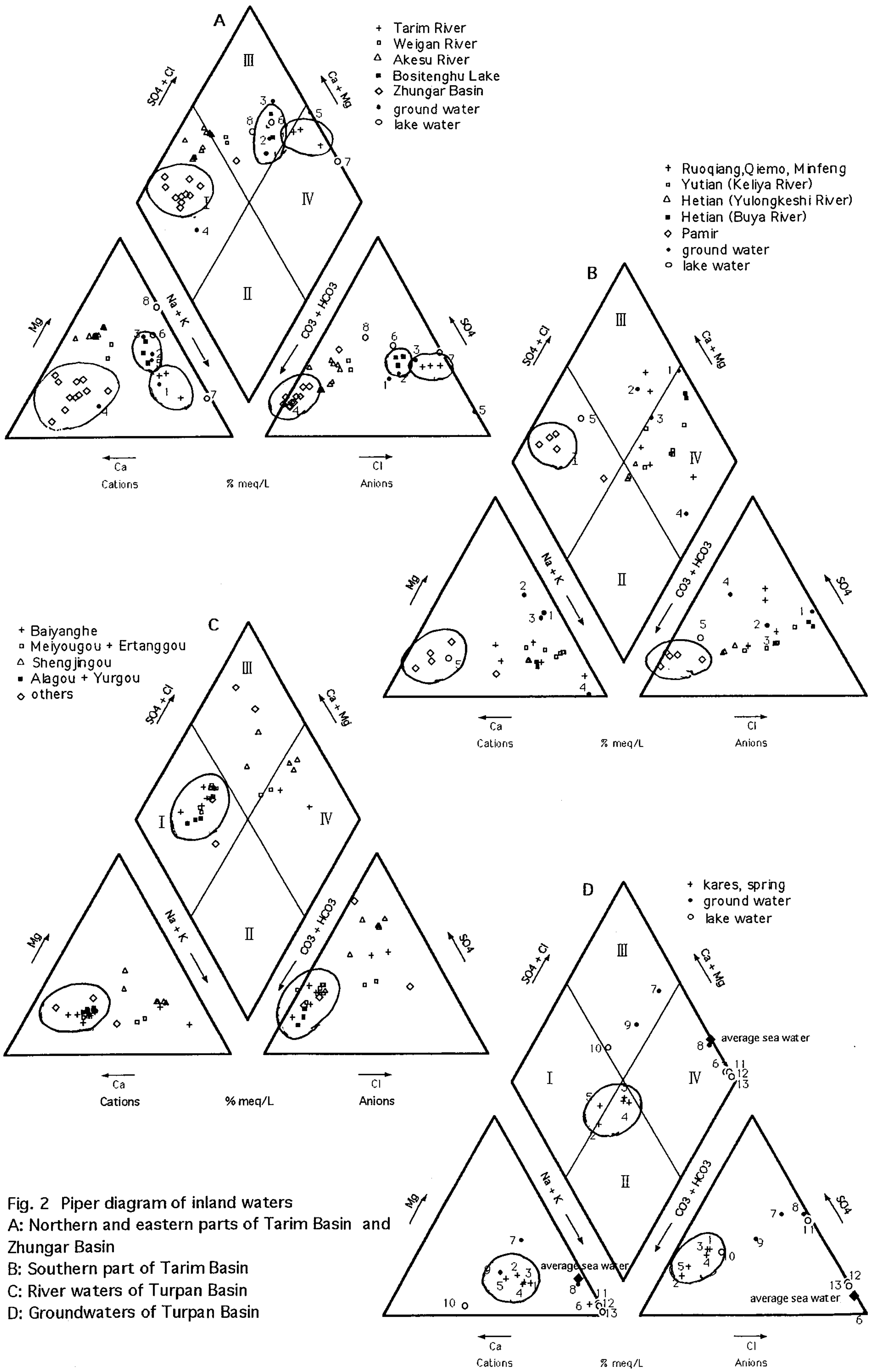
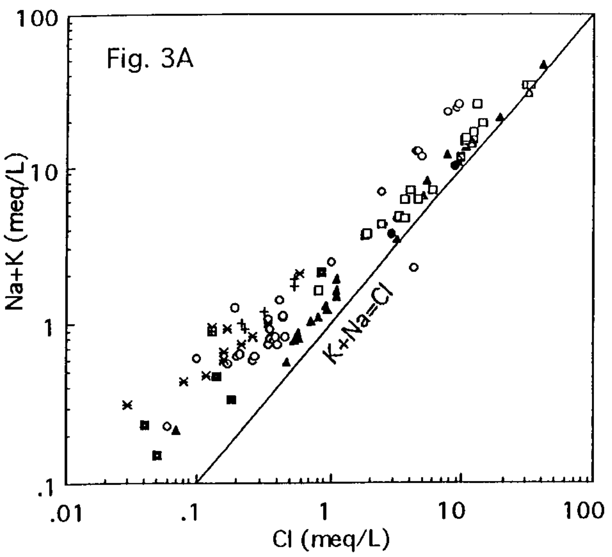


Fig. 2 Piper diagram of inland waters
A: Northern and eastern parts of Tarim Basin and Zhungar Basin
B: Southern part of Tarim Basin
C: River waters of Turpan Basin
D: Groundwaters of Turpan Basin



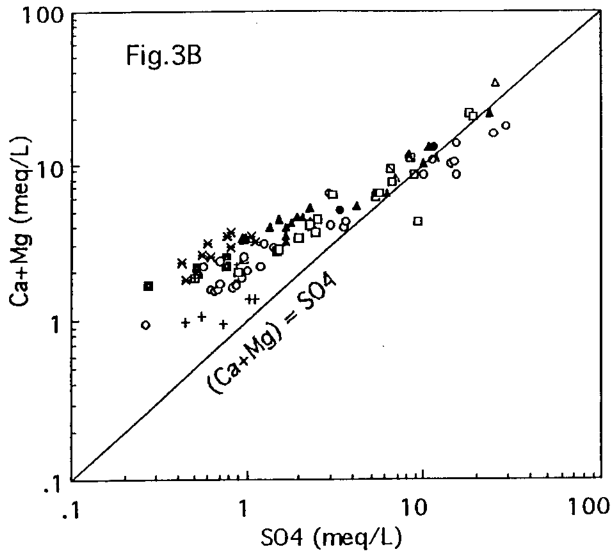
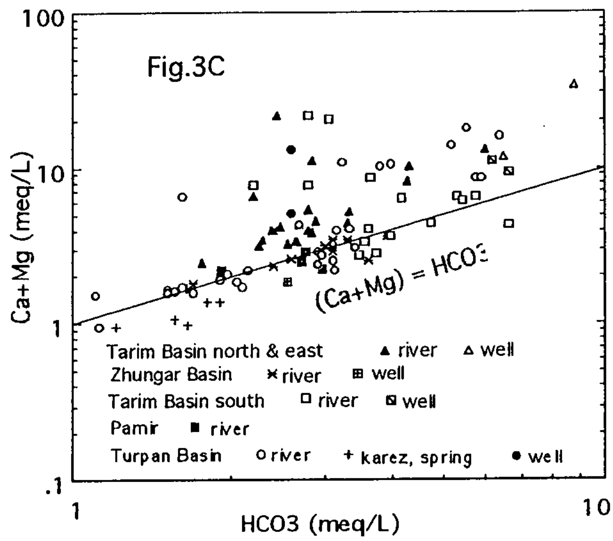


Fig.3 Correlation between major soluble ions
A: (Na+K)-Cl
B: (Ca+Mg)-SO4
C: (Ca+Mg)-CO3



3. Variation of strontium isotopic composition

Variation of strontium isotopic compositions of waters are shown in Fig. 4. It has conspicuous regional characteristics. $^{87}Sr/^{86}Sr$ ratios of waters from Turpan Basin have the lowest value (0.7069 - 0.7097), while increasingly higher values are found in the Zhungar Basin (0.7083-0.7104), northern and eastern parts of the Tarim Basin (0.7102-0.7113) and western and southern part of Tarim Basin (0.7104 - 0.7137). Each region has relatively constant strontium isotopic composition. Such regional uniformity suggests that strontium is mainly derived from evaporite minerals in sedimentary rocks in the mountain area and from salt deposits in the lower drainage. It is known that low strontium isotopic composition comes from carbonate rocks, and strontium of high isotopic composition is caused by igneous or metamorphic rocks. The source of strontium of low isotopic composition in Turpan Basin is considered to be carbonate rock in Bogeda Mountain.

In southern Tarim Basin, the variation of strontium isotopic composition is larger than that of other regions (0.7104-0.7126). Especially, $^{87}Sr/^{86}Sr$ ratios of Yulongkashi River are highest, 0.7130 - 0.7137. The high $^{87}Sr/^{86}Sr$ ratios could be due to the local sources, some igneous or metamorphic rocks in high mountain ranges of Kunlun Mountains.

Tritium concentration

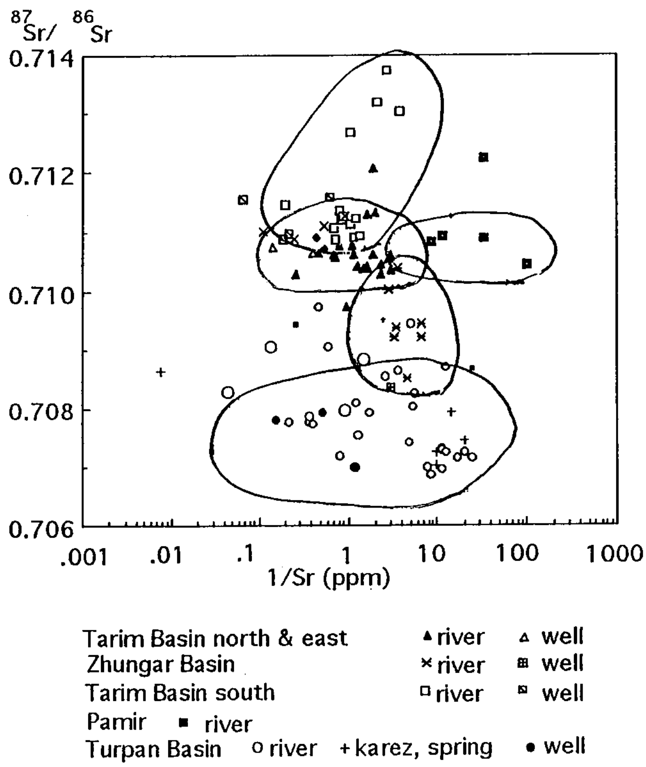


Fig. 4 Variation of strontium isotopic composition

4 Tritium concentrations in inland waters around desert areas in Xinjiang are classified into three groups.
4-1. Waters of nearly zero tritium concentration: Ground water, including well water and spring water. They belong to fossil waters or cycled waters with long residence time.
4-2. Waters of high tritium concentration, more than 5 to 17 Bq/L: River waters and lake waters at mountain areas. The results indicate that these waters are affected by glacier melts of high tritium concentration.
4-3. Waters, tritium concentration of which are between groups 1 and 2,: River waters and some ground waters at low altitude areas. They are possibly mixtures of both groups.

5. Deuterium and ^{18}O contents of inland waters

Regional distribution of the hydrogen and oxygen isotopic ratios are shown in Fig. 5 and Fig. 6, which show that river waters from Pamir Plateau have light isotopic ratios, then increasingly higher values are found in the Zhungar Basin, Turpan Basin and Tarim Basin. The isotopic compositions of river waters from the Turpan Basin are within the extent of those from Tarim Basin. Comparing with meteoric waters in Tarim Basin, δD values of inland waters are neither consistent with winter nor summer precipitation. The results suggest that river waters are not directly recharged by rain water, but recharged by glacier and/or frozen ground melt.

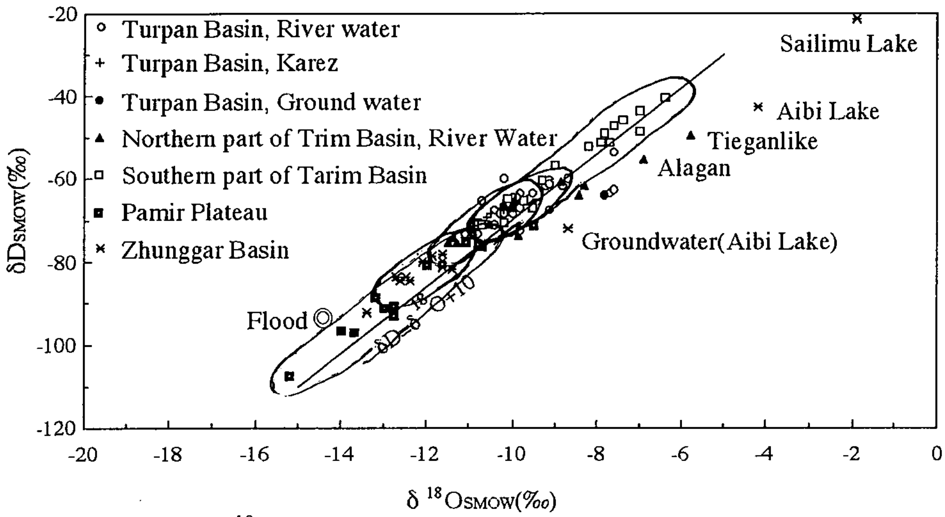


Fig. 5 δD vs. $\delta^{18}O$ of inland waters around desert areas in Xinjiang.
Data of northern part of Tarim Basin are from Wushiki et al., 1993

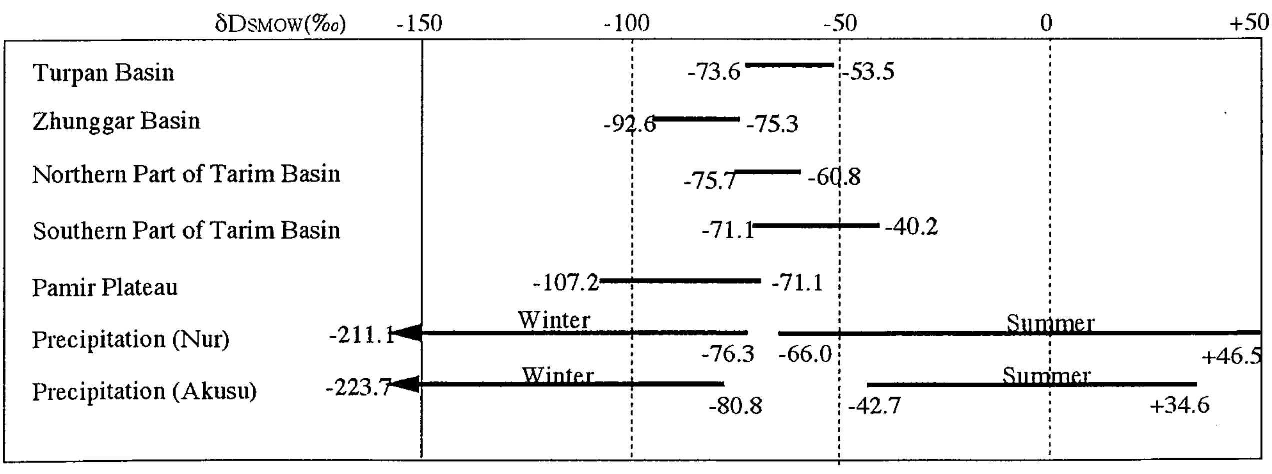


Fig. 6 δDSMOW(‰) of inland waters around desert areas in Xinjiang.
Data of northern part of Tarim Basin and precipitation are from Wushiki et al. (1993)

Conclusion

1. River waters in Xinjiang show Ca-HCO_3 type at upper reaches and change into Na-SO_4 and Na-Cl types reflecting soil properties around river drainage.

This result is consistent with the correlation between soluble major ions, i.e.. at the upper reaches, HCO_3 ions show good correlation with Ca+Mg ion, while at the lower reaches, Ca+Mg correlate with SO_4 ion

2. Strontium isotopic compositions have conspicuous regional variation. Each region has relatively constant isotopic composition. Such regional uniformity suggests that strontium is derived from evaporite minerals in sedimentary rocks in the mountain area and from salt deposits in the lower drainage.

3. Hydrogen and oxygen isotope composition show that river waters are not directly recharged by rain water, but by glacier and/or frozen ground melt, therefore the seasonal variation of isotopic composition is not so conspicuous as that of precipitation. The results of tritium concentration of waters also suggest that glacier and/or frozen ground melt are important source of water flow of the basins in Xinjiang.

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The Present Situation and Countermeasures of Groundwater Contamination in Japan

Shizuo Shindo and Changyuan Tang
(Center for Environmental Remote Sensing, Chiba University, Japan)

Abstract

Since 1982, thousands of groundwater pollution cases have been found in Japan. In order to improve the groundwater quality, Japan has developed strategies for protection of groundwater. In this paper, authors try to explain the present of groundwater use, groundwater pollution and remediation methods in Japan. From the results shown in this paper, it can be found that groundwater pollution problem has become very serious in Japan. Even many efforts have been made to improve the situation in past 15 years, there is still a long way to go to reach the goal since the characteristics of subsurface water movement and limitations of remediation technologies. Finally, groundwater pollution situation in Tokyo was discussed in more detailed.

Key words: Groundwater pollution, Remediation, Groundwater management

1. Introduction

Groundwater is immensely important for human water supply in both the urban and rural areas in Japan. Groundwater is naturally of excellent microbiological quality and generally of adequate chemical quality. According to results of census in 1994, 1.577×10^{11} m^3 of groundwater have been used for urban (4.05×10^{10} m^3), industry (6.04×10^{10} m^3) and agriculture (5.68×10^{10} m^3), which means that about 17.0% of water used in Japan comes from groundwater. Especially, 38.3% water used for industry, and 25.7% for urban life are groundwater. Figure 1 shows the variations of groundwater uses from 1974 to 1993. It was found that groundwater use increased for urban life, decreased for industry and kept constantly for agriculture in this period. It is clear that the demand of groundwater use now is the same as before.

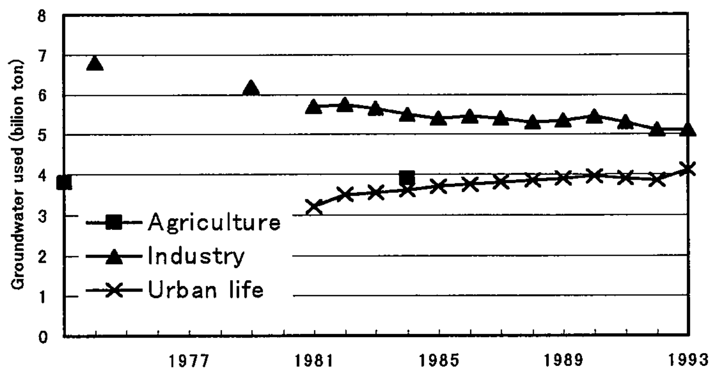

Figure 1 Variations of yearly groundwater used from 1974 to 1993.

2. Groundwater quality

Groundwater pollution due to volatile organochlorine like trichloroethylene and tetrachloroethylene has become a great environmental issue in Japan as well as in many developed nations. Comparing with surface water pollution, groundwater pollution was found later, but in larger regional scale, even contaminants had been put into subsurface at the same time. The nation-wide groundwater pollution survey for organochlorines started in 1982, and so for 2 through 5 percent of groundwater samples every year cannot meet the standard for drinking water of trichloroethylene and tetrachloroethylene. Figure 2 shows the variations of groundwater pollution cases found in the period of 1975 to 1995. In this period, 1,151 groundwater pollution cases have been found, and only 24.9% have been treated to meet Environmental Standard at the end of 1995. Most of contaminants found in groundwater were tetrachloroethylene, trichloroethylene, arsenic, 1,1,1-trichloroethane and cis1,2-Dichloroethane. About 67% of cases, the pollution area kept constant or expanded (Figure 3). It means that the groundwater pollution is a long-term problem. From viewpoint of groundwater use, 25% of pollution cases were found in the wells for drinking, and 75% for industry. However, only half cases of groundwater polluters have been identified. Also more than 50% of heavy metals pollution in groundwater occurred in nature.

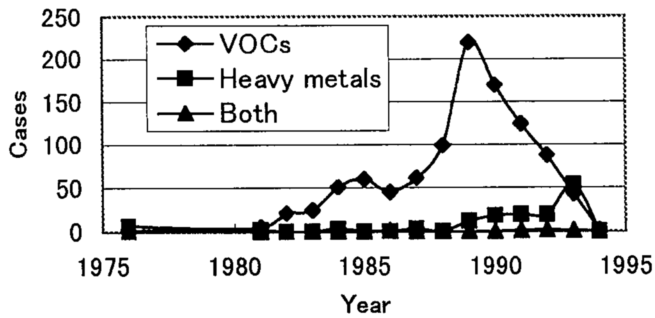

Figure 2 Variations of groundwater pollution cases found from 1975 to 1995.

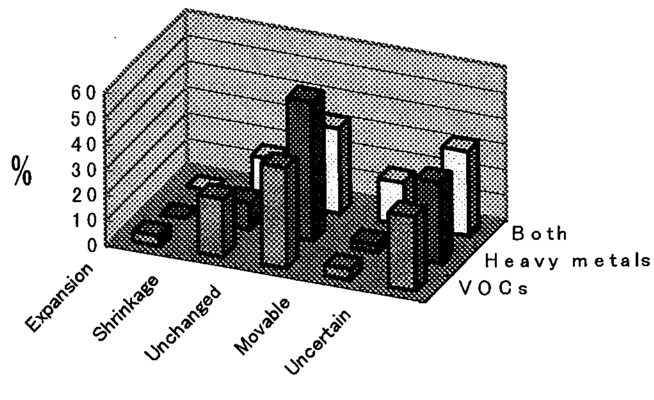

Figure 3 Variations of pollutants plume distribution.

3. Monitoring

As well known, VOC contaminants present underground can be in following four phases, i.e. gas, liquid, dissolved or sorbed.

A. As gas phase
  1. Contaminant vapors as a component of soil gas in the unsaturated zone

B. As liquid phase
  1. Liquid contaminants adhering to "water-dry" soil particles in the unsaturated zone
  2. Liquid contaminants in the pore spaces between soil particles in the saturated zone
  3. Liquid contaminants in the pore spaces between soil particles in the unsaturated zone
  4. Liquid contaminants floating on the groundwater table
  5. Liquid contaminants in rock fractures in either the unsaturated or saturated zone

C. As dissolved phase
  1. Contaminants dissolved in groundwater
  2. Contaminants dissolved in the water film surrounding soil particles in the unsaturated zone
  3. Contaminants that have diffused into mineral grains or rocks in either the unsaturated or saturated zone
  4. Contaminants dissolved in the mobile pore water of the unsaturated zone

D. As sorbed phase
  1. Contaminants sorbed to "water-wet" soil particles or rock surface (after migrating through the water) in either the unsaturated or saturated zone
  2. Contaminants sorbed on to colloidal particles in water in either the unsaturated or saturated zone
  3. Contaminants sorbed onto or into soil microbiota in either the unsaturated or saturated zone

According the above classification, there are three kinds of pollution cases. Firstly, pollutants move in unsaturated zone and have not reached to the groundwater. Secondly, pollutants can be found both in unsaturated zone and saturated zone. Thirdly, pollutants can only be found in groundwater. Clearly, the first type is an evil omen of groundwater pollution, the second type is usual case found in pollution points, and the third one can be found in the area around the pollution point. As a result, the monitoring methods used are strongly depended upon the pollution cases.

The success of remedial operation totally depends on how much information concerning the contaminants existing form and location in subsurface environment and the areal extent of pollution can be obtained. Therefore, groundwater monitoring is very important. Since 1989, groundwater qualities have been monitored throughout the country based on the revised "Water Pollution Protection Law". There are two kinds of monitoring systems, i.e. the routine monitoring and extraordinary monitoring. During the monitoring, pollution source, leakage, pollutant plume distribution should be checked. Based on the monitoring results, the assessments of groundwater pollution, groundwater remediation and environmental impacts can be carried out.

4. Solutions

The organochlorines have several insidious features to be little soluble in water and to be strongly resistant to biodegradation in subsurface environment. Such physic-chemical properties prolong the groundwater pollution once the undiluted liquids intrude into soil and groundwater zones. In addition, the groundwater pollution incidents involve difficulties to be solved, for example, not easy to identify the contaminant source and existing form in subsurface environment because of various usage in many industries, insufficient number of wells in existence to delineate the contaminant plume boundary in regional groundwater, etc.

Generally, the following steps will be taken for groundwater remediation.

a. Identification of pollution area and its sources;
b. Identification of pollution situation (in unsaturated zone or saturated zone);
c. Selection of suitable remediation technology;
d. Operation of remediation; and
e. Assessment of remediation result to meet the environmental standard.

Table 1 shows the remediation technologies used in Japan. It was found that single technology can not have a satisfying remedial efficiency, since no one can cover all steps for groundwater remediation. The most urgent problem at present to be solved is how long the remedial operations should be done because each technology has its own limitation for remediation. In this context, the suitable standard to finish the operation and the method to evaluate the effects of the remedial operations are desired.

5. Case Study

Table 2 shows the highest concentrations of trichloroethylene, tetrachloroethylene, 1,1,1-trichloroethane, 1,1-dichloroethane and cis1,2-dichloroethane found in the groundwater of Tokyo area. In many pollution cases, it was found that 1, 1-dichloroethane and cis1,2-dichloroethane had close relationships with trichloroethylene and tetrachloroethylene. As a result, both have been checked since 1995. From Table 1, the highest concentrations of trichloroethylene and tetrachloroethylene have decreased since 1992, especially in the area where groundwater remediations were on operation. On the other hand, the highest concentrations of 1,1,1-trichloroethane, 1,1-dichloroethane and cis1,2-dichloroethane increased slowly.

Figure 4 shows the variations of percentage of groundwater samples that could not meet the environmental standard in Tokyo area. It was found that groundwater quality had been improved greatly from 1986 to 1990, when groundwater remediation began. However, groundwater pollution by VOCs has not decreased, in spite of many efforts made to get contaminants out from groundwater after 1990. Here, we found that there are some limitations for the present remediation technologies. As a result, the groundwater pollution is a long-term problem.

Table 1 In-situ technology comparisons

In Situ Technology	Design Basis	Operational Mechanism	Applicability	Scale	Expected Efficiency	Commercial Availability
Aerobic Biodegradation	Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/ High	Pilot/ Available
Anaerobic Biodegradation	Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/ High	Pilot/ Available
Electro-Osmosis	Theoretical	Treatment/ Recovery	Dissolved phase only	Pilot	Low	Available
Electroacoustic Soil Decontamination	Empirical/ Theoretical	Treatment/ Recovery	Dissolved phase only	Labor atory	Low	Emerging
Slurry Walls	Empirical	Containment	Dissolved and separate phase	Full	High	Available
Grouting	Empirical	Containment	Dissolved and separate phase	Full	Intermediate/ High	Available
Hydraulic Gradient Control	Theoretical	Containment	Dissolved phase only	Full	Intermediate/ High	Available
Stabilization/ Solidification	Empirical	Containment	Dissolved and separate phase	Full	Intermediate/ High	Available
Permeable Treatment Walls	Empirical/ Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/ High	Pilot
Alkali Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate/ High	Pilot/ Available
Cosolvent Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Labor atory	Intermediate	Emerging
Surfactant Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate/ High	Pilot/ Available
Water Flooding	Empirical/ Theoretical	Recovery	Dissolved and separate phase	Full	Low/ Intermediate	Available
Air Sparging	Empirical	Recovery	Dissolved phase only	Full	Intermediate/ High	Available
Vacuum Vaporizer Wells	Theoretical	Recovery	Dissolved phase only	Full	Intermediate	Available
Steam Enhanced Extraction	Theoretical	Recovery	Dissolved and separate phase	Pilot	High	Pilot/ Available
Radio Frequency Heating	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate	Pilot
Vitrification	Empirical	Treatment/ Recovery	Vadose Zone only			

Table2 The highest concentrations detected from groundwater from 1992 to 1996

Year	trichloroethylene	Tetrachloroethylene	1,1,1-trichloroethane	1, 1-Dichloroethane	Cis1,2-Dichloroethane
1992	1.6	7.4	0.45	Unavailable	Unavailable
1993	1.2	4.7	0.11	Unavailable	Unavailable
1994	0.63	0.83	0.087	Unavailable	Unavailable
1995	0.81	0.93	1.5	0.058	0.22
1996	0.77	1.6	3	0.38	0.36

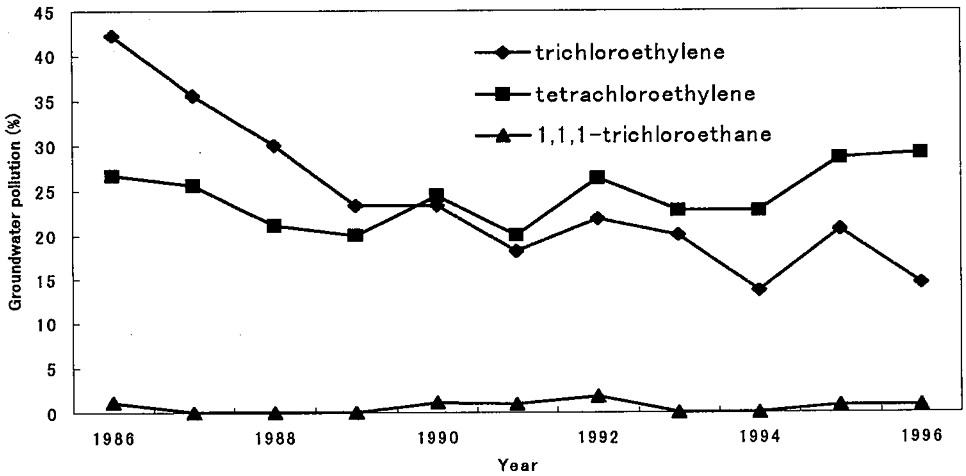

Figure 4 Variations of percentage of groundwater samples that could not meet the environmental standard in Tokyo area.

6. Conclusions

Management of our groundwater systems of necessity should be underpinned by sound science. By nature, management strategies should also be evolutionary and adaptive. There has been a very strong interest in groundwater in relation to environmental management generally, and more specifically to combat land degradation, for maintenance of healthy ecosystems, as well as for protection and maintenance of potable water resources.

From hydrological point of view, groundwater movement is one of slower parts in water cycle. At the same time, contaminants such as VOCs can remain in soil or aquifer for a long time. From the results shown in this paper, it can be found that groundwater pollution problem is very serious in Japan. Even many efforts have been made to improve the situation in past 15 years, there is still a long way to reach the goal.

The existing form and concentration of contaminant in the subsurface environment will change with local water movement and remediation processes. Moreover, the application of a single technique to the contaminated site is limited to reach the final goal, in which the subsurface contamination is repaired to meet the regional groundwater usage. From the cost-beneficial point of view, it is of great significance to pick the suitable techniques up or combination of techniques, and in particular to keep the flexible operation in changing remediation techniques, corresponding to the existing form of contaminant in the subsurface environment.

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Water Quarity of Wells in Me Kong Delta in the Rainy Season

Keizo NAKAMURA (Keiai Univ.)*, Yuichi TATSUZAWA (Keiai Univ.)
Koji KODERA (Hosei Univ.), Kunihide MIYAOKA(Bunkyo Univ.)

Following the economic development in Me Kong river basin, it is feared that the influence of the development spreads to Me Kong Delta area in Viet nam and the Hydro-environment become worse.

Therefore, the survey of the water quarity of wells was carried out in Hoa Thuan village in Me Kong Delta of Viet nam, August 1996. The village is situated beside the mouth of Me Kong River. The wells are on the sand ridge which extends from north to south. The results are summarized as follows:

1) The electric conductivity, the concentrations of NH3-N, Fe and Cl, the hardness and so on of the water of the deep wells are higher those of shallow wells. Those values of the deep wells on the sand ridge decrease as the well stands apart from the other toward the south. This is considered to occure from increase of the distance between the sand ridge and Co Chien River.

2) The value of NH3-N in the deep wells is higher than that of shallow well, and this is caused by the orgnic matter which is accumulated in the deep layer.

3) Excepting the well in the northern part which have water like sea water with respect to the salinity, the shallow wells have water exhibiting the low level salinity.

4) The deep wells are classified into three groups according to the water quality, that is, the well highly contaminated (located on the north end of ridge to about 4km point toward the south), medially contaminated (located to about 7km point) and low contaminated (located to about 10km point).

From these, it is suggested that the ground water is effected by the river water which is situated in tidal compartment.

A continual survey will hereafter be made on the problems of water Quality and use of ground water.

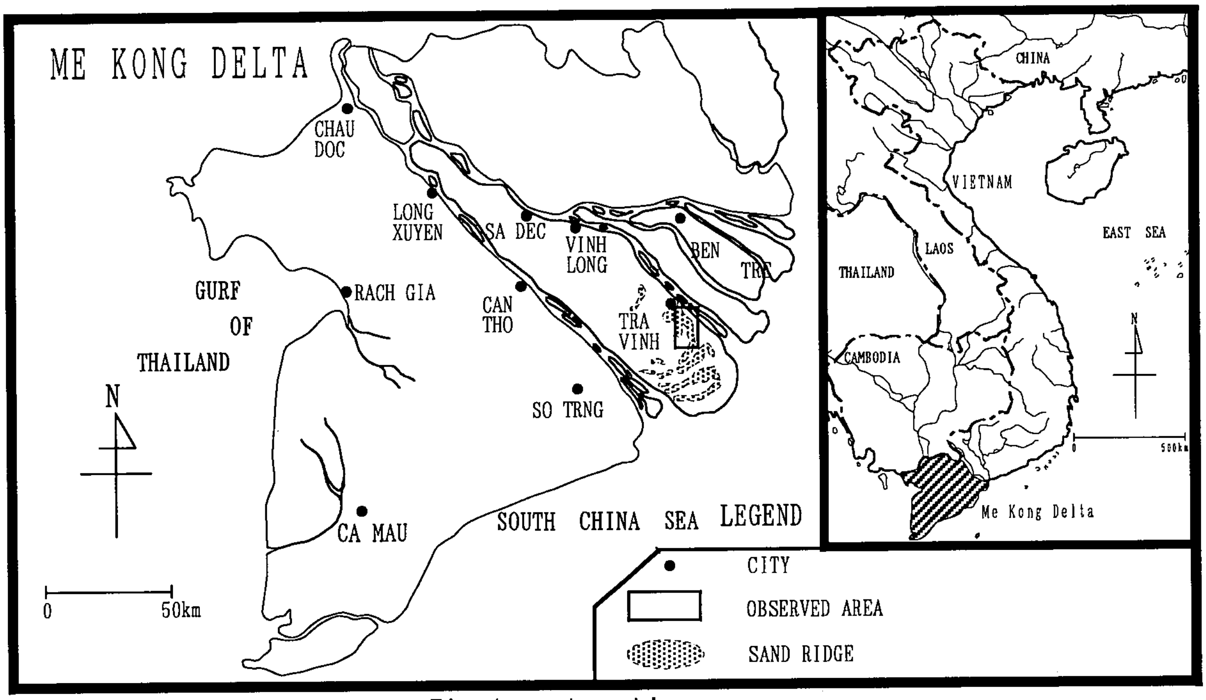

Fig.1 Location map

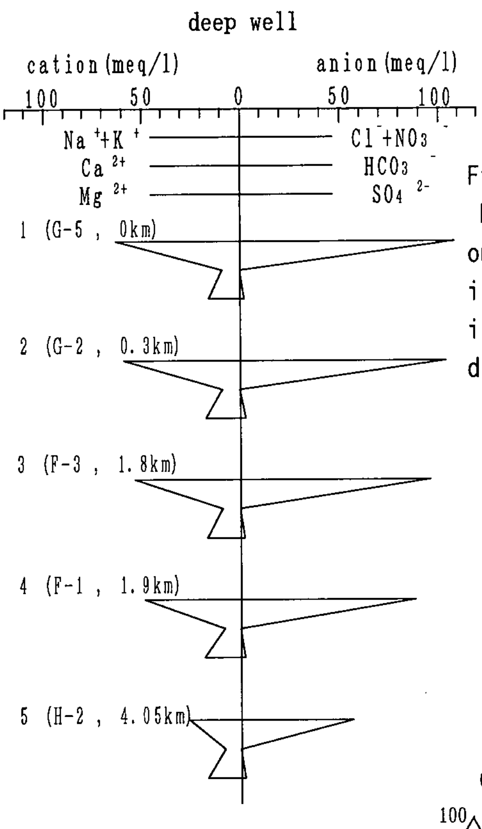
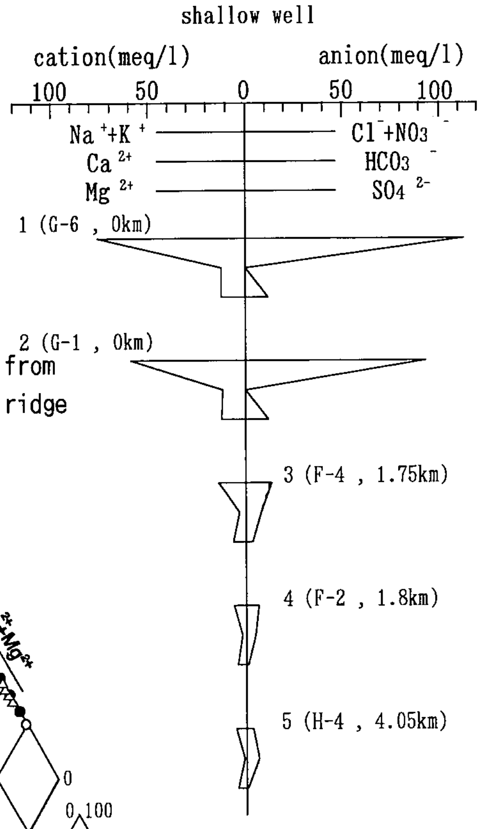

Fig.2
Hexadiagram
on the sand ridge
in Hoa Thuan village
in August,1996.
distance(km):surveyed from
the north end of the ridge

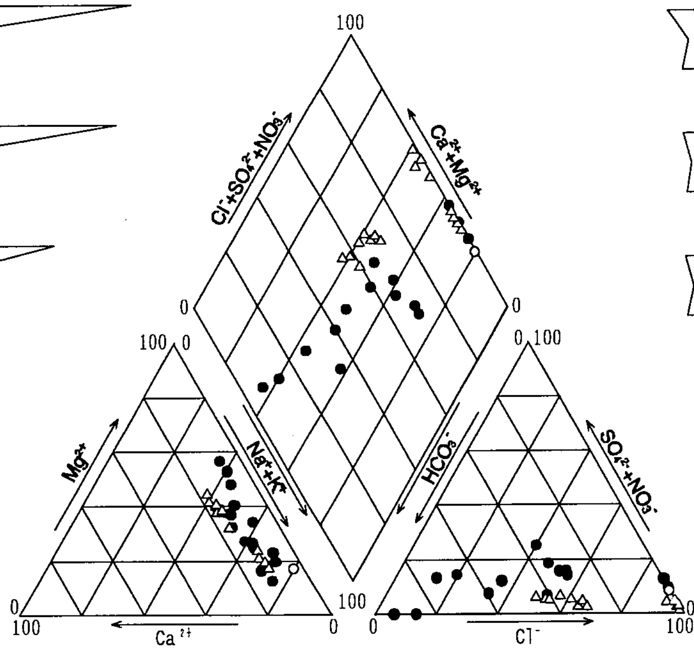

Fig.3
Trilinear diagram
on the sand ridge
in Hoa Thun village
in August,1996.
shallow and deep wells.

Comparison of Atmospheric Deposition and Substance Budget at the two Small Catchment of Tokyo and Beijing Suburbs

Feng Yanwen* Ogula Norio* Feng Zongwei**

* Tokyo University of Agriculture and Technology

** Research Center for Eco-Environment Sciences, Chinese Academy of Sciences, Beijing, China

Abstract

Information on air pollution,effects of air pollution and acid deposition on forest and soil, element budget have been investigated from May 1995 to May 1996 in Beijing suburban catchment (Shisanling) and Tokyo suburban catchment (Hakyuti). The pH annual average value of rainfall was 6.7 at Shisanling and 4.7 at Hakyuti. Air pollution at Shisanling was classified to sulfuric acid type and nitrate acid type at Hakyuti. Concerning material budget at the two small catchments, sodium and magnesium outputs were large than their atmospheric inputs, so sodium and magnesium leached from the two catchments. Other ions (SO_4^{2-}, F^-, NO_3^-, Cl^-, K^+, Ca^{2+}, NH_4^+) have been accumulated at Shisanling and Hakyuti. Discharge and accumulation of all elements (except NO_3^-) in Shisanling were larger than those at Hakyuti. That is because discharge and accumulation depended on deposition. Deposition at Shisanling was larger than that at Hakyuti. On the other hand, Fluoride was remarkably different between Shisanling and Hakyuti, 81% of the input was accumulated at Shisanling and 110% of the input was discharged at Hakyuti.

Introduction

Recently environmental acidification (acid rain) has become a major environmetal problem in the world. East Asia where has shown rapid ecomonic growth in recent years is receiving considerable international attention. It has already become a third biggest region of acid rain in the world. The regions to the south of Yangzi River occupied half of that (Wang,1997).

Since 1981, investigations on acid rain have been conducted at all regions in China. As a results , it was found that sulfur (SO_2) is the cause of acid rain in China, and regions where rainfall pH was below 5.6 have steadily extended to the northsouthern region in recent years. The damages of acid rain to forestry and agriculture were found in the regions to south past of Yangzi River. In most areas of the north, the amount of acid substances are high,but because alkaline particulates are rich and pH value of soil is high, there have been no reports of occurrences of acid rain . However if emission of atmospheric pollutants keeps at the recent level, in the future there will be the possibility of effects of acid rain on forestry and agriculture. A small catchment (Shisanling) at Beijing suburb was secelted for assessment of the condition of air pollution , including the effects on forest and soil.

On the other hand, The pH annual average value(1996) in precipitation was 4.8~4.9 in Japan. The extensive occurrences of forest decline and lake acidification have not been carried in the catchment of Tokyo suburb.

The objectives of this stude were to:

1) Identify the conditions of air pollution in Beijing and Tokyo suburb.
2) Study the effects of acid rain on forest and soil.
3) Discuss the difference what of element budget and buffering capacity of catchment between Beijing and Tokyo.

Methods

1. Site Description

Two experimetal sites were located at Shisanling in Beijing suburb and at Hakyuti in Tokyo suburb respectively. The forested area of Shisanling is 12.3ha. Elevation ranges from 138 to 400m (Fig1). The coniferous species is Chinese pine, and covers 7.39ha. The major species is cypress in deciduous forest and it's area is 4.93ha. Soil type is brown forest soil.

Hakyuti is located in the Tama Hill region of Central Japan(Fig2). The forested area of Hakyuti is 11.3ha and the studied area is 2.15ha(1.55mixed deciduous forest and 0.6ha mixed coniferous forest). The elevation ranges from 140 to 190m. The major tree species include Japanese red cedar, Hinoki cypress in coniferous forest and Oak in deciduous forest. Soil type is Andisols.

2. Sample collection

Rainfall, throughfall, stemflow, stream water and soil solutions at 20,30,40,50cm depth were collected once a month in 1995~1996 in Shisanling and Hakyuti respectively(soil solutions were very hard to collect).

3. Analysis

After collection, water samples were analyzed for pH and electric conductivity. After that all collected water was filtered with membrance filters(Millipore 0.45 μm in poresize) and stored at -20℃ and analyzed within a month for Cl^-,SO_4^{2-},F^-,$NO_3^-$and NO_2^- by ion chromatography (Yokogawa, IC 200 Ion Chromatographic analyzer), for Ca^{2+},Mg^{2+},K^+ and Na^+ by atomic absorption spectrophotometry(Shimadzu,670/AA Atomic adsorption spectrophotometer), and for NH_4^+ by colorimetry (Shimadzu,Spectrophotometer UV-140-01).

Results and Discussions

1. Chemical compositions in precipitation

Annual average concentrations of major chemical compositions in precipitation in Beijing and Tokyo suburbs are represented in Figure 3. The major chemical compositions in precipitation were different between Shisanling and Hakyuti. At Shisanling the annual average concentration of sulphate was 320 μ eq/l, and over 70% of all the measured anions.The ion of highest concentration was nitrate with concentration of 46.5 μeq/l and occupied 41% of all anions at Hakyuti. From Figure 3 it can be seen that the ion concentrations except H^+ and NO_2^- at Shisanling were higher than those at Hakyuti expecially Ca^{2+},K^{+},SO_4^{2-} were very high. At Shisanling F^{-} that has significant toxicity to human, animals and plants ,was 4 times as high than that at Hakyuti.

At Shisanling acidic substances like SO_4^{2-} and NO_3^{-},in rainfall were high, but the pH value was 6.7, which is higher than that at Hakyuti(pH 4.7) because of low precipitation and high cation concentrations (Ca^{2+},K^{+}) in aerosol and particulates in the atmosphere.

According to ratio of NO_3^{-} to SO_4^{2-} , it can be considered that air pollution at Shisanling is sulphuric acid type, and nitrate acid type in Hakyuti.

2. Atmospheric input

The annual precipitation at Shisanling was 498mm, and was 3 times smaller than in Hakyuti (1568mm). The atmospheric input of ions(except Ca^{2+},K^{+},SO_4^{2-}) at Hakyuti was higher than those at Shisanling,although ion concentrations in collected water at Shisanling were higher than those at Hakyuti(Fig 4).Because precipitation was small, therefore ions input was considered to be small. Concerning ions inputs of throughfall in coniferous and deciduous forests, it was found that inputs varied with different tree species. At Shisanling ion inputs except NH_4^{+} were high in deciduous forest. It may result from the climate in Beijing, which is symbolized by dryness and small precipitation. The precipitation in June, July, August and September covered 75% of the total in a year. The other eight months (October~May) are fallen season of the leaves in deciduous forest, therefore precipitation in deciduous forest is less than in coniferous forest. Almost all the throughfall in deciduous forest could be collected. At Hakyuti K^{+} and Mg^{2+} inputs in deciduous forest were higher than in coniferous forest, and therefore it can be considered that K^{+} and Mg^{2+} were leached from deciduous forest.

3. Stream water output

The discharge had a direct ralationship to precipitation(r=0.94). The discharges at Shisanling and Hakyuti occupied 7.5% and 6% of precipitations respectively, and average rates of flow were 0.16 and 1.21 l/s, respectively.

Concerning stream water quality, considerable differences can be seen . At Hakyuti average pH value was almost neutral, and was weak alkalinity(7.7~7.9) at Shisanling. The major chemical composition in stream water was NO_3^{-}, Ca^{2+},Mg^{2+} and Na^{+}, among which Mg^{2+} is the highest at Hakyuti(303 μeq/l). At Shisanling Ca^{2+}, Na^{+}, SO_4^{2-} and K^{+} were the major composition, and Ca^{2+} was highest in them. The concentrations of SO_4^{2-}, Ca^{2+}andK^{+} at Shisanling were 3.4~42 times as high as at Hakyuti. The proportion of K+ concentration in the precipitation at Shisanling to that at Hakyuti was 6.8, therefore the great difference was observed between stream water and precipitation. K+ concentration in soil solution derived from the brown forest soil at Shisanling was 14 times as high as than those from Andisols at Hakyuti, therefore the cause of the K+ difference is infered to be soil properties. In the view of ion balance at Hakyuti, cation concentrations were lower than anions, and therefore pH value was neutral, and at Shisanling cation concentrations were higher than anion concentrations. As a result, pH value has shown weak alkaline.

4. Soil solution

The concentrations of major chemical composition were found to be different in varions depths. Cation concentrations increased with depth,while anions decreased. As a result, pH value rised with depths.

At Hakyuti the major compositions were Ca^{2+}, NO_3^-, and Ca^{2+}, Mg^{2+} at Shisanlling. From the concentrations in soil solution, it was observed that ion concentrations except Cl^- and NO_3^- ions at Shisanling were higher than those at Hakyuti, especially cation concentrations were higher than anions. As a result, it is considered that the soil at Shisanling has a large buffering capacity to acid rain.

5. Material budget

Material budgets were compared between Shisanling and Hakyuti in July, August and September,1995. It was found that there were similar features at Shisanling and Hakyuti: Mg^{2+} and Na^+ have leached from the two catchments, and other ions have accumulated (Tab 1).

F- budget has been found remarkably diffetent between the two catchments. About 80% of the input was accumulated at Shisanling, and 110% of the input was discharged at Hakyuti . Discharges and accumulations of all elements were considerably different since the precipitations were different at two areas. It was found that sulphate at Shisanling was 8 times higher than at Hakyuti. At Shisanling acid substances were accumulated in soil, but the soil has large buffering capacity, effects of precipitation on plants and soil have not been indicated in the now.

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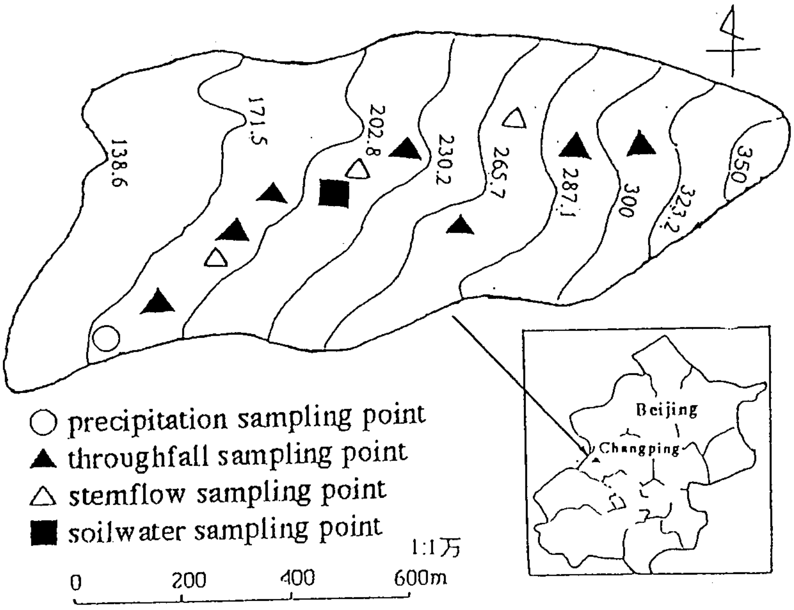

Fig 1 Location of experimetal station at Beijing, China

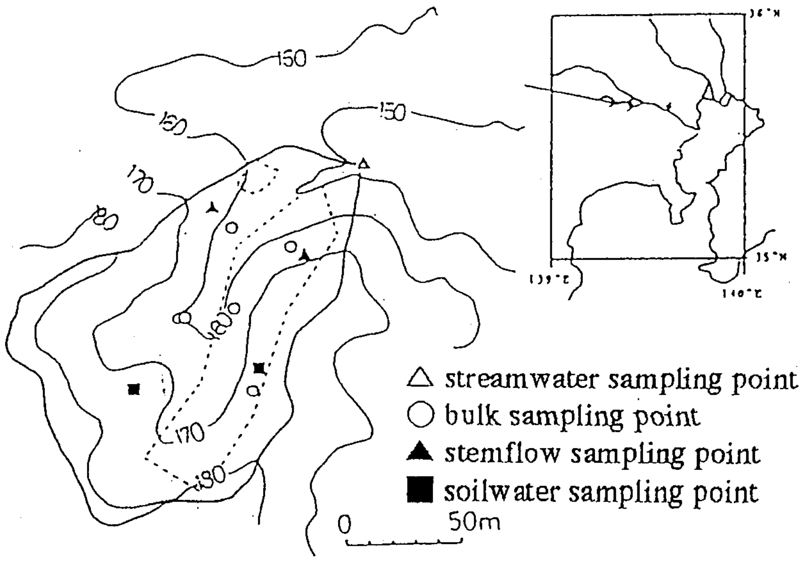

Fig 2 Location of experimetal station at Tokyo, Japan

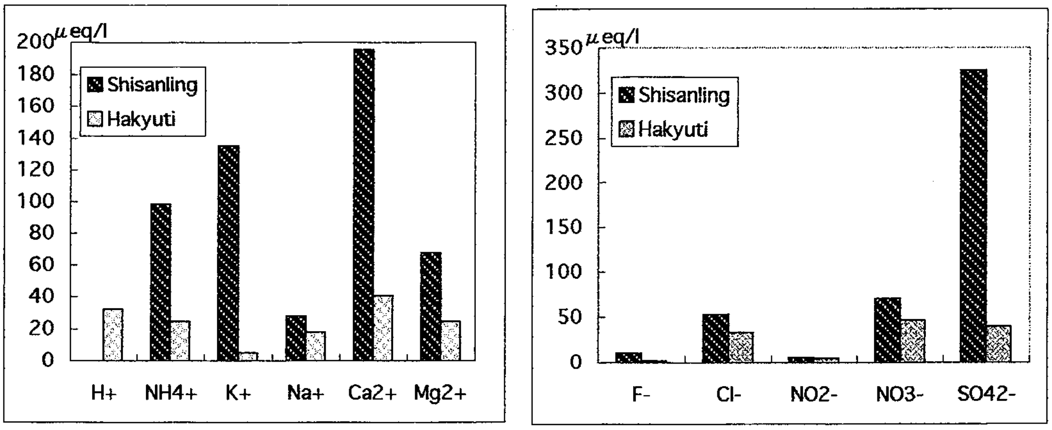

Fig 3 Comparison of major ion concentrations in precipitation at Shisanling and Hakyuti

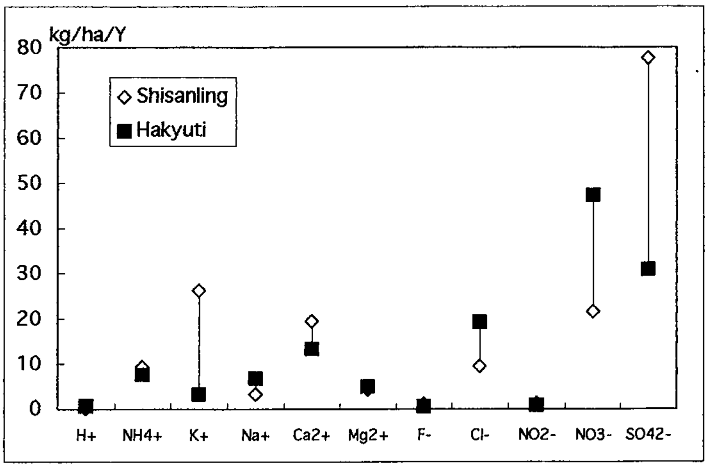

Fig 4 Comparison of annual ion depositions in precipitation at Shisanling and Hakyuti

Table 1 Comparison of material budgets between Shisanling and Hakyuti

	F	Cl	NO_2	NO_3	SO_4	K	Na	Ca	Mg	NH_4	H	vol
					kg/ha・3months							
Shisanling												
inputs	0.81	7.68	0.99	8.54	40.0	24.0	2.70	16.7	3.43	7.96	0.90	441mm
outputs	0.15	2.19	0.73	4.42	4.57	5.31	2.86	14.1	6.33	0.00	0.02	3260m³
discharge(%)	18.1	28.5	74.4	51.8	11.4	22.1	106	84.1	185	0.00	1.78	
save(+) leach(-)	0.66	5.49	0.25	4.11	35.4	18.7	-0.16	2.66	-2.91	7.96	0.88	
Hakyuti												
inputs	0.07	3.65	0.10	14.8	8.64	0.96	1.22	4.01	0.36	2.14	0.22	532mm
outputs	0.08	2.20	0.00	5.62	2.16	0.07	1.70	2.05	1.23	0.04	0.04	731m³
discharge(%)	107	60.3	0.00	38.0	25.0	7.33	140	51.0	340	1.68	16.4	
save(+) leach(-)	-0.01	1.45	0.10	9.16	6.48	0.89	-0.48	1.96	-0.87	2.10	0.18	

Thermal Water Resources and Development in China and Relevant Environment Problems

Wang Ji-yang
(Institute of Geology, Academia Sinica, Beijing ,100029,China)

Abstract

China is rich in thermal water resources and has a long history of utilization. In this paper, both high-temperature and low-medium temperature thermal water resources distribution and their developments are given. Some relevant environment problems are discussed as well.

Introduction

China is rich in thermal water resources and has a long history of using hot springs for agriculture, bathing and therapeutic purpose. Since early 1970's, extensive exploration and development of thermal water resources have been launched and quite good results were obtained. At present, a geothermal power plant with installed capacity of 25.18 MW was set up in Yangbajing Geothermal Field, which supplies about 41% (more than 60% in the winter time) electricity to the Lhasa city, the capital of Xizang (Tibet) Autonomous Region. Except for power generation, low-medium temperature thermal water resources are widely used for space heating, industry processing, agriculture, bathing and spas. In 1994, the total flow rate of thermal water for direct use amounts to 9534 kg/s, which provides the thermal power of 2143 MW and thermal energy of 5527 GWh equivalent. These figures showed that China nowadays is the first largest user of non-electric geothermal energy in the world (Ren et al., 1995; Freeston, 1995).

High Temperature Thermal Water Resources

High temperature thermal water resources in China are concentrated in recent volcanic and tectonically active areas (Fig.1). In southern Tibet, there are more than 600 hydrothermal manifestations including high temperature geysers, hydrothermal explosions, steaming grounds, fumaroles, boiling springs etc, among which 345 have been reconnaissanced and investigated by the Scientific Expedition Team under Commission for Integrated Survey of Natural Resources, Academia Sinica in late 1970's. Results indicate that most of thermal water in S.Tibet are of Cl^{-}-$HCO3^{-}$-Na^{+} type with enhanced contents of Li, Rb, Cs and B. The total dissolved solid appear between 1-3 g/l and the water is of meteoric origin as evidenced by isotope and geochemical studies. The estimated reservoir temperature varies from 170 to 270 °C and the total natural heat discharge at the Earth's surface amounts to $4{,}900\times10^{13}$ J/a. Strong hydrothermal activity in S.Tibet is the surface manifestation of extraordinarily high temperature regime at depth which is resulted from the collision of Eurasian and Indian Plates (Wang et. al.,1996).

Tengchong volcanic area is located at the border with Burma, which, tectonically and geothermally, is the southern extension of Himalayan Geothermal Belt. The main difference between Tengchong area and other part of the Belt is that, in Tengchong there exists extensive Cenozoic volcanic activity. According to Liao (1989), Mu and Curtis (1989), the Tengchong volcanism can be divided into four stages ranging from Miocene to Pleistocene with the K-Ar age of 2.93, 0.81, 0.31 and 0.13 Ma correspondingly. The climax of eruptions were occurred in late Pleistocene. It is evidenced that Tengchong volcanoes might not be extinguished but only dormant. In this context, the magma body at shallow depth may behave as the heat source of its overlying hydrothermal system in this area.

A total number of 58 hydrothermal areas were identified in Tengcheng among which the Rehai (Hot Sea) Geothermal system is the most promising one. Investigation revealed that the reservoir temperature in this system may reach 230 °C-240 °C. The heat source might be a cooling magma body which intruded into a shallow depth of about 5-7 km and created the circular area of surface manifestation. The input of magmatic heat at depth may have set the ground-water into motion in this geothermal system. However, the groundwater is meteoric in origin as evidenced by isotope (D, ^{18}O).

High temperature thermal water resources are mainly used for power generation. Except for Yangbajing geothermal power plant, other two plants in Langjue and Naqu are being planned in Tibet. In Tengchong volcanic area, a project on the development of thermal water resources for generating electricity will be started in the near future. It is estimated that the power generation potential from the Tibetan section of Himalayan Geothermal Belt is nearly 1000 MW , and the Tengchong section alone takes up about 450 MW .

Low-medium Temperature Thermal Water Resources

There are two types of low-medium temperature thermal water resources in China. One is thermal water from the low-medium temperature geothermal systems of convection type, not related to young magma body but heated by normal to relatively high regional heat flow, such as the Zhangzhou and Fuzhou geothermal systems in SE China. And another is the thermal fluid connected with the low-medium temperature geothermal systems of conductive type in large-scale sedimentary basins, such as North China Basin, Sichuan Basin and Tarim Basin (Wang et al., 1996).

It can be seen from Fig.1 that the thermal water resources of first type are concentrated in the following areas:

1) Coastal area of SE China including Fujian, Guangdong, Eastern Jiangxi and Southern Hunan Provinces. There occurred more than 600 hot springs mostly with temperature of 40-80 °C, some having temperature 80-95 °C. Several systems such as Zhangzhou, Fuzhou in Fujiaan Province; Dengwu, Yangjiang in Guangdong; Baoting in Hainan and Huitang in Hunan have been explored during the past 20 years;

2) E. Shangtong, E. Liaoning Peninsula to the East of Beijing along Tancheng-Lujiang deep-fault zone. There exist about 70 hot springs with temperature of 40-70°C. Higher temperature (80-90 °C) are observed in several springs;

3) Fen-wei (Shanxi-Shaanxi) graben area to the West of Beijing. The distribution of hot springs is somehow "S" shaped reflecting the graben configuration. Hot springs from the northern and southern parts of the graben are of higher temperature (60-80 °C)whereas those from the middle part are of lower temperature (40-60 °C). It might be resulted from the different circulating depth of hot spring water;

4) W.Sichuan-N.Yunnan area to the NE of Tengchong along "South-North" tectonic (or seismic) zone. A total number of 270 hot springs are recorded in this area. The temperature of springs is quite low (40-50 °C), only a few appear to be more than 80 °C.

Isotope and geochemical studies exhibit that the thermal water in these systems originated from meteoric water. Along coastal area, thermal water in some systems was revealed to be mixed up with sea water. As a result, the TDS and Cl^- content were increased. The reservoir temperature for this type of geothermal systems range from 40 to 150 C calculated by using different geothermometers. For example, reservoir temperature for Zhangzhou and Yangjiang systems are of 140 °C; for Dengwu--135 °C; for Baoting--120 °C.

Geothermal resources in low-medium temperature geothermal systems of conductive type are mainly occurred in large-scale sedimentary basins. In China, there exist a number of such basins among which 9 basins have an area more than 100,000 km^2. Namely they are: Songliao, North China, Eerduosi, Erlian, Jianghan, Sichuan, Talimu, Chaidamu and Zhungaer Basin. A total area of approximate 3.5 millions square kilometres is reached if the sedimentary basins with an area more than 200 km^2 are taken into consideration. It accounts for 36% total area of China continent(Fig.1).

Investigation and exploration demonstrate that sedimentary basins located in the eastern and central parts of China are most promising areas for development of low-medium temperature thermal water resources. Basins from western China such as Talimu, Chaidamu and Zhungeer are less promising because the water quality is not so good and the salinity seems to be too high (up to 30 g/l). In addition, W.China is less populated and, in fact, there is no user for the vast desert areas except for a few big cities and towns.

It must be noted that the potential of thermal water resources in 9 basins from eastern and central China is quite good and the recoverable thermal water resources amount to 1.854 billion tons of standard coal equivalent. The recoverable resources in North China Basin and N.Jiangsu Basin takes up 73% of the total and thus, these two basins are the most promising areas for the development of low-medium temperature thermal water resources in China. Although the extent of Feng-Wei Basin and Lei-Qiong Basin is not so large, these two basins are still quite promising for development because the water quality is good and the flow rate is large enough for exploration. Except for Chuxiong basin, the water quality for other Mesozoic basins such as Sichuan, Eerduosi and Songliao appears not so good. Therefore, these basins are not very promising for geothermal development.

In northern part of North China Basin, there exist two thermal water reservoirs: one is the reservoir of Neogene sediments and another is the so-called "Buried Hill" reservoir of Lower Palaeozoic and Mid-Upper Proterozoic carbonatite rocks. The Neogene sediments are a thick series of inter-bedding mudstone and sandstone of alluvial origin. The sandstone layers are the main aquifers in Neogene system with good water quality. The buried depth of aquifers varied from 400 to 2000 m and the water temperature is of 30 to 85°C. The chemistry of thermal water is of $HCO3^-$-Cl^--Na^+ type with low salinity (1-3 g/l). ^{14}C dating revealed that the "age" of thermal water in Neogene sediments is about 10,000 to 30,000 years old. That means the thermal water seems to be quite stagnant in the reservoir, and the water resources should be considered to be unrenewable. "Buried Hill" has been named by Chinese petroleum geologists to describe the karst-fissure reservoir of carbonatite rock strata in the basement of North China Basin. Thermal water with temperature up to 105°C at a depth of 2000-3000 m has been found in this reservoir but the water quality appears to be changeable. Sometimes saline water may be encountered. For this reason, utilization of thermal water from this reservoir should be kept with caution.

The formation mechanism of thermal water resources in North China Basin can be described as follows: on the relatively high regional geothermal background (62 mW/m^2) , two reservoirs exist in the Basin. Lateral flow of cold water heats up on the way from recharge area to discharge area and supplies the reservoirs with thermal water of different temperature. In the central part of a uplift, heat flow increased due to the refraction and concentration of heat, which led to the occurrence of high geothermal gradient (up to 50-60 °C/km) in the sedimentary cover strata on the top of a basement uplift. Along the faults and/or fracture zones, deep circulating thermal water arises and sometimes makes up the occurrence of locally small convection cell in certain parts of the reservoir. And finally, the low-medium temperature geothermal resources in North China Basin are thus formed.

It must be stressed that the formation of thermal water in North China Basin seems to be quite typical and may be regarded as the representative for the thermal water resources connected with the low-medium temperature geothermal systems of conductive type.

Development and Utilization

As stated before, China has a long history (over 2000 years) of utilization of thermal water resources. Early people used hot springs for irrigation and clothes-washing. During Han dynasty (206 BC to 220 AD), salt was extracted from thermal water in Zigong area of Sichuan Province. In the Ming dynasty (1368-1644 AD), Lishizheng, a famous medical doctor at that time, used hot spring water for disease treatments. He persuaded people: "If you got ill, go to hot spring area and take a bath". As a result, numerous bathing houses and spas were spread over hot spring areas throughtout the country. In Xiaotangshan (means "a little warm hill") hot spring area (25 km to the NW of Beijing), two thermal water pools were sunk in 1666, the 5th year of Emperor Kangxi of the Qing dynasty. And a bathing tank was constructed for the famous Empress Dowager Cixi. In Huaqingchi hot spring area near Xi'an city, the ancient capital of Tang dynasty, a quite fancy bathing house was built up for the Imperial Concubine Yang. However, all these uses were mainly for "health" and /or "recreation" purpose, rather than for energy.

Since early 1970's, with recognizing the importance of thermal water resources energy as an alternative new and renewable energy source, thermal water resources have been started to use for energy purpose. The experimental geothermal power station was set up in Dengwu, Fengshun Country, Guangdong Province in 1970 and followed by Wentang and Huailai in 1971, Huitang in 1975 and finally, Yinkou in 1977 (Fig.2).

As mentioned at the very beginning that China nowadays is the first largest user of non-electric geothermal energy in the World and is showing out as a prospective leader in direct uses. There are about 49 projects using thermal water for industrial processing such as dyeing, drying fruits and vegetables, paper and hide processing, air conditioning and preheating boiler feed water etc with a net energy consumption of 171 GWh.

Tianjin is the largest user of industrial processing mainly in dyeing. The energy consumption takes up 47.5% of the total. Yinshan County in Hubei Province, using thermal water of temperature 42-50 °C for tannin extract, saved 12,800 ton of standard coal per well within 12 years. The energy saving by using thermal water for hide processing at Xiongxian County, Hebei Province is equivalent to more than 5,000 tons coal annually. The local people at Tenchong County, Yunnan Province are using 92 °C thermal water for soaking pulp and paper drying and make quite a lot of money by exporting these products.

Space heating is mainly applied in North China where serve cold winter is usual. With an energy utilization of 334 GWh, the heating area is totalling to 1,313,800 m^2. Geothermal space heating systems in Tianjin are concentrated in Tanggu, Hangu and Dagan districts. About 50 wells provide a maximum flow of 300 t/h of up to 97 °C water to heat an area of 805,000 m^2. This is the largest single spacing heating project in China. The space heating projects in Beijing are spread over a large area of the city, but there's no central heating systems, usually one well for one unit only. The largest one is at Xiaotangshan sanatorium, where 4 wells provide 137 t/h of 50 C water to heat a total area of 4,000 m^2.

Greenhouses also feature as major users of thermal water in China. In 1994, China has greenhouse area of 1,159,156 m^2 in 17 Provinces and/or Autonomous Regions, of which 258,129 m^2 are in Hebei Province , amounting to 22.3 % of the total. Two standard designs of greenhouse are used to produce fresh vegetables, the main crops being cucumbers, tomatoes and lettuce. The farmers in Xiaotangshan County have built up 43,290 m^2 greenhouses and supply the grand hotels and fancy restaurants in Beijing with ten different kinds of special vegetables. In 1984, when President Reagan of the United States visited China, instead of getting vegetables by air from California, a variety of fresh vegetables from Xiaotangshan geothermal greenhouse were put on the table for the farewell banquet at Great Wall (Beijing Sheraton) Hotel, which surprised and enjoyed the guests and host very much. Fish farming by thermal water appears to be another fast growing application in China. At present, a total area of 1.6 million square meters of fish ponds was reported in 17 provinces and cities. The products include African carp, eels, shrimps, turtles, snails etc. In Fujian Province, a large number of eels have been raised in thermal water fish ponds and the products are partly exported to Japan.

Currently, there are 594 baths, 23 swimming pools and 179 sanatoriums, with many more local pools at hot spring sites. The swimming pools and baths using thermal water for athletic training have rapidly developed in recent years. The famous training centre for female volleyball team using thermal water is located in Zhangzhuo City, Fujian Province. It is interesting to note that the 4 areas making major use of thermal water for non-electrical processes are Hebei, 24% of the county total; Tianjin, 15%; Shandong, 12% and Tibet, 10%(Wang et al.,1996).

Relevant Environment Problems

If properly implemented, thermal water resources may be considered to be a sustainable resource and benign to the environment. The emission of greenhouse gases is minimal compared to fossil fuels. The removal of hydrogen sulphide from high temperature steam and the re-injection of spent thermal fluids into the ground make the potential negative environmental effect negligible (Fridleifsson, 1997). However, if removal of hydrogen sulphide and re-injection of spent thermal fluids have not been attempted, then the negative environmental effects will be in-negligible. For instance, in North China, thermal water has commonly enhanced content of fluoride, which is harmful for the environment and will cause serious teeth disease.

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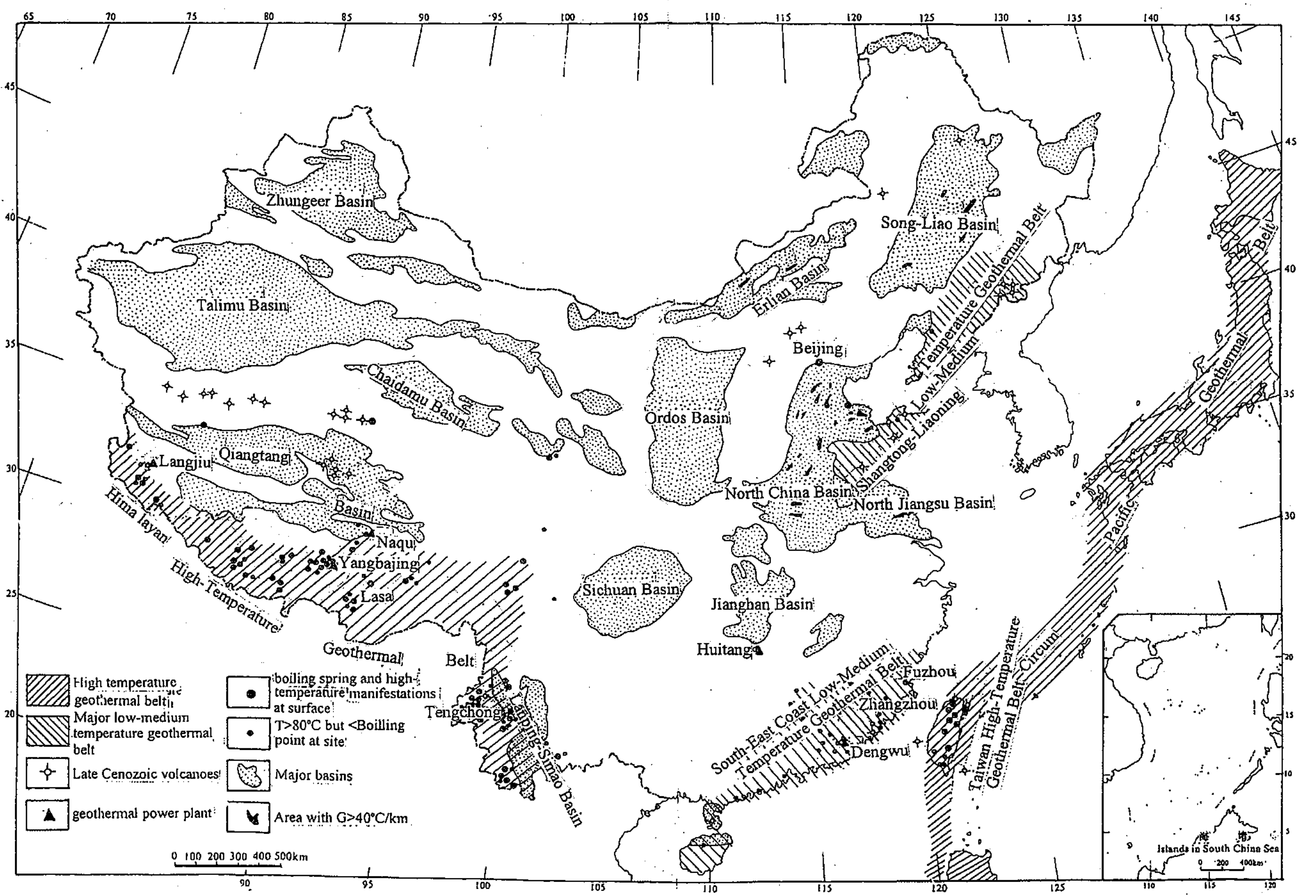

Fig. 1 Geothermal system and thermal water resources in China

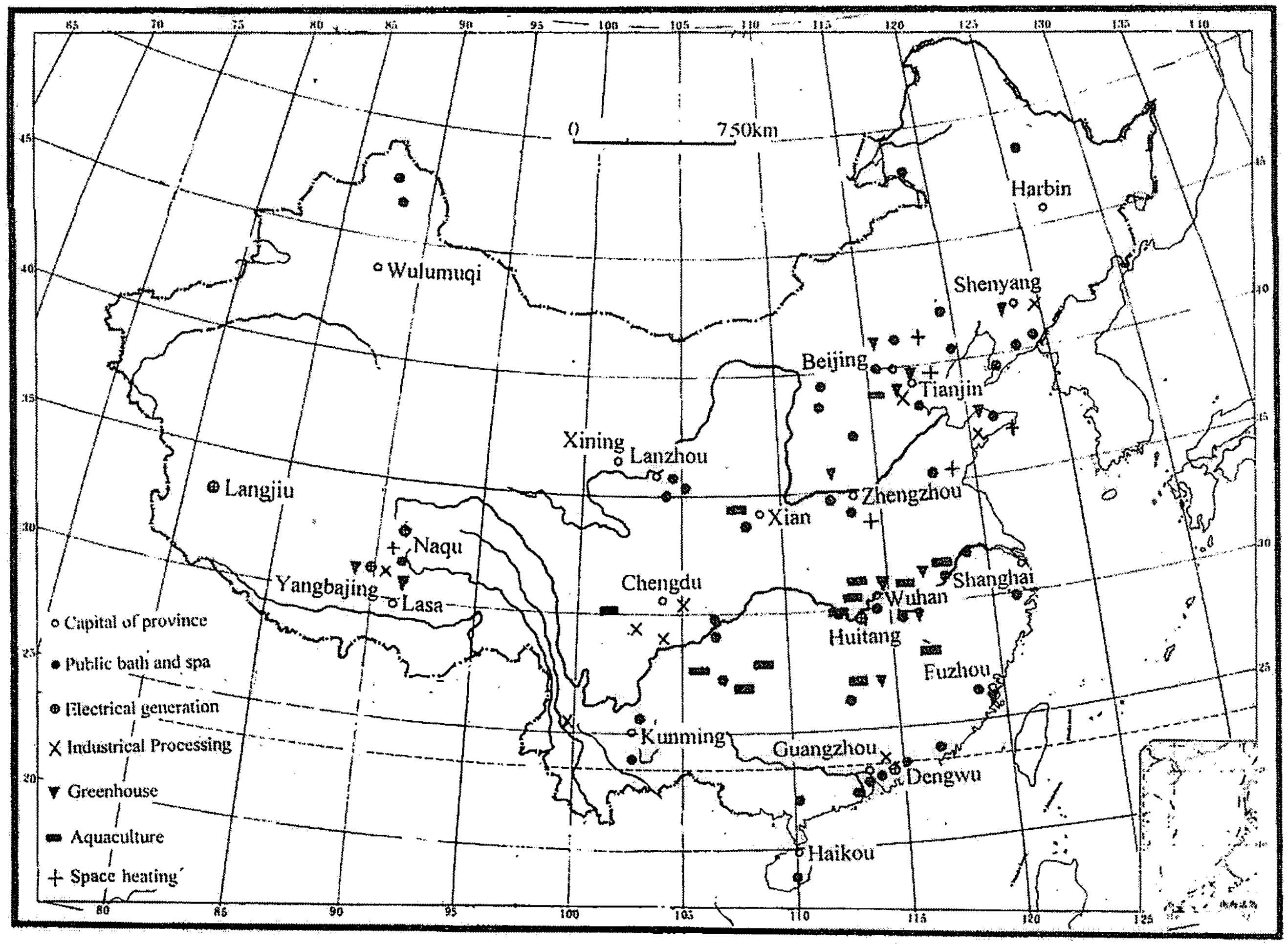

Fig.2 Thermal water utilisation sites in China

Characteristics of Groundwater Quality alone 38° N Latitude in the North China Plain

Changyuan Tang*, Shizuo Shindo*, Yasuo Sakura** and Liu Changming***
*Center for Environmental Remote Sensing, Chiba University, Japan
**Faculty of Sciences, Chiba University, Japan
***Institute of Geography, CAS, China

Abstract

Groundwater is one of major water resources in the North China Plain (NCP). The area from Taihang Mountain to Buohaiwan along 38° N latitude in NCP has been chosen to analyze the evolution of groundwater quality. In viewpoint of water cycle, the authors of present paper paid careful attentions to the fact that the basic characteristics of groundwater qualities are in close relation to groundwater flow system. It was found that groundwater quality changed from Ca-HCO_3 type to Na-Cl type, which matches well with groundwater flow direction from recharge area to discharge area. Based on the results of groundwater usage as well as chemical analysis, it is clearly that both nature and human activities effected greatly on the groundwater quality in NCP.

Key Words: Groundwater quality, the North China Plain, Groundwater flow system

I. Introduction

The North China Plain (NCP) is an important region of agriculture in China, and groundwater is widely used as a source of primary or supplementary irrigation. Radical changes in farming practice, aimed at increasing productivity and reducing reliance on imported food, have led to the widespread introduction of agricultural monocultures, sustained by major increase in the used of agrochemical and irrigation. As a result, many issues, such as the water table depression, soil salinization, groundwater pollution etc., are all subject to water-related constrains. Obviously, groundwater is the key to solve the environmental problems. From the viewpoint of water cycle, groundwater can be one renewable source, but from the viewpoint of groundwater resource or ecology, the groundwater may not be a renewable source if it is used unsuitably. By now, many works have been done in NCP to research groundwater and its quality. This paper will try to explain the evolution of groundwater quality by considering groundwater flow from recharge region to discharge region.

II. Geography Sittings and Method

The annual rainfall ranges from 400 to 600 mm in study area, and 70 to 80% of annual rainfall are found from July to August. There are only 40 mm to 60 mm of rainfall or even no rainfall available in more than one hundred days in Spring. The variation of seasonal precipitation is so large that it is the common case to have dry Spring and flooding Summer.

Historically, water in NCP has changed greatly in past forty years. At 1950s and 1960s, the main problems concerned with water in NCP were flood disasters since the plain was too flat for water to flow out to sea easily, and salinity since the water table was too shallow. To solve the first problem, many artificial channels were constructed. As a result, all rivers in study area dried up except the upper stream of Baiyangdian Lake since the mid-1970s. Even in rain season, there was hardly any river with water flow. At the same time, development of agriculture required more and more water. Groundwater became one of major sources for farming, since there was not enough river waters. However, the over exploitation of groundwater caused water table depression at the rate of one meter per year. On the other hand, billions m^3 of water has been transferred from Yellow River during the period from November to February next year.

In addition to variation of groundwater use for economic development and urbanization, groundwater quality have become another neck problem in NCP. As a pilot survey, we took groundwater samples along 38° N Latitude in NCP from June 29 to July 4. During field surveying, pH, Electrical conductivity and temperature of groundwater were measured in situ. The major ions such as NO_3^--N, SiO_2, Cl^-, SO_4^{2-}, Na^+, K^+, Mg^{2+}, Ca^{2+} and HCO_3^- were analyzed with standard methods.

III. Results

In order to match with the groundwater flow system in the study area, we set the Agriculture Ecological Experimental Station in Taihang Mountain, which belongs to Shijiazhuang Institute of Agricultural Modernization, as the start point, and took a line alone 38° N latitude from the start point to Huanghua Harbor near Bohaiwan. Alone this line, 13 groundwater samples were collected. Figure 1 shows the evolution of groundwater type in the study area. It is clearly, in the Taihang Mountain area the groundwater type was Ca-HCO_3. With the groundwater flowing from recharge area to discharge area, the groundwater type changed as following sequence.

$$\text{Ca-HCO}_3 \rightarrow \text{Ca+Mg-HCO}_3 \rightarrow \text{Mg-Cl} \rightarrow \text{Mg+Na-Cl} \rightarrow \text{NaCl}$$

Table 1 shows the correlation coefficients of distances, elevation, pH, EC, Temperature and major ions. It was found SO_4 had high correlation coefficients with Cl and cations. Elevation had negative coorelations with all kinds of ions analyzed

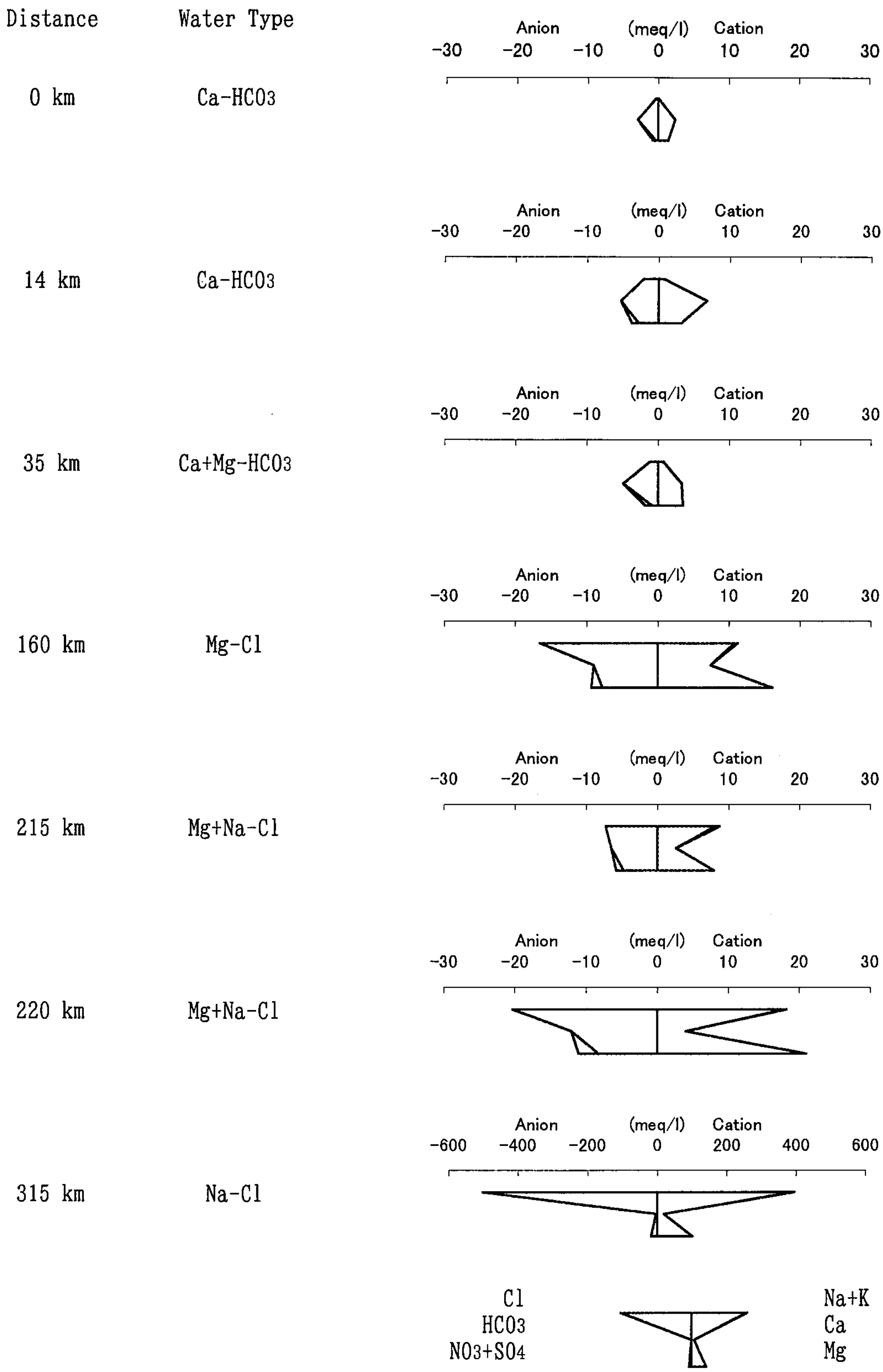

Figure 1 Evolution of groundwater type in study area.

in this study, which means the concentrations of ions increased from recharge area to discharge area. EC values showed negative correlations with NO_3 and HCO_3 and positive coorelations with other ions. The low correlations of pH with ions hinds that the pH variation with nothing to do with groundwater evolution in the study area.

Table 1. Results of correlation analyses for groundwater quality

	Dist.	Elev.	EC	pH	Temp	NO_3	HCO_3	Cl	SO_4	Ca	Mg	K	Na
Dist.	1.00												
Elev.	-0.69	1.00											
EC	0.69	-0.34	1.00										
pH	0.18	0.44	0.52	1.00									
Temp	0.40	0.26	0.64	0.84	1.00								
NO_3	0.15	-0.35	-0.46	-0.54	-0.52	1.00							
HCO_3	0.23	-0.42	-0.42	-0.59	-0.53	0.98	1.00						
Cl	0.67	-0.32	1.00	0.52	0.63	-0.50	-0.46	1.00					
SO_4	0.90	-0.60	0.86	0.19	0.41	-0.02	0.06	0.85	1.00				
Ca	0.60	-0.39	0.94	0.26	0.44	-0.44	-0.37	0.95	0.86	1.00			
Mg	0.76	-0.40	0.99	0.46	0.59	-0.36	-0.31	0.99	0.92	0.94	1.00		
K	0.71	-0.35	1.00	0.51	0.64	-0.49	-0.44	1.00	0.86	0.94	0.99	1.00	
Na	0.67	-0.32	1.00	0.52	0.64	-0.50	-0.45	1.00	0.85	0.94	0.99	1.00	1.00

IV. Discussions

Groundwater quality depends on two groups of interactive factors, which refer to hydrological states and human activities. The major criteria of sustainable groundwater resources systems are: groundwater resources systems keep on renewal of their quantity and quality; while groundwater resources development keeps up with a rapid growth of socio-economy. These two are mutually dependent. Table 2 shows the water variation in past 40 years. It was found that the rate of outflow to runoff decreased from 77% to 33%, which means that more and more water have been used in the study area.

Table 2. Decreases in runoff outflowing into the sea from NCP for last 4 decades. (in 100 million cu. m)

Decades	1950's	1960's	1970's	1980's
Runoff of NCP	291	295	293	330*
Outflow Runoff	224	165	120	100
Ratio in %	77	55	41	33

* Plus diverted water from the Yellow River

Figure 2 shows the evolution of chemicals along the 38° N latitude. It was found that the groundwater quality can be classified into 3 types, U-Type (pH and Temperature), inverse U-type (HCO_3 and NO_3) and monotony-type (EC, SO_4, Cl, Ca, Mg, K and Na). In addition recharge in side of catchment, waters from outside also

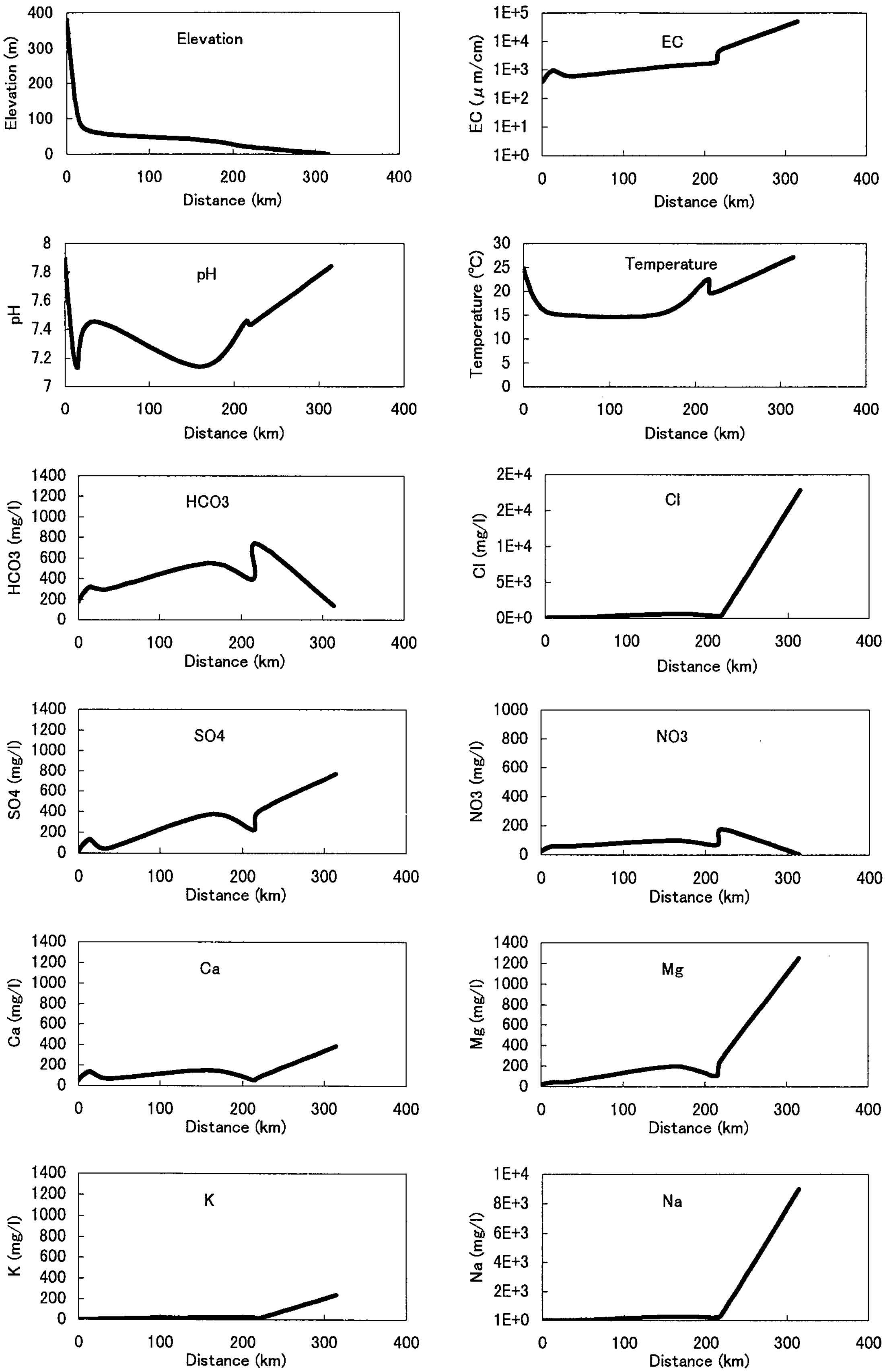

Figure 2 Concentration variations of chemicals in groundwater along 38° N Latitude in NCP

have been transferred into NCP, and effected on both water balance and water quality in study area. For example, the groundwater quality at Nanpi, 215 km from the start point, was effected greatly by the water from Yellow River. As a result, groundwater quality there was different from the groundwater in other area without the effects of Yellow River's water. Generally, intensification of agricultural production can lead (and has led) potential deterioration in groundwater quality. The principal problems were the leaching of nitrate and pesticide compounds in study area. From the Figure 2, distribution of NO_3 matched well with the region of agricultural activities. Also, the salinities that are found in groundwaters arise from the variety of natural sources and a variety of anthropogenic causes. Their control is obviously dependent on good resource management, but in order to exercise such management, a comprehensive hydrochemical and hydraulic assessment is required together with careful monitoring. In most environments, a total hydrogeological system assessment is necessary.

V. Conclusions

Groundwater is one of the most valuable natural resources that NCP posses. Information about the evolution of groundwater quality in this region is very important for economic development. In our study, it was found that groundwater quality changed from Ca-HCO_3 type to Na-Cl type along 38° N latitude, which coincided with groundwater flow from recharge area to discharge area. By considering the variations of groundwater use in past forty years, the groundwater quality was obviously affected by both nature and anthropogenic factors. NO_3 distribution in groundwater hinted that there exists a potential pollution in the study area. Therefore, there is an urgent need for rapid surveys of groundwater utilization, aquifer pollution vulnerability and subsurface contaminant load, to be undertaken. Groundwater pollution risk and susceptibility to overexploitation effects can then be assessed and protection measures prioritized and initiated.

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6. Lake, River Environment

Some Limnological Characteristics in Arid Basin, --A Case Study in Xinjiang Area, China

Seiji HORIUCHI[1] , Maki WATANABE[2], Koichi KITAOKA[3] , Tetuya TUBOI[1], Yuriko NAKAO [1] and Zhou HONGFEI[4]

1 Nihon University 2 Ochanomizu University 3 Kyoto University

4 Chinese Academy of Sciences ,Xinjiang

INTRODUCTION

The existence of water in arid zones is quite different from that in humid zones in many ways. In this paper, authors try to show the characteristics of inland water -river, groundwater and lake water - in arid zones compared with those in humid ones. A case study has been done on several lakes, groundwater and rivers in Xinjian .

Turfan and Jungar basins have several closed salt lakes and situated by ancient silk road in Northwestern China (Fig. 1).

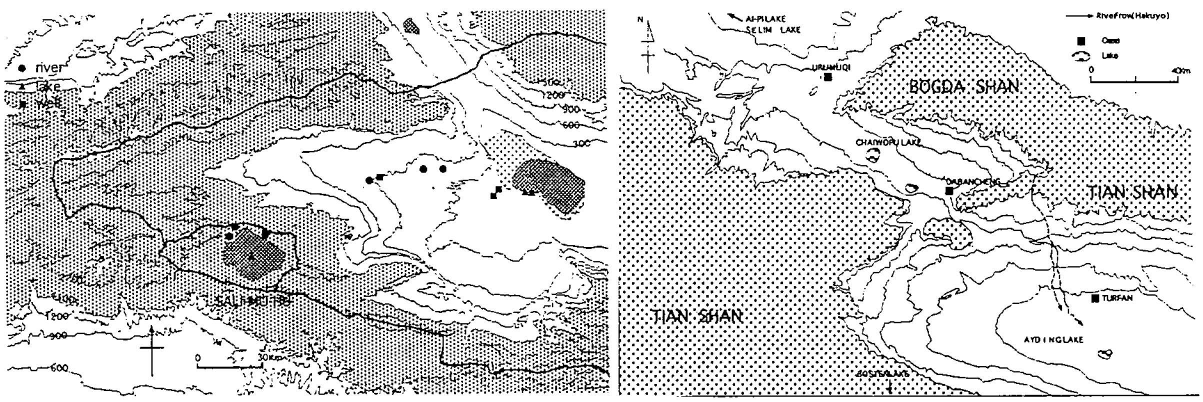

Fig. 1 Schematic maps of Turfan and Jungar Basins (right Jungar Basin , left Turfan Basin)

It is essentially a flat and little vegetated semi-arid region and is surrounded by high Tienshan Mountain with a mean annual rainfall of between 5 mm and 550mm. In the south of Turfan, there is a salt lake, Aydinghol, in a desert and in the western part of Turfan there are several salt lakes; one is Chaiwopu . Jungar basin has the same climatic condition as Turfan Basin and has two saline lakes , Aibir and Selim.

All these lakes shrinkage gradually as a result of the deficit of inflow water.

The most important problem on water usage in a arid region is the quantity and the quality of water. Increase of water demanded for agriculture and human lives caused the lowering of

groundwater level and changed the water quality to high salt content.
Our study began from 1992 under cooperation of China Academy of Geography in Xinjian , and continues now.

LIMNOLOGICAL CONDITIONS IN RESEARCHED REGION AND LIMNOLOGICAL PROBLEM

This region belongs to arid zone with annual precipitation 290mm in Urumqi and only 20 mm in Turfan. Surface water and groundwater are supplied by rain water in high Tienshan Mountain directly in summer season. In winter, precipitation is stocked as snow or glacier and supplied as melted water into rivers as well as in to surrounded areas in Urumqi in summer. There are ma ny lakes in this region. It has been pointed out by many papers (Street-Perrot, A. 1979,1983, 揚川徳 1993), that the surface areas of lakes have remarkably decreased for the past ,50 years. The decrease in inflow from rivers has been pointed out as this cause.
Lowering of lake water level, decrease in lake water volume, disappearance of lakes and the increased salinity have been observed. Moreover, the salinity in inflow rivers increased ,too. The recent expansion of irrigated areas has caused the decrease in the river inflows (買買提 1988, 依江風 1988). Lake Aibir in the north western part of Jungar basin, for example, has no inflows because of supplying water into the irrigated areas. As a result, the surface area of lake has become smaller from 1000km^2 in 1970 to 500km^2 in 1990 .
The drainage of filthy water from cultivated areas has worsened the quality of river water and at the same time caused the eutrophication of lake water. These phenomena can be observed not only in Central Asia but also all over the world. They have been discussed in the terms of co-relation with consistent climatic change in Quaternary (Benson.L.V. 1981) in the long time range and in the short range with the present artificial and natural environmental changes. The concentration of dissolved substances in the lake is remarkably high, caused by evaporation and dissolution of salt from aquifer, base ion exchange of water and the changes in chemical components are all serious problems. Turfan basin has a salt lake, Lake Aydinghol and the basin' s lowest point is -154 m. Some lakes are connected by rivers in Urumqi to Dabancheng and they change from fresh lakes to salt ones. In the surrounded area of Turfan, the ancient karezes spread and supply some water to villages. Canals are built recently and serve as irrigation water way. In Turfan basin, numerous karezes are constructed from the foot of mountain to the central part, some of which are still in use and new karezes are under construction now.

CHARACTERISTICS OF CHEMICAL CONSTITUENTS OF INLAND WATERS

The chemical characteristics of Urumqi river resemble those of river water in humid regions, but the absolute quantities of ions are larger. Electric conductivity shows approximately 100 ms/cm, which is about the same as that of rivers in Japan. Dissolved substances are determined by geology and climate and the amount of contents is largely determined by the contact time with rocks and the discharge of rivers.

From upstream to downstream all dissolved contents increase from about 1.2meq/l to 8 meq/l. No artificial pollutants seem to affect the dissolution mechanism but only contact with rocks and natural environments do. The characteristics of dissolved substances is shown in the composition ratio of Ca/Mg.

The ratio does not change as rivers flow down and dissolved contents increase at a certain ratio. The increase of Na and relative decrease of K is another characteristics where compared with rivers in humid regions. However, the total dissolved substances of rivers in Turfan basin is bigger than those of Urumqi river. Chemical components of each river are about the same but the concentration of dissolved substances differ.Less vegetation and less precipitation cause such a difference. Chemical characteristics of groundwater is Carbonate Hardness and Non Carbonate Hardness . The absolute quantities of ions of groundwater rapidly increase from the foot of mountains to the central parts of the basin and the maximum quantities reaches 400 meq/l. Groundwater from karez around Lake Ayding shows the high salinity. Fig. 2 shows that the salinity increase gradually from the foot of mountain to Lake Ayding in the central part of Turfan Basin. The dissolved substances are composed of Ca > Mg > Na > K as the salinity increase. The supply resources are from Tienshan mountain, rain and wadi. The differences of the ratio of each constituent between rivers and groundwater are thought to be the result that the surface water percolates to the ground and Na is dissolved through the long contact with rocks and Ca or Mg are absorbed in stratum. This is the ion exchange between Na and Ca(Mg) (Eriksson,E. 1985). The high salinity in karez water might be explained by the two reasons. One is that groundwater from surrounded areas stays in the center of the basin.

The other reason is that groundwater mixes with the paleo-lake water of high salt content as the result of Lake Ayding. The water quality of lake shows various aspects depending on the salt content, from the high concentrated ones represented by salt lakes to the low by fresh lakes.

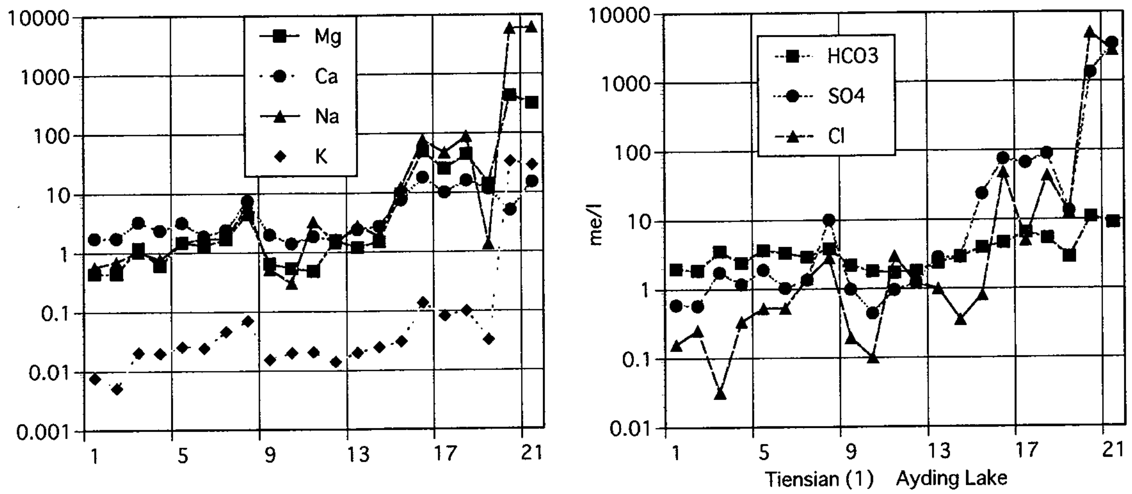

Fig. 2 Water quality in Turfan Basin, showing the increase of anion and cation to Lake Ayding (right NO21), in the central part from the foot of mountain(left NO1).

Na and Mg increase in accordance with the salt increase and anion changes from $HCO_3 > SO_4 > Cl$ to $SO_4 > Cl > HCO_3$ -as pointed out by Schoeller(1959) and Langbein (1961). HCO3-dissolutiondecreases and precipitates as salt increases and ,NaCl and $MgCl_2$ increases in lake water. Fig. 2 shows correlation between anion and salinity. HCO_3 shows the highest ratio at low salinity and decreases with increase of salinity but Cl and SO_4 increase with the increase of salinity. HCO_3 precipitates and SO_4 and Cl finally occupies most of it. Moreover in closed l akes, the evolution of water quality from bicarbonate, sulfate type to chloride type is recognized with the increase of salt content.

This condensation mechanism is the most important for the study of in arid zone limnology.

As to closed lakes at Xinjian area, evaporation , precipitation and lake basins are the main causes to effect changes in the water quality. The salinity of closed lake depends on response time of lake water, and response time relates to the ratio of evaporation and the mean depth of the lake. Then the authors presume that the salinity of closed lake is controlled by hydrological (morphological) factors as well as climatic factors.

As to pH, rivers, lakes and groundwater show weak alkali, while glacier shows weak acid. This shows that the inland water changes gradually from weak acid to weak alkali in the process of concentration. SO_4 and Cl originate from the rocks and HCO_3 from CO_2 in the air or is decomposed from organic materials.

LIMNOLOGICAL RECONNAISSANCE ON LAKE SELIM

Limnological research on Selim Lake was carried out from August of 1995 to August of 1997 using by a boat and the following results were pointed out. Lake Water levels in open lakes are mainly determined by the altitude of outflows and precipitation does not affect its level. Ho wever, in closed lakes such as Lake Selim, the increase or decrease in precipitation changes water levels. The lowering of lake water level is very large in closed lakes, such as Lake Aibir, Lake Ayding and Lop Nor As above mentioned, and as pointed out by 揚川徳 (1993), the lo wering of water level is caused by artificial reasons such as water use for irrigation and house use. There are no cultivated areas and no irrigation around Lake Selim. So we can say natural fac tors change water levels. The water level dose not change so much, which differs from other salt lakes such as Ayding and Aibir lake.

It rose gradually from June 1 to August 18 in 1995 with cyclic variation . Total increase value of water level is 95.5 mm in the same period and the increasing rate of water level is about 1.3 mm per day. By power spectrum analysis, one peak whose period is 30 min/c is shown.

The peak period is consistent with the theoretical value of surface seiches calculated from lake to pography. The bottom temperature at the depth of 86.9 m shows is 3.05 ℃ and the temperature profile from surface to bottom decreases gradually from 17.03 ℃ at the surface to 3.05 ℃ at th e bottom, except at the thermocline of the depth of 4-6m. From the point of thermal stratificatio n, Selim Lake is divided to three parts, epilimnion (0-3m), thermocline (4-6m) and hypolimnio

e bottom, except at the thermocline of the depth of 4-6m. From the point of thermal stratificatio n, Selim Lake is divided to three parts, epilimnion (0-3m), thermocline (4-6m) and hypolimnio n (6m-bottom) from the surface to the bottom and it is classified as holomictic lake.
It is remarkable characteristics that the bottom temperature shows 3.05 ℃ considering the temperature at the maximum density of fresh water is 4.0 ℃. respectively. (Fig.3)

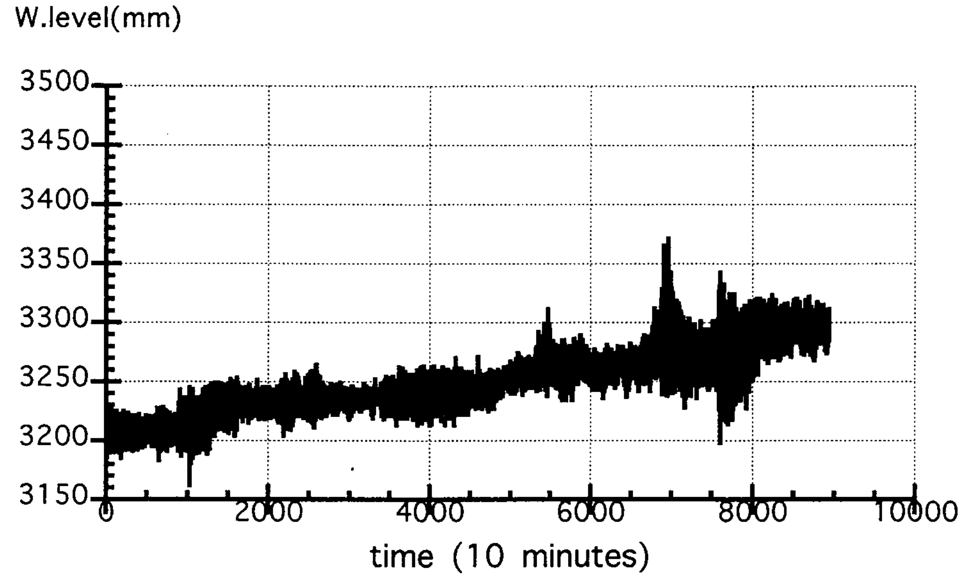

Fig. 3 Seasonal change of water level in Selim Lake by auto recording water gauge from June to August in 1995.

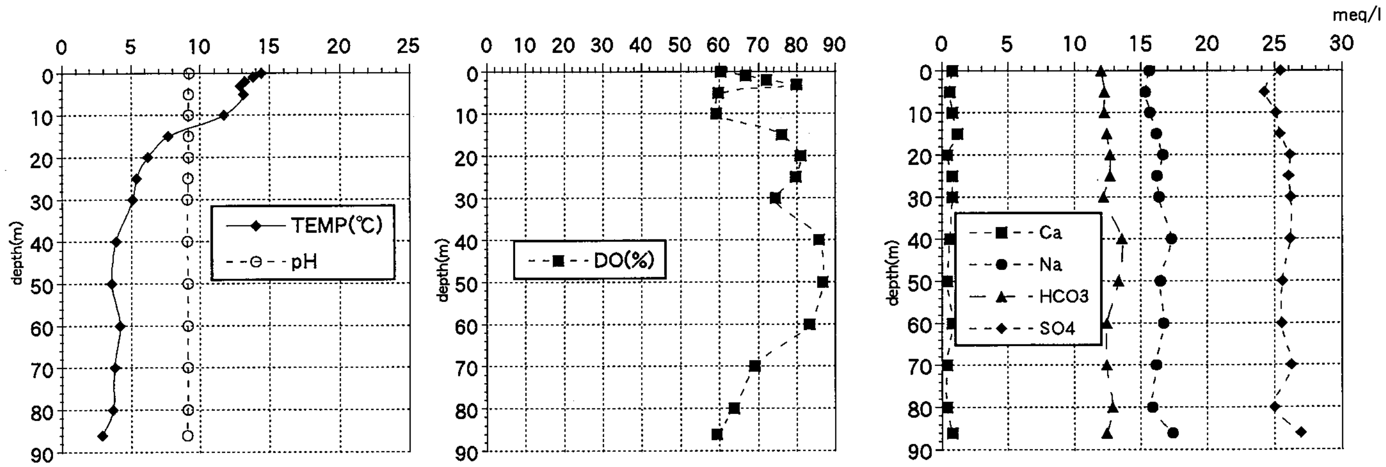

Fig. 4 Temperature , pH, electric conductivity 、 dissolved oxygen and dissoleved chemical substances (meq/l) in Selim Lake in summer stagnation period of 1996

The transparency is about 7-7.5m , not so high value as an oligotrophic lake.
The chemical stratification could not be recognized in summer stagnation period of August, in 1996 and 1997. In August of 1997, the authors set the auto recording temperature device to

measure water temperature from surface to bottom in the deepest point of Selim Lake.
By these analysis, the authors expect to be clarified the annual variation of thermal characteristics of deep saline lake.

CONCLUSION

As to water quality, concentration is distinct in rivers, groundwater and lake water. The constituti-on of dissolved substances changes remarkably and the change of anion is great. The chemical characteristics changes from carbonate type to chloride type. The concentration of inland water increase as it flows down and the maximum of it is recognized in the central part of the basin and its value reaches 400 meq/l in Lake Ayding. Generally speaking, all of these inland water except some rivers are high saline waters. The distinct change in water level of closed lakes is caused not by natural factors but by artificial ones. Lake Selim, which has no irrigated areas around it, shows very little change in water level, which is quite different from other closed lakes with irrigated area.

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A Study on Topographic Effect on the Floods in the Wengjiang River Basin

Chen Junhe
(Department of Geography, Zhongshan University,
Guangzhou 510275, P.R.China)

Abstract

Based on the topographic characterists of the Wengjiang river basin that is intermitted with gorges and basins, and on analysis of storms and floods on the catchment, the paper presents a flood calculation model for upstream gorge zones with deficent data in the view of slope runoff concentration and total runoff input. Test computation is made for the floods at the Shizikou basin in the middle and lower reaches. The paper discusses the effect of channels with intermitted gorge and basin on floods and regulation of the Wengjiang river. It concludes that flood return period decreases up and down streams, and suggests that reservoirs in down stream areas is relatively safe.

Key words: regional flood, flood retrun period, flood regulation, topographic effect.

1 Introduction

Lower reaches of the Wengjiang river is characterised by interimtted gorges and basins. The Changhu reservoir which is located in the lower reaches is a narrow and elongated in shape with narrower ends. The gorge channel stretches for over 20 km upstream the dam, and opens at the entrance with a basin, the Shizikou basin . Such a topographic condition has great effect of regulating major floods. When inputs of runoff to the basin exceed outflow discharge, floods detained by the gorges cause water level to grow, spill banks and submerge farm lands in the basin. A flood occured in Jun, 1964 caused sever damage and great losses. When a flood occurs, how it deforms at channels with intermitted gorges and basins? Questions like this should be solved in catchment hydrologic planning and management. However, without hydrologic surveys at the entrance basin, problems in flood calculation for the basin should be solved under situations of lack of hydrologic data so as to achieve input flood processes to the reservoir.

2 Flood calculaiton at Shizikou

With data of the surrounding gauges, floods at Shizikou can be calculated with the segmentation method. Upstream catchments of the Shizikou basin are segmented into 3 zones: (1) the Wengjiang zone, catchment above the Wengjiang gauge station, with a catchment area 2000 km^2; (2) the Wengcheng zone, catchment above the Wengcheng gauge station, area 533km^2; (3) the lower section, catchment between the two gauge stations and Shizikou, area 2000km^2. Since surveyed flood processes exist at the Wengjiang and Wengcheng gauge stations, the key problem for flood calculaiton in the lower section is to make sure how floods from zone (1) and zone (2) spread in the channels. To calculate flood at the lower section, the storm and runoff relation analysis, and runoff calculation approaches can be employed. Results are then taken as total input to the down stream reaches. The input flood processes to the reservoir at Shizikou can also be derived from progressive down stream calculaiton from the Wengjiang station and the Wengcheng station. The process of basin flood calculation are shown in fig. 1.

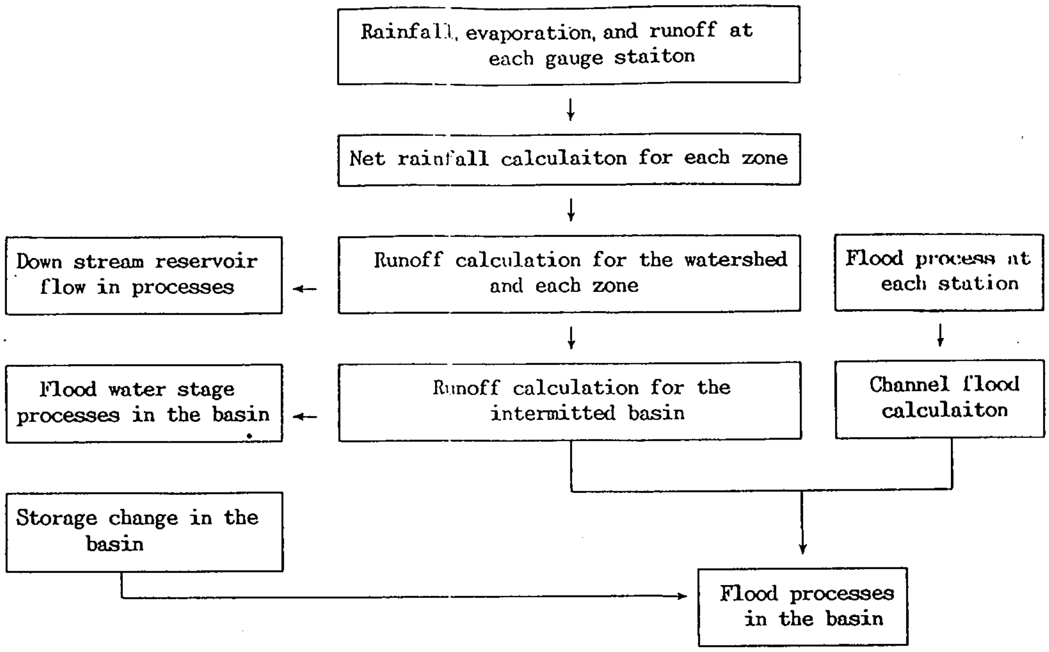

Fig. 1 Diagram of the flood computation at Shizikou basin

2.1 Runoff computation

Runoff computation is to calculate the loss of rainfall of a storm or net rainfall on a watershed. Runoff coefficients of 40 floods between 1964 ~ 1981 are plotted in a fig. 2 which shows that: (i) dots are discreted, especially for big floods such as No. 646 (June, 1964) whose dots are located in the left (smaller R value), and No.686 whose dots concentrate in the right (greater R value). (ii) the trend of the dot flock deviate from the theoretical 45 line, especially unstable for the upper part. Therefore, runoff of each flood is calculated with overflow approaches instead of saturation flow.

$$R = P - I_o - fc \cdot tc$$

where P represents rainfall, Io is initial loss, fc infiltration and tc net rain duration.

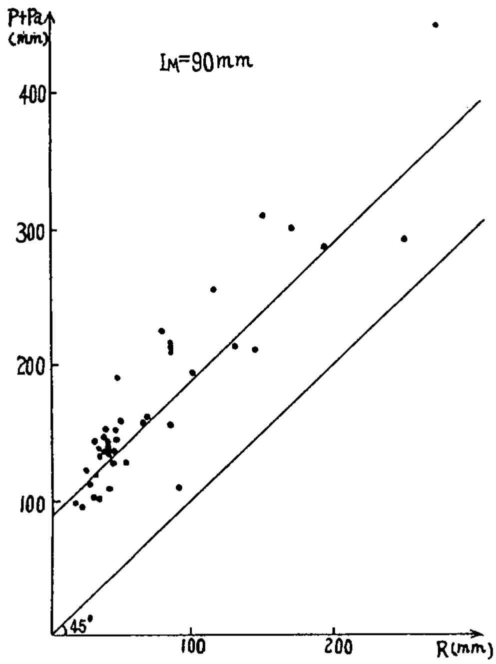

Fig .2 Corrlation between P+Pa and R in the Wengjiang river Basin

2.2 Slope flow computation

Slope flow compuation is to work out the total flow input of net rainfall. For the situation of Shizikou, total flow input is runoff processes of net rainfall flow into channels and reach the periphery of back flow area of the basin.

Since empirical flow unit hydrographs include effect of all factors of slope flow affecting each flood, of internal (the addition inclinaiton of flood wave) and external (such as water back up, indensity of surface and graound water, storm rainfall distribution etc.) factors, if the internal and external factors affecting each flood runoff are constant for a catchment, the empirical unit hydrographs of flood worked out from each flood should be constant. Analysis on 39 storm floods during 1954 ~ 1984 shows that the empirical unit hydrographs for catchments of all sizes upstream the basin are similar in the pattern. Therefore the empirical flow unit hydrograph approach is employed to calculate slope flow.

The principle of unit hydrograph approach is one time span in-flow (I) produces out-flow of several time spans (Q),

$$Q_n = I_1 q_n + SUM\ I_i q_{n-i+1}$$

therefore unit hydrograph q is expressed as:

$$q_n = 1/I_1\ (\ Q_n - SUM\ I_i q_{n-i+1}\ )$$

Where m is the number of net rainfall time units, n number of out-flow time units. Through a testing analysis on net rainfall of sub-total in-flow of the lower reaches, the 3 hour slope flow unit hydrograph is derived:

Δt	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
q (%)	0	4	10	14	19	15	10	7	5.5	4	3	2.5	2	1	1	0.5	0.5

The unit hydrograph shows that one time unit of net rainfall produces 16 time units of slope out-flow when drained completely. Such slow process of out-flow indicate that ground water accounts for a considerable ratio, and that ponded water in the basin plays a big role in backing up the flow during floods.

2.3 Channel flood computation

Ponding is are widespread during major floods. When water stage is 60 m, the water surface area is 37 km^2, when water level is 70 m, the surface is 68 km^2, and when 78 m the surface is 318 km^2. Water stage at Shizikou reached 77.84 m in 1964, back flow water approached the Wengjiang station, Wengcheng station and the Taiping station, therefore the surface lines of flood between each station and Shizikou are contineous without falls (riffles), and channel flood computation between the gauge stations and Shizikou can be taken as a common channel flow calculation. The method is employed in the study.

$$Q_2(t) = c_0 q_2(t) + c_1 q_1((t) + c_2 Q_1(t)$$
$$C_i = f(\Delta t,\ k,\ x),\ \ (i = 0,\ 1,\ 2)$$

3 Test of floods at Shizikou

3.1 Test of water stage

Figure 3 indicates that flood processes at Shizikou are in accordance with those of Huang-gang gauge station. The maximum water storage is 320,000,000 m^3 which was surveyed in 1964, with maximum water stage 77.82 m which approximates the result of flood investigation 77.84 m. The computation also indicates that the duration of water stage over 75 m is about 1 day, and over 70 m about 2 days, which agrees with the results of flood investigation made for the 1964 major flood at Dazhen district and Qiaotou district of Yingde county (city). The test results prove the computation methods.

3.2 Peak discharge test

Water stage surveys at Shizikou have been made for 9 years since 1955, with data from historic flood investigation since 1931, a water level series at Shizikou can be derived. Further more, analysis show that the rating curve at Huang-gang station is closely related with that of Shizikou, with a correlation coefficient of Qh and Zs as high as 0.99. Therefore, with the priciples of water balance, disharge at Shizikou Qs can be derived from discharge at Huang-gang Qh with the following equation:

$$Qs = Qh(t-1) + \Delta Vs(t) / \Delta t$$

The peak discharge of the flood in June 1964 is calculated 8900 m^3/s which is very close to 9400 m^3/s, the result of the runoff approaches described before (difference only 500 m^3/s). If the dynamic storage of the basin were taken into account, the peak discharge at Shizikou calculated from water balance approaches should be greater to some extent (greater than 8900 m^3/s). This also proves the reliability of the runoff method.

4 Analysis of regulation effect of basins to floods

Comparsions between floods at Shizikou and Huang-gang indicate that the regulation effect of basins to flood are:

(1) The regulation effect of the Shizikou basin to floods of the Wengjiang is related not only to the magnitudes of storm rainfall, but also to the intensity and distribution of storm rainfall. Generally, the higher the class of storm flood, the greater the intensity, and the closer the storm centre to lower reaches, the greater the regulation effect.

(2) Calculations indicate that the Shizikou basin begin to store when the in-flow to the basin greater than 2000 m^3/s, and the rate of storage increase with in-flow discharge.

(3) Calculation results also indicate that with the in-flow discharge of 1964 flood to the basin was 9400 m^3/s, the out-flow discharge was reduced by 45% by the regulation effect. With the in-flow 5540 m^3/s in 1968, the storage regulation reduced 18% of it. Whereas, with in-flow disharge 3400 and 4230 m^3/s in 1974 and 1976, the reduction by regulation are only 8% and 13% only.

The regulation effect (peak reduction) of the Shizikou basin is that floods in the down stream Changhu reservoir become moderate with smaller deviations (Cv), which is beneficial for flood protection of the reservoir.

where $q(t)$ and $Q(t)$ are discharge at upper and lower section respectively, subscript 1, 2 represent start and end time, x, k, Δt are parameters which can be derived by testing approaches. The parameters derived from several flood in 1959, 1964 and 1968 are $x = 0.1$, $k = 4.5\sim5h$, and $\Delta t = 3h$.

Based on above analysis and rainfall data of the catchment, the input flows at Shizikou are calculated for floods before and after the construction of the Changhu reservoir (1964, 1968, 1974 and 1976), results are shown in figure 3 and table 1.

Table 1 Summarigation on the elements of floods at Shizikou

Year	Sub-tr	ini los	PostLos	Qm(sh)	Qm(ch)	ΔQ	ΔQ(sh)	Hm(sh)	>Hm	T(h)
1964	366.2	34.9	2.8	9412	5160	4252	45.2	77.82	75	24
									70	60
1968	296.2	6.8	0.33	5539	4550	989	19.9	72.38	65	16
1974	189	27.5	0.80	3401	3115	286	8.4	65.34	60	19
1976	140	1.8	0.90	4231	3690 (4610)	541	12.8	71.09	65	

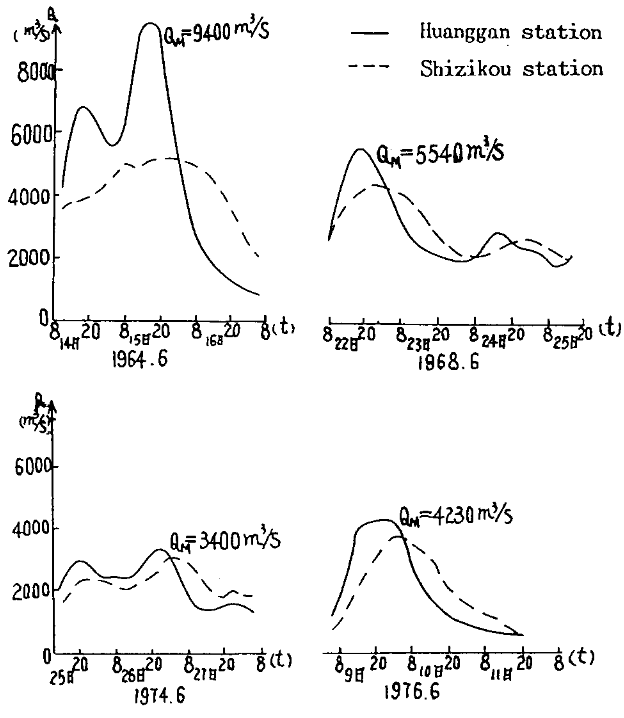

Fig.3 The flood hydrograph at Huanggan and Shizikou station

(4) Frequency analysis on historic flood series for gauge stations (the Wengjiang station, Mao-yuan-jie, and Huang-gang station) on the Wengjiang river derives the maximum peak discharge and return period of the 1964 flood for each station (table 2).

Tab. 2 The flood recurrence interval of the flood in 1964 at each station

	Wengjiang	Mao-yuan-jie	Huang-gang
Qm (m^3/s)	4800	4200	5160
N (year)	100	40	20

Factors affecting the recurrence of floods at different reaches of a river is many and diverse. However, the distribution of storms and catchment topography are among the major elements. The storm centre causing the 1964 big flood was located on the middle and upper reaches, however, the flood recurrence intervals decrease downstream instead of upstream, which indicates that the return period of the Wengjiang catchment is majorly defined by the relief. The particular topographic features of intermitted gorges and basins cause larger return periods (such as that of 1964) to decrease downstream. However, the trend is beneficial for flood protection for the downstream Changhu reservoir.

Runoff analysis of the Huai He River in China

T.Kishii(*) and Y. Kuzuha(*)

*National Research Institute for Earth Science and Disaster Prevention, Science and Technology Agency

3-1 Tenno-dai, Tsukuba-shi, Ibaraki 305 Japan
Fax:+81-298-51-3246, Email:kishii@ess.bosai.go.jp

(Abstract)

This study aims to clarify water balance of the regional scale in China. For these purposes hydrological data base, the elements are precipitation, runoff, evaporation, temperature, humidity and wind velocity are made. Using this data base, the characteristics of rainfall, runoff and evaporation is analyzed in the Huai he river basin.

This report shows the result of the hydrological characteristics at Hoai pin in the Huai he river basin by the runoff model (Tank model). As the result, hydrological characteristics of rainfall, runoff and evaporation was determined and runoff characteristics in the upstream of the Huai he river.

1. Introduction

This study aims to clarify the characteristics of the runoff in the upstream of the Huai he river in China. This river is located on the area between the Yellow river and the Chang Jiang river. The river basin is strongly affected by the Asian monsoon. Tank model is used for analyzing daily runoff in this river.

2. Runoff analysis

Tank model was used for runoff model. The analyzed area is the upstream of the Huai he river basin. The target station is "Hoai pin" , area of basin 16,005 km^2(Fig.1). Hydrological data used here are, rainfall, runoff and evaporation from 1983 to 1991 by "Remote Sensing Technology Application Center, Department of Water Resources of China". Areal rainfall amounts are calculated by arithmetic mean of two stations, Hoai pin and Shi shen. Evapotranspiration is calculated from evaporation data of Shi shen multiplied by some coefficients.

3. Results

a. Characteristics of monthly change of rainfall, runoff and evaporation.

Monthly and seasonal change of hydro-meteorological as follow. Rainfall occur's mainly in June to October. Especially much rainfall in June, July and October. Runoff amounts is also large from June to October similar to rainfall. Evaporation is larger than 4 mm/day from April to September. A example of the change of these elements are shown as Fig. 2 and Fig.3.

b. Runoff model (Tank model) analysis (Fig. 4)

Four series Tank model is used for analyzing runoff of the Huai he river. Evapotranspiration for this analysis is used for half amounts of observed pan evaporation at Shi shen. This is due to results by annual rainfall loss analysis.

Results are following. In summer season, of large amounts of discharge, the simulated result is coincided with observed one. But not so good in low flow period.

4. Conclusion

Runoff ratio and total discharge are shown as Table 1.

Annual rainfall ranges from 700 mm to 1400 mm, runoff 160 mm to 700 mm and runoff ratio from 0.22 to 0.48. Mean annual loss is about 600 mm.

From these results, runoff ratio is smaller than that of the river in Japan. That shows evapotranspiration have major role in water balance.

On the runoff model analysis, the simulated result was not coincided in low flow period. the part of the cause may be artificial drainage, irrigation for paddy field, cultivated land etc. Runoff coefficients of the first & the second tank of tank model larger than that of the down stream basin due to analyzed later. It means that rapid runoff component is larger than that of downstream basin.

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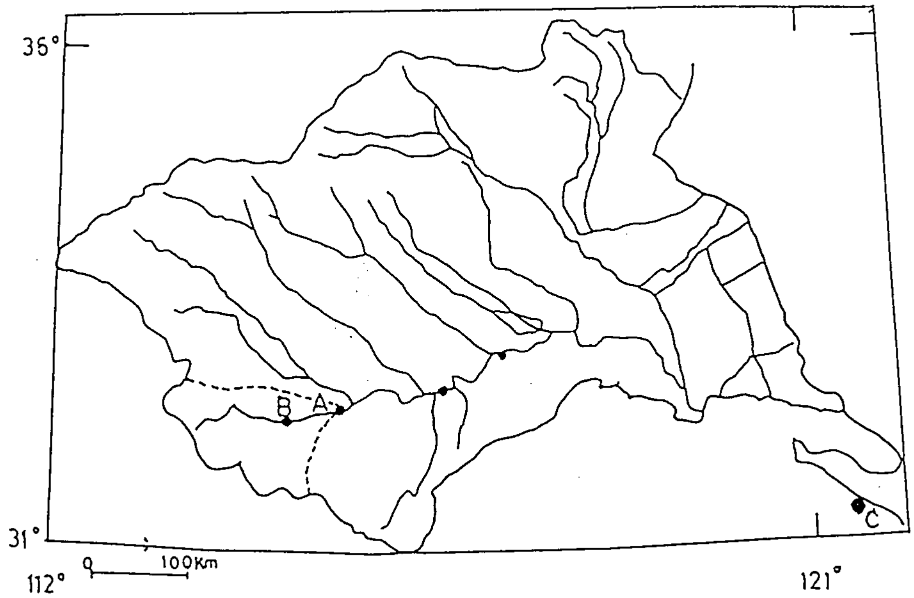

Fig. 1 Location of the hydrological stations in the Huai he river basin
(A: Hoai pin, B: Shi shen, C:Shang hai)

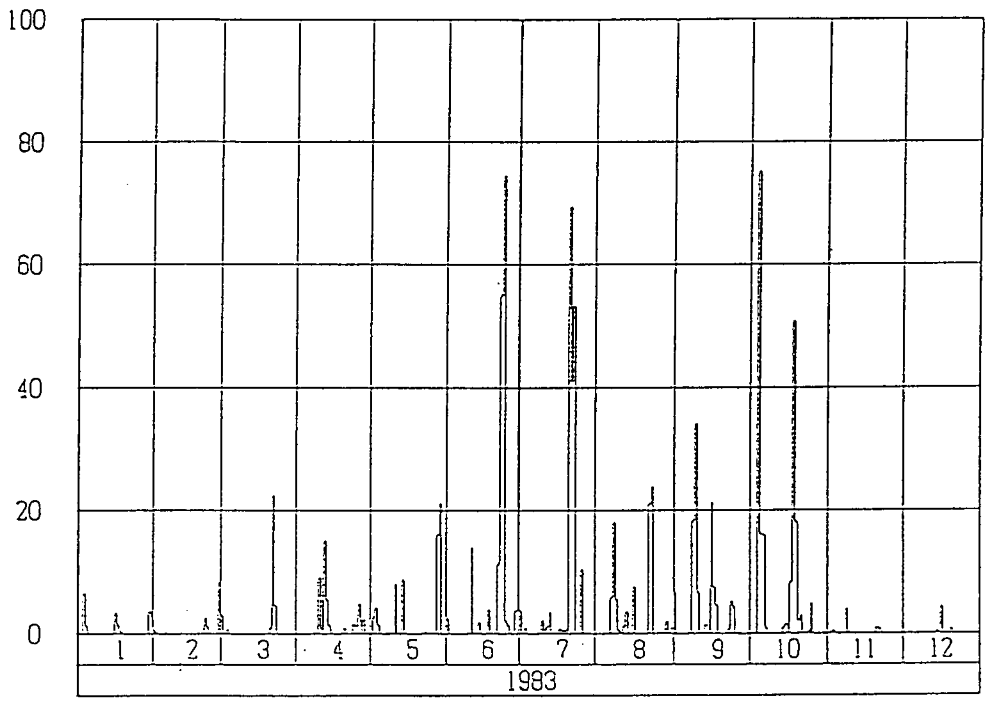

Fig.2 Daily mean rainfall(mm/day) to the upstream basin of Hoai pin

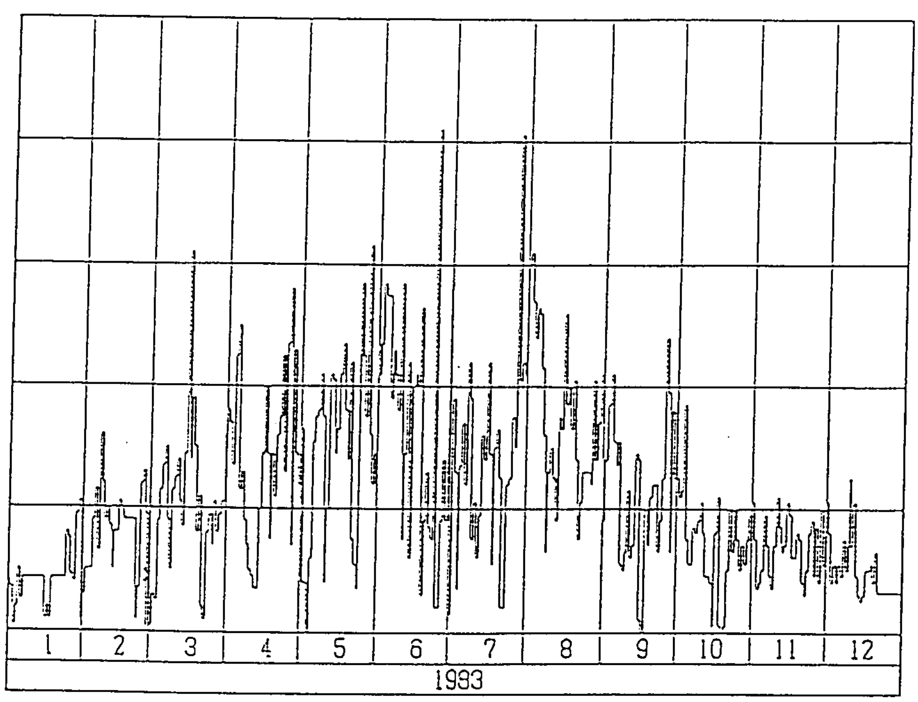

Fig.3 Daily evaporation(mm/day) at Shi shen

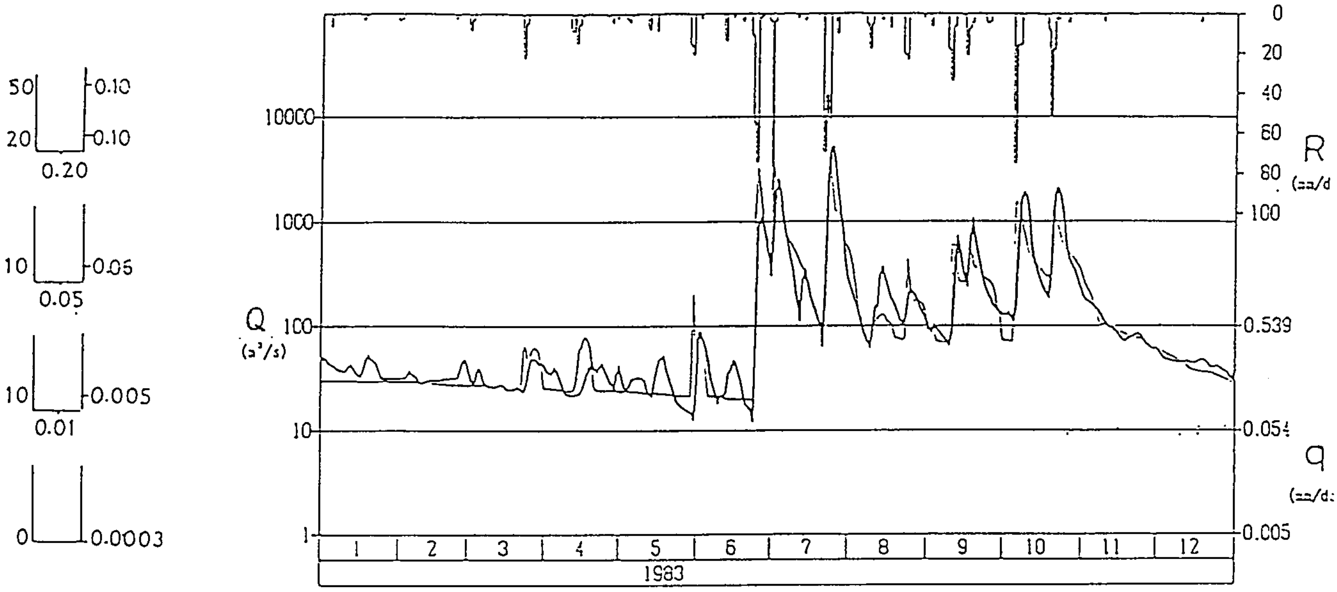

Fig.4 Tank model to the upstream basin of Hoai pin

Table 1 Rainfall, runoff and runoff ratio at Hoai pin in the Huai he river in China

item / year	Rainfall (mm)	discharge ($\times 10^6 m^3$)	Runoff (mm)		Runoff ratio	
			observed	calculated	observed	calculated
1983	1036.3	7232.7	451.9	441.1	0.44	0.43
1984	1356.1	6435.6	402.1	634.4	0.30	0.47
1985	822.1	4662.3	291.3	300.0	0.35	0.36
1986	701.1	2776.9	173.5	198.5	0.25	0.28
1987	1415.6	10793.8	674.4	646.4	0.48	0.46
1988	719.8	2584.8	161.5	227.2	0.22	0.32
1989	852.4	6080.3	379.9	256.7	0.45	0.30
1990	890.2	4323.0	270.1	271.2	0.30	0.30
1991	1358.0	9518.2	594.7	682.3	0.44	0.50
mean	1016.8	6045.3	377.7	406.4	0.36	0.38

Hydrological Characteristics and Water Balance of Bosten lake, Xinjiang, China

Zhao Jing-Feng and Hideki Nagashima

Department of Ocean sciences, Tokyo University of Fisheries
4-5-7 Kohnan Minato-ku Tokyo 108 Japan
Fax:+81-3-5463-0378, Email:nagasima@bimelan.tokyo-u-fish.ac.jp

Abstract

The hydrological characteristics of the lake Bosten are studied based on the analysis of available data obtained from 1976 to 1989 at the hydrological stations around the lake. The results are as follows: (1) The annual average of volume transport of main inflow river, named Kaidu river, varies from 80 to 120m^3/s. The maximum and minimum values are found in 1980 and 1986, respectively. (2) The other inflow rivers and the outflow river show almost steady volume transports during this period. (3) The water level of the lake Bosten decreases and has the minimum value at 1987, then increases slightly. (4) The seasonal water balance of the lake is investigated from March 1983 to February 1984 in detail. The result shows that only evaporation, precipitation, discharges of the main rivers, and the change of water level can not explain the water balance.

1.Introduction

The lake Bosten is the biggest freshwater lake in the inland of China nowadays. It plays a very important role in the development of agriculture, industries, and fisheries as well as the aspect of natural environment. However, the water area recently becomes smaller and smaller, and the water becomes salty and salty especially during 1980' decade. To avoid the similar old disastrous story of the lake Lop, which was the former biggest lake in China and had dried up since 1930's, it is very necessary to clarify the hydrological characteristics and water balance mechanism of the lake Bosten as early as possible. In the present study, by using the available data of the hydrological stations around the lake, we investigate the hydrological characteristics of the lake and water balance in the main lake and its surroundings. In the Section 2, Geographical characteristics and land utilization around the lake are introduced; the Section 3 demonstrates the hydrological characteristics; we give the water balance model of the Bosten lake and the each water budgets in the Section 4 ; as an analyzing results, we describe the conclusion in the Section 5.

2. Geographical characteristics of Bosten region

The lake Bosten, located in the Yanji Basin as shown in Fig.1, had been the third biggest lake following the Lop and Aibi lakes in Xinjiang Uygur Autonomous Region in northern part of China. Nowadays, however, the lake Bosten becomes the biggest one as the other two lakes had dried up or diminished their water area. The Yanji Basin is surrounded by the Tianshan Ranges and the lowest place in the basin is the lake Bosten. Most of the inflows are from the northwestern and northern mountain areas. The river Kongque is the unique outflow originated from the southern lake. The area of the lake is about 930km^2 and the depth is 7.7m in average with the maximum depth of 16m in the southern part. In addition, the lake Bosten is surrounded by a number of small water areas, duckweed areas, cattail and reed marshes and irrigation lands. The main agricultural areas are located to the western and northern sides of the lake where the irrigation water is easily got from upper reaches of the inflow rivers.

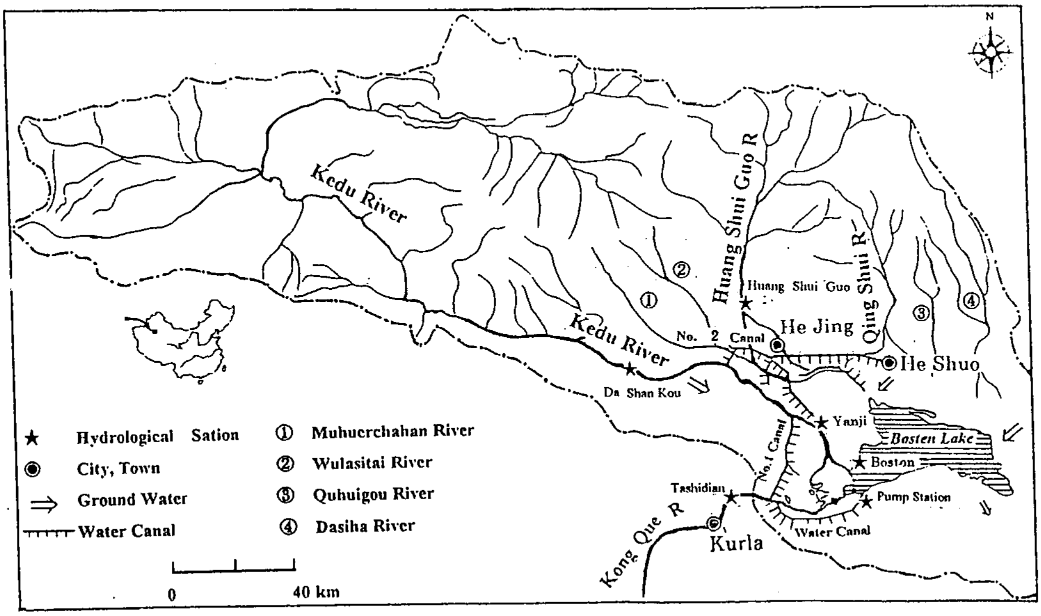

Figure 1. Locations of Bosten Lake and Hydrological Stations in Yanji Basin, Xinjiang, China

From the contour map of the lake, the area and capacity of the lake are estimated as a function of water level H referred to the altitude of 1040m. The results are as follows:

$$Sm_i=a_i \cdot H_i + b_i \qquad (1)$$

$$V_i=c_i \cdot H_i+d_i \qquad (2)$$

where Sm_i is the area of the main lake with the unit of square kilometer, Vi is the capacity with the unit of 10^8 m^3, and a_i,b_i,c_i,d_i are the coefficients in the formula (1) and (2). Their values are listed in Table 1.

Table 1. The Parameters for Calculating the areas (Sm_i) and the Capacity (V_i) from the Water Levels of Bosten Lake.

H_i-1040 (m)	a_i	b_i	c_i	d_i
$3\leq H_1<4$	75.0	520.0	8.0	11.0
$4\leq H_2<5$	60.0	580.0	9.4	5.4
$5\leq H_3<6$	50.0	630.0	9.6	4.4
$6\leq H_4<7$	38.0	702.0	9.5	5.0
$7\leq H_5<8$	24.0	800.0	8.7	10.6
$8\leq H_6$	13.0	888.0	9.8	1.8

In the Bosten region, the land types are generally classified into four groups such as reed lands, irrigation lands, cattail lands and uncultured lands with alkalized characteristics. The area of first two groups are much larger the others. The area of reed lands around the lake and its surroundings is estimated by aerial photograph as 495.87 km^2 in 1981. The value is 62.53km^2 smaller than the value 558.40km^2 in 1959. This means the area of reed land decreases with the degression rate of

$2.84km^2$/year during the past 22 years. In 1965, the reed resources were investigated by the local government at the southwestern side of the lake. The reed lands are classified into the four types by the criteria listed in Table 2. The areas of these for types are estimated respectively from the data taken in 1965 and 1981 and derive the following empirical relation of the area of reed lands:

$$SR_i = SR_i^* + (1981 - Y_k) \cdot \gamma_i \qquad (3)$$

where SR_i is the area of reed land of the i-th grade of reed type, Y_k is the year from 1965 up to now, SR_i^* is the area of reed land in 1981, and γ_i is the degrading rate per year. The estimated values of γ_i are listed in Table 3. Note that negative sign of γ_i in 4-th grade is due to an increase of the reed land area.

Table 2. The Criteria of Reed Land Types in Bosten Region

Grade	Height (m)	Diameter of Stem (cm)	Coverage (%)	Dried Biomass (kg/m^2)
1	>7.5	>1.2	>80	>1.5
2	2.5 ~3.5	0.8 ~1.2	60~ 80	0.8~ 1.5
3	1.5~ 2.5	0.5~ 0.8	40~ 60	0.4~ 0.8
4	<1.5	<0.5	5~ 40	<0.1

Table 3. The Grades of Reed Land with Areas(Km^2) and the Average Degrading Rate of Reed during 1965~1981.

Grade	SR* (1981)	SR' (1981)	SR' (1965)	Rate of Digression (γ) (km^2/year)
1	57.60	29.89	46.91	1.06
2	37.96	26.29	47.11	1.30
3	99.36	75.23	83.46	0.51
4	193.02	122.49	120.55	-0.12
Total	387.94	253.9	298.03	2.76

SR*: The areas of all reed lands in the Bosten region.

SR': The areas' changes of the reed lands in the sampling region in southwestern Bosten lake.

3. Hydrological Characteristics

The Fig. 2 shows the yearly variation of the Bosten Lake's water level from 1955 to 1993, and the annual variation between 1955-1993 is more than 3 meters. On the other hand, as the monthly data recorded after 1976, the seasonal changes of the water level fluctuate within 1 meter. Hydrological data are available at the several observation stations listed in Table 4, and the data up to 1989 are used in this study. In Fig. 3, the annual averaged values of river discharge are shown at the Dashankou, Huangshiugou and Qinshuihe for the Kaidu, Huanshugou and Qishui rivers, respectively. The Kaidu river is the biggest inflow in the Yanji basin with a wide catchment area and has the immense water discharge, which is about 80% of the total discharge. However, the annual variation of the discharge in Kaidu River is very large as shown in Fig. 4. The maximum discharge of $115m^3$/sec was recorded in 1980 and is 1.47 times larger than the value $78.2m^3$/sec in 1986. In contrast, the discharges of other rivers are rather stable. The Kongque River is the unique outflow that mostly flow out from the pump station at the northwestern Bosten Lake. The annual variation of the flows is very small as shown in Fig. 4.

Evaporation has been measured near the lake by using an evaporation pan whose diameter is 20cm. However, the measured values can't be used directly, because the evaporation is usually influenced by the local weather and the temperature of small pan. In 1983 to 1984, the evaporation experiment was carried out in the lake Bosten, where a larger evaporation pan with the diameter of 60.1cm was used. Moreover, meteorological factors are observed in detail. We used these data and

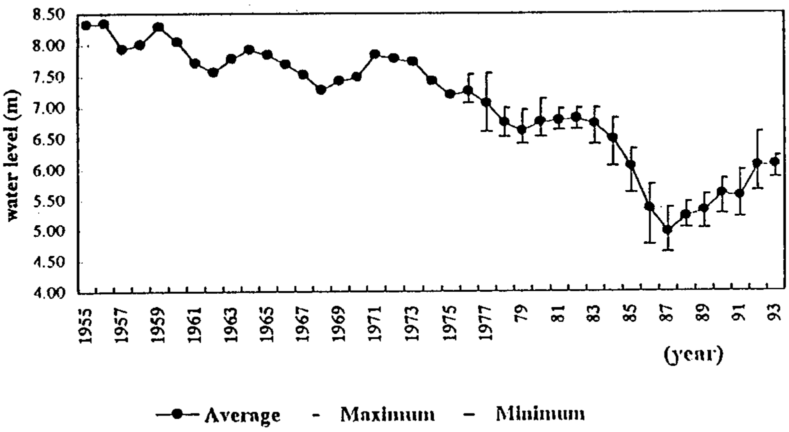

Figure 2. The Variation of the Bosten Lake's Water Levels from 1955 to 1993.

Table 4. The List of Hydrological Stations and the Observed Items

Station	Name of river	Catchment area (km^2)	Elevation (m)	Observation Period	Observation items[1)]
Dashankou	Kaidu	19,022	1338.9~ 1339.7	1955~present	H, Q, Sd ect.
Yanji	Kaidu	20,705	1056.2~ 1058.9	1947~present	H, Q, Sd etc.
Huangshui	Huangshuigou	5,000	1319.4~ 1323.3	1955~present	H, Q, Sd etc.
Kerguti	Qingshui	465	------	1956~present	H, Q, Sd etc.
Tashidian	Kongque	------	1048.2 ~1052.3	1948~present	H, Q, Sd etc
Bosten	------	------	1047.7 ~1049.1	1955~present	H, E*, P, Tw, Ta etc.

*: Evaporation with 20 cm evaporation pan.

1) H: Water level Q: Discharge Sd: Suspension sandtransport E: evaporation P: precipitation Tw: Water temperature Ta: Air temperature

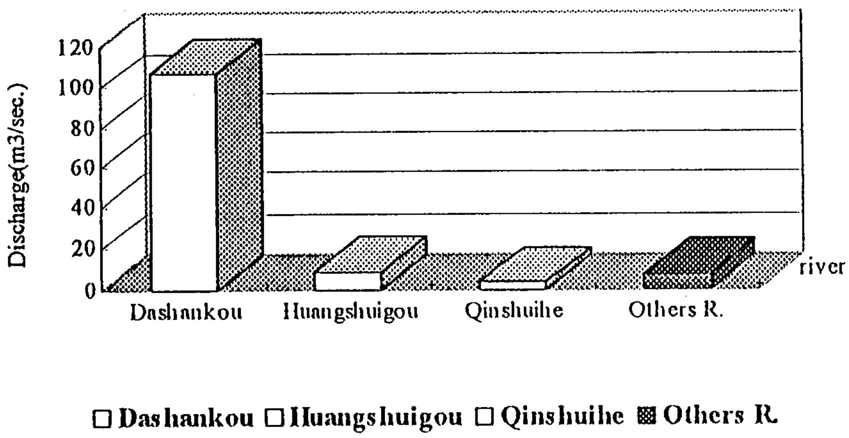

Figure 3. The Annual Discharges of the Inflows Rivers in Bosten Region.

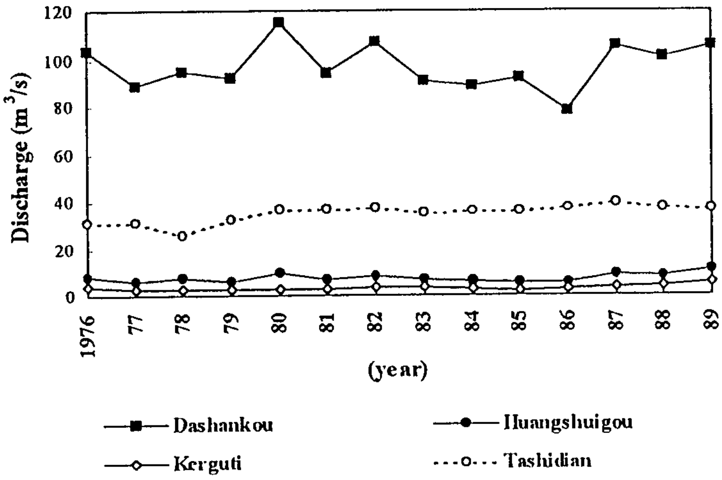

Figure 4. The Variations of Discharges of the Rivers in Bosten Lake. from 1976 to 1989.

calculated the evaporation from the water surface (E_w) by the bulk method. Comparing results of these three methods, we have the conversion constants $\lambda_w = E_w/E_{601}$ and $\lambda_{601} = E_{20}/E_{601}$, where E_{20} and E_{601} denote measured values by evaporation pans with diameters of 20cm and 60.1cm, respectively.

The annual precipitation in the Bosten region varies from 20mm in 1977 to 178.3mm in 1988 with the general ranges of 50-80mm.

4. Water balance of the lake from March 1983 to February 1984.

The water balance of the lake can be demonstrated as shown in Fig. 5. The equations of water balance is given by as follows:

$$QBI+QDI+P\cdot S_m+GI=QPO+Sm\cdot E_w+QH_m+GO+\delta \qquad (4).$$

The left-hand side of the equation (3) means inflows into the lake. QBI and QDI denote inflows of a river and irrigation drainage, respectively. P is the precipitation and Sm is area of the lake. GI is the unknown inflow of ground water. QPO in right hand side express the outflow from the lake. E_w is evaporation, QH_m is the increment of the lake water. GO is the unknown outflow of ground water. δ means the residual of water budget in the model. Annual values of these terms are listed in Table 5. By using monthly data, we calculate the monthly value of the term GI-GO-δ. As shown

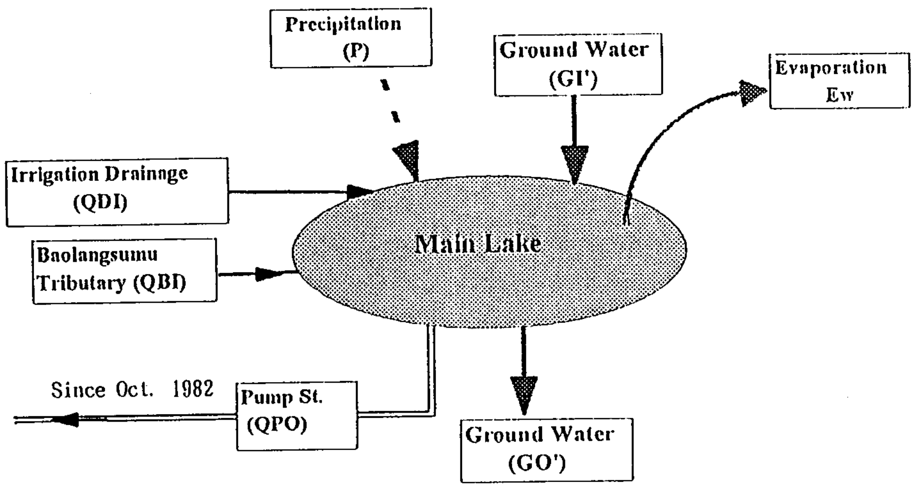

Figure 5. The Sketch Map of the Water Balance's Budget in Bosten Lake.

in Fig. 6, the term GI-GO- δ is not negligible and has positive value in winter season and negative value in summer season.

Table 5. The Annual Values of Water Budgets from March 1983 to February 1984.

$10^8 m^3$	inflows/outflows		Precipitation &. Evaporation	ground water	Water Level	Sum
input	9.64 (QBI)	2.00 (QDI)	0.72 ($P \cdot S_m$)	GI'		Σ QI'
output	5.94 (QPO)			037* (GO')		6.31 (Σ QO')
consume			9.31 ($S_m \cdot E_w$)			9.31 (Σ QC')
capacity increment					2.56 (QH_m)	2.56 (Σ QH')

*: 0.37 is quoted from the investigation carried out in 1983 **)

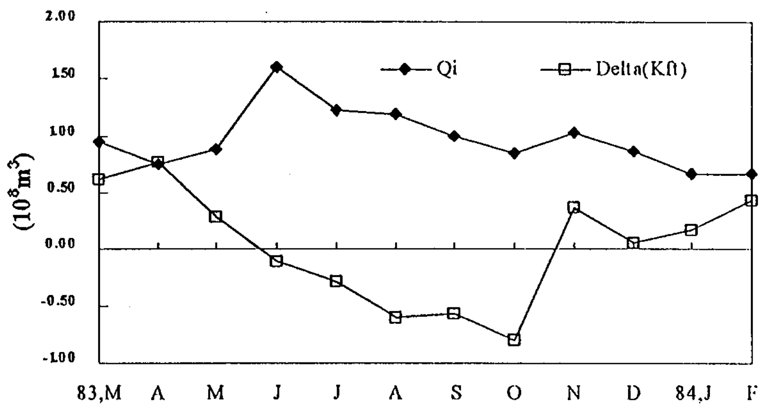

Figure 6. The Monthly Inflows(Q_I) at Bosten Lake's Inlets, and the Residual(GI-GO- δ) of Water Budget of the Model.

5. Conclusion

We analyzed available data of the lake Bosten from 1976 to 1989 at the hydrological stations around the lake. The results are as follows: (1) The annual average discharge of the main inflow river, called Kaidu river, varies from 78.0 to 115.4 m^3/s; and the maximum and minimum values occurred in 1980 and 1986, respectively. (2) The other inflow rivers and the outflow river show almost steady volume transports during this period. (3) The water level of the lake Bosten decreases and has the minimum value of 1044.73 meter at 1987, then increases slightly. (4) The seasonal water balance of the lake is investigated from March 1983 to February 1984 in detail. The result shows that the water balance can not be explained only by the evaporation, the precipitation and the water levels of the lake, as well as the discharges of the main rivers. It is known that the irrigation system play an impotent role in the water blalance model of the lake Bosten, thus, we should develop the model for a wide catchment area in future.

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Interannual variations and decrease of the river runoff in the Lake Balkhash basin, in Central Asia

Kader Kezer
Department of Geography, Tokyo Metropolitan University
1-1 Minami- Osawa, Hachioji-shi, Tokyo 192-03,Japan
E-mail: kader@geog.metro-u.ac.jp

ABSTRACT

The Interannual variations and decrease of river runoff draining into the lake Balkhash basin, in Central Asia are investigated by using meteorological and hydrological data over long term period.

At first, it is found that an apparent increase of decrease trend is not seen in the interannual variability of the meteorological elements in the basin. Next, interannual variations of the annual mean runoff in the rivers are investigated by the difference integral curves. From this analysis, it is determined that a low flow period begins in 1970 in the Ili-river and in 1973 in the eastern rivers, respectively.

Finally, the Characteristics of the integral curves of runoff in the runoff growing season (from Apr. to Sep.) and non-growing season (from Oct. to Mar.) of entire period are investigated concerning the 3 sections of the upper, middle and lower reach of the Ili-river .The following results are obtained. (1) The mean runoff of the non-growing season at the 3 section has remained virtually unchanged entire period.(2) The largest decrease of runoff growing period of the Ili-river has occurred in the middle and lower reaches, respectively. These amounting to 44%, 45%of mean runoff of the growing season before 1969,respectively. Also the effect of human activity is responsible for 58%, 60%, respectively.

This study has quantitatively made clear that the main reason of the apparent decrease of the runoff of the Ili-river is derived from the human activity.

INTRODUCTION

The Lake Balkhash basin is one of the largest internal drainage located in the arid and semi-arid region of in Central Asia. It covers 413,000 km^2 between 73° 20´ E and 79° 10´ E and 45° 00´ N and 46° 44´ N. 85%and 15% of drainage are in the republic of Kazahkstan and in P. R. China, respectively.

The major rivers draining into the lake Balkhash basin are Ili, Karatal, Aksu, Lepcy and Ayaguz (Fig.1). The latter four are draining from east part of the Lake , which are referred to as east rivers in this study. These rivers are originated from the Khrebet Dzhungarskiy Alatau mountains located in the north-east part of the basin and from the Tien- Shan mountains located in the south-east part of the basin (Fig.1).The lowland parts of the basins of these rivers are regions of runoff utilization or dissipation because of losses through evaporation and infiltration into the soil.

According to the investigations of Sidhikov J.S et al.,(1992) and Kader et al.(1996),the surface water resources of the east rivers are estimated at 6.4 km^3 /year and of the Ili-river is estimated at

17.4 km^3 /year, respectively. The latter accounts for the 730% of the total surface inflow into the lake .The total water resources of the lake Balkhash basin in the zone of runoff formation amount to 23.8 km^3/year. Ground water inflow is not so insignificant. According to Kawabata and Tsukatani (1996), it does not exceed 0.1-0.3% of the surface water resources.

Water resources are mainly used for the irrigation, industry, water supply to populated areas, and the fishing industry. According to Fukushima(1993) ,the interannual variability of the increase of irrigated areas in the last 20 years are estimated as follow.

Table.1

Year	1965	1970	1975	1980	1984
Irrigated areas (km^2)	3639	4288	4638	5259	5596

By analysis of the precipitation, surface inflow into the lake, and water level of the lake in the period before 1969, Kudrin and Rubinovich(1976) and Zhirkevich (1972) came to the conclusion that despite the development of irrigation and other types of water use in the basin in this century, the observed hydrologic series for 1969 can be taken as the natural conditions in the first approximation. The filling of the Kapchagay reservoir in 1970 produced a drastic change of the natural regime of the Ili-river and Lake Balkhash (Kudrin R.D et al.,1976; Sidhikov .J. S et al., 1992;Yang and Chao,1993).Before 1970,the fluctuations of the hydrologic budget and level of the lake were mainly determined by climatic factors (e.g., precipitation and temperature)as well as by the change of losses of water in the Ili-river delta which is associated with the development of its channel network (Kudrin, R.D et al.,1976). Because of the observed low flow, the over- development of irrigation, and the construction of the Kapchagay reservoir, the changes in the runoff of the Ili-river have become more pronounced and have led to a drop in the level of the Lake Balkhash by approximately 2.66 m since 1970.

Several previous studies devoted to water level fluctuations, water balance of the lake Balkhash, forecast of the change in the hydrologic budget using climatic and runoff data on the middle or lower reach of the Ili-river. However, there are few studies which investigated the interannual variation of annual /monthly runoff at the various gagging stations in the zone of runoff formation and in the zone of use of water resources in the basin, especially related variation of the runoff during the growing season (from Apr. to Sep.) or non-growing season (from Oct. to Mar.).

The purpose of the present paper is to analyze precipitation, air temperature and hydrologic data in the Lake Balkhash basin. Especially, the investigation refers to various gagging stations in the upper, middle and lower reaches of the Ili-river. Special attention is paid to the comparison among runoff in these reaches, concerning the interannual variation, annual runoff and runoff of growing season and non-growing season. The comparison is made between mean runoff over following period: (1)a natural or conditionally natural regime;(2) a modified regime of intensive development of irrigation.

DATA and METHOD

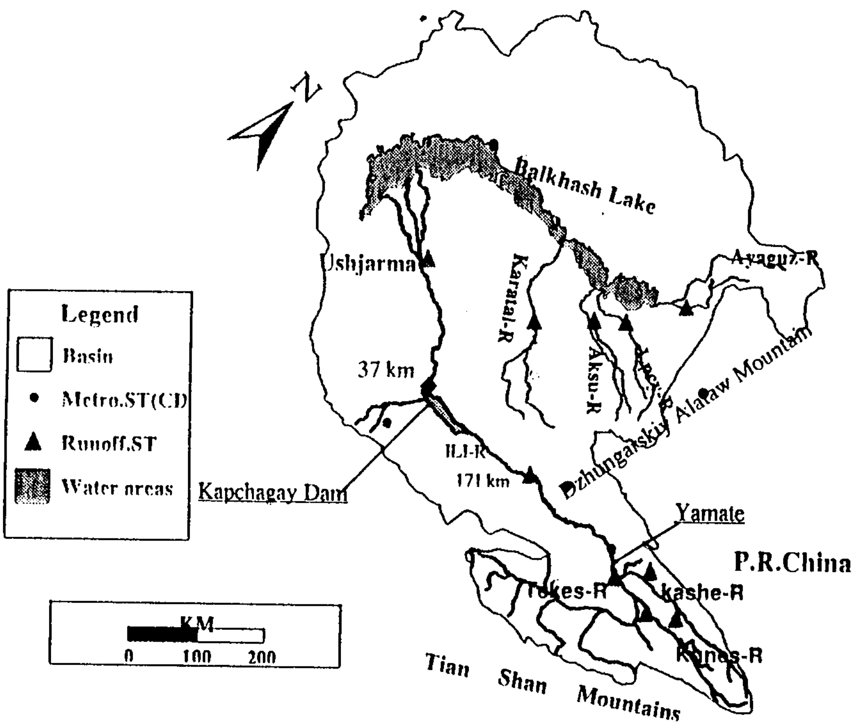

Fig.1 Map of Lake Balkhash basin in Central Asia, created by the Topographic map (scale;1: 5000,000)produced by the defense Mapping Agency Aerospace center in USA.

The long-term annual/monthly precipitation and air temperature are calculated with the data of GHCN(Global Historical Climtology Network) of CDIAC(Carbon Dioxide Information Analysis Center) in USA along with the data of RIHMI-WDC (Research Institute of Hydro-meteorological Information-World Data Center) in Former USSR.

In addition ,the following river discharge data are used in this study :

- Annual/monthly runoff data of the 171 km,37 km and Ushjarma gagging stations located in the upper and lower reaches of the Kapchagay reservoir and the delta of the Ili-river are available during 1966—1992,1911—1986,1949—1986 , respectively . Also, annual/monthly runoff data of the Karatal, Aksu, Lepcy and Ayaguz rivers are available from 1924 to 1986.These data are provided by Drs. J.Dostayev and A.A. Tursunov of Institute of geography, Kazahkstan Academy of Sciences).
- Annual/monthly runoff data of the Tekes, Kunes and Kashe rivers of the upper reach of the Ili-river and the Yamate gagging station in the Ili-river are observed about from 1954 to 1990 by Xinjiang general hydrometric station in China.

The relationship between runoff data at the Yamate and 37km gagging station of the Ili-river (Fig. 1) from 1954 to 1969 is investigated to reconstruct the data series of the annual discharge of the Yamate from 1911 to1954. The correlation coefficients R and standard error δ , of are estimated to be 0.95 , $\pm$23.1 m^3/sec,respectively. The regression equation (Q_y=0668Q_{37}+71.9) is defined.

In order to analyze interannual variation of annual mean precipitation and air temperature in the basin for the entire observation period. The data series are reconstructed using the equation below:

$$K=(X-x)/SDT \qquad (1)$$

Where K is the normalized value, SDT is standard deviation, X and x is the annual mean of the each year and the average of the entire observation period data, respectively.

For evaluating the interannual variation and decrease of the mean runoff of the rivers, difference integral runoff curves and integral curves of runoff depth are calculated, respectively, with the following equation:

$$F(t) = \Sigma\,[(K_t-1)\ /Cv\ ] \qquad (2)$$

Where F (t) is the difference integral runoff curves with time(t) , $K_t = Q / q$;here Q and q is annual mean runoff data(m^3/sec) ,and the average of the entire observation period annual mean runoff ; Cv is coefficient of the variation.

$$G(t)=\Sigma H=\Sigma Q/A \qquad (3)$$

$$W=(\Sigma H_o\ -\Sigma h)*A*10^{-6} \qquad (4)$$

Were G(t) is the integral curves of runoff depth with time(t); A is area of the watershed(km^2); H is mean runoff depth for the study period (mm) ; W is total decrease value of mean runoff for the study period(km^3); H_o is calculated value of the runoff depth(mm)after1969 by applying the extend line of regression equation of the Fig.5-7(b) ,which is considered as nearly natural condition before1969; h is the runoff depth(mm) observed value after 1969 .

RESULTS and DISCUSSION

In order to discern whether there is some trends in climatic conditions in the basin, the interannual variability are investigated over long-term period. Figure.2 (a) and 2(b) shows interannual variations of the normalized annual mean air temperature (K_t) and precipitation (Kp) for four meteorological stations in the basin. The apparent trends are not found in both temperature and precipitation time series, with the exception of annual mean the precipitation at the Balkhash city in 1976.

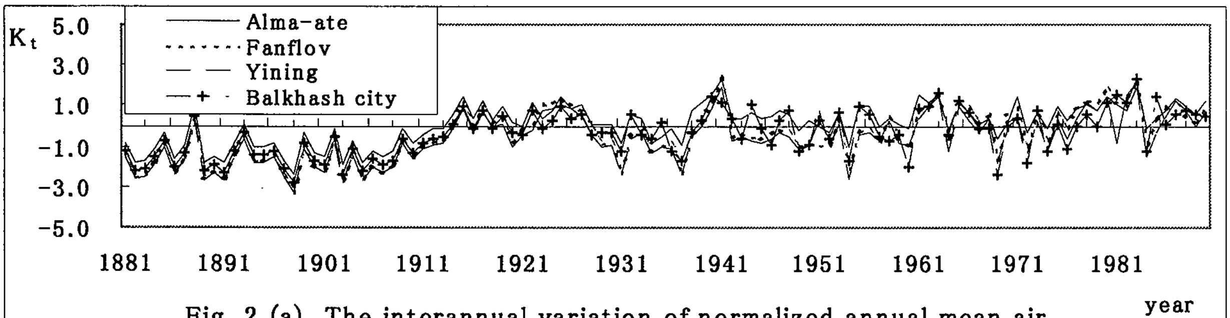

Fig .2 (a) The interannual variation of normalized annual mean air temperature (Kt) at the Balkhash city ,Alma-ate ,Fanflov and Yining meteorological station located in the Balkhash lake basin

Difference integral runoff curves in the Fig. 3 shows respectively the interannual fluctuations of the annual mean runoff in the upper and lower reaches of the Ili-river from 1911 to 1990. Also, Fig. 4 shows that of the zone of runoff formation of the Karatal, Aksu, Lepcy and Ayaguz rivers during

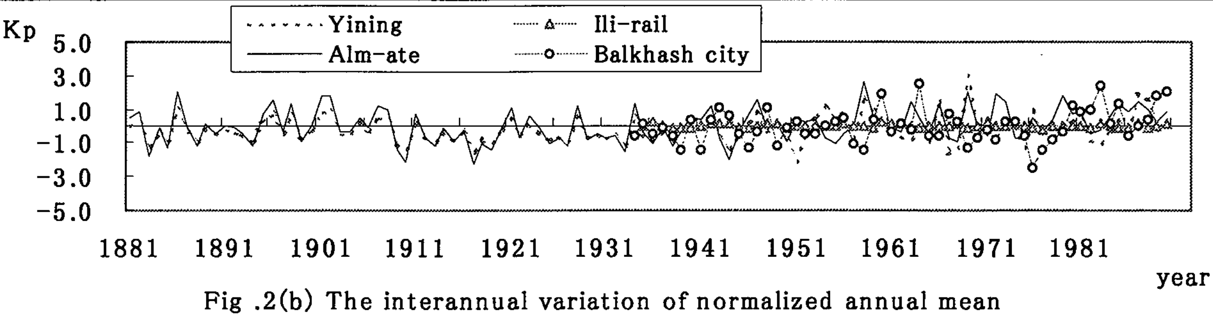

Fig .2(b) The interannual variation of normalized annual mean precipitation (Kp) at the Balkhash city, Alma-ate ,Ili-rail and Yining meteorological station located in the Balkhash lake basin

the entire observation period. Figure.3 and .4 illustrates that a low flow period begins in 1970 in the Ili-river and in 1973 in the east rivers, respectively. These low flow periods are responsible for the variation of the total runoff in the basin. In Fig. 3, we can see that the range of the decrease in annual runoff of the 37km gagging station, located lower reach of the Kapchagay reservoir in the Ili-river, is a sharper than 171Km or Yamate gagging station after 1970.

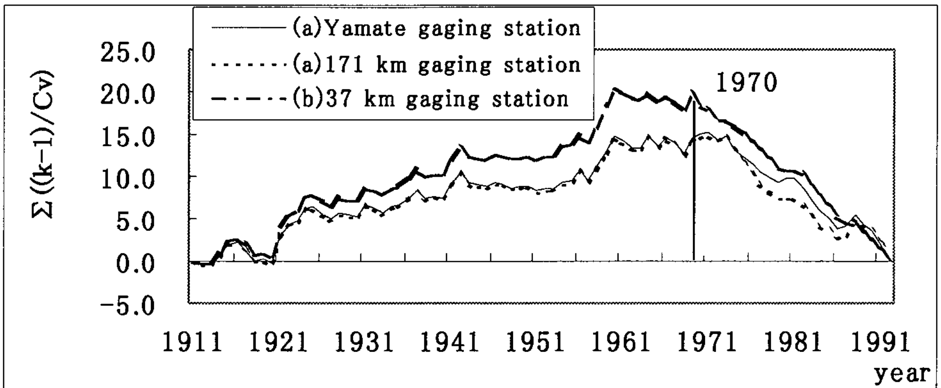

Fig.3 Difference integral curves of the annual mean runoff in the upper reach (a) and middle reach (b) of the Ili-river from 1911 to 1990.

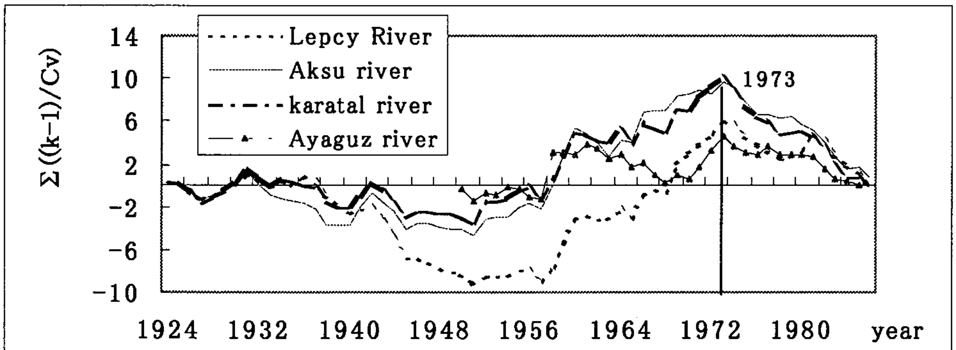

Fig.4 Difference integral curves of the annual mean runoff in the Lepcy ,Aksu , Karatal and Ayaguz rivers from 1924 to1986.

By comparing the average runoff before 1973 and 1970,respectively, the decrease of the annual mean runoff in the karatal, Aksu, Lepcy and Ayaguz rivers for from 1973 to 1986 are respectively 20.2 m³/sec, 1.7 m³/sec, 2.3 m³/sec and 5.0 m³/sec. As for Yamate gagging station in the Ili-river from1970 to 1990, the decrease of the annual mean runoff is 59.7 m³/sec.

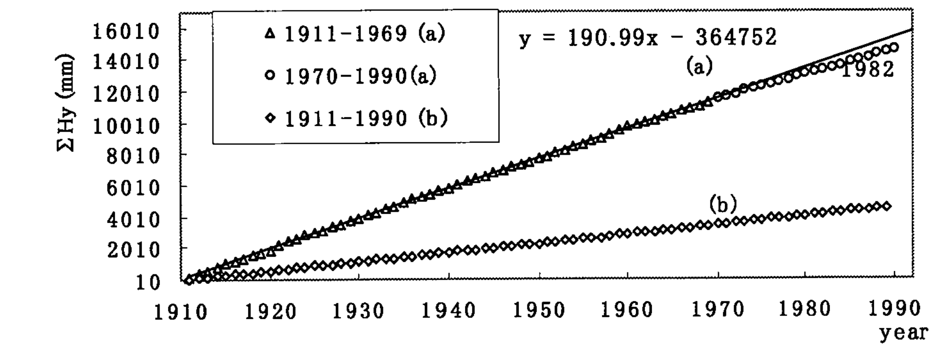

Fig.5 Integral curves of the mean runoff depth in the growing season(a) and non-growing season(b) at the Yamate gagging station located in the upper reach of the Ili-river from 1911 to 1990.

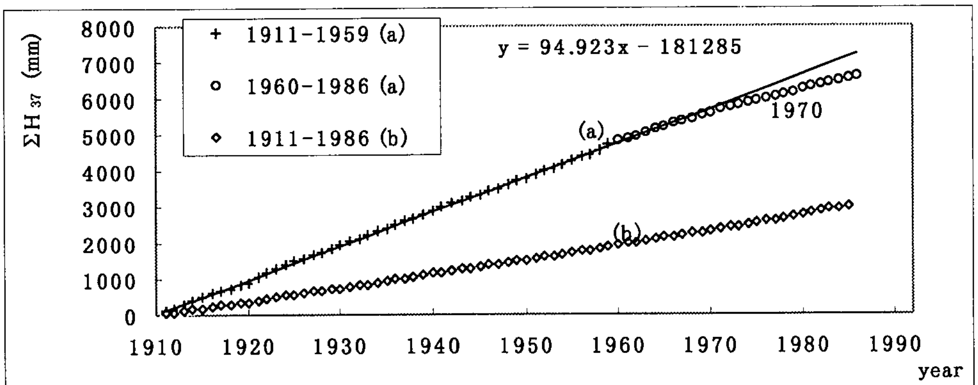

Fig.6 Integral curves of the mean runoff depth in the growing season(a) and non-growing season (b) at the 37 km gagging station located lower reach of the kapchagay reservoir in the Ili-river from 1911 to 1986.

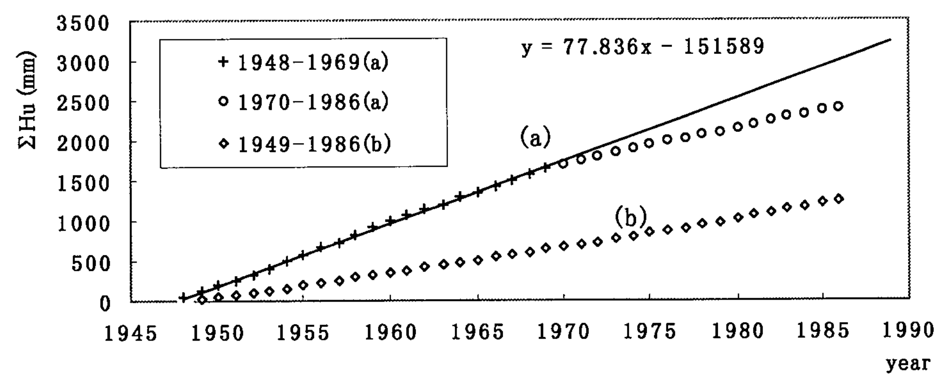

Fig.7 Integral curves of the mean runoff depth in the growing season (a) and non-growing season (b) at the Ushjarma gaging station located in the delta of the Ili-river from 1948 to1986.

In order to discern the effect of the development of irrigation including the filling of the

Kapchagay reservoir, and natural variability, the integral curves of the runoff depth (ΣH) is calculated based on Eq.(3). This equation is applied for both the runoff growing season and non-growing season at Yamate gagging station, at the 37 km gagging station in the lower reach of Kapchagay reservoir and at the Ushjarma gagging station located in the delta of the Ili-river. These results are presented in Figs .5 –7, respectively. It should be remembered that the integral curves on runoff depth(ΣH) of these figures represent the combine effect of natural condition and human activity, which are related to the variability of mean runoff in the 3 sections of the upper, middle and lower reaches of the Ili-river.

Before analysis the Fig.5-7, it should be noted that the observed data series of the Yamate from 1954 to 1990 is taken into account in constructing the relationship between annual mean runoff at the Yamate and (ΣQ)sum of annual mean runoff at the reference gagging for Kashe, Tekes and Kunes rivers in the upper reach of the Ili-river. This correlation coefficient is 0.97 (significant level 5%). Therefore, it is evident that the mean runoff fluctuations at Yamate may be considered as nearly nature condition although there are somewhat under influences of the human activity.

The integral curves of Fig. 5 (b), Fig. 6(b) and Fig. 7(b) show that the distribution point of the mean runoff depth of non-growing period is approximation to corresponds to a straight line. It is also made clear that the mean runoff of the non-growing season at the 3 section of upper, middle and lower reaches of the Ili-river has remained virtually unchanged before 1969 or after that.

The integral curves of Figs.5 (a), 6 (a) and 7(a) represents that the distribution point of the mean runoff depth of growing period before 1969 approximately corresponds to a straight line. After 1970,however, these figures show that the points are fairly deviated from the line of before 1969 and show some decreasing trend. This feature is especially apparent in Fig.6 (a) and 7(a).

The results of computation of runoff decrease of the Ili-river with Eq.(4) are presented in Table.2. It is clarified that the largest decrease of runoff during growing period has occurred in the middle and lower reaches, respectively. These amounting to 44%, 45% of the mean runoff before 1969,respectively. Also the effect of human activity is responsible for 58%, 60%.

Table.2. Runoff decrease of the runoff growing season in the Ili-river (1970-1986)(km^3/yr)

Station name	Q	ΔWs	%	ΔWs	ΔWe	%
Yamate	9.4	1.9	20	1.9	0	0
37 km	10.4	4.6	44	4.6	2.7	57.7
Ushjarma	10.7	4.8	45	4.8	2.9	60.4

*** ΔWs=w/n ;runoff decrease value of each year under the combine effect of the natural factors and human activity.**

*** ΔWe-runoff decrease value under the human activity.($\Delta We = \Delta Ws - 1.9$),Q-mean runoff before 1969**

CONCLUSION

Based on the results and discussion of this study, following conclusions were obtained:

- An apparent increasing or decreasing trend is not found in the interannual variations of annual mean air temperature and precipitation over long-term period in the Lake Balkhash.

- The difference integral runoff curves of Fig.3 and .4 determine respectively that the low flow period begins in 1970 in the Ili-river and in 1973 in the eastern river. According to hydrometric series, the decrease of annual mean runoff from 1973 to1986 of the Karatal, Aksu, Lepcy and Ayaguz rivers are 20.2 m^3/sec, 1.7 m^3/sec, 2.3 m^3/sec and 5.0 m^3/sec respectively. It is 59.7 m^3/sec at the Yamate in the Ili-river from 1970 to 1990.
- It is made clear that the integral curves on depth of runoff (ΣH) represent the combine effect of natural condition and human activity ,which are related to be runoff variation on the 3 sections of the upper, middle and lower reaches of the Ili-river. The largest decrease of the Ili-river has occurred in the middle and lower reaches, respectively in Figs .6-7(a). These amounting to 44%, 45% of mean runoff of the growing season before 1969,respectively. Also the effect of human activity factors is responsible for 58%, 60%, respectively.
- This study has quantitatively made clear that the main reason of the apparent decrease of the Ili-river is derived from the human activity.

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The Simulation of Hydrological Processes in Lake Qinghai, China

Qin, Boqiang

Nanjing Institute of Geography and Limnology, Chinese Academy of Science, 73 East Beijing RD, Nanjing 210008, P.R. China

Abstract: Qinghai lake is the biggest one in China. It is a mountainous lake with a closed drainage basin located in the north-eastern Qinghai-Tibet plateau. Since the beginning of this century, the lake level has dropped significantly and the lake area has shrunk dramatically. The water balance analysis show that the deficit of water budget and the decrease of runoff is the main reason of the lake level falling. In order to investigate the changes of hydrological conditions within the lake basin, a catchment model coupled with a lake thermal model has been developed to simulate the lake water balance and the water thermal properties of Lake Qinghai. The simulated water balance and lake level are quite consistent with observations. This model can be used in the evaluation of changes in hydrological conditions induced by the external forcings such as the climate changes.

Key words: Qinghai lake, simulation of water balance, simulation of lake thermal regime

1. Introduction

Lake Qinghai is the biggest one in China and known with a series distinguishing characteristics such as vast water area, the high elevation and the closed drain basin as well as the natural attractive landscape. Since the beginning of this century, the lake level has dropped dramatically, which has caused a series environmental problems, e.g. degeneration of grazing grassland around the lake, desertification in the beach area, aeolian erosion of the exposed lake bed, decrease in water supplies for irrigation and increase in the water minerality etc. In the central Asia, most of the well-known greater lakes are facing the same environmental problems, including the lakes such as Issyk-kul (Sevastyanov and Smirnova, 1986) and Aral Sea (Leontyev, 1986; Glazovsky, 1990). This study attempt to develop a model about the hydrological environments including the water balance and water thermal properties for the further investigation of the interactions between the hydrological regime and the surrounding environments.

2. The Hydrography, Lake Level Decline and Water Balance of Qinghai Lake

Qinghai Lake is located in the north-eastern part of Qinghai-Tibet Plateau (100°E, 37°N) (Fig. 1). It has a closed basin in an area of 29691 km^2. Most of the catchment is covered by grazing land and alpine shrub and meadow. The permafrost is widely spreading above ca. 3600m, and virtually there are no forest in the basin, only a limited area of desert, and some irrigated farmland to the north and northeast of the lake. But the basin is not glaciated. More than forty rivers flow Qinghai Lake, but six of the inflows contributed ca. 75% of the total runoff. The longest and greatest river is R. Buha, with a discharge volume equal to almost half of the total runoff.

The area of Qinghai Lake has shrunk since the beginning of this century from 4980 km^2 in 1908 to 4304 km^2 in 1986. Study on the lake water balance in the period of 1958 to 1990 shows that the evaporation exceeding the water input resulted in the drop of the lake level (Fig. 1). The investigation of moisture condition of the lake basin shows a slight decrease of precipitation in the catchment area, however, the total flowing lake runoff has declined considerably during the period of 1958 to the end of 1980s (Tab. 1), this is the main reason of the lake level falling continuously during the period of 1958 to 1990 (Qin, 1993).

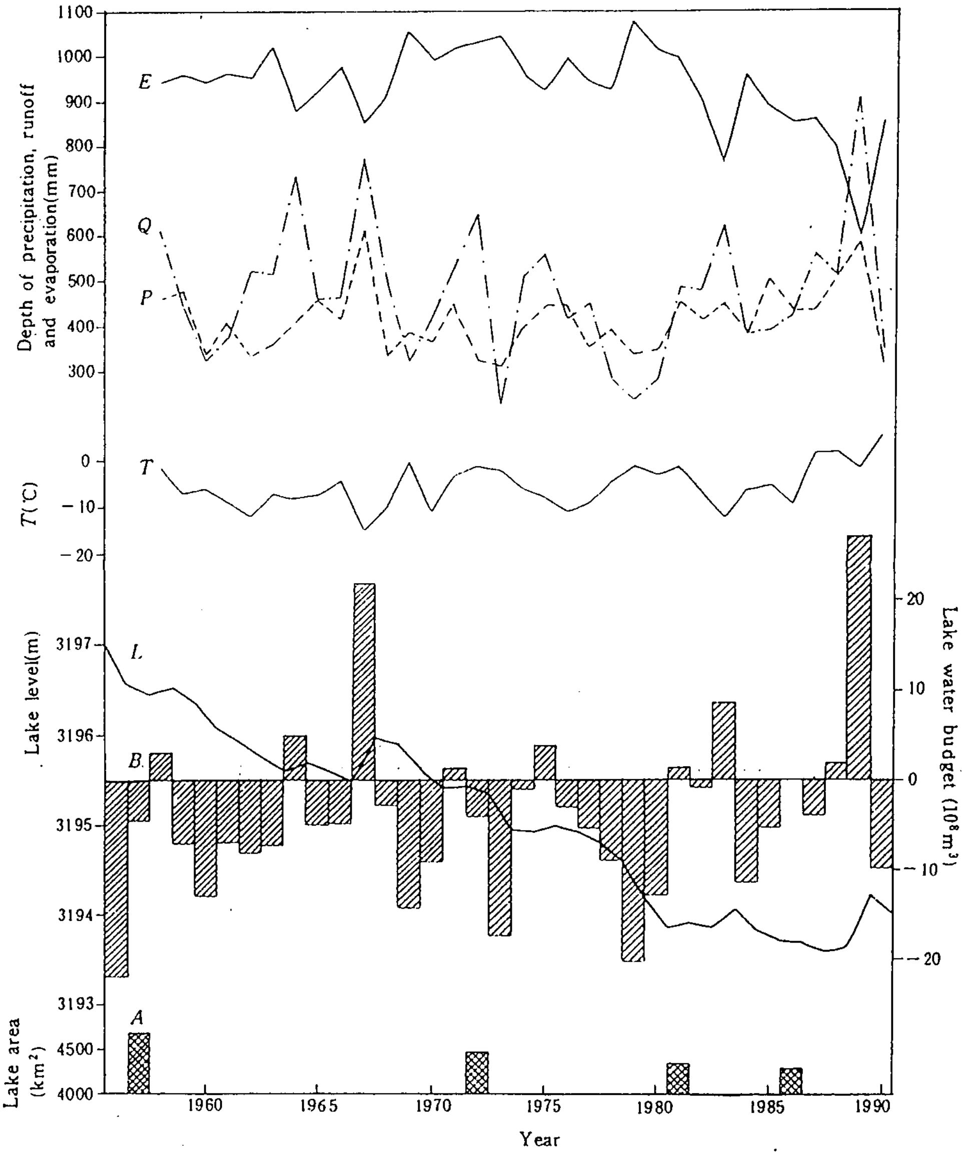

Fig. 1 The water budget and lake level fluctuation of Qinghai Lake and the relevant factors. E-evaporation, P-precipitation, Q-runoff, T-temperature, A-lake area, L-lake level, B-water budget

Table 1 The changes of hydrological parameters in the Qinghai lake basin

Items	Unit	1958-1967	1968-1977	1978-1986
Lake level	a.s.l.m	3195.99	3195.37	3194.10
Lake area	km^2	4522	4467	4336
Annual temperature	°C	-0.76	-0.61	-0.53
Winter temperature (Dec-Feb)	°C	-12.4	-12.1	-11.7
Evaporation	mm/yr	942.2	988.0	930.8
Runoff of R. Buha	m^3/s	30.88	25.38	19.47
Runoff of total basin	10^8m^3	19.1	16.03	12.82
Runoff coefficient		0.19	0.176	0.135
Precipitation over the	mm/yr	333.3	293.8	288.9

3. Model Construction

The complete model runs with three sub-models, one is the lake thermodynamic model which is used to simulate the surface temperature and estimate the evaporation, the formation and thaw of ice and snow. The other is the catchment model that is designed to model the runoff feeding the lake, and the third is the lake water balance model which is used to predict the lake level change.

3.1 Thermodynamic model of lake

The lake thermal model is developed by Hostetler and Bartlein (1990) and used in this study in order to get precise estimates of evaporation. This is a physically based eddy diffusion model that simulates lake temperature and evaporation from an input set of meteorological variables (short-wave radiation, atmospheric long-wave radiation, air temperature, wind speed and air vapor pressure). The model equation is written as

$$\frac{\partial T}{\partial t}=\frac{1}{A(z)}\frac{\partial}{\partial z}A(z)\left[k_m+K(z,t)\right]+\frac{1}{C}\frac{1}{A(z)}\frac{\partial A(z)\phi}{\partial z} \qquad (1)$$

where T lake temperature, t time, z lake depth, $A(z)$ the area of lake at depth z, k_m molecular conductivity, $K(z,t)$ eddy conductivity, C the heat capacity of water, and ϕ a heat source term representing subsurface absorption of solar radiation. At the surface of lake, the Eq. (1) is substituted by the boundary condition and energy balance and written

$$\left[k_m+K(z,t)\right]\frac{\partial T}{\partial t}=Q_s(1-\alpha)+Q_{ld}-Q_{lu}\pm Q_e\pm Q_h \qquad (2)$$

where Q_s is downward short-wave radiation, α lake surface albedo, Q_{ld} downward long-wave radiation from the atmosphere and Q_{lu} up-ward long-wave radiation from the lake surface, Q_e and Q_h flux of latent and sensible heat respectively. For a relative deep lake, it is valid to assume no heat transfer between underlying lake sediments and water, so that the Eq. (1) becomes

$$\left[k_m+K(z,t)\right]\frac{\partial T}{\partial t}=0 \qquad (3)$$

In order to apply this model to Qinghai Lake basin, some modifications are made according to the local characteristics such as the flux of downward radiation and evaporation (Qin and Huang, in press). In addition, the ice and snow formation and melt model has been developed and embedded inside the lake thermal model during winter season. The equation for the ice formation and thaw is (De Bruin and Wessels, 1988):

$$\frac{dh_i}{dt}=-(\frac{G+Q_w}{\rho_i\lambda_m})-(\frac{E}{\rho_i}) \qquad (6)$$

where G amount of per unit area and time, Q_w heat flux from the water to the ice layer, ρ_i density of water and λ_m latent heat of melting or freezing, E water vapor flux. G is determined by

$$G=Q-Q_e-\lambda_m E=Q_n+A_e(T_i-T_s) \qquad (7)$$

in which Q is the global solar radiation and T_e is the equilibrium temperature given by

$$T_e=T_i+Q_n/A_e \qquad (8)$$

The surface temperature T_s is given by

$$T_s=T_f+(A_r h_i/k_i)(T_e-T_f-Q_i/A_e) \qquad (9)$$

where T_f the freezing point. A_r is determined as follows

$$1/A_r=1/A_e+h_i/k_i \qquad (10)$$

in which h_i and k_i is ice thickness and heat conductivity, Q_i is the solar radiation got inside the ice layer and identified as 75% of net radiation Q_n. Making use of above equations, the ice thickness h_i can be derived from following equation:

$$\lambda_i \rho_i \frac{dh_i}{dt} = -A_r(T_e - T_f) - Q_w \qquad (11)$$

where $T_e < T_f$ for ice growth and $T_s = T_f$ for ice melt.

During the frost periods, the snow will be stored up above the ice sheet in the cooling stage and prior to the ice thawing to be melted when the weather turn to be warm. The up-layer snow coverage has the different thermal conductivity. Thus the equation (10) can be re-written as:

$$1/A_r = 1/A_e + h_i/k_i + h_s/k_s \qquad (12)$$

where h_s and k_s the snow depth and thermal conductivity. k_s is determined by:

$$k_s \cong 3.10^{-6}\rho_s^{\ 2} \qquad (13)$$

where ρ_s the density of snow which is determined by the time of snow aging and the depth of snow cover. If R_j is the precipitated snow mass at jth day after the first snowing and the corresponding snow density is ρ_j, thus the snow depth of jth day is:

$$h_s = \sum_{j=1}^{J} R_j/\rho_j \qquad (14)$$

and

$$h_s/k_s = \sum_{j=1}^{J} h_j/k_{sj} \cong \sum_{j=1}^{J} R_j/(k_{sj}\rho_j) \qquad (15)$$

The snow density is approximately estimated by (De Bruin and Wessels, 1988):

$$\rho_j = 90 + 0.5(J-j)\Delta t \qquad (16)$$

where j is the day which has snowing and J is the total snowing days. Similarly, the snow albedo can be estimated by (De Bruin and Wessels, 1988):

$$a_j = 0.95 - 0.002\,(J-j)\Delta t \qquad (16)$$

with the equations from (6) to (16), the ice thickness and forming and melting processes, snow depth and snow aging processes can be predicted.

3.2 Catchment Model

The catchment model is developed to simulate the runoff feeding the lake. The primary version was developed in Hohai University, China, and known as the Xin-An-Jiang model (Zhao, 1984, 1992). With the basic concept of the local mass balance at one point, the runoff occurs only on the repletion of the tension water storage at that point. Some simplifications of the model structure have been made when the model is applied. Only surface and ground runoff are considered and discriminated with the stable infiltration rate. The surface runoff is assumed to empty into the lake in the current month and the ground runoff are routed following groundwater reservoir. The potential evaporation is calculated with the simple climatic parameters (Shuttleworth and Wallace, 1984; Shuttleworth et al., 1988), then converted to the actual evapotranspiration rate.

3.3 Lake water balance model

The lake level change is derived from the lake water budget, that is

$$H_2 = H_1 + P - E + R \qquad (17)$$

where H_1 and H_2 the lake level of the beginning and the end of the time step respectively, P and E the precipitation and evaporation over the lake surface, R the runoff (surface runoff and ground runoff) flowing lake. This model runs monthly step. For each month the input and output represent the values of current step.

4. Results

The simulated runoff is in good agreement with the observed runoff (Fig. 2). The correlation between the simulation and observation is 0.8 in annual and 0.95 in monthly sequence. Nearly three-fourth simulated runoff match the observation with the deviation less than 25%. The extremely flooded 1967 caused the simulated curve of runoff to deviate from the observation significantly. This may reflect the uneven distribution of precipitation estimates in space due to less rainfall observed gauges, especially in the alpine area. In addition, the simulation shows that the slightly falling trend of precipitation over the catchment results in the relatively significant reduction of total runoff, which is associated with the dramatic decrease of soil tensile water leading to the reduction of the productivity of runoff.

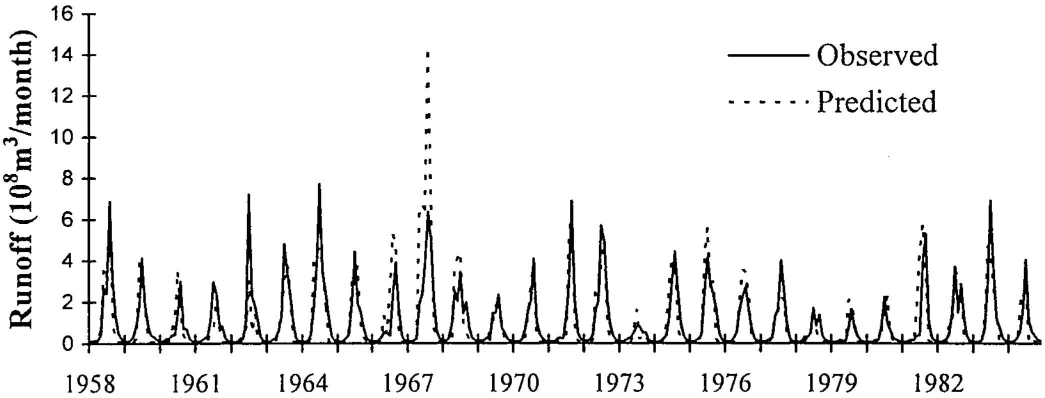

Fig. 2 The simulated and observed runoff within the Qinghai lake basin.

The lake thermal model predicts taking place in the autumn, i.e. August and September when the lake water is warmest (Fig. 3). In the ice cover period, the evaporation is about 20 mm/month to 35 mm/month. The monthly variation of simulated water surface temperature is close to the trend of changes in air temperature varied from -12°C in winter to 16°C in autumn, and the highest water temperature is ca. 20° to 25°. The maximum ice thickness is about 0.6-1.0 meter and the maximum snow depth is about 35 mm. The length of ice and snow is ca. 133 days which roughly accounts for one third of year round, starting in the middle December and terminating before the end of April (Fig. 3). The simulated changes of temperature in vertical direction show that there are stratified layers in the lake (Fig. 4). This stratifications diminish during the winter and spring, but start to occur in the summer and culminate in the Autumn (Fig. 4). Unfortunately, there are no observations to validate these predictions of water temperature, ice thickness and snow coverage.

The model predicts a decline lake level between 1958 and 1984, which matches the observed trend very well (Fig. 6). The simulated annual rate of lake level drop is -10.0 cm/yr that is quite comparable with the observed -9.6 cm/yr. Correlation between prediction and observation of lake level is as high as 0.97. Overestimates of runoff in 1967 also produce the largest discrepancy (about 0.45 m) between the observed and simulated. In general, however, the model has done better job in the simulation of hydrological conditions in such mountainous and semi-arid lake basin.

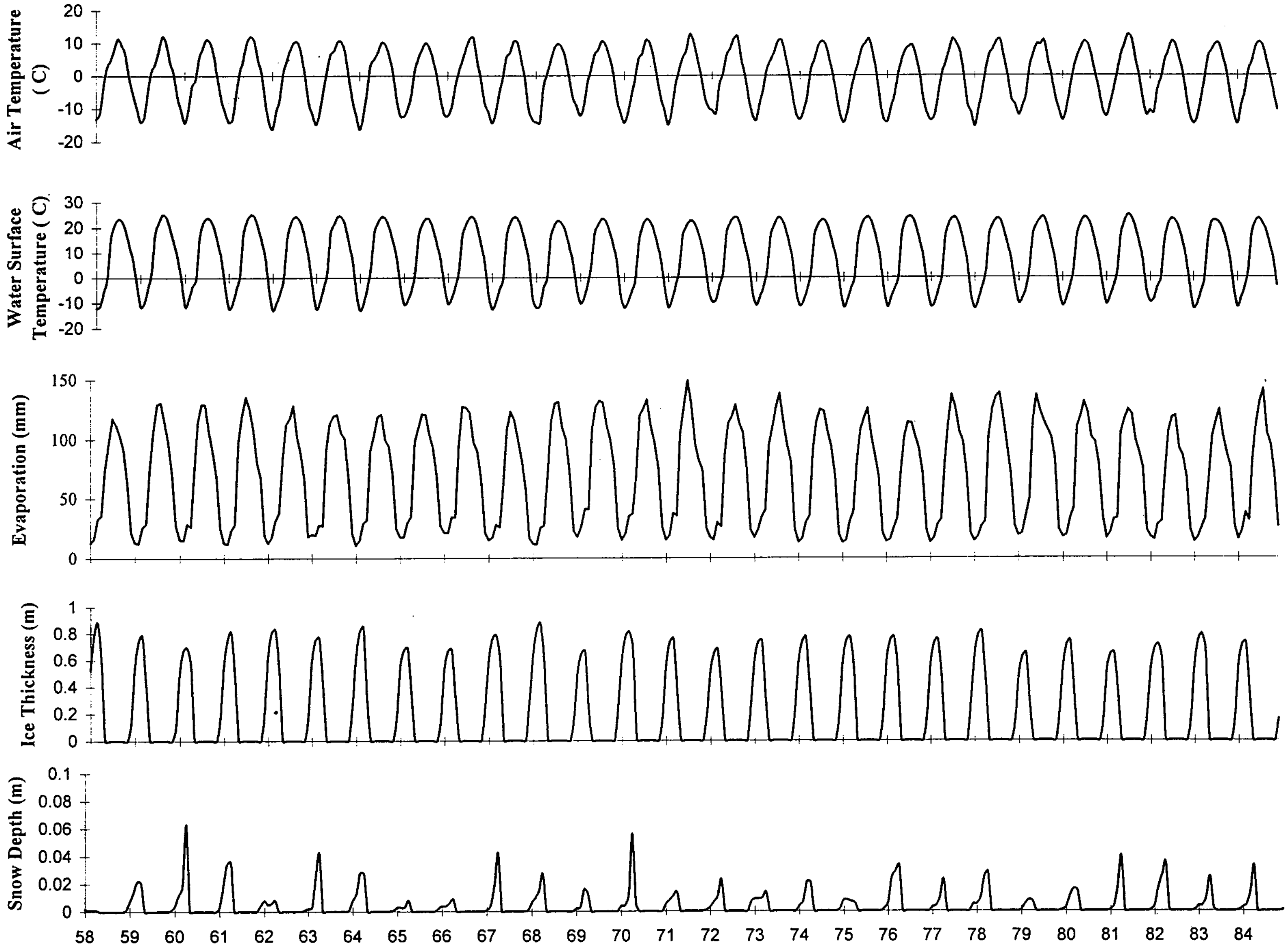

Fig. 3 The air temperature and the simulated water surface temperature, ice thickness and snow depth in Qinghai Lake.

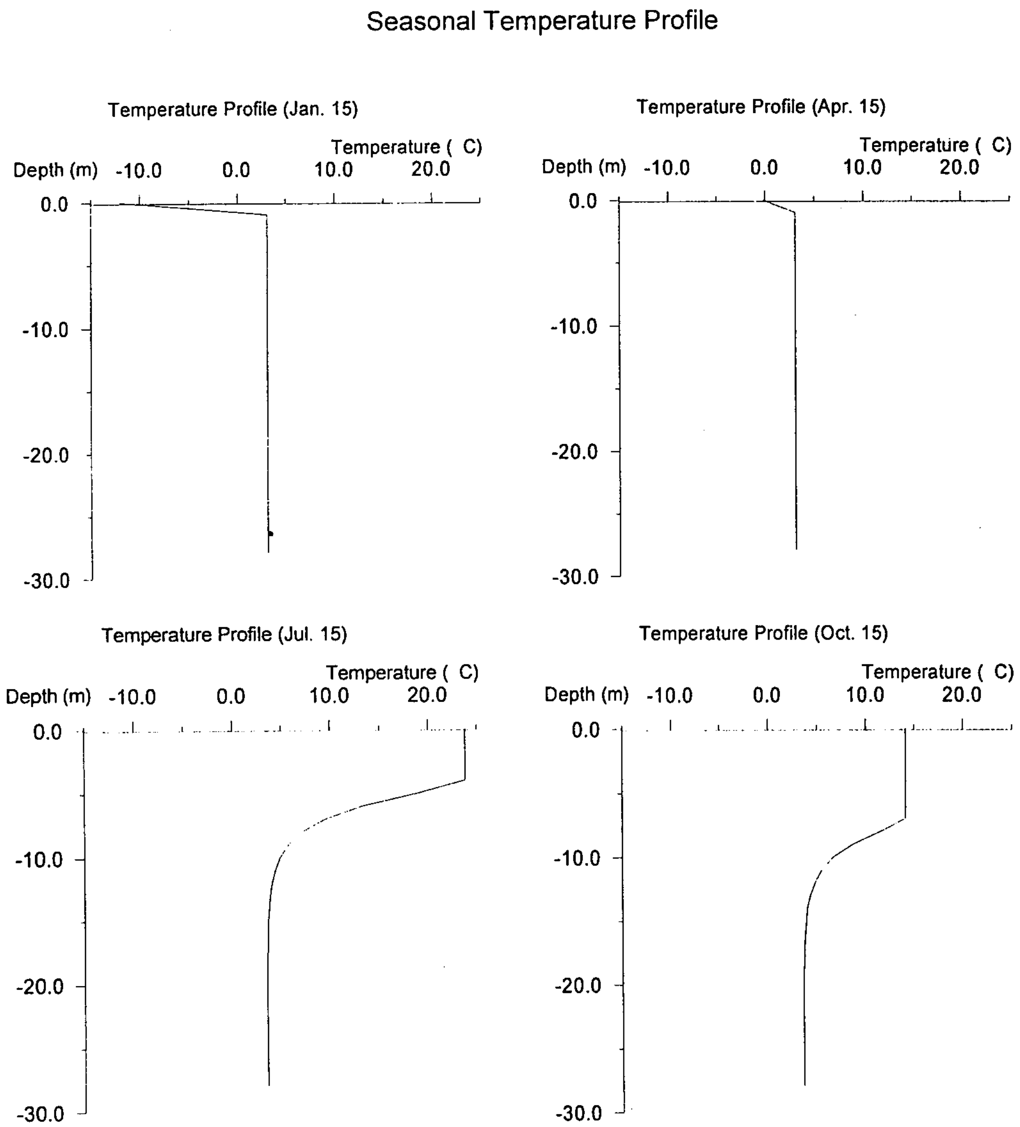

Fig. 4 Simulated multi-yearly averaged water temperature profile of Qinghai Lake
(a) Winter (Jan. 15) , (b) Spring (Apr. 15), (c) Summer (Jul. 15), (d)Autumn (Oct. 15)

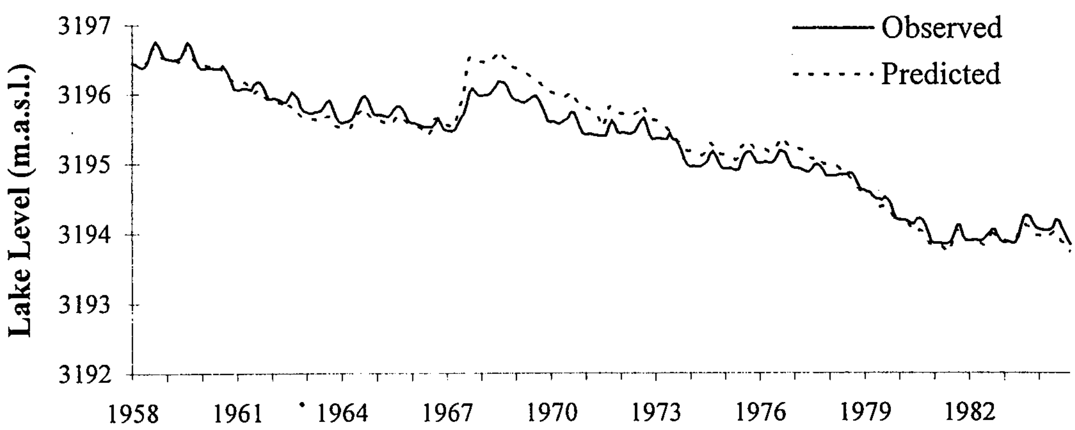

Fig. 5 The simulated and observed lake level fluctuation from 1958 to 1986 in Qinghai lake.

5 Conclusive Remarks

The simulation of lake water budget and lake thermal properties make it possible to further evaluating the impacts of external forcings such as the climate changes or anthropogenic environmental changes on the hydrological conditions of lake surrounding areas, the water thermal regime inside the lake body and the potential changes of aquatic ecosystem. Because the hydrological conditions and ecological environments in the arid or semi-arid areas such as Qinghai lake are believed more sensitive and more vulnerable than the water resources and aquatic ecosystem in the humid regions, this should be attached more importance to.

This research works also is a attempt to provide a strategy to insight into the hydrological processes within the lake basin, and further to investigate the interaction between the hydrological regimes and the surrounding environments. For example, the simulation of water volume and thermal properties is possible to create a linkage between the hydrological system and ecosystem within the lake. But the catchment model used here is still a lumped and integrated hydrological model which is unable to consider the spatial heterogeneous of landscape and the hierarchy of hydrological regime, thus this kind model would be limited in the application of extrapolation in the prediction of future conditions and the investigation of the interactions between the hydrological processes and atmospheric processes, between the hydrothermal and hydrodynamic processes and aquatic ecosystem. These problems will be studied in the coming research projects such as the "The physically-based distributed hydrological model and the application in Lake Qinghai " funded by the Chinese National Science Foundation.

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Hydrologic Characters and Exploitation of Water Resources in the Arid Area of the Qaidam Basin

Liang Jiyang

Institute of Geography, Chinese Academy of Sciences

Datun Road 917 Building, Beijing, 100101, China

Fax: +86-10-6491-1844

Email: Liangjy@mimi.cnc.ac.cn

Abstract

This paper deals with the hydrologic conditions of the Qaidam Basin, a typical inland basin of China, which include precipitation and runoff character, and water resources state characterized with a small absolute quantity and large relative quantity. Finally, the design of water resources decision support system for the basin is presented.

There exist several arid inland basins in the northwest area of China: the Tarim Basin, the Junggar basin, the Qaidam Basin etc..These basins are common in many ways: surrounded by high mountains, extremely dry in the centers, and all water resources originated from the runoff of those surrounding mountains.

1. Hydrologic character of arid area of the Qaidam Basin

1.1 General situation of the Qaidam Basin

The Qaidam Basin is situated in the northwest part of Qinghai province of China. On the South, it adjoins the Kunlun Mountains and borders the Qilian Mountains on the Northeast, the Altun Mountains on the Northwest. The highlands are all more than 4,000 meters above sea level while the elevation at the bottom of the basin is usually between 2,600 meters and 3,200 meters. From east to west, the basin is 850 kilometers long and 250 kilometers wide. It covers an area of about 270 thousand square kilometers.

The Qaidam Basin is a huge confined basin that goes deep into the mainland, with extremely dry climate and small precipitation. The precipitation decreases gradually from the highlands to the basin, amounting to 200 mm in the highlands, and dropping to less than 20 mm at the center.

The Qaidam Basin is rich in mineral resources, and the reserves of potassium chloride, sodium, magnesium, lithium, iodine and asbestos are all second to none in China, Also, the resources of natural alkali, calcification, mirabilite, and boron rank among the leading position in the country . There is still a large quantity of uncultivated land that can be applied to farming or stock raising. These lands, with sufficient sun shine and great air temperature deference between day and night, are favorable to crop growth. If water resources supply enough, great potentialities of farming can be brought into full play.

1.2 Hydrologic character of the Qaidam Basin

Because the Qaidam Basin goes deep into the mainland and is confined by the highlands whose elevations are much different from it, its annual precipitation appears nearly a concentric ellipse. With the elevation lowering from the highlands to the basin center, the yearly precipitation reduces gradually from the highlands to the basin center. On the highlands it reaches 200 mm , and it goes below 20 mm while at the center.

Flowing from the highlands to the basin , all rivers of the Qaidam Basin become many radialized solitary water system and have short flow paths. Floods, at the south edge, north edge, and northeast edge of the basin mainly, consist of the water from rainfall and melting snow . Snow-melting water makes up a certain percentage of the runoff. As the west pare of the basin faces mountains on three sides, and vapor is not easy to arrive there, the precipitation is little, and the annual number is only scores of millimetre.The sources of rivers exist at glacial area and snow field, so the rivers receive recharge mainly from glacial and Snow. The annual precipitation is less than 20 mm in the west and middle part of the basin, and the evaporation occurs so strongly that it reaches 3,000 mm per year, As a result the surface runoff becomes extremely small or does not occurs.

Due to the effect of terrain and surface materials, most runoffs of the rivers in the basin are characterized with vertical zonations. Generally the basin can be zoned into three regions from the mountain areas to the foot of the mountains. [Zhang, 1990]

Runoff formative zone: As the mountain areas receive relatively large precipitation and snow-melting recharge, most runoffs that consist of the river flows occur in this zone. The amount of runoffs increases in accordance with the expansion of catchment area.

Runoff dispersive zone: When the mountain rivers discharge into the basin at the mouth of the mountain, topographic gradient decreases. There are Gobi desert zones at the top of alluvial flood splays in the front of mountains. The surface materials are loose and of strong permeability, so the river channels are disordered, and a large quantity of water of the rivers permeates the ground and becomes interflow.

Runoff overflow zone: When phreatic water flows into the basin, ground water overflows by way of springs on the fine soil zone at the edge of the alluvial splay. When the water quantity of those springs is large enough, a river may occur. See Fig 1.

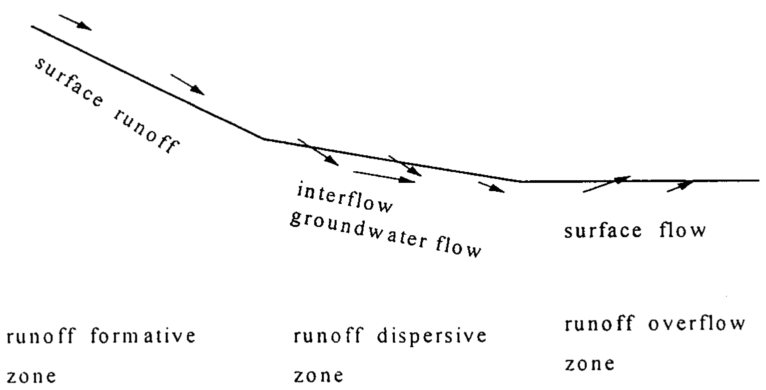

Fig. 1 A sketch map of the exchange between surface flow and ground water

The runoffs that originate mainly from snowmelt water have a close relationship with atmosphere temperature. It means that seasonal temperature change has a great influence upon the flow distribution in a year. Some rivers' flowing processes also obviously show a cycle that expresses a distinct snowmelt-fed stream feature. See Fig 2.

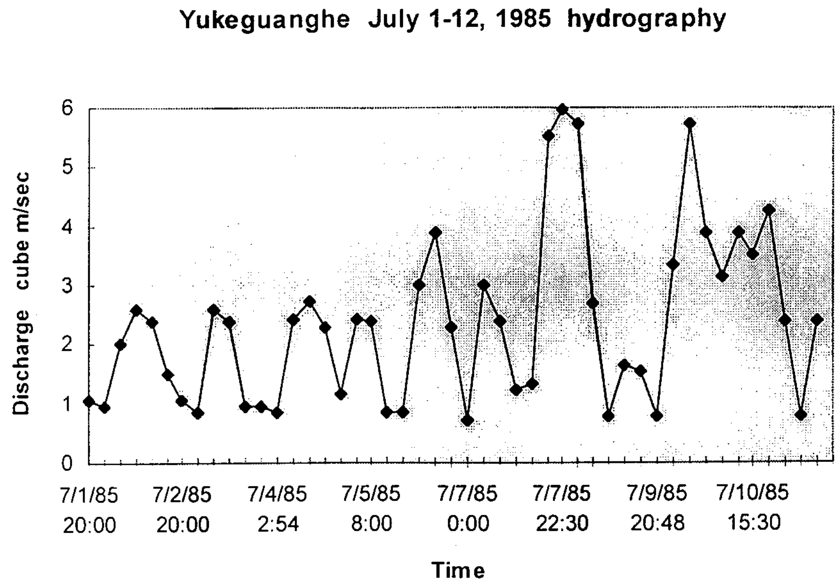

Fig. 2 Yukeguang river dairy cycle feature of melt-fed runoff

2. Water resources character and exploitation at the Qaidam Basin

2.1 General situation of water resources of the Qaidam Basin

In the Qaidam Basin, there are more than 70 long or short streams that are all radialized solitary water system flowing from the mountain areas to the basin. The greater ones include the Nalenggelai River, the Golmud River, the Xiangride River, the Chahanwushu River, the Bayin River and so on. The Golmud River with some observation stations, the greatest one, covers a catchment area less than 20,000 square kilometer. About 49 rivers with a catchment larger than 500 square kilometers run all year. The amount of surface water resources in the whole region is 4.4 billion cube meters on an average of many years. The underground water in the basin is recharged by overland water by seepage, and streams and aquifers interact frequently. The totally quantity of water resources is 4.7 billion cubic meters.

Owing to a small population and less farmland (271.7 thousand people and 38.2 thousand ha. respectively),the per capita water resources and unit area water resources are all on higher level than that in Qinghai province and the nation.

Because the streams have short flowing paths, heavily seeping beds, irregular hydrologic systems and seasonal features, it is difficult to exploit the water resources.

2.2 Utilization of water resources in the Qaidam Basin

As the basin has a sparse population and a small irrigation farmland, it can be concluded that water resources have a great exploitation potential.

According to the statistics in 1993, about 740 million cubic meters of water were developed in the basin, among which 60 percent water used for irrigation, 33 percent for stock raising water and fishing , and the rest for industry and citizen's life. At present, the exploitation rate of ground water is only 15.8 percent in the whole region of Qaidam basin, and the utilization rate of underground water is much lower, just 1.6 percent.

Although the total water resources are relatively plentiful, the exploitation is hindered by many difficulties and problems. At first, it is the space distribution of water resources. For example, the Nalinggalai River is the biggest river in the basin, but it has been undeveloped for the natural conditions at the west of the basin. Next, the distribution of water resources do not well match the land distribution. As a result, the farmland which requires water can not be ensured to be irrigated. However, on the other hand, some farmlands that are fully irrigated have been secondarily salinized, caused by the rise of the underground water level which is effected by topography and poor drainage. Presently, many irrigation districts in the Qaidam Basin have been stopped cultivation for secondary salinization. Secondary salinization has become an important issue of water resources exploitation. Without exiting any outlet in an inland basin, water can not be discharged so that wastes have to be accumulated. The Qaidam Basin with very weak ecological envoirment is facing serious environmental problems caused by industries and cities waste water pollution. Takes the Golmud River and the bayin River for examples. The lower reaches of rivers through cities or industrial areas have been seriously polluted. Moreover, polluted water infiltrates into soils and aquifers, causing soil pollution and underground water pollution, which are difficult to deplete. This has critically deteriorated the environment.

3. Design of decision support system for water resources utilization of the Golmud River

3.1 General situation of water exploitation of Golmud city

Golmud city is located in the middle south part of the basin and at the north foot of the Kun Lun Mountains. and has become the largest industry center and a communication center in the basin. The Golmud River, the second largest river in the basin, serves as water supply for the industry and agriculture demand of Golmud city. Golmud city, including urban, suburb and farms etc., occupies about 30 thousand square kilometers with a population of 80,000. The cultivated lands cover about 3.3 thousand ha.., mainly consisting of the state-owned Hedong farm and the Hexi farm. There are 28 enterprises in the city, containing some larger or medium size state-owned enterprises such as the Qinghai potassium fertilizer plant. The gross value of industrial output has attained RMB a hundred million yuan.

The surface water resources and the underground water resources in the Golmud city are estimated an 860 million cubic meters and 700 million cubic meters, respectively. With the repeated part deducted, the water resources total 112,6 million cubic meters.

The Golmud city has a reservoir with a designed storage capacity of 24 million cubic meters, 30 water diversion channels, a few dipping works and pumping wells etc. Statistics shows that the whole water supply at a normal year is 105.22 million cubic meters, and the water consume of the Golmud city was 81.75 million cubic waters in 1990. It means that the current water supply is sufficient. But with the economic development, it can be predicted that more water resources will be demanded.

3.2 Design of water resources decision support system

The purpose of developing the water resources decision support system of the Golmud River (WRDSS) is to provide decisions for the water resources management and planning in consideration of the requirement of present and future, social and economical states in the Golmud River watershed, the water supply and demand state in industry and agriculture, ecological environment and sustainable development. The object of the management and planning is to maximize the efficiency of the limited water resources.

The main parts of the WRDSS are computer-person dialogue & interface, data base module , models module, and multi-objective optimization and decision module etc. .

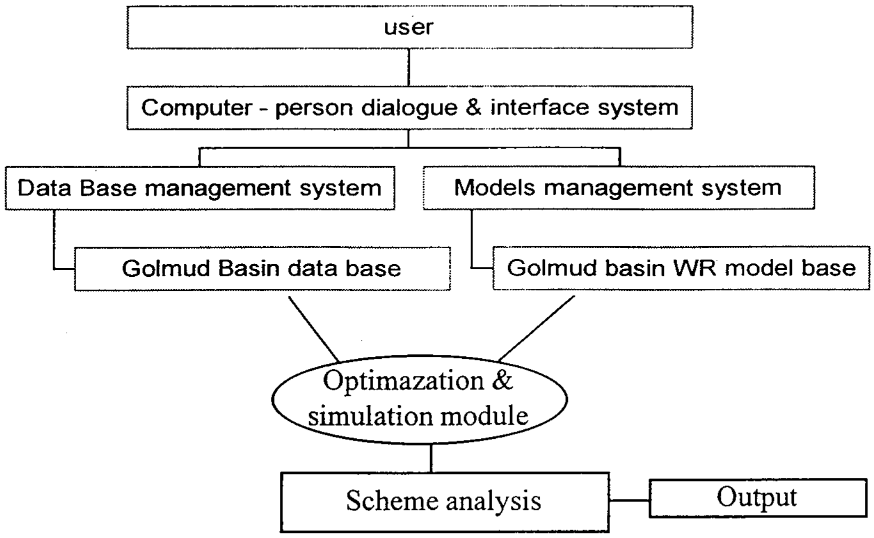

Fig 3. The structure chart of water resources decision support system of the Golmud River (WRDSS)

The computer-person dialogue & interface system, which is associated between computer and custom, is to be written in Visual Basic and shall have a friend interface and a simple operation. The interface shall have the following functions: data input, inquire, display, interface dialogue, output and help.

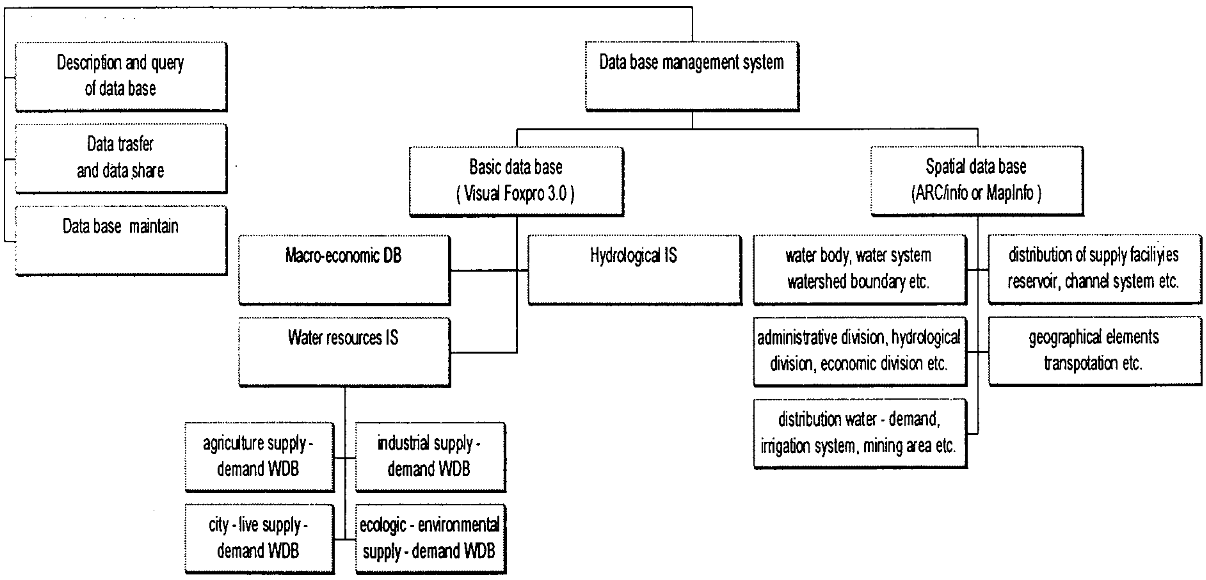

Fig 4. The chart of data base management system and data base module.

The data base management system and data base module is to be written in Visual Foxpro and is spatial data base of water storage space distribution. ARC/Info or MapInfo. will be employed as GIS software.

The models base management system and models base plan to be written in FORTRAN or C. The main parts consist of industry water-demand models, agriculture water-demand models and macro-economic models.

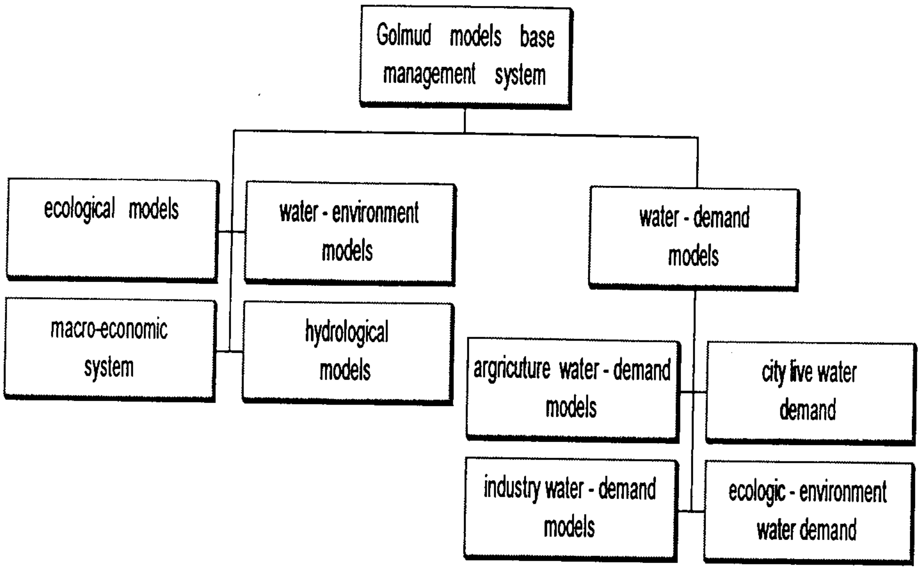

Fig 5. The models base management system and models' base.

The Golmud city is a rapidly developing industrial city and a communication center and the Golmud River provide the necessary water resources. The Golmud water resources decision support system will offer the decision support for water resources optimization distribution, ensuring the limited water resources in the arid area to yield the best economical and social benefits and sustainable development.

It can be known from the above analysis that although the Qaidam Basin has a small quantity of water resources, it is relatively plentiful. The present water resources exploitation rate is much lower and its developing prospect is broad. In addition, the Qaidam Basin has abundant mineral resources and uncultivated land resources that can not be developed unless sufficient water resources are available. Plentiful water resources will make these resources developments possible.

The investigation indicates that the Qaidam Basin has potential expansions of overland water resources development and the exploitation rate of underground water is much lower. Underground water has been mainly used by municipal and not by agriculture irrigation. The joint use of overland water and underground water has a great potential and is an efficient approach to prevent secondary salinization.

Golmud city is an economic and communicative center of the basin and has a great potential in water resources development. Expanding the underground water exploitation will relax the threat to the city caused by the raising of underground water level.

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Hydrological Characteristics of the Mae Klong River Basin in Thailand

Adahi Botou*, Hironobu Sugiyama** and Varawoot Vudhiranich***

* Graduate Student, University of Tsukuba, Japan
** Research Institute of Agricultural & Forest Engineering, University of Tsukuba, Graduate School of Science & Technology, Niigata University, Japan
*** Department of Irrigation Engineering, Kasetsart University, Thailand

Abstract

This paper discusses hydrological characteristics in the Mae Klong River Basin in Thailand. Firstly, rainfall distribution characteristics are examined by using daily rainfall data in sixteen rainfall observatories. Secondly, hydrological events of the two dam basins were qualitatively analyzed. It was found that, there was a relationship between the Western Monsoon and the rain occurrences; Si Sawat (Sri Nagarind) zone was draughtier in the Mae Klong River Basin. Si Sawat Dam Basin and Khao Laem Dam Basin, although they are close to each other (50 Km in distance), their differences concerning hydrological characteristics are high.

1.Introduction

A lot of papers on hydrological characteristics in a tropical Monsoon region have been published by many hydrologists. Particularly, discussions in Chao Phraya River Basin have been done since there is a reliable hydrological data base. However, there are few academic papers on the Mae Klong River Basin. Therefore, Hydrological characteristics of the Mae Klong

River Basin is examined.

2. Outline of the Mae Klong River

The Mae Klong River is located in the west of Thailand and has a border with Myanmar. The basin total area is 30800 km^2. The Mae Klong River is composed of two main tributaries: the Khwae Yai River and the Khwae Noi River. The khwae Yai River is 450 km in length and has a catchment area of 14630 Km^2. The Khwae Noi River has a length of 320 km with a catchment area of 10960 km^2.

The climate of the Mae Klong Basin may be divided into three seasons: summer (February to May), the southwest monsoon season or rainy season (May to October), Winter or the northeast monsoon season (October to February). But there is no real winter in the Mae Klong River basin.

2.2 Geology

The Mae Klong River Basin is composed of the hard base rocks with a linear distribution from North to South and belongs to the Mesosoic, the Paleozoic or proterozoic era. The tertiary soft sedimentary rocks, form a flat topography along the upstream tributaries of Kwae Noi and Kwae Yai rivers. The quaternary deposits forming an alluvion downstream of Kanchanaburi and terrace along the Kwae Noi and Kwae Yai rivers, cover the tertiary rocks.
The granite, granidiorite and diorite, intrusive rocks of the base rocks are not distributed linearly.
the soils of the Mae Klong Rivers (table 1) are mostly alluvial with a relatively high content of clay. The soils show a high natural fertility but present a poor acidity and a poor internal drainage capacity accentuated by the topographic conditions.

2.3 Topography

The Mae Klong River is surrounded, in its northern part and its central part by mountains from where its two tributaries , the Kwae Yai and the Kwae Noi, originate to flow in a hilly zone intercepted with some plains up to Kanchanaburi. From Kanchanaburi where the two tributaries join up to form the main river, the plains cover, southward, largely both banks of the Mae Klong River.

2.4 Discharge and Rainfall observational system

Sixteen rainfall stations (Fig.1) are used for the analysis of the Mae Klong Basin rainfall characteristics. The period is chosen between 1952 and 1994. The stations have different recording lengths. The station 13013 has the longest length with 43 years and the station 13142 the shortest length with 13 years. The 16 stations are spatially chosen, in an attempt to meet a uniform map repartition. The lenght takes into consideration the time series without any break. If the south west is well furnished in stations, the north mountainous and the west, bounded by Myanmar is lacking stations to have a uniform covering of the Mae Klong River.
The gaging station records at Thong Pha Phum and Si Sawat will be used to study the discharge characteristics. The study recording period at Khao Laem Dam is from 1984 to 1996, and from 1980 to 1994 at Sri Nagarind Dam.

2.5 Land use

The Mae Klong River is mainly covered by the forest land, with 73% of the total basin area. Agriculture is the second largest area with 18.5% of the total basin area. the major crops are: sugar cane (78.7%), rice (3.6%), field crop (3.21%), orchard trees (2.72%). The water surface occupies 7.06% of the total basin area.

2.6 Rainfall and Discharge Characteristics in the Mae Klong River Basin

The northeast monsoon begins later in the Mae Klong Basin than in the northern and northeastern parts of Thailand. The northeastwind comes at October ending or early November and is directed easterly. It creates a decline in temperature but less colder than in the North.

In February, the northeast wind, present in the Mae Klong River from October to February, shifts easterly or more southeasterly and are then called the southeast winds.

There are many rainfall observatories in the Mae Klong River Basin. In order to examine rainfall characteristics over the Mae Klong River Basin, sixteen rainfall observatories were selected by taking into account the homogeneity of their distribution. Figure 2 shows time series of maximum and minimum annual rainfall of each year picked up from the given data. Smoothing was done with the moving average method because periodicities in hydrologic time series could not be derived.

Figure 3 shows time series smoothed with a five terms moving average.

It is indicated that oscillation is large until 1977, but is smaller after that, and then long time trend gradually descends. On the other hand, the curve of minimum annual rainfall shows that although a decreasing trend is shown until 1983, time trend after that increases more or less radically.

The probability assessment for annual rainfall over a given basin area is done by using sixteen rainfall points. In figure 4, the annual rainfall less than any chosen probability (10, 50 and 90 percent) are shown. This Figure shows that the two regions (rainfall stations 13083 and 47012) are in a very drought condition accentuated by the mountainous zone in the central area of the upstream basin area.

The rain in the Mae Klong River Basin is subject to the Southwest Monsoon. The rainy months are from May to October. They are in accordance with the occurrences of the Southwest Monsoon (Fig. 6 and Fig. 7). The droughty months are December, January and February. The histograms of the 16 stations show that a maximum annual rainfall of 2889 mm with a not exceedence probability of 97.73 % , a return period of 44 years, and a minimum of 202 mm have been observed in the Mae Klong River Basin.

Annual rainfalls with the highest absolute frequency are given in the following table:

Station	1301	1302	13032	13053	13063	1308	13142	13171	13211
mm	900	1000	900	1550	2550	850	1650	850	1350

Station	47012	47022	47042	47052	52022	53012	63042
mm	1050	600	1050	1250	1450	1150	1400

For each station, a cumulative frequency distribution curve was obtained by plotting the annual rainfall data against the calculated values of not exceedence probability (Weibull method), on a arithmetic probability paper. For all the stations, the annual rainfall values plot as a straight line indicating that they are normally distributed. therefore, the mean (50% probability), the standard deviation and the drought probability can be derived, (table 2).

The lowest standard deviation (178.41mm) is given by station 63042 and the highest by Si Sawat Station (600 mm).The highest mean (2216 mm) is given at station 13063 and the lowest mean at station 13032 with 895.35 mm.

Hydrological Characteristics between the two Dam Basin, Sri Nagarind (Si Sawat) and Khao Laem Dam Basin Areas are also compared in this paper.
The relationship between rainfall and runoff is given in fig. 7. In the two areas, runoff depth is less than rainfall depth. In Khao Laem Dam Basin Area, yearly runoff rate is about 65 to 75%. In Sri Nagarind, yearly runoff rate is about 39 to 49%.
Rainfall amount Comparison is given in Fig.8. The rainfall amount is higher as much as twice at Khao Laem Dam Basin area.
The flow duration curves of the two stations were drawn and the results in the Basin Area Characteristics (Table 3) show that higher discharges are obtained in Khao Laem Dam Basin area (Fig. 10).

Conclusion

In Mae Klong River Basin, the northern part receives more rainfall than the south (about double), reaching an annual peak of more than 2500 mm. From station 13013, southward, annual rainfall is less than 1500 mm. Station

61'3083 is the station with the highest severe droughty condition.

The general annual rainfall trend in the Mae Klong River Basin shows a continuous decreasing of rainfall amount from year to year. The Southwest Monsoon brings the maximum quantity of rain to Khao Laem Dam Basin area, from May to October or November, explaining the double quantity of rainfall in Khao Laem Dam.

Yearly runoff rate is higher as much as twice at Khao Laem Dam Basin area. Although its catchment area is three times less than that of Sri Nagarind, Khao Laem Dam Basin area presents the highest discharges, such as the annual maximum discharge, the 95, 185, 275 and 355 day discharge, predicting therefore a better prospective of rural development (Fig. 10).

Reference

Ray K. Linsley, JR., Max A. Kohler, Joseph L. H. Paulhus, 1949, Applied Hydrology. McGraw-Hill Civil Engineering Series.

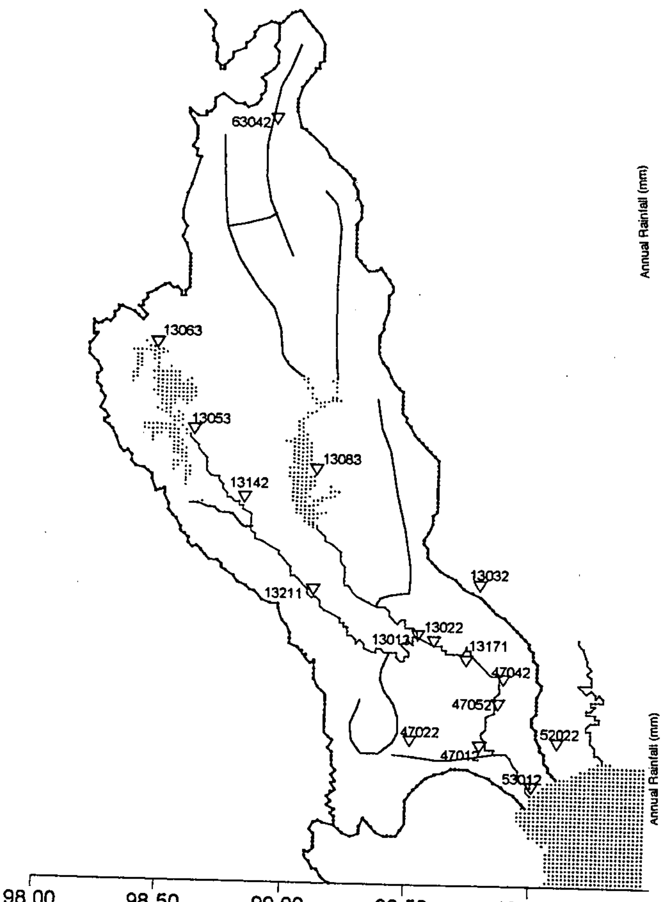


Fig. 1:
Location of Rainfall Station in The Mae Klong River Basin

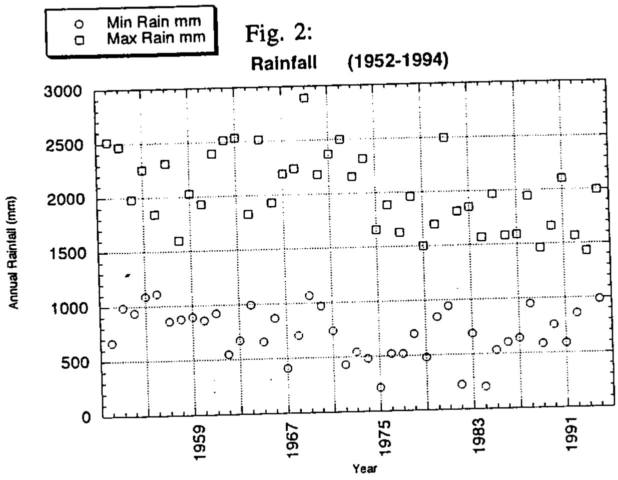


Fig. 2:
Rainfall (1952-1994)

Fig. 3: Moving Average (Annual Rainfall)

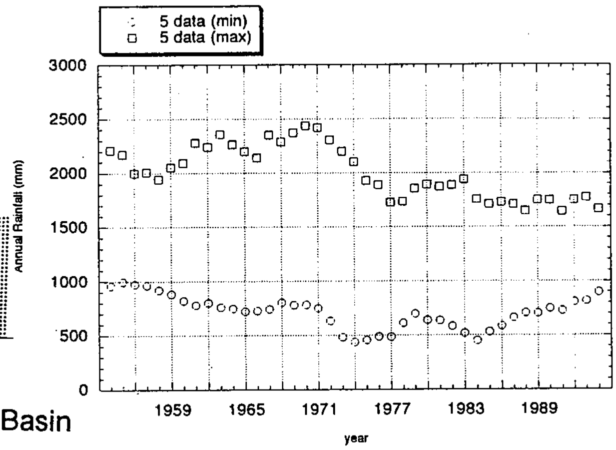
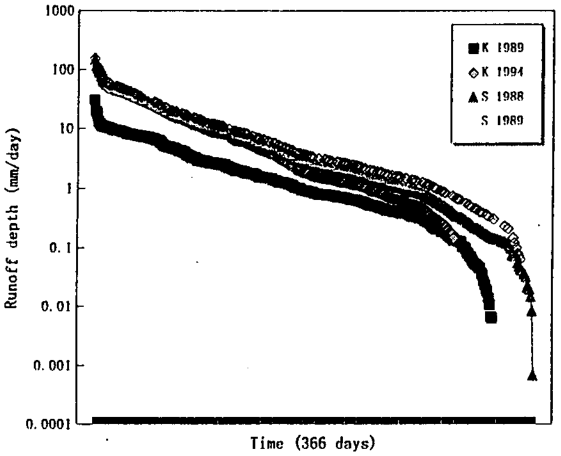
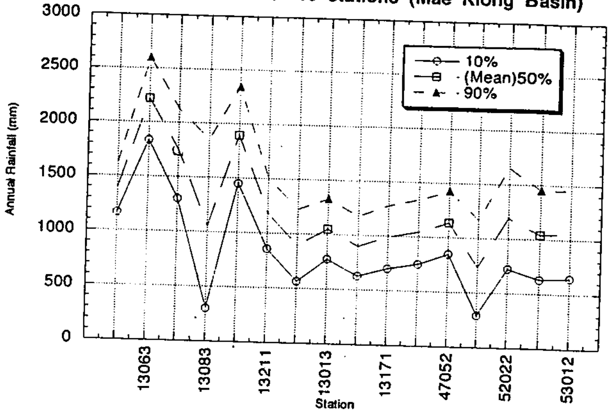


Table 10 Flow Duration Curves
Sri Nagarind Dam (88 & 89) Khao Laem Dam (89 & 94)



K 1994 & S 1988: maximum daily discharge
K 1989 & S 1989: minimum daily discharge
K: Khao Laem Dam
S: Sri Nagarind Dam

Fig. 4: Annual Rainfall of 16 stations (Mae Klong Basin)



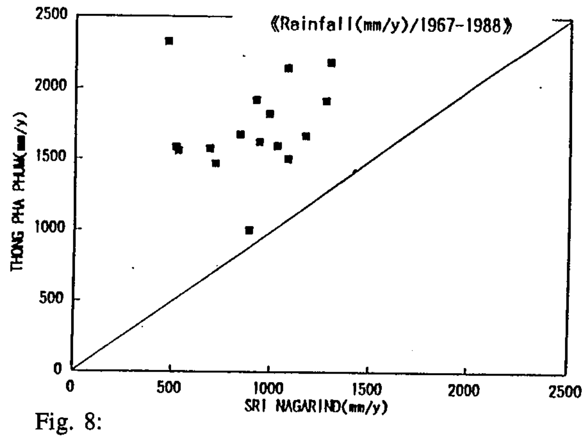
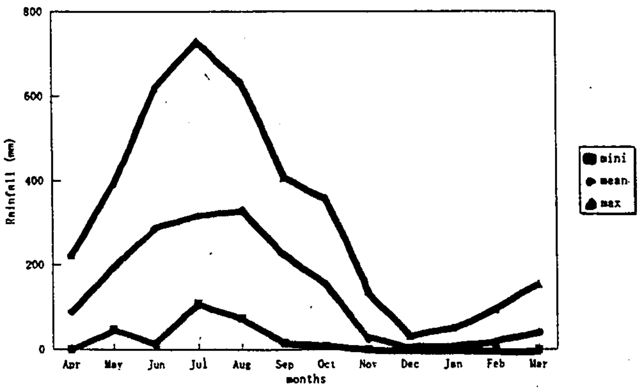


Fig. 8:
Rainfall Comparison between Sri Nagarind and Khao Laem Dam Basin areas

Fig. 6: St13053 A. Thon Phum, Kanchanaburi
Changes of monthly rainfall pattern (1952~1994)



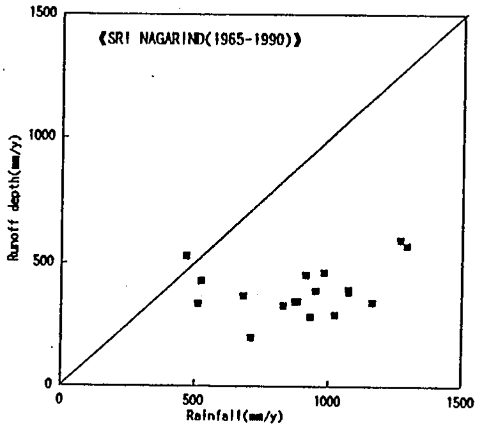


Fig. 9a:
Relation between Rainfall and Runoff Depth in Sri Nagarind Dam Basin

Table 2 ≠Annual Rain.(16 St) 10%-50%-90%ξ

	Station	Stand Deviat	10%	(Min)16%	25%	(Mean) 50%	(Max) 84%	90%
0	63042	178.41	1163.8	1215.6	1273.2	1394.0	1572.4	1624.2
1	13063	296.50	1833.4	1919.5	2015.3	2216.0	2512.5	2598.6
2	13053	375.00	1300.0	1375.0	1500.0	1750.0	2075.0	2125.0
3	13083	600.00	300.00	450.00	650.00	1050.0	1650.0	1850.0
4	13142	343.57	1450.9	1550.5	1661.5	1894.1	2237.7	2337.3
5	13211	252.91	856.61	929.99	1011.7	1182.9	1435.8	1509.2
6	13032	255.71	565.45	639.64	722.24	895.35	1151.1	1225.3
7	13013	225.00	775.00	825.00	900.00	1050.0	1275.0	1325.0
8	13022	225.00	625.00	675.00	750.00	900.00	1125.0	1175.0
9	13171	230.00	700.00	760.00	840.00	990.00	1220.0	1280.0
10	47042	229.44	748.10	814.66	888.78	1044.1	1273.5	1340.1
11	47052	224.32	846.40	911.48	983.94	1135.8	1360.1	1425.2
12	47022	339.29	290.30	388.74	498.34	728.03	1067.3	1165.8
13	52022	361.29	723.59	828.41	945.12	1189.7	1551.0	1655.8
14	47012	318.48	628.92	721.32	824.19	1039.8	1358.3	1450.7
15	53012	313.47	643.98	734.93	836.19	1048.4	1361.9	1452.8

Table 3 **Basin Area Characteristics**

	Sri Nagarind Dam	Khao Laem Dam
Catchment Area(Km^2)	10880	3720
Period	1980—'94	1985—'94
Record Length(year)	15	10
Geology		
Predominant Rock Types	Limestone, shale	Shale, sandstone, and limestone
Annual max, discharge(mm/d)	1.3—25.4	19.3—121.4
Plentiful—water discharge(mm/d) (95—day discharge)	0.18—2.38	2.62—7.73
Ordinary—water discharge(mm/d) (185—day discharge)	0.26—0.95	0.47—1.74
Low—water discharge(mm/d) (275—day discharge)	0.12—0.32	0.0—0.53
Scanty—wateer discharge(mm/d) (355—day discharge)	0.0—0.04	0.0—0.0

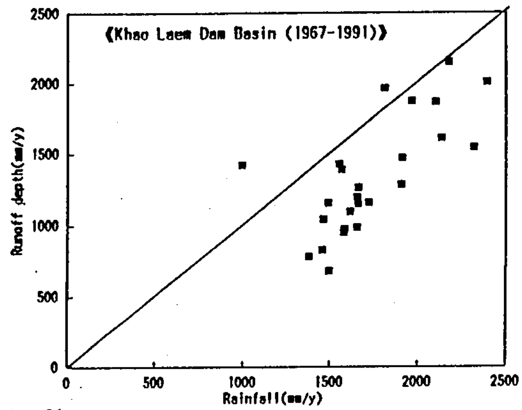


Fig. 9b:
Relation between Rainfall and Runoff Depth in Khao Laem Dam Basin

Table 1 GEOLOGY OF THE TWO BASIN AREAS

SEDIMENTARY, METAMORPHIC AND IGNEOUS ROCKS	Khao Leam Dam	Sri Nagarindra Dam
Alluvial deposits: Gravel, sand, silt, and clay, unconsolidated to semiconsolidated.	31%	7%
Dolomitic limestone, sandstone: and shale, gray, and red, thick-bedded to massive.	0%	23%
Limestone, limestone conglomerate and shale, grayto dark gray, and red, well bedded.	3%	46%
Shale, sandstone, and limestone, alternated, grayish black.	35%	5%
Shale, dark brown to black, well-bedded.	11%	5%
Limestone with argillaceous bands.	9%	3%
Granite .	11%	11%

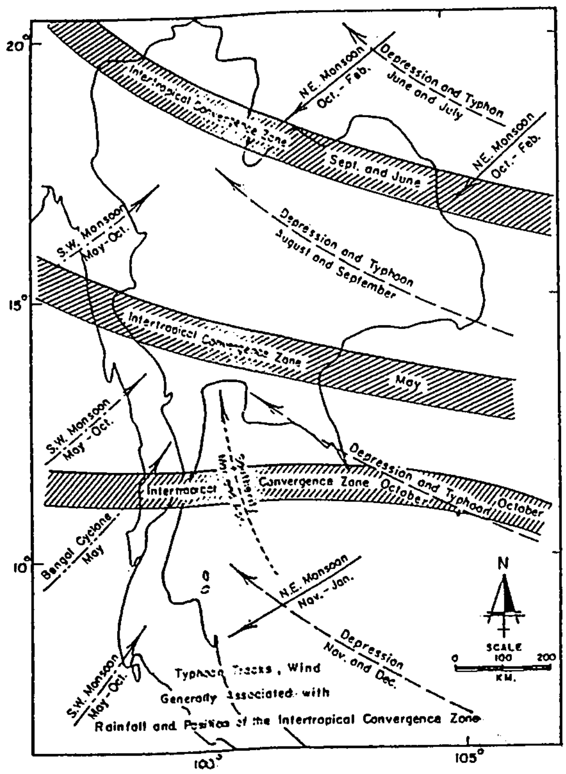


Fig. 7: Storm Tracks in Thailand

Utilization of Water Resources on Tarim River and its Effects to Hydrological Characters

Xin Li

Xinjiang Institute of Geography, Chinese Academy of Sciences
40-3 Beijing Road Urumqi Xinjiang 830011 China
Fax: +86-991-3837482
Email: xjgi@ms.xjb.ac.cn

Abstract

The effects of human activities are in many ways such the expansion of oasis, the change of soil quality, the expansion of artificial vegetation area the decrease of natural vegetation, replacement of some lakes and marsh with artificial reservoirs, shortening of river, degeneration of natural environment in the lower reaches of river, and so on so forth. The hydrological change caused by human activities in continental river is usually difficult to convert. Human activities in Tarim River Basin after 1950 has developed rapidly. The development of human activities has changed the hydrological characteristics of the river, especially in the middle and lower reaches of Tarim River. It is quite typical in arid land of the change of river course and the redistribution of water in time and space.

1. Conditions and the development of human activities in Tarim River Basin

Tarim River rises in the north slope of Kunlun Mountains, east Pamir Plateau and the south slope of Tianshan Mountains. More than eight rivers formerly flowed to Tarim River. But now it has only three tributaries — Hotan River, Yarkant River and Aksu River. And water from Konqi River can flow to Tarim River through artificial canal, drained water from irrigated land in Weigan River Basin flows to Tarim River.

Runoff in the tributaries of Tarim River is mainly from snow melt, glacial melt and rainfall in the mountains, a small amount of it is from groundwater and spring water. The yearly change of runoff is not great because the source is multiple. Evaporation in the plain area and irrigation are main way to consume water, and proportion of the water used by human being has increased year after year.

Formerly runoff in Tarim River was in natural condition, it irrigated natural popular diversifolia and meadow, permeated into ground to supply groundwater for the requirement of natural vegetation, and flows to depression forming lakes and swamp.

It has developed in large scale to open up waste land and launch water conservancy project after 1950, and large area of oasis has built for agriculture and stock raising in Tarim Basin. Complete agricultural zone along the river was built, but effective utilization ratio of water resources is quite low, especially using water to irrigate meadow almost depends on flood irrigation, so it is serious to waste water there.

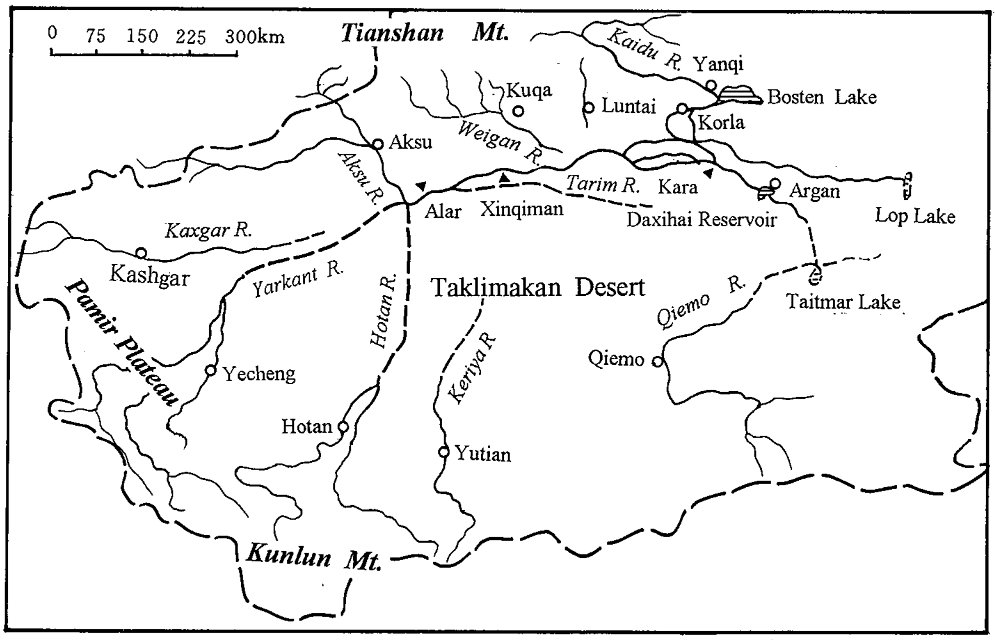


Fig.1 Water system of Tarim River

2. Utilization of water resources

Runoff in Tarim River is $19.66\times10^9m^3$, $15.81\times10^9m^3$ of it was channeled to farmland for irrigation, the rest $3.85\times10^9m^3$ of river water and some drained water from farmland is used to keep ecological environment and to consume for evaporation in the basin. Ground water resource is $0.43\times10^9m^3$ in Tarim River Basin but few of it has exploited to used for drought-relief, industry and human's life.

Agricultural production in Tarim River Basin developed rapidly in resent years, the irrigation area of oasis farmland in 1993 was more than two times of that in 1949, quantity of used water increased rapidly.

Table 1 Change of irrigating area in the tributary rivers of Tarim River

year	irrigation area (10^3hm^2)			
	Aksu River Basin	Yarkat River Basin	Hotan River Basin	total
1949	101.3	186.6	63.3	351.2
1993	300.0	380.0	96.6	776.6
increased area from 1949 to 1993	198.7	193.4	33.3	426.4

Up to the early 1990's, 56×10^3km of canal for irrigation has been built in Tarim River Basin and $15.81\times10^9m^3$ of water was drained from river every year, and 36.2% of it can arrived in farmland, that is $5.72\times10^9m^3$ of water is really used for irrigation. Irrigating area in Tarim River Basin is $730.4\times10^3hm^2$, 71.9% of it ($525\times10^3hm^2$) is farmland, in which land $13.21\times10^9m^3$ of water was used for irrigation. 20.14% of it ($147.1\times10^3hm^2$) is forest land, in which $1.97\times10^9m^3$ of water was used. 7.96% of it ($58.3\times10^3hm^2$) ,in which $0.44\times10^9m^3$ of water was used.

Water quantity channeled by human at the tributaries area of Tarim River is increased continuously after 1950, channeling water from river is in high ratio, especially in Yarkant River Basin, 92% of runoff is channeled by human and that caused the runoff has hardly arrived in Tarim River since 1970's. In Hotan River Basin, 64.5 of runoff is channeled, and in Aksu River Basin, 64.5% of runoff is channeled. Water supply in tributaries to Tarim River has continuously decreased, and it affects the hydrological characteristics of Tarim River in many ways.

The trunk area of Tarim River was the ecological basin with natural vegetation, river course was in natural State on the whole. Recent ten's years, water consumption increased rapidly in the upper reaches and middle reaches of the trunk of Tarim River, and runoff decreased seriously in the lower reaches under the effects of human activities, hydrological conditions of river has changed too.

3. Change of hydrological characteristics

3.1 Change of yearly runoff

Yearly change of runoff in the three tributaries of Tarim River is little without the trend of increase or decrease. Resent 40 years a great quantity of river water was channeled to irrigating area in the tributaries along with the expansion of farmland area, so that the supplied runoff to Tarim River has decreased year by year.

Alar Hydrological Station, that is located in the upper reaches of Tarim River, was established in 1957. Yearly runoff change in Alar from 1957 to 1994 can be divided into four periods: 1957~1964, 1965~1974, 1975~1984, 1985~1994. From the first period to the fourth period, yearly runoff has decreased $1.04 \times 10^9 m^3$, is about 20.38% off.

Not only has the supplied water from tributaries to Tarim River decreased, but also has the consumption of water in the upper reaches and middle reaches of the trunk stream increased, and runoff in the lower reaches has decreased continuously. Water consumption in the upper reaches (from Alar to Xinqiman) has increased from 14.77% of total runoff in Tarim River in 1960's to 23% in 1994, in the middle reaches (from Xinqiman to Kara) it has increased from 61.54 in 1960's to 72.56% in 1994. 1994 is a bumper year for runoff in Tarim River, 95.56% of yearly runoff was consumed in the upper reaches and middle reaches, only 4.445 arrived in lower reaches. Runoff in upper reaches, middle reaches and lower reaches has decreased in different ranges since 1960's, it has decreased mostly in the lower reaches.

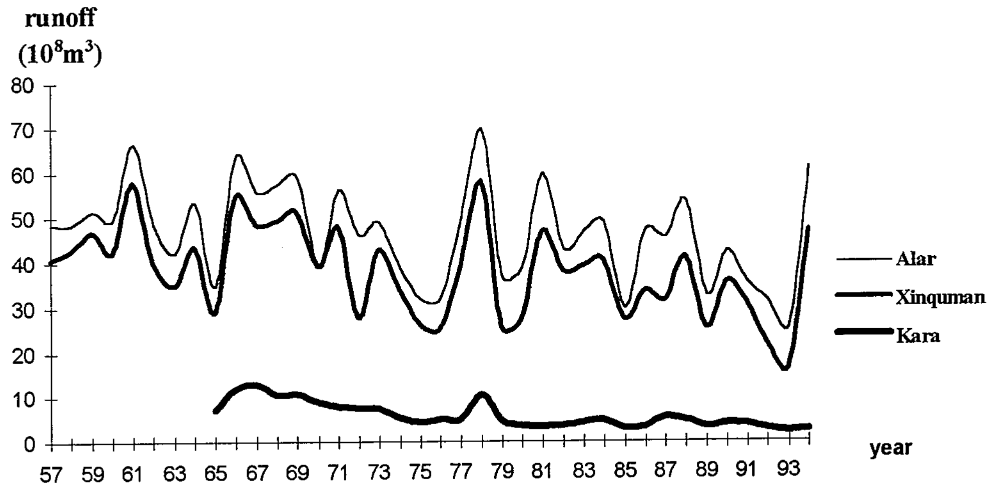


Fig. 2 Yearly runoff change in the upper, middle and lower reaches of Tarim River

3.2 Seasonal runoff change and flood

Monthly runoff change greatly in Tarim River, it mainly concentrates in the flood season from July to September, and it is fewer in the dry season from March to July. Runoff percent in flood season of yearly runoff has increased and that in dry season has decreased because the channeled water in dry season is in a large part of the runoff in that period. For instance, runoff in flood season was 66.2% of the yearly runoff by average from 1957 to 1974, but was 70.86% from 1981 to 1994. In the second period it was 4.66% more than in first period. So did it in the middle reaches. But it is opposite in the lower reaches, runoff in flood season was 47.2% of the yearly runoff by average from 1957 to 1964, but it was 40.08% from 1984 to 1994. In the second period It was 7.42% less than that in first period. The reason of above change is that in the upper and middle reaches runoff was channeled to irrigate meadow and water flows to low-lying land through the artificial cuts in river bank in the flood season, so that flood can not arrive in lower reaches. The seasonal change of runoff in lower reaches is stable, flood time is later now than in 1950's, that is 36 days later in 1980's than in 1950's. The runoff change is under the effects of nature and human activities in same time.

It is the reflect of human activities that in the process of agriculture and animal husbandry, people cut the bank of river to channel water for irrigation, especially in the dry season they build dams in river bed to raise water table in order to channel more water from river. But this way for channel water decreases the passable ability of runoff is less than $200m^3/s$. The passable rate of runoff in the upper reaches has reduced from 0.737 in 1950's to o.566 in 1990's, and from 0.371 in 1950's to o.139 in 1990's. The process of runoff to the lower reaches has changed under human activities, and the natural regulation of runoff has changed too. For instance, yearly runoff is $2.56\times10^9m^3$ in Alar Hydrological Station of upper reaches, and is $0.216\times10^9m^3$ in Kara Hydrological Station of lower reaches in 1993, but it is $6.084\times10^9m^3$ in Alar and is $0.296\times10^9m^3$ in Kara. The corresponding relativity of runoff between upper reaches and lower reaches becomes complex because a great quantity of water was channeled out river in the upper and middle reaches.

3.3 Quality change of river water

Water quality of Tarim River has changed along with the change of supplied water quality from tributaries and also affected by drained water from farmland in trunk stream area. The irrigation--drainage system was not built in the tributaries in 1950's and 1960's, drainage water after irrigation flows to the low-lying land, it is hardly to flow into river course and flood could bring the saline water to the lower reaches, so the quality of river water was fine in that time. In 1970's and 1980's, drainage water system had built and a great quantity of saline water drained into river, water quality of Tarim River is not fine, and it getting worse in the later of 1980's. For instance, in Alar Station during the period from October, 1976 to September, 1977, mineralization of river water was higher than 1g/l in six months, was higher than 3g/l in three months, the highest was 5.46g/l. From October, 1984 to September, 1985, mineralization of river water was higher than 1g/l in eight months, was higher than 3g/l in four months, the highest was 5.86g/l. In 1991, , mineralization of river water was higher than 1g/l all the year, was higher than 5g/l in three months. And the highest is over 6g/l in 1997. The obvious rise of water mineralization is due to the expression of irrigation area and increase of drainage water with salt from farmland to river.

Change regulation of river water mineralization in arid land is that it is increased along with the stream of river, but it becomes complex under the effect of human activities. Compared with water mineralization in Alar and Xinqiman Hydrological Station at the upper and middle reaches, water mineralization in Kara at the lower reaches was less during irrigation period from March to December in 1991(tab.2). The section of water course down Alar is drainage area of saline water from farmland, the drainage area of saline water from farmland, the drainage saline water has increased rapidly along with the development of channel and drainage project in irrigation area, so that water mineralization in the upper and middle reaches has gone up. It is estimated that water mineralization in Alar will be 2.84 g/l by monthly average in 2000.[1]

Tab. 2 Monthly mineralization of river water at different sites along Tarim River in 1991(g/l)

site	Jan.	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug	Sept.	Oct.	Nov	Dec.
Alar	1.21	1.73	2.24	5.76	4.57	1.85	3.40	1.12	5.99	1.98	5.64	2.87
Xinqiman	1.99	1.25	2.34	2.49	4.74	1.76	2.86	0.59	0.93	2.34	3.81	4.93
Kara	1.94	2.10	0.91	2.07	0.93	1.45	1.42	0.84	0.22	0.28	0.92	1.76

Drained water from farmland in Tarim River Basin mainly causes the reduce of water quality in the river, if it is not controlled to drain saline water to river continuously, the environment of river water, soil and living conditions in the middle and lower reaches would be worse.

3.4 Change of river course

Tarim River was 1321 km in early 1950's, Lop lake was the destination. Because the increase of channeled water in the tributaries, parts of tributary separated from Tarim River as the independent basins, runoff in the lower reaches of Aksu River, Yarkat River and Hotan River has decreased, the river course in the lower of Tarim River has dried so that the river was shortened. A dam was built up in Layin River Mouth in 1952, and Taitmar Lake became the destination of Tarim River. After 1950's, runoff in the lower reaches has continuously decreased because irrigation developed in a large scale in the tributaries, the river was further shortened. Daxihai Reservoir became the destination of Tarim River and the length of river is 1055 km.

Sand content of runoff in flood season is heavy in Tarim River, flood runoff in tributaries brings a great deal of sand to Tarim River. For instance, sand content of runoff in flood season (from July to September) is 12.9 kg/m^3 in Hotan River, and is 4.87 kg/m^3 in the upper reaches of Tarim River. For Tarim River course is obstructed caused by human activities, water flows slowly and a great deal of silt deposits in the riverbed in the upper and middle reaches, so that riverbed has gone up. People have cut the river bank in 137 sites to channel water for irrigating farmland and meadow, 28 of the cuts are wider than 5 m. The distribution are changed to a certain extent in Tarim River.

Some branch rivers and main river were exchanged in the course of channeling water by human. For example, Usman River was a small canal dug by a farmer whose name was Usman for irrigation in the middle reaches of Tarim River. The canal was lain in depressed place and channeled water was out of control, water easily flowed into that canal, and eroded the canal gradually to make the canal wider and deeper. Since 1978, most runoff of Tarim River has flowed into the canal formed Usman River as the main stream of Tarim River in the middle reaches, original river course became the branch of Tarim river. Some branches of Tarim River are formed in nature, and some are formed by human activities.

4. Relationship of human activities and hydrological change in Tarim River

Tarim River as a continental river in arid land, is sensitive to outside effect, when human interfere a factor of the river, such as building reservoir to change the process of runoff, building water conservancy project to change water distribution. The other characters of river will change indirectly caused by human activities. The hydrological effect caused by human activities in continental rivers mainly are: some artificial canals replace natural river courses, some reservoirs replace natural lakes, most rivers have shortened, water consumption in upper reaches has increased and in lower reaches has decreased, saline water from irrigating farmland drains into rivers causing river water in low quality in the lower reaches, flood peak is cut down when flood arrive in the lower reaches of river, the flood flows gently, and yearly change and monthly change of runoff become complex, and so on. In Tarim River Basin with its special conditions, part of the river course is choked with silt, river bank is cut in many sites, flood is over the river course, many stream river and branches exchange and so forth.

Human has raised the productivity greatly through exploiting and using surface water resources. They has built artificial oasis ecological system but changed the natural distribution and change of water, and indirectly caused environmental change in river basin. In Tarim River basin, most part of water consumed in upper and middle reaches, the natural vegetation declined seriously, water table has fallen, soil is very dry, desertification developed in the lower reaches of river basin.

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ABOUT CHITOSE RIVER FLOOD CONTROL CHANNEL PLAN

Hitoshi Yonetsu
Hokkaido Development Bureau

I Introduction

The basin of the Chitose River, which is a tributary of the Ishikari River, is in central Hokkaido, the base of Hokkaido's continuing development. In addition to its importance to paddy and dry-field farming, central Hokkaido has been developing industrially as well as for suburbs for the Sapporo area. Central Hokkaido also includes industrial areas near New Chitose Airport, the air gateway to Hokkaido and the center of the district. However, because of this area's rainfall characteristics and topographic and geologic features, flooding frequently occurs, causing damage about every two years.

Full-scale flood control measures for the Chitose River, in conjunction with those for the main stream of the Ishikari River, have been taken since the latter half of the Meiji period, in step with the development of the vast low-lying area along the river. However, adequate improvements have yet to be realized. As a drastic flood control measure, the Chitose River Floodway Project is in planning, toward the creation of a new water environment that affords the grand splendor of the north and toward the construction of secure infrastructure, with careful attention to environmental preservation. This paper outlines the significance of the floodway project as an element in the overall flood control system, studies the effects on the surrounding environment entailed in execution of the project, and examines environmental preservation measures.

II Characteristics of the Chitose River Basin

The Chitose River has a drainage area of 1,244 km^2, and the watercourse of the trunk river stretches about 108 km. This class-A river, with Lake Shikotsu at its headwaters, is located at the lower reaches of the Ishikari River, which is one of Japan's major rivers and which has a drainage area of 14,330 km^2 and a main stream that extends 268 km. The Chitose River flows through Chitose city to join the Ishikari River at Ebetsu city (Figure 1).

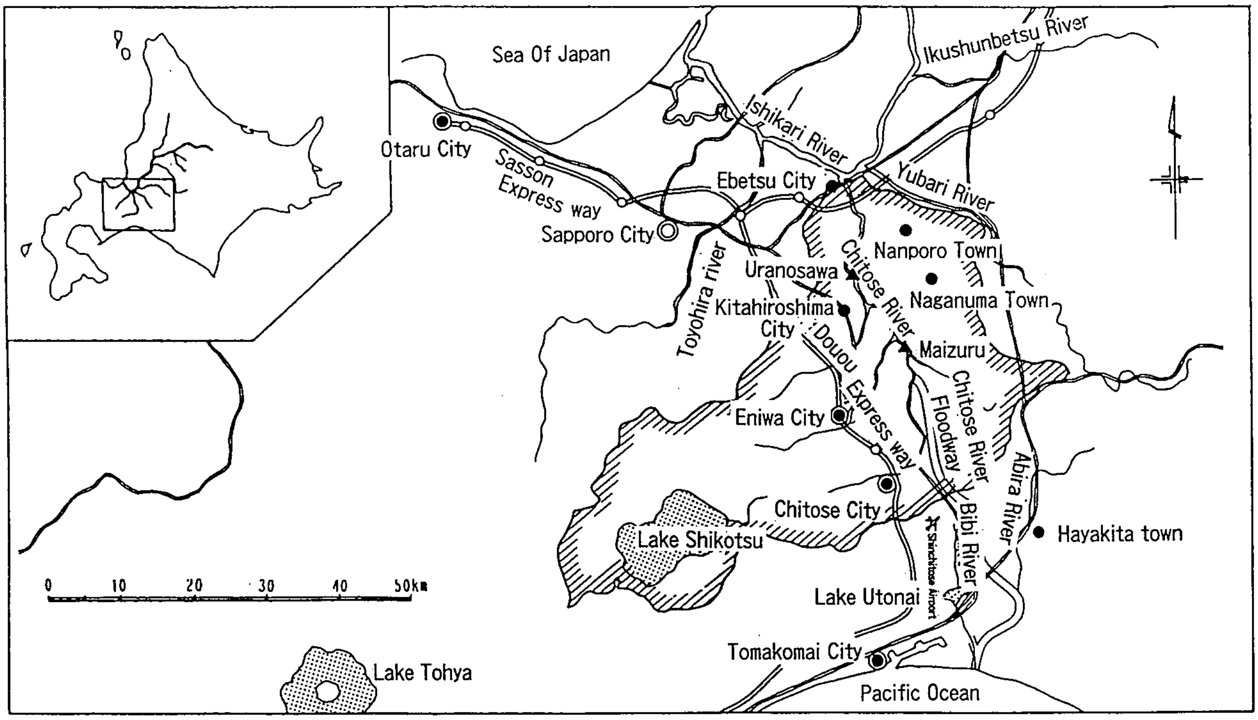


Fig. 1 Location of Chitose River and the Chitose River Diversion Channel

The river basin includes the cities of Chitose, Eniwa, Ebetsu and Kitahiroshima, and the towns of Naganuma and Namporo. These municipalities, whose combined population exceeds 340,000, have been growing in recent years, given their strategic location adjacent to Sapporo (pop. 1.7 million) and within easy access of New Chitose Airport.

Annual mean precipitation in the Chitose River basin is about 1,500 mm, or slightly more than the roughly 1,300 mm in the Ishikari River basin as a whole. However, localized torrential rain often falls, because of weather prone to such rainfall and topographic conditions. During the two floods in August 1981, the mean rainfalls in the basin were 339.5 mm and 220.1 mm.

Since a vast lowland of 40,000 ha stretches along the middle and lower reaches of the Chitose River, it has an extremely gentle bed slope of about 1/7,000.

Moreover, the river shows a peculiar flooding characteristic. During flooding, it is influenced by the high water level of the Ishikari River, which makes it difficult for floodwaters to flow into the Ishikari River. As a result, the level of the Chitose rises higher than the surrounding ground in a section extending as long as 40 km. Such overflow lasts for a long time.

Some hundreds of thousands of years ago, the Ishikari lowland (from the southern part of the Ishikari Plain through the middle and lower reaches of the Chitose River, to the Yufutsu Plain) was a sea. As the sea level dropped, sediment transported from rivers, including the Ishikari, and pumice from the Shikotsu Volcano were deposited. Thus this area became dry land. Consequently, weak ground composed of soils such as peat and volcanic ash is widely found in this basin, which gives rise to some flood control problems, such as difficulty in creating embankments and preventing seepage at their foot.

For these reasons, the Chitose River basin is the site of frequent flood damage. In one such instance (August 1975) in the abovementioned municipalities, about 1,000 houses were flooded, and the flooded area was about 8,000 ha. In early August 1981, flooded houses numbered about 2,700, and an area of 20,000 ha was flooded.

These successive floods caused great damage throughout the river basin, which led to the March 1982 revision of the master plan for river improvement works for the Ishikari River system. Construction of the Chitose River Floodway was planned as a drastic flood control measure.

III Flood Control Plan for the Chitose River

1. Design Discharge of the Ishikari River

1) Method of deciding design discharge

Figure 2 shows the process of setting the design discharge. The plan is made so as to cope with 150- years storm floodwaters in the Ishikari River and certain of its tributaries flowing through Sapporo and Asahikawa, and 100-year storm floodwaters in the other tributaries. Furthermore, probability evaluation of actual rainfall was made, and design rainfall (i.e., probability rainfall that will determine the project scale) at each observation point of the main stream and the tributaries were determined. Next, the actual rainfall patterns of all the major floods were expanded to equalize the design rainfalls. Using a flood runoff model, the runoff of these design rainfalls was calculated by the storage function method, which represented the characteristics of the rainfall runoff from the Ishikari River. Then, hydrographs were obtained. From these hydrographs, those of the design flood were determined.

2) Design rainfall

The design rainfall was determined as follows: 1) The mean rainfall for three days in the Ishikari River basin was calculated by isohyet line method, based on the data of rainfall recorded from 1926 to 1981 at the rainfall gauging stations in the Ishikari basin and its vicinity. 2) Probability evaluation was made on the maximum annual mean rainfall at each observation point, by using Iwai's method, the Gumbel method and the method of moments. 3) The evaluation results were compared to determine the design rainfall. As a result, the design rainfall at the observation point at the Ishikari Ohashi Bridge (probability: 1/150) was determined to be 260 mm/3 days (Figure 3).

As the next step, the rainfall patterns were selected from the actual rainfalls after 1955, which were recorded by area and the time of rainfalls in the entire Ishikari River basin. At the Ishikari Ohashi Bridge observation point, all of the seven patterns with total rainfall exceeding 100 mm were selected, and each was expanded so that the actual rainfall would equal the design rainfall of 260 mm/3 days. The expansion was almost a doubling, to keep the short-term rainfall intensity from being excessive.

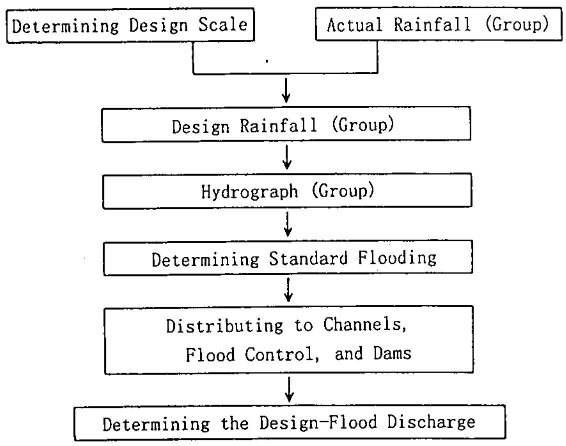


Fig. 2 Flowchart of Determining Design-Flood Discharge

3) Maximum probable flood discharge

As a calculation method of the flood runoff of the Ishikari River, the storage function method was used to compute the volume of runoff from the basin. In making a calculation for tracing flood waters in the river channel, the storage function method was employed for the upper reaches of the river and the tributaries except for the Chitose River, while the river channel pond model was used for the middle and lower reaches of the Ishikari River, whose gradient is gentle, and for the Chitose River. (The river channel pond model is a method to formulate the discharge exchange between adjoining reservoirs, with consideration given to the equation of motion, by assuming that the entire channel comprises a series of reservoirs (ponds) in the river, each of a certain length, and that the discharge exchange between adjoining reservoirs occurs through hypothetical orifices.)

Table 1 shows the calculation results of the runoff, based on the seven rainfall patterns. From the results, the hydrograph of the pattern in August 1975, when the calculated discharge is the highest of all the peak values, was chosen as the hydrograph of the maximum probable flood at Ishikari Ohashi Bridge observation point, and the peak discharge of the new maximum probable flood was determined to be 18,000 m^3/s (Figure 4).

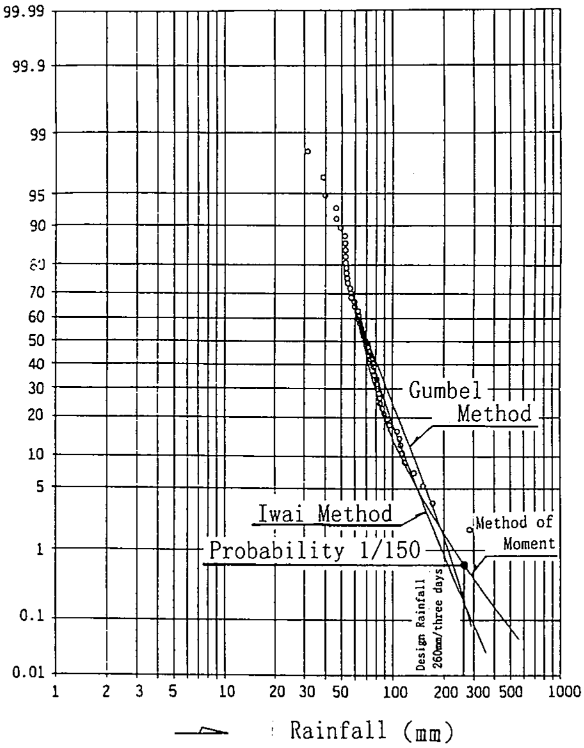


Fig. 3 Probability of Average Annual Rainfall at Maximum Basin (Datum Point: Ishikari Grand Bridge, Upper Stream)

Table 1 Calculated Peak Discharge of Standard Flooding (Datum Point: Ishikari Grand Bridge)

NO	Rainfall Pattern	Actual Rainfall (mm/three days)	Prolongation Rate	Calculated Peak Discharge
1	Early August, 1981	282.2	1.00	Approx. 14,400
2	August, 1975	173.0	1.50	Approx. 18,000
3	August, 1973	113.6	2.29	Approx. 16,400
4	August, 1966	109.9	2.37	Approx. 11,400
5	Mid September, 1965	107.0	2.43	Approx. 12,500
6	August, 1962	133.0	1.96	Approx. 17,600
7	July, 1961	151.5	1.72	Approx. 16,100

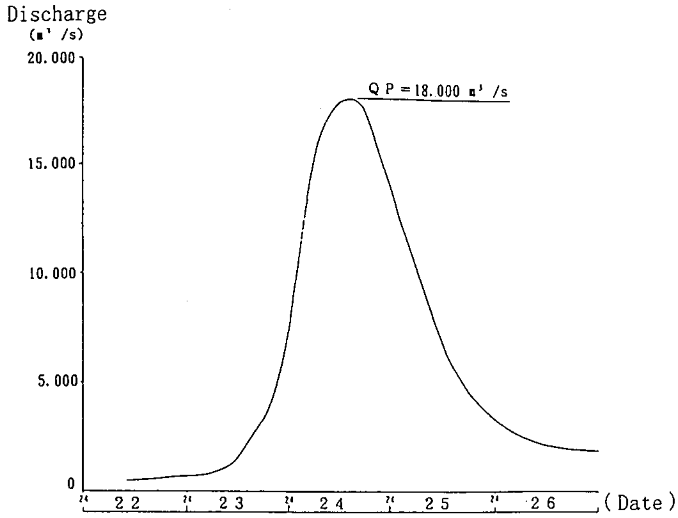


Fig. 4 Standard Flooding Hydrograph (Datum Point:Ishikari Grand Bridge)

4) Design probable flood discharge

After the discharge of the maximum probable flood is determined, it is properly distributed to the channels, dams and retarding basins, then a design flood discharge is decided which is the base of the plan for the channel and flood control facility at each point. In a flood control plan, the principal and fundamental step is to cope with floodwaters by increasing the channel capacity to flow down as much as reasonably possible. The overall capacity to flow down will be increased by excavation and dredging of the channels, with careful attention given to the stability of the levee.

The capacity to flow down at the Ishikari Ohashi Bridge observation point was planned to be increased from 9,000 m^3/s to 14,000 m^3/s. Furthermore, a portion of the floodwater would be controlled by dams and large-scale retarding basins whose construction was topographically and geologically feasible.

With respect to the Chitose River, recognizing that this river is characterized by being greatly influenced by the water level of the Ishikari River during flooding, the Chitose River Floodway Plan was made, as a drastic flood control measure, to allow floodwaters to flow directly into the Pacific Ocean. The calculation results snowed the volume of water flowing into the Ishikari River could be reduced by 1,000 m^3/s. Consequently, the total amount of the floodwater that could be controlled by the floodway, the dams and retarding basins, at the Ishikari Ohashi Bridge observation point, would amount to 4,000 m^3/s, and the design probable flood discharge was determined to be 14,000 m^3/s. Figure 5 shows the distribution of design flood discharge of the Ishikari River.

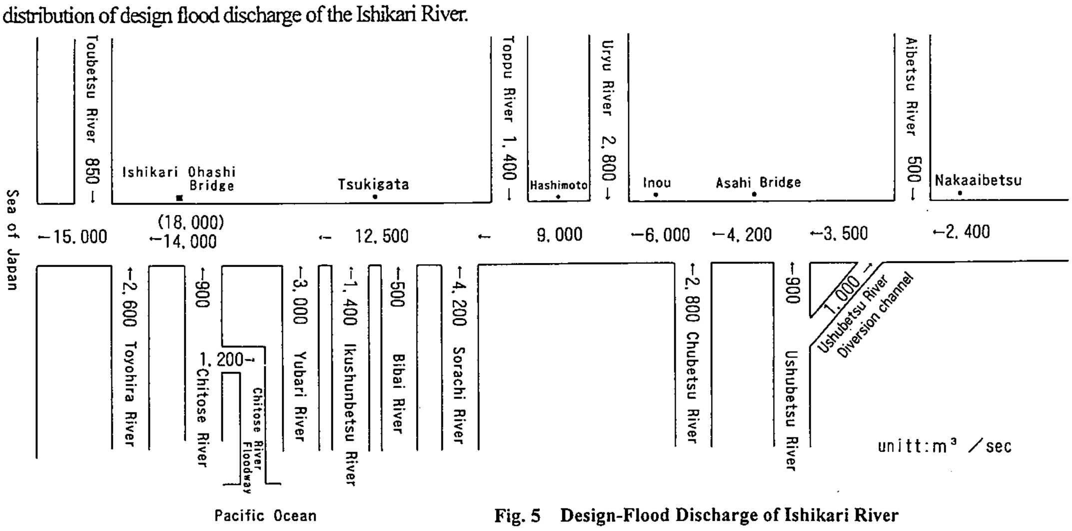
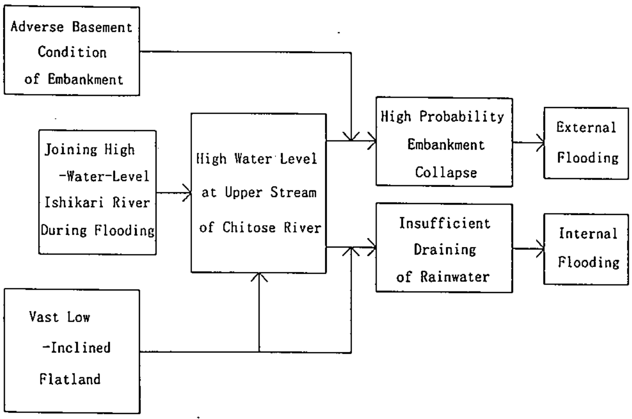


Fig. 5 Design-Flood Discharge of Ishikari River

Fig. 6 Causal Relation of the Flooding of Chitose River



2. Reviewing Flood Control Plan for the Chitose River

Figure 6 shows a cause-effect relationship regarding inundation on the Chitose River. Lowering of the water level of the river and reduction of flooding duration are essential for drastic flood control.

Given this, various proposals for flood control measures -- floodway, separation levee, retarding basin, et al. -- were compared and discussed when the master plan for river improvement works was revised, and the Chitose River Floodway Project was selected. Furthermore, various recent opinions on the floodway project and suggestions made as alternative plans were also reviewed.

The main proposals for flood control measures follow.

- Back levee

Construction of large, high banks: These would be designed to withstand a flow as high as the water level of the Ishikari River. The banks would be constructed on both sides of the Chitose River and its tributaries.

- Separation levee

Construction of a separation levee where the Chitose River meets the Ishikari River: The proposed separation levee would shift the present junction downstream, and lower the water level. The water level of the Chitose River thereby would be lowered.

- Chitose River retarding basin

Construction of a cutoff gate at the junction with the Ishikari River: A 10,000 ha retaining basin would be constructed in the lower reach of the Chitose River. This retarding basin would lower the water level by storing the floodwater in the basin.

- Widening of the low-water channel of the Ishikari River

Lowering of the water level of the Chitose River by widening the low-water channel of the Ishikari River: The low-water channel of the Ishikari River would be significantly widened downstream of the junction of the Chitose River and the Ishikari River.

- Introduction of a shortcut on the Ishikari River

Construction of a shortcut that would divert the Ishikari River to the Sea of Japan: The water level of the Chitose River would be lowered by an Ishikari River shortcut that would flow into the Sea of Japan from the point near the mouth of the Ishikari River.

- Compound proposal

A proposal consisting of any two of the above stated proposals.

- Chitose Floodway proposal

A comparative examination was extensively conducted on the above flood control proposals. As a result, the Chitose Floodway proposal was evaluated as the best of these flood control measures. The examination was based on the possible effects on lowering the river water level during flooding and on shortening the flooding duration. Studies were conducted on the costs of construction, annual management and maintenance, replacement of equipment, and land acquisition. Impact on society, such as regarding relocation of houses in the project area, and impact on the surrounding environment were also carefully studied.

3. The Chitose River Floodway Project

The Chitose Floodway will measure approximately 40 km in length, with a low-water channel 180 - 280 m wide. The planned discharge is 1,200 m^3/s. During construction, a total of 110 million m^3 of earth will be excavated. The total project cost will be approximately 370 billion yen, or 480 billion yen if the Chitose River Improvement Project cost is included. Construction will take twenty years.

A cutoff gate for the floodway will be constructed near the mouth of the Chitose River at the junction with the Ishikari River. The floodway will start at an intake gate on the Chitose River to draw in floodwater from the river and end with a final closure gate at the mouth of the floodway to prevent inflow of the seawater.

4. The Operation of the Floodway and its Flood Control Effects

At normal times, the floodway is to be operated as follows: The cutoff gates are left open; the flow-intake gates are left closed. The water in the Chitose River flows into the Ishikari River. During flooding, the flow-intake gates of the floodway are opened and the gates of the final closure weir are moved, thus the water of the Chitose River flows safely into the Pacific Ocean. At the same time, when the water level of the Ishikari River becomes higher than that of the Chitose River the cutoff gates are closed to avoid backflow into the Chitose River (Figure 7).

The flood control effects of the Chitose Floodway are compared with the data from the flood of early August, 1981: The water level will be greatly lowered throughout the Chitose River area, especially in the middle reaches, where the land is low. The peak water level will be greatly lowered, to 4 m at the Maizuru point and 3 m at the Uranosawa point. The period during which the water level during flooding exceeds the ground level within the embankment will be shortened from 100 hours to 6 hours at the Uranosawa point, and will be even more greatly shortened from 170 hours to 0 at the Maizuru point. The effect of shortening the duration of flooding will be particularly great in the middle reaches of the Chitose River where the ground level is low (Figure 9).

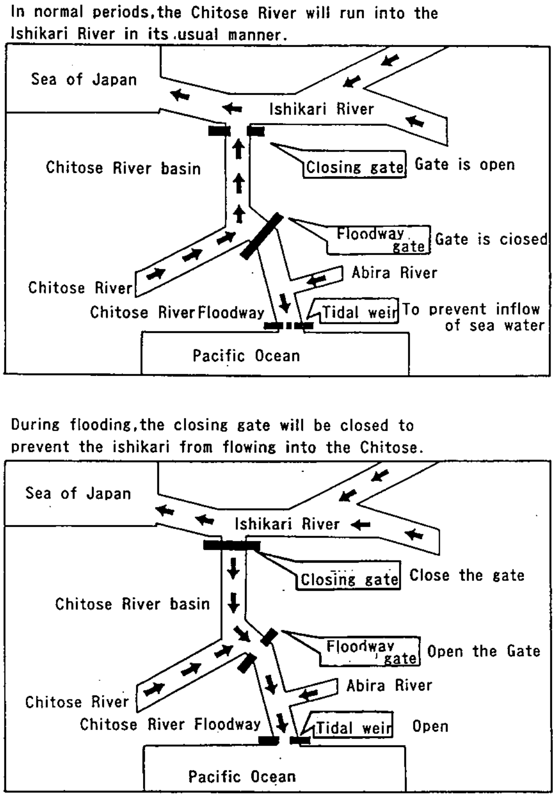


Fig. 7 Operation of the Chitose River Diversion Channel

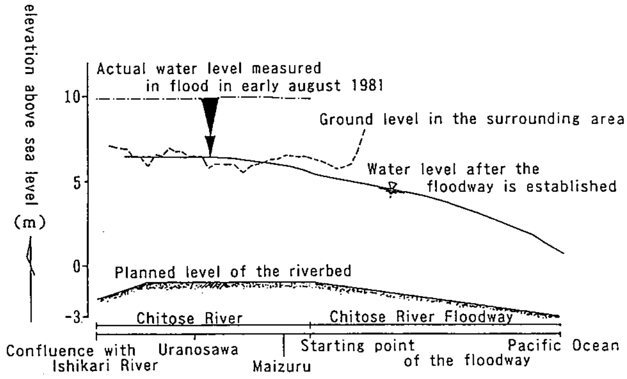


Fig. 8 Effect of Drawdown at the Chitose River Diversion Channel

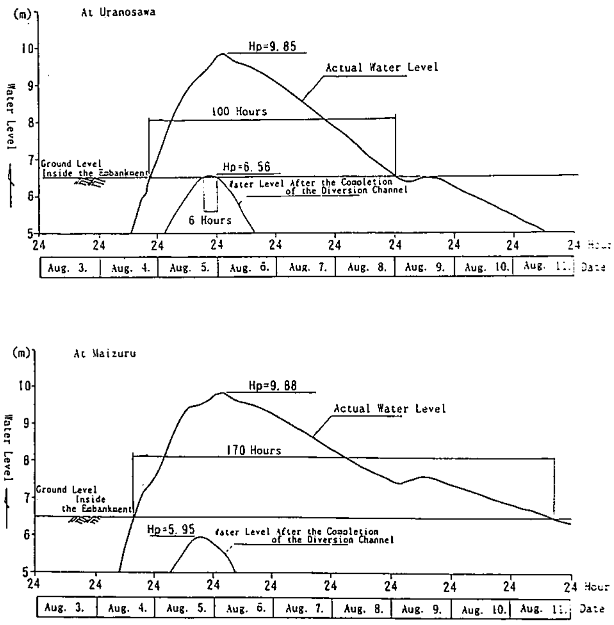


Fig. 9 Reduction of Flooding Hours at Chitose River Diversion Channel

IV Environmental Impact, and its Countermeasures

1. Preservation of the Natural Environment, including Lake Utonai

In the areas surrounding the floodway lie Lake Utonai, a wetland registered under the Ramsar Conference, and the Bibi River, which is the main water source of the lake. The lake and river are located near an urban area and are elements in the beautiful landscape of the area. The wetland is also an ideal habitat for many kinds of animals and plants.

In June 1992, the governor of Hokkaido submitted an official request toward the preservation of the precious natural environment of the Bibi River (the first of five such requests).

At the fifth meeting of the Ramsar Conference (officially: Fifth Meeting of the Conference of the Contracting Parties to the Convention on Wetlands of International Importance, Especially as Waterfowl Habitat) held in Kushiro in June 1993, the Chitose Floodway Project was discussed in relation with Lake Utonai. On this occasion, the Japanese government expressed the following opinion.

- The government fully recognizes the importance of Lake Utonai. In examining the route for the floodway, the Hokkaido Development Bureau is appropriately considering the environmental preservation of that lake. The Bureau will summarize the results of the examination as soon as possible.

- The Bureau will conscientiously prepare an environmental impact assessment and take responsibility toward preserving the environment of Lake Utonai. Based on this national government policy, the Bureau has decided to preserve the natural environment of the area around the Bibi River and Lake Utonai by conducting groundwater preservation measures.

2. Examination on the Groundwater Preservation Measures

1) The groundwater environment in the areas around the Bibi River and Lake Utonai

The Bibi River originates in a hilly area northeast of Chitose Airport. Forming a wetland, it flows south into Lake Utonai. At the lower end of Lake Utonai, it joins the Yufutsu River and empties into the Pacific Ocean east of downtown Tomakomai.

The main water resources of the Bibi River are the many springs in the marshes and dales of its tributaries. Figure 10 shows the east-west geological profile and levels of the groundwater tables near the Bibi riverhead.

The area around the Bibi River consists of strata of the Quaternary period. These strata includes those of volcanic eruptions from the Shikotsu Volcano that formed the Shikotsu Caldera from about 39 thousand to 32 thousand years ago, and strata formed before and after that age. The strata formed during the volcanic eruptions are divided into the Shikotsu pyroclastic flow sedimentary layer (Spfl) and the Shikotsu pumice fall layer (Spfa). The Spfa layer consists of three sub-layers: Spfl-1 to Spfl-3, from top to bottom. The strongly to weakly welded layers Spfl-2 and Spfl-3 form the aquiclude, Spfl-1 forms the unconfined aquifer, and Spfa forms the artesian aquifer.

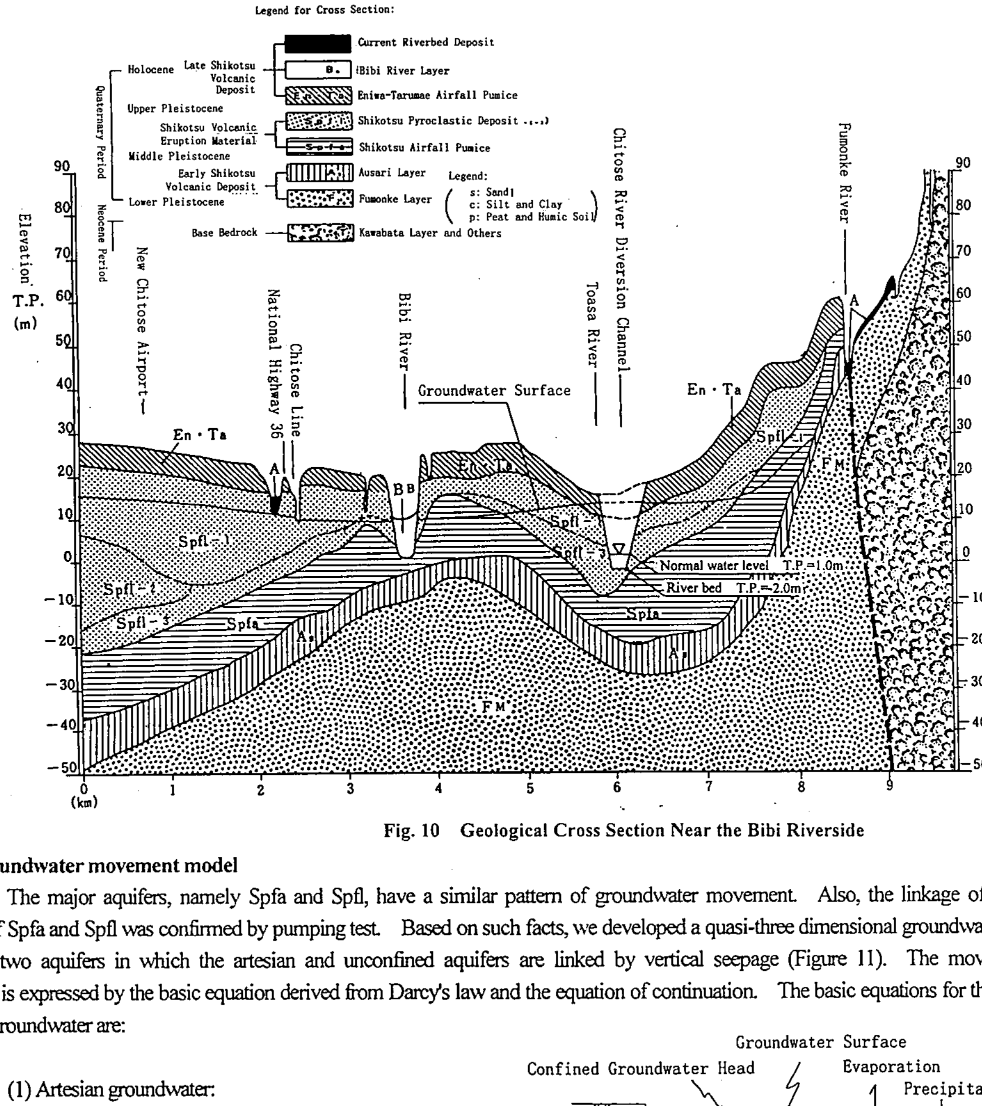


Fig. 10 Geological Cross Section Near the Bibi Riverside

2) The groundwater movement model

The major aquifers, namely Spfa and Spfl, have a similar pattern of groundwater movement. Also, the linkage of groundwater movement of Spfa and Spfl was confirmed by pumping test. Based on such facts, we developed a quasi-three dimensional groundwater movement model with two aquifers in which the artesian and unconfined aquifers are linked by vertical seepage (Figure 11). The movement of the groundwater is expressed by the basic equation derived from Darcy's law and the equation of continuation. The basic equations for the artesian and unconfined groundwater are:

(1) Artesian groundwater:

$$\frac{\partial}{\partial x}\left\{K\cdot m(x,y)\frac{\partial h}{\partial x}\right\}+\frac{\partial}{\partial y}\left\{K\cdot m(x,y)\frac{\partial h}{\partial y}\right\}=S\frac{\partial h}{\partial t}+L$$

(2) Unconfined groundwater:

$$\frac{\partial}{\partial x}\left\{K\cdot(h'-h_0)\frac{\partial h'}{\partial x}\right\}+\frac{\partial}{\partial y}\left\{K\cdot(h'-h_0)\frac{\partial h'}{\partial y}\right\}=S\frac{\partial h}{\partial t}-L+W$$

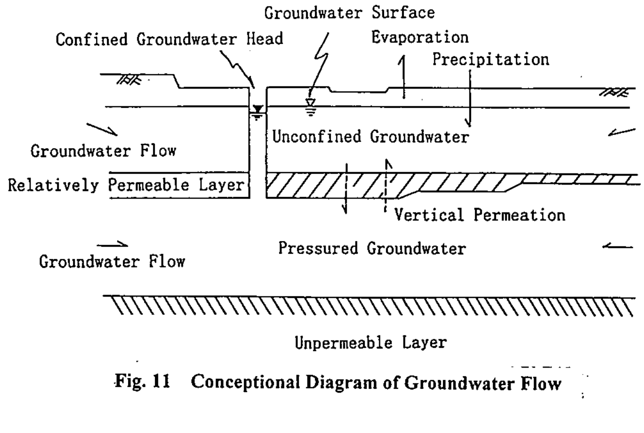


Fig. 11 Conceptional Diagram of Groundwater Flow

where, h is the head of artesian, x and y are the spacial coordinates, m (x, y) is the thickness of aquifer, t is time, K is the permeability coefficient, S is the storage coefficient, h' is the level of the unconfined groundwater, W is the groundwater supply by precipitation, h_0 is the level above the sea level of the bottom of the unconfined aquifer, and L is the vertical infiltration amount. The vertical infiltration amount (L) is calculated from Darcy's law by the following equation.

$$L = \frac{K'}{b'}\bar{h}$$

where, K'/b' is the leakage coefficient, K' is the seepage coefficient of the aquiclude, b' is the thickness of aquiclude, and is the difference between the heads of upper and lower aquifers.

The subject of the calculation is the area extending 40 km north-south and 15 km east-west that includes the Chitose River Floodway. Calculation is made by dividing the area into triangular elements, which take into consideration the topographical features, such as boundaries between lowland and table land, the water area of the floodway, and the locations of major river channels including that of the Bibi River.

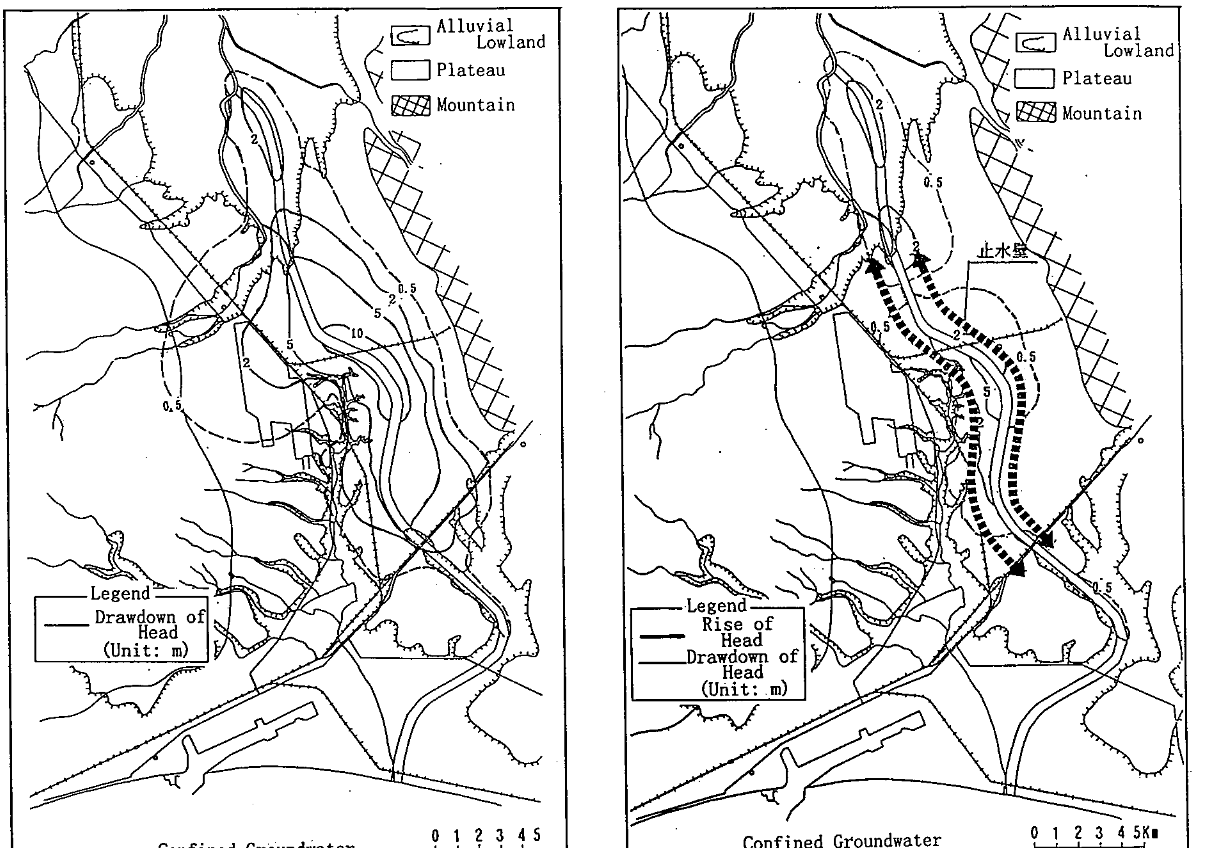
3) Groundwater preservation measures

As shown in Figure 10, the bed of the floodway will almost reach the depth of the top of the Spfa layer. The ordinary water level of the floodway (1 m above sea level) is lower than the groundwater level at the Bibi riverhead (8 m above sea level). If the floodway is excavated without any environmental countermeasures, the groundwater level will fall. A calculation based on a groundwater flow model has predicted that the groundwater level would fall 10 m at the area around the floodway and about 2 m on the left bank of the Bibi River.

The lowered groundwater level would reduce the runoff of groundwater to the Bibi River from the east side. As a measure to preserve the groundwater, cutoff walls are planed to be constructed on both sides of the floodway in order to prevent the groundwater from flowing into the floodway from the aquifer. This will raise the groundwater level on the left bank of the floodway 0.5 to 2 m higher than that before construction. On the right bank, the volume and the area of lowered groundwater will be smaller than if no measures are taken (Figure 12).

The results of the comparative examination are shown in Figure 13. Here three volumes of groundwater runoff to the Bibi River are indicated: before the excavation of the floodway, after the excavation but without environmental countermeasures, and after the excavation but with introduction of cutoff walls. From this examination, the groundwater runoff into the Bibi River is predicted to be smaller than that before construction, even though cutoff walls will be constructed. In addition to the cutoff walls, the water on the left bank will be collected to balance this insufficient amount and supplied into the main left bank tributary of the Bibi River. This will maintain the present water volume of the Bibi River (Figure 14).

These measures enable the securing of the discharge and water level of the Bibi River. However, the groundwater level on the left bank of the river is still predicted to drop. The environmental impact on the vegetation of the Bibi River caused by this lowered groundwater level was examined based on the relation between the present vegetation distribution and the river water and groundwater levels.



After Excavating Without Countermeasure With Cut-Off Walls Set Up

Fig. 12 Drawdown of Groundwater Level

3. Impact on the Natural Environment

1) Impact on the marsh

The predominant vegetation around the Bibi River consists of wetland vegetation in communities of two species of reed (Phragmites communis, C. longsdorffii) and groves of black alder (Alnus japonica), and forest vegetation of two types of oak (Quercus mongolica, Quercus serrata Murray). Figure 15 shows the changes in the water level of the river and the groundwater level at the areas where the predominant species of vegetation are growing. The water level of the Bibi River shows an annual cyclical change in spite of the slight changes of monthly average flow volumes. The river water level rises because the resistance against the water flow increases when the water plants grow abundantly, from summer to fall, and the level becomes low when the plants die away in winter.

As seen in Figure 15, the communities of reeds grow in areas (a) where the water level changes are the greatest or where floodwaters enter. In contrast, the black alder groves are in areas (b) where the groundwater level is high or where floodwaters almost reach the level of the ground surface, or (c) in areas that sometimes flood. The forest of oak grows in areas (d) where the river water level does not influence the forests, and where the groundwater level is 20 cm deep or changes in groundwater occur relatively deeply.

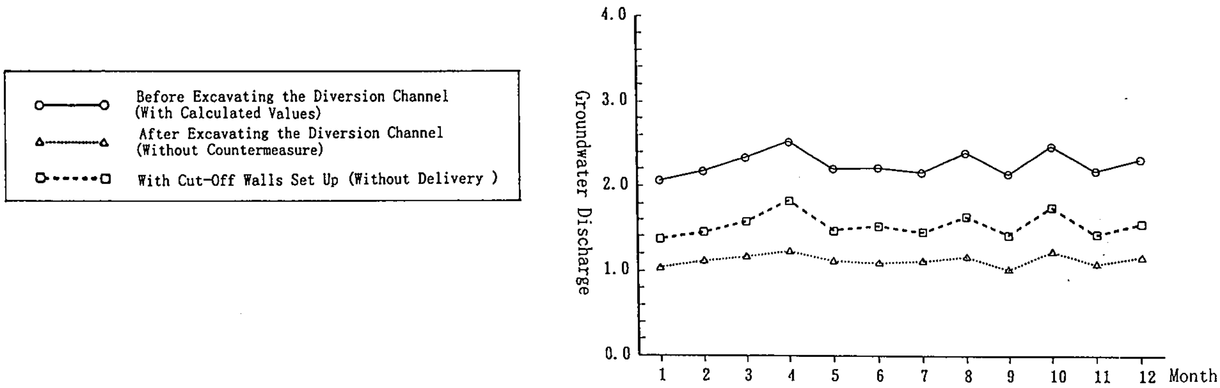
Figure 16 shows a representative section view of the distribution of the vegetation. The black alder groves are roughly divided into three types according to the kinds of undergrowth: reeds, spireas (Spiraea salicifolia) and sasa (bamboo grass). The former two species grow in relatively low areas and the latter in the higher areas. Sasa cannot grow in the areas where the groundwater level is high. Therefore, the wetland's drying progresses in areas where the bamboo grass grows, and the vegetation of the areas is in the transitional stage.

Based on the distribution characteristics of vegetation along the Bibi River, summarized below is how the river water level that is expected to be maintained by the groundwater level preservation measures will influence the vegetation.

Changes in the groundwater levels will not affect the reed communities, because the river water level is the controlling element of the growing environment of reeds. In the black alder groves, there is the possibility that the lowered groundwater level at a section of the left bank of the Bibi River will result in changes in the undergrowth, even if the river water level is maintained. The forest vegetation, such as oak forest, will not be influenced because the growing environment does not relate directly to the groundwater level.

As for the influence on wetland vegetation, a portion of the black alder groves may be influenced, including through changes in the undergrowth vegetation or transition to oak grove. About 38 ha falls into this category, or about 3% of the marsh vegetation in the Bibi River area.

Fig. 13 Fluctuation of Groundwater Discharge to Bibi River



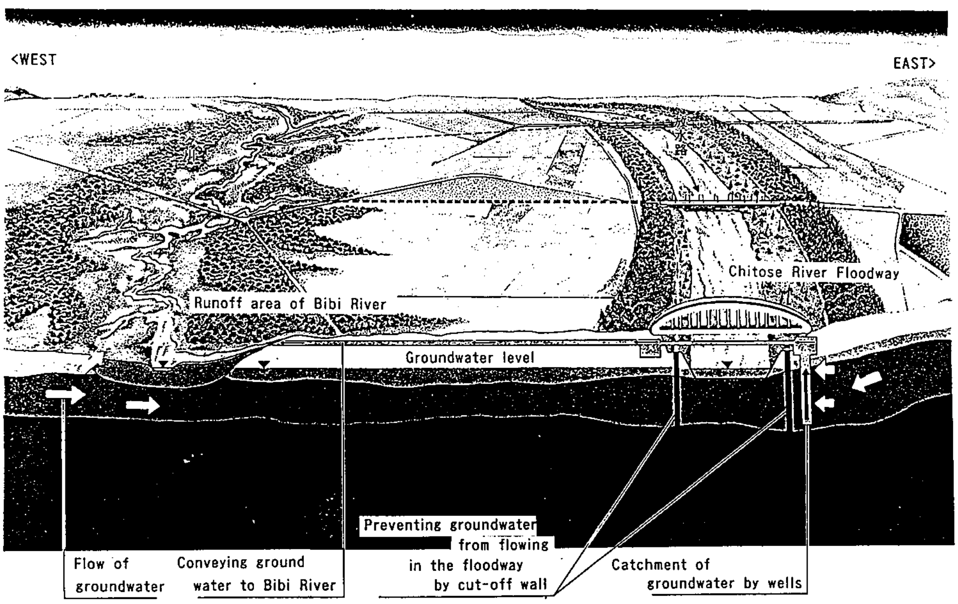


Fig. 14 Collection of Groundwater

2) Influence on Lake Utonai

Figure 17 shows the groundwater level of the area between the floodway and Lake Utonai. There is a groundwater watershed below the tableland between the lake and the floodway. The calculation using the groundwater model revealed that the areas where the groundwater level may drop because of the excavation of the floodway will be limited to those close to the floodway and that the groundwater watershed will be preserved. Therefore, the present relative condition of the flows of the groundwater will not change, and the groundwater will not flow from the lake toward the floodway.

The geological condition of the bottom of Lake Utonai, where thick silt and clay layers form an aquiclude, makes it extremely difficult for the lake water to infiltrate. Because of this condition, the excavation of the floodway will not cause the lake water to exfiltrate into the floodway.

The present level of discharge into the lake will be maintained by groundwater level preservation measures that maintain the discharge of the Bibi River.

Since the level, discharge and quality of the lake water, the elements important to the natural environment of the lake, will be preserved by the measures, the landscape and natural habitat of the wild animals and plants at Lake Utonai will be preserved.

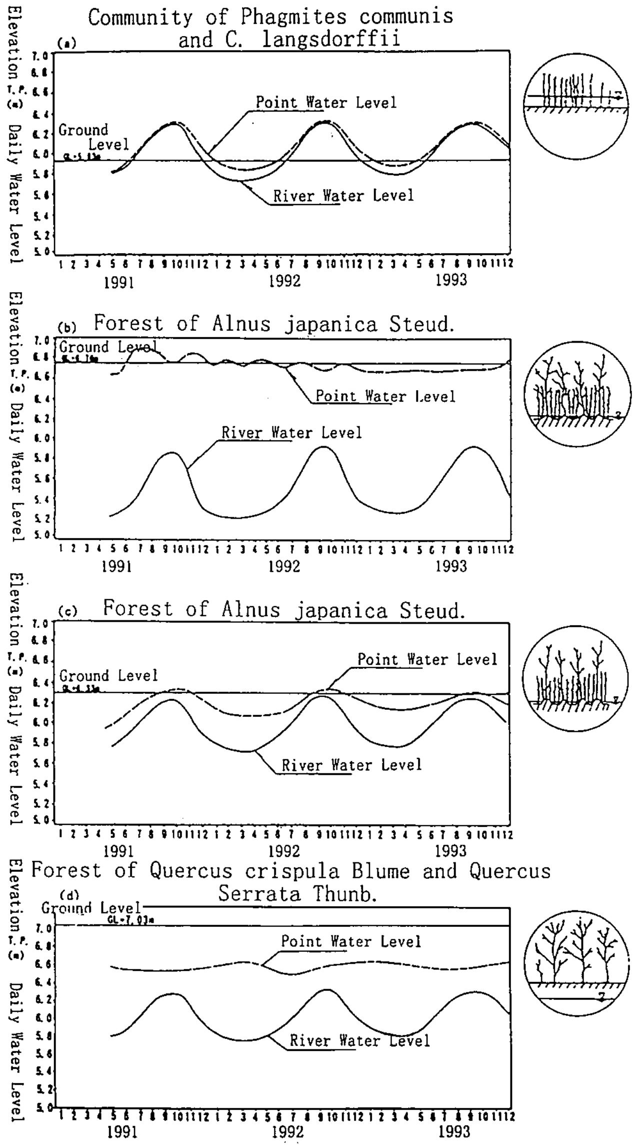


Fig. 15 Yearly Fluctuations of River and Groundwater Stages

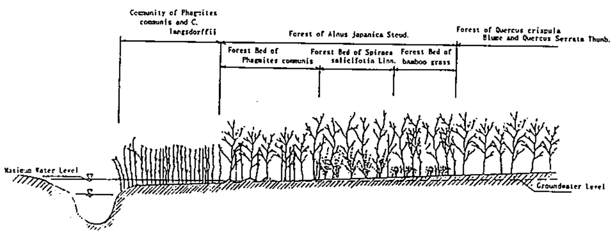


Fig. 16 Typical Vegetation at Marsh Near Bibi River

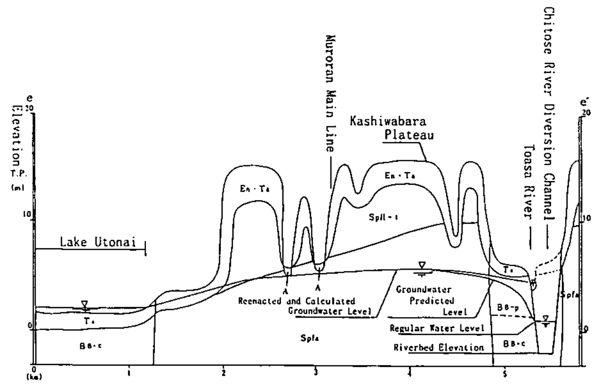


Fig.17 Cross Section of Predicted Fluctuation in Groundwater Stage Near

V Influences on Agriculture and Fishery in the area, and their Countermeasures

1. Influence on Agriculture, and its Countermeasures

Most of the areas along the floodway belong to the Western Pacific climatic district. Summers are cool and southerlies from the Pacific ocean carry in sea fog. Winters are cold, with prevailing seasonal northerlies from the continent.

The influence of winds, temperature, fog, etc., on agriculture is a matter of concern, because rice paddy, dairy, and dry-field farms are managed there under severe climatic conditions in the area along the floodway. The following influences were predicted from various studies, including on-site surveys, wind-tunnel tests, and value analyses for predicting possible climatic changes after the construction of the floodway.

1) Winds

In the 200 - 300 m bordering each side of the floodway and at 2 m above the ground, the wind velocity will increase a maximum of 1.2 times the present velocity.

2) Temperature

The monthly average temperature in the area near the floodway will drop 0.1 - 0.2 ℃ during certain summer months (July and August), because the winds will pass over the water of the floodway.

3) Fog

When southeasterlies blow and very limited weather conditions occur, sea fog will enter about 1 km farther inland on the area over the floodway.

To deal with these weather changes, a study was conducted on the fog mitigating effects of a windbreak and fog-break planting strips on both banks of the floodway. As a result, the area where the wind velocity will increase was predicted to be confined inside the floodway area, and the influence of lower temperatures was predicted to be mitigated by the dissipated wind velocity and raised earth temperature due to the planting strips.

2. Influence on Fishery, and its Countermeasures

Studies to devise countermeasures against influences on fishery in the Pacific area where the floodway flows were conducted by a research institute. The impact also considered here was that on the Chitose River, a river important for artificial propagation of salmon and trout. The study focused on the impact on anadromous parent fish and catadromous fry. The results of the research were explained to fishery groups. Research and studies including supplementary studies will be conducted to elucidate the floodway's impacts on fishery, and to devise new measures.

3. Disposing of Excavated Earth

The earth that will be excavated during construction of the floodway will total approximately 110 million cubic meters. Part of the earth will be used for embankments and other earthworks related to the floodway. The locations of these earthworks will be based on protecting the environment of the area. The locations basically include places where the land is already used or will be newly developed. Plans for depositing the excavated earth should be made in accordance with the land utilization plans of the area for vitalization of the areas along the floodway. The excavated earth will be used mainly for raising the land, including of farmland and suburban areas.

VI Creation of a New Environment of Forests and Waterfront

A space about 200 - 300 m in width, 40 km in length and approximately 800 ha in water surface will incorporate nearly 400 ha of 50 m-wide planting strips to functions as wind- and fog breaks. This will be developed into an environment rich in water and greenery to serve as a public space with a grand, pleasant landscape.

The environment expected to be created around the floodway will be suitable as a habitat for wild birds and other animals. It will also provide places for fishing, playing in the water, and enjoy water sports such as canoeing and boating. All in all, the new environment is expected to enrich the living environment of the people in the area.

VII Closing

Today, when a large-scale flood control project is conducted, sufficient preliminary studies, impact assessment and examination of countermeasures based on the viewpoint of environmental preservation and toward easing the social impact are demanded by many parties concerned. Disclosure of information related to the project is also called for.

In this Chitose River flood control project, the Hokkaido Development Bureau has been conducting studies and examinations that consider every possible perspective. The Bureau published the Technical Report on the Chitose River Floodway Project with the purpose of explaining the technical aspects of the project, of assessing the environmental impact and of considering countermeasures. Furthermore, the Bureau will carefully continue its studies and examinations in the future and will work on improving understanding among the parties concerned. This paper has summarized the position of the floodway project in the overall flood control system and the groundwater preservation measures that are the most important element in environmental preservation. Evaluation of the impact, and preservation measures and their effects, have been illustrated.

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Eco-environmental Impacts of Yellow River's Dry-up

Yanchun Gao & Changming Liu
(Institute of Geography, Chinese Academy of Sciences, Beijing, 100101)

ABSTRACT

Yellow River is the mother-river for Chinese people. Due to rapid economic development and poor water resources management, Yellow River's dry-up occurs frequently and becomes even more year by year. Except the huge loss to social life and economic growth, Yellow River's dry-up brings about great potential impacts to eco-environment. In this paper, the authors have analyzed the impacts in detail from multi-aspect: impacts to delta's eco-environment, to aquatic life resources of estuary and Bohai Sea, to agricultural eco-environment, to water pollution and flood prevention as well.

Key Words: Yellow River's dry-up, eco-environmental impacts

1 Introduction

Yellow River, the second river in China, originates from the north foot of Bayekela Mountain, flows through nine provinces of China: Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Henan and Shandong, and finally pours into Bohai Sea at Kengli County in Shandong province. The total length of the river's main course amounts to 5464km with a vast drainage area of 752443km^2. It locates between N32° ~ 42°, E96° ~ 119°, in which there is the largest loess plateau in the world. According to its physical geography feature, Yellow River is divided into three parts: upper, middle and lower reaches. The whole basin belongs to continental climate with an average annual precipitation of 478mm, equal to 3.6×10^{11} m^3. The runoff of Yellow River is mainly fed by rainwater and with an obvious feature of extreme uneven distribution in seasons and space.

Seen as the cradle of Chinese civilization, Yellow River is regarded as the mother-river for Chinese people. For its long history and splendid civilization, the river's basin has been the center for politics, economy and culture of China for quite a long time in history. There are about 20 million hectares of arable land(Liu Changming, 1989) and more than 100 million people inhabit the basin. Many heavy industries have been developed and highly productive oilfield at Zhongyuan and Shengli have been exploited in the river's lower reaches and estuary respectively. Yellow River is the most important water resources for North- and Northwest China, and plays an irreplaceable role for economic development and social life in these regions(Chen Xiande etc., 1996).

However, along with the rapid development of economy, water resources has been consumed at a unprecedented growth speed. The exploitation rate of Yellow River's runoff reaches 52%, the highest one among the seven largest rivers in China. Over-exploitation and irrational use have directly caused the frequent dry-up at the lower reaches of Yellow River(Jiao Enze, 1997). Furthermore, the situation of dry-up becomes worse year by year.

Since 1972, the first occurrence of Yellow River's dry-up, frequency and duration of dry-up, and the length of dry-up river channel in lower reaches increased rapidly in the past 26 years(1972 ~ 1997). In 1995, dry-up channel length reached 662km, accounting for 86% of the whole lower reaches' length. The dry-up point traced back to Jiahetan section, near Kaifeng city, Henan province, and the dry-up duration of the river's estuary exceeded 152 days(Cui Shubin etc., 1996). The great harm caused by dry-up to social life and economic development has received much attention from the center and local governments, and from personalities of social various circles, but the deep issues of Yellow River's dry-up, its potential hydrological, eco-environmental impacts, which, in a long run, are mostly irreversible and will causes much more great loss to eco-system and economic development in future, in a sense, have been neglected for quite a long time.

2 Impacts to Delta's Natural Eco-environment

Yellow River's delta is one of the three largest deltas in China. It is a valuable place to be exploited in near future and favorable for building a coastal developing district due to its advantageous conditions: large arable land, vast natural resources, good environment and advantageous geographical location. However, the river's dry-up has brought about great impacts to the delta's natural eco-environment.

2.1 Coastal Erosion and Retreat

The delta is formed by deposition of soil and sand sediment. In average, each year 10.5×10^8 tons sediment is transported to the estuary, and about 73% of the sediment deposits at the delta, only 27% is transferred to deep sea by sea flow. Therefore, the coast expands at an average rate of 20km^2 each year, becomes the place with highest growth rate of land resources in the world. However, it is well-known that delta is such a place where coast expends or retreats depend on the interaction between coastal erosion and sediment deposition. It expends when the deposition speed exceeds erosion speed. Conversely, it retreats. Based on calculation by experts, coast would be in balance when the sediment reduces to 3.7×10^8 tons each year, it would retreat when sediment is less than 3.7×10^8 tons. In the light of statistical analysis, the soil and sand sediment reduced at a rapid speed since 70's. In average, the annual sediment was 13.2×10^8 and 10.9×10^8 tons in 50's and 60's respectively, and reduced to 9.0×10^8 and 6.4×10^8 in 70's and 80's separately. In the first four years of 90's, it reduced to 4.0×10^8 in average. According to the data on sediment deposition and coast erosion in the time from 1968 to 1980, the erosion speed was only 1/4 of the deposition speed. In the meantime, the occurrence rate of dry-up was 54%, and the average annual dry-up time was 6.9 days. But in the time from 1991 to 1995, the occurrence rate reached 100%, and the average dry-up time came to 68 days each year, and the erosion speed had increased by 10 times. At this speed of deposition reduction and erosion increase, the delta coast will be changed from expansion now to retreat by the year of 2000, and unavoidably, a series serious environmental issues will be brought about.

2.2 Impacts to Ground-water

Almost all ground-water of Yellow River's delta is pore water in loose rock. It consists of three types: fresh, salt and halogen ground-water. Fresh water occupies 4% of the total area of ground-water, while salt and halogen ground-water account for 70% and 20% or so respectively. Variation of ground-water depth is controlled by the changes of hydrological, meteorological conditions and the alternation of seasons. Yellow River's dry-up, on the one hand, directly reduces the ground-water supply from river seepage. On the other hand, the consumption of fresh ground-water is raised because there is no water from Yellow River for irrigation. Therefore, It is inevitable that Yellow River's dry-up brings about the descent of ground-water depth in the delta, and the depth descent of ground-water certainly causes sea water invasion, and sea water invasion necessarily worsens the quality of ground-water, intensifies the crisis of fresh water shortage.

2.3 Vegetation Degeneration

The delta's vegetation is mainly grassland. It consists of four types of vegetation: common meadow, saline-hygric meadow, saline meadow and saline vegetation. It is an eco-system which is very fragile, unstable and easy to degrade. Water and sand resources are two basic conditions for beneficial evolution of the grassland system, while natural tidal invasion and human over-cultivation and grazing are the important reasons for retrogressive evolution of the eco-system. There are 2.18×10^5 hm^2 grassland in the delta now, among which natural grassland is more than 1.85×10^5 hm^2. In recent years, Yellow River has been diverted for grassland irrigation and the area of artificial grassland is more than 2×10^4 hm^2. The river's dry-up directly brings about serious impact on the growth of artificial and natural grassland. By 1994, irrigation area of fodder grassland reduced to less than 200 hm^2. Without water and sand resources, eco-system of grassland is easy to retrogressively evolve, that forage grasses will be substituted by saline-hygric meadow or by common meadow even saline meadow. Obviously, Yellow River's dry-up is great unfavorable to beneficial evolution of the eco-system of grassland in the delta.

2.4 Impacts to Offshore Aquatic Life

There are rich aquatic resources in and around the estuary of Yellow River due to the large quantity of land nutrient material. So, the river's dry-up will produce unfavorable influence in multi-aspects on aquatic life of Bohai Sea:

① Reproduction and growth of aquatic life in Bohai sea will be greatly impacted for loss of their most important food source.

② Many migration fishes will migrate to other place. So, the biological chain of Bohai Sea will break. It will cause great and irremediable loss to Bohai Sea eco-system.

③Chlorine density around estuary will rise, which is greatly unfavorable for fish and shrimp's reproduction and growth.

④Waste water release will not stop after Yellow River's dry-up. Thus, water pollution of Bohai Sea will be aggravated. It produces great harm to the reproduction and growth of aquatic life resources.

3 Impacts to Agricultural Eco-environment

There is flood land about 3155km^2 between dykes in the lower reaches of Yellow River, among which farmland is more than 2×10^5 hm^2 and about 2×10^6 people inhabits there. Most of the sediment which deposits in river channel or on flood land is coarse sand and soil with feature of low water retaining capacity. Vegetation cover rate of the flood land is extremely low because of obstacle remove in flood season each year for flood release. Because of the river's dry-up, ground-water depth descends. Under the situation of poor protection of vegetation cover, the flood land is very likely to change into a huge sand band. If so, series unfavorable influences will bring about on local climate and biocommunity, such as local climate drying and biotic population decrease etc.

The channel of Yellow River is higher than the farmland along both banks in the lower reaches. It is well-known that sand content is very high in Yellow River. Thus, there are many sand 'dragons' and hills in the past flood inundation area and current irrigation regions. In dry season, sand flies up with wind, and the phenomenon of soil desertization is severe. Additionally, the river's dry-up directly reduces water quantity for farmland irrigation, and supply of ground-water is decreased while exploitation quantity of ground-water is raised. Therefore, series eco-environmental issues is produced, such as depth descent of ground-water, decrease of land evapo-transpiration, local climate drying, soil desertization, reduction of biotic population and simplification of biocommunity structure etc.

4 Impacts to Aquatic Environment Pollution

Yellow River is the most important water resources for Northwest China and North China. It is the river in China which is under the strongest influence of human activities. Along with rapid economic growth and population expansion in the river basin, water demand and waste water release increases at a unprecendent speed. In early 80's, annual actual water demand was 3.44×10^{10} m^3, accounting for 60% of the total amount in the basin. In 90's, it increased to 4.10×10^{10} m^3, accounting for 70%. In early 80's, annual waste water release was 2.18×10^9 m^3. It increases to 3.26×10^9 m^3 now(Nature Protection Dept., 1995). Contrastingly, runoff in the lower reaches of Yellow River is reduced at a rapid rate, and dry-up occurs frequently. As runoff is reduced, the ratio of waste water to runoff increases. So, river's purification capacity decreases, and so is the aquatic environmental capacity. Water pollution in Yellow River's basin, especially in its lower reaches, is aggravated rapidly(Chen Jinhao, etc., 1997).

For many tributaries of Yellow River, their pollutant concentrations exceed water quality standard for fishery purpose. Especially, in the middle and lower reaches of some major tributaries, such as Fenhe, Weihe, Huangshui, Yiluohe, Dawenhe, and Sushui rivers etc., their pollutant concentration has already reached or surpassed the lethal concentration for fishes. Almost all fishes has been extinct in those rivers except in some dams or river sources.

5 Impacts to Flood Prevention

Flood has been the most important issue in Yellow River's control ever since ancient history of China. Frequent flood brought about tremendous loss to Chinese people and repeatedly destroyed eco-system balance in the lower reaches.

Occurrence of Yellow River's dry-up has produced new difficulties to its flood prevention. Firstly, discharge decrease and seasonal dry-up have changed the scouring model of river channel. Due to small discharge and low velocity of water flow, sediment of soil and sand becomes more likely to deposit in river channel, and the capacity of channel's flood release decreases. Secondly, Yellow River's dry-up has aggravated soil desertization and produced more sand dunes in the channel's flood land. It most likely produces cross-flow when flood occurs(Li Dong etc., 1997). Once dykes be breached, the loss of economy and eco-system will be larger than ever before.

6 Conclusion

Yellow River's control has ever been the most important thing for Chinese people. Yellow River's dry-up has fully exposed the problems in river administration in China. Same as other rivers in the world(Zhou Ruizhuang, 1995), basin overall management is the only feasible way for Yellow River's control(Cai Weiwu, 1996), which requests unified planning and overall consideration, requests concert relationship between upper and lower reaches, industry and agriculture, city and country, economic growth and eco-system balance, water exploitation and saving, short-term benefit and long-term objective, law constraint and common education etc.

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