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Editing Committee of the Proceedings of the 3rd International Yellow River Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance

Welcome

I, On behalf of the Organizing Committee of the 3rd International Yellow River Forum (IYRF) on Sustainable Water Resources Management and Delta Ecosystem Maintenance and the conference host, Yellow River Conservancy Commission (YRCC), warmly welcome you all over the world to Dongying to attend the 3rd IYRF.

Yellow River Conservancy Commission hosted the 1st and 2nd IYRF successfully in Zhengzhou in October of 2003 and October of 2005, respectively. The central theme of the 1st IYRF is "River Basin Management" and the 2nd IYRF is "Keeping Healthy Life of the River", which got high response and big support from water field around the world. We still remember, on the plenary and technical sessions of the past two forums, delegates carried on wide exchanges and discussions, which showed their latest research achievements sufficiently and analyzed the experiences of river harnessing and river basin management from different aspects. We collected all the valuable viewpoints and advanced experiences presented on the forum into proceedings, which promote the river basin management to keep healthy life of the river and scientific research etc. actively.

The central theme of the 3rd IYRF is sustainable water resources management and delta ecosystem maintenance. It is developed into eight sub – themes: (1) sustainable water resources management and basin ecosystem construction; (2) delta ecosystem protection and maintenance; (3) delta ecosystem and delta development modes; (4) strategies and practices on keeping healthy life of rivers; (5) river engineering and river ecology; (6) regional water resources allocation and interbasin water transfer; (7) water right, water market and water – saving society; and (8) high – tech application in modern basin management and its development trend. The Conference also arranges 18 special sessions jointly hosted by YRCC and the international well – known organizations as follows: Sino – Hispanic Water Forum; Sino – Dutch the 8th Joint Steering Committee; EU – China River Basin Management Programme; WWF – Integrated River Basin Management Forum; GWP High – level Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance; Sino – Norwegian Seminar on Sustainable Water Management; DFID – Special Session on Water and Soil Conservation; Yellow River Basin CPWF Workshop; EURO – INBO Special Session; Sino – Italian Cooperation Project on Environmental Protection; GWSP Session: Global Climate Change and

Water Resources Risk management of the Yellow River Basin; Sino – Dutch Project: Environmental Flow and Environment Protection for River Delta & Sino – Dutch Environmental Flow Training; Sino – Dutch Cooperation Project on "Satellite Based Water Monitoring and Flow Forecasting System in the Yellow River Basin"; Special Session of International Centre of Excellence in Water Resources Management (ICE WARM) Maximising the Benefits of Professional Development Activities; Post – evaluation Session on UNESCO – IHE – YRCC Professionals Training Program; Water Resources Allocation in China; Water Engineering Construction and Management in River Basins; and Management and Safety for Water Supply.

At present, about 800 experts and scholars from 64 countries and regions have registered for participating in the Forum and submitted more than 500 papers. After examined by the Scientific Committee, more than 400 papers are collected into the proceedings of the 3rd IYRF. Compared with the past two forums, the content of the 3rd forum is more abundant and the form of sessions is more multiform. The Conference will omni – directionally show the achievements on water conservancy of China and the Yellow River basin management, deeply discuss the focus and crux of river basin management, and hope to develop a mechanism for international cooperation and exchange more widely.

I am sure that with the effort of the Advisory Committee, the Organizing Committee, the Scientific Committee and all of the representatives will benefit from the conference in the professional field, and have a good time in Dongying. I believe that your experiences exchanged and your good suggestions for sustainable water resources management and delta ecosystem maintenance in the conference will influence the management of Yellow River and other river basins in the world actively in future.

Finally, I hope the 3rd IYRF be successful; hope the conference make a strong impression to every participant; and hope every participant be in good health and have a pleasant stay in Dongying.

Li Guoying
Chairman of the Organizing Committee, IYRF
Commissioner of Yellow River Conservancy Commission, MWR, China
Dongying, China, October 2007

Foreword

The International Yellow River Forum (IYRF) is a great event in water field, also a good chance for scientists who are engaged in river basin management, hydraulic research and management to exchange and discuss the river basin management and the science of water.

The 3rd IYRF is held on October 16 ~ 19, 2007 in Dongying, China. The central theme focuses on: Sustainable Water Resources Management and Delta Ecosystem Maintenance. The central theme involves the following eight sub – themes:

A. Sustainable water resources management and basin ecosystem construction;

B. Delta ecosystem protection and maintenance;

C. Delta ecosystem and delta development modes;

D. Strategies and practices on keeping healthy life of rivers;

E. River engineering and river ecology;

F. Regional water resources allocation and interbasin water transfer;

G. Water right, water market and water – saving society;

H. High – tech application in modern basin management and its development trend.

Eighteen special sessions jointly hosted by YRCC and relevant governments and well – known international organizations are arranged on the 3rd IYRF as follows:

As. Sino – Hispanic Water Forum;

Bs. Sino – Dutch the 8th Joint Steering Committee;

Cs. EU – China River Basin Management Programme;

Ds. WWF – Integrated River Basin Management Forum;

Es. GWP High – level Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance;

Fs. Sino – Norwegian Seminar on Sustainable Water Management;

Gs. DFID – Special Session on Water and Soil Conservation;

Hs. Yellow River Basin CPWF Workshop;

Is. EURO – INBO Special Session;

Js. Sino – Italian Cooperation Project on Environmental Protection;

Ks. GWSP Session: Global Climate Change and Water Resources Risk Management of the Yellow River Basin;

Ls. Sino – Dutch Project: Environmental Flow and Environment Protection for

River Delta & Sino – Dutch Environmental Flow Training;

Ms. Sino – Dutch Cooperation Project on "Satellite Based Water Monitoring and Flow Forecasting System in the Yellow River Basin";

Ns. Special Session of International Centre of Excellence in Water Resources Management (ICE WaRM) Maximising the Benefits of Professional Development Activities;

Os. Post – evaluation Session on UNESCO – IHE – YRCC Professionals Training Program;

Ps. Water Resources Allocation in China;

Ar. Water Engineering Construction and Management in River Basins;

Br. Management and Safety for Water Supply.

The preparation work for the 3rd IYRF was started after the 2nd IYRF. Since the Bulletin one was released, more than 500 papers have been submitted by about 800 decision – makers, experts and scholars from 64 countries and regions. Through the examining of the Technical Committee, more than 400 papers are collected into proceedings, including 322 papers are put into the following six volumes:

Volume I: including 52 papers under the sub – theme A

Volume II: including 50 papers under the sub – theme B and C

Volume III: including 52 papers under the sub – theme D and E

Volume IV: including 64 papers under the sub – theme E

Volume V: including 60 papers under the sub – theme F and G

Volume VI: including 44 papers under the sub – theme H

After the forum, Volume VII and VIII will be published, including about 100 papers. Total more than 300 papers are selected to present in 77 technical sessions and 5 plenary sessions.

We appreciate the generous supports of the co – sponsors, especially Dongying Municipal Government of Shandong Province, Shengli Petroleum Administrative Bureau of China, EU – China River Basin Management Program, Yellow River Water & Hydropower Development Corporation (YRWHDC), Comprehensive Development Bureau of MWR, Yellow River Wanjiazhai Water Multipurpose Dam Project Co. Ltd, Ministry of Environment of Spain, WWF (World Wide Fund for Nature), UK Department for International Development (DFID), Global Water Partnership (GWP), World Bank (WB), Asian Development Bank (ADB), Challenge Program on Water and Food (CPWF), International Network of Basin Organizations (INBO), National Natural Science Foundation of China (NSFC), Tsinghua University (TU), China Institute of Water Resources and Hydropower Research (IWHR), Nanjing Hydraulic Research Institute (NHRI), International Economic

Technical Cooperation and Exchange Centre of MWR (IETCEC, MWR).

We also would like to thank the members of the Advisory Committee, the Organizing Committee and the Scientific Committee, and all the authors presented in the proceedings for their outstanding contributions.

We sincerely hope that the publication of the proceedings of the 3rd IYRF will give an active impulse to the sustainable water resources management and delta ecosystem maintenance.

Shang Hongqi
Secretary General of the Organizing Committee, IYRF
Dongying, China, October 2007

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Contents

High – tech Application in Modern Basin Management and its Development Trend

High – tech Application in Modern Basin Management and its Development Trend

Modeling Study of Long – term Forecast of Annual Runoff on the Yingluoxia Station of the Heihe River

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Abstract: Through analyzing the flow changeable regularity on Yingluoxia station of the Heihe River, the annual runoff of the station is divided into three kinds according to frequency 25% and 75%: plenty water year $x_i > 55.0$, medium water $42.1 \leqslant x_i \leqslant 55.0$, less water year $x_i < 42.1$. By figuring out the shifting frequency, it is found that the annual runoff will have all sorts of possible changes from a state to another state, but the dataset of shifting frequency will be 81.8%. Thereby changeable process of annual runoff are random and mutuality. To forecast the process, the pre – atmosphere cyclic factor and average annual flow forecasting model as well as the time series composition model of average annual flow are set up. It has a highl forecasting precision for annual runoff. Through error evaluation of the two models, it can be found that both models are top level ones. Tests show they are rather steady.

Key words: runoff forecast, modeling study, Heihe River

1 Introduction

Heihe River, the second largest inland river in northwest China, flows through Qinghai, Gansu. The river basin lies to north of the Qilian Mountain and south of Mongolia People's Republic, the east and west is the Shiyang River and Shule River respectively. The gross area of river basin is 142,900 km^2 and 61,800 km^2 in Gansu province, 10,400 km^2 in Qinghai province, 70,700 km^2 in Inner Mongolia. The Heihe River has 35 tributaries, with water use increasing continuously, some of which lose the surface hydraulic connection with main river gradually, forms the east, middle and west three independent sub – water systems. The eastern sub – water system named Heihe River (main river water system), includes Heihe River, Liyuan River and more than other 20 streams, 116,000 km^2 of catchment area. The overall length of the Heihe River main course is 821 km. Above the Yingluoxia station, called upstream, 303 km of length, 10,000 km^2 of area, is the main runoff generation area of the Heihe River. From the Yingluoxia station to Zhengyixia is the middle stream, 185 km of length, 25,600 km^2 of area. The downstream is below Zhengyixia, 333 km of length, 80,399 km^2 of area. Because of the climatic influence and human activities, water resource and population, social economy and ecosystem environment are not in correct relation in the basin. Accompanied with the growth of the population and development of economy, the water consumption increases quickly, causing the downstream water quantity reduced from 1,160 million m^3 in the beginning to 50′s to 730 million m^3 in the late in the 90′s, added the intercepted water quantities of the upper and middle stream, the water entering the downstream

Ejina county only 300 million m^3 or so. The excessive development of water resources of the middle reaches leads the deterioration of the ecological environment of the lower reaches and the supply and demand contradiction of water resources prominently. Therefore, the study of the annual runoff long – term forecasting model and forecasting effectively of the Yingluoxia station is very important for the water scientifically dispatching and reasonable utilization of the water resources.

2 Laws of runoff changing

2.1 Characteristic of annual runoff

In the control hydrological station—Yingluoixa station of the Heihe River main course, the average annual discharge is 49.3 m^3/s, and average annual runoff 1,580 million m^3, runoff modulus 4.900 L/(s · km^2), the value of *cv* 0.16, extreme ratio 2.09. The annual variety of the runoff is low area of the northwest region and China. So the annual variety of the runoff is relatively steaby. In the west tributary of upper stream , the Zhamashike, the average annual discharge is 22.7 m^3/s. The average annual runoff is 715.9 million m^3, accounting for 46.0% of the total runoff. The runoff modulus is 4.947 L/(s · km^2). In the east tributary Qilian Station, the average annual discharge is 14.0 m^3/s, average annual runoff 441.5 million m^3, accounting for 28.4% of the total runoff. The runoff modulus is 5.710 L/(s · km^2); From the lower east and west tributaries to Yingluoxia station, the average annual discharge is 397.3 million, accounting for 25.6%, runoff modulus 4.245 L/(s · km^2).

2.2 Status shifting possibility of the annual runoff variation process

In early 20th century, the famous Russian mathematician found: A. A. Markov found: the change of the some things have strongly relation to the near condition. And, at the same time, there is few relation with the future condition, thus, it can be ignored. This phenomenon is called "NONLATER – EFFECT", Hydrological phenomena is also in line with the process. If hydrological processes is under the $X_{n-1} = a_i$, the probability of No. n shifting frequency is a_j, so the $X_n = a_j$ is not associated with n. marked the frequency $p_{i,j}$, namely:

$$p_{i,j} = P\{X_n = a_j / X_{n-1} = a_i\} \quad i,j = 1,2,\cdots,N; n = 1,2,\cdots, \tag{1}$$

it is called A. A, Markov one – step shifting frequency, It has the following properties:

$$p_{i,j} \geqslant 0, i,j = 1,2,\cdots,N$$

$$\sum_{j=1}^{N} p_{i,j} = 1, i = 1,2,\cdots,N$$

So the $p_{i,j}$ matrix is:

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1N} \\ p_{21} & p_{22} & \cdots & p_{2N} \\ \vdots & \vdots & & \vdots \\ p_{N1} & p_{N2} & \cdots & p_{NN} \end{bmatrix} \tag{2}$$

Capital p is Markov shifting frequency, and it decided the probability principle of runoff series $x_1, x_2, \cdots$.

Taking the frequency of 25% (55.0 m^3/s) and 75% (42.1 m^3/s) of the annual runoff as a boundary, the annual runoff series is divided into three types: plenty water year $x_i > 55.0$, medium water $42.1 \leqslant x_i \leqslant 55.0$, less water year $x_i < 42.1$. The shifting frequency calculation is shown in Table 1, as can be seen from the table, the probability of the runoff process from one state to another is feasible, but the difference of the shifting frequency value is very big. If one year is a plenty water condition, then the next year shifting to the medium water year maximal probability is 72.7%, to the less water situation is 18.2%, to the plenty water 9.1%, with medium water, then the maximal probability of medium water 52.8%, to the plenty water is 25.0%, to less water 22.2%; and, with plenty water, then the maximal probability of medium water is 81.8%, to less water 18.2%, to plenty water zero. So the process of runoff variation is not only random, but also of a strong dependence.

Table 1 Shifting frequency calculation of the annual runoff at Yingluoxia station

Grade of Annual Runoff		<43.3 (a little water)	43.3 ~ 53.4 (medium water)	>53.4 (plenty)	Total
Frequency		12	36	11	59
Shifting Frequency	From a little water to	2	8	1	12
	From medium water to	8	19	9	36
	From plenty to	2	9	0	11
Shifting Probability	From a little water to	18.2	72.7	9.1	100
	From medium water to	22.2	52.8	25.0	100
	From plenty to	18.2	81.8	0	100

3 Forecasting model of annual runoff

Currently, there are many methods for annual runoff forecasting in scientific research for the super long – term forecasting, which focus on the forecasting of the long term annual runoff (about 10 years) or supper long term annual runoff(above 20 ~ 30 years), the accuracy of forecasting is lower for a specific year. But the lead time is often relatively shorter for a administration department (1 year), the accuracy of a particular forecast is needed to be high. By comparison and examination of various methods, the author, who has been engaged in the runoff forecasting for many years, think that the following two methods are good, for the accuracy is higher, capability is steady by the flowing methods of year by year runoff forecasting, which results satisfy the needs of practice.

3.1 Model of earlier – influence factor prediction

For the water quantity of a river, the earlier – influence factors are very complex. From the cause of formation, the process of runoff resulted from the large – scale weather process development. Studying the long – term forecasting of runoff by the long – term rules of atmospheric circulation is the main methods of physical elements. So by analyzing the relationship of the characteristic of former atmospheric circulation and later hydrologic elements, the forecasting model is established. The basic theory is the change of weather according to the former and later transformation rules. For a certain period, the weather and circulation for a considerable period of evolution can be traced back to the past. Therefore, we use the characteristic of circulation and later hydrologic factors to establish quantitative forecasting relations. The area of runoff yield of the Heihe River locates in the Qilian Mountains, which are occupied by big mountains, Therefore the key factors in the selection of predictors are as follows: ①early atmospheric circulation situation; ②the energy sources of air campaign – solar activity; ③underlying surface conditions of basin; ④early hydrologic elements. In this paper, the author adopts 74 atmospheric circulation features of the month by month from 1951 to 2001 to filtrate the elements.

3.3.1 Selection methods of prediction factors

Many factors act on the runoff phenomenon; in general, the linear relationship between the runoff and former factors is not good. But from the cause of formation, it has also some relationships to some single factor, so to establish the linear relationship between the runoff proceed and one by one factors, the correlation coefficient(R) is used to measure the size of single factor affecting the size of the runoff. Then, how much is the obvious correlation? The answer is to carry through stat. measure by the supposition of α. Currently the general method is t checkout.

Give the statistics value of T:

$$T = \frac{\sqrt{N-2}}{\sqrt{1-R^2}} R \tag{3}$$

Here N is the number of observation years; the meanings of other signs are the same with the formers.

After the confirmation of α, from the table of t distribution, t_α is obtained, if $T > t_\alpha$, the linear is true; if $T \leqslant t_\alpha$, the linear is false, then it can be removed from the primary factors.

Since the length of the data series for 46 years, when $R = 0.30$, $T = 2.085$, from the t distribution table $\alpha = 0.05$, we get $t_\alpha = 2.013$, $T > t_\alpha$. So: when $R \geqslant 0.30$, the factor is selected, if $R < 0.30$, factors is discarded.

3.1.2 Establishing of the prediction model

Join or eliminate the selection factor one by one by stepwise regression analysis, the prediction model is obtained:

$$\hat{Q}_t = 149.06 - 0.71x_{2,t-1} - 0.42x_{6,t-1}\,)\,0.088x_{10,t-1} - 1.673x_{13,t-1} + 0.767x_{18,t-1} - 0.116x_{20,t-1} - 0.203x_{24,t-1} + 0.637x_{28,t-1} + 0.936x_{29,t-1} - 2.4x_{30,t-1} + 1.085x_{32,t-1} \tag{4}$$

where: $\hat{Q}_t$ is the annual average runoff(m^3/s) of t year and $x_{i,t-1}$ is earlier - influence predictors. And also: $x_{2,t-1}$ is the position of northern boundary in April in No. $t-1$ year of the sub - tropic high of northern Africa (20W—60E); $x_{6,t-1}$ is the position of northern boundary in May in No. $t-1$ year of the Eastern Pacific sub - tropic high (175W—115W); $x_{10,t-1}$ is the July in $t-1$ Indian Ocean sub - tropic high intensity index(110E - 180E); $x_{13,t-1}$ is the serial number of typhoon in July in $t-1$; $x_{18,t-1}$ is the intensity index of sub - tropic high of South China Sea in September in $t-1$(100E—120E); $x_{20,t-1}$ is the area index of Northern Hemisphere ridge (50 area, 0—360); $x_{24,t-1}$ is the area index of Northern Hemisphere in Nov. in $t-1$ (5 E - 360E); $x_{28,t-1}$ is intensity index of North America in Nov. in $t-1$ (110W—60W); $x_{29,t-1}$ is area index of India Ocean sub - tropic high in Dec. in $t-1$ (65E - 95E); $x_{30,t-1}$ is area index of North America sub - tropic high in Dec. in $t-1$(110W - 60W); $x_{32,t-1}$ is intensity index of North American sub - tropic high in Dec. in $t-1$(110W - 60W).

In the model, R is 0.907, standard deviation is 5.386. It passes the reliability tests. The forecast is compared with the measured values in Fig. 1.

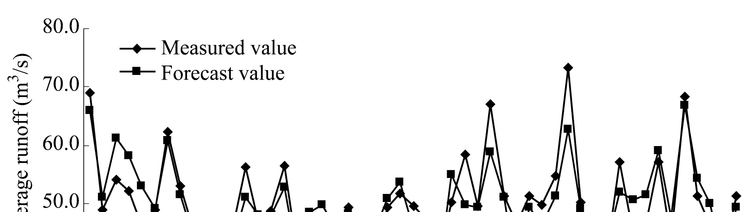

Table 3 Yellow River delta vegetation succession knowledge table (five years)

Vegetation	Soil salt	0 d/a				0 ~ 30 d/a				30 ~ 120 d/a				> 120 d/a			
		0 ~ 0.5 m	0.5 ~ 1 m	1 ~ 2 m	>2 m	0 ~ 0.5 m	0.5 ~ 1 m	1 ~ 2 m	>2 m	0 ~ 0.5 m	0.5 ~ 1 m	1 ~ 2 m	>2 m	0 ~ 0.5 m	0.5 ~ 1 m	1 ~ 2 m	2 m
Forest	Low	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow
	medium	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow
	High	seablite	tamarisk, seablite	tamarisk	tamarisk	tamarisk, seablite	tamarisk, seablite	tamarisk	tamarisk	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	bare land	bare land	bare land	bare land	seablite	seablite	bareland	bareland	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed march	reed march	reed march	reed arch
Farmland	Low	farmland	farmland	farmland	farmland	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	S – T – R	tamarisk – reed	tamarisk – reed	tamarisk	S – T – R	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	seablite	tamarisk, seablite	tamarisk	tamarisk	tamarisk, seablite	tamarisk, seablite	tamarisk	tamarisk	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	bare land	bare land	bare land	bare land	seablite	seablite	bareland	bareland	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
Paddy – field	Low	lalang	lalang	lalang	lalang	lalang	lalang	lalang	lalang	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field
	medium	S – T – R	tamarisk – reed	tamarisk – reed	tamarisk	S – T – R	tamarisk – reed	tamarisk – reed	tamarisk	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field
	High	seablite	tamarisk, seablite	tamarisk	tamarisk	tamarisk, seablite	tamarisk, seablite	tamarisk	tamarisk	tamarisk_reed	tamarisk_reed	tamarisk_reed	tamarisk_reed	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	bare land	bare land	bare land	bare land	seablite	seablite	bareland	bareland	seablite – tamarisk	seablite – tamarisk	seablite – tamarisk	seablite – tamarisk	reed marsh	reed marsh	reed marsh	reed marsh
Reed – marsh	Low	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	reed meadow	reed meadow	reed meadow	bareland	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
lalang	Low	lalang	lalang	lalang	lalang	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	Bare land	Bare land	Bare land	Bare land	seablite	seablite	bareland	bareland	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed marsh	reed marsh	reed marsh	reed marsh
reed meadow	Low	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	S – T – R	S – T – R	S – T – R	S – T – R	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh

3.2 Time series combination model

Hydrological series X_t can be considered as a combination of synthetic ingredients. How to separate the various components from the synthetic sequences is the primary methods of studying X_t. Generally, X_t is composed by deterministic and stochastic components. Deterministic components have some physical concepts, including cyclical and non – cyclical components; stochastic components are caused by irregular vibrations and random effects, which don't clarify from the physics concept strictly, only can be used to study the theory of stochastic processes.

Assume X_t is a linear superposition, then X_t can be expressed as:

$$X_t = Y_t + N_t + R_t + \varepsilon_t \tag{5}$$

where : Y_t is trend composition, reflecting the general evolution of the long – term hydrological factors sequence; N_t is cycle components, reflecting their own hydrological cycle wave component; R_t is linked components, described in the linear dependence of internal hydrological sequence; ε_t is random element (the actual work is calculation error).

3.2.1 Test of the trend composition

To the notable trend component test of the annual runoff, $\alpha = 0.05$. the test results are as follows:

(1) Kendall correlation test: $|U| = 0.87 < U_{\alpha/2} = 1.96$, the trend is not obvious.

(2) Spearman correlation test: $|T| = 0.814 < T_{\alpha/2} = 2.004$, the trend is not obvious.

(3) Linear trend regression test: $|T| = 0.885 < T_{\alpha/2} = 2.004$, the trend is not obvious.

From the three methods mentioned, all the tests are not obvious. This shows that there is no trend composition in the annual runoff.

3.2.2 Extraction of the periodic components

The periodic components are extracted by periodic wave extension phase regression coupling model. The equation of the laboratorial hefts of periodic wave, namely:

$$N_t = \sum_{i=1}^{b} a_i x_{t,i} + e_i \tag{6}$$

where: N_t is cycle components; a_i is regression index in the No. i test periods wave; $x_{t,i}$ is the No. t value in the No. i test periods wave; b is the number of test periods wave; others as the former.

Obviously, formula (6) is a multiple regression equation, if the number of year is even, then $b = n \times (n-1)/2$, if it is odd, then , $b = n \times (n-1)/2$. So we can say, formula (6) is an over determined linear equation whenever the number of years. In the formula, we eliminate the unimportant variable (test periods wave), which need stepwise regression analysis. So the forecasting model of periods components:

$$N_t = 3.492 - 1.5x_{t,4} + 1.179x_{t,8} + 0.84x_{t,12} + 0.314x_{t,16} + 0.592x_{t,18} + 0.296x_{t,19} + 0.595x_{t,20} + 0.25x_{t,22} + 0.309x_{t,28} + 0.412x_{t,30} \tag{7}$$

where: Symbolic significance with the former.

In this model, R is 0.938, standard deviation is 0.216. It passes the $\alpha = 0.05$ test.

3.2.3 Analysis of Dependent component

After analysis, we can see that the correlation coefficient of random sequence $R(t)$ changes to be small gradually when the t values changes to be big gradually, which shows that the random interdependent component is true. By the binomial autoregressive model $AR(2)$, the dependent component is described. For the autoregressive model is linear model, we adopt the linear least squares to identify the model parameter, namely:

$$R_t = 0.069R_{t-1} + 0.402,5R_{t-2} + 1.54 \quad (8)$$

Extensive superposition of three components is the forecasted annual runoff. The comparison of measured values and forecasting values are in Fig. 2.

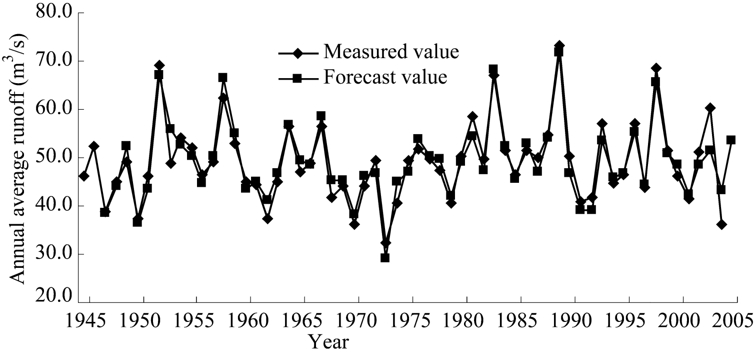

Fig. 2 Annual average runoff comparison of the measured values and forecasted values of model 2 in Yingluoxia station of Heihe River

4 The modeling prediction accuracy

The access accuracy of model prediction error is noted as with QR, that is, one prediction error is less than permissive error (permissive error should be less than or equal to ± 20 %) as qualified. The passed rate is the ratio of the number of qualified to the total number, it shows that the overall accuracy level of multi – forecasting. The higher is QR the greater of the accuracy. "Hydrological information and forecast Standards" provides that: if $QR \geq 85.0$ % is the top level solution, $75.0\% \leq QR \leq 85.0$ % is the second level solution, which can be used as a reference. The overall passing rate of model 1 is 94.1 %, the maximum relative error is 37%, the forecasting test year is 2001 and 2002, and the forecast and observed values of the relative error are −5.4 %, −3.8 %. The overall passing rate of model 2 is 100 %, the maximum relative error 19.4 %. The forecasting test years are 2003 and 2004, and the forecast and observed values of the relative error are −14.8 %, 19.4 %. So, the two forecasting models are the first programs, which can be applied in practical work.

5 Conclusions

(1) Model 1 uses the atmospheric circulation value as early predictors, carrying out regression analysis directly with the annual average runoff to create certainty mathematical model. This belong to the cause analysis category, which has advantage of avoiding the error transferring created by the process of first weather forecast (precipitation forecast) and then runoff forecast by weather forecasts. Model 2 establishes the model by analyzing of the rules of self – evolvement of hydrological processes, which is the time – series analysis. Practice has proved that the model can be operated in the actual work.

(2) The atmospheric circulation eigenvalue and hydrological series are the time – varying system. Long experiences tell us that the forecasting model is time – varying too. So, with a new variable, we should re – establish prediction model, for this is the only way we guarantee the accuracy of the prediction model.

(3) Currently, the study work of long – term hydrological modeling is still under exploration and development stage. Some notable factors, such as El Nino La Nina phenomena etc, with the

limitation of data condition, are not involved in the analysis. If the values of the two forecasting models are not coincident, Qualitative analysis should also be carried out, such as state shifting frequency, weather analysis and prediction results etc, and then, the forecasting results should be taken reasonably.

IDIAS—A Tool for Analysis and Monitoring of Direct and Indirect Effects of Interdependent Interventions in IRBM
—An Example from Pahang River, Malaysia

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Abstract: Integrated management and inter – disciplinary assessment (IDA) are ambiguous terms often used in planning of water management and urban/rural development strategies and projects. These terms generally represent an attempt to evaluate the environmental and/or socio – economical effects of various management interventions in one or more sectors, and in neighbouring catchments. Some tools and procedures for environmental impact assessments (or strategic environmental assessments) have been broadly used for evaluation of the environmental effects of a set of management/project scenarios in connection with policy development and project implementation. These tools, however, separately assess the effects on different sectors from a planned project or a set of policy/development strategies and management actions. The inter – sectoral (or multi – disciplinary) relationships are seldom addressed quantitatively due to the complexity of the procedure and lack of data/information.

It is necessary to ensure some degree of transparency in the process from decision – making, planning to implementation, monitoring and follow – up. Hence, a systematic approach is required in the otherwise generally qualitative assessment and evaluation of impacts where the cause – effect relationships are mutually interdependent. IDAs need to be reassessed with the passage of time, and data therein should be open to scrutiny and revision as new data become available. The paper will discuss various aspects of how to make IDA operational in river basin management and design/implementation of monitoring programmes. A decision support tool (Inter – Disciplinary Impact Assessment System – IDIAS), which incorporates the above specifications, is presently being developed.

The IDA – methodology presented is based on experiences gained during a number of concrete river basin management projects/programmes. A simplified example from Pahang River in Malaysia is used to illustrate the principles and procedures of the IDIAS. In Pahang River the objective was: ① to establish plans and policies of how to develop the downstream part of the river; considering the prevailing socio – economic setting (fishery, environmental constraints, infrastructure, flood protection); ② to assess the inter – disciplinary effects of a number of proposed project options.

Key words: Integrated River Basin Management, inter – disciplinary assessment (IDA), environmental impact assessments, Pahang River

1 Introduction

1.1 Context

Strategic Impact Assessment (SEA) and Environmental Impact Assessments (EIA), e. g. in connection with infrastructure development, have been broadly used for introductory evaluation of impacts on a number of sectors/disciplines for a set of management/project scenarios, e. g. RIAM (1998). Various tools and procedures have been developed over the last 2 ~ 3 decades (e. g. CEQ 1978; CEU 1997; World Bank 1988; Danida 1994) to streamline and generalise the SEA/EIAs. Such procedures are typically used by consultants, national and multilateral agencies in their effort to include relevant/significant considerations in various sectors into the decision procedure for larger projects/management interventions, e. g. in IRBM.

These impact tools/procedures, however, generally assess separately the impacts on different sectors from a planned project or a set of development strategies and management actions. The inter - sectoral and multi - disciplinary relationships are seldom addressed quantitatively due to the complexity of the procedure and lack of data/information. Yet, in IRBM and urban/rural development these multi - disciplinary links and spatial dependencies (e. g. upstream versus downstream) have proven to be of major importance - often in the retrospective when undesired and unexpected results/effects appear. Therefore, an approach based on inter - disciplinary assessments (IDA) should be used in planning development strategies and projects in order to evaluate the direct effects in one discipline of various management interventions in other disciplines - and vice versa - and to identify and measure potential indirect effects.

It is necessary to ensure some degree of transparency and systematic approach in the generally qualitative assessment and evaluation of impacts where the cause - effect relationships are interdependent. IDAs need to be re - assessed with the passage of time and the data therein should be open to scrutiny and revision as new data become available. Therefore, there should be a direct link between inter - disciplinary assessments, interventions and the monitoring/data collection programme for the particular catchment area.

1.2 Shortcomings of present assessment procedures

In EU, SEA and EIAs are being applied according to the EC - Directives with the objective to contribute to, inter alia, the preservation, protection and improvement of the quality of the environment, the protection of human health and the rational utilisation of natural resources. These tools/procedures, however, to a large extent are employed in single - sector - based planning, and the focus is primarily on the unidirectional impact of the intervention on environmental aspects. Sustainability and efficiency/optimality in a broader multi - sectoral, societal and development perspective is difficult to address systematically and quantitatively in SEAs and EIAs.

There are important lessons to be learned from these existing SEA systems and experiences. A major limitation for the effective development of SEA practice is however the shortage of information on such practical examples. For a better understanding of the procedural and practical application of SEA, a project was initiated with the objective to identify, analyse and compare a number of SEA cases that have been recently undertaken in different EU Member States and in various sectors (EC 2004. B; EC 2004. C; EC 2005. A). The case findings were analysed and compared according to key topics that reflect the kind of information addressed in the SEA. The key - findings and gaps that emerged from this comparative analysis are:

(1) SEA practice differs greatly among countries and sectors. SEA is becoming well established

in sectors such as energy, waste management and transport. SEA application in the sectors of water management, industry, agriculture and tourism is still very rare, and needs to be encouraged by e. g. undertaking pilot studies and developing appropriate methodologies that a. o. takes into account the interdependence of policies and plans over sectors, time and spatial scales.

(2) A wide range of prediction and evaluation techniques are available for SEA, but not all of these are optimally applied. This indicates an overall weakness in the dissemination of knowledge and information. Efforts should be made to optimise existing methods and tools and to make them widely known. Uncertainties in impact predictions and evaluations should be acknowledged, analysed and reported.

(3) Only in a consent – related approach can SEA effectiveness be measured. In an integrated approach there is no reference for changes identification, and effectiveness becomes difficult to establish. Effectiveness indicators need to be established.

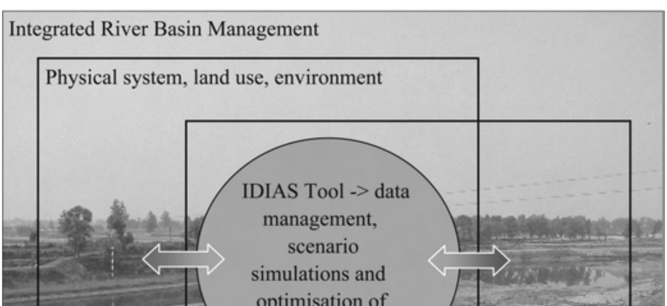
(4) Monitoring and post – evaluation are the major weakness in the current SEA practice. Efforts should be undertaken to install monitoring systems, both in establishing guidelines on indicators and methods as well as in providing an institutional framework. Indicators must be agreed upon to make it measurable.

In short, the present state is to generally apply sector – based and environmental assessments, and there is a widely expressed need to develop an integrating tool for planning and management at sector policy, program and project level, however, a tool that can be used to analyse and assess the potential direct and indirect links between management interventions within the sector, and across sectors.

The IDA – tool, IDIAS (Inter – disciplinary Impact Assessment System), presented here is a first step in the development of such an inter – disciplinary impact assessment tool that can assist to improve policy and project coherence and intervention efficiency/optimality. The back – bone of the IDIAS is a systematic, quantitative and transparent (measurable) multi – sector impact assessment tool, which can be used to predict and illustrate consequences of a variety of policy, planning or programme intervention decisions between and across sectors and disciplines.

2 The overall concept – idias

IRBM inherently requires balancing of interests distributed over sectors, sub – basins (and sometimes across basin boundaries) and temporal scales (present vs. future), and it is generally very difficult for policy/programme planners to overview all the links between these interests, and the likely/expected effects of different interventions (Fig. 1). Here a systematic/transparent modelling and decision support systems approach can function as a means to keep track of knowledge and decisions in an optimal way.



Such a system shall not only organize data/information in a database, but must also be able to keep track on data, experiences/documentation, causal connections, physical links, and mutual relationships between decisions, interventions and states. In general, a computational DSS, like economical or environmental modelling systems, should be regarded as an intelligent database, where relevant data and information is organised according to a set of stringent rules – physical, empirical, economical and/or logical. The function of the IDIAS is therefore to host and organise data and relations between data and information in a systematic and transparent way.

When analysing and delineating catchment areas and the influence spheres for the planned interventions (programmes/projects), some general concerns have to be taken into consideration:

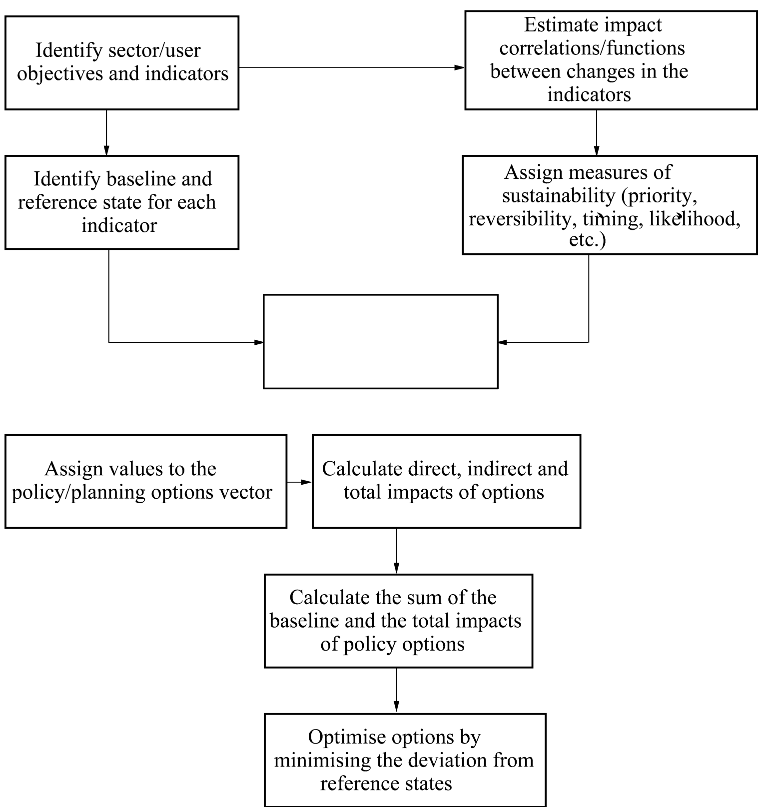
(1) Ability to deduce the baseline situation.

(2) Possibility to obtain the necessary planning and monitoring objectives and indicators, including data and other relevant information.

(3) Clear spatial delineation: Administrative boundaries, Geographical boundaries, e. g. watersheds and coastlines.

(4) Temporal delineation (analysis period, discrimination of implementation of previous plans→existing cause – effect relationships).

The approach, which is the backbone of the IDIAS, is based on the matrix methodology (e. g. EC 2005. B), where inter – dependencies between options/indicators are formulated in a correlation matrix (IDA – Matrix). The flow diagram of the perceived computational steps is shown in Fig. 2.



The IDIAS user interface now being developed is based on a general GIS – application, which contains all relevant geographical and land – use information. On top of the GIS – application, a data management system and a computational system is being developed. The data management system will host the policy/planning specific data/information for the river basin (land – use, core areas and buffer/downstream zones) in question, e. g. sectors, users, policy options, the environment (broadly speaking), indicators and documentation. An example of how the user interface of IDIAS is organised is presented in Fig. 3.

The left panel in the screen (Fig. 3) is related to land – use and definition of the reference (preferred, balance, carrying capacity) and baseline (actual) situation. The map layers are placed in the central part. The right panel is reserved for model set – up and model data input. The bottom panel controls the selection of policy/management options/interventions and calculation of the consequences/impacts of the chosen management options.

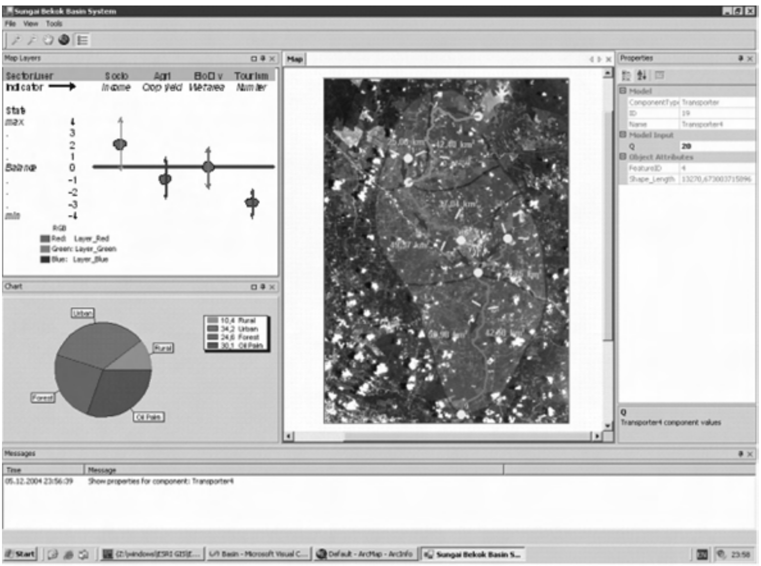


Fig. 3 Illustration example of the GUI of IDIAS

3 The inter – disciplinary impact assessment matrix

This section describes the methodology and calculation procedures of scoring within a correlation matrix that has been designed to allow inter – disciplinary relationships to be quantitatively recorded – and later systematically linked to a monitoring programme. Hence, the procedure provides inter – disciplinary evaluation and a record of knowledge (links between indicators) that can be re – assessed and updated (using Bayesian updating techniques) when new data are collected.

3.1 Definitions

The basic assumption is that a given catchment area can be said to be in an optimal situation or state of balance for all of the disciplines engaged in the assessment. It should be noted that not all disciplines necessarily applies to all catchment areas. Due the individual characters of river basins, the varying environmental, natural resources, land – use and socio – economic settings will determine the state and issues to be addressed. In general, though, socio – economy/land – use and secondly natural resources (e. g. water, minerals and forests) are the main factors/disciplines that can be manipulated/managed – and which therefore also generally exercise the most significant drivers to the development in a given catchment area.

Firstly, it is requisite to establish a baseline description of the actual catchment area, which functions as a basis for monitoring and comparison of the temporal development in the selected indicators. The baseline state is assessed and a score is assigned to each of the indicators under consideration.

For the present purpose, the baseline state for each of the indicators is given a value (numeric or alpha – numeric) according to where the resource lies in relation to a presumed balance state – or preferred state (see Fig. 4). Preferred state is interpreted as a management characteristic that describes the overall objective of the actual river basin.

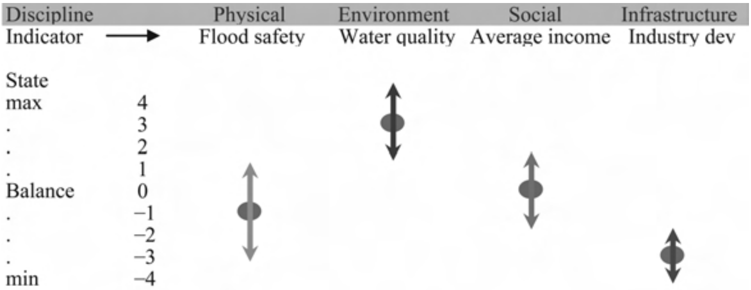


Fig. 4 Definition of baseline and changes in indicators (example)

According to the baseline, for example Industry is recorded as being developed below the carrying capacity (the balance state) in the catchment area. Consequently there is a potential of increasing industrial activities in the area. On the other hand, Water quality is on the positive side of the balance state meaning that the carrying capacity in terms of pollution in the river system is higher than the present pollution load. These two factors, however, can counteract each other (industry generates pollution and pollution may hinder industrial/urban/agricultural development), and will certainly affect other social (e. g. health) and water supply activities. How to analyse and quantify these interactions will be illustrated in the following chapter.

3.2 Overall approach

The IDIAS is based on a set of indicators categorised in disciplines and a standard definition of the important assessment criteria as well as the means by which quantitative values for each criteria can be collated to provide a score for each indicator. The IDA – Matrix contains the cause – effect relationships between the indicators.

The impacts of management interventions are evaluated for the selected indicators in such a way that a score is given to each indicator as a measure of the direct impact of the intervention – and a score that measures the indirect impact caused by the cross – correlation between indicators. If the indicators are independent, then the score evaluation degenerates to standard single – disciplinary impact assessment methods such as the RIAM.

3.2.1 Evaluation criteria

Formulation of the evaluation criteria course of action is based on the RIAM methodology, however, extended to operate on pairs of indicators (conditions) instead of single independent conditions. One important difference, therefore, is the use of 2 – dimensional criteria in the IDA – Matrix describing the relationships between changes in one indicator on all indicators. The evaluation criteria fall into two groups:

(A) Criteria that are of importance to the indicator, and which can individually change the score obtained.

(B) Criteria that are of value to the situation, but individually should not be capable of changing the score obtained.

Four criteria, two in each group, have been selected for the present IDIAS. These criteria, together with their evaluation scores are defined in Box 1 and 2. Previously, RIAM has been applied to a number of projects and the method has demonstrated that the selected criteria represent the most fundamental assessment conditions, and satisfies the universality principle that allows them to be used in different EIAs.

Interdisciplinary impact magnitude of indicator (A_1) (matrix).
Magnitude is defined as a 2-dimensional measure of the scale of benfit/dis-benefit of change in one indicator on another indicator. The scales are defined:

+3 = strong positive impact(sp)
+2 = moderate positive impact(mp)
+3 = weak positive impact(wp)
0 = no change/neutral(n)
+3 = weak negative impact(wn)
+3 = moderate negative impact(mn)
+3 = strong negative impact(sn)

Importance(political priority) of indicator (A_2) (matrix). A measure of the importance of the indicator, which is evaluated against the political priorties/interests of spatial scale changes will affect:

3 = Very important/high priority
2 = Moderately important/normal priority
1 = Less important/low priority
0 = Not important

Box 1: Group (A) criteria

Timing of indicator (B_1) (matrix).
Timing describes whether an change in one indicator will have an immediate, delayed or neutral impact on the other indicator:

3 = Immediate
2 = Delayed
1 = None/NA

Reversibility of indicator (B_2) (matrix).
This measure defines whether the indicator change will affect irreversible changes in other indicators:

3 = Irreversible
2 = Reversible
1 = Neutral/NA

Box 2: Group (B) criteria

The scoring system requires simple multiplication of the scores given to each of the criteria in group (A). The use of multiplier for group (A) is important to ensure that the weight of each score is expressed, whereas simple summation of scores could provide identical results for different conditions. Scores for the value criteria group (B) are added to provide a single sum. This ensures that the individual value scores cannot influence the overall score, but that the collective importance of all values in group (B) is fully taken into account. The sum of the group (B) scores is then multiplied by the result of the group A scores to provide a final evaluation score (E) for the indicator – also denoted the IDA – Matrix in the following. This process can be mathematically expressed:

$$\begin{cases} A_m = A_1 \cdot A_2 \\ B_s = B_1 + B_2 \\ E = A_m \cdot B_s \end{cases} \tag{1}$$

where, the dot – operator denotes element multiplication.

3.2.2 Evaluation procedure

The IDA – Matrix calculation procedure is presented in the following:

(1) Identify the indicators for each discipline (x_j).

(2) Identify the baseline state for each of the indicators (b).

(3) Identify/estimate the impact correlation between changes in the indicators (the Magnitude – matrix – $A_1 = \rho(\Delta x_i, \Delta x_j)$).

(4) Assign priorities to the indicators (The Priority – vector – a_2 and $A_2 = [a_2 \quad a_2 \quad a_2 \quad a_2]$).

(5) Assign values to the Timing – matrix – B_1.

(6) Assign values to the Reversibility – matrix – B_2.

(7) Calculate the IDA – Matrix based on the input matrices – E.

(8) Assign values to the management vector – m.

(9) Calculate the direct impacts, indirect impacts and the total impacts – i_d, i_i and i_t.

This is the basic procedure. For management purposes a number of further activities will be part of the IRBM – plan:

(10) Evaluate and optionally define alternative management vectors or calculate the optimal impact vector using linear programming technique.

(11) Formulate policies/measures that reflect the suggested interventions.

(12) Follow – up from regular monitoring programme (adjust the input matrices).

IRBM is, as the term expresses, based on integration of the relevant disciplines (inter – disciplinary) and close interaction between planning and the indicator monitoring programme. Monitoring and data assessment will link the effects as recorded in the real world to the management interventions and to their assumptions and relationships.

3.3 Calculation procedure

Having prepared the input data the direct as well as the indirect impacts of the management interventions can be calculated (step 9). Calculation of the total impact vector is in actual fact simple and straightforward once formulated in a matrix – notation. The direct impact (i_d) from the management interventions quantified in the management vector (m) is calculated as:

$$i_d = m^{\mathrm{T}} \times E \tag{2}$$

where, the x – operator denotes matrix multiplication and the superscript $^{\mathrm{T}}$ denotes matrix transpose. The indirect impact vector (i_i) is calculated by multiplying the cross – correlation terms in the IDA – Matrix (E) and sum over each indicator:

$$i_i = \sum_{row} (-1)(D - U)(E \cdot E^{\mathrm{T}}) \tag{3}$$

where, D is a diagonal matrix and U is the unity – matrix. The dot – operator denotes multiplication element by element. The total impact vector is found as the sum of the two vectors:

$$i_t = i_d + i_i \tag{4}$$

This corresponds to step 9 in the procedure outlined in the previous section. Having obtained the impact vector from one set of management interventions, other management scenarios can be evaluated and results compared in order to achieve the most optimal solution – and illustration of those mitigation measures that have to be implemented for the dependent indicators (e. g. biodiversity and environment) in order to mitigate any negative impacts arising from indirect effects when introducing interventions in the independent indicators (typically socio – economy/land – use and water/infrastructure development).

4 Example—Pahang River, Malaysia

The methodology is demonstrated using a simplified example from a river system, Pahang

River, which exhibit some of same challenges as those of the Yellow River.

4.1 Brief description of the Pahang River basin

Pahang River is the largest river in Peninsular Malaysia and flows into the South China Sea. The estuary of Pahang River is located approximately 8 km from Pekan town, the Royal Town of Pahang State. A major fishery complex is located 1 km upstream of the river mouth in the northern channel.

Fig. 5 shows the project area of the Pahang estuary. The estuary is approximately 2 km wide at its mouth measured from bank to bank but the numerous sandy islands that formed between Pekan City and the estuary have hindered the river flow to the sea. Hence, safe passage to Pahang River has long been hindered by the formation of sand shoals and sand bars at the river entrance. As a result, river transport is significantly reduced over time and fishermen cannot fully utilize the existing harbour facilities as the river mouth now only allows the passage of small boats of size 25 t and below. This is the major factor hindering expansion of fishing industries and navigation in the area.

Fig. 5 The Pahang River Estuary

Dredging and other river improvement works have been undertaken in past years in an attempt to improve navigability. However, the improvement so far has not lasted long as a result of forest logging and developments in the upstream catchment, and sand bars have reformed and created continuous navigation difficulties.

Pekan City and villages along Pahang River have been subject to periodic flooding with durations of up to two months in a year. The most severe floods occurred in 1967, 1971, 1999 and 2001, where houses at the estuarine and coastal area were hit by the combined effect of high tides and high waves. The dual threat of flooding and coastal erosion has, therefore, become a major concern to the local residents.

The objective of the project is to construct a breakwater system that can protect the harbour and to allow usage of a bigger range of fishing boats, which is expected to increase the living standard of the local/regional fishing industry. The main harbour in the northern channel shall also serve to provide general mooring and berthing facilities for shelter during the monsoon period. The breakwater solution, however, may affect the flood conveyance capacity of the river as well as the environmental/ecological qualities (e. g. mangrove islands, spawning grounds) of the estuary.

4.2 Example

In order to overcome the various problems in the downstream part of Pahang River, a number of measures could be employed. The complexity and inter – dependencies of the public and private interests of the functionality of the estuary, however, called for thorough planning phase involving a. o. inter – disciplinary assessment tools, partly to analyse appropriately the cause – effect chains and partly to facilitate and structure stakeholder involvement. Four main sectors and a total of 25 management options/indicators were identified and included in the assessment. For the sake of simplicity in the present example, four key indicators have been emphasised:

(1) Physical/Structural → Harbour safety (by construction of breakwaters)

(2) Environment/Ecology → Water quality

(3) Socio – economy/Cultural → Increased income from transport and fishery activities

(4) Infrastructure/Operation → Flood safety

The indicators are selected for demonstration purpose only and the numbers/assessments assigned to the indicators have no bearing on the ongoing development projects in Pahang River.

4.2.1 Baseline vector

The balance situation is defined qualitatively or quantitatively for each of the four indicators (see Table 1).

Table 1 The balance sitnation of the four indicators

Management option/ key indicator	Quantification and units
1. Harbour safety	Present: Maximum wave height (H_{max}) >1 m Balance: Maximum wave height (H_{max}) ~0.3 m
2. Water quality	Present: Water Quality Index (WQI) ~90 Balance: Water Quality Index (WQI) ~70
3. Income Fishery	Present: Average income from fishery <1.000 MYR/year Balance: Average income from fishery ~2.000 MYR/year
4. Flood safety	Present: Proportion of monsoon period with river water level below levee crest at Pekan City <30% Balance: Proportion of monsoon period with river water level below levee crest at Pekan City ~90%

It should be noted that specific carrying capacity assessments should be made for each of the indicators for each region/sub – catchment, e. g. using river and coastal models. Following the methodology shown in Chapter 2, the baseline vector b is given as shown in Table 2.

Table 2 Baseline vector describing the present state of the four indicators relative to the optimal balance state. State is given a character between –4 and 4 as shown in the graphical representation

Indicator	Value

Harbour safety	−3
Water quality	2
Income	−2
Flood safety	−3

The baseline vector specifies that Harbour safety in the estuary area is less than could be desired. The Water quality level is higher than the carrying capacity, the income from fishery is significantly less than the fishing capacity would allow for, and flood events have been occurring more often than the existing flood protection works were designed for as a consequence of the increased river siltation.

4.2.2 Assessment matrices

The assessment variables are organised in the two groups defined in Chapter 3, and exemplified in the following. It should be noted that values entered are only for the purpose of illustration.

Table 3 Interaction magnitude (correlation) between indicators (A_1 matrix)

Effect on Change (increase) in	Harbour safety	Water quality	Income fishery	Flood safety
Harbour safety	1.00	−0.67	1.00	−0.67
Water quality	0.33	1.00	0.67	0
Income	−0.33	−0.67	1.00	−0.33
Flood safety	0.50	0	0.67	1.00

The correlation matrix (Table 3) indicates the interaction between the indicators, that is, it describes the effect that changes in one indicator will have on the others. The correlation matrix takes values between −1 and 1 indicating strong negative impact and strong positive impact, respectively. A value of 0 is given when changes in two indicators are independent.

Table 4 Overall importance/political priority (a_2 vector)

Indicator	Priority
Harbour safety	2
Water quality	2
Income	3
Flood safety	3

The importance criteria vector can be used to assign particular interests in the management planning. Due to regional political interests it may be that income generation is chosen to have a greater importance compared to e.g. environmental concerns, which is illustrated in Table 4.

Effects of indicator interventions can be immediate, delayed or neutral – within and between indicators (Table 5). Any change in Harbour Safety, for example, will have an immediate effect on itself but a delayed effect on Water Quality. A change in Water Quality could have a delayed effect on itself meaning that even though measures are taken to increase the water quality, the effect may be delayed because there is an inherent inertia in environmental systems. Interventions may also have a tendency to result in irreversible effects on some indicators (Table 6), whereas the effects of changes in other indicators in the future can be reversed to the original state. Significant changes in environmental/ecological systems are often irreversible on a generation time scale due to the general non – linear behaviour of such systems.

Table 5 Timing (B_1 matrix)

Effect on Change (increase) in	Harbour safety	Water quality	Income fishery	Flood safety
Harbour safety	3	2	2	3
Water quality	2	3	2	1
Income	1	3	3	2
Flood safety	3	1	2	3

Table 6 Reversibility (B_2 matrix)

Effect on Change (increase) in	Harbour safety	Water quality	Income fishery	Flood safety
Harbour safety	3	2	2	3
Water quality	1	2	2	2
Income	1	3	3	2
Flood safety	2	1	3	3

Finally, the Evaluation Score matrix (E) is calculated based on the procedure given previously. The IDA – Matrix (Table 7) contains the effective scores (scaled between – 1 and 1) for the indicators including their interdependence. A positive number indicates a positive impact.

Table 7 IDA – Matrix (E matrix)

Effect on Change (increase) in	Harbour safety	Water quality	Income fishery	Flood safety
Harbour safety	0.67	–0.30	0.44	–0.45
Water quality	0.11	0.56	0.30	0
Income	–0.11	–0.67	1.00	–0.22
Flood safety	0.42	0	0.56	1.00

4.2.3 Management vector

The main purpose of the IDIAS – approach is to relate monitoring to management and further to follow – up and introduction of corrective measures (indicator monitoring programme). The management vector (Table 8) is used to include various management options formulated by the responsible authority/agency. Based on the baseline situation, the authorities can specify a set of management interventions for one or all indicators that have the purpose of correcting unwanted developments.

Table 8 The management vector (example)

Indicator	Priority
Harbour safety	1
Water quality	1
Income	0
Flood safety	2

Note: The example shows the decision to increase moderately the harbour safety and water quality, and the flood safety significantly. Interventions towards boosting income generation in general are not considered.

In fact, the management vector can be established via mathematical optimisation (e. g. linear programming) by seeking solutions that minimise the variation of the baseline state plus total impact around the balance state (the preferred optimal state).

4.2.4 Calculation of the impact vectors

The impact vectors for the example data are shown in Table 9.

Table 9 The calculated impact vectors

Impact	Harbour safety	Water quality	Income fishery	Flood safety
Direct (i_d)	1.61	0.26	1.86	1.55
Indirect (i_i)	−0.27	−0.23	0	−0.62
Total (i_t)	1.34	0.03	1.86	0.94

The direct impact vector (id) expresses that from a management intervention stipulated in Table 7, the direct effect is a further increase in all four indicators. The indirect effects, however, counteract these direct effects to a certain extent due to the negative feed – back properties of the IDA – Matrix. The total impact scores are obtained by adding the direct and the indirect impact scores, and the result of the example management interventions is a net increase in Harbour Safety, no actual change in Water Quality, a net increase in Income from Fishery and an increase as well in Flood Safety. Other management interventions can be tested in order to find an optimal/satisfying overall impact level, and to identify indicators where certain levels of mitigating measures must be taken in order to avoid undesired indirect effects.

4.3 Discussion of the example

A general pattern can be deducted by presenting the IDA – Matrix itself without taking into account the management interventions. Fig. 6 shows the IDA – Matrix for the example data presented earlier. For each indicator the direct effect on all indicators can be quantified relative to each other.

For Harbour Safety, for example, an intervention increasing safe mooring and navigation in the project area by 1 unit (relative on a –4 to 4 scale) will have a direct impact (taking into account Importance, Timing and Reversibility) of approximately 0.6. It will have a net positive effect on Socio – economy (increase of Income from Fishery), and a negative impact on Environment (Water Quality) and Infrastructure (Flood Safety). An increase in Environment (improvement of water quality) will generate positive impacts in two of the other three indicators (Physical and Socio – economy), whereas a positive increase in fishing activities is likely to cause a negative effect on particularly the Environment.

Hence, the influence factors are weights that measure the impact from any management interventions (changes in indicators) on all indicators. These weights transform the indicator changes (the management vector) into direct and indirect impacts. The management impacts given in Table 7 are shown in Fig. 7. Here the manager can evaluate the effect of various activities (quantified/translated into matrix – notation) and design appropriate mitigating measures for undesired indirect effects.

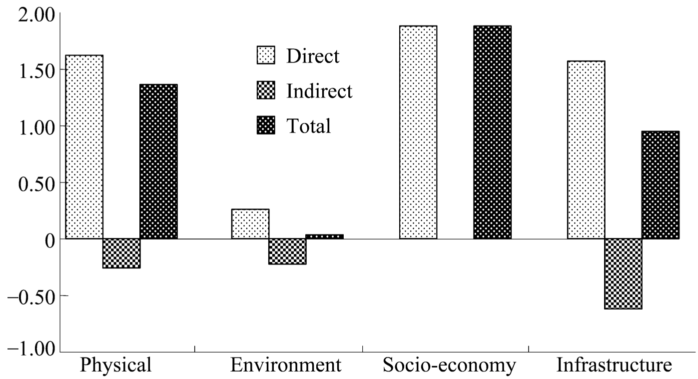


Fig. 7 Management impacts for the selected indicators

Having calculated the total impacts of a set of management interventions, the management impacts can be added to the baseline evaluation in order to obtain a situation in the actual catchment that conforms as good as possible to the preferred/optimal state. The result of this calculation is presented in Fig. 8.

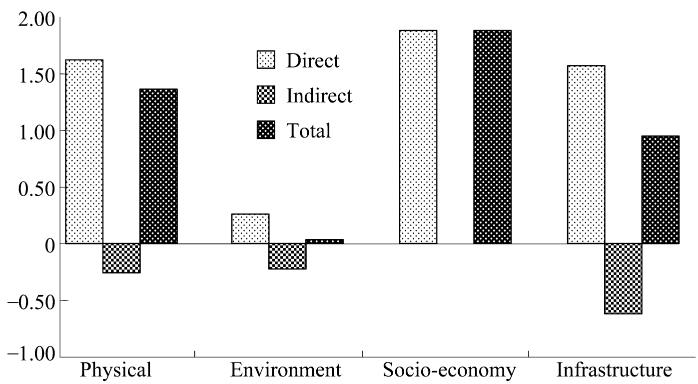


Fig. 8 Influence factors for the selected indicators

The resulting evaluation shows that because of the planned interventions, all key indicators are expected to be over the balance level, in particular the Socio – economy indicator thus demonstrating that the main objective of the development plans is likely to be achieved. A mathematical optimisation procedure can be formulated in order to estimate the management vector in such a way that the total sum of the results over the indicators is equal to 0 (meaning that the river basin is in balance on average), or to ensure that impacts on all indicators are positive.

5 Conclusions

The IDA – tool (IDIAS) is described here on a theoretical basis with a simplified illustration to demonstrate the functionality. Further development and testing is continuing in order to assess the use of the methodology in the complex world of IRBM. One strong argument for following a stringent mathematical procedure is to establish objective documentation for decision – making in connection with future social and economical development without compromising natural resources and the environment. Another immediate benefit of a stringent mathematical formulation is that a systematic analysis of the uncertainties in assumptions, decisions and effects can be made and reported.

The IDIAS approach links closely together baseline evaluation, data collection/monitoring and decisions in an adaptive and transparent environment. The IDA – Matrix can be established based on general experience and information from general research and other practical IRBM plans. Based on the selected indicators, the monitoring programme should then be designed to verify or refute the inter – relationships stipulated in the correlation matrix, e. g. relationships between physical/structural measures and the socio – economic effects, between infrastructure and environment, between fishing industry or tourist development on one side and pollution on the other.

Hence, the IDIAS can assist decision makers in making proper use of the increasing amount of data and information that is collected in connection with river basin management. Generally, it is not possible to get the picture of all data and synthesise the complex relationships without proper analysis and decision support tools. By setting up the matrix – system described in this paper, it is possible to compare a number of management scenarios and make comparisons between them in order to find a satisfying solution and also to identify measures that can mitigate indirect and unwanted effects. Furthermore, it facilitates in a systematic way monitoring, follow – up and up – dating of knowledge.

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The research of LL Fully – distributed Hydrologic Model and Application in the Yellow River Basin *

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Abstract: LL Fully – distributed hydrologic models were established upon physical basis and have been developed to the forth generation since 1997. 3S techniques and grid cells based LL – Ⅲ, a fully – distributed hydrologic model in which the effect of natural factors and human activities has been considered was introduced. And the model was employed to study to water cycle, water resources estimation, and flow forecast in the 4 typical catchments which include headwater area (above Tangnaihai station), Ningmeng irrigation area, Wudinghe River watershed, and lower reaches of the Yellow River, and application of flood forecast for Wangyao station of Xingzi watershed, Luhun Reservoir and Taoqupo Reservoir with LL – Ⅲ model was briefly introduced as well in the paper.
Key words: fully – distributed hydrologic model, effect of human activity, water resources hydrologic cycle

1 Introduction of LL fully – distributed models

Conceptual hydrology models is involved single subject and adopted a large number of hypothesis. Evgeny McNair Cavic (1968) thought it was one of the reasons for hydrology stagnation that hydrology was considered to be the appendant of hydraulics and irrigation works. Much hydrologic experimentation were focused on technology of unit hydrograph and flow routing, but they were just research hydraulics. Hydrology research should include the complex of air – plant cover – soil and the influence of the complex acted to moisture movement. Thus, it needs a trans – subject research method. The distributed model with physical basis (fully – distributed models) is the new right trans – subject research method suit to the complex in world sphere. The distributed model is combined with new technology, and is used widely in solving the problems about water on land in variable environment.

LL fully – distributed models are the multi – disciplines research product to the complex of air – plant – soil and have been developed to the forth generation. LL models have been applied to flood forecast, flood control and water resources management in 15 domestic watersheds and 7 abroad watersheds. When calculating flood and daily runoff in southern humid area in China, the results can arrive grade A prescribed in national hydrology calculation criterion, and the results can arrive grade B in northern arid or semi – arid areas.

The author has developed the first generation LL – Ⅰ distributed model combining with the flood control system of Fengman reservoir in 1997, and taken it into practice in 1998, and published related paper in the meeting of intercostals science communion between Mainland and Taiwan in the same year. During 1999 ~ 2000, LL – Ⅰ distributed model was also applied to flood control project in Luhun reservoir and Xingzi River watershed in Yellow river.

The author attended the Distributed Model Inter – comparison Project (DMIP) hosted by the Hydrology Laboratory (HL) of the Unite State National Weather Service (NWS), applied digital

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information such as radar rainfall data, DEM, land use and soil structure to distributed model and developed successfully LL – Ⅱ model based on LL – Ⅰ, which was listed one of the twelve distributed models by the Unite State National Weather Service during 2001 ~ 2002. In 2005, LL – Ⅱ model was used to establish flood forecast project and develop flood control system for Taoqupo reservoir in the middle reaches of the Yellow river.

In order to enhance the research of global hydrologic cycle and solve the problem of water resource management in the changing environment, LL – Ⅲ fully – distributed model has been successfully developed through 4 typical watersheds which include headwater area of the Yellow River (above TangNaihai), Ningmeng irrigation area, Wuding River catchment and lower reaches of the Yellow River (below HuaYuankou) during 2003 ~ 2004. The developed model is based on 3S technology and grid cells, and in which all influences of nature factor and human activities have been considered. In 2004 and 2005, the model was applied to develope the water resource management system, food control and short – term electricity operation project of 7 reservoirs and Dongfeng irrigation zone in Huangbo River watershed in Yichang.

LL – Ⅲ fully – distributed model is advanced to LL – Ⅳ combined with environment – zoology protection during 2003 ~ 2006. Non – point pollution transference model is founded upon LL – Ⅳ in 2003. One dimension and two dimension environment fluid dynamic model were built. In addition, water quality pre – warning and forecast system in Xi river and the Yellow River (Xiaolangdi – Gaocun) was separately developed, as well as installation and operation in Guangdong hydrology bureau and Yellow River water resources protection bureau separate during 2003 ~ 2005. In 2006, the author combined LL – Ⅲ with water, sediment and non – point pollution model, put forward a model which can describe variable mechanism of zoology and environment on wetland. The author also applied LL – Ⅳ to forecast eco – environmental water requirements progress, carry out zoology and environment assessment, and take it to city water business management. What's more, zoology and environment cumulate effect of reservoir cascade was researched and a mode of reservoir zoology operation was advanced in the same year. Therefore, LL – Ⅳ is a integrated model containing models such as hydrology, environment and zoology.

LL Fully – distributed hydrologic model has been published in some papers. And the paper focus on introduction of flood forecasting application of the hydrological model in the Yellow River. The basic framework of LL – Ⅲ fully – distribution hydrologic model was briefly introduced in the paper as well.

2 Structure and Basic content of LL fully – distributed models

LL – Ⅲ fully – distributed model was an improved runoff model aimed at energy balance and water – heat change between land surface and atmosphere bottom, atmosphere bottom and vadose Zone region surface, vadose region and saturated zone surface. The model considered the reaction between land and atmosphere with 4 typical watersheds in upstream, midstream and downstream the Yellow River. LL – Ⅲ model included rainfall – snowmelt processes, ice forecasting, irrigation water evaluation reservoir control, industry and life sewage process, vegetation ecosystem process, water and land temperature calculation, a new energy balance mode, a calculation mode of evaporation, interception, infiltration and runoff for six types and a mode of water resource estimate. The output hydrology process contained long wave radiation, short wave radiation, net radiation, sensible heat, latent heat, evaporation, soil moisture content, vegetation ecosystem process, water temperature, land temperature, interception, infiltration, pore water, runoff, snowmelt, ice melt, ice density, drainage, as well as ice melt date and frozen date (Fig. 1).

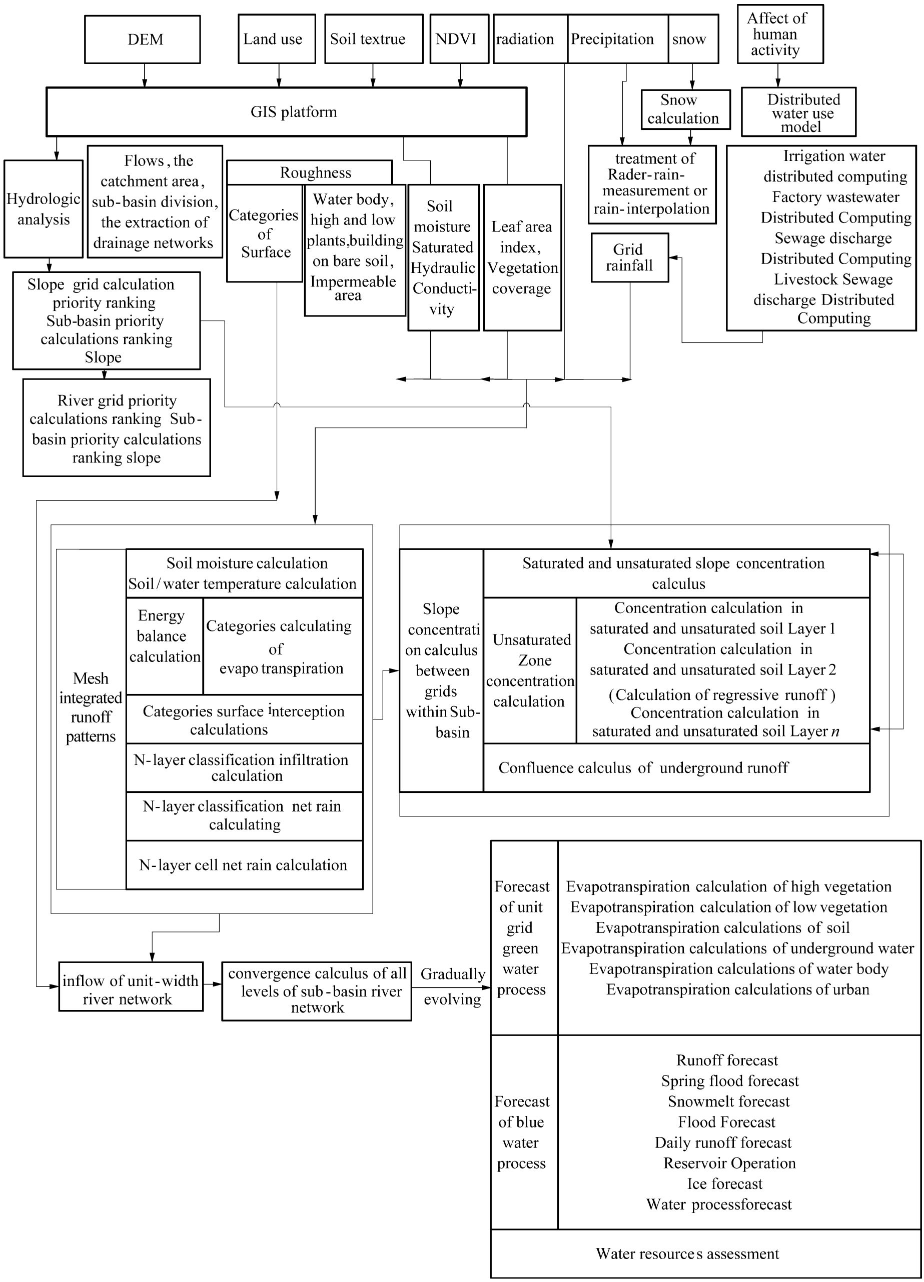

Fig. 1 structure of LL – Ⅲ distributed hydrologic model

According to the LL – Ⅲ distribution hydrological model with physical basis, we can take the narrow or wide water resources evaluation. LL – Ⅲ model considers the impact of human activities, especially the various cross – basin water diversion and drainage projects. In the input of irrigation and drainage works, using conceptual hydrologic model to predict daily runoff process will meet the problem of input – output water imbalance. Distributed hydrologic model uses GIS and GPS to determine water diversion, drainage direction and input location, adds and deducts reasonable runoff, then integrates land use remote sensing information and irrigation fixed quantity to rationally determine net irrigation as a watershed unit Grid import water in the irrigation grid unit, finally puts it in the runoff concentration calculation. The research contents of LL – Ⅲ model ranges from flood forecasting to the prediction of water use, drainage, water cycle, Water resource, snowmelt – spring flood, ice and water resources assessment, it can carry out green or blue water process forecasting within grid unit and water resources process forecasting in none information basin. Water resources assessment includes narrow and generalized evaluation. LL – Ⅲ model has studies case or application case in 11 basins in our country.

3 Application of LL – models to flood forecast in the Yellow River

LL – Ⅰ was applied to Iuhun reservior and Xingzi River reservoir in 2000. Luhun reservoir is a large reservoir whose collecting area is 3,492 km^2. Its runoff is characterized by both storage full mode and excess infiltration mode. Xingzi River watershed in Yan'an is located in arid loess area and of excess infiltration mode. The rainfall in this area is irregular. In 2005, LL – II was applied to develop flood forecast project and flood control system based on DEM in TaoQupo reservoir in Ju River mid – stream the Yellow River. The system has been operated for two years, and through the project acceptance this spring.

Table 1 is flood simulation precise statistics of LL – Ⅰ and LL – Ⅱ models in the three areas above. The results acquire grade B ordained by the office of state flood control and drought relief headquarters.

Table 1 Flood simulation precise statistics of typical areas in the Yellow River

Watershed name	Model efficiency coefficient(%)	Peak mean relative error(%)	Quantity mean relative error(%)	Percent of peak time gap(%)	Flood number
Luhun reservior	91.01	8.02	0.71	100	50
Xingzi River	80.08	19.5	10.1	100	5
Taoqupo reservior	84.1	12.71	–8.7	86.77	25

4 Application research of LL – Ⅲ fully – distributed hydrology model in Yellow River Basin

The author carried out the research of water resource forecast and assessment included green water forecast and blue water forecast with the background of 4 typical watersheds in Yellow River based on LL – Ⅲ fully – distributed model. A united LL – Ⅲ model suitable to the 4 typical watersheds was built. The calculation unit gird in every watershed was 5 km. Underlying in every grid was divided into six kind: high vegetation, low vegetation, waters, bare ground, building area and impervious surface. Green water quantity was calculated based on classification of six kind underlying. With the limit of paper, the author only introduced precise results of water resource forecast in 4 typical watersheds. Parameters in model were soil saturated hydraulic conductivity, manning roughness, water celerity and diffusion coefficient of channel, interception, evaporation and infiltration. Part of physical parameters is determined by experiment or RS information, others by optimum seeking. The rules are given as: ① The minimum of mean relative error; ② The maximum of model efficiency coefficient.

The author adopted 19 years (1980 ~ 2000) of observed runoff data and rainfall data in 4 typical watersheds to simulate daily runoff. The blue water process listed calculation precise result of daily runoff in drainage sectional, other blue water process was not introduced here (water depth, water quantity and simulation result of arbitrary grid). Runoff data from 1980 ~ 1983 was used to seek the optimal parameter. Runoff data from 1984 ~ 1989 was the first period to calibrate the model. 1990 ~ 1994 was the second period; 1995 ~ 2000 was the third period. So, the author checked the model amply.

(1) Downstream Yellow River (Huayuankou to Lijin): Took Huayuankou as inflow station

and Lijin as outflow station then calibrated the model through daily runoff of Lijin station. The main consideration for choosing downstream of the Yellow River as representative is the characteristics that irrigating from it and drainage from a nearby valley and the problem of predicting cut – off of Yellow River. Table. 2 was the daily runoff of Lijin station.

Table 2 Simulation result of Lijin daily runoff

Calculation period	Observed annual runoff($10^8 m^3$)	calculated annual runoff($10^8 m^3$)	Relative error (%)	model efficiency coefficient	correlation coefficient
Simulation period	330.89	311.59	5.83	0.93	0.968
Calibration period 1	275.39	252.63	8.26	0.91	0.960
Calibration period 2	184.56	164.77	10.72	0.84	0.932
Calibration period 3	88.89	91.06	–2.45	0.72	0.889

(2) Xiaheyan to Shizuishan: The segments has less natural precipitation, takes irrigation water as the main input source, Irrigation water participate in the two process: runoff and convergence cycle, and its cross drainage ditches make the convergence calculation difficulty; Similarly, the basin has exchange problems between surface water and groundwater. Adopted daily runoff of Shizui shan station to calibrate the model. We could conclude that LL – Ⅲ fully – distributed model was suitable for this watershed. We could get high precise in simulation period as well as three calibration periods(see Table 3).

Table 3 Simulation and calibration result of Shizuishan daily runoff

Simulation and calibration periods	Relative error of water quantity(%)	Correlation coefficient
Simulation period(1980 ~ 1983)	–9.0	0.96
Calibration period 1(1984 ~ 1987)	–6.31	0.99
Calibration period 2 (1990 ~ 1994)	2.13	0.97
Calibration period 3(1995 ~ 2000)	2.31	0.99

(3)There are over 100 reservoirs (large or small) in Wuding River Basin. As it is a typical loess area, problem of silt dams、irrigation water ,arid and watershed runoff intervention by human activities is very serious. The calculation chooses more than 50 large and medium – sized reservoirs for water resource management, considering agricultural irrigation water, industrial water, living water and water for livestock that intervened by human activities, also forecasts the spring flood and ice. Use LL – Ⅲ model to forecast and estimate water resources. Wuding river watershed was divided into 2,115 grids. The unit gird was 5 km. , then calibrated the model through daily runoff of Baijiachuan station(see Table 4).

Table 4 Simulation and calibration result of Baijiachuan daily runoff

Calculation periods		Observed discharge(10^8 m^3)	Calculated discharge(10^8 m^3)	Relative error (%)
Simulation period	1980 ~ 1984	10.14	9.89	2.4
Calibration period 1	1985 ~ 1989	10.59	10.74	–1.49
Calibration period 2	1990 ~ 1994	9.65	10.59	9.79
Calibration period 3	1995 ~ 2000	8.62	10.29	–19.33

(4) Upstream Tangnaihai to original area: The source of Yellow River is an icy permafrost region, so need to take consideration of calculation of permafrost soil's temperature and melting problem to setup a mixed runoff model of precipitation and snow. The area of upstream Tangnaihai to original area was divided into 12,324 grids. The unit gird was 5 km, we calibrated the model through daily runoff of Tangnaihai station which was the original control station(see Table 5).

Table 5 Simulation and calibration result of Tangnaihai daily runoff

	Year	Model efficiency coefficient(%)	Relative error of water quantity(%)	Nash - sutcliffe model efficiency coefficient	Correlation coefficient
Simulation period	1980	68.07	-11.16	0.5	0.93
	1981	84.62	-4.90	0.35	0.95
	1982	74.65	21.58	0.24	0.95
	1983	80.84	24.53	0.24	0.98
Calibration period 1	1984	85.3	13.94	0.26	0.96
	1985	78.1	-15.03	0.29	0.97
	1986	85.79	9.14	0.21	0.96
	1987	79.97	5.23	0.27	0.95
Calibration period 2	1991	77.65	4.44	0.29	0.9
	1992	88.98	1.62	0.23	0.97
	1993	87.68	2.45	0.19	0.97
	1994	81.45	-0.04	0.21	0.97
Calibration period 3	1995	80.09	-7.20	0.22	0.98
	1996	68.71	4.16	0.26	0.96
	1997	66.97	4.65	0.27	0.95
	1998	71.06	-10.9	20.34	0.97

5 Conclusions

LL models have been applied to flood forecast, flood control and water resource management in 15 watersheds at home and 7 watersheds abroad from 1997 and listed one of the twelve distributed models by the Unite State National Weather Service. The area LL models applied mostly was the Yellow River. Its application included flood forecast, moisture cycle calculation, blue water forecast, green water forecast, ice forecast, snowmelt forecast, water resource assessment, soil erosion and non - point pollution. With the limit of the paper, the author only introduced LL models with physical basis and listed the calculation results of flood forecast and water resource assessment in detail. LL models have specific physical basis. The model describes Holton runoff and hill - slope hydrology runoff mechanism. Collective flow calculation adopted hydrodynamics partial differential equations. Most equations were developed by author herself and theory basis was sufficient. As the calculation precise as concerned, LL fully - distributed models have developed to utility level and could be applied to hydrology, water resource, ecology environment protection and wetland research.

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The Three – dimensional Environmental Fluid Dynamics Model for the Water Temperature of Manwan Reservoir *

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Abstract: The water temperature prediction has been one of the important contents of the environmental impact assessment on the hydropower projects. The paper summarized the advances in water temperature research for reservoir in china and abroad and studied the structure of the three – dimension environmental fluid dynamics (EFDC) model. Based on hydrological and water temperature data of Manwan Reservoir in Yunnan province, the EFDC model was calibrated for February 2004 and validated for 2003 and January 2004. The calibrated result shows that averaged absolute mean error of the three vertical on front of dam is −0.15 ℃ and averaged relative error is approximately 2.0%. The model was verified with a comparison to continuous time series of surface water temperature in front of the dam. The absolute mean error is −0.36 ℃, but the model simulations exhibit the same trends as the observations.

Key words: EFDC model, water temperature simulation, reservoir

1 Introduction

Reservoirs form in river after building dams. The water flows in reservoirs become slow and have a longer period of renewal. By mixing solar radiation and convection and heat transfer, the reservoir water temperature has a special structure which directly affects not only the water application but also lots of water quality process. So the basic task of the reservoir water environment analysis and forecast is to establish reservoir water temperature model and forecast its spatio – temporal variation.

According to the property, the predicted method of the reservoir water temperature is divided into two major types: the empirical formula method and mathematics model method. The empirical formula brings forward on basis of comprehensive analysis of the experimental data with the advantage of simple and practical. For example, water temperature analysis in Chinese Water Resources and Hydropower Engineering Hydrology calculation criterion recommended for using the empirical formula method. Empirical formula bases on the measured data from the general statistics, and reflects the statistical rule of temperature changes, not from the temperature changes to study the process of forming the inherent laws. To reflect the impact of hydrologic and hydraulic, climate, geological, reservoir characteristics and human factors, a mathematical model about the water temperature must be established to reflect the rule of temporal and spatial distribution to predict the temperature has better accuracy. In late 1960s, American advanced WRE model and MIT model, which is the most representative one – dimensional vertical reservoir temperature distribution model. Many researchers then continually revised, and one – dimensional mathematical model has been added so perfectly. In addition to the mature one – dimensional water temperature model, many foreign and domestic scholars have also set up some two – dimensional models, and have a wide range of applications. But when the water density of vertical stratification obviously, have re – flow temperature difference, the average vertical two – dimensional model has been less suitable. Vertical two – dimensional or three – dimensional models need to establish. CE – QUAL – W2 is the most mature vertical two – dimensional model that develops by U. S. Army Corps of Engineers waterways Experiment Station (WES). Laterally averaged 2D and 3D models appear late in china.

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In the early 1990s, Chen Xiao – hong developed a vertical 2D water temperature model coupling hydrodynamic equations with temperature equation and the $k-\varepsilon$ model to apply to the research on large water body in lakes and reservoirs. The interactions between flow and temperature are reasonably considered. Luo Wen – sheng, Zhou Zhijun developed a vertical 2D water temperature model and water quality model coupling hydrodynamic equations with temperature and quality equation to apply to the research on large water body in reservoirs. The interactions between flow, temperature and quality are reasonably taken into consideration, and technique of coordinate transformation is employed in the research. Jiang Chun – bo, et al established a free – surface elevation changes in the two – dimensional model for predicting the thermal stratified flow and turbidity transportation in the vertical section of a river. Because the scheme is explicit for velocity components, pressure and scalar quantities, the model is efficiency and able to simulate long period transportation process of suspending materials in reservoirs and rivers. Deng Yun developed a 2D laterally averaged temperature model for the temperature prediction of the huge and deep reservoir, and probed the movement mechanism of the turbulent buoyant flow in reservoir and the rule of the thermal stratification forming, developing, varying. Xiong Wei, et al., explored to use 1D and 2D coupling model in the temperature prediction of the three – gorge reservoir. Base on these previous studies, the three dimensional environmental fluid dynamics model (EFDC) for the temperature simulation of Manwan reservoir is applied in this paper.

2 Description of the EFDC model

The Environmental Fluid Dynamics Code or EFDC (Hamrick, 1992) comprises an advanced three – dimensional surface water modeling system for hydrodynamic and reactive transport (for example: sediment, temperature, water quality, and ecological factors) simulations of rivers, lakes, reservoirs, estuaries and the coastal ocean. The EFDC model couples hydrodynamics model with reactive transport model into a single software systems. It solves the vertically hydrostatic momentum and continuity equations for turbulent flow in a coordinate system which is curvilinear and orthogonal in the horizontal and sigma coordinate in the vertical direction. The numerical methods and systems development methods represent the current international main research direction of the environment simulation system. The interface that is a friendly platform for the adjustment of input data and documents uses a text form. The calculation makes fewer restrictions. The EFDC model is readily configured as a one – dimensional model or two – dimension model in either the horizontal or vertical planes. The EFDC model has been extensively tested and documented for rivers, reservoirs, lakes, estuaries, wetland systems.

2.1 The hydrodynamic governing equations

To accommodate realistic horizontal boundaries, it is convenient to formulate the equations such that the horizontal coordinates, x and y, are curvilinear and orthogonal. Transforming the vertically hydrostatic boundary layer form of the turbulent equations of motion and utilizing the Boussinesq approximation for variable density results in the momentum and continuity equations and the transport equations for temperature in the following form:

$$\partial_t(mHu)+\partial_x(m_yHuu)+\partial_y(m_xHvu)+\partial_z(mwu)-(mf+v\partial_x m_y-u\partial_y m_x)Hv$$
$$=-m_yH\partial_x(g\zeta+p)-m_y(\partial_x h-z\partial_x H)\partial_z p+\partial_z(mH^{-1}A_v\partial_z u)+Q_u \quad (1)$$

$$\partial_t(mHv)+\partial_x(m_yHuv)+\partial_y(m_xHvv)+\partial_z(mwv)+(mf+v\partial_x m_y-u\partial_y m_x)Hu$$
$$=-m_xH\partial_y(g\zeta+p)-m_x(\partial_y h-z\partial_y H)\partial_z p+\partial_z(mH^{-1}A_v\partial_z v)+Q_v \quad (2)$$

$$\partial_z p=-gH(\rho-\rho_0)\rho_0^{-1}=-gHb \quad (3)$$

$$\partial_t(m\zeta)+\partial_x(m_yHu)+\partial_y(m_zHv)+\partial_z(mw)=0 \quad (4)$$

$$\partial_t(m\zeta)+\partial_x(m_yH\int_0^1 u\mathrm{d}z)+\partial_y(m_xH\int_0^1 v\mathrm{d}z)=0 \quad (5)$$

In these equations, u and v are the horizontal velocity components in the curvilinear, orthogonal coordinates x and y, m_x and m_y are the square roots of the diagonal components of the metric tensor, $m = m_x m_y$. $H = h + \zeta$, is the total depth, p is pressure. In the momentum equations (1), (2) f is the Coriolis parameter, A_v is the vertical turbulent or eddy viscosity, and Q_u and Q_v are momentum source – sink terms. The density, ρ, is in general a function of temperature, T. The buoyancy, b, is defined in equation (3) as the normalized deviation of density from the reference value. The continuity equation (4) has been integrated with respect to z over the interval (0, 1) to produce the depth integrated continuity equation (5) using the vertical boundary conditions, $w = 0$, at $z = (0, 1)$, which follows from the kinematical conditions and equation (6).

The vertical velocity, with physical units, in the stretched, dimensionless vertical coordinate z is w, and is related to the physical vertical velocity w^* by:

$$w = w^* - z(\partial_t \zeta + u m_x^{-1} \partial_x \zeta + v m_y^{-1} \partial_y \zeta) + (1 - z)(u m_x^{-1} \partial_x h + v m_y^{-1} \partial_y h) \tag{6}$$

To provide the vertical turbulent viscosity and diffusivity, the second moment turbulence closure model developed by Mellor and Yamada (1982) and modified by Galperin et al (1988) will be used. The model relates the vertical turbulent viscosity and diffusivity to the turbulent intensity, qq, a turbulent length scale, l, and a Richardson number R_q by:

$$A_v = \phi_v q l = 0.4(1 + 36R_q)^{-1}(1 + 6R_q)^{-1}(1 + 8R_q) q l \tag{7}$$

$$A_b = \phi_b q l = 0.5(1 + 36R_q)^{-1} q l \tag{8}$$

$$R_q = \frac{gH\partial_z b}{q^2} \frac{l^2}{H^2} \tag{9}$$

where, the so – called stability functions ϕ_v and ϕ_b account for reduced and enhanced vertical mixing or transport in stable and unstable vertically density stratified environments, respectively. The turbulence intensity and the turbulence length scale are determined by a pair of transport equations:

$$\partial_t(mHq^2) + \partial_x(m_y H u q^2) + \partial_y(m_x v q^2) + \partial_z(m w q^2) = \partial_z(mH^{-1} A_q \partial_z q^2) + Q_q \\ + 2mH^{-1} A_v((\partial_z u)^2) + (\partial_z v)^2) + 2mgA_b \partial_z b - 2mH(B_1 l)^{-1} q^3 \tag{10}$$

$$\partial_t(mHq^2 l) + \partial_z(m_y H u q^2 l) + \partial_y(m_x H v q^2 l) + \partial_z(m w q^2 l) = \partial_z(mH^{-1} A_q \partial_z q^2 l) + Q_l \\ + mH^{-1} E_1 l A_v((\partial_z u)^2) + (\partial_z v)^2) + mgE_1 E_3 l A_b \partial_z b - mHB_1^{-1} q^3 (1 + E_2 (kL)^{-2} l^2) \tag{11}$$

$$l^{-1} = H^{-1}[z^{-1} + (1 - z)^{-1}] \tag{12}$$

where, B_1, E_1, E_2, and E_3 are empirical constants and Q_q and Q_l are additional source – sink term such as sub – grid scale horizontal diffusion. The vertical diffusivity, A_q, is in general taken equal to the vertical turbulent viscosity, A_v.

2.2 The transport equations for water temperature

$$\partial_t(mHT) + \partial_x(m_y H u T) + \partial_y(m_x H v T) + \partial_x(m w T) = \partial_z(m \frac{A_b}{H} \partial_z T) + Q_T \tag{13}$$

In the transport equations for temperature (13) the source and sink terms, Q_T includes sub – grid scale horizontal diffusion and thermal sources and sinks, while A_b is the vertical turbulent diffusivity.

The system of eight equations (1) ~ (13) provides a closed system for the variables u, v, w, p, ζ, ρ and T, provided that the vertical turbulent viscosity and diffusivity and the source and sink terms are specified. The numerical scheme employed in EFDC to solve the equations of motion uses second order accurate spatial finite differencing on a staggered or C grid. The code uses a three time level, a combination of finite volume and finite difference scheme with an internal – external mode splitting procedure to separate the internal shear or baroclinic mode from the external free surface gravity wave or barotropic mode. Details of the definite difference numerical schemes of the EFDC model are given in Hamrick(1992) and will not be presented in this paper.

2.3 Transformation to sigma coordination in vertical

To provide uniform resolution in the vertical direction, a time variable mapping or stretching transformation is desirable. Sigma coordinate is an effective way to capture free surface, as well as a body – fitted coordinates. The mapping or stretching is given by:

$$z = (z^* + h)/(\zeta + h) \tag{14}$$

where * denotes the original physical vertical coordinates and $-h$ and ζ are the physical vertical coordinates of the bottom topography and the free surface respectively, Fig. 1.

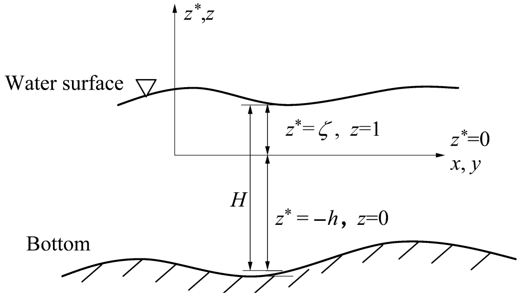

Fig. 1 Sigma coordinate transformation sketch map

3 Model application

3.1 Introduction of Manwan Reservoir

Manwan Hydropower Station locates on middle reaches of the Lancang River where Yun County march with Jingdong County in Yunnan Province. It is the first hydropower station of the Lancang River that is mainly used for power generation combining to control flood and improve the efficiency of shipping and other comprehensive benefits. Manwan Hydropower Station is a strip – shaped reservoir from north to south, approximately 78 km long. Widths range from approximately to 150 m to 500 m. The dam site locates in the tortuous river. The main channel has located on the left bank of the river. The two banks are asymmetric. The left slope is about 40 degrees, the right bank is about 20 ~ 30 degrees, the reservoir has very complex terrain. The largest depth is about 99 meters in front of dam. The normal high water level is 994 m, corresponding capacity of 920 million m^3; the death water level is 982 m, corresponding capacity of 662 million cubic meters. The effective reservoir capacity is approximately 257 million m^3. The storage coefficient is only 0.67%. Manwan Reservoir is an incomplete quarter adjustment reservoir.

Manwan environmental monitoring station was the first environmental monitoring station for major reservoirs. The water temperature, water quality and other environmental monitoring data are very important to environmental protection of the Lancang basin and environmental impact assessment for cascade hydropower stations on the lower reaches of the Lancang basin. Based on hydrological and water temperature data of Manwan Reservoir, the three – dimensional environment hydrodynamic model (EFDC) was calibrated and validated.

3.2 Model configuration and boundary

The model calibration data on February, 2004 were collected, which include: Time series inflow and outflow; vertical water temperature data for seven transects; the left, middle, right vertical water temperature data in front of dam site on February 18, 2004. Hydrologic and flow forcing for the model include inflow to Manwan Reservoir and outflow at Manwan Reservoir, Fig. 2 Thermal forcing for the model included inflow temperature Manwan Reservoir. Atmospheric data is necessary for thermal simulation, including air temperature, pressure, relative humidity, direct rainfall, wind speed and direction were obtained for Goutoupo Meteorological Station, the closest comprehensive observation station.

As the monitoring water temperature scope was only 30 km away from the dam site (seven

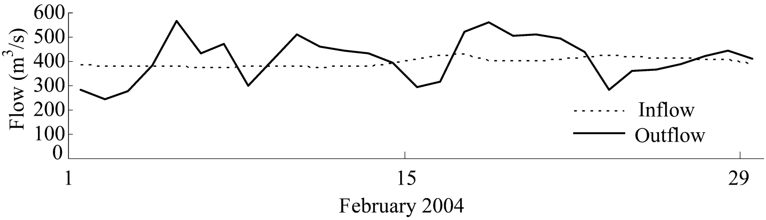

Fig. 2 Inflow to Manwan Reservoir and outflow at Manwan Reservoir

transects), the calculated region ranges 30 km away from the dam site, a horizontal curvilinear – orthogonal grid of Manwan Reservoir, Fig. 3. Horizontal grid resolution ranges from approximately 50 ~ 150 m. Model simulations were conducted using 10 layer in the vertical. The time step is one minute.

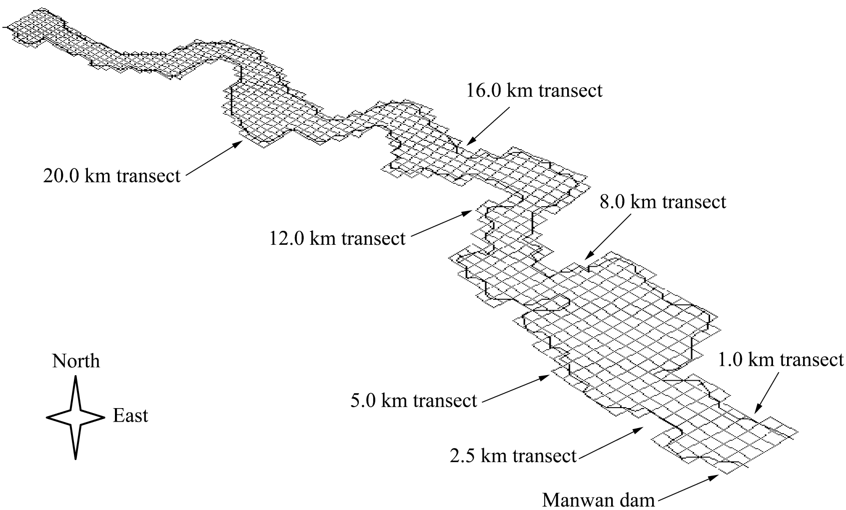

Fig. 3 Horizontal curvilinear – orthogonal grid of Manwan Reservoir

3.3 Model calibration

The model was calibrated using the vertical temperature observations of Manwan Reservoir on February, 2004. The calibration of the model primarily involved adjustment of boundary conditions and roughness and thermal parameters. Parameter calibration adopted trial – and – error method, with initial parameter values based on experience at first. According to compare the test results with the observation results, the parameter were adjusted repeatedly until far better results with the measured results. Two of the useful statistics are absolute mean error (*AME*):

$$AME = \frac{(Predicted - Observed)}{\sum mumber\ of\ observations}$$

And relative error (*RE*):

$$RE = \frac{\sum |Observed - Predicted|}{\sum Observed}$$

Fig. 4 shows model predicted and observed temperatures at the left, middle, right vertical water temperature data in front of dam site on February 18, 2004.

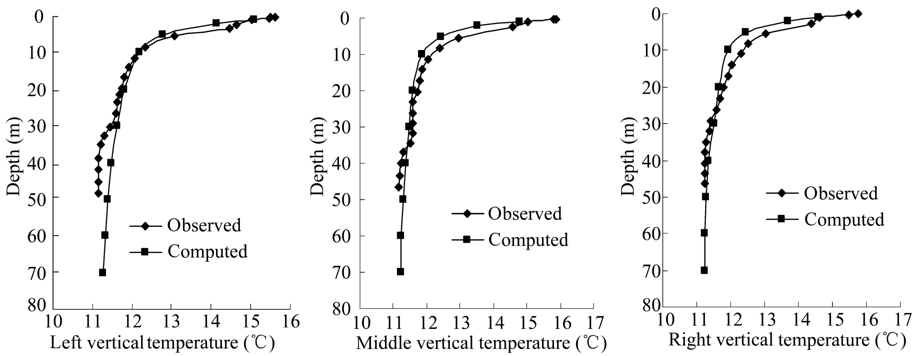

Fig. 4 Model simulated and observed water temperatures of the left, middle, right vertical in front of dam site on February 18, 2004

The simulated temperature distribution of three vertical lines agreed with observations. Model simulated thermal stratification is generally in agreement with observations. The vertical averaged absolute mean error is −0.15 ℃. The absolute mean error of the right vertical, which is the largest of the three vertical lines, is approximately −0.22 ℃. The absolute mean error of the left vertical, which is the smallest, is approximately −0.04 ℃. The averaged relative error of the three vertical is approximately 2.0%.

Fig. 5 shows model simulated and observed temperature in seven transects , which are approximately 1.0 km, 2.5 km, 5.0 km, 8.0 km, 12.0 km, 16.0 km, 20.0 km northwest of the dam site.

3.4 Model validation

The model was verified with a comparison to continuous time series surface water temperature in front of the dam from Feb, 2003 to Jan, 2004. Table 1 shows that computed versus observed surface water temperature in front of dam. The absolute mean error is −0.36 ℃, but the model simulations exhibit the same trends as the observations.

Table 1 Computed versus observed surface water temperature in front of dam

Month	2003.2	3	4	5	6	7	8	9	10	11	12	2004.1
Observed(℃)	17.1	19.0	22.5	23.2	21.2	20.8	22.8	19.7	19.7	18.6	15.6	13.9
Computed(℃)	16.8	19.1	21.4	22	22.7	20.9	22.6	19.7	18.3	16.5	15.1	14.7
Absolute error(℃)	−0.3	0.1	−1.1	−1.2	1.5	0.1	−0.2	0	−1.4	−2.1	−0.5	0.8

4 Conclusions

This paper has presented a description of the capabilities and formulation of the EFDC hydrodynamic and reactive thermal transport model relevant to simulating the huge reservoir on surface water systems. The model's calibration and verification is illustrated by simulating the water temperature structure of Manwan Reservoir from February, 2003 to January, 2004. Operation of the model is economical with a 365 day simulation taking approximately 10 hours on a 2 GHz personal computer. The calibration and validation results showed that the model is more reasonable, and the parameters of model are more appropriate. The model can be used for large − scale and deep reservoir temperature structure prediction, and the accuracy can be guaranteed.

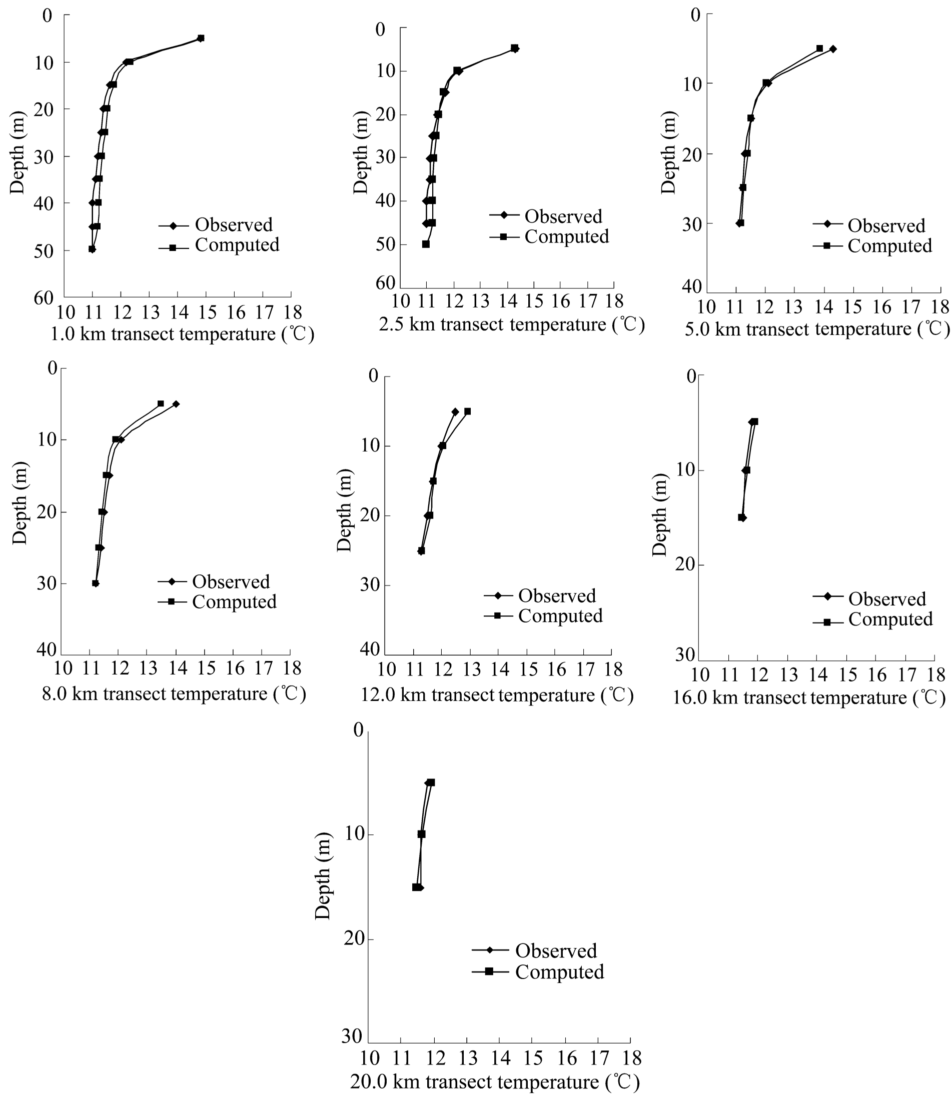

Fig. 5 Water temperature vertical distribution for seven transects

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Market – based Instruments in Water and Environmental Management in China

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Abstract: China is facing great challenges in the areas of water scarcity, water pollution, air pollution as well as soil erosion. The conventional Command and Control approach has failed in many cases and market – based instruments are starting to be introduced to improve management of water and the environment.

The paper analyzes the institutional setting for water and environmental management in China, and summarizes and discusses experimental pilots of SO_2 emission permits trading, effluent permits trading, surface water use rights transfer and groundwater service market and auction for land conservation.

Based on the analysis and discussions, the paper concludes that ① MBIs in China are at its infancy stage, but has a great potential; ② Legislation and institution should be improved and perfected to accommodate the theory and local context; ③ MBIs is not going to replace CAC, but to complement it; ④ More detailed quantitative studies should be undertaken to fully explore the benefits and weakness of MBIs in the Chinese context.

Key words: water resources management, market – based instruments, water tariff, water rights market, emission permits trading

1 Water challenges in China

Water is a key factor for the social stability and economic development in China. The challenges and water crisis in China come from its specific demographical, physical conditions and unsustainable water use in the past decades. Water scarcity, sedimentation and water pollution are the three major challenges in China (Liu & Chen, 2001).

(1) Water Scarcity. On average, the total availability of water resources in China totals 2,812.4 billion m^3. The quantity of water resources per capita in China was 2,220 m^3 in 1997, only one fourth of the world average, and one tenth of the Australian level, as shown in Fig. 1.

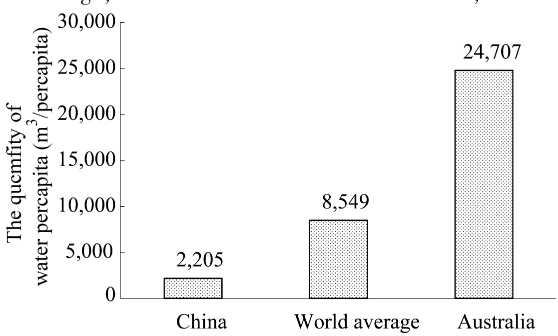
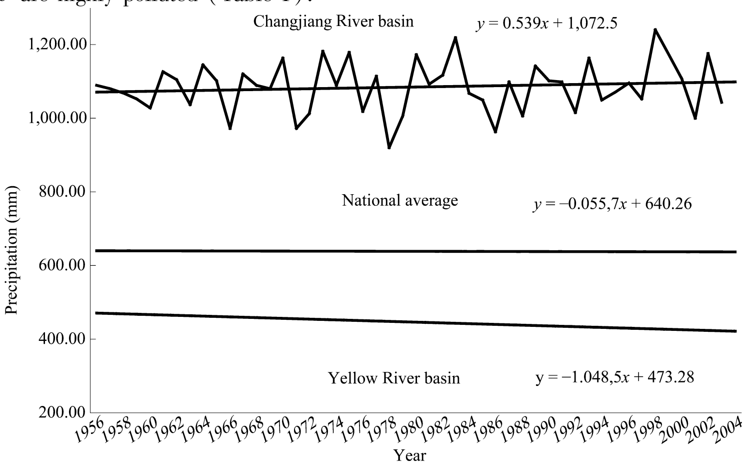


Fig. 1 Water availability per Capita

Besides the deficiency of water availability, the temporal and space distribution of water in China is extremely unmatched with demand. Due to the monsoon climate, the amount of precipitation between July and September makes up to 60% ~80% of the annual total. About two – thirds of the water resources appear as flood runoffs (Liu & Chen, 2001). One the other hand, global climate change has led to consecutive droughts in 1980s and less precipitation in 1990s on average, as shown in Fig. 2. The national average is relative stable but there is trend of decline in the Yellow River Basin, which is in northern China and receives less rainfall. On the contrary, there is an increasing trend in the Changjiang River Basin, which is mainly influenced by monsoon.

(2) Sedimentation. The high sediment concentration is a specific characteristic of rivers in China, in particular the Yellow River, which carries 1.6 billion t of sands to downstream areas, in which, 400 million t into the Bohai Sea. Western China exhibits marked topographical relief and covers extensive regions of loess plateaus and karsts formation. Unfavourable natural conditions and adverse human activities persisting for a long time have resulted in a serious loss of soil and water in many places that reduces the local land resources and degrades ecological systems (CAE, 2001).

(3) Water Pollution. Rapid economic development and improving of living conditions have resulted in unavoidable water pollution. The national total wastewater in 2002 was 63.1 billion t, including industrial discharge of 61.5% and domestic sewage 38.5% (Ministry of Water Resources, 2003). Assessment of 123,000 km of rivers indicate water pollution is very serious as almost 20% are highly polluted (Table 1).



Note: Though the trend lines of national average and the Yellow river basin have negative slopes, all three of them are not statically significant in the current time series as the P - values are respectively 0.85, 0.50 and 0.09 for national average, Changjiang river basin and Yellow river basin. (Source: MWR)

Fig. 2 Average annual precipitations (1956 ~ 2004)

Table 1 Water Quality of Major River Sections

Category	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ
Length (In percentage)	5.6%	33.1%	26%	12.2%	5.6%	17.5%

Note: Category Ⅰ and Ⅱ can be drunk while category Ⅲ and Ⅳ have to be treated before drinking. Category Ⅴ means highly contaminated. Ⅵ is worse than V. (Source: MWR, 2003).

The final factor is that China's population is forecast to continue to increase until 2043, by which year forecast says the population will reach a peak at 1.557 billion (China Population Net, 2005), near 20% increase than that in 2004 (SBS, 2005), and then begin to decline. All of these increase the severity of water scarcity in China.

2 Water management legislation/institution

Existing water and environmental management institution in China were set up in line with a planned economy favouring command and control methods. In that case, the State Council, the highest governance authority in China, forms the central governmental structure and mandates responsibilities to various ministries and administrations. At provincial level, provincial governments set up the same structure so that provincial departments can follow technical instructions from ministries and administrations in the central government.

In terms of water resources management, the Ministry of Water Resources (MWR) is mandated by the State Council with the responsibilities of water administration, service provision and resource management in the central level. In terms of environmental management, State Environmental Protection Agency (SEPA) takes the main responsibility. As explained above, provincial Environmental Protection Agency and the Dept. of Water Resources accept technical guidance from SEPA and MWR.

Both water and environmental management takes the form of segmented management—many players are involved in the decision – making process and they all represent different interests. It is one of the reasons why water and environmental challenges can not be solved successfully.

The corresponding legislation system has been set up for aspects of water and environmental management but the system is not complete. Many water and environmental acts were issued in thte 1980s and 1990s. Among them, Water Act, Water Pollution Prevention and Control Act and Environmental Protection Act are the three most important ones.

Water Act issued in 1988 is the fundamental and backbone law for water management in China. It states clearly identifies state ownership of water resources, a pay – for – use principle and water withdrawal permission systems. MWR is mandated for the implementation of the Act (ADB, 1999).

Water Pollution Prevention and Control Law was firstly passed in 1984, and then revised in 1996. The Law focuses on preventing water pollution, protecting and improving the environment to ensure human health and effective utilization of water resources. The Law declares that SEPA is the primary agency to implement the Law by issuing water quality standards and wastewater discharge permits. MWR and other agencies also have functions concerned with water quality planning and control (SEPA, 2005).

Environmental Protection Law passed in 1989 is the basic law for environment legislation. It defines the objectives of environmental protection, states the fundamental principle, basic institutions and its corresponding requirement, details the basic requirement of natural environment protection and legal obligation of user/developer of environmental resources, clarifies jurisdiction, accountability of environmental agencies for monitoring and supervision. The wastewater discharge permit requirements and other provisions of the water pollution prevention and control law are applicable under the Law and a separate fee is charged for any discharges exceeding the prescribed standard. The fees collected can only be used for prevention and control of pollution. SEPA is responsible for carrying out this law (SEPA, 2005).

3 Market – based instruments in water and environmental management

Market – Based Instruments (MBIs) appeared in 1970s in developed countries, as it can provide permanent incentives to technical innovation and achieve pollutants abatement in a least – cost manner (Sprenger, 2000).

Chinese government is active in exploring various management methods, as it adopts market economy and conventional management tools have failed in many circumstances. The degraded environment and water quality within China indicates that the outcomes from licence systems (water withdrawal, pollutant discharge/emission), which is the dominant approach in the existing system, is not ideal.

Since the 1990s, pilots of MBIs started in China in environmental management first (Environmental Defence, 2001), then this spread to water management. Meanwhile, groundwater markets at village level have emerged in rural areas in northern China, where water scarcity is most critical.

3.1 Environmental taxes

Environmental taxes (emission or effluent charge) were levied as early as 1982 for pollution control. But the rate was quite low (emission charges generally were less than $1.25 cents, effluent charges varies from $1.25 cents to $2) (China Investment Business Consultants, online database). The enforcement was weak as local government leaders only concerned with economic growth. The policy was not sufficient cnough to prevent water and air quality worsening.

In order to change this position, the State Council in 2003 published the Managerial Provision on Emission/Effluents Charge Standards, which adopts the principle of polluter pays and covers effluents, emission, solid waste and noise. The Provision also endorses the sharp increase of charges, charging pollutants discharge in accordance with types and volumes; double charge (penalty) for exceeding standard discharging, etc (State Council, 2003).

It is expected that with the increased environmental charges and strict regulation, polluters will reconsider their pollution control strategy to control their pollution. But enforcement and monitoring remain as key factors for success.

3.2 Market for tradable emission permits

Market for tradable emission permits only exists in Jiangsu and Guangxi Provinces so far in reports and all trades were bridged by local environmental agencies (Conghui Net, 2005). The pollutant involved is sulphur dioxide. In the two areas, emission permits were allocated to local power plants and factories freely in accordance with their previous emission level (Economy, 2004).

Table 2 summarises all trades reported so far and key features are: ① all trades are temporary. The longest period is 6 years while the shortest one is 3 – year; ② the unit price increases from 250/t in 2001 to 1,000/t in 2003 and 2004; ③ most trades take place in Jinagsu Province where its economic development is strong and demand exists for extra emission permits. Temporary trading of permits reflects that at the early stage of permits trading, there are too many uncertainties, such as period of policy validation, market price for permits, etc. The increasing unit price of permits trading depicts that the demand for permits increases lately.

Table 2 Emission permits (SO_2) trades in China

Year	Type	Province	Trading sides (sale – buy)	Period (years)	Trade volume	Trade value (RMB)	Unit Price (RMB/t)
2001	In – city	Jiangsu	Power Plant (P. P) – Chemical Plant (C. P)	6	1,800	450,000	250
2002	In – city	Guangxi	Timber – C. P	na	200	80,000	400
2003	Trans – city	Jiangsu	P. P – P. P	3	1,700	1,700,000	1,000
2003	Trans – city	Jiangsu	P. P – P. P	5	2,800	na	
2004	In – city	Jiangsu	C. P – Paper	na	1,200	1,200,000	1,000

Note: na refers to not available.

Though trading is encouraging, there are a number of factors constraining the trade, according to Mingjiu Zhang (2005). Firstly, the institutional setting for tradable permits is not well established. Enterprises were reluctant to trade surplus permits and the majority of trading that occurred so far was completed by the intervention of environmental agencies. On the other hand, local governments do not share the same objectives of the environmental agency. They may support it if a local power plant can buy emission permits because the expansion of the power plant will bring employment and revenues. On the other hand, if a local plant plans to sell permits, they may refuse to approve the sale as they worry about possible unemployment. Market failure can be led to by such governmental intervention. Secondly, emission quotas are allocated in line with jurisdiction territories by grandfathering. It is better to trade permits in the whole affected region to control pollution instead of establishing many small pieces.

3.3 Tradable effluent permits

Compared with the market for emission permits, the market for tradable effluent permits is less active. There are only two trades so far in 2004. In that year, under the bridging of local EPA, two temporary trades took place in Nantong. In the first case, a towel company bought 30 tons of Chemical Oxygen Demand (COD) permits from another local company, which had a surplus of 85 tons of COD permits obtained from investing in sewage abatement, at a price of 1,000 RMB/t for three years. In the second case, a newly established water treatment plant sold 30 tons of COD permits to a local textile company at a price of 1,000 RMB/t for three years (China Environment News, 2004).

As these two trades are the only reported ones in China, no conclusion can be drawn but it is expected that more trades may follow as pollution control becomes stricter.

3.4 Surface water use rights trading

MWR has been actively promoting the introduction of water rights markets from 2000 (Wang, 2001, 2004) and surface water markets in China are emerging.

3.4.1 Dongyang—Yiwu

The first water use rights trading took place in Zhejiang Province in 2000, where Yiwu City purchased permanent water use rights of 52 million m^3 at a price of 200 million yuan from nearby Dongyang City. Both cities lie in the Qiantang River Basin with Dongyang upstream and Yiwu is downstream. Yiwu's economy is strong as a national wholesale centre for small products but water source is scarce—only 1,132 m^3 per capita while Dongyang has 2 times the water availability of Yiwu. Yiwu carefully calculated and balanced various options for water supply and found that the most cost - effective and timely option was to buy water from Dongyang.

The water use rights trade is a win - win situation. Dongyang gains 200 million from the sale of permanent water use rights and 5 million per annum for water charges from the trade and Yiwu can increase its water supply in time. Fig. 3 illustrates that Dongyang conserves 52 million m^3 water by investing in 4.75 million dallar for canal lining and spillway innovation and 5.1 million dallar to develop a backup water source. A margin of 15 million dallar can be made by Dongyang.

Because it is the first water use rights trade in China, questions of legitimacy, equity and environmental flow have been raised. Firstly, since MWR and the provincial government have not allocated the initial water rights in the rive basin, theoretically nobody is entitled to sell any water rights. There is uncertainty as whether the Yiwu - Dongyang deal is illegal. This requires the improvement of legislation. Secondly, in terms of equity, farmers in the irrigation district are used to accessing water when they need. But after the canal improvement, when there is an extreme drought, they may be denied such kind of access as water has flown to Yiwu. There is no compensation clause in the agreement. They may be worse off from the trade. Finally, the environmental flows are not considered in the deal, which may cause river ecosystem degradation (Fig. 3).

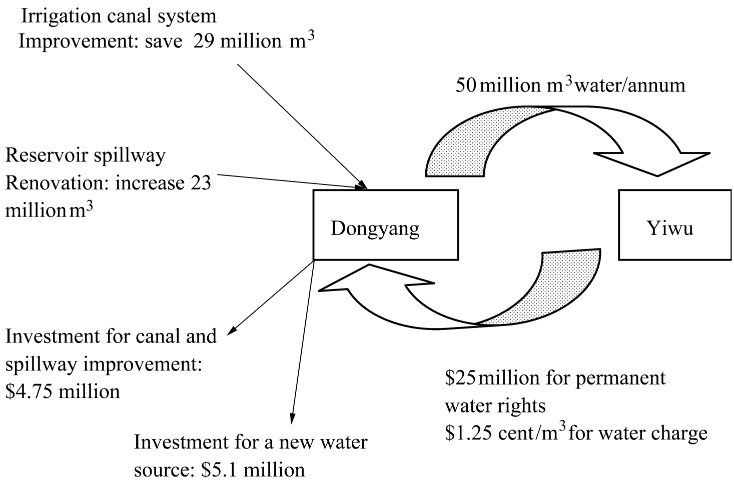


Fig. 3 Water rights transfer in Dongyang—Yiwu

3.4.2 Zhangye Pilot

The second case can be labeled as a water rights initiation rather than a real rights transfer, in Zhangye, Gansu Province. The case has a unique background as the central government strictly requires the area to reduce water consumption (extraction from Black River) by 55 million m^3 annum, so that the downstream ecosystem can recover. High water consuming but low – value crops (for example, paddy rice) are prevailing in the local agriculture and the average GDP/m^3 is very low in Zhangye, only $0.35 while the national average was $1.83 in 1999. Therefore, the approach local government takes is to reduce agricultural water consumption and promote high – value production (Tian, 2003).

In order to achieve the expected reduction, local government jointly with MWR has implemented a pilot project of Water – efficient Society, focusing on initialization and allocation of water rights to farmers. The pilot was first implemented in Irrigation Districts (ID) under Zhangye by February, 2002 (MWR, 2003). The universal tasks done in all pilot IDs include formulation of a work plan for the piloted irrigation districts, working out water allocation plan, completion of the definition of water rights by levels, setting up relevant regulations and provisions, establishing farmer water user associations, promoting water ticket system and implementing the control of total quantity; and setting up model water conservation demonstration areas with proper facilities.

The seven principles followed to allocate initial water rights include: ① to respect the historical status; ② to guarantee social stability and food security; ③ to match with investment for the Black River Recovering Scheme and water saving index; ④ fairness under the total quantity control; ⑤ no allocating all of the water available; ⑥ water saving; ⑦ conjunctive allocation of surface water and groundwater.

45 water user (farmer) associations have been established to allocate water rights to individual households and supply water according to water tickets (quantified water use rights), maintain water facilities and structures, and arbitrate water conflicts. The water tickets saved could be traded within the same canal system and the price is set not to exceed twice the basic water charge. The result so far is encouraging: the ratio between grain and cash crops has been adjusted to 48:52 from 73:27. The district has reduced the water diversion by 23 million m^3 in 2003 and the irrigation charge/mu has decrease by $0.88 cent (Wang & Hu, 2002).

However, this achievement is not actually made by trading water use rights (water tickets in this case). There are three reasons why farmers are reluctant to trade water tickets. Firstly, farmers prefer holding their defined and legal water rights constant as their irrigation rights were not fully guaranteed in the past. Secondly, in order to avoid speculation and excessive trade of all water tickets, local government caped the upper threshold of the unit price (\$2.5 cent/m^3). This intervention also discourages farmers to save and trade water tickets as they can hardly benefit much from it. Thirdly, water scarcity in the region has existed for centuries and local residents have a concept that water is life. So, though water rights are initialized in Zhangye, historical, institutional and cultural barriers still stand in the way of the efficient functioning of the market.

3.4.3 Ningxia and Inner Mongolia

The third case also took place in a water scarce area of Ningxia and Inner Mongolia where no new water sources can be identified and all water has been allocated to existing sectors. Both regions are rich in coal mines and rely totally on water extraction from the Yellow River but the Yellow River Water Allocation Plan agreed in 1986 sets the upper limit for them to withdraw from the Yellow River.

When investors went to the regions in 2002 for thermal energy plants, they found that the cost would be too high if no water is available for the cooling system. They came to know that about 4 billion m^3 of water can be saved in two large irrigation districts (close to the proposed power plant sites) in Ningxia and Inner Mongolia through water saving technology (Dept. of Economic Regulation, 2004).

The agreement arrived between the power plants and ID authorities provide that power plants invest in two thirds for total canal lining and local government funds the rest. By doing so, the power plants can have the water rights over water volume conserved through canal lining. As the power plant can have the rights of 1 m^3 of water with investment of \$0.25 (Dept. of Economic Regulation, 2004), the traded water price is \$0.25/m^3.

The case arrives at a win – win status: the local economy will increase from investment and tax associated with development; investors in power plants will have a good return with stable water supply; agricultural yield will increase by improved irrigation condition and farmers will have a reduced water cost (China Water Resources News, 2004).

As in the first two cases, post – deliberation of the case also points out weakness. Firstly, no opportunity cost or use value, nor operation cost of water use rights were take into consideration. Secondly, the agreement did not cover the cost of regular maintenance and upgrading of the canal system. When the aged canal system needs renovation again, there is no clause in the agreement to define which party should fund this.

3.5 Auction in land conservation

Auctions for land conservation are not so prevalent. The primary purpose in using the auction approach is to encourage farmers, urban residents and enterprises to utilize patches of local land and water resources, which were not used in the past due to difficulty of development or low rate of return (State Council, 1996).

It is noteworthy that priority goes to local villagers during the implementation, and development of those resources must remain in agricultural or forest production. They can not be changed into other non – agricultural purposes. The maximum period to have the use rights of those resources can not be beyond 50 years. Funds derived from auctions must be used for the local (village/township) purpose of soil conservation, installation of small – sized water facilities and construction of water structures.

The statistics show that the auctioned price for use rights per ha varies from \$18.8 to \$225 in line with the local economy, the condition of land, etc. According to MWR, by the end of 1998, 1.8 million farmer households, 102,000 urban residents and 14,000 urban enterprises have participated in such auctions. 1.4 million ha of high yielding farmland have been cultivated, 1.5 million ha of fruit trees have been planted and 4.9 million ha of soil – break trees been developed plus hundreds of small – sized soil conservation structures (MWR, 2000).

The only concern expressed by farmers is that funds from such auctions may not be used for the sake of the village, instead, may go to pay off debts of the village in the past.

3.6 Groundwater markets

The distinction between markets for groundwater and surface water rights trading is that there is no governmental intervention in groundwater market (GW markets). In a study conducted by Zhang, et al. (2005), it is found that increased private ownership of tubewells, scarcity of water and land in North China are the two main reasons for selling of well water (groundwater markets). In accordance with the finding, GW markets are unregulated—75% villagers are in towns which do not regulate groundwater markets; localized—94% of well owners sell water in their own village; and fragmented—most households only buy from 1 well owner, and a quarter of households both buy and sell well water.

It is too early to derive any policy implications from GW markets since the effects that GW markets have on efficiency, equity, poverty and water resources are not understood yet. But there are worries that rapid expansion of GW markets may result in adverse environmental outcome. Therefore, polices or legislation should be formulated to regulate the process and resolve possible conflicts (Zhang, et al, 2005).

4 Conclusions

Basing on these small but encouraging pilots, it can be concluded that:

(1) MBIs in China are at the infancy stage, but have a great potential. The market economy has been widely adopted by Chinese society and the introduction of MBIs will be easier in the future. On the other hand, the challenging water and environmental problems will force governmental agencies to develop ways out from the current dilemma. In addition, citizens will prefer flexible methods to rigid administrative orders.

(2) Government is the major player while emerging legislation and institutions should be improved and perfected to accommodate the theory and local context. It is not strange that government has played, and will continue to play, a key role in this process because if it disagrees, no progress can be made. Besides, the practice can not go along without improved legislation. Complexity of society and differences between various interest groups may require a clear defined legal framework to work together and cover interests of groups.

(3) MBIs are not going to replace CAC, but to complement it. Though some pilots mentioned in the paper are successful, CAC will remain as a dominant method to manage water and the environment in China. On the one hand, significant change can not be made overnight; on the other hand, even in developed countries MBIs are mixed with CACs. It can be expected that MBIs will be applied in broader scope, but still act as a complementary method in general.

(4) More detailed quantitative studies should be done to fully explore the benefits and weakness of MBIs. Current pilots are useful but the data and analysis are not enough. In addition, more detailed economic analysis should be done to provide insights on how to avoid shortcomings and possible weakness of MBIs.

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Models, Methods and Software Development of Contaminant Transport in Meandering Rivers

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Abstract: This paper reports a tentative computation aiming to investigate flow and contaminant transport in meandering river. The developed quasi – 3D hydrodynamic model is closed by both turbulence depth – integrated $\tilde{k}-\tilde{\varepsilon}$ model and $\tilde{k}-\tilde{w}$ model, respectively. The advanced SIMPLE (Semi – Implicit Method for Pressure – Linked Equation) algorithm for FVA (Finite Volume Approach), ILU (Incomplete Lower – Upper) decomposition, PWIM (Pressure Weighting Interpolation Method), SIP (Strongly Implicit Procedure), under relaxation and multi – grid iterative method have been used to solve the fundamental governing equations, discretized on non – orthogonal boundary – fitted collocated grid. Except for steady flow and pollutant side discharge, the processes of pollutant inpouring and plume development at the beginning of discharge have been numerically investigated.

Key words: river modeling, contaminant transport, depth – averaged $\tilde{k}-\tilde{\varepsilon}$ model, depth – averaged $\tilde{k}-\tilde{\varepsilon}$ model, meandering river

1 Introduction

Almost all flows in natural rivers are turbulence. Dealing with the problems of turbulence, related tightly of river diversion, stream pollution and accidental discharge, are challenging both for scientists and engineers. For example, turbulent transport associated with pollutant and (or) cooling – water discharges into natural waters (rivers, estuaries and coastal regions) is one of great concern, because of their damaging effects on our limited water resources and aquatic ecosystem. It is important to develop adequate mathematical models, numerical methods and analytical tools for timely simulating and predicting the transport behaviors and characteristics of interested waters.

Although the significance of modeling turbulent flows and transport phenomena with a high precision is clear, the numerical simulation and prediction for natural waters with complex riversides and bottom topography are still unsatisfied. This is mainly due to the inherent complexity of considered problems. Any successful numerical computation and simulation for flow and transport processes should critically depend on setting up applicable turbulence closure models, efficiently treating geometrical boundaries, correctly adopting suitable algorithms as well as developing corresponding engineering software. At present, engineers frequently use depth – integrated hydrodynamic models in shallow and well – mixed waters. However, most of these models used in practice merely take the turbulent viscosity/diffusivity as approximated constants or simple phenomenological algebraic formulas, to a great degree, estimated in terms of the numerical modeler's experience. In addition, the simplified treatment of riverside contours, such as zigzagging natural river boundaries, greatly reduces computational precision.

Current development of turbulence model theory has provided more realistic and advanced models of turbulent flows. From the point of view of engineering, turbulence two – equation closure models can establish a higher standard for numerically approximating main flow behaviors and corresponding transport phenomena in terms of efficiency, extensibility and robustness. On the other hand, recent advancements of grid generation techniques and numerical methods have provided many selectable effective approaches, such as non – orthogonal boundary – fitted coordinate system, collocated grid and multi – grid acceleration technique, and so on. In addition, the appearance of visual object – oriented programming tools, such as Delphi, Visual Basic and C + + Builder, greatly help us to integrate the developed models, algorithms and methods into an applicable tool with up – to – date Graphical User Interface (GUI), map support tool and help system as well as data/results visualizations and analyzers for both pre – and pro – processing.

This paper reports a developing quasi 3 – D hydrodynamic model and corresponding tool for modeling flow and contaminant transport in strongly meandering natural rivers.

2 Governing equations

By using the vertical Leibniz' integration, considering the variation of bottom topography and water surface and neglecting minor terms in the depth – averaged procedure, the continuity and momentum equations as well as the transport equation of scalar $\bar{\phi}$ (depth – averaged temperature or concentration) for depth – averaged flow and transport in the simple Cartesian Coordinates (xoy) system can be written by:

$$\frac{\partial \rho h}{\partial t} + \frac{\partial \rho h\bar{u}}{\partial x} + \frac{\partial \rho h\bar{v}}{\partial y} = 0 \tag{1}$$

$$\frac{\partial \rho h\bar{u}}{\partial t} + \frac{\partial \rho h\bar{u}^2}{\partial x} + \frac{\partial \rho h\overline{uv}}{\partial y} = -h\frac{\partial \rho g\Delta h}{\partial x} + 2\frac{\partial}{\partial x}\left(\frac{\tilde{u}_{eff}h}{Re}\frac{\partial \bar{u}}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\tilde{u}_{eff}h}{Re}\left(\frac{\partial \bar{u}}{\partial y} + \frac{\partial \bar{v}}{\partial x}\right)\right) + \tau_{sx} - \tau_{bx} + \bar{S}_{mx} \tag{2}$$

$$\frac{\partial \rho h\bar{v}}{\partial t} + \frac{\partial \rho h\overline{uv}}{\partial x} + \frac{\partial \rho h\bar{v}^2}{\partial y} = -h\frac{\partial \rho g\Delta h}{\partial y} + 2\frac{\partial}{\partial y}\left(\frac{\tilde{u}_{eff}h}{Re}\frac{\partial \bar{v}}{\partial y}\right) + \frac{\partial}{\partial x}\left(\frac{\tilde{u}_{eff}h}{Re}\left(\frac{\partial \bar{u}}{\partial y} + \frac{\partial \bar{v}}{\partial x}\right)\right) + \tau_{sy} - \tau_{by} + \bar{S}_{my} \tag{3}$$

$$\frac{\partial \rho h\bar{\phi}}{\partial t} + \frac{\partial \rho h\overline{u\phi}}{\partial x} + \frac{\partial \rho h\overline{v\phi}}{\partial y} = \frac{\partial}{\partial x}\left[\frac{\tilde{\Gamma}_{\phi,t}h}{Re}\frac{\partial \bar{\phi}}{\partial x}\right] + \frac{\partial}{\partial y}\left[\frac{\tilde{\Gamma}_{\phi,t}h}{Re}\frac{\partial \bar{\phi}}{\partial y}\right] + \bar{S}_{\phi} \tag{4}$$

where, " – " stands for depth – averaged values; $\bar{u}$ and $\bar{v}$ stand for the depth – integrated velocity components in x – and y – directions; h represents the local water – depth which usually is a variable of position in steady flow and both of time and position in unsteady flow; Re, g and ρ denote Reynolds number, gravity acceleration and density; $\bar{S}_{mx}$, $\bar{S}_{my}$ and $\bar{S}_{\phi}$ stand for the source terms; τ_{sx}, τ_{sy}, τ_{bx} and τ_{by} are surface wind shear stresses and bottom shear stresses in x – and y – directions, respectively. The local water – depth h is equal to $z - z_b$, where z and z_b represent the elevations of water surface and bottom, respectively; Δh stands for the difference between h and local static water – depth h_s.

3 Turbulence depth – averaged closure models

The depth – averaged turbulent effective viscosity $\tilde{\mu}_{eff}$ and diffusivity $\tilde{\Gamma}_{\phi,t}$ are dependent on the molecular dynamic viscosity μ and depth – averaged turbulence dynamic viscosity $\tilde{\mu}_t$, *i. e.* $\tilde{\mu}_{eff} = \mu + \tilde{\mu}_t$ and $\tilde{\Gamma}_{\phi,t} = \tilde{\mu}_t/\sigma_{\phi,t}$, where $\sigma_{\phi,t}$ denotes the turbulent Prandtl number or Schmidt number for temperature or concentration diffusion, respectively. According to turbulence two – equation closure theory, $\tilde{\mu}_t$ can be determined by two turbulence parameters. However, the so – called 'standard' turbulence two – equation closure models, used widely by various industrial departments, can not be directly adopted in depth – averaged modeling, *i. e.*, depth – integrated versions of suitable turbulence model should be established and investigated in advance.

3.1 Depth – averaged $\tilde{k} - \tilde{\varepsilon}$ model

For quasi 3D hydrodynamic modeling, the turbulence kinetic energy and dissipation rate of turbulence kinetic energy in the depth – averaged sense ($\tilde{k}$ and $\tilde{\varepsilon}$) are usually used to relate $\tilde{\mu}_t$, through the expression: $\tilde{\mu}_t = \rho C_\mu \tilde{k}^2/\tilde{\varepsilon}$, where the superscript " ~ " is a quantity symbol characterizing depth – averaged turbulence. The turbulence parameters $\tilde{k}$ and $\tilde{\varepsilon}$ are determined in terms of following two transport equations:

$$\frac{\partial\rho h\tilde{k}}{\partial t}+\frac{\partial\rho h\bar{u}\tilde{k}}{\partial x}+\frac{\partial\rho h\bar{v}\tilde{k}}{\partial y}=\frac{\partial}{\partial x}\left(\frac{\tilde{\mu}_t h}{\sigma_k}\frac{\partial\tilde{k}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{\tilde{\mu}_t h}{\sigma_k}\frac{\partial\tilde{k}}{\partial y}\right)+\rho hP_k+\rho hP_{kv}-\rho h\tilde{\varepsilon} \quad (5)$$

$$\frac{\partial\rho h\tilde{\varepsilon}}{\partial t}+\frac{\partial\rho h\bar{v}\tilde{\varepsilon}}{\partial x}+\frac{\partial\rho h\bar{v}\tilde{\varepsilon}}{\partial y}=\frac{\partial}{\partial x}\left(\frac{\tilde{\mu}_t h}{\sigma_\varepsilon}\frac{\partial\tilde{\varepsilon}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{\tilde{\mu}_t h}{\sigma_\varepsilon}\frac{\partial\tilde{e}}{\partial y}\right)+C_1\rho hP_k\frac{\tilde{\varepsilon}}{\tilde{k}}+\rho hP_{\varepsilon v}-C_2\rho h\frac{\tilde{\varepsilon}^2}{\tilde{k}} \quad (6)$$

where, P_k denotes the production of turbulent kinetic energy due to interactions of turbulent stresses with horizontal mean velocity gradients. The values of empirical constants ,C_μ, σ_k, σ_ε, C_1 and C_2 are equal to 0.09, 1.0, 1.3, 1.44 and 1.92, respectively. The additional source terms P_{kv} and $P_{\varepsilon v}$ in Equations (5) and (6) are mainly produced by the vertical velocity gradients near the bottom, and can be expressed as $P_{kv}=C_k u_*^3/h$ and $P_{\varepsilon v}=C_\varepsilon u_*^4/h^2$, respectively, where the local friction velocity u_* is equal to $\sqrt{C_f(\bar{u}^2+\bar{v}^2)}$ and the empirical constants C_k and C_ε for open channel flow are $C_k=1/\sqrt{C_f}$ and $C_\varepsilon=3.6C_2C_\mu^{1/2}/C_f^{3/4}$. The coefficient C_f represents an empirical friction factor and 3.6 was determined by using Laufer's experimental result in open channel.

3.2 Depth - averaged $\tilde{k}-\tilde{w}$ model

In 1989, the first author and his colleague also provided a turbulence depth - integrated second - order closure model, symbolized by $\tilde{k}-\tilde{w}$. This model originated from $k-w$ model, developed by Ilegbusi and Spalding in 1982 [14]. Actually, $k-w$ model is a revised version of $k-w$ model (w: time - mean - square vorticity fluctuations of turbulence), whereas the primitive $k-w$ model was developed as early as in 1969 by Spalding. The turbulence parameters $\tilde{k}$ and $\tilde{w}$ in $\tilde{k}-\tilde{w}$ model are determined in terms of following two transport equations:

$$\frac{\partial\rho h\tilde{k}}{\partial t}+\frac{\partial\rho h\bar{u}\tilde{k}}{\partial x}+\frac{\partial\rho h\bar{v}\tilde{k}}{\partial y}=\frac{\partial}{\partial x}\left(\frac{\tilde{\mu}_t h}{\sigma_k}\frac{\partial\tilde{k}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{\tilde{\mu}_t h}{\sigma_k}\frac{\partial\tilde{k}}{\partial y}\right)+\rho hP_k+\rho hP_{kv}-C_\mu h\tilde{k}\tilde{w}^{-1/2} \quad (7)$$

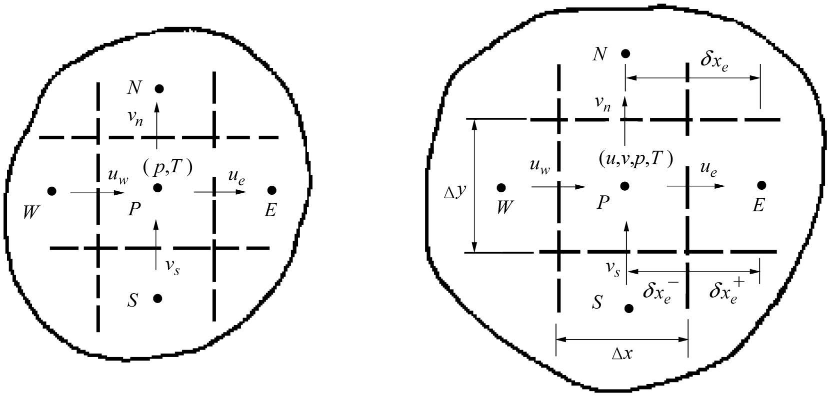
$$\frac{\partial\rho h\tilde{w}_t}{\partial t}+\frac{\partial\rho h\bar{u}\tilde{w}_t}{\partial x}+\frac{\partial\rho h\bar{v}\tilde{w}_t}{\partial y}=\frac{\partial}{\partial x}\left(\frac{\tilde{\mu}_t h}{\sigma_k}\frac{\partial\tilde{w}_t}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{\tilde{\mu}_t h}{\sigma_k}\frac{\partial\tilde{w}_t}{\partial y}\right)+C_{1w}\tilde{\mu}_t h\left|{}^2\frac{\partial}{\partial y}\left(\frac{\partial\bar{v}}{\partial x}-\frac{\partial\bar{u}}{\partial y}\right)\right|-C_{2w}$$

$$\rho h\tilde{k}^{3/2}\left[1+C'_{2w}\left(\frac{\partial}{\partial x}\left(\frac{\tilde{k}}{\tilde{w}}\right)^{1/2}+\frac{\partial}{\partial y}\left(\frac{\tilde{k}}{\tilde{w}}\right)^{1/2}\right)^2\right]+C_{3w}\rho h\frac{\tilde{w}}{\tilde{k}}P_k+\rho hP_{wv} \quad (8)$$

In Equations (7) ~ (8), the depth - averaged turbulence dynamic viscosity $\tilde{\mu}_t=\rho\tilde{k}^2/\tilde{w}^{1/2}$; the values of empirical constants C_μ, σ_k, σ_w, C_{1w}, C_{2w}, C'_{2w} and C_{3w} are the same as those of $k-w$ model, i. e., equal 0.09, 1.0, 1.0, 3.5, 0.17, 17.47 and 1.12, respectively. The corresponding additional source terms P_{kv} and P_{wv} also mainly due to the vertical velocity gradients near the bottom can be expressed as $P_{kv}=C_k u_*^3/h$ and $P_{wv}=C_w u_*^3/h^3$, respectively. The empirical constants C_w for open channel flow is 47.26 $C_{2w}/C_\mu^{3/2}C_f^{3/4}$, where 47.26 was determined by using Laufer's experimental data. The suggested $\tilde{k}-\tilde{w}$ model and corresponding numerical techniques have been successfully applied to simulate and predict the flows and passive mass transports in open channel, river and estuary, respectively.

4 Discretization outlines

It is well known that the advantage of staggered grid brings the pressures at the nodal points of both sides of velocity naturally into the pressure difference term of discretized velocity equations, and then assures the linkage between velocity and pressure. Hence the staggered grid obtained widely applications in engineering computations, when Finite Volume Approach (FVA) and implicit scheme using pressure - correction were used. However, along with the development of Computational Fluid Mechanics and Computational Hydraulics, the computed problems turn from orthogonal coordinates into non - orthogonal grids, the disadvantage of staggered grid, *i. e.*, the complexity and inconvenience of programming become more prominent. Since the beginning of the eighth decades of last century, academics have started to investigate if one could solve velocity field and corresponding scalar quantity fields by using same suit of grid with the help of the successful experiences on staggered grid. The method to place all variables on one suit of grid, called by variable collocated arrangement, is developed quickly. Fig. 1 presents the comparison between staggered and collocated grids.



(a) Staggered grid (b) Collocated grid

Fig. 1 Staggered and collocated grids

By using the same suit of grid for setting up various variables, the so - called velocity - pressure decoupling appears in the discretized momentum equations, which may result in solved pressure field unreasonable. In order to overcoming the decoupling phenomenon, according to the staggered grid experience, one should try to introduce a pressure difference between two adjacent nodal points, relative to the computed velocity, into the solution of momentum equations. Taking the so - called Momentum Interpolation Method (or say PWIM), one can implement the linkage between velocity and pressure on collocated grid under orthogonal grid. On the other hand, the solution of a practical problem with non - orthogonal curvilinear coordinates is usually to transform the problem from the physical plane into a computational plane through grid generation technique, and then to complete numerical calculation on the computational plane. Hence, the so - called problem of collocated grid under non - orthogonal coordinates is how to implement the collocated grid on computational plane. This computation selects two velocity components $\bar{u}$ and $\bar{v}$ of Cartesian Coordinates on computational plane as solved velocity variables and contra - variant velocity components $\bar{U}$ and $\bar{V}$ as interface velocities; such kind of selection is popular in most literatures.

The computational "engine", coded by FORTRAN Language, can be divided into two parts: grid - generator and flow - transfer - solver. The grid - generator generates a set of non - orthogonal boundary - fitted grids with pre - determined grid level number and spatially collocated variable arrangement. The flow - transfer - solver can solve complete depth - averaged fundamental governing equations, in association with passive mass transport equation (s) and turbulence parameter transport equations, discretized by FVA, by using SIMPLE algorithm, ILU decomposition, SIP, under relaxation and multi - grid iterative method. Due to the limitation of space, the details of numerical discritization have been omitted in the paper.

5 Grid generation

A tentative computational example has been performed with the aim to develop models, codes and corresponding numerical tool. A reach of typical meandering river was selected, which curved riverside contours can be obtained from the digital map of Google Earth. With the help of a map support tool, developed by the authors, one can conveniently determine map - scale, collect and insert riversides' geometry data into the tables of software through mouse click technique, and then to generate a text file that contains all of necessary data to describe characteristics of multi – grids and corresponding four boundaries of computational domain, and can be read in by grid – generator.

Fig. 2 presents the generated non – orthogonal boundary – fitted coarse grid, with a grid solution of 22 nodal points in ξ – direction and 422 nodal points in η – direction, respectively. The computation adopted two levels of grid. The resolution of corresponding fine grid is 44 mm × 842 mm. The expansion factors of cross – river grid lines are 0. 95 and 1. 05. The total length of calculated river reach is up to 25. 343 km. The grid – generator can generate an unformatted file, in which all of geometric data needed in computation should be storied and can be read by the flow – transport – solver.

6 Solutions of flow and side discharge

The flow behavior with a confluent tributary from the right side of river was simulated. The calculated main stream flow – rate is 600 m^3/s, while the empirical friction factor (C_f) equals 0. 003,704,2, where $C_f = g/C^2$ (C – Chezy ' s coefficient and g – gravity acceleration). The tributary flow – rate and concentration are 120 m^3/s and 50 mg/L, respectively. In computation, the variation of bottom topography was considered. Fig. 3 illustrates the bottom topography on generated fine grids, where the data of bottom topography corresponding to the coarse grid were read in by the solver and extrapolated to the fine grid. The turbulence depth – averaged $\tilde{k} - \tilde{\varepsilon}$ and $\tilde{k} - \tilde{w}$ closure models were used both for coarse and fine grid iterations. The velocity components and turbulence parameters on main stream inlet section and tributary inpouring section are uniform, and on outlet section of main stream satisfy the constant gradient condition. The turbulence parameters at inlet sections can be calculated by empirical formulae with mean velocity at main stream inlet section $U_0 = 0.89$ m/s and mean velocity at tributary inpouring section $U_{tri} = 0.56$ m/s, *i. e.* , $\tilde{k}_0, \tilde{\varepsilon}_0, \tilde{w}_0$, equal 0. 031 m^2/s^2, 0. 000,87 m^2/s^3, 0. 298 m^2/s^2 and $\tilde{k}_{tri}, \tilde{\varepsilon}_{tri}, \tilde{w}_{tri}$, 0. 06 m^2/s^2, 0. 005,5 m^2/s^3 and 1. 022 m^2/s^2, respectively. The wall function approximation has been used for determining the values of velocity components and turbulence parameters at nodal points in the neighborhood of boundaries. The under – relaxation factors for velocity components, pressure, concentration and two turbulence parameters are 0. 6, 0. 6, 0. 1, 0. 7, 0. 7 and 0. 7. The maximum allowed number of inner iteration for solving velocity components, pressure, concentration and two turbulence parameters are 1, 1, 20, 1, 1 and 1; and corresponding convergence criterions for inner iteration are 0. 1, 0. 1, 0. 01, 0. 1, 0. 01 and 0. 01, respectively. The α parameter of the Stone ' s solver is equal to 0. 92.

Fig. 2 Non – orthogonal boundary – fitted coarse grid

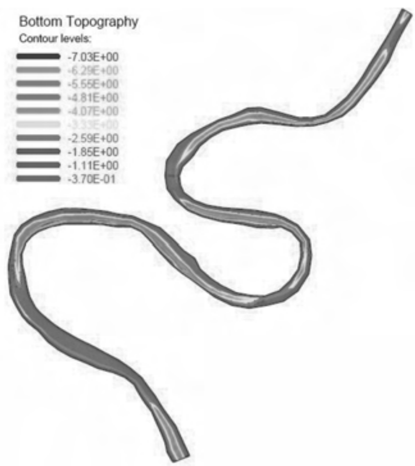


Fig. 3 Bottom topography

The simulation can obtain various flow, concentration and turbulence parameter distributions, which are useful to analyze interested problems in engineering. From Fig. 4 to Fig. 11, a part of simulated results by using depth – averaged $\tilde{k} - \tilde{\varepsilon}$ model are presented. Fig. 4 denotes the color velocity vectors on fine grid, where every 2 nd vector in ξ – direction and 4 th vector in η – direction were plotted. Fig. 5 displays the color streamline distribution on fine grid. Fig. 6 and Fig. 7 illustrate the calculated depth – averaged concentration distributions with 50 ppm difference between main stream and confluent tributary. It is clear that the pollutant plume well develops along the right riverside at the lower reach of tributary inpouring. Fig. 8, Fig. 9, Fig. 10 and Fig. 11 demonstrate the distributions of pressure, turbulence parameters $\tilde{k}$ and $\tilde{\varepsilon}$ as well as turbulence dynamic viscosity on fine grid, respectively.

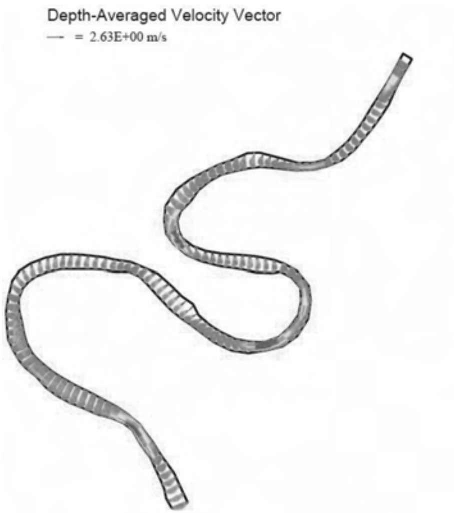


Fig. 4 Color flow pattern on fine grid

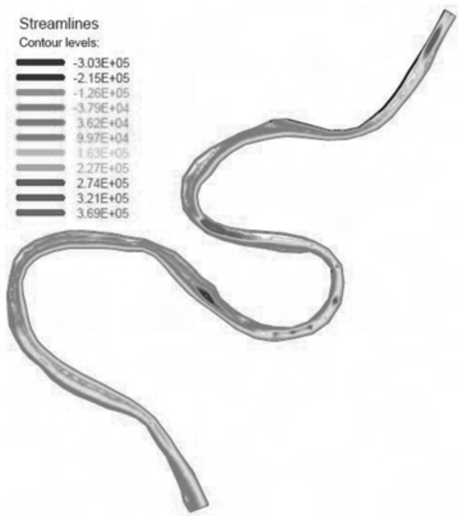


Fig. 5 Color streamline distribution

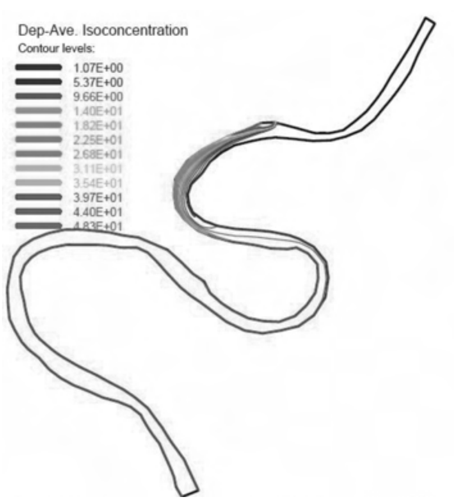


Fig. 6 Color concentration contour lines

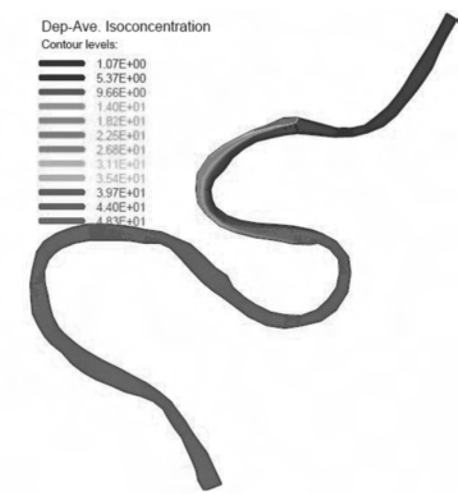


Fig. 7 Color – filled concentration distribution

7 Plume development at the beginning of discharge

In order to well understand the development process of pollutant plume, a special simulation was performed for the case described as follows. Supposing the concentration of confluent tributary firstly to equal zero, and then, the value of concentration instantaneously reach at 50 mg/L at Time = 0, while the flow – rates, either of main stream or of tributary, keep constant. Fig. 12 ~ Fig. 19 present the plume development and variation in the local region of the lower reach of tributary outlet section, where Fig. 12 illustrates the situation of clean water confluence; Fig. 13 ~ Fig. 19 display the process of contaminant inpouring and plume development, with an equal time difference Δt each other. The hydrodynamic fundamental government equations of this simulation were closed by both turbulence depth – averaged $\tilde{k} - \tilde{\varepsilon}$ model and $\tilde{k} - \tilde{w}$ model. However, the presented results are a part of those, modeled by using $\tilde{k} - \tilde{w}$ model closure only.

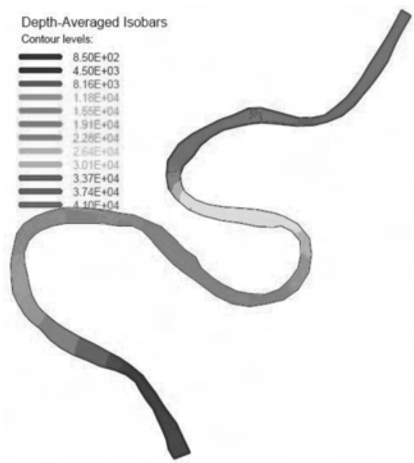


Fig. 8 Color – filled pressure image

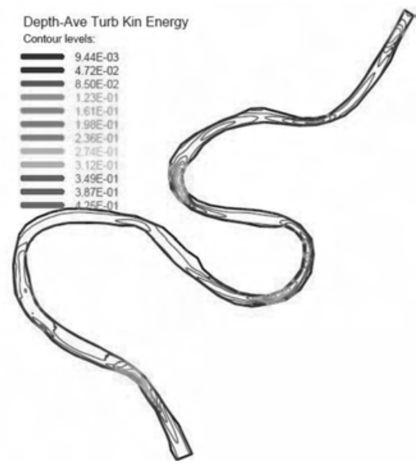


Fig. 9 Color $\tilde{k}$ contour lines

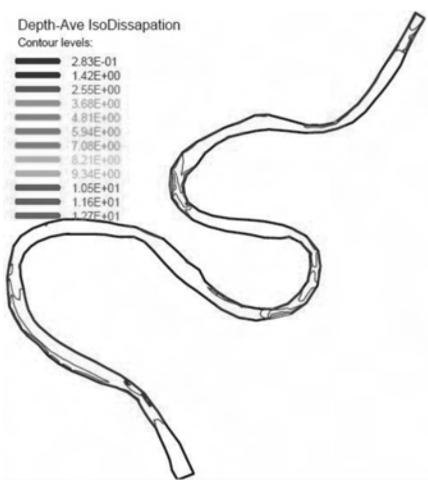


Fig. 10 Color $\tilde{\varepsilon}$ contour lines

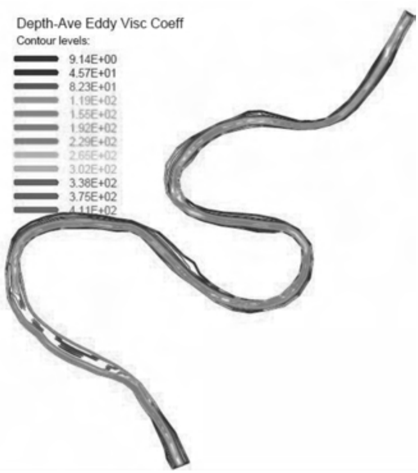


Fig. 11 Color $\tilde{u}_t$ contour lines

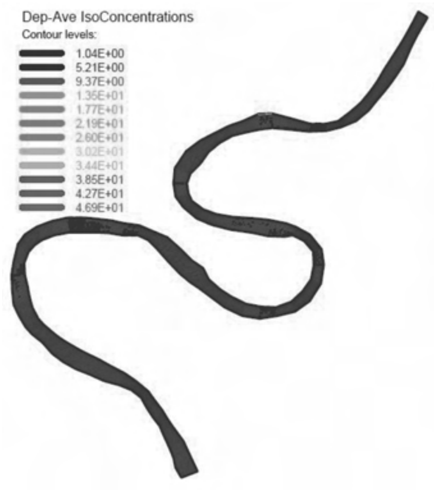


Fig. 12　Case 1, $\Delta C = 0$, time = 0

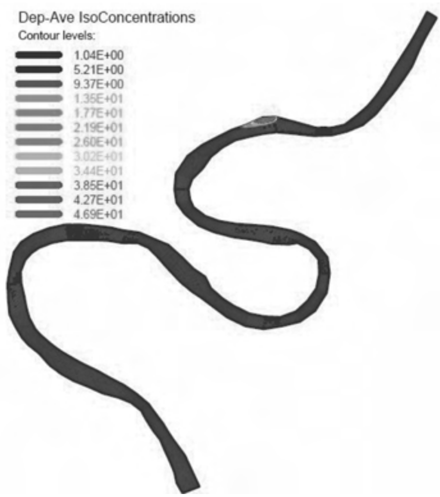


Fig. 13　Case 2, $\Delta C = 50$ ppm with time = Δt

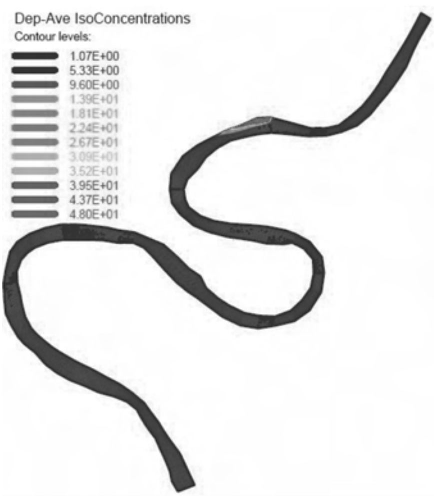


Fig. 14　Case 3, $\Delta C = 50$ ppm with time = $2\Delta t$

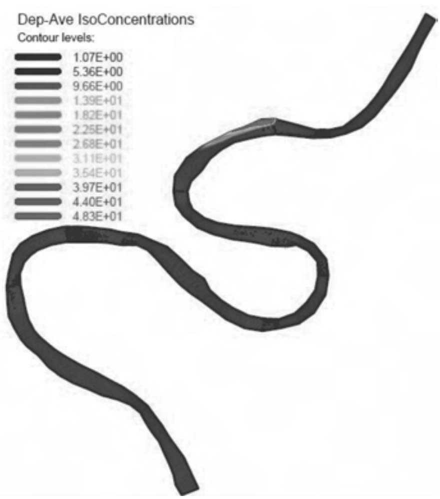


Fig. 15　Case 4, $\Delta C = 50$ ppm with time = $3\Delta t$

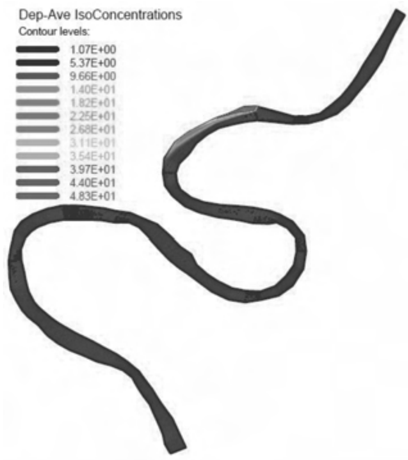


Fig. 16 Case 5, ΔC = 50 ppm with time = $4\Delta t$

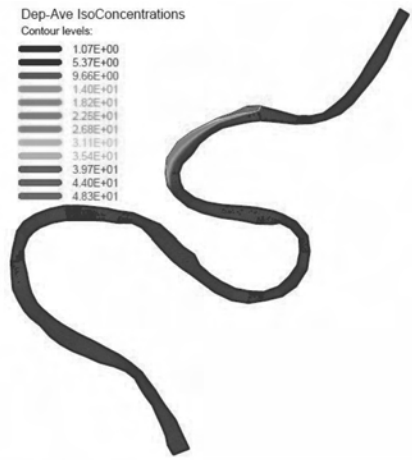


Fig. 17 Case 6, ΔC = 50 ppm with time = $5\Delta t$

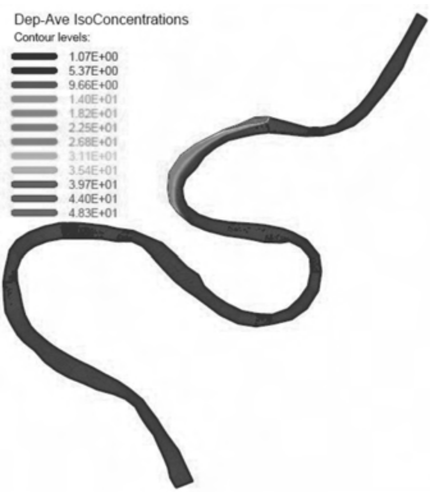


Fig. 18 Case 7, ΔC = 50 ppm with time = $6\Delta t$

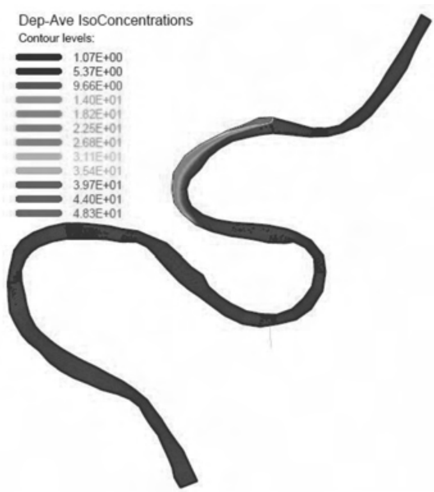


Fig. 19 Case 8, ΔC = 50 ppm with time = $7\Delta t$

8 Discussions

The strong mixing of tributary with main stream, caused by a side discharge from tributary into a meandering natural river, have been simulated by using turbulence depth – integrated $\tilde{k}-\tilde{\varepsilon}$ and $\tilde{k}-\tilde{w}$ models. The development process of pollutant plume is well modeled. At the same time, a pre – processing Graphical User Interface (GUI) has been developed, which may form a part of an expected useful numerical tool. In this example, the computational results, both from turbulence $\tilde{k}-\tilde{\varepsilon}$ model closure and $\tilde{k}-\tilde{w}$ model closure, are similar. This also coincide with the first author's previous research that the turbulence depth – averaged $\tilde{k}-\tilde{\varepsilon}$ model and $\tilde{k}-\tilde{w}$ model are all suitable for modeling "strong" mixing turbulence. However, other turbulence depth – averaged models and models' behaviors for "weak" mixing turbulence should be further investigated.

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An One – dimensional – two – dimensional Integrated Hydraulic Model for the Yellow River Delta

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Abstract: Within the environmental flow study for the Yellow River Delta (YRD) a 1D – 2D integrated hydraulic model for the YRD, based on the SOBEK – Rural modelling system, has been set up. The model simulates the flow in the river and channel networks (1D) as well as the overland flow in the wetlands (2D). It is interactively linked with a groundwater flow model based on MODFLOW. The two models together supply the physical condition data to a landscape ecological model based on LEDESS. This system of the three models together makes it possible to evaluate the effect of water allocation strategies on the ecological system of the YRD wetlands. This paper describes the background principle of the SOBEK – Rural modelling system as well as the set up, calibration and verification of the 1D – 2D integrated hydraulic model for the YRD.

Key words: one – dimensional, two – dimensional, integrated hydraulic model , the Yellow River Delta

1 Introduction

The Yellow River Delta forms the most complete and extensive young wetland ecological system in China, with abundant nature resources and a unique ecological status. It is a wintering, stop – over and breeding site for migratory birds of the inland of Northeast Asia and around the Pacific Ocean. The sustainability of this fresh wetland system requires a certain fresh water and sediment supply from the Yellow River.

The Yellow River Basin is very deficient in water resources. With the strong social – economic development of the river basin and the area around it the water shortage problem is becoming more and more serious. In order to meet the increasing demand for water from agriculture, industry and urban development upstream of the YRD more and more water is diverted from the Yellow River. Recently the water diversions have reduced the base flow of the river in the delta to virtually nil. In 1998, the river was even dry during more than 200 days.

The increasing water shortage problem sharpens the conflict between industrial, agricultural and urban water demand on the one hand and the environmental and ecological conditions on the other hand, and can lead to deficiency of suitable water needed by the ecological system of the estuarine delta. To counteract the drying up of the lower Yellow River and the associated ecological damage, the Chinese central government has implemented a regulated discharge regime of the river since 1999. This will relieve the problem in the estuarine delta to a certain extent. However, there is still a long way to go to the optimal allocation of water resources required by ecological system development of the delta. Knowledge about the exact water demand for ecological system development of the delta and about the ecological effect and influences of allocation of water is urgently needed for developing optimal water allocation strategy. The YRD environmental flow study is meant to meet this need.

Within this environmental flow study a 1D – 2D integrated hydraulic model for the YRD, based on the SOBEK – Rural modelling system, has been set up. The model simulates the flow in the river and channel networks (1D) as well as the overland flow in the wetlands (2D). The model is interactively linked with a groundwater flow model based on MODFLOW. The two models together supply the physical condition data to a landscape ecological model based on LEDESS. This system of the three models together makes it possible to evaluate the effect of water allocation strategies on the ecological system of the YRD wetlands.

This paper describes the background principle of the SOBEK – Rural modelling system as well as the set up and calibration of the 1D – 2D integrated hydraulic model for the YRD.

2 Brief Description of SOBEK – Rural

SOBEK – Rural is a product line out of the main SOBEK line of water flow models developed at WL | Delft Hydraulics (Verwey, 2001). The module "1D Flow" deals specifically with hydrodynamics of one – dimensional river or irrigation channel flow. SOBEK – Rural thus provides a high – quality tool for modelling irrigation system, drainage systems, natural streams and river in lowlands and hilly areas. Applications areas include those related to design of irrigation channels, reservoir operations, control of water structures etc.

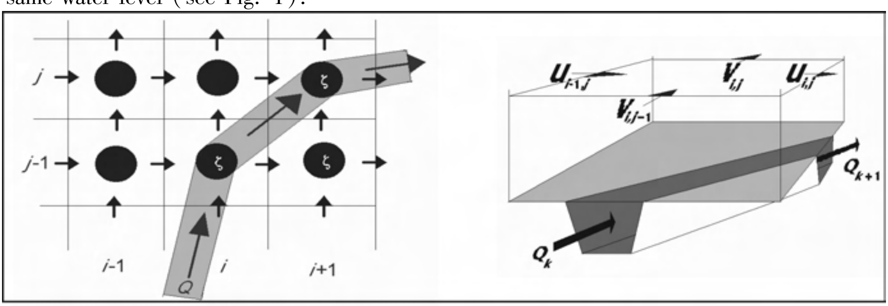
The functionality of two – dimensional overland flow is provided by the SOBEK – Rural module "2D Flow". Thus it not only provides a high – quality tool in areas mentioned above but also overland flooding, simulation of dike or dam break, planning emergency rescue operation in case of flooding. This functionality of integrating the one – dimensional river / channel flow and two – dimensional overland flow is also named as "SOBEK – 1D2D".

The SOBEK – 1D2D system is designed for the simulation of overland flooding or inundation when in normal conditions (in case of no flooding) hydrography can be modelled as a one – dimensional (1D) network. If large areas are inundated then assumptions for 1D flow are normally no longer valid. In that case the system becomes truly two – dimensional (2D).

3 Background Principles of Numerical Model

The computational domain is split into a 1D network, with general volumes of arbitrary cross sections, and a 2D system with rectangular computational cells. The 1D network and 2D system are implicitly coupled and solved simultaneously based upon the momentum balance and the conservation of mass between separate computational layers.

For the momentum balance the 1D and the 2D system remain strictly separated. That means that velocities or discharges belong either to the 1D part or to the 2D part. For the conservation of mass, being a scalar quantity, the appropriate 1D and 2D volumes are combined so that they share the same water level (see Fig. 1).



(a) combined 1D/2D staggered grid; (b) combined finite mass volume for 1D/2D computations

Fig. 1 Schematisation of the hydraulic model

Both the 1D and the 2D computational layers have finite difference formulations for volume and momentum equations, based upon a staggered grid approach. (Fig. 1a). In other words, the approach is equivalent to a mass – conservative finite volume scheme, the momentum volumes are different from the mass volumes, and there exists no interaction between the 1D and the 2D momentum volumes. This means that vertical velocities and shear stress interaction between 1D flow and 2D flow are neglected.

For each momentum volume the following law is applied:

$$\textit{Rate of change of momentum} + \textit{transport of momentum} + \textit{integrated hadrostatic pressure} + \textit{friction} - \textit{kisses} = 0 \quad (1)$$

The numerical implementation is such that in the vicinity of steep gradients proper shock conditions are being fulfilled, both for 1D and 2D volumes (Stelling et al., 1998).

The interaction between the 1D and the 2D part takes place via mutual volumes, see Fig. 1b. For mutual 1D/2D mass volumes the following equation is solved:

$$\frac{dV_{i,j}(\zeta)}{dt} + \Delta y\left[(uh)_{i,j} - (uh)_{i-1,j}\right] + \Delta x\left[(vh)_{i,j} - (vh)_{i,j-1}\right] + \sum_{l=K^1_{i,j}}^{l=K^L_{i,j}} (Q_n)_l = 0 \quad (2)$$

where: V is combined 1D/2D volume; u is velocity in x direction; v is velocity in y direction; h is total water height above 2D bottom; Δ is water level above plane of reference (the same for 1D and 2D); Δx is 2D grid size in x (or i) direction; Δy is 2D grid size in y (or j) direction; Q_n is discharge in the direction normal to the mass volume faces; i, j, l, K, L is integer numbers for modal point numbering.

For Fig. 1(b), equation (2) becomes:

$$\frac{dV_{i,j}(\zeta)}{dt} + \Delta y\left((uh)_{i,j} - (uh)_{i-1,j}\right) + \Delta x\left((vh)_{i,j} - (vh)_{i,j-1}\right) + Q_{k+1} - Q_k = 0 \quad (3)$$

After discretisation in time by the "θ method" the velocities are eliminated by substitution of the momentum equations into the continuity equation. The resulting system is linear for purely 2D volumes, but if a 1D part is involved the equation might be non – linear with respect to the volume V(ξ). This is solved by Newton iteration. The resulting linearised equations, per Newton iteration step, are positive definite and symmetric (Casulli, 1990). The method used for the solution is a combination of the so – called "minimum degree algorithm" (Duff et al., 1986) and of the pre – conditioned CG (conjugate gradient) (Golub and Van Loan, 1983).

The continuity equation is discretised in a way that excludes the possibility of negative volumes. This allows for very efficient and also realistic flooding of dry beds when the 1D rivers are flooding their 2D surroundings. In normal conditions, i. e. if there is no flooding, the 2D part is not activated. This means that in equation (2) the uh and vh values are supposed to be zero.

3.1 Advantages of Combined 1D – 2D Modelling

The main advantage of combined 1D – 2D modelling is bringing the model behaviour closer to the real physical behaviour. It simulates the flow in river / channel network with extensive details within 1D system, to name a few, incorporating structures, like weir, culverts, gate, and on – line controls of these structures along the stretch of river/channel. It also simulates the overland flow with extensive details within 2D system by e. g. incorporating physical obstructions, like roads, railways, dikes, etc.

Secondly, Using combined 1D – 2D modelling often allows the grid cells to be significantly larger than purely 2D modelling. The reason is that, using combined 1D – 2D modelling, the river, channels, streams etc is not modelled within 2D system, but as 1D system. For a very narrow channel / stream or curving streams, one requires within purely 2D system a high local grid refinement. This would make 2D system numerically less feasible and almost impossible to model. Here combined 1D – 2D modelling often proves advantageous.

Thirdly, the modeller works in the same user interface, for both pre – processing of data as well as post – processing of the 1D – 2D results.

In general, integration offers wide range of modelling options. It is also easy to combine an urban drainage model to simulate the street flow, and flow over, for example, parks and parking places (Bishop and Catalano, 2001). This combined 1D – 2D system with urban drainage system and street flow, also developed at WL | Delft Hydraulics, is named as "SOBEK – Urban". Further, the combined 1D – 2D modelling is capable of modelling problems related to flood hazard and risk mapping (Frank, et al., 2001) and water quality.

3.2 The Yellow River Delta

The present Yellow River Delta is a fluvial – dominated delta. It started developing in 1855 when the Yellow River turned to flow into Bohai Bay instead of into the Yellow Sea. The vast amount of sediment from the upstream river has caused the river bed to rise up to 10 cm per year and the river mouth to propagate into the shallow Bohai Bay with an average velocity of 2 km per year. Every year approximately 25 km^2 of land is gained by sediment deposition. As the delta develops the river course has been changing more than 10 times in the delta. The last major change was in 1976 when the river turns from Diao Kou He to Qing Shui Gou, and the last minor change was in 1996 when a new channel was dug in the downstream reach of Qing Shui Gou channel (Fig. 2).

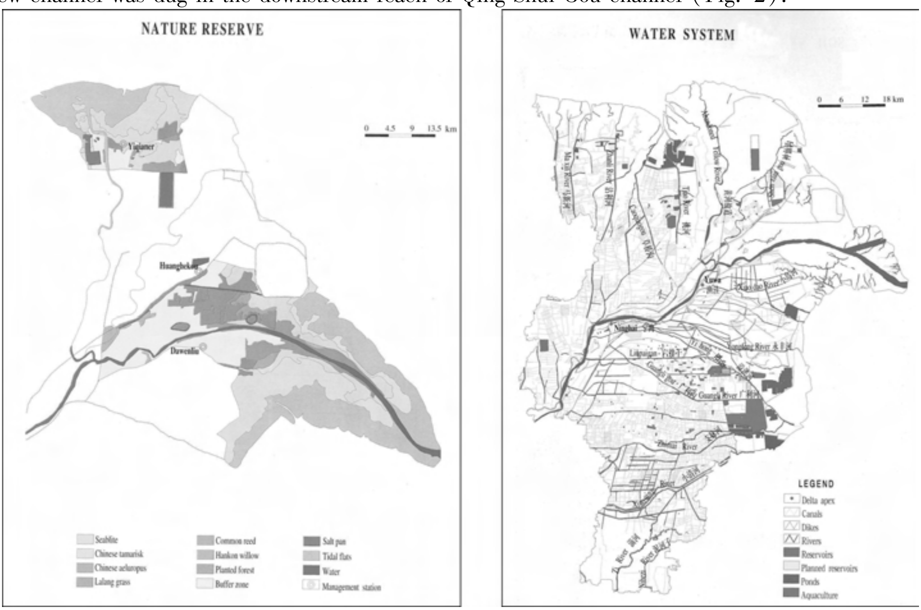


Fig. 2 Yellow River Delta, natural reserve (left) and the water system (right), After Liu and Drost (1997)

Fig. 2 shows the natural reserve and the water system in the Yellow River Delta. The natural reserve includes two areas, one around the downstream reach of the present river, the Qing Shui Gou channel, and one at the mouth of the former (before 1976) river. The wetlands under consideration in the present study are located in these two areas. The water system includes the (present and former) river channels and also many canals. The distribution of the wetlands and the structure of the water system form the basic information for the set up of the 1D – 2D model.

3.3 Set up of the model

The general modelling approach for the YRD is presented in Fig. 3. The SOBEK model is linked to the MODFLOW groundwater model by a two – way interchange of data. Water level and flow width of the 1D river and channel network as well as the 2D wetlands are computed in SOBEK and transferred to MODFLOW. In the opposite direction, MODFLOW supplies seepage losses to SOBEK. Both models supply data to LEDESS for performing an overall analysis on landscape and ecology.

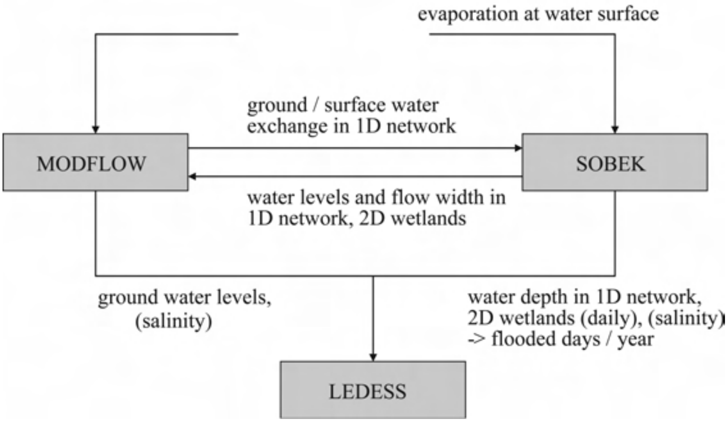


Fig. 3 Embedding the SOBEK model into the general modelling approach for the YRD

Keeping in mind the objective of the final model to simulate the YRD over a period of several years within a limited computational time, we fully want to exploit the advantages of the 1D – 2D modelling approach. To do so, the river and channel network is modelled as a one – dimensional sub – model. The location of the Yellow River and the identification of the major channel network are derived from satellite images. Furthermore, measured cross – sections are implemented in the Yellow River branch. Since no measured cross – sections are available for the channel network, the width of the channels is derived from a 2.5 m satellite image and a typical cross section is estimated. The elevation of the channel network is extracted from a Digital Elevation Model (DEM). The refinement of the channel geometry and elevation will be an activity of future work.

The 1D network is completed by two two – dimensional model domains which represent the sweet and salt water wetlands and the coastal parts of the Bohai Bay close to the natural reserve. The domain also includes sea dikes preventing certain inland sections from a coastal overflooding. The topography of the total SOBEK model is presented in Fig. 4.

The resolution of the two – dimensional model is 400 m resulting in a total number of 10,929 active cells. On the one – dimensional domain, an equidistant grid of 600 m is used. We chose a time step of 30 minutes to dissolve the tidal movement in the tidal flats and the Bohai Bay. The schematisation results in a computational time for a simulation period of 1 year of about 6 hours on a standard Notebook with 1.3 GHz CPU.

An inflow boundary condition is used at the upstream model boundary at LiJin where continuous discharge measurements are available. The downstream boundary of the model is represented by a couple of water level line boundaries in the 2D sub – model. The given water levels are derived from a typical tidal cycle. The discharge of water from the Yellow River to the channel network is controlled by hydraulic structures.

As Fig. 5 shows, the complete model (model A) includes several lateral outtakes along the Yellow River. Besides their location, data on the dimensions of these structures is not available and only estimated in the model. Therefore a second model (Model B) is set up which includes only a lumped representation of these outtakes (Fig. 5). For example, all withdraws downstream of LiJin, which are not linked to the natural reserve, are represented in only one outlet structure. Concerning the 2D domains Model A includes the natural reserve areas and a coastal section of the Bohai Bay. Model B only includes the wetland restoration areas, but then in a higher resolution.

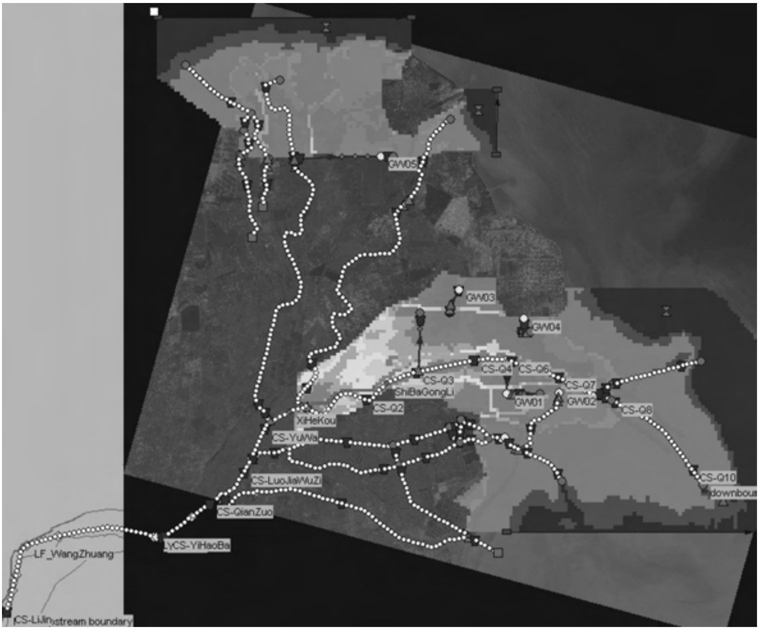


Fig. 4　Topology of the SOBEK model

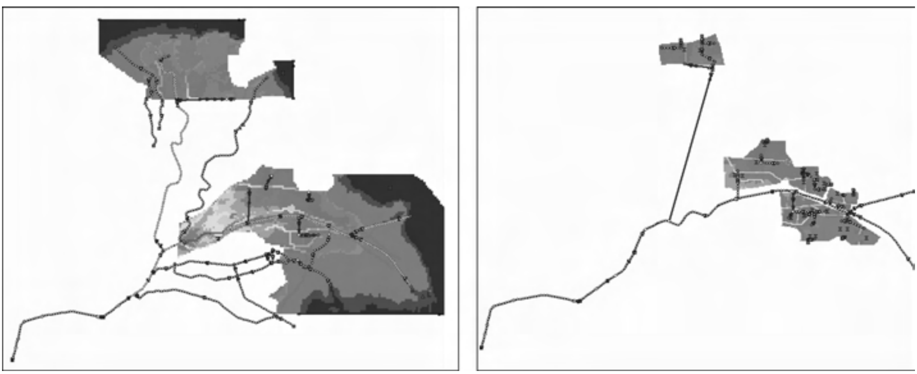


Fig. 5　Layout of models A (left) and B (right)

The implementation of the water resources management is schematised in Fig. 6.

3.4　Model calibration

The model calibration is focusing on the Yellow River between the measurement station LiJin and the estuary mouth. Besides at LiJin, there are three additional measurement stations at YiHaoBa, XiHeKou, and ShiBaGongLi with continuously water level recordings available. The year 1990 was chosen as the period for model calibration.

The calibration is performed by adapting the cross section roughness and fitting the water levels. The final Manning roughness n of the model is in the range from 0.08 to 0.01 s/m 1/3. Fig. 7 presents observed and simulated water levels at the stations LiJin and XiHeKou. The agreement at the stations YiHaoBa and ShiBaGongLi is comparable to the ones presented. A major water level difference is observed in the period from January 16 till February 8. It is referred to an ice blockage in the river and causes an overestimated discharge in the simulation for the upstream boundary condition at LiJin.

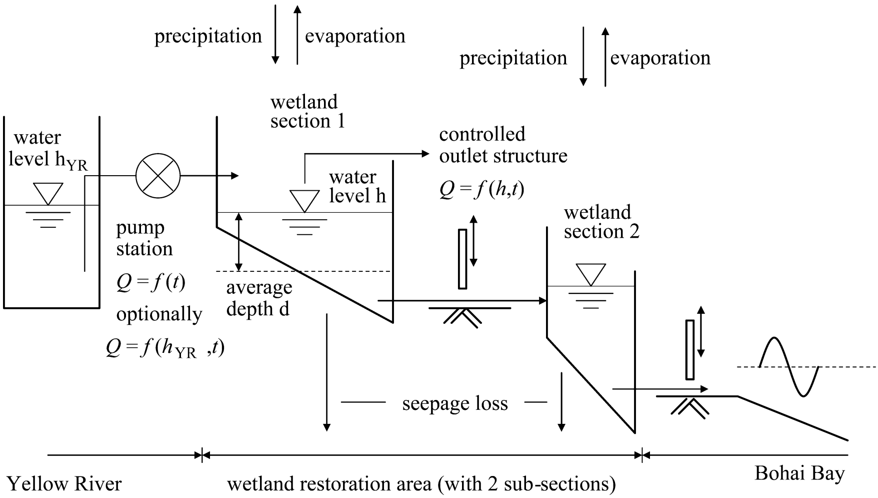


Fig. 6 Hydraulic implementation of the water resources management in the wetlands

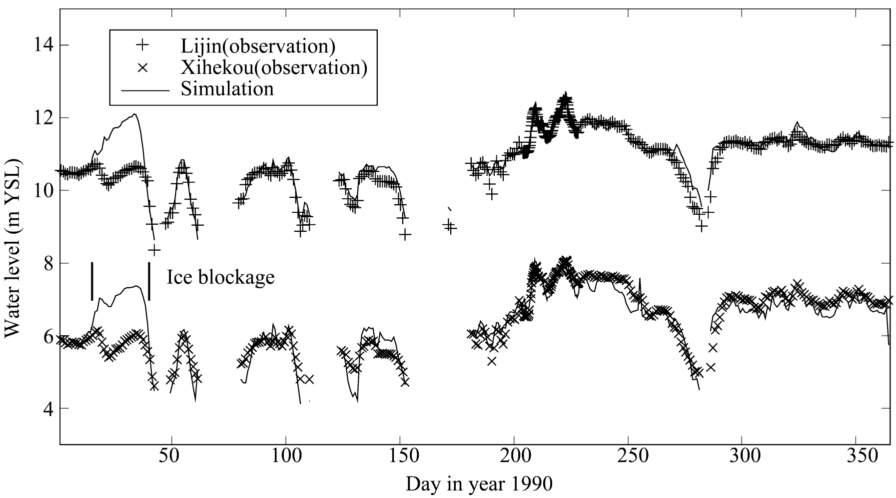


Fig. 7 Measured and simulated water levels at stations Lijin and Xihekou

Table 1 presents a quantitative analysis of the calibration results based the indicators bias, standard deviation, and Nash – Sutcliff model efficiency. If the period with ice blocking is excluded, the indicators show a very good model agreement.

A comparable calibration of the channel network cannot be done because of a lack of available observations. Therefore, we focus mainly on the correct water balance of the system, i. e. the consideration of the observed discharges from the Yellow River to the channel network and into the Bohai Bay.

4 Summary and conclusions

A 1D – 2D model for the Yellow River Delta is set up on the basis of the SOBEK modelling system. The model contains a 1D network model for the major waterways and a 2D model for simulating the overland flow in the wetlands in the Yellow River Natural Reserve.

Table 1 Calibration of water levels

	Bias(cm)	Standard Dev(cm)	Nash – Sutcliff(–) *
year 1990:			
LiJin	14	30	0.84
XiHeKou	2	43	0.76
year 1990 exept 16 – 1 till 8 – 2:			
LiJin	8	16	0.96
XiHeKou	–7	28	0.89

* Nash – Sutcliff model efficiency (Nash and Sutcliffe, 1970) – a perfect model is indicated by a model efficiency = 1。

The model has been calibrated and verified with field data collected in the main course of the Yellow River. Very good agreement between observed and simulated water levels in the YR has been achieved. SOBEK proved to be an efficient instrument for performing a hydraulic simulation over a period of several years.

The model is suitable for designing detailed measures for restoring the wetlands. It performs detailed simulation of channel flow, taking into account controlled and uncontrolled hydraulic structures. It dissolves the tidal cycle in detail and supplies more information than water balance modelling.

The model can be made even more a powerful tool if more field data will be implemented. Detailed data of measured cross – sections for channel network, additional data for Yellow River (also to check morphological developments), data for calibrating the overland flow, etc. are required for further improvement of the model.

The model can also be extended by a water quality module for simulating e. g. salinity and suspended sediment.

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Estimation of Daily to Annual Regional Evapotranspiration with MODIS data in the Yellow River Delta Wetland

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Abstract: Evapotranspiration (ET) from the wetland of the Yellow River Delta (YRD) is one of the important components in the water cycle, which represents the water consumption by the plants and evaporation from the water and the non – vegetated surfaces. Reliable estimates of the total amount of water required to protect this natural environment are necessary. Due to the heterogeneity of the vegetation types and canopy density and of soil water content over the wetland (specifically over the natural reserve area), it is difficult to estimate the regional evapotranspiration extrapolating measurements or calculations done locally for a specific land cover type. Remote sensing can provide observations of land surface conditions with high spatial and temporal resolution and coverage. In this study, a model based on the Energy Balance method was used to calculate daily ET using instantaneous observations of land surface reflectance and temperature from MODIS when the data were available on clouds – free days. A time series analysis algorithm is then applied to generate a time series of daily ET over a year period by filling the gaps in the time series due to clouds. A detailed vegetation classification map is used to help identifying areas of various wetland vegetation types in the YRD wetland. Such information is also used to improve the parameterizations in the energy balance model to improve the accuracy of ET estimates.

This study shows that spatial variation of ET is significant over the same vegetation class at a given time and over different vegetation types in different seasons in the YRD wetland.

Key words: energy balance, remote sensing, time series, evapotranspiration, Yellow River Delta wetland

1 Introduction

The Yellow River run into Bohai Sea between the Bohai gulf and Laizhou gulf, coming to being the widest, the most integrated and the youngest natural wetland ecosystem. Recently, because of the decreasing supply of water and sediments, built – up of dikes along the river, agriculture exploitation and urbanization, the wetland ecosystem in Yellow River Delta is under significant environmental stress. Rational exploitation of water resource becomes an important, hotspot problem now. Evapotranspiration (ET) from the wetland of the Yellow River Delta (YRD) is one of the important components in the water cycle, which represents the water consumption by the plants and evaporation from the water and the non – vegetated surfaces. Moreover, better understanding of wetland response under different water supply and consumption scenarios will help the water authority to release water amount in different seasons on a scientific basis.

Due to the heterogeneity of the vegetation types and of canopy density over the wetland (specifically over the natural reserve area), it becomes difficult to estimate the regional evapotranspiration by means of measurements done locally for a specific land cover type. Remote sensing can provide observations of land surface with high spatial and temporal resolution and coverage. Therefore, monitoring of ET in the YRDW using the remote sensing technology is a very important contribution to scientific water management in the wetlands area.

A model based on the Energy Balance was developed to estimate regional ET using observations of reflectance and land surface temperature from satellites (Menenti and Choudhury, 1993, Su, 2002, Jia et al., 2003). This model has been evaluated over many experimental areas with different surface types.

In this study, we have used this method to calculate daily ET, using instantaneous observations of land surface reflectance and temperature from MODIS (MODerate – resolution Imaging Spectroradiometer) when the data were available on clouds – free days. A time series analysis algorithm is then applied to generate a time series of daily ET over a year period by filling the gaps in the time series due to clouds. A detailed vegetation classification map is used to help identifying areas of various wetland vegetation types and their spatial distribution over the YRD wetland. Such information is also used to improve the parameterizations of the energy balance based model to improve the accuracy of ET estimates.

2 Study area and Data

2.1 Study area

The study area of the Yellow River Delta (YRD) Wetland is located in Dongying of Shandong province in China between the Bohai gulf and Laizhou gulf. The wetland is located between 118°10′E and 119°15′E, and 37°15′N and 38°10′N. The administrative districts include Dongying district, Hekou district, Guangrao county, Lijin county and Kenli county. This region has prominent monsoon climate characterized as warm temperate zone with typical rainfall season in June, July and August. The wetland area covered by this study starts at Yuwa and ends at Tiaohekou in the north and Songchunrong river in the south. The total area is about 2,400 km^2 characterized by various wetland vegetation types, agricultural crops and other land cover types. Two nature reserve areas, currently recovering, have been identified by the national nature reserve and protection program in recent years. One is named Northern Nature Reserve (NNR) area located in the north of the YRD with an area about 35 km^2. The other one is named Southern Nature Reserve (SNR) area located in middle – east of the YRD with an area about 201 km^2.

2.2 GIS and Satellite Remote Sensing Data

2.2.1 Land cover map

A land cover map was generated based on one high spatial resolution (pixel size 2.5 m × 2.5 m) SPOT satellite image. Intensive field investigation was done in the summer of 2006 to collect geo – information and vegetation information in the YRD wetland area, which helped to have better classification of vegetation using SPOT images. The original very detailed vegetation classes were grouped into seven major vegetation classes: reed – swamp, reed – meadow, Chinese tamarisk, Suaeda heteroptera and Black Locust Forest, Chinese tamarisk / Suaeda heteroptera (mixture of the two classes), agricultural croplands, and another seven classes dominated by intertidal / foreshore, bare saline soil, inland (open fresh) water, brine pond, shrimps pond and buildings/towns. Statistics of fractional area of each landsurface/vegetation type in the whole wetland area and in the two natural reserve areas are given in Table 1. The high spatial resolution vegetation map is also resampled to 1km resolution to match the pixel size of MODIS images used in the estimation of evapotranspiration using the surface energy balance model described in section 3.

Table 1 Fractional areas of the major vegetation classes and other land surface types in the whole YRD wetland and in the northern and southern natural reserve areas (in percentage)

Classification	Whole YRD wetland(%)	NNR (%)	SNR (%)
Reed – swamp	3.8	—	16.0
Reed – meadow	10.3	42.9	7.0
Chinese tamarisk	7.4	51.4	7.5
Chinese tamarisk/Suaeda heteroptera	4.3	5.7	4.0
Black Locust Forest	2.7	—	10.4
Suaeda heteroptera	2.2	—	2.5
Cropland	30.1	—	10.9
Tideland/Foreshore	16.5	—	33.8
Bare soil	3.8	—	0.5
Saline soil	1.7	—	—
Inland (open fresh) water	4.3	—	5.0
Shrimp pond	3.8	—	1.5
Brine pond	3.0	—	—
Buildings/Towns	2.7	—	—
Others	1.6	—	1.0

2.2.2 MODIS data

Land surface temperature, vegetation cover and land surface albedo are three essential surface variables in determining heat and water exchanges between land surface and the overlying atmosphere and the partitioning of available energy between soil and vegetation. We have used data from MODIS for its optimal spectral bands, frequent re – visits and user – friendly data products. The utilized MODIS standard products in this study are listed in Table 2 which are available from the MODIS data distribution website. Single band reflectance in each of the seven optical bands provided by MOD09A1 is converted to albedo using the algorithm proposed by Liang (2000).

Table 2 MODIS standard products and land surface parameters

MODIS standard products	Land surface parameter	Spatial resolution(m)	Temporal resolution(d)
MOD09A1	Land surface reflectance, (NDVI)	Bands 1 ~ 2: 250 Bands 3 ~ 7: 500	8
MOD11A1	Land surface temperature	1,000	1
MOD15A2	Leaf area index (LAI)	500	8

2.2.3 Meteorology Data

Meteorological data needed by the surface energy balance model to estimate evapotranspiration include wind speed, air temperature, humidity, air pressure, solar radiation, etc. In this study, meteorological data at Dongying and Kenli meteorological stations were collected. Other data, like Pan evaporation, precipitation, daily solar hours, daily clouds amount, are also collected.

3 Methodology

3.1 Energy Balance based model for evapotranspiration estimate

Only a brief description is given in this paper, readers are referred to Menenti and Choudhury (1993), Su (2002) and Jia et al. (2003) for the details of the model SEBS.

The surface energy balance is commonly written as

$$R_n = G + H + \lambda E \tag{1}$$

where R_n is the net radiation, G is the soil heat flux, H is the turbulent sensible heat flux, and λE is the turbulent latent heat flux.

The net radiation flux is the difference between downwards and upwards radiation fluxes at the land surface both in shortwave length and longwave length, and is calculated by

$$R_n = (1-\alpha)R_{swd} + \varepsilon_s \varepsilon_a R_{lwd} - \varepsilon_s \sigma T_s^4 \tag{2}$$

where α is the land surface albedo, R_{swd} is the downward solar radiation, R_{lwd} is the downward longwave radiation, ε_a is the air emissivity, ε_s is the emissivity of the surface, T_s is the surface temperature, σ is the Stefen – Bolzmann constant.

Soil heat flux is the heat flux into soil or water. Generally, it is determined by a relationship with net radiation as the following

$$G = R_n[\Gamma_c + (1-f_c)(\Gamma_s - \Gamma_c)] \tag{3}$$

We assumed the ratio of soil heat flux to net radiation $\Gamma_c = 0.05$ for full vegetation canopy and $\Gamma_c = 0.315$ for bare soil. An interpolation is then performed between these limiting cases using the fractional canopy coverage f_c. The ratio is set as 0.5 for water surface.

Sensible heat flux is calculated using Monin – Obukhov Similarity (MOS) theory knowing atmospheric conditions and surface conditions. The atmospheric conditions are characterized by windspeed, air temperature and humidity at a reference height in the near surface layer or at the blending height of atmospheric boundary layer. The surface conditions are characterized by surface or canopy roughness length both for momentum and for heat transfer, fractional vegetation coverage, land surface albedo and temperature. Equations are not given here, instead we will give a brief description on the determination of some crucial surface parameters for the wetland in section 3.2.

Latent heat flux is then calculated as the residual of the energy balance equation Eq. (1). Latent heat flux is converted to evapotranspiration ET in mm.

After all the terms in the energy balance are determined, the evaporative fraction, i.e. the energy used for the evaporation process divided by the total amount of energy available for the evaporation process, is then calculated by

$$\Lambda = \lambda E / (R_n - G) \tag{4}$$

3.2 Total daily ET

Since all the terms in the energy balance equation are estimated using instantaneous observations by MODIS, the calculated instantaneous ET must be integrated to a daily total ET. This is based on the assumption that evaporative fraction remains constant approximately though the sensible and latent heat fluxes fluctuate strongly during a day. This leads to the equation for total daily ET,

$$ET_{daily} = 8.64 \times 10^7 \times \Lambda \times (R_{ndaily} - G_{daily}) / (\lambda \rho_w) \tag{5}$$

where, R_{daily} is the daily net radiation, G_{daily} is daily soil heat flux, ρ_w is density of water, λ is the latent heat of water taken as 2.47×10^6 J/kg. For a clear day, the daily average soil heat flux cancels out for positive fluxes occur during night and negative during daytime.

3.3 Annual ET by Gap – filling method

Satellite based methods to estimate evapotranspiration often encounter the problem of clouds contamination so that limited numbers of images are available for the ET calculation during a year cycle. To fill the gaps on the missing days due to clouds, a time series analysis algorithm HANTS (Verhoef, 1996) is used to generate a gap – filled new set of ET maps based on a certain number of clouds free observations. The algorithm involved in HANTS allows the use of irregularly spaced observations over a certain period and allows the user to choose the frequencies of the periodic functions used to model the observed time series. As such, it is possible to follow to a certain extent the fluctuations of the water exchange between land surface and the atmosphere due to changes in weather and surface water conditions.

4 Results and Discussions

4.1 Method evaluation

4.1.1 Evaluation of the modeled evapotranspiration

Since there were no direct measurements of latent heat flux or actual evapotranspiration over the wetland in 2005, we have proposed alternative methods to evaluate the calculated ET. The principle of the evaluation is based on the assumption that evapotranspiration of wet vegetated surfaces should be very close to the reference evapotranspiration (denoted as ET_{ref}) derived from FAO56 Penman – Monteith equation (Allen et al., 1998). In the YRD wetlands the ideal wet vegetated targets are "reed swamp" and "Suaeda heteroptera". Soil water conditions may vary due to less water flow to the wetland or less precipitation for a certain period, "reed swamp" or "Suaeda heteroptera" may not be all the time under water unlimited condition. To select pixels which were under wet conditions, pixels with "reed swamp" standing perennially in water and pixels with "Suaeda heteroptera" near to the inter – tidal areas are identified first by checking the vegetation classification map. As second step, land surface temperature of pixels classed as "reed swamp" and "Suaeda heteroptera" is plotted against albedo. Wet pixels are identified by both lower LST and lower albedo (figure is not shown). The evaluation of the model estimated evapotranspiration is done using these wet targets pixels.

4.1.2 Gap – filled ET on cloudy – days by time series analysis

The time series analysis algorithm HANTS is used to fill gaps in the modeled evapotranspiration. After preliminary clouds check on the MODIS images, 153 images are selected as quasi cloud – free images though there might still be some pixels contaminated by clouds in the images on different days. The estimated daily ET maps using MODIS observations on the 153 quasi – clouds – free days are taken as the basis for time series analysis carried out by HANTS.

Fig. 1 shows examples of the time series of daily ET values in 2005 estimated by the SEBS model and the gap – filled ET values after using HANTS for one pixel of wet 'reed swamp'. The reference ET estimated from FAO56 equation (ET_{ref}) is also given. The gap – filled curve of ET have followed the ET_{ref} during the year cycle indicating that the algorithm HANTS is efficient to re – produce the time series of ET values with acceptable errors. Outliers (outliers mean that estimated ET is far below the gap – filled curve) are supposed to be from pixels with clouds. It appears that the frequency and duration of the gaps is limited and not sufficient to degrade the information on the temporal evolution of vegetation cover and surface temperature contained in the irregularly spaced observations retained after pixel – wise clouds screening.

A smaller dataset was made out of the 153 quasi – clouds – free images by meeting the criterion "daily amount of clouds measured at Dong Ying meteorological station is zero". There are 67 days that meet this criterion over the year 2005. Fig. 2 shows the values of the estimated ET by SEBS, the gap – filled ET by HANTS, reference ET and Pan evaporation on the 67 clouds – free days. It is apparent to see that some outliers remain still (outliers mean that estimated ET is far below the

ETref) after the clouds – screening procedures.

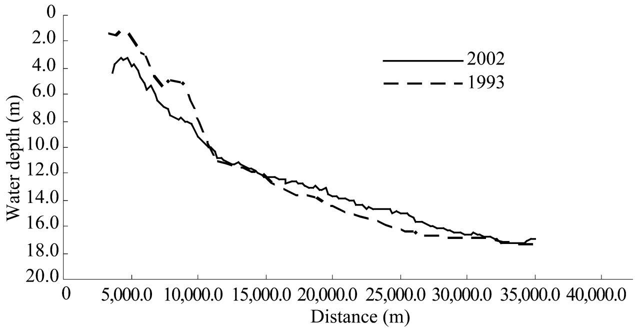

Fig. 1 Time series of estimated daily ET in 2005 (ETest, '+') and the gap – filled ET by using HANTS (ETest_hants, '·') in one pixel of 'reed – swamp'. ETref is given as a reference ('□').

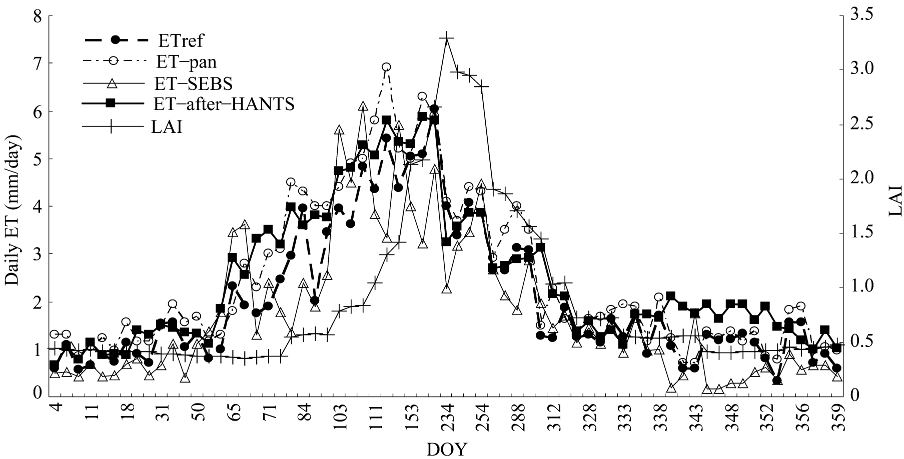

Fig. 2 Comparison between estimated daily ET, estimated daily ET after gap – filling by HANTS, reference ET and Pan evaporation measured in Dong Ying meteorological station over 'clouds – free' days in 2005

4.1.3 Relationship between vegetation potential ET and reference ET

Commonly, maximum ET of a vegetation canopy is calculated from ET value of a reference crop, i.e. reference ET as mentioned earlier by multiplying a 'crop coefficient',

$$ET_{max\_veg} = K_c\, ET_{ref} \tag{6}$$

Our analysis on the regression between the estimated ET (both before and after applying HANTS) of two wet target (reed – swamp and Suaeda heteroptera) and the ET_{ref} are shown in Table 3. The actual ET of the two wet target vegetation types can be considered their maximum ET since there was no water limits. The modeled actual ET values shown in Table 3 are the average over selected wet pixels corresponding to the 'reed swamp' and 'Suaeda heteroptera' respectively for each of the 67 clouds – free days. When the regression was forced through the origin, the slope of the regression line can be interpreted as the bulk 'crop' coefficient. After applying HANTS to the estimated ET, the generated new ET values are much closer to the ET_{ref}.

Different slopes are indeed found in different growing seasons (Table 3). Since the selected pixels are supposed to be well watered throughout the year (except in the winter months when it might be frozen for some days), changes in slope in different seasons are likely due to changes in leaf area index. Such changes are significant in the growing season when leaf area is increasing dramatically (April to June). However, a big shift is observed between the phase of daily ET and phase of vegetation growth presented by LAI (Fig. 2). Weather condition is another possible cause. July and August are in rainfall season in the YRD wetland, heavy rainfall and low solar radiation resulted in low ET due to too high atmospheric moisture and low available energy for evapotranspiration. The combination of canopy growth and atmospheric conditions may lead to the consequence that simple empirical relationship may be not sufficient for actual ET calculation for the wetland vegetation canopies.

Experimental study on reed beds ET over Ramsar wetland in UK (Peacock and Hess 2004) showed that ET from reed bed is generally smaller than ET_{ref}. Only on the days with a combination of greater cloud cover, lower radiation and high rainfall the ratio of the two are close to unity. We have also found smaller slope in regression between the estimated ET of reed – meadow and ETref. For reed – meadow class in the YRD wetland, reed plants were not in standing water perennially as reed – swamp. There is very rare information available in the literature about 'crop coefficient' for reed beds from measurements.

Table 3 Regressions of estimated ET with reference ET over 'reed – swamp' and 'Suaeda heteroptera' over clouds – free days in 2005 in the YRD wetland. (* **means too few points for regression**)

	Reed – swamp			Suaeda heteroptera
	Before HANTS	After HANTS	Before HANTS	After HANTS
Whole year	$ET_{est}=0.875,5\ ET_{ref}$, $R^2=0.72$	$ET_{est}=1.119,3\ ET_{ref}$, $R^2=0.81$	$ET_{est}=0.806,9\ ET_{ref}$, $R^2=0.46$	$ET_{est}=1.022,4\ ET_{ref}$, $R^2=0.62$
Jan. – March	—	$ET_{est}=1.240,9\ ET_{ref}$, $R^2=0.74$	—	$ET_{est}=1.177,5\ ET_{ref}$, $R^2=0.72$
April – June	—	$ET_{est}=0.500,7ET_{ref}+2.954$, $R^2=0.81$	—	$ET_{est}=1.609\ ET_{ref}+3.604,8$, $R^2=0.078,8$
	—	*	—	*
Oct. – Dec.	—	$ET_{est}=1.240,9ET_{ref}$, $R^2=0.737,6$	—	$ET_{est}=0.582,6\ ET_{ref}+1.154,1$, $R^2=0.46$

4.1.4 Spatial and temporal variability of daily ET

The full time series of the estimated daily ET after gap – filling by applying HANTS algorithm is analyzed for the three different vegetation types: reed – swamp, reed – meadow and Suaeda heteroptera (figures are not given here). For each vegetation type, the daily mean ET is averaged over all pixels with the same vegetation type in the YRD wetland in 2005. Spatial variability is significantly large over the same vegetation type on the same day characterized by the difference between the maximum and the minimum values of the same vegetation type over pixels on the same day. This is particularly obvious for reed – meadow which has large spatial variations of soil water content and fractional cover (Fig. 3).

In addition to the impact of growing season, large spatial variability in daily. ET over the same vegetation type makes the crop coefficient method difficult to use. Spatial variability in daily ET is caused by several factors, e. g. large spatial heterogeneity in vegetation density, spatial variation in soil water content, solar variation in space, ground water table variation in the wetland, etc.

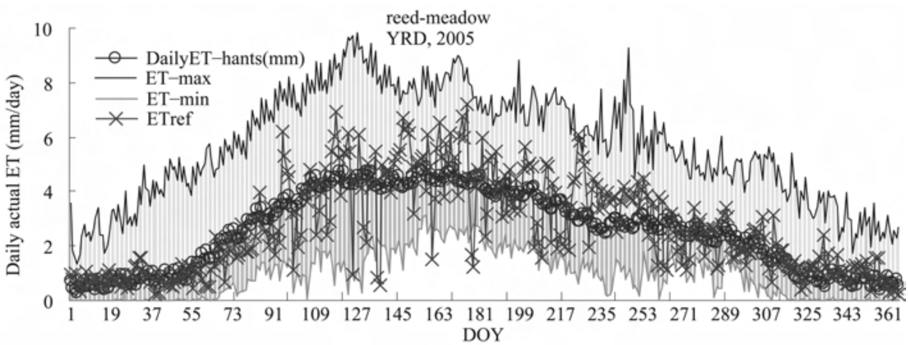

Fig. 3 After – HANTS daily ET averaged over all pixels of reed – meadow over the YRD wetland in 2005. Spatial variability is represented by the difference between maximum and minimum values of each day over the same vegetation type as 'reed – meadow' (shaded areas)

4.2 Seasonality and spatial heterogeneity of ET in the YRD wetland

Evapotranspiration in the YRD wetland shows strong seasonality as illustrated by the integrated monthly ET maps over April – May – June and over July – August – September. Along the course of the year 2005, monthly evapotranspiration followed the variations in annual meteorological conditions and vegetation growing seasons. As a consequence, larger values appeared in May, June and July with the peak of evapotranspiration about 130mm in June (Fig. 4).

Except winter months in January – February and November – December, ET patterns over the entire wetland vary dramatically in the growing seasons, particularly during April, May and June. Crops and grasslands were at the beginning stage of growth in April and May with lower LAI, the land surface was very close to bare soil with sparser leaves. The major contributor to the total ET in the drylands (including croplands, grasslands and trees) was soil. With insufficient rainfall in April and May, cropland may have low soil water moisture comparing to the swamp areas. The ET distribution in turn shows smaller values in the drylands (croplands, Black Locust Forest, and Chinese tamarisk), while increasing in steps to swampland vegetations with wetter soil (e. g. reed – meadow,), swampland vegetations in standing water (e. g. reed – swamp and Suaeda heteroptera) and inter – tidal zones which might be flooded by seawater or fresh water.

In June and July, a smaller difference in ET spatial variation between dryland and swampland vegetations is observed (monthly ET maps are not shown here). Vegetations in the drylands have developed during this period, implying that transpiration from well developed green plants is the major contributor to the total ET in dryland areas. Moreover, sufficient rainfall encountered in June and July ensured soil is in an optimal moisture condition both over dryland and swampland areas. Differences existed between vegetation in standing water (reed – swamp, Suaeda heteroptera), tideland, cropland vegetations and other wetland vegetations (Black Locust Forest, and Chinese tamarisk).

In September LAI of most vegetation species started decreasing due to senescence of leaves, which resulted in transpiration from vegetations, except those in standing water, to decrease sharply.

During the winter months, i. e. January/February and November/December, ET from the entire wetland area is quite uniform (maps are not shown).

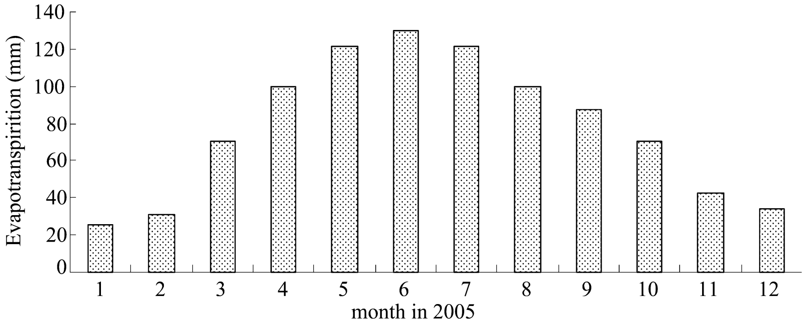

Fig. 4 Mean monthly ET in YRD wetland in 2005

4.3 Annual ET and wetland water requirements

4.3.1 The whole YRD wetland

The annual average of evapotranspiration over the whole study area of the YRD wetland is about 934 mm with a standard deviation of 452 mm. Large ranges of evapotranspiration are found between 400 mm on average observed in the class of towns and buildings and about 1,400 mm on average in the tideland/foreshore areas along the coast and in inland open water surfaces. The spatial distribution of evapotranspiration of various vegetations is also shown , with large heterogeneity as expected, in particular among dryland vegetation (e. g. croplands) and swampland vegetations in standing water (e. g. reed – swamp). Mean annual ET values of all major vegetations are listed in Table 4.

Areas of the classified land surfaces and amount of water used for evaporation or evapotranspiration are also given in Table 4. Among the vegetation classes, two wetland vegetations often in standing water, reed – swamp and Suaeda heteroptera, have the largest annual ET on average. The reed – swamp and reed – meadow have very close annual ET indicating that transpiration from plants is higher than from the interspersed water. Likely, water table is high enough for reed – meadow to pump ground water for transpiration, but this should be investigated in further studies.

Table 4 Annual mean ET and water requirements in the YRD wetland in 2005. ET_std denotes the standard deviation over space among the same class

Whole wetland	Areas (km^2)	ET (mm)	ET_std (mm)	ET ($10^8 m^3$)	ET_std ($10^8 m^3$)
Reed – swamp	99	1,036.6	195.3	8.552	0.193
Reed – meadow	315	934.2	171.1	7.707	0.539
Chinese tamarisk	198	822.8	197.3	6.788	0.391
Chinese tamarisk/ Suaeda heteroptera	127	889.1	215.7	7.355	0.274
Black Locust Forest	102	773.4	174.2	6.381	0.178
Suaeda heteroptera	53	1,099.4	236.4	9.070	0.125

Continued to Table 4

Whole wetland	Areas (km^2)	ET (mm)	ET_std (mm)	ET ($10^8 m^3$)	ET_std ($10^8 m^3$)
Cropland	825	833.8	164.8	6.879	1.360
Tideland/ Foreshore	455	1,433.8	291.0	11.829	1.324
Bare soil	107	716.6	206.1	5.912	0.221
Saline soil	46	910.2	271.7	7.509	0.125
Inland (open fresh) water	138	1,188.6	299.1	9.806	0.413
Shrimp pond	96	1,273.0	170.8	10.502	0.164
Brine pond	84	1,332.2	221.0	10.991	0.186
Buildings/Towns	82	470.2	187.8	3.879	0.154
Others	44	858.9	158.3	7.086	0.070
Total	2,771			120.246	5.717

Salty water bodies seem evaporating much more than open fresh water bodies in the YRD area in 2005.

The total amount of water evaporated by water bodies and soil lands and evapotranspiration from vegetation – soil/water canopies of the whole wetland area of about 277,100 hectares (2,771 km^2) in 2005 was about 120×10^8 m^3 with a standard deviation about 5.7×10^8 m^3. Since this is the actual ET from the area, it can be considered as the minimum water requirement by the wetland system for vegetation growth and water loss due to evaporation process to remain in its current conditions.

The total water needed by vegetation canopies in 2005 in the YRD wetland was about 52.7×10^8 m^3, of which about 45.9×10^8 m^3 were consumed by natural wetland vegetations with an areas about 89,400 hectares (894 km^2).

4.3.2 Water requirement in the Natural Reserve areas

One of the objectives of this study was to provide a picture of how much water is needed by the two nature reserve areas in the YRD wetland: the Northern Nature Reserve (NNR) and the Southern Nature Reserve (SNR). Such information is important both for water authority and Nature Reserve society.

Currently the NNR is defined as 3,500 hectares (35 km^2) and has only three major types of vegetations (many more vegetation types and species with very small and scattered areas were grouped into these three major classes). The annual total water consumed by the vegetations in the NNR in 2005 was about 0.318×10^8 m^3 with a standard deviation of 0.055×10^8 m^3 (Table 5).

Table 5 Annual mean ET and water requirements in the Northern Nature Reserve (NNR) area of YRD wetland in 2005. ET_std denotes the standard deviation over space among the same class

Northern NR	Areas (km^2)	ET (mm)	ET_std (mm)	ET ($10^8 m^3$)	ET_std ($10^8 m^3$)
Reed – meadow	15	1,234.8	199.2	0.222	0.036
Chinese tamarisk	18	843.0	51.4	0.152	0.009
Chinese tamarisk/ Suaeda heteroptera	2	867.5	89.8	0.017	0.002
Total	35			0.391	0.055

In the current definition of the two natural reserve areas, the area of SNR is much larger than the NNR with many more land surface and vegetation types than the NNR. The annual total water requirement by the SNR in 2005 was about 2.264×10^8 m^3 with a standard deviation about 0.3×10^8 m^3 (Table 6). Reed – swamp and reed – meadow among others are the major wetland vegetations to be protected and areas of reed – swamp and reed – meadow will be extended by replacing cropland in the future to recover the SNR wetland area for the purpose of protection of wetland birds. In 2005, water consumed by reed beds in the SNR was about 0.5×10^8 m^3. Under the similar meteorological conditions as in 2005, one can estimate how much water would be consumed in a year by the perspective reed beds assuming all or part of current croplands would be replaced by reed beds. By analyzing the monthly water requirement for each vegetation type, water supply planning can be scheduled according to the water needs in the growing seasons of the major vegetation types in the nature reserve area.

Table 6 Annual mean ET and water requirements in the Southern Nature Reserve (SNR) area of YRD wetland in 2005. ET_std denotes the standard deviation over space among the same class

Northern NR	Areas (km^2)	ET (mm)	ET_std (mm)	ET ($10^8 m^3$)	ET_std ($10^8 m^3$)
Reed – swamp	32	1,131.3	129.8	0.362	0.042
Reed – meadow	14	982.6	79.4	0.138	0.011
Chinese tamarisk	15	1,019.0	135.3	0.153	0.020
Chinese tamarisk/ Suaeda heteroptera	8	1,018.1	142.0	0.081	0.011
Suaeda heteroptera	5	1,099.4	0.0	0.055	0.000
Black Locust Forest	23	950.6	182.2	0.219	0.042
Cropland	22	986.7	153.1	0.217	0.034
Tideland/Foreshore	68	1,295.1	210.3	0.881	0.143
Bare soil	1	716.6	0.0	0.007	0.000
Inland(open) water	10	1,167.8	41.2	0.117	0.004
Shrimp pond	3	1,153.6	146.1	0.035	0.004
Total	201			12.265	0.311

Water supply to the natural reserve areas can be scheduled according to the consumed water by the wetland vegetations on the basis of estimated daily and monthly ET.

5 Conclusions

Through this study, we can draw the following conclusions:

(1) Evapotranspiration over the YRD wetland was estimated using remote sensing observations of land surface parameters. The calculation was first done using instantaneous MODIS observations by taking into account the detailed vegetation classifications to improve the parameterizations in the model used. Daily values of evapotranspiration were obtained by integrating the instantaneous values assuming a constant evaporative fraction during daytime. Comparison of the estimated daily ET over wet targets showed consistent trends with the reference ET values from FAO56 formula using meteorological measurements indicating that the model performance in simulating daily ET is acceptable. A method was proposed to fill the gaps in ET estimate on cloudy days when the satellite observations, in particular the land surface temperatures, were not available. Though the method needs to be carefully evaluated using in – situ measurements of land surface fluxes or actual

evapotranspiration, the comparison between the trends in the time series of the gap – filled daily ET over wet targets during the year 2005 and the reference ET from FAO56 using meteorological data showed good consistency. The gap – filled daily ET might still be with relatively larger errors, while the monthly and yearly values of ET are expected to achieve good accuracy, since random errors are filtered out by averaging.

(2) In the YRD wetland area, spatial variability in daily, monthly and annual ET is significant due to various wetland vegetations, their heterogeneity in space and different growing seasons, and variation in soil water content. Seasonal variation in the ET of the YRD wetland is very strong and varying among different vegetations, which leads to the fact that water requirement by different wetland vegetations and agricultural crops are changing with vegetation phenology and the wetland weather conditions.

(3) Classical 'crop coefficient' method may not be suitable for wetland ET estimates due to the complications of land surface properties characterized both by various wetland vegetation types and by varying soil water content over the YRD wetland. Method for regional ET estimates using remote sensing observation as demonstrated in this study is a promising and powerful tool for wetland ET monitoring.

(4) Further study should focus on detailed analysis on the relationship between ET from different vegetation and ground water table, and vegetation conditions (e. g. LAI). The latter will need to use remote sensing images with higher spatial resolution. Moreover, careful evaluation of the parameterizations in the model used and the method used for gap – filling should be in the consideration in the further study.

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Application of a Distributed Hydrological Model on Runoff Simulation in the Lower Weihe River

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Abstract: With the wide use of distributed hydrological models, YRCC has been carrying out research on application of a distributed hydrological model in the source area of the Yellow River and the lower Weihe River through Sino – Dutch project, and has achieved some good results. The distributed hydrological model consists of land and river flow components, the model input is the rainfall, snowmelt and evapotranspiration derived by the Energy and Water Balance Monitoring System or observed rainfall and runoff data at hydrological stations. The model has been put into use in simulating the daily runoff process of 2003 and 2005 at major hydrological stations of Xianyang, Lintong and Huaxian on the lower Weihe River, and good results have been achieved. This shows that the distributed hydrological model adopted can fundamentally reflect the daily runoff process of the basin.

Key words: distributed hydrological model, effective rainfall, runoff simulation, the lower Weihe River

1 Introduction

In recent years, based on the platform of the Sino – Dutch cooperative project "Establishment of a Satellite Based Water Monitoring and Flow Forecasting System in the Yellow River Basin", YRCC has set up runoff forecasting system in the source area of the Yellow River and flood forecasting system in the lower Weihe River, the core of both systems is a distributed hydrological model that is a large – scale spatial distribution grid based distributed hydrological model developed by UNESCO – IHE whose one of cooperative partners of Sino – Dutch project. The input of the model is the rainfall, snowmelt and evapotranspiration derived by the Energy and Water Balance Monitoring System of the project and observed runoff data at hydrological stations, and the model can be used for runoff / flood process forecast and simulation. The grid resolution is of 5 km × 5 km. The model has been applied on runoff simulation in the source Yellow River (122,000 km^2) and the lower Weihe River (19,800 km^2) with satisfactory results achieved.

This paper describes the principle of the model and its application on daily runoff simulation in the lower Weihe River. For convenience, the model is called WHFS model for short in the following sections.

2 Description of the model

The WHFS model consists of land and river flow components and divides the basin into DEM grid cells while as a calculated cell for each. The land component accumulates lateral flow from each grid cell towards the river drainage system. The discharge is subsequently routed downstream to the outlet through the river network component. The parameters of the model have specific physical senses and can be calibrated directly using observed data or quoted indirectly from the similar research values in other basins presented by literatures.

2.1 The land component

The land component is structured as a single – layer grid simulated by two – dimensional lateral flow. For the imprecise knowledge about the subsurface structure and hydraulic properties, the model variable is characterized as total yield in each grid node. This approach shows good results in application of small scale basin with complex terrains (Venneker, 1996). Conceptually, each grid cell is regarded as a non – linear storage reservoir in which terrain topography is calculated explicitly. The input boundary variables for the land surface component are rainfall, snowmelt and actual evapotranspiration. These values are obtained from the EWBMS, which is directly coupled to the grid by alignment with the same node spacing (approximately by 5 km). The transport is simulated as a diffusion process.

In order to represent total outflow in a grid cell, we define the volumetric water potential per unit area, p, given by:

$$p = z + w \tag{1}$$

where: z is the surface elevation above a common datum and w is the water deficit below saturation with respect to the surface. Fig. 2 illustrates the concept. Given that in most cases $p < z$, the value for w will be negative.

The two – dimensional lateral flow between the grid cells redistributes the water potential and is represented by:

$$\frac{\partial}{\partial x}\left(D_x \frac{\partial p}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y \frac{\partial p}{\partial y}\right) = \frac{\partial p}{\partial t} + r - q_l \tag{2}$$

where: D_x and D_y are the horizontal diffusivities in x and y directions, respectively, r is the net rainfall rate and q_l is the lateral flux from the land cell towards the river channel, if present. For those cells connected to the river network, the lateral flow from the land component towards the river channel, Q_l is represented by

$$Q_l = D_r(p - p_r) \tag{3}$$

where: D_r is the diffusivity at the boundary between the river channel and the land cell connected to that river and p_r is the water level potential. It is important to note that the single – layer 2 – D representation (Eq. (2)) assumes that the vertical process scales are significantly smaller than the horizontal process scales.

The diffusivity is, however, not constant along the vertical profile. Moreover, D represents a vertically aggregated effective value that is likely to vary with the amount of water present. Therefore, the variation of D with the variation of water content along the vertical is represented by the relationship

$$D = D_0\left(\frac{w_m}{w_m + w}\right) \tag{4}$$

where: D_0 is the lateral diffusivity when the soil is just saturated, which is a constant value for a given location and w_m is the water content deficit at which $D = 0.5D_0$.

Since the water potential p varies in time, w and D also vary in time. The w_m controls the rate of change of D with respect to w. Fig. 3 shows the variation of D/D_0 with w for different values of w_m. It is observed that the shape of the curve can be varied considerably by changing w_m.

The parameterisation of the diffusivity (Eq. (4)) is analogous to that of the transmissivity in TOPMODEL (Beven and Kirkby, 1979; Beven, 2001). In the original form of the TOPMODEL, the lateral transmissivity T is given by:

$$T = T_0 \exp(-M/m) \tag{5}$$

where: T_0 is a lateral transmissivity when the soil is just saturated, M is a local storage deficit below saturation and m is a model parameter controlling the rate of decline of transmissivity along the soil profile. The basic distinction between the present approach (Eq. (4)) and TOPMODEL (Eq. (5)) is that the present approach represents transport non – linearity by a rational function, whereas TOPMODEL uses an exponential function. A comparison between the two functions, substituting values for w, M and w_m, m is shown in Fig. 1.

The diffusion flow Eq. (2) is described by using central finite difference method, then the total outflow in each node of the grid can be obtained.

2.2 The river flow component

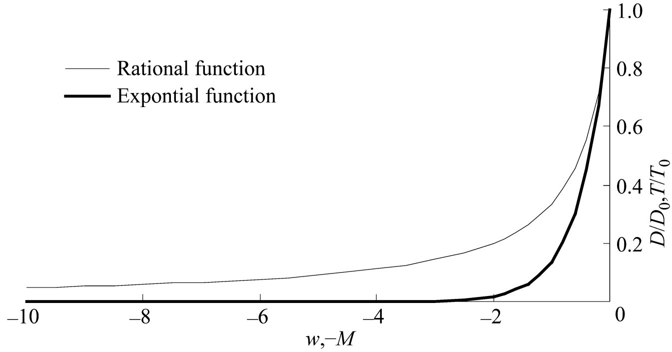

Fig. 1 Comparison of rational and exponential functions of *D* or *T*

The one – dimensional river flow component is based on the Muskingum – Cunge routing method (Cunge,1969) with lateral inflow. This model routes the flow through a river network from upstream to downstream points over specified time intervals Δt. The flow propagation from time step n to $n+1$ between points j to $j+1$ in a segment of the channel network is given by:

$$Q_{j+1}^{n+1} = C_0 Q_j^{n+1} + C_1 Q_j^n + C_2 Q_{j+1}^n + C_3 Q_l \quad (6)$$

where: $Q\ (j,n)$ is the discharge at a point j along the channel reach and time step n and Q_l is the lateral inflow contribution of the land component to the river network (Eq. (3)). Following Ponce (1986), the coefficients in Eq. (9) are given by

$$\left.\begin{aligned} C_0 &= \frac{-1 + C + R}{1 + C + R} \\ C_1 &= \frac{1 + C - R}{1 + C + R} \\ C_2 &= \frac{1 - C + R}{1 + C + R} \\ C_3 &= \frac{2C}{1 + C + R} \end{aligned}\right\} \quad (7)$$

here: C is the Courant number and R is the Reynolds number. The specification is shown in literatures.

2.3 Data requirements and fuzzy parameterization

Besides boundary input data, which come from the EWBMS, the data requirements for this model can be classified as three types, basic data, data for model calibration and verification and model parameter data.

The basic data concern the data regarding elevation, and river network and geometry. The elevation z can be obtained from the 1 by 1 km USGS DEM, which is re – sampled and aligned to the EWBMS remote sensing grids. Stream network and sub – basin boundaries are also available from the USGS HYDRO1k data. Channel cross – section (with the distance between two cross – sections nearby less than 10 km) data are available along the river owned by the Yellow River Conservancy Commission (YRCC). Daily rainfall at about 70 rain gauges and runoff data at 11 stations for several years are also available from the YRCC. These data will be used for model calibration and verification.

The model parameter data refer to the parameters that are used in the equations for the land and river flow components. In particular, they are the diffusivity for the land component and the Manning's roughness for the river flow component. The Manning's roughness can be estimated using the available literature, e. g. Chow (1959), expert judgement and field surveys (Maskey et al., 2000). Estimation of the diffusivity requires more careful treatment. The diffusivity is primarily a function of the soil types, vegetation and land use, and geology. A database of spatial information on soil type and land use is available for the entire basin of the Yellow River. Such information can be used to delineate areas of similar hydrological response, or hydrotopes. Based on the delineated hydrotopes, qualitative estimates of the diffusivity can be made.

Fuzzy variables are best suited to represent qualitative variables. Therefore, the diffusivity is defined as a fuzzy variable, which is derived using Fuzzy – If – Then rules for soil type and land use, which are also defined as fuzzy parameters. To further illustrate the Fuzzy – If – Then concept, let the types of soil and vegetation/land use be characterised as:

Soil type $= \{S_1, S_2, \cdots\}$

Vegetation/land use type $= \{V_1, V_2, \cdots\}$

Diffusivity $= \{D_1, D_2, \cdots\}$

Then the Fuzzy – If – Then rules look like, if soil type is S_1 and vegetation is V_1 then the diffusivity is D_k.

The advantage of defining the model parameter by a fuzzy membership function is that the estimated parameter is not a single value but constitutes a range of values with different level of belief representing the uncertainty in the parameter. This allows the possibility of assessment of uncertainty in the model output.

3 Application of the model

3.1 General situation of the lower Weihe River

The study area is the lower Weihe River, ranging from Zhangjiashan on the Jinghe River, Xianyang on the Weihe River and Zhuangtou on the Beiluohe River to estuary of Weihe River, with a drainage area of 19,600 km^2. The area belongs to the continental climate with average annual temperature of 6 ~ 13℃, average annual precipitation of 500 ~ 700 mm and of that reaches up to 800 mm on Qinling Mountain area. Most of rainstorm events occur in the period from July to October, and rainfall from July to September occupied 50% ~ 60% of the whole year. It often suffers continuous rainfall usually lasting for 5 ~ 10 days or even longer in this area, but with lower intensity.

As a main runoff producing area, the southern bank of the lower trunk Weihe River is located in the northern slope of the Qinling Mountain with steep topography and good vegetation. There are nine larger tributaries flowing into the Weihe River. The northern bank is Weibei tableland mostly with flat topography but small portion of mountainous and hilly area as well as small inflow water into Weihe River.

The runoff in this area mainly comes from reaches upper Zhangjiashan, Xianyang and tributaries on the southern bank, so Zhangjiashan and Xianyang stations are treated as inflow control boundaries (see Fig. 2).

3.2 Data selecting and processing

From late August to middle October in 2003, it experienced the most serious weather so – called "Fall Rains in West China" in the Yellow River basin since over ten years, there occurred six successive floods in the Weihe River. Affected by continuous rainfall events from late September to early October in 2005, people in the middle and lower Weihe River basin suffered the largest flood since 1981. Thus the data both in 2003 and 2005 are selected for simulation. As above mentioned, the input of WHFS model are rainfall and evapotranspiration derived from EWBMS, presently for the application and research of EWBMS in Weihe River is still ongoing, so here using observed rainfall data at rain – gauge stations ruled by hydrological departments. In convenience to analyze rainfall distribution, we totally selected 103 rain – gauge stations from the whole Weihe River basin, and among with 23 study areas. Runoff data using daily mean discharge at Zhangjiashan, Xianyang, Lintong and Huaxian hydrological stations, daily evaporation data observed by evaporation pan at Xianyang station.

As the input of the model is effective rainfall (the net rainfall after the total rainfall deduct the evapotranspiration) or total rainfall and evapotranspiration, but only Xianyang Station provides available observed evaporation data, so the rainfall and evapotranspiration data need to be made some processing before simulation. Two ways are adopted. One is using rainfall loss coefficient, based on the data analyzing of rainfall, runoff and evapotranspiration, the value ranges from 0.55 and 0.6, namely effective rainfall makes up 40% ~45% of total rainfall. Then the effective rainfall is interpolated into each grid cell by using the Space Interpolation Module in WHFS. The other is to estimate the actual evapotranspiration based on the evaporation data at Xianyang station, then the total rainfall and estimated evapotranspiration is interpolated into each grid cell respectively.

3.3 Simulation results and analysis

According to the different ways of effective rainfall estimation, three schemes are made as the input of the model:

Scheme 1: rainfall loss coefficient as 0.55;

Scheme 2: rainfall loss coefficient as 0.60;

Scheme 3: total rainfall and evapotranspiration.

In each scheme, two scenarios without any control boundary and with control boundary respectively is to be considered. Without any control boundary means that runoff simulation of Xianyang, Zhangjiashan, Lingtong and Huaxian stations are made only by using the input of rainfall data. With control boundary means that runoff simulation of Lintong and Huaxian station are made by using the input of rainfall and the inflow of Xianyang and Zhangjiashan (taking Xianyang and Zhangjiashan as boundary stations).

Fig. 3 and Fig. 4 shows main user interface and simulation result display interface of WHFS respectively. Runoff simulation results at Huaxian station are shown in Fig. 5 ~ Fig. 14.

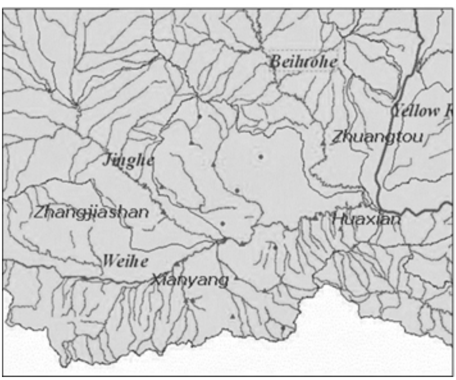

Fig. 2 Sketch map of the lower Weihe River

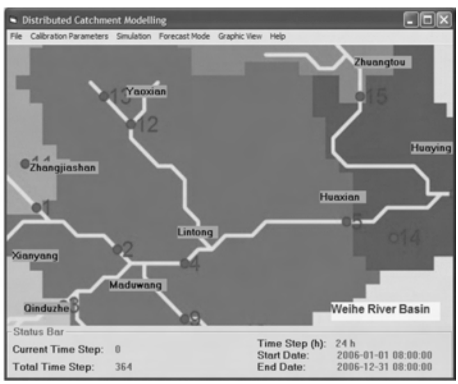

Fig. 3 Main user interface of WHFS

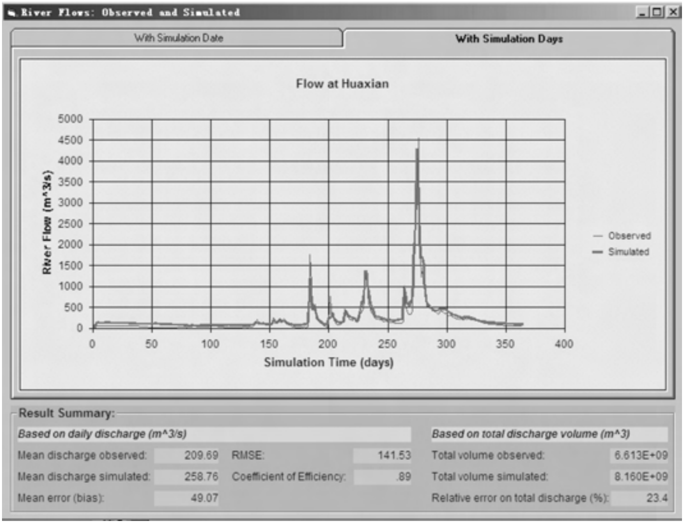

Fig. 4 Simulation result of WHFS

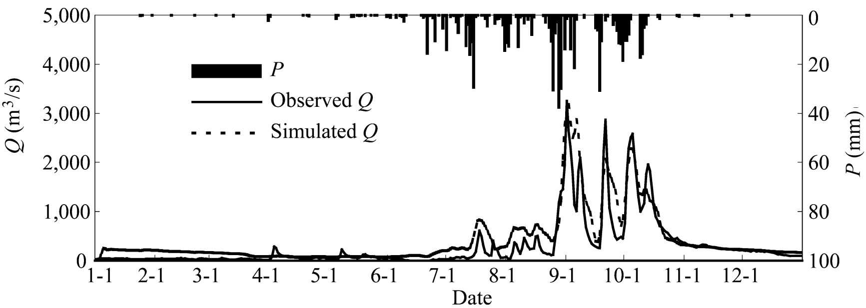

Fig. 5 Runoff simulation of Huaxian (2003, Scheme 1, without any control boundary)

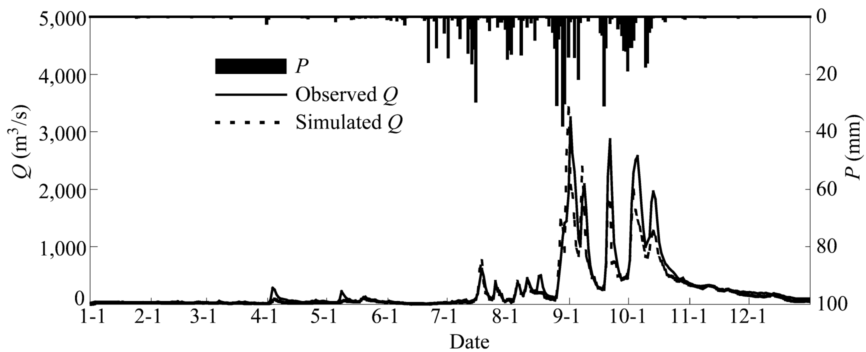

Fig. 6 Runoff simulation of Huaxian (2003, Scheme 1, with control boundaries)

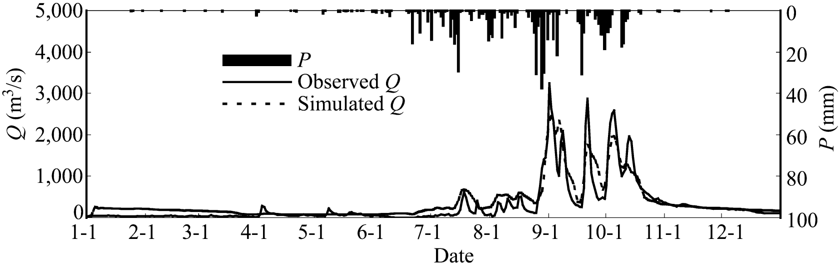

Fig. 7　Runoff simulation of Huaxian (2003, Scheme 2, without any control boundary)

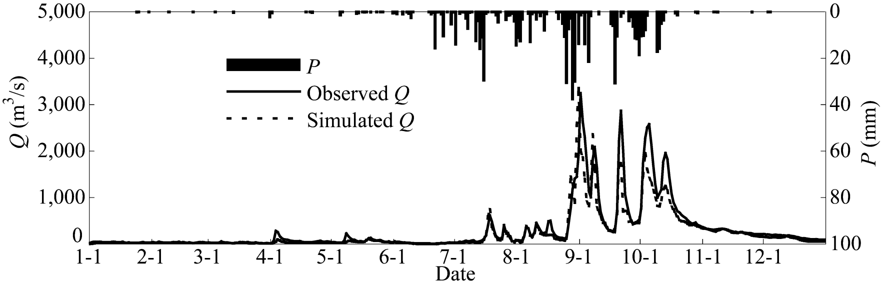

Fig. 8　Runoff simulation of Huaxian (2003, Scheme 2, with control boundaries)

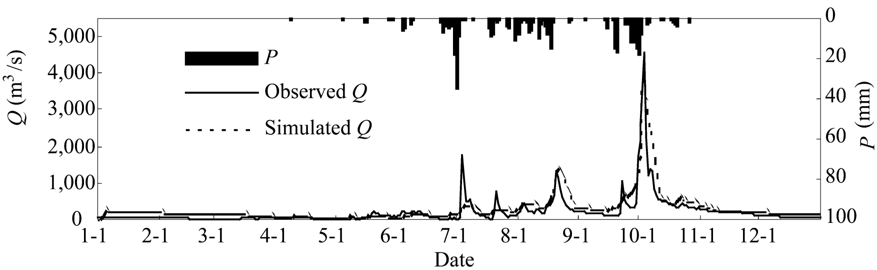

Fig. 9　Runoff simulation of Huaxian (2005, Scheme 1, without any control boundary)

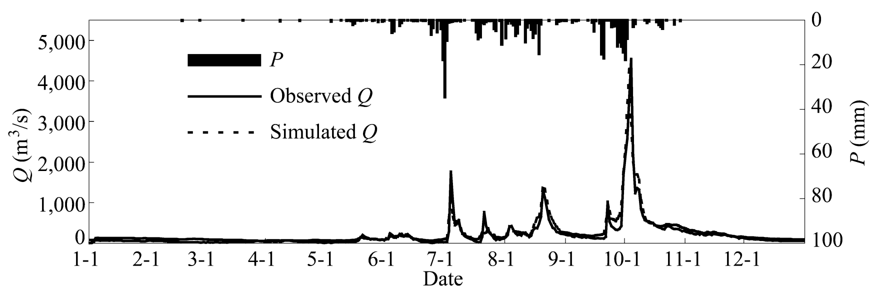

Fig. 10　Runoff simulation of Huaxian (2005, Scheme 1, with control boundaries)

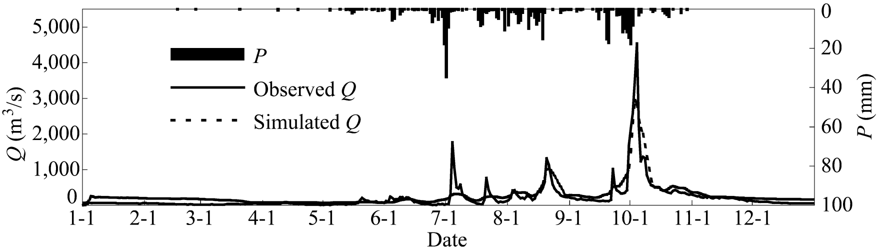

Fig. 11 Runoff simulation of Huaxian (2005, Scheme 2, without any control boundary)

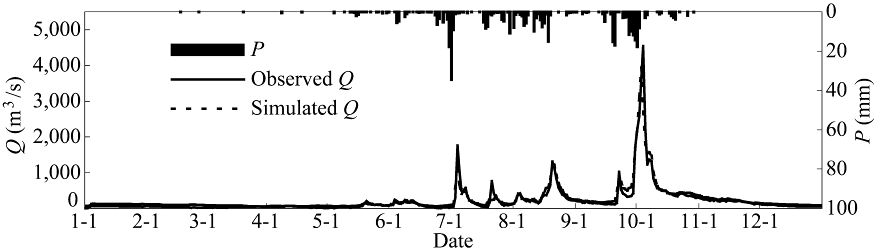

Fig. 12 Runoff simulation of Huaxian (2005, Scheme 2, with control boundaries)

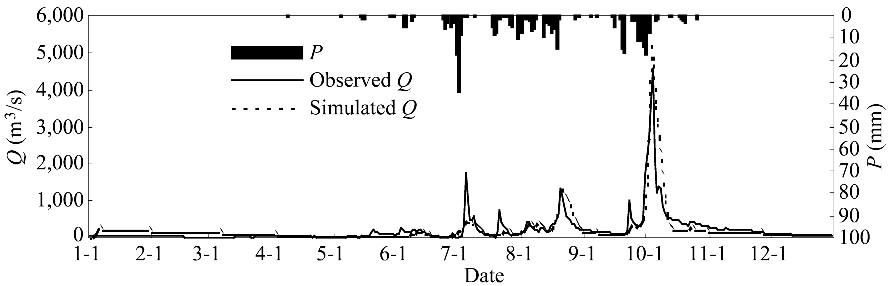

Fig. 13 Runoff simulation of Huaxian (2005, Scheme 3, without control boundaries)

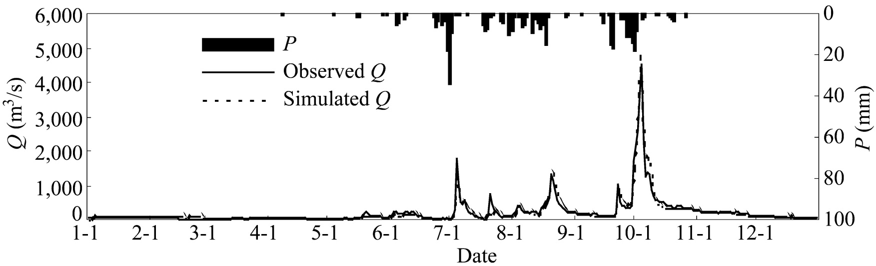

Fig. 14 Runoff simulation of Huaxian station (2005, Scheme 3, with control boundaries)

Table 1 and Fig. 5 ~ Fig. 14 shows that the simulation results are good and the simulated runoff trends are perfect, total error of the flood peak occurrence time is smaller. All of the large flood peaks can be simulated especially in 2005. But for some flood peaks in 2003, the simulation is not good, perhaps owing to the continuous flood events. The simulation of runoff for single flood is better than that of continuous floods.

Table 1 Simulation results of 2003 and 2005

Year	Station name	Deterministic coefficient					
		Scheme 1		Scheme 2		Scheme 3	
		Without any control boundary	With control boundary	Without any control boundary	With control boundary	Without any control boundary	With control boundary
2003	Xianyang	0.66		0.61			
	Lintong	0.43	0.51	0.32	0.28		
	Huaxian	0.80	0.74	0.70	0.80		
2005	Xianyang	0.74		0.58		0.72	
	Lintong	0.66	0.84	0.5	0.82		
	Huaxian	0.74	0.89	0.70	0.74	0.81	0.9

No matter which kind of the scheme, the simulation accuracy at Huaxian station is better. The deterministic coefficient of the runoff simulation is 0.7 ~ 0.9. At the same rainfall loss condition, the simulation accuracy with control boundaries is better than that without any boundary (except the Scheme 1 in 2003). The deterministic coefficients of runoff simulation of two scenarios in Scheme 3 are 0.81 and 0.90 respectively, which is the best one among three schemes. The reason is monthly evapotranspiration variation within a year is considered in Scheme 3. While rainfall loss coefficient used in Scheme 1 and Scheme 2 is fixed value inner year, means the evapotranspiration within a year is a constant. Actually the monthly evapotranspiration variation in a year is great. The simulation of Scheme 1 is a little bit better than that of Scheme 2. The simulation of 2005 is much better than that of 2003 at Lintong station. Especially for 2005, the deterministic coefficients of runoff simulation by Scheme 1 and Scheme 2 with boundaries achieved 0.84 and 0.82 respectively.

4 Conclusions

The WHFS distributed hydrological model has been applied to simulate runoff of 2003 and 2005 at major hydrological stations of Xianyang, Lintong and Huaxian on the lower Weihe River, with satisfactory results showing that the model can fundamentally reflect the daily runoff process of the basin. This is of great significance for understanding of the runoff generation mechanism and water circulation modeling in the basin, at the same time, exploiting a technical road for application of distributed hydrological models on flood forecast in the basin. Distributed hydrological models have high data requirement, especially for information of rainfall and evapotranspiration, etc. The modeling described in this paper uses observed rainfall at stations, restricted by sparseness of rainfall stations and lacking of evapotranspiration data, it failed to produce very ideal result, though distributed hydrological models have many advantages. With the advance of the research and application of EWBMS to rainfall and evapotranspiration estimation in the Weihe River basin, the accuracy of runoff simulation is expected to be further improved.

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Analysis and Design of Flood Remote Sensing Monitoring System in the Lower Yellow River

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Abstract: Flood remote sensing monitoring system in the Lower Yellow River was designed with remote sensing engineering idea. Based on geography information system (GIS), integrating image process, flood inundation interpretation and engineering disaster analysis, the system will do strong support for decision – making of flood control. The system requirement, work flow and function design were discussed and the water sideline automatic interpretation technology used in this system was introduced in this paper.
Key words: remote sensing application, flood remote sensing monitoring

The main channel length in the Lower Yellow River is 786 km. The area between levees in the Lower Yellow River is about 4,240 km^2, in which the floodplain area is about 3,500 km^2 and the farmland area is 3.74 million mu. There is about 1.8 million population living in 2,030 villages in the floodplain area. The floods happening frequency has been run – upping year by year for the increasing of the riverbed, which often frightened the safety of the residents living in floodplain area during flood season. It is significant for ensuring the safety of the resident, avoiding and mitigating economic loss in the area to quickly offer flood inundation area and to exactly evaluate the situation of floodplain disaster with remote sensing technology monitoring flooding in the Lower Yellow River.

In recent years, the application of remote sensing (RS) technology has been developed quickly in china. Its characteristics represented as multi – sources, quantification, making – toolkit, intelligentization, and analysis engineering (Qi Haoping, 2004). As the first phase project of building the Yellow River Remote Sensing Center, which is one part of the "Digital Yellow River (DYR)" (Li Guoying, 2003), this system was designed with the RS engineering idea, integrating with GIS, image processing, information interpreting, works and disaster information. Using radar satellite data, multi – spectrum satellite data, airborne data and ground remote sensing resources, flood monitoring can be implemented to quickly analysis the flood disasters in the floodplain area for decision – making in the weatherproof, all – day time and near real – time operation.

1 Requirements analysis

"Flood remote sensing monitoring system in the Lower Yellow River" will service the flood control leaders and people related, remote sensing analysis persons, with the remote sensing image collection, image processing, interpretation and product submission, forming the assistant analysis environment on the whole process of flood control. The whole process includes data collection, image processing and image analysis, and decision – making and the monitoring information querying for the leaders and some related staffs. There are different tasks and requirements during different processing phase.

1.1 Requirement of flood control decision – making

Monitoring results with flexibility, convenience, intuitionistic, entire situation, local situation, combination, disassemble and telescopic drawing and so on were required during flood control decision – making processing. The system should be integrated with existing flood control decision – making system. Also the system could conveniently display at different occasions, used in conference, discussion and other forms. The system should be operated at different system flat.

1.2 Requirement of decision – making analysis

The synthetically information contrast analysis such as remote sensing monitoring information, water information and engineering situation was required based on above – mentioned functions. The expert acknowledges can be input and updated in the system, so the image interpretation results can be corrected with man – machine mutual. The decision – making analysis can be done on the Web operation system and powerful desktop.

1.3 Requirement of information retrieving

RS monitoring information was required for general user. The synthetical RS monitoring information could be conveniently and flexibly provided for flood prevention analysis, usually using a Web manner.

1.4 Requirement of data service

The requirements of data service often can be divided into two classes: one is the submission of the RS monitoring results and other is the thematic map serve and data distribution. For the former, multi – information could be flexible combined under the system, and the system should have strong data process ability after the results submission to the user, all of which should be done on the desktop system. For the latter, the system should have powerful function such as sustaining the users to draw thematic maps, inputting the existent images, and supporting data distribution for information service. The information service needs higher access right, and their tasks often should do under the desktop system.

1.5 Requirement of remote sensing analysis

Automatic interpretation, interactive interpretation, and nickel – eye review interpretation was required for the remote sensing analysis. Also the system needs powerful commercial software system and performance ascendant hardware management system. The tasks often should do on the desktop system.

1.6 Requirement of image process

As the same as remote sensing analysis, image process needs powerful commercial software system and predominant hardware management system. The system plat of image process and analysis software should have the corresponding model at the professional level to different kinds of image data sources, so that all kinds of information data can be obtained in maximum on desktop system.

2 Work flow analysis

According to the analysis of the present flood – control status and further requirements of flood remote sensing monitoring in the Lower Yellow River, the working flow of flood monitoring mainly include five stages i. e. data collection, image process, image interpretation, assistance analysis and decision – making, which were shown as Fig. 1. Flood control operation includes the analysis of floodplain disaster, water influence and engineering danger.

2.1 Working flow

Data acquisition: The collected data include satellite remote sensing image, airborne image and ground observing data by ground remote sensing system carried on vehicle. Satellite data is collected from data providing commerce; Airborne data is collected based on actual situation of flood control; Ground observation data can be obtained through field remote sensing monitoring system carried on vehicle.

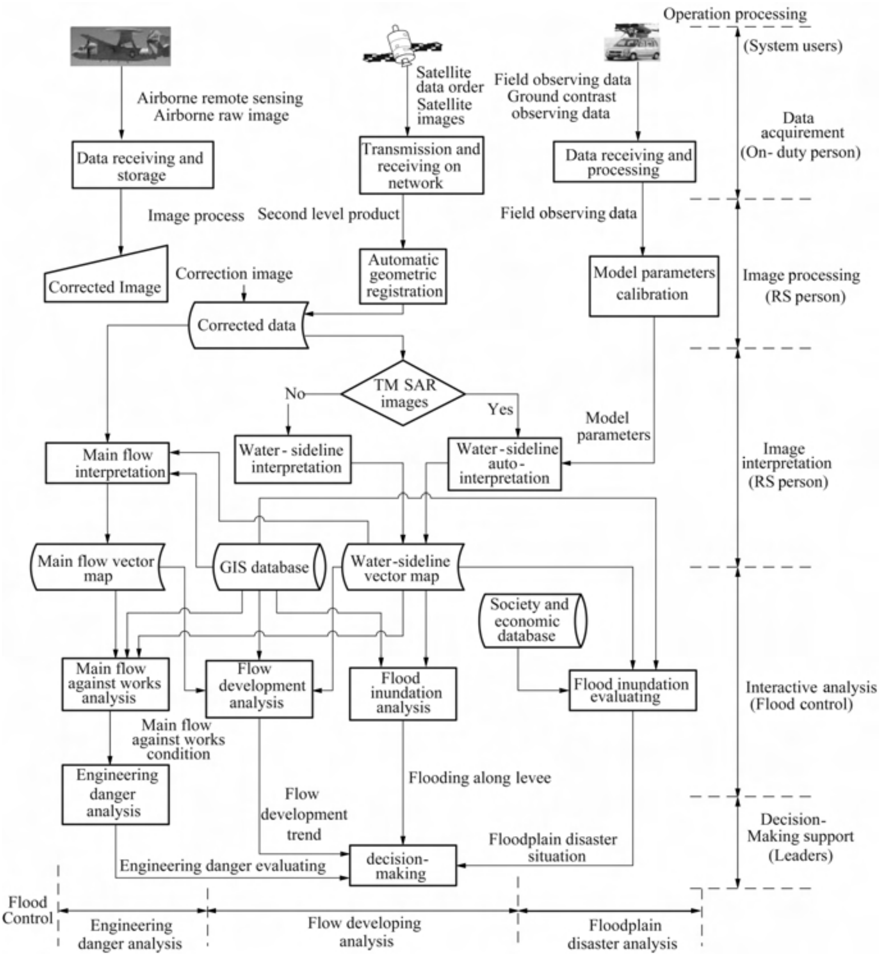

Fig. 1 Working flowing of RS flood monitoring system

Image process: The data correction processing will be done manually for airborne data and automatically for satellite remote sensing data. Ground observation data is used to calibrate the parameters of the automatic interpretation model.

Interpretation: For the TM and SAR images, water sideline can be interpreted automatically, and others can be interpreted manually. The main flow can be interpreted interactively. The condition of main flow against works can be interpreted interactively also.

Assistant analysis: According to the interpretation results of water sideline, main flow and the situation of main flow against engineering works, disaster situation in floodplain area, water flow trend and the engineering danger can be analyzed.

Decision – making support: The information can be referenced on the flood control meeting including: water sideline, main flow map, the situation of main flow against engineering works, water flow status, water flow development, the description of estimation and analysis, engineering status, engineering disaster estimation report and so on.

2.2 Flood control operation

Floodplain disaster analysis: According to the interpretation results of the water sideline, under the integrated environment of RS and GIS, flood disasters and its loss evaluation was analyzed for decision – making support of mitigating and rescuing.

Water flow trend analysis: According to the interpretation results of the water sideline and main flow of the Yellow River, water flow status, water flow development and water flow trend can be analyzed for flood control decision – making support.

Engineering analysis: According to the interpretation results of the water sideline, main flow and the situation of main flow against works, engineering danger was estimated for flood control decision – making support.

3 Function design of the system

Flood RS monitoring system in the Lower of the Yellow River includes five function subsystems, which are data acquisition, image process, image interpretation, interactive analysis and decision – making. The function of the system function structure is shown in Fig. 2.

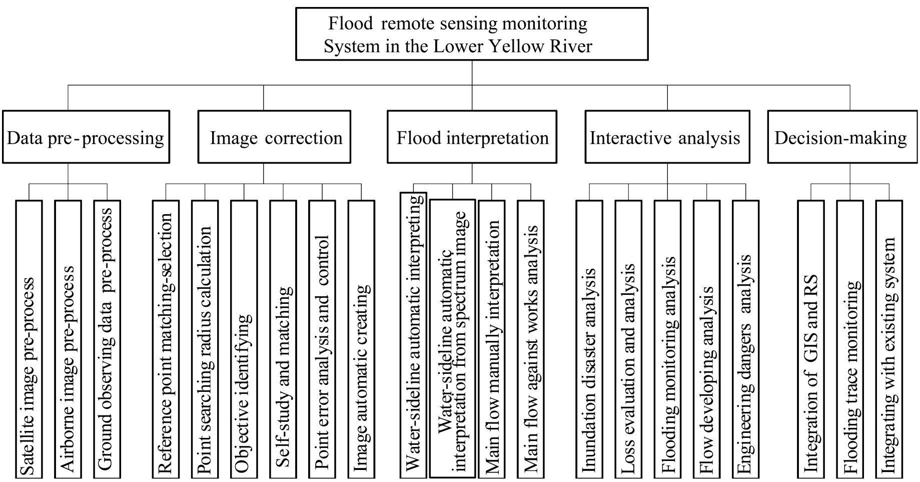

Fig. 2 Function structure of RS flood monitoring system

3.1 Data collection and processing subsystem

On network, satellite image can be processed automatically including satellite image pre – process, airborne data collection pre – process and ground contrast observation data collection pre – process.

3.2 Image correction subsystem

With the support of the multi – source image process software flat, all kinds of satellite images and airborne image can be processed and analyzed. At the same time, the automatic correction system for satellite data based on the database of reference point, will be developed to enhance the automatic degree of image process.

3.3 Image interpretation subsystem

Automatic interpretation of water sideline from RS image, interactive interpretation of main flow and the situation of main flow against engineering can be realized with this subsystem to provide monitoring interpretation information for the analysis of flood inundation analysis.

3.4 Interactive analysis subsystem

Flood monitoring information interactive analysis environment will be developed for flood control leaders and some people related to analyze the floodplain disaster, water flow trend and engineering danger under this subsystem. The function mainly includes the loss evaluation and statistic analysis of the situation of floodplain inundation, the situation analysis of water flow against works, water flow status and its trend analysis, and watercourse engineering danger evaluation and analysis etc.

3.5 Decision – making support subsystem

The information support shall be given to flood control leaders and some people related for flood control decision – making. The function includes the integration environment of RS and GIS, flood dynamic track monitoring, integrating with the existing flood control decision – making system.

4 Water – sideline interpretation and application

During the flood control in the Lower of Yellow River, the flood inundation area at the floodplain is the very important information to the decision – making. Water sideline automatic interpretation from RS image is the key technology to acquire the information. Inundation area of the floodplain reflects the inundation degree and the distribution of the floodplain. Inundation area is the important data to analyze the flood condition, disaster statistic and loss evaluation etc.

Remotes sensing image is sensitive to water body, which has a very different tone from the surrounding object on image, and can be distinguished easily. Through statistic analysis on the brightness of image, two obvious wave crests can be found, in which, the horizontal axis represents brightness and the vertical axis the total number of brightness level. As water has a less brightness and dark colour, it is collected in the scope of the left wave crest. Based on this principle, adopting symbolic statistic and artificial intelligence calculation methods, the water area can be separated on the image, so the flooded area can be obtained.

At present, the development group has made some tests on automatic interpretation flood information, and obtained good effect. In the test, flooded area of the Lower river was interpreted automatically with Radar satellite image. The results precision and rapidity can meet the design demand. Anciently interpretation once operation using radar data should take 3 ~ 5 hours with manual method. And now all the tasks can be done within 5 minutes with automatic interpretation technology.

5 Conclusions

Flood monitoring system in the Lower Yellow River is a part of DYR project, which is an important tool to improve the ability of flood control and decision – making. In this project, the automatic interpretation and 3S integration technology have been improved greatly through the cooperation with Golder Associated Ltd in Canada. This system is under constructing, and will play an important role in the flood control in the Lower of Yellow River.

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Towards a User Oriented Generic Tool for River Basin Management: the Example of the Elbe DSS in Germany

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Abstract: Over the last decades river basin management has become increasingly complex. Increasing demands of society regarding use and protection of water bodies, new views and strategies towards (the making of) policy for river basin management call for a multidisciplinary approach for river basin management. Since methodologies and tools for such a multidisciplinary approach are not readily available, the German Federal Institute of Hydrology in the year 2000 initiated the project 'Towards a generic tool for river basin management', focused on the development of an integrated decision support system for the Elbe rive catchment in Germany. The ultimate goal of the project was to develop a generic tool, which helps water managers to formulate policy for river basin management and to take appropriate measures to realize policy objectives. The software realization of such a tool is called a Decision Support System (DSS) or more specific for the domain at hand: Integrated River Basin Management Decision Support System (IRBM – DSS). In this paper we focus on two main questions:

(1) What is a Generic Integrated River Basin Management Decision Support System?

(2) What lessons can be learned from the example of the IRBM – DSS for the Elbe river in Germany?

Key words: generic tool, IRBM – DSS, elbe river catchment

1 What is a generic integrated river basin management decision support system

Decision Support Systems can be described and categorized from a variety of viewpoints. For our purpose here it is sufficient to distinguish between two main groups of DSS, namely data – oriented and model – oriented DSS. Data – oriented DSS are primarily concerned with retrieval, analysis and presentation of data. Model – oriented DSS include activities such as simulation, goal – seeking and optimization. The domain of integrated river basin management is concerned with understanding and acting upon a highly complex and dynamical system of interrelated physical and non – physical processes. The DSS provides a representation of this system in form of an integral model. Although data analysis and presentation are important functions of the IRBM – DSS, it therefore clearly falls under the category of model – oriented DSS. A DSS can be distinguished from more straightforward engineering applications by its capability to address ill – defined problems.

To achieve this, the DSS often features a knowledge engine that applies various artificial intelligence methods to a formal representation of expert knowledge from the problem domain. Integrated river basin management confronts the decision maker with numerous possible measures, as well as multiple, possibly conflicting objectives. Together these measures and objectives form the decision space, and the decision maker uses the simulation facilities provided by the DSS to explore and navigate it. Nowadays policy makers more than ever need to apply the latest scientific knowledge to their decision – making. They need to provide scientific justification for their decisions.

1.1 Scope and functions of a IRBM – DSS

1.1.1 Analysis

A complex integral model provides a holistic representation of the system, byexplicitly defining the linkages between the natural system and the socioeconomicsystem. In general analysis functions require a description of the system at the appropriate levels of spatial detail and temporal scales. In practice analysis skills are one of the most important functions of the DSS. Analysis capabilities will be important at different points/levels of the DSS system. First of all the user may want to analyze the current state of the river basin. This includesan inventory of all relevant functions of the river basin (e. g. socio – economical and ecological functions) for the desired decision process. Secondly analysis functions are necessary for evaluation of the effects and impacts of the measures on the river basin. The calculated projected state of the river basin has to be compared to the current state as well as to the desired state. By comparing projected and desired state the user will be able to decide if further measures arenecessary to reach the desired state.

1.1.2 Communication

An integral IRBM – DSS can facilitate communication between policy makers and stakeholders in participative planning efforts. Interactive simulation of the integral model shows the stakeholders how their different views on the system are related to each other. Transparency of the system guarantees that the stakeholders recognize their domain explicitly represented in the system. Transparency and user friendliness thus are the key factors for the system to function as a mediating device in a collaborative planning context. Part of the user friendliness is theresponsiveness and speed of the system, which are particular important in brainstorm – like sessions, where one wants to explore different scenarios during a discussion.

1.1.3 Library (knowledge base)

An IRBM – DSS based on an integral model can serve as a knowledge management infrastructure. It gathers, orders and links existing knowledge about a system and therefore can fulfill the function of a dynamic library. It may reveal knowledge gaps, and thereby give impetus to further research and data collection. Through the IRBM – DSS knowledge about a system becomes available in operational form. The IRBM – DSS can be a common infrastructure for storage and transfer of the knowledge for participating organizations and possibly the general public.

1.1.4 Management

Management is a function of the DSS that is important for the users that have to evaluate general decisions and turn them into realizable measures. From the set of possible measures they have to select those that fit best to the objectives. Of course financial aspects must be taken into consideration and therefore have to be evaluated.

1.1.5 Learning

A DSS cannot only be used for analysis, communication or other of the already above mentioned functions but also for learning purposes. Primarily this means learning about the linkage of processes, natural and user functions, which build a complex network of the system with multiple interdependencies. Even if experts are familiar with the dependencies in their special field of interest they may use the DSS for learning about the linkage to unknown functions.

1.1.6 Generality and flexibility

In a sense generality and flexibility can be seen as meta – requirements, because they define conditions for the development of other functional and non – functional requirements of the system.

1.2 Critical management success factors for an IRBM – DSS

(1) Highly motivated end – users, with both, a visionary as well as pragmatic attitude towards the domain at which the DSS is targeted.

(2) Highly motivated development team, with a broad interest in the application domain, DSS development, formal analysis and knowledge representation methods…

(3) A small group of highly motivated software engineers with outstanding skills in knowledge engineering, software architecture, user interface design, object – oriented development

environments, distributed systems, standards…

(4) A small group of highly skilled modelers, with experience in combining various spatial and temporal scales in one model. Furthermore the modelers should have a broad interest for the application domain and should be able to take a pragmatic attitude as well as to achieve compromises, when they need to discuss solutions to technical problems with the software engineers.

(5) A DSS architect, perhaps the most difficult role in the process. Like a building architect, this generalist is responsible for the overall vision of the product and must be able to professionally communicate with all participating specialists and stakeholders.

(6) A project manager. For small projects this role is sometimes taken by the DSS architect. The project manager should have experience in managing interdisciplinary projects with participants coming from scientific, technical as well as public administration backgrounds.

(7) Sufficient time and budget to build a high quality first prototype of the system. A successful prototype will further increase the end – user commitment and eventually will trigger further investments in the DSS development.

(8) Early and ongoing end – user involvement in the development.

(9) Respect for the role and knowledge of participants from other disciplines than your own.

(10) Willingness and ability to take a calculated risk by putting substantial effort in the development of a highly innovative product.

1.3 Critical technical success factors for an IRBM – DSS

(1) Use object technology and component based development.

(2) Use existing application frameworks for spatial decision support systems.

(3) Integrate GIS and database functionality as a component layer.

(4) Separate the front – end (user interface) from the underlying tool –, model – and database with clean interfaces.

(5) Keep in mind that re – implementation of existing scientific models is sometimes a more efficient and cost – effective 'integration' solution compared to extensive 'wrapping'.

(6) Techniques for handling various spatial and temporal scales simultaneously are new. They should be implemented early in the pilot phase, to allow some experimentation.

(7) Provide templates and standard interfaces for sub – models (model building blocks).

(8) Use standard data formats and protocols for inter – application information exchange

(9) Test the behavior of the integral model under realistic conditions early and often.

(10) For the pilot project maintain a realistic balance between generality and feature completeness.

2 What lessons can be learned from the example of the IRBM – DSS for the Elbe river in Germany

2.1 The background of the Elbe DSS

After the flood catastrophe in 2002 the German federal government issued an action program to reduce the risk of flooding in the future and mitigate the effects. A variety of river engineering works such as large – scale dike shifting, channel dredging, and retention were in a planning or implementation stage. Usually the initiative for such measures is taken from a local or sectoral point of view. Therefore, it is not always clear how different measures will interact or how the natural conditions in the floodplains are affected. Moreover, uncertain future conditions related to climate change and land – use development may interfere with the expected results. In order to examine different strategies for sustainable management of the river, its floodplains, and the river basin the German Federal Institute of Hydrology initiated a project to develop a prototype tool for integrated river – basin management, which includes functionalities related to inland navigation, water quality, flood safety, and vegetation ecology in the floodplain. The project started in the spring of 2002 and was completed by the end of 2005 with the delivery of a DSS prototype for the Elbe River, its floodplains, and the catchment. The development team included researchers of several universities, as well as consultants and software engineers. From the beginning of the project onwards much attention was paid to the involvement of end – users in the design process.

This was achieved by following an iterative approach for the design, with room for regular user feedback, and an emphasis on the functional aspects of the design, as reflected by the selection of measures, indicators, and scenarios. The first version of the DSS is now being presented to a mixed audience of potentially interested stakeholders, decision – makers, and researchers involved in the Elbe River. The experience of the project learns that the main difficulty is to find a proper balance between scientific standards, the availability of models and in particular data, and the requirements of users. Both the users and their requirements may change during the design process, which can take several years if data and models are partially under development. Ideally the design of a DSS follows an iterative path which ends in an optimal balance between technical functionality, scientific quality, and user involvement .

Iterative design of a DSS with typical problems that arise if one of the aspects of the design is overemphasized. If one of these three aspects becomes overemphasized the acceptance of a DSS will reduce considerably due to a lack of functional flexibility (because complex research models are less easy to adapt in terms of measures and scenarios) or, on the other hand, a lack of scientific soundness (because simple and more flexible models lack scientific underpinning). Obviously practical limitations and unexpected problems are inherent to any large – scale project involving multiple users and developers. Nevertheless the acceptability of the final product and efficiency of the design process can be increased by sufficient awareness of the aforementioned trilemma. As will be explained this can be achieved by employing simple but adequate models and data, regular communication between developers, researchers and users, and striving for internal system consistency.

2.2 Designing the Elbe DSS

The pilot Elbe DSS is based on the interdisciplinary coupling of available models and data collected in a research program funded by the German Federal Ministry of Education and Research (BMBF) (Gruber and Kofalk, 2001). The functionalities that are included in the DSS are: water quality (point and diffuse sources of pollution), floodplain vegetation, flooding safety, and shipping (testing stage). In view of the multi – objective nature of the prototype DSS and scale differences of models and data, the choice was made to use a modular design pertaining to three scale levels: catchment, main channel (including floodplains), and a river section (a section of 20 km near the town of Havelberg).

The development of the DSS comprised three distinct activities . During the problem formulation contacts with stakeholders and users were established, and the relevant problems, indicators and tentative measures were identified. In this phase the difficulty was that the users were not known yet, and that the problems mentioned were sometimes not in line with the strategic purpose of the DSS, for example because of their local, operational or sectoral character. The measures to address the problems were even less clear at this stage. Nevertheless, a preliminary choice of problems, indicators and measures could be made. The qualitative design concerned the linking of measures and indicators. A system diagram proved a very useful tool for communication with the end – users and within the design team, and formed the basis for the user interface of the Elbe DSS as well as the modeling, with a similar distinction between the system, measures, objectives, and scenarios. Due to changes in the functionality and priorities of the users the design of the system diagram was a continuous activity although most of the effort was made during the first half of the project. Absolute perfection of the system diagram was not considered meaningful.

After several iterations the system diagram was considered consistent and only limited changes were implemented because adaptations become more difficult towards the final stage of the project in view of the consistency with other models and the user interface. Most resources, however, were spent on the quantitative design of the DSS: the collection of existing models and data or formulation of new models or preparation of additional data. For practical reasons the design was based on existing models and data as much as possible, although it was noticed that, for example, the elevation and dike data for the main channel module had to be completed during the project. The completion of these data turned out to be more time consuming and difficult in terms of pre – processing than was anticipated. A partial discrepancy between the functionality reflected in the system diagram and the availability of models and data proved to be a bottleneck for which a solution had to be found. Shifting resources to other project activities only temporarily solved the problem. More complex "research" models usually require more accurate and expensive data, and have a scientific, discipline – oriented purpose. View on the user interface of the Elbe DSS with the system diagram, interactive maps and dialogue boxes, and part of the online model documentation (example measure of retention polders). a part of an integrated software tool. The application of research models caused both scientific and technical challenges. The scientific challenges were due to the interaction of models with different types and quality of input, which had to be addressed by aggregation of some models. In a number of cases the consistency of models and data was determined by means of uncertainty and sensitivity analyses.

For example, the required vertical accuracy and spatial resolution of the elevation data for the floodplains could be derived from the sensitivity of the ecological model that used the elevation data as input.

The technical problems were related to the question whether "heavy" models are to be incorporated in the DSS directly or indirectly. In the first case a software integration shell is needed, whereas in the latter case a simpler (meta) model or a representation of model results can be used. Both approaches have been used in the Elbe DSS. For example, the point – source pollution model GREAT – ER (Matthies et al., 2001) and conceptual rainfall – runoff model HBV (Krysanova et al., 1998) have been integrated directly, whereas rating curves are used for the hydraulic model HEC – 6 (HEC – 6, 1992, Otte – Witte et al., 2001).

The hydrodynamic model SOBEK1D2D of WL | Delft Hydraulics has been used to simulate a dike break at different locations, but only the results of the simulations have been incorporated. This limits the choice to precalculated locations, but in this case this was not a problem because these were chosen by the users. Although the direct integration of a model has the advantage that the functionality becomes fully available for the users of the DSS, a drawback is that the interface and architecture require adaptations. In addition the computational load can become too large for iterative use of the DSS in, for example, a workshop with stakeholders. Simpler models are less flexible for the users, but are easier to replace or generalize to new locations as data and calibration demands are generally smaller. At several stages during the project iterations between the three design activities (problem formulation, qualitative design and quantitative design) were allowed for and also proved to be necessary. After the August 2002 flood, for example, the decision was made to extend the functionality of the channel module with retention polders, which affected not only the system diagram and model base, but also the user interface. At later stages of a project such changes become more and more difficult to implement, mainly for organizational and technical reasons. In addition to internal consistency of model and data, and flexibility for changes the acceptance of a DSS benefits more than from anything else from effective communication between the developers, users, and researchers. The communication with the users was organized in different forms. During the feasibility study that preceded the project the users had to be identified first. This meant that a large number of institutes and persons with an interest in the management of the Elbe River were contacted and consulted. The results of these consultations provided the basis for the problem formulation. At the beginning of the main project a steering committee was formed to monitor the progress and give feedback on the achievement of milestones. Halfway the project a stage was reached where a tentative functionality of the DSS could be shown to selected stakeholders. Their feedback has been used to adapt and improve the design. In the beginning of the project the comments would have been less detailed useful due to the lack of concrete examples of a DSS, which again justifies the iterative approach, In addition to the communication with the users and stakeholders the activities of the developing team had to be coordinated in view of the different interdependent tasks allocated. This was achieved by bi – monthly meetings, during which the progress could be verified and problems discussed or prevented. These meetings were essential to ensure that the models and data provided by the different developers were integrated in a consistent way.

2.3 Lessons to be learned

During the design of a DSS sufficient attention should be paid to the consistency of models and data, in addition to effective communication with users. During the application of a DSS a lack of flexibility to cope with changing priorities or different demands with regard to the functionality may endanger its acceptance among a wider audience. Our experiences with the design of the Elbe DSS lead to the following recommendations:

(1) A regularly but not excessively updated qualitative system diagram is a very useful tool for communication and can form the basis for the design of the user interface.

(2) The availability of models and data does not guarantee their applicability in a DSS because of the need to integrate research models not designed for this purpose. To reduce problems this applicability should be verified in addition to the availability and, when possible, uncertainty and sensitivity analyses should be carried out to ensure consistency of models with data and other models.

(3) In some cases direct (online) incorporation of larger research models may not be feasible or desirable. Here the scientific challenge is to develop more flexible but simpler meta – models with sufficient scientific quality.

(4) The communication with users should take place regularly during a project, and be used both to keep expectations realistic and to make a serious effort to adapt the design at a stage where this is still possible. This calls for an iterative instead of a sequential design process.

(5) We propose to integrate users as project partners with a certain budget in such developments. Defined responsibilities, e. g. for data deliveries and design of the user interface, can ensure the acceptance and later on the maintenance of the DSS.

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Multi – object Flexible Decision – making for Water Resources Utilization in Yellow River Basin

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Abstract: Analyse the Multi – object character of water resources utilization, Multi – object optimization model for Yellow River basin water resources with the combination of comprehensive social, economic and eco – environmental benefits is established. On the basis of multi – target flexible decision – making principle, method for multi – target flexible by – level decision – making for water resources is put forward, flexible decision – making model of real – code accelerating genetic algorithm (RAGA) is established and the research on applying it to Yellow River basin allocation is conducted, and a set of multi – target optimization allocation scheme to maintain the harmonious development of the basin water resources with high utilization efficiency is worked out.
Key words: Yellow River basin, water resources, flexible decision – making, allowable value, satisfaction degree, membership function

Single – object decision – making problem generally has an only optimal solution which is dominated by the optimality of scalar quantity optimization problem, while the solution for multi – object decision – making problem is generally not the only one which is dominated by non – inferiority of scalar quantity and the solution can not be absolutely optimal to each object at the same time. The solution of multi – object problem is normally called as compromise solution in planning. Consequently, Herbert Simon, the winner of Nobel Prize in Economics, proposed that the traditional optimization rule can be substituted with satisfaction rule, the decision – maker can make a satisfaction selection based on the information which he has owned and shall not be exigent for the only optimal solution, leading to greater flexibility. The turning of optimization rule of decision – making to satisfaction rule is the turning of rigidity rule to flexible rule.

1 Characteristics of multi – object of water resources exploitation

In the traditional economic development mode, water resources development and utilization simply seek for economic benefit at the cost of sacrificing environment quality and consuming water resources with a free hand, resulting in quite prominent impact on ecosystem from human being, serious ecologic degradation, and even sacrifice of part local benefit, and all these have produced problems on society, economy and politics.

Requirements for maintaining water resources sustainable development, the object of water resources utilization can not only be the "high" economic benefit, but also include "good" ecologic benefit and social benefit. Economic increase shall breaks through the original relationship between water supply and utilization, so as to have a high – efficient utilization of water resources, enlarge the environmental capacity, and it shall take social, economic environmental factors and some others into comprehensive consideration based on harmony of the entire properties of water resources (natural, environmental, ecologic, social and economic properties), and shall promote the sustainable and harmonious development in society, economy and environment. Therefore, the general object of water resources utilization shall be the sustainable and harmonious economic development, the gradual improvement of eco – environment quality, the health and stability of society, etc. , including the followings:

(1) Harmonizing and optimizing economic, ecologic and social benefits, seeking for efficiency in economy, minimizing negative impact on environment, keeping social stability, and ensuring comprehensive utilization efficiency in economic, eco – environmental and social development;

(2) Harmonizing water utilization for living, industry, agricultural irrigation, eco –

environmental vegetation cover;

(3) Reasonable regional distribution to satisfy the demands for water resources in various regions for the purpose of basin balance development.

2 Establishment of multi – object optimization allocation model for water resources in Yellow River basin

2.1 Model establishment

Being a typical multi – object decision – making problem, utilization of Yellow River basin water resources covers flood control and deserts mitigation, eco – environment protection, social development, etc.. The establishment of general object function is as follows:

$$\max f(x) = f(S(x), E(x), B(x)) \quad (1)$$

(1) Social object : It mainly includes ensuring the safety against flood and ice jam and the harmonious regional economic development, and guaranteeing the living water and the food safety, etc. Regional development harmony is adopted comprehensively, namely, taking the maximization of minimum social total welfare as the object:

$$\max\{\min U(s,j)\} \quad (2)$$

in which: $U(s,j)$ is the regional social welfare function, namely, the satisfaction degree for social development.

(2) Eco – environment object $E(x)$: providing necessary eco – environmental water to maintain the normal river function, basin ecosystem balance and to satisfy the standard for environmental water, taking the maximization of the Green quantum area and the minimization of main pollutant COD discharge synthesis:

$$\max \sum_{s=1}^{m} \sum_{j=1}^{n} GREEN(s,j) \quad (3)$$

$$\min \sum_{s=1}^{m} \sum_{j=1}^{n} COD(s,j) \quad (4)$$

in which: $GREEN(s,j)$ is Green quantum area of regional ecologic synthesis index; $COD(s,j)$ is main pollutant factor in the water discharged.

(3) Economic object $B(x)$: taking the maximization of total of gross domestic product (TGDP) in the basin as main economic object.

$$\max\left\{TGDP = \sum_{s=1}^{m} \sum_{j=1}^{n} GDP(s,j)\right\} \quad (5)$$

in which: $GDP(s,j)$ is regional gross domestic product, j refers to regions, $j = 1, 2, \cdots, n$, $s = 1, 2, \cdots, m$ is economic sector.

2.2 Decision – making index

(1) Industry structure decision – making and industry structure harmonization:

$$Y_{i\min} \leqslant (1-\alpha) QP_i \leqslant Y_{i\max} \quad (6)$$

in which: $Y_{i\,\min}$ and $Y_{i\,\max}$ are the upper and lower limits respectively for development of industry i, α is the matrix of production technology coefficient, and QP is water supply volume.

(2) Food safety decision – making, guaranteeing regional food supply, minimization of the sum of food production quantity of each region and of the expected deviation in object duration:

$$\min\left\{TFOOD = \sum_{s=1}^{m} \sum_{j=1}^{n} (TFOOD(s,j) - FOOD(s,j))\right\} \quad (7)$$

in which: $TFOOD(s,j)$ and $FOOD(s,j)$ are the expected object of food consumption quantity of each planned level year at each node and the total quantity of actual food production respectively.

(3) Water environment bearing decision – making, water environment satisfying the standard:

$$\sum_{k=1}^{K} \sum_{j=1}^{J(k)} 0.001 \cdot d_j^k p_j^k \left(\sum_{i=1}^{I(k)} x_{ij}^k\right) \leqslant C_0 \quad (8)$$

in which: C_0 is water environment bearing capacity, d_j^k is the content of the most important pollution factor in the unit wastewater discharge quantity from user j in sub – region k, p_j^k is the wastewater drainage coefficient for user j in sub – region k.

(4) Inside – channel ecologic water demand decision – making, satisfying the main inside – channel ecologic water demand:

$$Q(t) \geqslant Q\min(t) \tag{9}$$

in which: $Q(t)$ is the discharge quantity at cross – section, $Q\min(t)$ is the minimum ecologic demand quantity at cross – section.

(5) Water resources bearing level decision – making: economic water utilization quantity being smaller than water resources bearing capacity:

$$\sum_{i=1}^{n}\sum_{k=1}^{m} x_{ij}(t) \leqslant R(t) \tag{10}$$

in which: $x_{ij}(t)$ is water utilization quantity of region j in sector at t time, $R(t)$ is water resources bearing capacity at t time.

3 Multi – object flexible and fuzzy ratiocination method

Multi – object decision – making is a kind of decision – making problem which often appears during decision – making, and it is used extensively in production planning and conduction. Because there are mutual contradictions and non – commensurability among each object in multi – object decision – making problem, it is difficult to find an absolute optimal solution. Decision – maker can only make a compromise among each object according to his experience and preference to obtain he Pareto optimal solution which he needs. Therefore, the key of multi – object decision – making is how to integrate object function based on decision – maker's preference and turn multi – object decision – making problem to sole – object optimization decision – making problem which can show decision – maker's preference. Fuzzy ratiocination system can directly adopt the decision – maker's preferential knowledge to integrate each object function, without working out the decision – making preferential function in a certain form or decision – making mechanism in a specific interactive mode.

3.1 Membership function of decision – making index satisfaction degree

Supposing L_{i0} is the allowable value of each index and H_{i0} is the desired value of each index, the membership function of satisfaction degree for benefit index which is more optimal at bigger value (economic benefit, social development level, etc.) is formed as follow:

$$u_i(x) = \begin{cases} \dfrac{r_i - L_{i0}}{H_{i0} - L_{i0}} & r_i \geqslant L_{i0} \\ <0 & r_i < L_{i0} \text{ refused} \end{cases} \tag{11}$$

As for the cost index which is more optimal at smaller value (e. g., pollutant discharge, eco – environment damage level, etc.), the membership function of satisfaction degree is formed as follow:

$$u_i(x) = \begin{cases} \dfrac{H_{i0} - r_i}{H_{i0} - L_{i0}} & r_i \leqslant H_{i0} \\ <0 & r_i \geqslant H_{i0} \text{ refused} \end{cases} \tag{12}$$

Membership function of satisfaction degree $u_i(x)$ is the decision – maker's satisfaction degree for the object. It can be seen from equations (9) and (10) that $u_i(x)$ is both the function of decision – making variable x and the function of decision – making allowable value L_{i0} of desired value. In case of $u_i(x) < 0$, it means the object $f(x)$ can not reach the allowable range, and the decision – maker can not accept the object. In case of $u_i(x) = 0$, it means the object $f(x)$ reaches the allowable lower limit, and the decision – maker is in the critical situation to accept or refuse the object. In case of $u_i(x) = 1$, it shows the object has reached the effect expected by decision –

maker. But in case of $u_i(x) \gg 1$, it means the waste of resources can not be accepted by decision – maker. Therefore, $0 \leqslant u_i(x) \leqslant 1$ is the range for decision – maker to make decision.

3.2 Integration of basin total object satisfaction degree function

Total satisfaction degree function of basin decision – maker can be obtained through harmonizing the integration of satisfaction degree function among each specific region and among each decision – making index. If the satisfaction degree for allocation scheme i from each specific region or sector is $u_{ki}(x)$, the basin total object satisfaction degree membership function can be created through linear integration:

$$\max U = \sum_{l=1}^{3} \lambda_l u_l(x) \text{ 或 } \max U = \sum_{i=1}^{n} \sum_{k=1}^{m} \lambda_{ki} u_{ki}(x) \tag{13}$$

in which, U is total satisfaction degree function, $u_l(x)$ $(l = 1, 2, 3)$ is satisfaction degree of the three main object. λ_{ki} is the weighing of membership function of satisfaction degree of object i for the total object satisfaction degree, $\sum_{l=1}^{3} \lambda_l = 1$ or $\sum_{i=1}^{n} \sum_{k=1}^{m} \lambda_{ki} = 1$, it can be the harmonized index from expert or relative importance, showing the consistence of a certain benefit non – conflict. It can be set as equal weighing at initialization.

3.3 Multi – object and by – level decision – making method

Based on the characteristics of multi – object and by – level utilization of Yellow River basin water resources, model solution adopts 3 – level flexible decision – making:

The first level decision – making: Harmonize the sustainable utilization of the basin water resources among 3 large sectors, and make an initial allocation scheme according to the key construction of the 3 large objects, namely, economic, social and eco – environmental objects by decision – maker and on the water resources management requirement.

The second level decision – making: Harmonize the benefit conflict among all the regions, and make out a satisfactory regional allocation scheme.

The third level decision – making: In each specific region, each of agricultural water utilization sector, eco – environmental water utilization sector and social living water utilization sector only seeks for its own maximum benefit without considering the benefit conflict among them. Through the competition and harmonization, the limited water resources can be allocated among each water utilization sector reasonably to harmonize and mitigate the benefit conflict among the sectors, a satisfactory allocation scheme can be worked out to realize the optimization of sector benefit. The decision – making is in the follow procedures (Fig. 1).

Through the above procedures, multi – object problem has been turned into 3 – level decision – making problem, and working out equation (13) can get a solution which can most satisfy the whole basin decision – makers for the planning problem. If decision – makers are all satisfied with the solution, the calculation can be ended, otherwise, correct the lower limit of each fuzzy satisfaction degree function or decision – making weighing and repeat the above calculation.

4 Flexible decision – making model of Real – code Accelerating Genetic Algorithm (RAGA)

The coding mode of traditional genetic algorithm, namely, simple genetic algorithm (SGA), is a binary system, and its defects are that the random of genetic algorithm will lower the local searching capacity. Real – coding genetic algorithm which is also referred as RAGA is standard genetic algorithm with larger space range for genetic searching and higher calculation precision, it can improve the complication of the genetic algorithm, raise the calculation efficiency, be convenient for the combination of genetic algorithm and classical optimization algorithm, be convenient for designing the knowledge – type genetic operator for the special knowledge of the problem and be convenient for dealing with the restricting condition of decision – making variables.

Apply the flexible decision – making model (FDM) based on real – code accelerating genetic

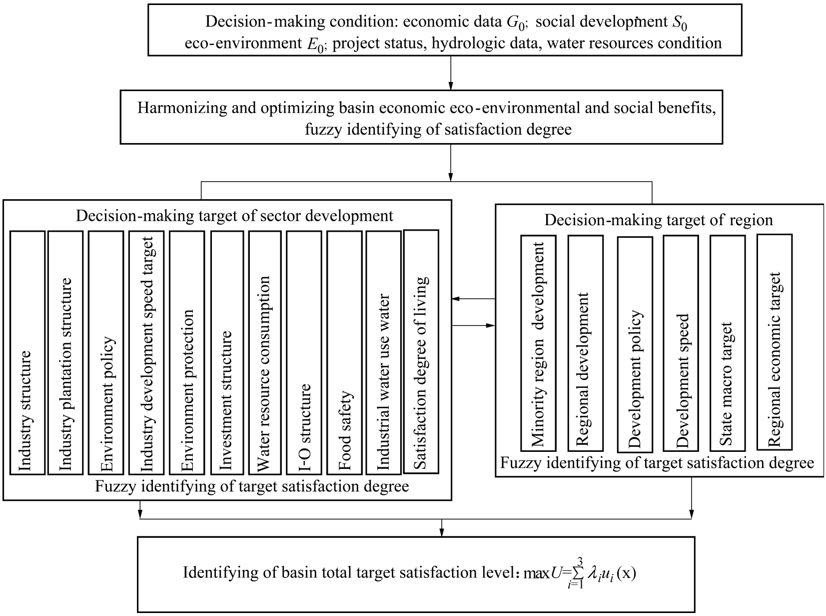

Fig. 1 Flow Chart of Multi – target Decision – making

algorithm (RAGA) to multi – object optimization of Yellow River basin water resource. The procedures are as follows:

(1) Creating function for general object satisfaction degree and setting initial weighing for index;

(2) (RAGA) solve optimization object function;

(3) Recommending of ranking, and ending up if decision – maker is satisfied or modifying and solving again.

5 Decision – making attributes index and threshold value

From the reality effect of economic, society, eco – environment and water resources utilization, we select 11 indexes as the decision – making attributes of water resources allocation in Yellow River Basin, shown as Table 1.

The lower limit for allowable value of each decision – making index is to keep the healthy life of Yellow River and the sustainable and harmonious development of Yellow River basin, mainly including:

(1) Water quantity to keep the life of Yellow River. The life of Yellow River can be reflected in three aspects: the first is the ability to discharge flood at a certain degree, the second is the ability to resist pollution at a certain degree, and the third is the ability of river course and estuary ecosystem to resist disturbance and maintain ecologic balance at a certain degree. The water quantity at the allowable value includes 15 billion m^3 for course scouring, 5 billion m^3 for ecologic base flow, and wetland ecosystem, totaling 20 billion m^3. The main cross of Yellow river set allowable values to meet the low need of ecology and environment. The decision – making allowable vale shall be set for each main cross – section discharge according to eco – environment demand at the low limit.

Table 1 Attributes of the effect about water resource utilization in Yellow River basin

Item	Index	Unit	Content of Index

	GDP	100million Yuan	Level of regional economic development
Economic Effect	Added Value of Industry	Yuan/m^3	Level of industrialisation
	Water shortage of Agriculture and Industry	100 million m^3	Efficient of economic
Social Effect	Harmonization of regional development		Development in equilibrium
	Food product per	kg/per	Food security
	Water utilization coefficient of irrigation		Efficient of irrigation
Water utilization Effect	Ratio of sewage recycled	%	Cleanliness Product and emission control
	Ration of industrial water usage	m^3/10 thousand Yuan	Efficient of industry water usage
	Marginal product	Yuan	Efficient of social water usage
environmental Effect	Water Discharge of main Section	100 million m^3	Keep balance of ecosystem
	Water of eco – environment	100 million m^3	Satisfy degree of eco – environmental water need

(2) Water quantity to maintain the living and development of each region in the basin. The water demand from the resident living in city and countryside shall be satisfied at first. The water demand from regional industry and the water demand from agriculture for regional food safety shall also be satisfied as the allowable values in order to maintain the basic requirement for regional economic development and the safety of food. Harmony degree of regional development is tolerance of the ratio of the most developed region and most undeveloped region in the per capita GDP, the allowable value is 0.5, and 1.0 is optimal. Coefficient of irrigation water utilization is 0.42 of the current one. The selection of ideal values for each decision – making index mainly bases on the planning for State macro strategic development, economic planning of each region, 11th 5 – year planning for Yellow River Basin and other related index.

6 Analysis on multi – object optimization result of basin water resources utilization

6.1 Flexible decision – making model of Real – code Accelerating Genetic Algorithm (RAGA)

In the allocation decision – making for Yellow River Basin resources, flexible decision – making model of real – code accelerating genetic algorithm is used and the level year 2010 is taken as example. The runoff data of 45 years in 1956 ~ 2000 series in Yellow River basin is adopted, the annual mean runoff is 53.48 billion m^3, and the available groundwater is 11 billion m^3. In forecast, the total GDP is 1,830 billion Yuan and the total water demand is 56.61 billion m^3.

6.2 Analysis of the result

The main decision – making matrix of model is made up of 11 attributes ($r_1 \sim r_{11}$) of eight provinces ($G_1 \sim G_8$, Sichuan, Hebei are excluded) and three main sections ($G_9 \sim G_{11}$), shown as Table 2. Using of the strong iterative and searching functions of the model, find the excellent genus in the allowable range of decision – making and recommend the scheme with the highest satisfaction degree. In fuzzy decision – making calculation based on RAGA, the selected scales of genus is $n = 400$, probability of intersect is $p_c = 0.80$, probability of variation $p_m = 0.80, \alpha = 0.05$, through change of the weighing of decision – making to form mode of alternation decision, the ultimately weighing of Decision – making is fond, the degree of satisfaction in Yellow river basin is $U = 0.829,1$, is the solution which Decision – making most satisfy. The calculation shows that each object and attribute is in good status if the main decision – making objects and index values are within the decision – making scope of the decision – maker and the satisfaction degree is in the range of (0,1), shown as Table 2.

Table 2 Decision – making matrix of attributes for Yellow River water resource utilization

Object	Attributes										
	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9	r_{10}	r_{11}
G_1	0.490	0.207	0.255	1.000	0.578	0.570	0.163	0.650	0.695	0.728,3	0.568
G_2	0.604	0.226	0.263	0.794	0.672	0.602	0.178	0.650	0.286	0.734,2	0.599
G_3	0.798	0.387	0.264	0.629	0.767	0.652	0.305	0.950	0.695	0.741,7	0.619
G_4	0.830	0.623	0.268	0.422	0.800	0.660	0.491	0.950	0.286	0.738,5	0.677
G_5	0.604	0.528	0.258	1.000	0.651	0.604	0.416	0.650	0.695	0.743,0	0.535
G_6	0.625	0.471	0.259	1.000	0.669	0.611	0.371	0.650	0.695	0.746,6	0.529
G_7	0.730	0.510	0.266	0.794	0.755	0.640	0.401	0.650	0.286	0.750,1	0.561
G_8	0.898	0.740	0.267	0.629	0.837	0.686	0.583	0.950	0.695	0.753,0	0.588
G_9	0.928	0.981	0.271	0.422	0.871	0.693	0.772	0.950	0.286	0.748,4	0.645
G_{10}	0.646	0.430	0.261	0.928	0.690	0.616	0.339	0.650	0.695	0.826,9	0.525
G_{11}	0.745	0.526	0.267	0.722	0.768	0.644	0.414	0.650	0.286	0.835,5	0.558

Sediment transfer and deposition mitigation in the joint dispatch of the key reservoirs in the basin on the basis of satisfying the sediment transfer requirement in flood season through the regulating with Yellow River stem reservoirs and improving the spatiotemporal distribution of basin resources, reduce the ineffective into – sea flow, and turn water from flood into favorable water resources. Arrange the economic scale and industry structure in the basin reasonably with a flexible adjustment, turn wastewater into favorable water resources, improve the basin eco – environment. The discharge volume at the main cross – sections on Yellow River main stem can all satisfy the environmental capacity requirement, shown as Table 3. The into – sea water volume at Lijin is 20.268 billion m^3, meeting the lowest requirement for into – sea water volume from Yellow River. The water requirement for residents in the basin is fully satisfied, the shortage rate of industry water is only 2.9%, the regional food safety is supported (the food production per capita is 433 kg). Regional economic development is harmonized. In the basin, the harmonization rate is 0.58, the economic increasing rate is 104%, GDP per capita is 12,100 Yuan in the smallest province Qinghai with the annual economic increase rate of 11.2%. The result of multi – object optimization allocation of Yellow River water resources is shown as Table 4.

Table 3 Discharges at Each Main Gauge Station on Yellow River Unit: m^3/s

Stations	Controlled runoff					Controlled water volume				
	Lanzhou	Hekouzhen	Sanmenxia	Huayuankou	Lijin	Lanzhou	Hekouzhen	Sanmenxia	Huayuankou	Lijin
Low limit requirement	200	250	150	150	100	197	180	200	53.6	5.7
Regulating discharge	202.8	272.3	151.6	156.7	99.9	202.3	188.9	2021.6	57.4	6.1

Table 4 Result of multi – object optimization allocation of Yellow River basin water resources utilization Unit: $10^8 m^3$

Districts	Water demand			Water supply volume	Allocated volume	Water Lack in demand and supply balance			
	Agriculture	Living	Industry, the 3rd industry			Industry	Agriculture	Subtotal	Lack (%)
Qinghai	1.32	18.44	4.57	21.61	11.36	0.68	2.04	2.72	11.2
Sichuan	0.02	0.20	0.01	0.23	0.12	0	0		0
Gansu	5.03	34.28	16.65	48.60	28.16	0.53	6.82	7.35	13.1
Ningxia	1.65	71.92	6.39	67.25	33.09	0.54	12.17	12.71	15.9
Inner Mongolia	2.88	86.27	12.05	85.39	51.41	0.56	15.25	15.81	15.6
Shaanxi	8.64	54.51	22.02	72.12	43.35	0.48	12.57	13.05	15.3
Shanxi	5.98	40.85	12.13	55.79	39.08	0.3	2.87	3.17	5.4
Henan	5.12	54.59	17.00	73.08	53.44	0.04	3.58	3.62	4.7
Shandong	2.35	66.50	14.73	79.77	67.24	0	3.81	3.81	4.6
Tianjin and Hebei				5		5	0	0	
Total	32.99	427.56	105.55	508.84	332.25	3.13	59.11	62.24	10.9

7 Conclusions

The multi – object flexible decision – making can take each decision – making object and the corresponding index into consideration, realize the good coupling between economic and social development, eco – environmental protection and water resources system, guarantee the basin water resources utilization object on the basis of high – efficient, harmonious and healthy development of water resources, and realize the renewable maintaining of water resources and the sustainable basin development.

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Research on Satellite Based Drought Monitoring in the Yellow River Basin

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Abstract: Drought is the natural phenomenon which the water scarcity occurred in the ground ecosystem of the specific regions, with periodic occurring climatic features. The efficient cause of the drought is little precipitation during long time period which can't meet water requirement of ground ecosystem. Drought is one of the most natural disasters to affect the society, economy and environment, and also a key restricting factor for agriculture production. In order to reduce the influence and loss by drought disaster and timely understand the occurrence, development of drought events using effective ways, it is necessary to conduct and develop the drought monitoring and forecasting research. At present, drought index method is adopted for the drought monitoring and forecasting research, usually including meteorological drought index, agricultural drought index, hydrological drought index and remote sensing drought index, etc. This paper mainly introduces the meteorological drought index and remote sensing drought index methods applied to calculate the drought index and monitor the drought events, and their application and validation of the drought monitoring in the Yellow River Basin.

Key words: the Yellow River Basin, drought, index, monitoring, satellite based

1 Introduction

Drought is a complex natural phenomenon, its formation and intensity has the procedure of gradually accumulation, and difficulty to find because the formation of drought is slowness. Generally the drought can be understood as the budget of moisture or supply and requirement is unbalance which brings the moisture scarcity phenomenon. The occurrence of the drought consists of complex procedure and factors, not only relates with the precipitation and its allocation, also with the evaporation, soil water content, runoff amount etc. And drought has the direct relation with the different region, different crop type and different growth period.

Due to the uneven temporal and spatial distribution of the climatic variation and precipitation, and the large scale drought occurred frequently in China. The severe drought has been occurred once two year in average since 1949, and average annual drought area is over 20 million hectare, and average annual crop loss is about 5 billion kg. So the drought has been the important factor which affects the national agriculture and the whole national economic sustainable development. In recently years, following the development of the society and economy and affection of humanity activities, the supply and requirement contradiction of the water resources of the Yellow River Basin become more and more serious. The drought disaster not only affects the agriculture and herd, also affects the industry, and cause the serious economic loss. The water scarcity and high temperature which induced by drought also affects the living and life of the humanity. The drought also destroy the environment and strengthen the dry of the soil and dry up of the lake and river, aggravate the pollution of the water body, and worsen the water environment, degenerate the soil texture, and strengthen the harm of the soil desertification.

For the drought monitoring, there has two types which are short – term and long – term. For the short – term, the temporal scale is from ten days to three months, and indicates the recent drought conditions, and require real time and quickly reflect the development and variation of the drought. For the long – term drought, the monitoring is annually, the precipitation variation from one year to two or three year to indicate the condition of the water budget.

At present, the methods for the drought monitoring is using precipitation and other weather data to estimate, and also can using the remote sensing data.

2 Precipitation anomaly index

Precipitation anomaly is the basic and direct method to indicate the moisture budget of the region. The calculating procedure is using the actual precipitation divided by the multi – annual average precipitation (usually 30 years average) and multiply 100%. The advantage of the precipitation anomaly or precipitation anomaly percentage is simple and intuitionist, generally indicates the variation and abnormity, for the different region has the comparability, which the drought can be defined as the monthly or yearly precipitation anomaly percentage under the multi – annual average value., and reflect the short – term climatic abnormal condition. According to the regulation of the China Central Meteorological Station, for the continuous three months precipitation is under 25% ~ 50% of the multi – annual average defined as the ordinary drought, under 50% ~ 80% defined as severe drought; for the continuous two months precipitation is under 50% ~ 80% of the multi – annual average defined as the ordinary drought, under over 80% defined as severe drought. The ordinary precipitation is 100%.

Because of the affection of regional and seasonal condition, and the varied different temporal scale, the single and fixed period precipitation anomaly percentage can not correctly indicate the drought condition of the region, one is the present drought has the relation with the previous dry and wet status, the other is difficult to describe the temporal scale of the drought, however, these are important characteristics of the drought. In order to apply the precipitation anomaly percentage preferably, selecting the Precipitation Anomaly Index (PAI) and through the integration of the temporal scale to indicate the above mentioned drought characteristics, and furthermore to obtain more information than precipitation anomaly data, and realize the objective and effective monitoring of the drought.

PAI is to synthesize consider the affection of the near 10 days precipitation anomaly and previous one month and three months precipitation anomaly, and suitable for the short – term drought monitoring.

The theory of PAI is for single station the precipitation anomaly weighted sum of 0 ~ 10 days, 10 ~ 30 days, 30 ~ 90 days.

The formula of PAI is $PAI = 0.6R_1 + 0.25R_2 + 0.15R_3$

here R_1 is the accumulated precipitation anomaly percentage from the calculate time to past 10 days; R_2 is the 20 days accumulated precipitation anomaly percentage from the calculate time of past 10 days to previous one month; R_3 is the 60 days accumulated precipitation anomaly percentage from the calculate time of previous one month to previous three months.

The PAI value and drought and wetness classification is as following Table 1.

Tab 1 The PAI value and drought and wetness classification

PAI value	Drought and wetness classification
< –80	Extreme drought
–80 ~ –45	Severity drought
–45 ~ –25	Moderate drought
–25 ~ –15	Light drought
–15 ~ 20	Normal
20 ~ 40	Light wetness
40 ~ 75	Moderate wetness
75 ~ 120	Severity wetness
>120	Extreme wetness

3 Remote sensing monitoring drought index

The drought monitoring initially is using the meteorological data, and the data mainly came from the meteorological station. Due to the spatial distribution and its representative problem of the meteorological station, at some region the point observed data to express the areal condition can not objective to reflect the actual condition. However, the remote sensing technology can quickly acquire the temporal and spatial continuous areal terra spectrum information, not only macro monitoring the surface water budget condition, and micro indicating the terra spectrum and surface evapotranspiration variation due to the budget of the moisture. It is unable to reach using the ordinary observation network, and the representative of the remote sensing is higher than that of the ordinary data.

Relate to the traditional methods, the remote sensing technology has the advantage of macro, objective, quickly and cheap and its fast development in recent years, make the new approach for the drought monitoring. The satellite system can provide the global scale temporal and spatial continuous data, and the potential to process the drought monitoring has been strengthened based on the satellite data.

Up to now, the main methods to carry on the drought monitoring using the remote sensing method are utilizing the NOAA AVHRR or MODIS data to process the vegetation green condition drought monitoring, ground surface character drought monitoring, vegetation condition and ground surface temperature monitoring and leaf area water content drought monitoring etc.

According to the Energy and Water Balance Basic Theory, the Environmental Analysis and Remote Sensing (EARS) company of the Netherlands developed the meteorological satellite (FY – 2C) and ground observed precipitation data based Energy and Water Balance Monitoring System (EWBMS) to carry on the retrieve of the precipitation and evapotranspiration, and selecting the United Nations Convention to Combat Desertification (UNCCD) defined the Climatic Moisture Index (CMI) and Soil Moisture Index (SMI) and the Evapotranspiration Drought Index (EDI) used in agriculture drought to carry on the drought monitoring.

3.1 Climatic moisture index

The CMI was defined by the UNCCD in 1994 as:

$$\mathrm{CMI} = P/LE_p$$

here, P is precipitation, LE_p is potential evapotranspiration.

The CMI indicates a climatic condition. In order to obtain the meaningful products, it is better for the temporal scale of the CMI using one year. Although there can produce the short period product, and for the meaningful product, at least using half year as temporal scale.

The areal precipitation can be calculated through cloud duration method from the meteorological satellite cloud picture, and using the precipitation data observed from the rain gauge station to do the verification. The areal potential evapotranspiration can be obtained from the Energy and Water Balance Theory (EWBMS) and using the satellite cloud picture to retrieve.

3.2 Soil moisture index

The SMI was defined by the UNCCD in 1994 as:

$$\mathrm{SMI} = LE/LE_P$$

here, LE is actual evapotranspiration.

The SMI indicates the actual desertification state of the ground surface. In order to obtain the meaningful products, it is better for the temporal scale of the SMI using one year. Although there can produce the short period product, and for the meaningful product, at least using half year as temporal scale.

The areal actual evapotranspiration and potential evapotranspiration can be obtained from the Energy and Water Balance Theory (EWBMS) and using the satellite cloud picture to retrieve.

3.3 Evapotranspiration drought index

Agricultural drought is defined as drought that occurs when there is not enough moisture available to meet the needs of the vegetation, the Evapotranspiration Drought Index (EDI) indicates the availability of moisture for crop/vegetation growth. The EDI is an agricultural drought indicator. This means that EDI is more than an indicator of the actual drought state of the ground surface. Not only it gives information on the amount of soil water present, it also gives information on the physical and biological properties of the soil and on crop conditions. Crop/vegetation conditions and photosynthesis are directly related to the amount of water that is available for the plants. EDI also includes influences from stage of growth, biological characteristics of the plant, cattle grazing and weather conditions.

The EDI value is defined as the average of relative evapotranspiration for a two month period:

$$EDI = \sum(RET)/N = \sum(LE/LE_P)/N$$

here, N is the number of days during two months.

The agricultural drought classification according to the EDI value is as follows (see Table 2):

Tab 2 Agricultural drought classification based on EDI value

EDI value	Agricultural drought classification
0.9 ~ 1	Optimal water availability
0.8 ~ 0.9	Near optimal water availability
0.6 ~ 0.8	Light agricultural drought
0.5 ~ 0.6	Moderate agricultural drought
0.3 ~ 0.5	Severe agricultural drought
0.0 ~ 0.3	Extreme agricultural drought

The agricultural drought indicator gives information on water availability for crops and vegetation. The agricultural drought indicator is strongly related to soil moisture and the actual drought conditions of the ground. Moisture availability is the most important factor influencing the conditions of crops and plants. The agricultural drought is evaluated over a two months period, a suitable time period to evaluate the growth conditions of the crops and to estimate possible crop yield losses during the growing season.

4 Application and verification

Using the method and theory of PAI can make the PAI figures of the Yellow River Basin day by day. The Fig. 1 shows the PAI for Dec. 31, 2006 of the Yellow River Basin. The Fig. 2 shows the precipitation anomaly of the Yellow River Basin from Dec. 20 to Dec. 31, 2006. The Fig. 3 shows the precipitation anomaly of the Yellow River Basin from Dec. 1 to Dec. 31, 2006. The Fig. 4 shows the precipitation anomaly of the Yellow River Basin from Oct. 1 to Dec. 1, 2006. From the Fig. 1 to Fig. 4, the API of the Shan – Shaan Region (Shanxi and Shaanxi) and Lanzhou upwards of the Yellow River Basin is relatively wet in Dec. 31, 2006, the main reason is from Dec. 20 to Dec. 31, 2006, the precipitation anomaly of the Shan – Shaan Region is excessive over 100%, and from Dec. 1 to Dec. 31, 2006 the precipitation anomaly of the Lanzhou upwards is excessive over 100%. Due to the PAI is the comprehensive result which consider the recent 10 days and previous period precipitation, it is sensitive to the recent dry and wet condition, and more objective and accurate.

Using the EWBMS, from the satellite data to retrieve the areal precipitation and relative evapotranspiration and actual evapotranspiration and potential evapotranspiration, to calculate to obtain the EDI and SMI, from Fig. 5 and Fig. 6, comparing with the API the dry and wet region has the same region and also has different region, the reason is the drought index emphasize point and corresponding calculating time period is different, totally can reflect the dry and wet conditions of the Yellow River Basin.

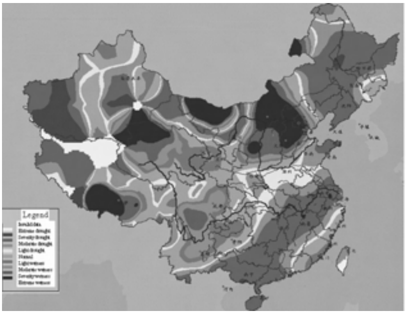

Fig. 1　PAI for Dec. 31, 2006 of Yellow River Basin

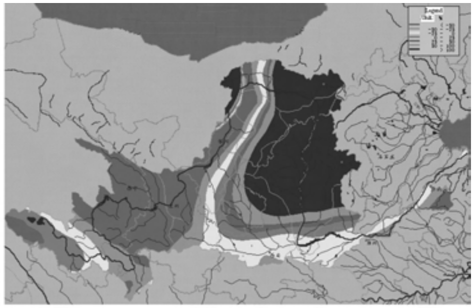

Fig. 2　Precipitation anomaly from Dec. 20 to 31, 2006

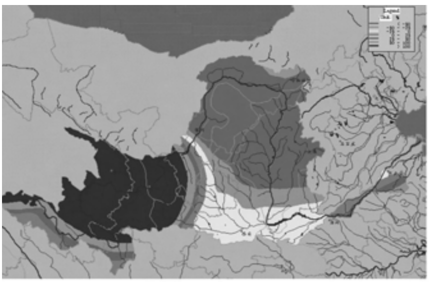

Fig. 3　Precipitation anomaly from Dec. 1 to 31,2006

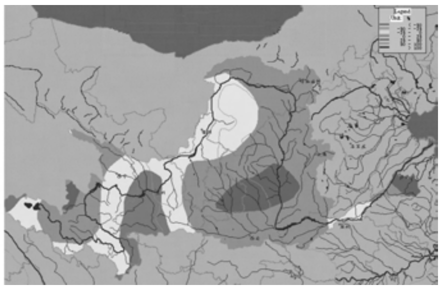

Fig. 4　Precipitation anomaly from Oct. 1 to Dec. 1,2006

Fig. 5　EDI of the Yellow River Basin from Oct. 1 to Dec. 31, 2006 (Unit: legend/10)

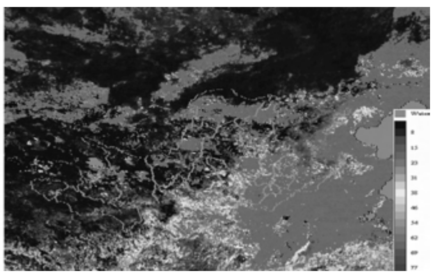

Fig. 6　The SMI of Yellow River Basin from Oct. 1 to Dec. 31, 2006 Dec. 31, 2006

Application of a Regional Climate Model to the Yellow River Basin for Precipitation Modeling

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Abstract: To evaluate the change of water resources over the Yellow River basin, an examination of precipitation was carried out using the Weather Research and Forecasting (WRF) model, a nest generation regional climate model over the Yellow River domain from 1980 to 1997. The results show that the inter – annual variations of precipitation could be represented compared with a dataset based on gauge record at four watersheds over Sanmenxia. The simulated precipitation at two watersheds in upper reaches is in agreement with observed values. There is underestimation at other watershed in middle reaches. The distribution of annual precipitation over the whole basin is almost reproduced. The estimated decreasing areas of precipitation between the period of 1980 ~ 1989 and 1990 ~ 1997 also agree well with the dataset.

Key words: application, regional climate model, the Yellow River Basin, precipitation modeling

1 Introduction

Precipitation as a main input item plays an important role in water budget. The variation of precipitation in the Yellow River basin was very large. Especially, a decrease tendency was continued from 1990. Therefore, how to understand the precipitation system is a one of the key points to understand the water resources change in the Yellow River basin. In this paper, the Weather Research and forecasting (WRF) model (http://wrf – model. org), a next – generation mesocale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs developed by a collaborative partnership, principally among the NCAR, NOAA – NCEP/FSL, AFWA, etc. For easy comparing, four watershed regions above the Sanmenxia hydrological station were selected, namely, Tangnaihai watershed (W1), Tangnaihai – Lanzhou watershed (W2), Lanzhou – Toudaoguai watershed (W3) and Toudaoguai – Sanmenxia watershed (W4) from upper reaches to lower reaches. A 0.1 – grid resolution precipitation data set, one of the products of the Yellow River project based on gauge observation data cover the Yellow River domain was used to evaluate the WRF performance in the basin in the period of 1980 ~ 1997.

2 Model setting

The calculation domain was showed in Fig. 1, the center point was set to be 35.5°N and 105°E. Horizontal resolution was set to be 20 km, and there are 160 and 92 grids in x – and y – axis, respectively. NCEP reanalysis dataset in 6 hour interval is used as the lateral boundary condition. A sensitivity experiment was carried out to check to the performance for each microphysics and cumulus scheme in two wet years (1989 and 1992) and two dry years(1986 and 1997). Two cases are selected to run in whole period. The model was run in 60 seconds time step under the SGI Altix 4700 system.

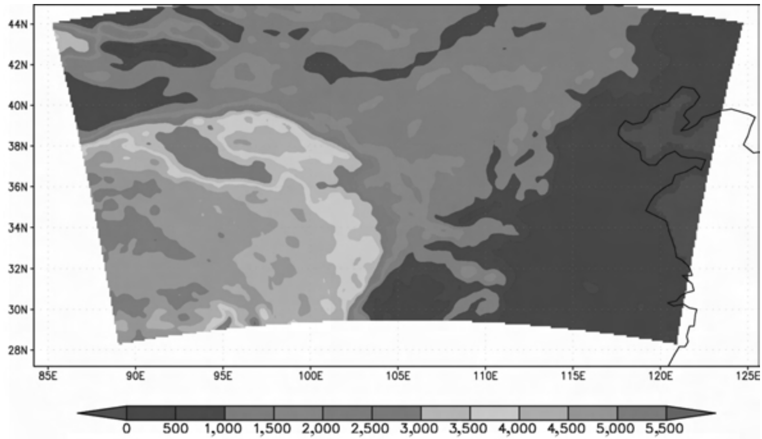

Fig. 1 Elevation of the calculation domain selected in this study (Unit: m)

3 Results

Two - case run results are shown in Fig. 2. In case 1, WSM 6 - class graupel scheme and Kain - Fritsch scheme are used as microphysics and cumulus. A combined of Lin et al. scheme and Kain - Fritsch is used in Case 2. A 0.1 - grid precipitation, one of the products of the Yellow River Projet (YRP) based on gauge data is used as observed value in this study.

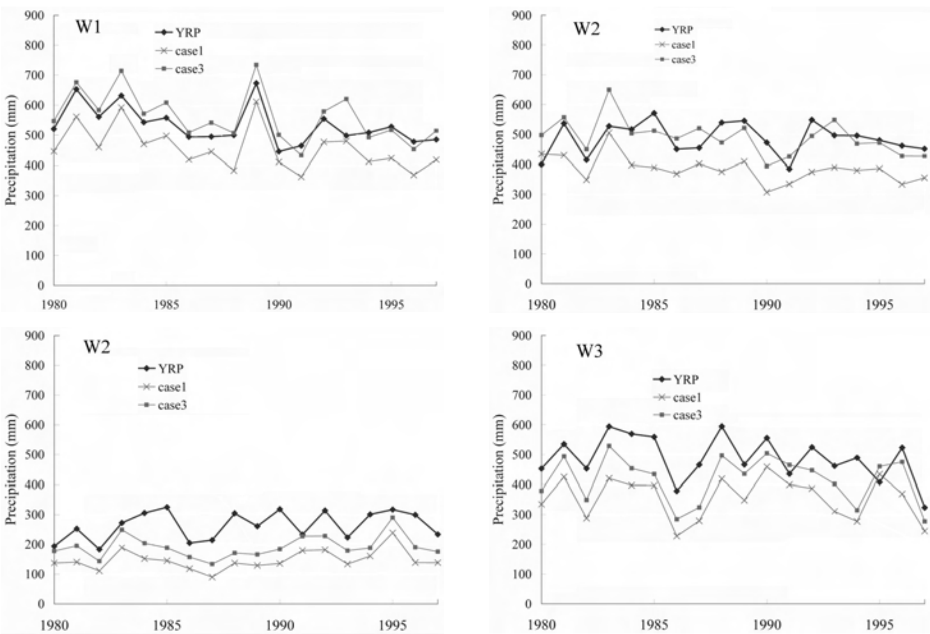

Fig. 2 Comparison of annual precipitation at four watersheds of the Yellow River over Sanmenxia hydrological station between WRF output and YRP dataset from 1980 to 1997

An inter – annual variation of precipitation was represented for all watersheds. The simulated precipitation at two watersheds in upper reaches (W1 and W2) is in agreement with observed values. There is underestimation at other watershed in middle reaches (W3 and W4). The distribution of annual precipitation over the whole basin is almost reproduced. The estimated decreasing areas of precipitation between the period of 1990 – 1997 and 1980 – 1989 agree well with the dataset (Fig. 3).

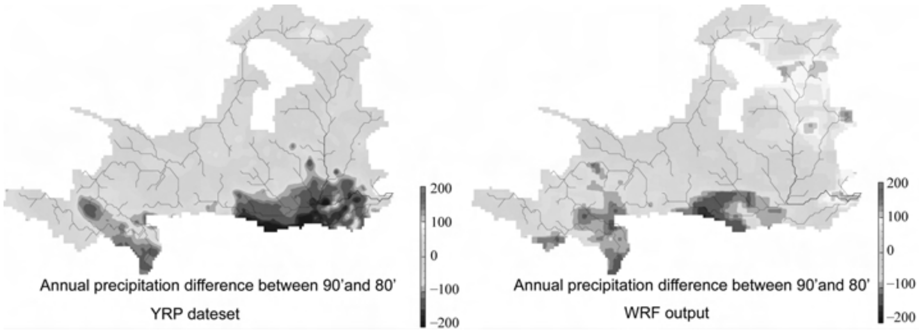

Fig. 3 Comparison of precipitation difference between the period of 1990 ~ 1997 and 1980 ~ 1989 from YRP dataset and WRF (case 3) output (Unit: mm)

For the watershed W3 and W4, more detailed investigation is required to improve the accuracy of precipitation modeling. An integrated water cycle simulation using a climate model and hydrological model will be done in the near future.

Co – operation on Flow Forecasting between YRCC and DG Rijkswaterstaat

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Abstract: It gives the background information on the co – operation between YRCC and DG Rijkswaterstaat regarding to set up rainfall – runoff model for the Rhine River Sieg basin and the Yellow River Heihe basin in the paper, and the technical approach to carry out the work. The structures and applications of the semi – distributed precipitation – runoff HBV model and Xin'anjiang (XAJ) model are introduced as keystone here, as well as the further co – operation on hydrological model between YRCC and DG Rijkswaterstaat.
Key words: flow forecasting, the Rhine River Sieg basin, HBV model, the Yellow River Heihe basin, XAJ model

During the second International Yellow River Forum (IYRF) first contacts were made between hydrological experts from the Yellow River Conservancy Commission (YRCC) and the Dutch Ministry of Transport and Public Works and Water Management DG Rijkswaterstaat (RWS RIZA). It was concluded that both organisations use similar methods for flow forecasting in the basins of the Yellow River and the Rhine and Meuse. Both use hydrological models within a similar designed user interface build upon a database. As input data, hydrological and meteorological measurements from ground stations are used. Both China and The Netherlands plan to use data from precipitation radar in the near future. During the forum technical information in the form of articles and presentations on the subject were exchanged. In a follow up meeting in April 2006 in The Netherlands cooperation on the topic flow forecasting was further discussed between staff from YRCC and RWS RIZA and it was decided to carry out a joint project on hydrological modelling.

Both YRCC and RWS RIZA are responsible for the development of models for flow forecasting as well as for the operational process for flow and river stage forecasting, YRCC for the basin of the Yellow River and RWS RIZA for the border stations of the Rhine and the Meuse in the Netherlands. Both institutes have operational models and an operational information and warning service and both are currently adapting their systems to the latest technical state of the art, both regarding modelling as well as regarding data technology. YRCC and RWS RIZA decided that they can support and learn from each other during the course of the common project. In the initial phase of a long – lasting and consistent co – operation, it was decided to investigate the suitability of different rainfall runoff models in sub catchments of the Rhine and the Yellow River. Aim of this pilot is to learn more of the mutual river basins and the hydrological models that are used and to see whether these models can be exchanged between the Yellow River and the Rhine.

1 Objectives and methods

1.1 Selection of the sub – catchments

It was decided to carry out the pilot in medium size sub catchments and with representative characteristics for a large part of the basin. Furthermore, hydrological processes in the catchment should not be influenced too much by anthropogenic activities (like weirs etc.). Also sufficient data to set up a hydrological model should be available; this concerns both geographical data of the basin as well as meteorological and hydrological time series. A sub basin of the Rhine the river Sieg was chosen and as sub basin of the Yellow River the Heihe River.

1.2 Description of the Sieg basin

The Sieg is a tributary of the Rhine, entering the Rhine on the right side 660 km downstream Lake Constance and about 200 km upstream the German Dutch border. The area of the basin is 2,861 km^2 and the length of the river is about 150 km. The Sieg is a mountainous river with steep slopes and a network of tributaries. The gradient of the river is rather uniform, with a slope of about 2.5 m/km in the upper basin, slowly decreasing to about 1 m/km near the confluence (Fig. 1).

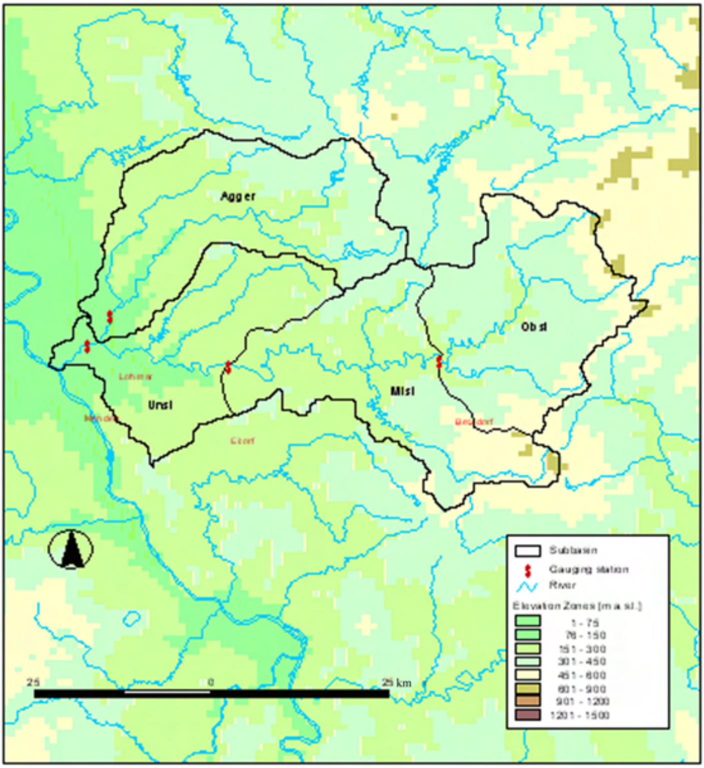


Fig. 1 Map of the Sieg basin

The geology of the basin is dominated by rocks with low permeability and a large contribution of overland flow and subsurface runoff to flood generation. The contribution of groundwater to flood generation is neglectable. The vegetation of the basin is a combination of cultivated land and forest.

Floods in the Sieg basin are formed by different weather types, depending on the season. In summer, convective thunderstorms can lead to high - intensity local rainfall. The resulting floods are severe on smaller tributaries, but only major thunderstorms over a large area will lead to floods at the outflow. In winter most rainfall is due to frontal system, which are characterised by relatively low intensity rainfall of long duration (often several days) over a large area. Floods resulting from this type of weather can be locally unimportant, but may lead to major floods at the point of outflow and as such also on the Rhine.

The average yearly rainfall over the Sieg basin is between 800 mm and 1,000 mm, but the sub catchment of the northern tributary Agger has a much more unequally rainfall pattern with yearly values up to 1,500 mm. The discharge pattern reflects the rainfall pattern and most of the floods occur in winter. Snow can be important for the hydrology of the Sieg basin. Snow occurs regularly each year. In theory snow is important in periods of temperature increase and/or rainfall on the snow, but the flood wave is much stronger correlated to rainfall than to snow.

Only a small part of the Sieg is in natural state. From about 1900 dykes were build along the river. Along the main river inundation areas are present, that are flooded during a flood with a return period of 100 years. In the upper part of the river 6 reservoirs exist with a total volume of about 1.23×10^8 m^3. In general the influence of reservoirs is small in flood situations.

1.3 Description of the Heihe basin

The Heihe Basin originates in the Qinling Mountains. It is a tributary of the Weihe River, the largest tributary of the Yellow River, entering into the Weihe on the right hand side about 20 km upstream of the Xianyang gauging station. The area of the basin is about 2,250 km^2 and the length of the main stream is 126 km. Heiyukou gauging station is the control station of the river with a drainage area of 1,481 km^2 and 35 km upstream of the river outlet(Fig. 2).

Fig. 2 Map of the Heihe basin

The Heihe is a mountainous river with steep slopes and a network of tributaries. The average slope of river is about 8.6‰, that of the main channel about 14.5‰. The geology of the basin is dominated by rocks with thin layers and good vegetation (covering more than 85% of the basin). It has low permeability and a large contribution of overland flow and subsurface runoff to flood generation. The contribution of groundwater to flood generation can be neglected.

The area belongs to the continental climate zone. The average annual temperature is 13.1 ℃. The average yearly rainfall is 700 ~ 900 mm. Storms usual occur in the period from June to October and heavy storms mostly in July and August. Rainfall from July to September makes up 50% ~ 60% of the yearly total. Continuous rainfall with relative low intensity over a long duration (5 ~ 10 days or even longer) and over a large area is very common in the basin.

Floods in the Heihe basin are mainly caused by high – intensity local rainfall or long duration rainfall over a large area. The recorded maximum flood peak at Heiyukou is 3,040 m^3/s (1980), while the investigated maximum flood peak is 3,620 m^3/s (1898). The flood has the characteristics of a quick confluence with a relative large volume. The runoff coefficient for an event is about 0.3 ~ 0.5.

There is a medium sized reservoir 1.5 km upstream of Heiyukou, built in 1987. The main objectives of the reservoir are flood control, irrigation and water supply. The influence of the reservoir in general is small on hydrological conditions upstream Heiyukou but big on the flood peak and water volume downstream Heiyukou in a flood event.

2 Existing data

2.1 Data available for the Sieg basin

Hourly meteorological data is available for about 20 stations in de basin for 14 selected flood periods between January 1980 and February 1995. Six hourly meteorological data is available for 3 stations in the basin for the complete period 1996 ~ 2006 Daily meteorological data is available for 3 stations in the basin for the entire period 1961 ~ 2000.

Hourly discharge data is available for about 8 stations in the basin for 14 selected flood periods between January 1980 and February 1995. Hourly discharge data can be made available for 3 stations in the basin for the period 1961 ~ 2006.

Land use is available in digital form in the Corine lay out. Soil data is available in digital form in the lay out of the European soil database. A digital elevation model with grid size of 75 m is available. Delineation of catchments and rivers, location of meteorological and hydrological stations is available in digital form.

2.2 Data available for the Heihe basin

Daily and hourly rainfall data are available for 7 stations in the basin for 11 selected flood periods between 1990 and 2005 (see Table 1).

Table 1 Available data for the Heihe basin

Station Name	Items	Period	Note
Houzhenzi	Daily & Hourly rainfall	1990 ~ 1996, 1999 ~ 2005	1997, 1998 missing
Shaliangzi	Daily & Hourly rainfall	1990 ~ 2005	
Banfangzi	Daily & Hourly rainfall	1990 ~ 1996, 1998 ~ 2005	1997 missing
Laoshuimo	Daily & Hourly rainfall	1990 ~ 2005	
Xiaowangjian	Daily & Hourly rainfall	1990 ~ 2005	
Jinjing	Daily & Hourly rainfall	1990 ~ 2006	
Chenhe	Daily & Hourly rainfall	2000 ~ 2005	
	Daily & Hourly discharge	2000 ~ 2005	
	Measured discharge	2002 ~ 2005	
Heiyukou	Daily & Hourly rainfall	2000 ~ 2005	
	Daily & Hourly discharge	2000 ~ 2005	
	Measured discharge	2000 ~ 2005	
	Daily evaporation(by Pan)	2000 ~ 2005	
	Cross section	1991 ~ 2001, 2005	

Daily and hourly discharge data are available for 1 station in the basin for flood periods between 2000 and 2005.

Land use data, soil types and a 90 m × 90 m DEM can be obtained from the USGS website. The stream network, vegetation data, topography, geology and elevation data is available from the YRCC database. Also information on the location of meteorological and hydrological measuring stations are available in digital form.

3 Existing hydrological models

3.1 Description of the HBV model

In the Rhine basin the HBV modelling software is used for hydrological modelling. The HBV model is a conceptual semi – distributed precipitation – runoff model. It was developed at the

Swedish Meteorological and Hydrological Institute (SMHI) in the early 1970s.

As the HBV model is a conceptual model it describes the most important runoff generating processes with simple and robust structures. The following points give a short overview of the three main components in the model together with examples for related parameters.

3.1.1 Precipitation and Snow Routine

The precipitation as the initial input into the model is divided into rainfall and snowfall. This process is ruled by a threshold temperature (parameter *tt*) below which precipitation is supposed to be snow; the transition from rain to snow can be realised continuously over a temperature interval (parameter *tti*). Snow melt computations are based on a day – degree relation (snow melt factor *cfmax*). The snow distribution is computed separately for different elevation and vegetation zones in the basin (see later on in this chapter).

3.1.2 Soil Routine

This part of the model controls which part of precipitation forms excess water and how much water is evaporated or stored in the soil. The runoff coefficient depends on the ratio of actual soil moisture and the maximum water storage capacity of the soil (parameter *fc*) as well as an exponent representing drainage dynamics (parameter *beta*). The parameter *lp* defines the water storage in the soil at which actual evaporation is starting to be equal to potential evaporation. Values of potential evaporation are required as input data and there is a special correction factor for evaporation in forest areas (*cevpfo*). Interception in forest areas and open land can also be simulated (parameters *icfo* and *icfi*).

3.1.3 Runoff Generation Routine

This routine is the response function which transforms excess water from the soil routine to runoff. The routine consists of one upper, non – linear reservoir (parameters *khq*, *hq* and *alpha*) and one lower, linear reservoir (recession coefficient *k*4). The upper one represents direct runoff. The lower reservoir represents the base flow which is fed by groundwater. Groundwater recharge is ruled by a maximum amount of water that is able to penetrate from soil to groundwater (parameter *perc*). Timing and distribution of the resulting runoff is further modified in a transformation function by means of a retention parameter (*maxbas*); this routine is a simple filter technique with a triangular distribution of the weights as shown in the figure below at the bottom on the right (SMHI, 1996). This figure illustrates the general way of discharge formation in the HBV model and states the main parameters and formulas implemented in the model.

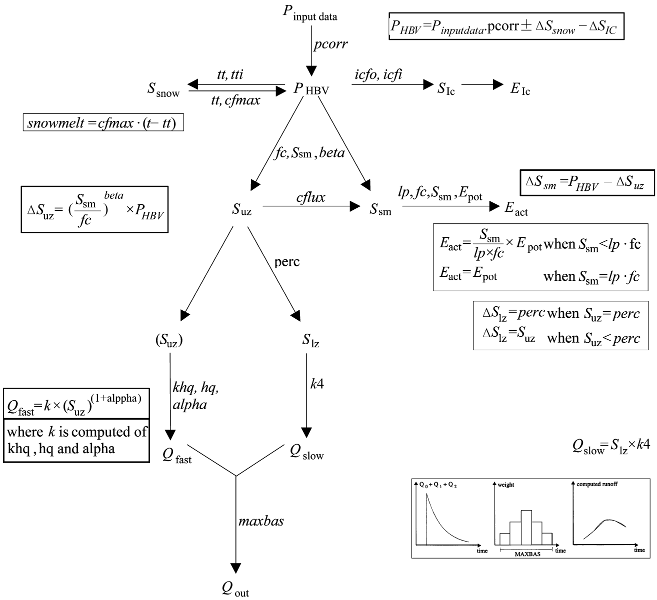
For more information on the HBV model, check www.smhi.se/en/index.htm and look under Hydrology - HBV – Model(Fig. 3).

The spatial units of the semi – distributed HBV model are sub basins, which represent real river catchments. These are further divided into zones of different elevation and land cover (only forest and non forest). The zone area is proportional to the occurrence of its characteristic in the sub basin, however, zones cannot be geographically localised.

The whole river basin that is simulated is called a district. The sub basins that form a district can be linked together with a simplified Muskingum approach to simulate flood routing processes.

3.2 Description of the XAJ model

The Xin'anjiang (XAJ) model is a distributed rainfall – runoff model, for use in humid and semi – humid regions. Its core is runoff generation on repletion of storage to capacity values, which are assumed to be distributed throughout the catchment. Runoff is separated into three components, namely surface runoff, interflow and groundwater runoff. The evapotranspiration component is represented by a model of three soil layers. A lumped model is adopted when the basin area is small and, adversely, block models are used, that solve mainly the non – uniformity of the rainfall distribution. The basin is divided into a set of sub – basins, the outflow hydrograph from each of which is first simulated and then routed down the channels to the main basin outlet. There are many parameters in the model, but it is not very difficult to calculate every parameter separately on account of that most of them have special physical meanings. The flow chart for XAJ model is shown in Fig. 4.



$P_{\text{input data}}$ = recorded precipitation data S_{sm} = soil moisture storage Q_{fast} = fast runoff component

P_{HBV} = precipitation in the HBV model E_{act} = actual evapotranspiration Q_{slow} = slow runoff component

S_{snow} = snow storage S_{uz} = storage of upper zone Q_{out} = computed runoff

S_{Ic}—interception storage $(S_{uz}) = S_{uz}$ after percolation

S_{Ic} = evaporation from interception S_{lz} = storage of lower zone parameters in italics

Fig. 3 Simplified scheme of the HBV model

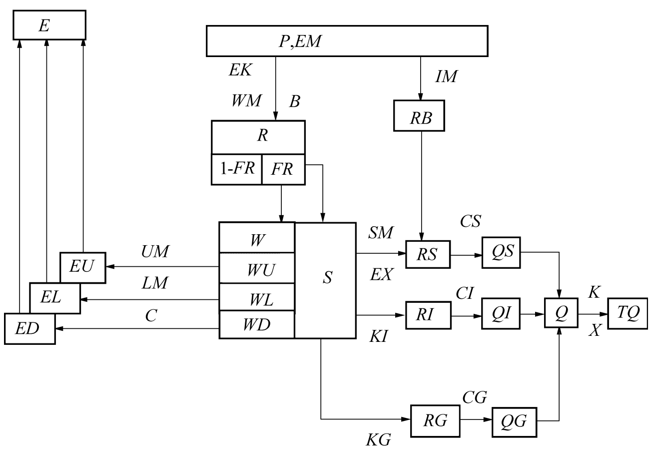


Fig. 4 Flow chart for the XAJ model

The symbols for inputs, outputs and state variables appear inside the blocks of Fig. 3; those for parameters (constants on each – basin) appear outside the corresponding blocks.

The XAJ model consists of the following three routines.

3.2.1 Evapotranspiration

Evapotranspiration is related to potential evapotranspiration through a three – layer – soil moisture model depending on four parameters EK, UM, LM and C. When the storage WU of the uppermost layer is sufficient, evaporation from each layer shows that

$EU = EK \cdot EM, EL = 0.0, ED = 0.0$

When the storage WU of the uppermost layer is insufficient and the storage of the lower layer is sufficient, evaporation from each layer shows that

$EU = WU, EL = (EK \cdot EM - EU) \cdot WL/LM, ED = 0.0$

When the storage of the lower layer is insufficient, but WL is more equal than $C(K \cdot EM - EU)$ then each layer evaporation shows that

$EU = WU, EL = C(EK \cdot EM - EU), ED = 0.0$

Else if WL is less than $C \cdot (EK \cdot EM - EU)$ then each layer evaporation shows that

$EU = WU, EL = WL, ED = C(EK \cdot EM - EU) - EL$

3.2.2 Runoff generation

Runoff generation at a point occurs only on excess of the water retaining storage at that point.

$$A = MM\left[1 - \left(1 - \frac{W}{WM}\right)^{\frac{1}{1+B}}\right]$$

$$MM = WM\,\frac{1+B}{1-IM}$$

If $P - E < 0$, then

$R = 0$

If $P - E + A < WM$, then

$$R = P - E - WM + W + WM\left[1 - \frac{P-E+A}{WM}\right]^{(1+B)}$$

Otherwise

$R = P - E + W - WM$

3.2.3 Runoff separation components

$SSM = (1 + EX)SM$

$$AU = SSM\left[1 - \left(1 - \frac{S}{SM}\right)^{\frac{1}{1+EX}}\right]$$

The total runoff R, generated in a wet period, must be separated into its three components: RS is the surface runoff, RG is the ground water contribution, RI is the contribution to interflow.

$$FR = \frac{R - IMP(P-E)}{P-E}$$

$RG = S \cdot KG \cdot FR$

$RI = S \cdot KI \cdot FR$

If $P - E < 0$, then $RS = 0.0$

If $P - E + AU < SSM$, then $RS = \left[P - E - SM + S + SM\left(1 - \frac{P-E-AU}{SSM}\right)^{1+EX}\right]FR$

Otherwise

$RS = (P - E + S - SM)FR$

3.2.4 Flow concentration

Runoff concentration includes two steps, which is overland runoff concentration and channel flow routing. Runoff concentration to the outflow of each sub – basin is usually represented by a unit hydrograph or by a lag and route technique, also Muskingum method can be used here. But at most time Muskingum method is applied to channel flow routing.

4 Description of the activities

A joint project was carried out in which YRCC has set up a hydrological model for the Sieg basin with the XAJ model. RWS RIZA has provided all the necessary data and information for these activities. Parallel RWS RIZA has set up a hydrological model for the Heihe basin with the HBV modelling software. YRCC has provided all the necessary data to carry out this work. The work has started late 2006 with a kick off meeting in Zhengzhou. First results of the project will be presented during the third IYRF in October 2007 in Dongying.

In the project the suitability of the HBV model in the sub catchment of the Heihe River and the suitability of the XAJ model in the Sieg catchment were tested. For both catchments a spatial modelling structure was made. The available time series were analysed and the model parameters were determined and verified based on separate calibration and verification data sets.

The Examination along with the Presentation of Flood – forecasting System in Real Time in the Maroon River Reservoir Dam through Using WMS Software (Watershed Modeling System)

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Abstract: The optimum exploitation of dams reservoir requires the short and long term time steps projecting. In general , the exploitation of dams reservoir depends on the amount of the river flow. The how muchness of the water importing into dams reservoirs may be different in regard to hydrologic & climatologic conditions. The main concern of this study is the presentation of the Maroon river flood – warning system in Real Time manner and in the Maroon dams reservoir cross section. In order to prepare a Flood – Warning system WMS software has been used. Totally we should pass two basic stages for presenting the Flood – Warning system. The stages are as follows: A. The calibration of the basin model, based on the recorded historical data such as: RIVER DISCHARGE, PRECIPITATION as well as TEMPERATURE. B. The flood routing in different cross sections of the river by making use of hydraulic & hydrologic methods.

Key words: the analysis of the river flow, flood – warning system, the optimum exploitation of dam reservoirs

1 Introduction

In regard with the population increase, human activities , the important hydraulic changes on the Earth, being our country located in a dry zone and insufficiency of rainfall, this is a necessity to make some plans to get the best use of water resources in terms of developmental along with the constructive projects in our country , Iran, is felt more than ever.

If you want to meet having a sound planning as well as an increase in the exploitation yield output of the bounded water resources, one of the most important efforts you should undertake is to innovate a novel order in terms of census taking and getting access to the accurate statistics together with the information on water resources.

Nowadays, due to technology progress , applying the improved sciences as well as getting to the point use of the exact – working electronic machines not only the accuracy of statistics but also the translation speed has been developed.

The more the statistics accuracy & the translation speed, the more rational and economical the decisions which have been made on water resources exploitation.

Therefore capitalization on the work of water resources studies and researches, is the most important factor in making the economical as well as social goals of our country , Iran , gains a great value.

Khuzestan province from the surface waters in our country, Iran, basins point of view has a high potentiality. The Maroon river with the basin (to where the Maroon river dam reservoir is) measuring 3,824 km^2 surface area between 49 degree and 50 minute, to 51 degree to 10 minute eastern longitudes , and 30 degree and 30 minute to 31 degree and 20 minute northern latitudes is located at the elevations of Behbahan city.

The Maroon basin is surrounded by the Zohre and the Karoon rivers in Khuzestan as well as Kohkiloye & Boyerahmad provinces. The Maroon river is made up of the headbranches of Loadab, Absaghaveh, Abshoor, Abcharusagh and Abghellat joining together. Passing the Maroon dam, enters into the Behbahan plain, irrigating this plain comes into the narrow slopes.

Crossing about 45 km of the mountain direction, the river goes on to the western north and enters into the narrow plain of Jayzan.

This river receives some other subbranches down the Jayzan plain, afterwards it links to the Allah river & creates the Jarahi river. Irrigating the Khalafabad plain, the river enters to the Shadegan plain.

At the times of flood, this river scatteres around the Shadegan plain to large extent, then flows down to the Persian Gulf.

Generally speaking, 71% of the Maroon dam reservoir basins is more than 1,500 m high. Due to the specific climatical situation, this zone is taken into account as a part of the wet Zagros & has got a considerable precipitation that is the main source of the maroon river water resources. Table 1 and Fig. 1 show the Surface Area Distribution In terms of The Height.

Table 1 Show the surface area distribution in terms of the height

ROW	Elevation limits	Average height	Basin surface area		Surface area percentage	
			Partial	Total	Partial	Total
	(msl)	(msl)	km^2	km^2	(%)	(%)
1	360 ~ 500	430	29	29	0.8	0.8
2	500 ~ 1,000	750	720	749	19.1	19.9
3	1,000 ~ 1,500	1,250	955	1,704	25.3	45.2
4	1,500 ~ 2,000	1,750	980	2,684	26.0	71.2
5	2,000 ~ 2,500	2 250	825	3 509	21.9	93.1
6	2,500 ~ 3,000	2,750	240	3,749	6.4	99.5
7	3,000 ~ 3,415	3,028	21	3,770	0.6	100.0

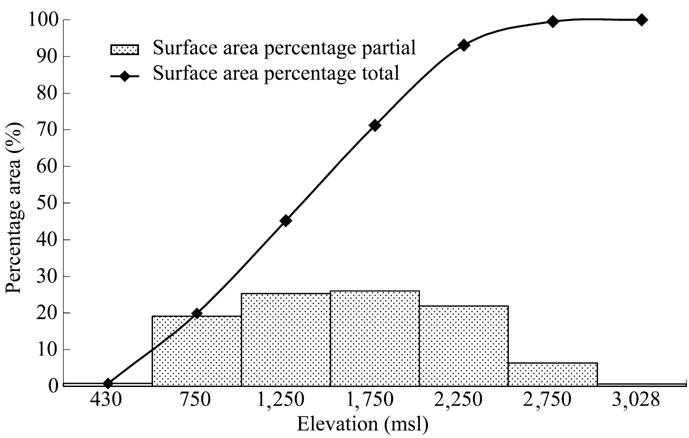

Fig. 1 The altimetrical histogram & the hypsometric curve of the maroon River Basin in Terms of height & surface area percentage

2 The summary of the maroon river physiographic features at the given hydrometric stations

This survey has been accomplished in the Maroon river basin as well as the three subbasins of Idenak, Behbahan and Chamnezam. Table 2 show The concise Physiographic Features Of The Given Subbasins.

Table 2 The concise physiographic features of the given subbasins

Station	river	Shape & surface area of basin			Equivalent rectangle			Basin elevations		Linear profile of river		
		Surface area	Peri meter	Gravlious coeffici-ent	Long	Wide	Slope	Mini-mum	Maxi-mum	Lenght	Impure slope	Pure slope
		km^2	(km)		(km)	(km)	(%)	(m)	(m)	(km)	(%)	(%)
Idenak	Maroon	2,754.0	314.9	1.68	136.4	20.20	2.05	610	3,400	97.5	1.72	1.13
Behb ahan	Maroon	3,824.2	413.0	1.68	185.5	20.62	1.66	325	3,400	146.3	1.33	0.99
Cham nezam	Maroon	5,401.0	493.4	1.68	227.8	23.71	1.41	195	3,400	201.3	1.03	0.61

3 The homogeneity test the maroon river hydrometric stations

Before dealing with the analysis & ingestion of data, it is necessary for a hydrologist to be assured of the quality and completeness of the statistical series. If you don't assess the data, the complicated statistical analysis will not show an authentic result. There are many ways to know whether these data and the figures which are analyzed are homogeneous or not. These ways can be classified into two groups: ①Graphical; ②Non - graphical.

In this study the non - graphical one has been used to do homogeneity test. According to this test, Idenak, Behbahan and Chamnezam hydrometric stations data are homogeneous at the confidence level of 5%.

For example, the homogeneity test of Idenak hydrometric station data is shown in Table 3 (Alizadeh Amin, 2001).

Table 3 The homogeneity test of Idenak hydrometric satiation average flow (in the statistical time span 1976 ~ 2000)

Sequence number	Based onaverage sequences	Sequence number	Based on sequences medians	Annual discharge average	Year
1	a	1	a	27.61	1967
	a		a	40.05	1968
1	b	1	b	89.79	1969
2	a	2	a	23.01	1970
	a		a	30.76	1971
2	b	2	b	58.75	1972

Continued to Table 3

Sequence number	Based onaverage sequences	Sequence number	Based on sequences medians	Annual discharge average	Year
3	a	3	a	22.28	1973
	a		a	44.94	1974
	a		a	46.89	1975
3	b	3	b	108.60	1976
4	a	4	a	30.89	1977
4	b	4	b	69.31	1978
5	a	5	a	41.12	1979
5	b	5	b	78.24	1980
6	a	6	a	42.81	1981
	a		a	41.99	1982
	a	6	b	51.41	1983
	a	7	a	28.00	1984
	a		a	41.99	1985
	a		b	51.18	1986
6	b	7	b	88.68	1987
7	a		b	48.69	1989
	a	8	a	35.52	1990
7	b	8	b	67.75	1991
8	a	9	a	44.96	1992
8	b	9	b	90.23	1993
	b		b	115.28	1994
9	a	10	a	18.10	1995
9	b	0	b	74.87	1996
	b		b	63.91	1997
10	a	11	a	32.69	1998
10	b	11	b	85.64	1999
11	a		b	46.67	2000
	a	12	a	24.06	2001

MEDIAN	AVERAGE	na = 11	nb = 11
45.82	53.14	nb = 12	nb = 12
		u = 7 ~ 19	u = 7 ~ 19

4 To complete the maroon river the statistics of hydrometric stations

The statistics of Idenak hydrometric station in the statistical time span (1967 ~ 1999) has some flaws. Most of them are related to the water year of (1986 ~ 1987).

Consequently it necessitates for the statistics of the chosen years to be completed. To do so regarding to the monthly statistics of Behbahan hydrometric station being perfect, a correlative relation between these two stations is established so that the results are as follows:

$$R = 0.98$$
$$Y = 0.96X - 0.18$$
$$N = 323$$

In this relation X is equal to the monthly discharge of Behbahan hydrometric station in (m^3/s), Y is equal to the monthly discharge of Idenak hydrometric station in (m^3/s).

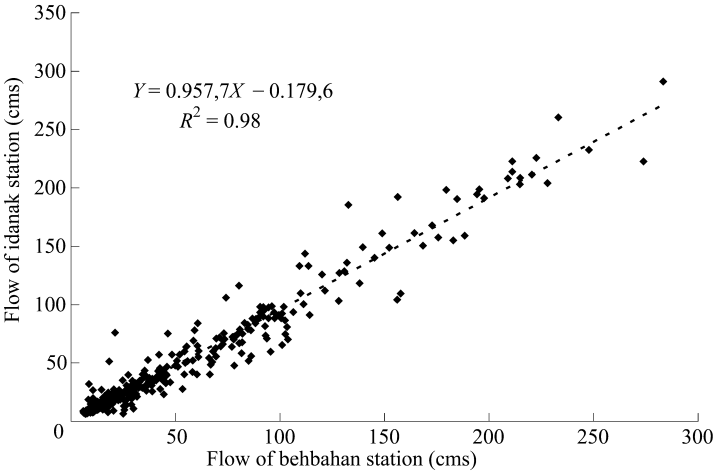

Fig. 2 Shows the correlative relation between the Maroon river Flow at the cross sections of Idenak & Behbahan hydrometric stations (1967 ~ 1999)

5 The analyses of the occurred floods at the given hydrometric stations

As it was discussed previously, this survey has been done in three subbasins of Idenak, Behbahan & Chamnezam hydrometric stations in turn since 1977, 1956, 1987 are available. In these three stations most of the floods have been occurred in November. For instance, the results of the occurred floods analysis in Idenak subbasin are shown in Fig. 3.

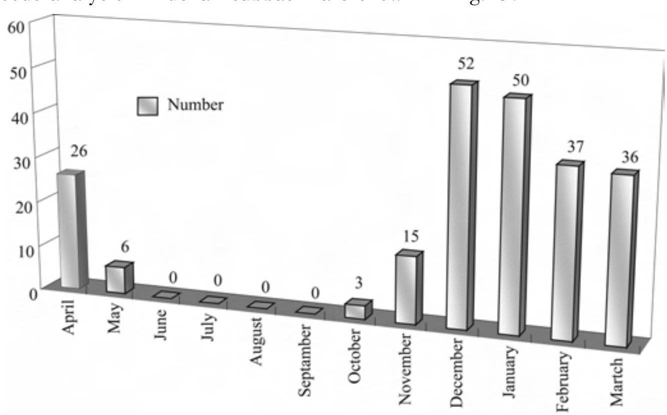

Fig. 3 The frequency of the occurred floods peaks in Idenak hydrometric station in the time span of April to March (1967 ~ 2000)

It is well to say that this process has been repeated for Behbahan as well as Chamnezam hydrometric stations too.

6 The precipitation analysis in the maroon pluviometric stations to reservoir dam cross section of it

Idenak pluviometric station is located in the vicinity of the hydrometric station & its altitude to sea – level is 560 m. The rainfall statistics of Idenak pluviometric station from 2000 on are available. The information on the precipitation of 1973 to 1974 water years is completed and prolongated through using the correlative relations to Behbahan pluviometric station. This relation is as follows:

$$R = 0.94$$
$$Y = 0.540,3X$$
$$N = 323$$

where, X is equal to the amount of the monthly precipitation in Idenak hydroclimatological station and Y is equal the amount of the monthly precipitation in Behbahan hydroclimatological station. This subject is shown in Fig. 4.

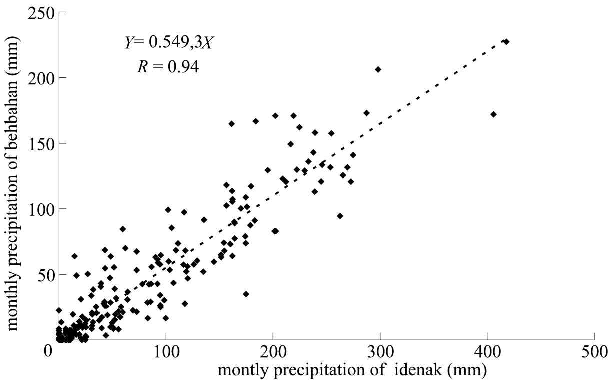

Fig. 4 The precipitation correlative relation between Idenak & Behbahan pluviometric stations in the observed statistical span (1970 ~ 2000)

By the way the horal precipitation statistics have been used in the calibration process of the run – off rainfall in the related basin.

The pluviometric station of Behbahan has nearly located close to the Maroon reservoir dam and its altitude to sea – level is 333 m. The precipitation statistics of Behbahan pluviometric station from 1966 on are available. The pluviometric station of Chamnezam is nearly located in the vicinity of Chamnezam hydrometric station & its altitude to sea – level is 190 m.

The precipitation statistics of Chamnezam pluviometric station from 1977 on are available. The monyhly precipitation correlative relation of this station as well as Behbahan pluviometric station is as follows:

$$Y = 0.924,7X$$
$$R = 0.90$$
$$N = 235$$

where, Y is the amount of monthly precipitation of Behbahan hydroclimatological station; X is the amount of monthly precipitation of Chamnezam hydroclimatological station.

7 Some pieces of information on the snow covering situation of the maroon river basin

situations At the present time , there are many snow – measuringin the Dez & the Karoon basins by which the size of the snow thickness, the equivalent water depth together with the snow considerations are measured in a turn & in the yearly manner.

Unfortunately , up to now this has not been donable in the Maroon river basin & no snow –

measuring stations has been established. At the result it has been tried to make use of the taken statistics out of the available stations in Khuzestan river basin(one of the main headbranches of the Karoon river) that is positioned near the Maroon river & is very helpful to determine the amount of the Maroon river snow budget.

For the same reason we get use of the taken statistics of Lordegan & Yasooj synoptic stations to assign the days in which snowfall has been happened.

It is good to mention that by means of satellite pictures which are accessible on the Internet from 1989 on, the snow cover percentage of the Maroon & the Karoon basins is . computed . Fig. 5 and Fig. 6 show this matter

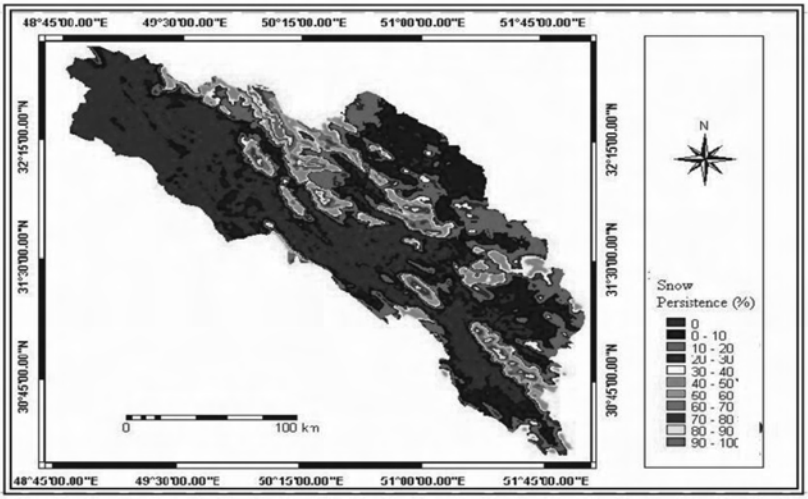

Fig. 5　The snow – cover region of the Karoon river in the statistical time span (1989 ~ 2003) along with the percentage of snow existence in these regions

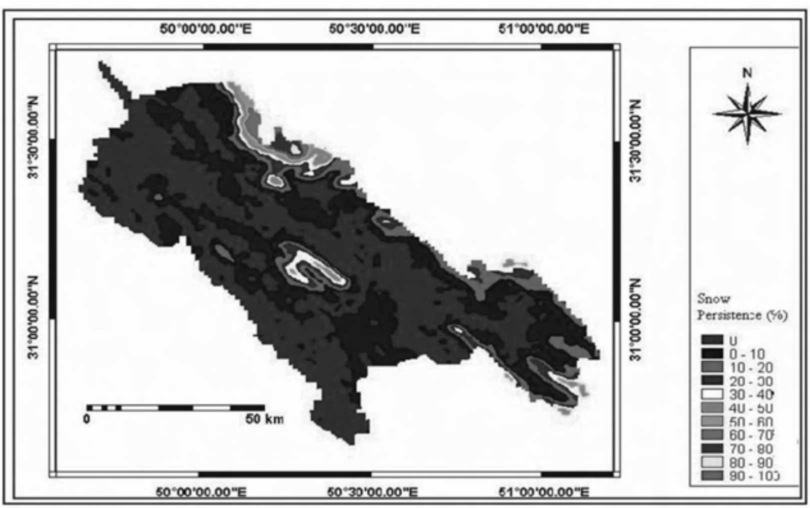

Fig. 6　The snow – cover region of the Maroon river in the statistical time span (1989 ~ 2003) along with the percentage of snow existence in these regions

8 The calibration process of run – off & flood routing simulation parameters in different chosen cross sections

This survey has been achieved by getting help of WMS software . This software simulates the floods in a single – event manner. The procedure is that at first some prevailing floods in those basins which are chosen for calibration. (For example, in this study 29 floods have been selected for calibrating the sub basins of Idenak, Behbahan & Chamnezam). Each flood is defined individually & separately for the software then some parts of the basin model such as the surface area of the subbasins , the Lat – Lon of the hydrometric & pluviometric stations as well as water deviation are determined . Afterwards the methods of computing precipitation damages such as penetration, evaporation as well the computing method of unit hydrograph is defined. Moreover for simulation of the snow – melting, you should define the flood starting & stopping dates, the snow – covered elevations o f the basin along with the aerology stations temperature for the software.

It is helpful to say that for the calibration of the run – off of precipitation model, WMS can be applied in to two ways: The first one is when no information on snow – covering conditions is accessible. In this case we can make use of the recorded size of precipitation as well as discharges to calibrate the run – off precipitation model.

The second case is when some data on the snow – covering basin is accessible.

To determine the size of the temperature rate decrease , precipitationTimes as well as the 24 hour forecasting rainfall we get use of some Websites like WWW. IGES. ORG, WWW ACCUWEATHER. COM.

Routing the flood in the Maroon river different cross sections requires using MUSKINGUM hydrologic method. The results of the Maroon river basin calibrating by means of WMS are shown in Table. 4 distinctly. (NEWAR Engineering).

Table 4 The final computed parameters of precipitation, snow – melting, unit hydrograph & MUSKINGUM routing method refers to the trinary chosen stations by WMS software

Hydrometric Station	Penetration					Snow Melting		Klark Unit Hydrograph		Muskingu	
	Strkr (mm)	Dltkr (mm)	Rtiol (mm)	Erain (mm)	Rtimp (%)	Strks (mm)	Rtiok (mm)	TC (h)	R (h)	K (h)	X —
Idenak With Snow – Melting	4.20	10.61	1.79	0.46	0	5.28	1.77	2.69	9.11	0.91	0.45
Idenak Without Snow – Melting	4.04	10.00	1.79	0.46	0	—	—	3.25	6.82	0.91	0.45
Behbahan	1.16	2.48	1.83	0.50	0	—	—	5.01	5.52	0.90	0.35
Chamnezam	0.72	3.17	3.06	0.50	0	—	—	14.11	6.97	0.91	0.45

9 Conclusion & comparing the results

In these days the developed countries have fixed some useful mechanisms & censors in their rivers basins to be able to record the occurred events as well as to avoid of some stubborn happenings(calamities) such as floods & the destructive avalanche crash as much as possible. The censors which are appointed in the basins are capable of recording the data about the amount of the occurred precipitation, temperature degree, the depth of the available snow on the elevations, snow condensation along with the height of the water within the river in the different cross sections.

Applying these softwares can smooth the direction of the uniformity of the even basins management , consequently we can be able to prevent of some probable damages in the essential times. Table 5 shows the comparison of the results of the applied software in a chosen flood. (24/01/1983) for these three subbasins. The error percentage of computation is less than 10%.

Table 5 The computation of the differential percentage in the degree of the maximum discharge of the floods & the occurance time in these triple hydrometric stations in the flood of 24/01/1983 by using WMS

Hydrometric Station	Maximum Amount of Real Peak (m^3/s)	Maximum Amount of Computational Peak (m^3/s)	Differential (m^3/s)	Deviation Percentage (%)	Maximum Time of Computational Peak (h)	Maximum Time of Real Peak (h)	Differential (h)	Differential Percentage (%)
IDENAK	697.00	635.00	62.00	9.76	15.00	15.00	0	0
BEHB AHAN	732.00	710.00	22.00	3.10	15.00	16.00	-1.00	-6.25
CHAM NEZAM	1 060.00	980.00	80.00	8.16	21.00	22	-1.00	-4.55

Acknowledegment: The writer of this article seems it important to appreciate the immense support of the Research & Standards Office of Khuzestan KWTA Dam & Power Center.

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Application of Distributed Hydrological Model in Water Resources Assessment within Ningmeng Irrigation Area

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Abstract: Water resources are very important for social sustainable development. Due to the impact of hamuan activities and the climate change, which has led to the larger temporal and spatial changes of the water resoures, it is very difficult for the traditional hydrological model to adapt the requirements of the water resources study in the present changing envirnment. Therefore, the LL – Ⅲ distributed hydrological model was used to study the basin water resources and its distribution, to analyze the impact of the climate change and human activities on them, in which the information of GIS, remote sensing, DEM, land use, soil structure, land cover, etc. was used to simulate the the basin hydrological process. The model was applied to simulate the daily runoff in the Ningmeng irrigation area during 18 years, and to analyze the spatial and temporal variation of the water resources and its distribution. Based on them, the interaction between human activities especially for agricultural irrigation and the quantity of the water resources and its distribution was analyzed. The results showed that the LL – Ⅲ had truly described the water circulation mechanism and can be served for water resources analysis in arid and semi – arid area.

Key words: distributed hydrological model, water resources, Ningmeng irrigation area, LL – Ⅲ, GIS

1 Introduction

Water resources is one of the most important resources for social development, and it is the foundation of basin planning and sustainable development. Water resources research includes water circulation simulation, water resources assessment and so on. The traditional research is mainly based on water balance method, conceptual model (Xin'anjiang model, 1973) or semi – distributed hydrological model (SWAT, 2000). But because of the impacts of the human activities and the climate change on the hydrological processes, it will inevitably lead to the distribution changes of the basin water resources with time and space. In order to learn the basin water resources more detail, we have done some researches on the basin water resources through adopting the distributed hydrological model based on a physical basis.

Physically – based distributed hydrological models can accurately describe the mechanism of the hydrological processes, and give full consideration to the changes of the hydrological parameters in space. With the rapid development of the information technology, the distributed hydrological model, the digital information and radar rainfall data can be closely integrated, which can effectively use the space information of the digital elevation, land use, soil texture and so on, supplied by the geographic information system (GIS) and the remote sensing (RS) technologies, and the informatin of the flood diversion, water storage and water diversion and others of all water conservancy projects and flood plain, which can describe the basin features and the change with time and space from the impacts of the human activities, and consider the spatial and temporal variability.

2 Model

2.1 Introduction to model

In this research, the LL－Ⅲ distributed hydrological model (Lilan, 2003) was used to analyze watershed water circulation. The LL model is a physically－based fully distributed hydrological model (Lilan, 2002) which was developed for flood forecasting within the Fengman reservoir area (LL－Ⅰ for short). The model is based on field experimental data describing the hill slope hydrology (Kirkby M. J., 1978) and the basin interface theory. A 2D convection－diffusion model was adopted to simulate soil moisture contents. In 2001, the LL－Ⅱ distributed hydrological model (Lilan, 2003) based on LL－Ⅰ model was combined with 3S technology. In this model, there was much improvement in modeling and programming, such as exchange information data with ARCINFO and the construction of an interface program to derive grid topological relations of watersheds, complex network confluence and problem of multi－dimensional numerical solution were handled using 3 point technical linking with grid topological relations. The convection－diffusion equations of subsurface flow and underground flow were improved for confluence routing. The LL－Ⅰ and LL－Ⅱ were used to predict the flood forecasts and the hourly runoff forecasts. In 2003, a new model version (LL－Ⅲ model) was released (Li Lan, 2005), which adds the ice forecasting, the rainfall－snowmelt processes, the irrigation water evaluation, the industrial and agricultural water quantity, and the vegetation ecosystem processes. Interception and evaporation were described for six types: high vegetation, low vegetation, nudation, impervious surface, building area and waters, which were used to compute the water circulation and energy balance. Also it was applied in the Yellow River basin water resources forecasting and evaluation. This paper is the application of the LL－Ⅲ model in the water resources evaluation of the Ninmeng Irrigation district in the Yellow River basin.

The LL distributed hydrological model was applied to flood control for 14 reservoirs and flood forecasts of 8 catchments in China, in which the areas range from 30 km^2 to 11,900 km^2, to test the evaluation effectiveness and the forecasting accuracy in the flood forecasting and the water resources forecasting. According to the results of the testing, the model has showed a very high accuracy, and it can fully meet the requirements of the State's standards. In 2002, the LL model was used in the Distributed Model Intercomparison Project (DMIP) hosted by the Hydrology Laboratory (HL) of the National Weather Service (NWS) to simulate and verify floods in the BLUE watershed and in the Baron Fork River.

2.2 Model structure

The Soil－vegetation－atmosphere system includes the vertical water movement, the vertical energy balance, and the vegetation ecosystem water cycle. Its corresponding model called the runoff model, which included the rainfall －snowmelt model, the estimation model of the irrigation water model, the vegetation water cycle model, the energy balance model, the evaporation model, the interception model, the infiltration model, the runoff model and so on. In the vertical direction, the various hydrological components in the hillside water runoff have been considered, and the multi－mode of the soil－vegetation－atmosphere was calculated, which was divided into seven layers as shown in Table 1.

Table 1 Layers in vertical

Layer	Name	Layer	Name
1	Storey, includes canopy and undergrowth	6	Shallow underground
2	Litter	7	Deep underground

3 ~ 5	Soil

The confluent runoff model is composed of ice forecast, confluence of subsurface flow, underground water, overland flow, and channel flow, diversion water for industry and agriculture, and reservoir discharge. Flow paths were generated using GIS software (ArcGIS8.3, ESRI) in the horizontal direction. Based on pre – processing, the hydrodynamics continuity equation and momentum equation were used to calculate the confluent routing to all nodes in all layers according to the sequence and numerical difference solutions. Fig. 1 shows the partition of layers and runoff.

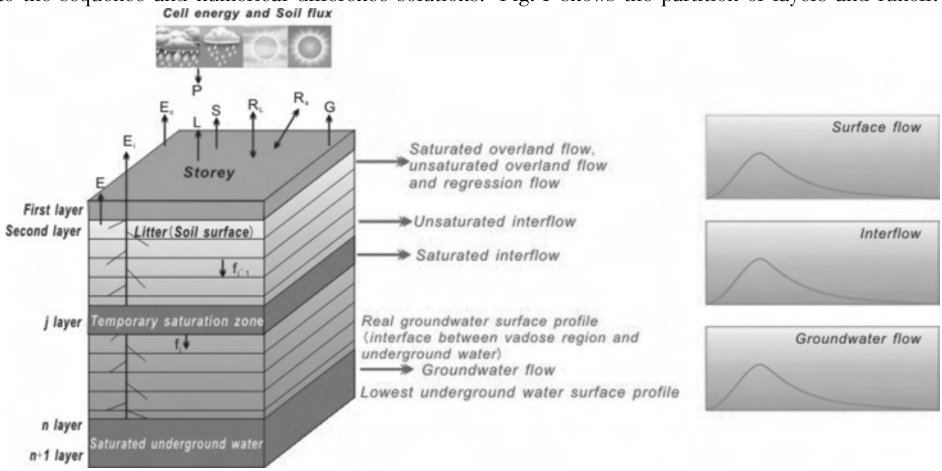

Fig. 1 Layers and runoff in model

3 Overview of the study area

The study focuses on the Ningxia irrigation area of the Yellow River, and it includes the Qingtongxia irrigation area and the Weining irrigation area. Among them, the Qingtongxia irrigation area is the major part, in which there are 7,061 km^2 irrigation area (including the tilt plain), and the area occupies 88.5% of the total irrigation area (7,983 km^2). The Ningxia irrigation area belongs to the Yinchuan Plain and the Weining Plain from the view of the geological structure.

The basin is situated inland and is located in the western edge of China's monsoon climate zone, in which in winter the climate is controlled by the Mongolia high pressure, and it locates in the key part of the cold climate which runs from north to south. In summer it is located in the end of the south – east monsoon wind, which forms a classical continental climate. The basin area is 56,185.63 km^2, and its length is 397 km, which accounted for the 7% of the total length. Annual mean inflow is 31.7 billion m^3, and the outflow is 29.4 billion m^3. The basin is characterized by the scare precipitation, strong evaporation, and larger dry degree. Rainfall decreases from south to north, and the variation range is between 170 mm and 800 mm. There are dramatic changes in precipitation. Yearly evaporation capacity is 1,309.02 mm, which is 6.88 times of the total precipitation, and its changing trend is opposite with that of the precipitation, i. e. it decreased from north to south. These two opposite trends decide the big difference between the north and south, which ranges from 1 to 9, and most regions is from 3 to 9 from south to north (Xie Xingming et al., 2002).

4 Pre – processing of the data

The information of the topography, the distribution of vegetation and soil structure, and the land use in the basin is available from GIS and RS data, which is the needed data of the model got from the pre - processing of the corresponding information. The pre - processing consists of:

(1) The mesh slope, size, height and river networks, drainage area, flow path and flow direction, and the generated slope mesh, river basin mesh and the sub - division documents can be available by analyzing the DEM. In this study the position of the grid is 5 km, and the whole basin is divided into 29 sub - basins (Fig. 2).

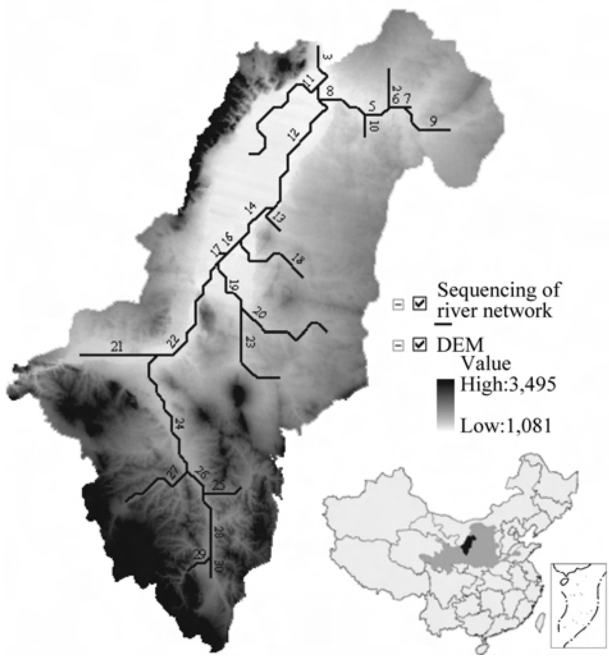

Fig. 2 DEM and sequencing of river network

(2) The distribution of the basin's soil types were extracted from soil structure data. There were 44 soil types in the watershed. The soils were generalized to four main soil types: gray desert soil, chestnut soil, Aeolian sandy soil and clay. Soil characteristics such as infiltration capacity, permeability coefficient, hydraulic conductivity, etc. can be determined based on soil types.

(3) The distribution of six different land uses was obtained, which extracts the remote sensing data of the land use. The water consumption of the human activities was considered in the model, which include water for living and industrial and agricultural activities. According to the distribution of the land use in urban, rural and irrigation area, the water consumption in each grid cell was calculated.

(4) There are 108 rainfall stations in the research basin. The whole basin rainfall data was spatially interpolated by applying a trend surface method to the DEM.

5 Results and discussion

5.1 Water consumption

From Table 2 it can be seen that the irrigation water accounted for most of the whole basin water consumption, and the rest included the water of living, industry, forestry, animal husbandry, and fishery. The total water consumption in 1990s is five times that of the 1980s. From the table it was shown that because of the growth of the other water demand, the irrigation water in the total water consumption showed a downward trend in the 1990s and the industrial water was 49 times of the 1980s. The annual water consumption in the basin was shown in Table 2.

Table 2 Annual water consumption in the basin from 1980 to 2000 Unit: $10^4 m^3$

Year	Living	Industry	Irrigation	Forestry, graziery and fishing	Total
1980	1,719	802	133,838	2,430	138,789
1985	2,123	1,216	130,025	13,741	147,105
1990	6,868	45,214	698,189	79,984	830,255
1995	1,1895	58,288	699,436	76,336	845,956
2000	16,091	45,870	673,091	86,903	821,956

The impact on runoff from changing water consumption is obvious. Comparison of the total inflow and outflow, it was found that the average margin of two number was 23.5×10^8 m^3 in 1980s and 20×10^8 m^3 in 1990s, which meant that all water resources generated in local were consumed by human activities and the remain was supplied by inflow. Comparison between irrigation Water and total water consunption (Fig. 3). Percentage in total consumption of water quantity and variation trend of lwing, livndustry irrigation and other (Fig. 4).

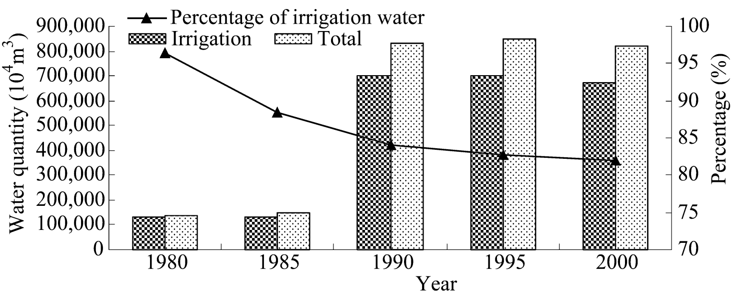

Fig. 3 Comparison between irrigation water and total water consumption

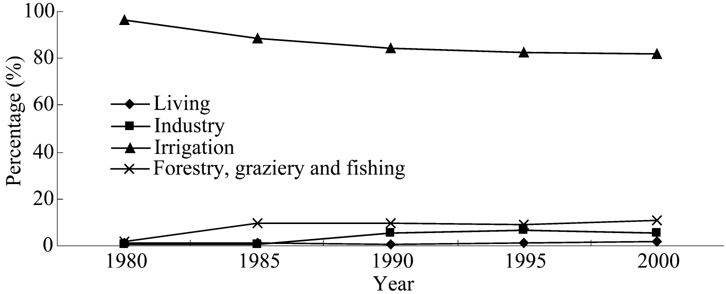

Fig. 4 Percentage in total consumption of water quantity and variation trend of living, industry, irrigation and others

5.2 Daily runoff simulation

The observed daily runoff and rainfall in 18 years were split into two sets (1980 ~ 1986 and 1990 ~ 2000) and used to simulate daily runoff. Runoff data from 1980 ~ 1982 was used to calibrate the model. The calculated runoff in the calibration period (Fig. 5) has a model efficiency coefficient of 93 %. The runoff was then simulated for the remaining period with model efficiency coefficient of 93.64%, 84.21% and 81.63% in the periods 1983 ~ 1986, 1990 ~ 1994 and 1995 ~ 2000 (Fig. 6 ~ Fig. 8).

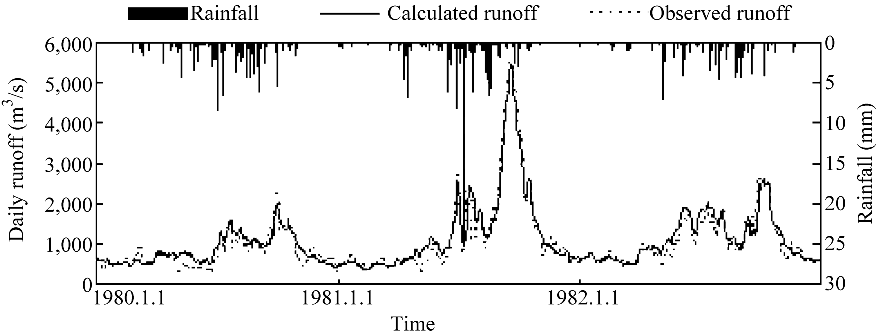

Fig. 5 Rainfall and comparison of calculated and observed runoff of outlet in watershed (1980 ~ 1982)

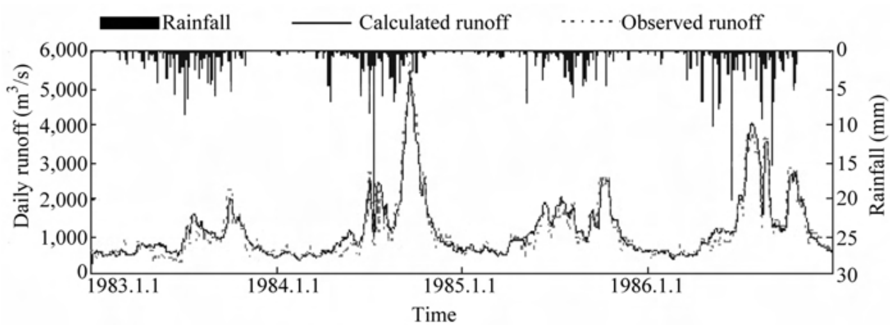

Fig. 6 Rainfall and comparison of calculated and observed runoff of outlet in watershed (1983 ~ 1986)

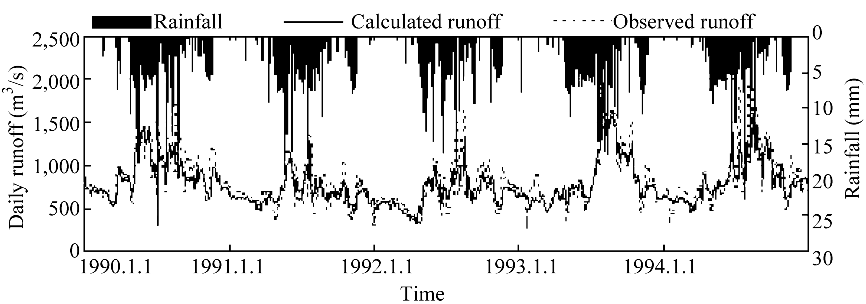

Fig. 7 Rainfall and comparison of calculated and observed runoff of outlet in watershed (1990 ~ 1994)

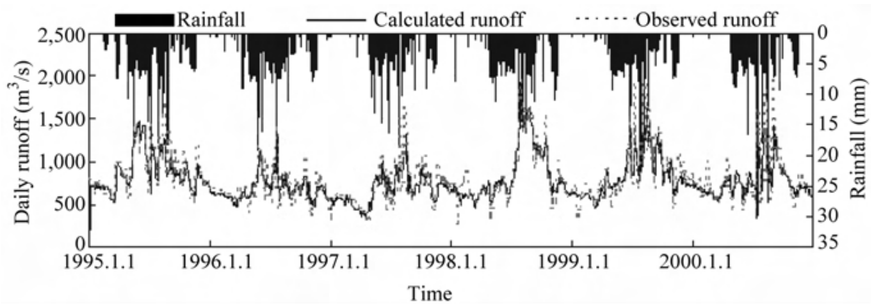

Fig. 8 Rainfall and comparison of calculated and observed runoff of outlet in watershed (1995 ~ 2000)

5.3 Water resources assessment

According to the statistics data of rainfall, evaporation, runoff and so on from periods 1980 ~ 1986 and 1990 ~ 2000, the water resources assessment was made as shown in Fig 9.

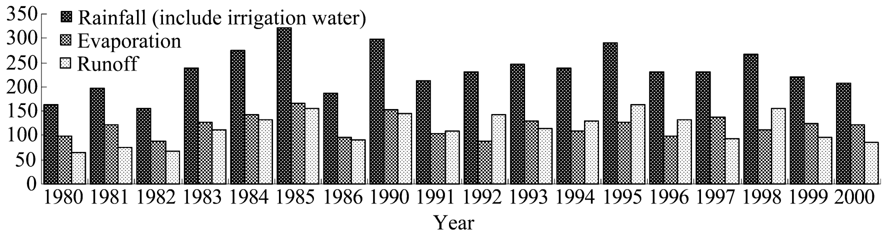

Fig. 9 Yearly rainfall, evaporation and runoff

Affected by the climate of the Loess Plateau, the basin precipitation has been on the downward trend. According to the analysis of the annual precipitation in 18 years from the periods 1980 ~ 1986 and 1990 ~ 2000, the multi - year average rainfall was 187.9 mm. In 1980s, the multi - year average number was 200.75 mm, and the number changed to 179.67 mm in 1990s, which decreased 10.5%. The spatially interpolated rainfall data and irrigation water use are seen in Fig. 10. Rainfall decreases from south to north and the water consumption is concentrated in the Qingtongxia irrigation area. The re - distribution of water (due to irrigation) greatly affects evaporation, overland flow, groundwater flow, interception and infiltration.

Evaporation is composed of surface evaporation, land evaporation and vegetation evapotranspiration. The annual average evaporation is 119.44 mm which constitutes up 51% of rainfall and irrigation water. Annual average evaporation in the 1980s was 120 mm and 119 mm in the 1990s. In the model, the basin surface is divided into six types, and according to the statistic data of the evaporation, the proportions were calculated (Table 3). Evapotranspiration is shown in Fig. 11.

Table 3 Proportion of evaporation for six kinds of underlying

Name	Waters	High vegetation	Low vegetation	Nudation	Building area	Impervious surface
Proportion (%)	83.88	0.91	0.49	3.25	4.6	6.87

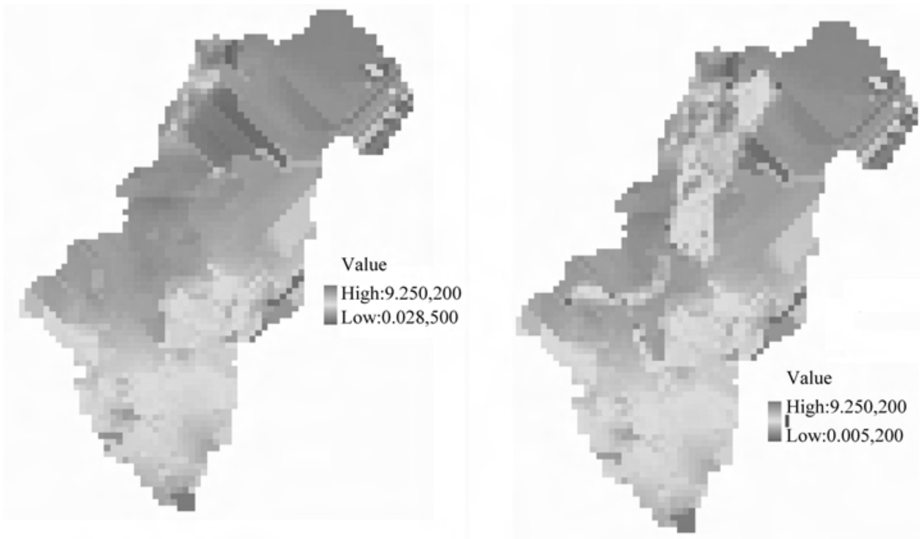

Fig. 10　Map of distributed rainfall (left) and distributed rainfall and irrigation water use (right)

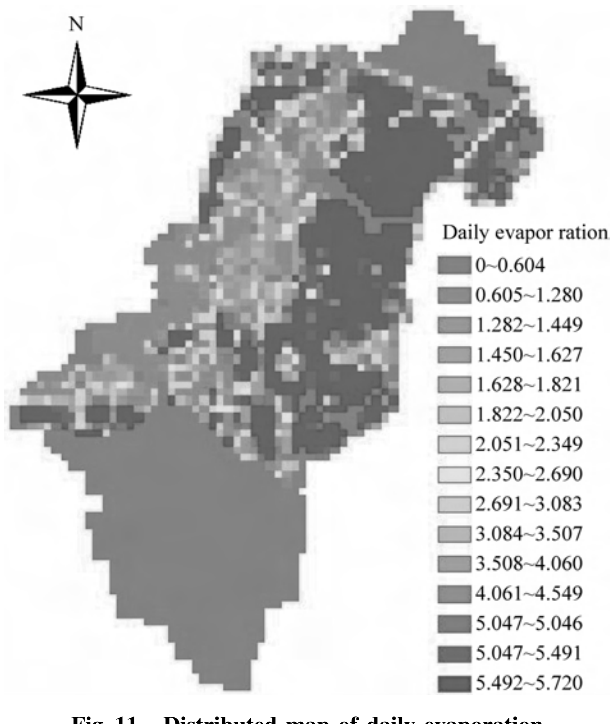

Fig. 11　Distributed map of daily evaporation

The former analysis demonstrated that the basin owned less rainfall but more evaporation, so the inflow afforded mostly consumption of water in whole watershed. In 1980s, average yearly inflow of seven years was $281.47\times10^8 m^3$, but in 1990s it changed to $220.7\times10^8\ m^3$, which decreased 21.6%.

Using simulation result of daily runoff and deduction of inflow, annual mean runoff depth was calculated and the number was 114.8 mm. In 1980s, the runoff depth was 99.7 mm and in 1990s, it increased to 124 mm.

In the model, the runoff was partitioned to several components, included overland flow, underground water, and interflow. So after simulation, overland flow and groundwater flow of every cell were collected to draw distribution map (Fig. 12 and Fig. 13). The topography of watershed from south to north is transition from mountainous area to plain. So, in the figures, the distributions of the groundwater flow and the overland flow were opposite. In mountainous area, the intensity of infiltration was lower than the plain area, so more rainfall was used to generate overland flow. In plain area, especially in irrigation area, irrigation work made soil easy to infiltration and raised water level of shallow underground water, which made more rainfall and irrigation water to replenish groundwater flow.

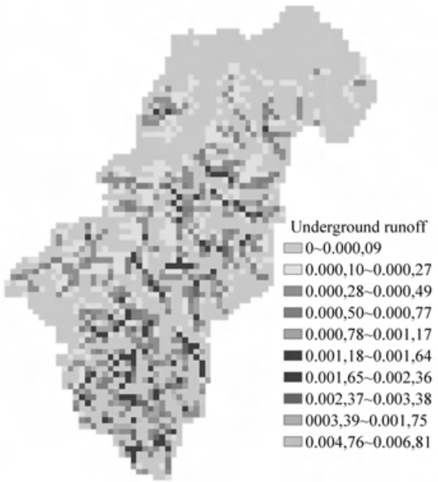

Fig. 12 Distributed map of groundwater flow

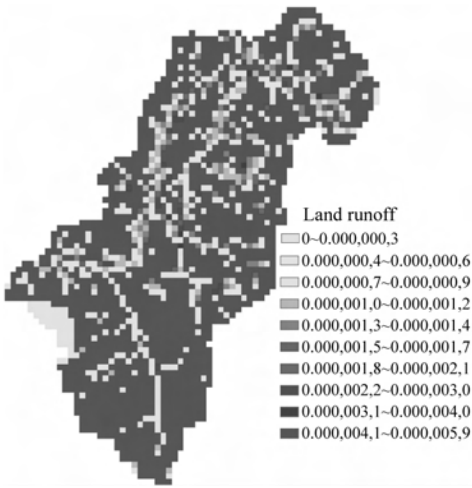

Fig. 13 Distributed map of overland flow

According to the calculated result of daily runoff, the two items were calculated separately and then total water resources were gained (Table 4).

6 Conclusions

Through applying the LL – Ⅲ distributed hydrological model based on GIS, daily runoff simulation of 18 years the water resources assessment were made. In the research, DEM, land use, soil data and other digital data were proposed and extracted to build models for water circulation calculation and water resources assessment.

For research, the pre – processes were done which included sorting and generalization of the soil type data, extraction of land use information and distribution, hydrological analysis and interpolation of rainfall. Then, based on these work, daily runoff calculation and water resources assessment were run. The simulated result of daily runoff proved that the model described the water circulation mechanism truly and an ideal precision was obtained. So the water resources assessment based on calculation of daily runoff and analysis of consumption of water showed the spatial and temporal variation trend and the influence of irrigation work which raised the underground water level, increased the evaporation of shallow underground water and the replenishment of underground water. All above facts proved that the LL – Ⅲ distributed hydrological model was competent for the water resources research.

Table 4 Statistical data of total water resources Unit: $10^4 m^3$

Year	Surface water resources	Underground water resources	Replenishment of infiltration	Total water resources
1980	11,619	20,727	1,695	29,372
1981	13,825	24,833	2,365	34,949
1982	12,295	21,917	1,932	31,083
1983	20,164	41,689	1,986	50,974
1984	23,855	51,040	1,977	60,305
1985	24,719	53,298	1,944	62,491
1986	16,479	32,470	1,942	41,658
1990	27,985	61,654	1,899	70,747
1991	19,733	40,397	2,079	49,886
1992	25,906	56,763	1,732	65,491
1993	17,290	34,269	2,057	43,710
1994	23,545	50,274	1,969	59,522
1995	29,714	65,610	2,088	75,118
1996	24,081	51,589	1,987	60,876
1997	17,056	33,615	2,085	43,117
1998	31,907	71,197	2,068	80,662
1999	19,095	38,454	2,230	48,273
2000	15,532	29,721	2,104	39,265

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Research and Application of Project Maintenance System of Digital Construction and Management

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Abstract: Project maintenance system is a sub – system of digital construction and management in the Yellow River. The system sets up maintenance criterion and project database. Based on GIS, this system realizes information statistics, consultation and analysis, and the rapid maintenance strategy for weak project, and the maximum profit of project investment.

Key words: digital construction and management, maintenance, system, criteria model, the Yellow River

1 Background of the project

The riverbed in the lower reaches of the Yellow River suspends quite higher than two banks. Dikes were constructed by successive reinforcement on basis of historical levees. Because of the weak quality, the poor layers joints and human activities, there are many fissures and holes in these dikes.

Additionally, riverbed rises continuously and still suspends in the lower reaches for a long period. Therefore, it is still possible for the dikes to be breached. Particularly, historical breached dikes, where there are silts and straws when blocking up the breaches, are the weakest sections. Once floods overflow the floodplains, danger situations, such as sliding slope, collapse and piping etc., can easily take place. Since the flood in the Yangtze River in 1998, our country increased investment of harness in the Yellow River. Except for infrastructure investment, Asian bank loans are used to construct the project of flood management in the Yellow River.

In August 2001, the international consultant company evaluated the feasibility report for the flood control project in the Yellow River. In terms of the evaluations, the ADB loan office of YRCC worked out the design task report, and demands relative departments to write down the design report and the plan of project implementation.

Therefore, cooperated with information center of YRCC, construction and management department of YRCC carried out the research and application of maintenance and management system for hydraulic project in the Yellow River. This system was established primarily in the end of 2003. After continuous development during the past three years, the system has been improved gradually and played an important role in project maintenance in lower Yellow River.

2 System functions

(1) According to requirement and criterion, the basic data for the project maintenance can be collected, packed up and saved in database.

(2) Based on GIS, the system realizes information statistics, consultation, the rapid maintenance strategy of weak project, and the maximum efficiency of investment.

(3) By layout supervision and monitor instruments, the system can collect real – time information of water level, penetration, sedimentation, displacement and vision image, and further realizes the safety monitoring and vision image.

(4) By automatic monitoring control system and cable transport of supervision data and images,

the data can be saved in database automatically and safety and can be warned on line.

3 System construction

System of project maintenance and management is one of these five systems of digital construction and management in the Yellow River, and is regarded as the first construction task. The construction includes collection system of basic information, project database, information management system, information service system, project safety monitoring system and maintenance criteria model for flood control projects.

By the project implementation, the maintenance system can be established based on data management. And the rapid consultation and statistics of project basic information can be also realized. Furthermore, the real – time running of project can be obtained, the maintenance plan can be automatically formed, and finally the modern standard of project management can be improved.

4 Main innovation of the system

(1) By computer and internet, the system realize information management of project maintenance, and cause great changes of project management in the Yellow River.

(2) It is the first time to make out and issue data dictionary and data table structure of projects in the Yellow River. This criterion is comprehensive, the structure division is scientific, and database is authoritative. All kinds of projects and their running can be classified and summarized rapidly and correctly.

(3) The system has the intellectual input format and automatic identifying system. By LAN and Internet, the system realized intellectual input of database on web.

(4) It is the first time to uses the criterion of Digital Yellow River to set up an authoritative database of project basic information.

(5) It is the first time to install monitor instrument in sluices and realize real – time monitoring for project safety.

(6) It is the first time to adopt ArcSDE spatial information storage technology, which meet the demand of Digital Yellow River. It realizes concentrative management and data share of basic project information.

(7) The system development adopted integrated Geo – information and attribute information, and accordingly improved maintenance property and the development degree of the system.

(8) The system developed the standard model of project maintenance in the Yellow River. This standard model applied the model of maintenance system of digital construction and management. The system realized intellectual disposal of maintenance works, automatic maintenance plan and the support for maintenance policy. The system also enhanced the standard of policy – making and realized optimized allocation of resources.

5 Evaluation on application effects

Since the running for 3 years, the system has played an important role in project management of the Yellow River. The system realized information consultation by vision on web, on basis of GIS and intellectual data input. Moreover, it realized the remote supervision and real – time monitoring as well as maintenance plan. The system obviously improved the efficiency of basic information collection and consultation. It realized real – time supervision of project safety, and enhanced the policy – making. It is a breakthrough of project management measures in the Yellow River. In the end of 2006, the maintenance system has been widely applied by Shandong, Henan, Shanxi and Shaanxi Yellow River Bureau.

6 Conclusions

Project Maintenance System of is an important symbol of project information construction in the Yellow River. By the establishment of the system, it will greaty enhance modern management level of project management in the Yellow River. The system has been widely applied in the Yellow River due to its rapidity, accuracy, comprehension and intellectualized characteristics.

With the development of computer science, the system will be improved continually. It will be more comprehensive that its function will be more intellectual, and the project management level in the Yellow River will be enhanced step by step.

Research Progress and Trend of Models of Non – point Source Pollution of Aquatic Environment

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Abstract: Abroad Research on Non – Point Source (NPS) pollution models can be generalizes into three stages: lumped model stage, distributed model stage and the stage of integrated models of RS, GIS and NPS pollution. Domestic NPS pollution models can be divided to two big classes: statistical model of empirical analysis and physical model based on mechanism. Integration, coupling, practicality and modernization is the trend of the research on NPS pollution models lately. Combining the China national condition, it is the focal research point to develop NPS pollution model with a certain mechanism foundation and suitable in big and middle scale river basin in our country from now on.
Key words: non – point source(NPS) pollution, mathematical models, mechanism

Aquatic environmental pollutions are result of point source and Non – Point Source (NPS) pollutions, NPS pollutions become consequentially main factor of aquatic pollutions when the point source pollutions control reached certain level. According to the scholastic research of USA, Japan and China, the NPS has turned into important pollution source of aquatic environment, even the chief pollution source. Researcher shows: even if the point source pollutions are completely controled, up to par rate of surface water quality such as river, lake, reservoir also is only 42% ~ 65%. Compared with point source pollutions, NPS pollutions present uncertain characteristics such as stochastic occurring, unfixed source and emission place, great range of spatialand temporal change of pollution load etc., therefore the monitoring, control and handling of NPS pollution are difficult and complex. People always describes this complex problem by mathematical models for tens of years.

1 Sort and structure of the NPS model

Formation and transfer of Non – point source pollution is related closely with the water cycle in nature, the Non – point source pollution model includes normally 4 sub – models: the rainfall runoff sub – model, the soil erosion and silt transport sub – model, the contaminant move and transformation sub – model, the water quality sub – model of the received water body. The rinse and scour of rainfall runoff is the source power of Non – point source pollution formation, therefore the rainfall runoff model is the foundation of overall research; the soil erosion and silt transport model is used to research the soil erosion and the sediment yield and transfer in river basin; the pollutant move and transformation model is key content of the Non – point source pollution research, it is used to confirm the pollutant (including liquid and solid state) transform and move course in runoff formation; the water quality model of the received water body is the Non – point source pollution research aim, it is used to research the influence of the Non – point source pollution load on the received water body. Because the research history of water quality model is longer than that of Non – Point Source pollution and the water quality model simulation technology is increasingly mature, usually the water quality model of the received water body is not included in Non – Point Source pollution model.

According to the different dealing method on research region, the mathematical model of Non – Point Source pollution can be divided into two kinds: lumped parameter model (lumped model) and scattered parameter model (distributed model). In lumped model, the study area is considered as a whole, even property and consistent condition are assumed; in distributed model, the study area is firstly divided into a lot of small units that have equality property, every unit is then simulated respectively, finally total output is gained through stacking method.

2 Abroad advances on NPS model

The systematic study of the NPS pollution model began in 1970s abroad. Reviewing the research progress in more than 30 years, it can be partitioned approximately as 3 stages: the stage of lumped model study period from the beginning of 1970s to the middle of 1980s, the stage of distributed model development period from the middle of 1980s to the middle of 1990s, the late stage of integrated model of RS, GIS and NPS pollution since 1990s.

2.1 Study stage of lumped model

People have known the potential harm of the Non – Point Source pollution in 1960s, but because of shortage of effective quantificational evaluation means, people only established statistical relation between pollution loads and river basin land using or runoff according to causal and statistical analysis method then simply figure out pollution loads of river basin outlet. In 1971, the Hydrocomp Co. began to develop the pesticide transfer and runoff model (PTR) for USEPA and primal city rainstorm water management model (SWMM). In 1972, the working – out and implementation of "USA Water Pollution Control Law Amendment" is a major turn in the course of the Non – Point Source pollution research, therefrom began the great development period of the Non – Point Source pollution model, many models come out in succession. Such as Non – Point Source pollution series models PTP – HSP – ARM – NPS developed by Hydrocomp company and SWMM, STORM, ACTMO, UTM, LANDRUN etc.

The period from the end of 1970s to 1980s was another climax of the development of Non – Point Source pollution mathematical model, CREAMS (Chemicals Runoff and Erosion from Agricultural Management Systems) explored by the Agricultural Research Institute of United States Department of Agriculture established the Non – Point Source pollution model developmental landmark, it firstly made systemic synthesis of the hydrology, erosion and contamination transfer course in Non – Point Source pollution. And then a series of similar structure models, such as farmland model EPIC (Erosion Productivity Impact Calculator), model about influence of agriculture on groundwater GLEAMS (Groundwater Loading Effects on Agricultural Management Systems) etc. were developed. Those models are all made up of rainfall runoff sub – model, sediment yield sub – model and water quality sub – model. The runoff calculation applies the concept method, SCS method and seep model; the sediment yield calculation applies the USLE and concept model; pollutant loads calculation applies statistical model and concept model. On aspect of model application, the CREAMS model is mainly used to research the influence of land management on water, sediment, nutriment and insecticide. EPIC model is mainly used to calculate the influence of soil erosion on crop productivity. GLEAMS model is mainly used to simulate influence of insecticide loads in groundwater.

In development stage of lumped model, NPS pollution research was improved from simple experience statistics to complex mechanism model analysis, it is a great development of NPS pollution models. But these models have very high demands on all kinds of resources, and most models are only applicable on very small conflux area, for example, CREAMS applicable area is only 0.1 km^2 so the further popularization and use of model are restricted.

2.2 Stage of distributed model

According to above defects and the development of distributed hydrology model, the distributed model of Non – Point Source pollution has been put forward that could apply to larger scale river basin which can divides river basin with grid and simulates spatial and temporal variation. The period from the middle of 1980s to the middle of 1990s was the climax of distributed models development. In this period, representative models are ANSWERS (Areal Non – point Source Watershed Environment Response Simulation), AGNPS (Agricultural Non – point Source), HSPF (Hydrological Simulation Program – Fortran), SWRRB (Simulator for Water Resources in Rural Basins), SWAT (Soil Water Assessment Tool) and WEPP (Water Erosion Prediction Project) etc.. As for the calculation method, those models divide river basin with grid or sub – basin to extend the study area. But in unit grid, some methods of lumped models were still used to calculate the runoff, sediment yield and pollutant content. The influx of runoff, sediment and pollutant amount was calculated by means of river network converges, river sediment pollutant and transportation. Thereinto, ANSWERS model is a distributed model based on precipitation incident, can control the Non – Point Source pollution through simulating the influence of land using pattern on hydrological and erosion response. AGNPS is used to evaluate the influence of agriculture on Non – Point Source pollution, includes hydrology, erosion and sediment transportation, nitrogen, phosphorus, COD transportation etc.. The disadvantages of these two models are that they cannot simulate thaw course and insecticide, nutriment's transfer and losing in transportation is also out of models' consideration.

The models of ANSWERS and AGNPS are single incident models, can't simulate the courses of conflux and pollutant transportation, but the models of HSPF, SWRRB, and Continuous, AnnAGNPS improved from ANSWERS and AGNPS have overcome this defect. HSPF is colligation and development of many previous models (SWM, HSP, ARM, NPS, SERATRA), divides simulated section into 3 parts: pervious ground, impervious ground, river or completely mixed lakes and reservoirs, simulates 3 different courses of surface water hydrology and quality. The 3 great modules are divided into some sub – modules, to realize continuous simulating the move, translation and loads of sediment and pollutants such as BOD, DO, N, P and pesticide. HSPF have been developed Windows interface and conformed in BASINS produced by USEPA. SWRRB model is mainly used to judge the influence of managing factors such as crop cultivation, plant and harvest date, chemical matters use date and dosage on Non – Point Source pollution. It includes weather, sub surface transverse current, pondage of pond and reservoir, vegetation growth, transfer loss, sediment movement element, move elements of nutriment and pesticide, agriculture management etc.. ANSWERS – Continuous model is a continuous simulating developed from ANSWERS model, adds modules simulating nutriment transfer and loss based on GLEAMS, EPIC. AnnAGNPS (Ann Agricultural Non – point Source) model is the latest upgraded edition, can be used to continuously simulate hydrology, soil erosion, transfer of and sediment, nutriment and pesticide, is mainly used to evaluate the best management measures in agriculture – dominated river basin.

Although HSPF and SWRRB model keep continuous time, but are short of particular spatial description. In 1990s, people have begun to research temporal change model that could reflect spatial information, and then founded SWAT and WEPP model. Objectively, SWAT and WEPP model are both improved and innovated from the original models. SWAT model absorbed advantages of CREAMS, GLEAMS, EPIC and SWRRB models, especially many methods of SWRRB, it not only can be applied in bigger scale riverbasin, groundwater quality simulating, but also can be used to forecast influence of land management measures on big comples river basin with kinds of soil, land utilization and management conditions and influence of hydrology, sediment, nutriment, agricultural chemical matters on water quality. Since the model was established in beginning of 1990s, it had been improved to SWAT 94.2, SWAT 96.2, SWAT98.1, SWAT99.2, SWAT2000 according to the demands, the latest edition is SWAT2005. WEPP model inherited steady sediment continuous equation in CREAMS, the river runoff calculation method in EPIC, calculation methods on soil water content and plant transpiration loss in SWRRB, when calculating the seeping, Green & Ampt equation is applied, when forecasting the runoff, efficient conductivity is applied, erosion model is calculated bases on hydraulics, also the descriptions of spacial variable such as thaw, giblets degradation and irrigation are added.

In stage of distributed model development, the improvement from the analysis of long – term load output or single rainstorm to response analysis of successive time serial, then to the temporal change model reflecting spatial information is a great leap on the phylogeny of Non – Point Source pollution model. Although the distributed model specializes in finding local influence and abnormity, can well reflect the regional variation condition of land, but its disadvantage is that its operation is complex, in oder to improve data processing ability and utilization value, large amount of data need to be inputed to describe differences of landscapes or land utilization types.

2.3 Recent development stage

With the development of advanced technology RS, GIS, problems in NPS pollution distributed model such as large amount of data inputed and deficient information have been resolved in recent years. RS collects the physical geography data with rapid speed, good macroscopical degree, high precision and repeatability, those data and information may be utilized in NPS pollution process analysis and calculation. GIS, especially its powerful DEM data processing ability, can offer a new platform of data management and visualization for model users. GIS users can exceed the data processing and management stage through combination of RS and GIS, utilize the modeling technology to describe and imitate the complex mechanism of Non Point Source pollution. Arc/Info, GRASS etc. models are usual GIS applications. For examples Rewerts etc. used GIS in ANSWERS Model, He etc. utilized GiS' powerful data processing ability to combine GRASS with AGNPS, Engel developed the interface of GRASS, AGNPS and ANSWERS, Line etc. simulated the cattle farm sediment and nutrimental matter output in north of Carolina by AGNPS GRASS (GIS), Liao etc. connected GISArc/Info with AGNPS then simulated a river basin pollution loads in Iowa.

In combining processing of RS, GIS and Non – Point Source pollution model, establishing river basin Non – Point Source pollution database by GIS is the most basic level, is also the foundational work to realize GIS and model integration; RS, GIS and model integration is second level of combination of RS, GIS and Non – Point Source pollution model, the spatial and property information from RS and GIS are used in model parameter estimation, calibration and model verifying, taking GIS as major technical platform and realizing the simulated result visualization, taking GIS technology to define the model researching areal unit etc.; Basd on this, the third level is taking GIS as platform and taking RS as major database to establish all – around compositive system, which means relation of RS, GIS and Non – Point Source pollution model develop from common combination to integrative compositive direction. BASIPNS (Better Assessment Science Integrating Point and Non – Point Sources) discovered by USEPA includes subassemblies such as basic information, database avaluation tool, river basin Non – Point Source model (HSPF) and water quality model (QUAL2E), after – treatment system, which compose a unified software system. DePintoetc. discovered GEO – WAMS (Geographically based Watershed Analysis and Modeling System), besides the combination of watershed Non – Point Source loads model and Arc/Info is realized, a groundwater transport model and an improved WASP4.0 water quality model are also included. Design, feasibility and application effect of the system was validated through the archetypal system applied in Buffalo River basin.

In recent years, introducing Spatial Decision Support System (SDSS) based on GIS technology, whose principal part is integrated database, model base and repository, main feature is scheme choosing, in control and the management of Non – Point Source pollution have become a new development tendency. Negahban etc. explored LOADSS (Lake Okeechobee Agricultural Decision Support System), Okeechobee lake agricultural decision – making support system, aimming at the environmental problem of lakes phosphorus load caused by rainwater eroding, considers Non – Point Source control, point source control and comprehensive river basin control; Lametc. explored RAION (Regional Analysis Information System), which emphasizes decision – making support and expert system. Leonetc. combined AGNPS model with RASION, established SDSS to realize the simulation of Non – Point Source pollution, carried out visualization statistical analysis for calculating result. So, introducing SDSS is a new developmental stage and trend of combination of RS, GIS and Non – Point Source pollution model.

3 Research process in China

In China research on Non – Point Source pollution began from 1980s. In 1983, in EIA of the diversion project from Luan River to Tianjin, the water quality and quantity synchronous process of the 3 heavy rain floods was monitored for the first time and water quality ~ quantity correlativity was established. In subsequent more than 20 years, In Tianjin Yuqiao reservoir, Xi'an Heihe River basin, Baoxianghe River in Yunnan, Hanjiang River, Danjiang River, Hangjiahu Plain, Qingping reservoir in Sicuan, Chaohu watershed, Weihe River water system in Guanzhong, Taihu lake watershed in south of Jiangsu, Miyun reservoir, Dianchi Lake, Erhai Lake watershed in Dali canton, Fuxian lake, Panjiakou reservoir, East lake in Wuhan, Jinghe River and Luohe River in middle reaches of the Yellow River etc., the Non – Point Source pollution research was continually conducted. In addition, city Non – Point Source pollution research was also carried out, such as in Beijing, Nanjing, Shanghai and Wuhan etc. The research of Non – Point Source pollution model in china can be summarized in two aspects: experience statistical analysis model and mechanism discussion model.

The experience statistical analysis model lies on the hydrology, quality and landscape parameter monitored in research area, formation process from rainfall to runoff and the inner move mechanism of Non – Point Source pollution is not considered, statistical analysis method is applied to establish experience relation model aiming at contaminant output. Because the model is simple, its application is very broad. For examples, Liu Feng et al. brought forward quantification identify method of river basin NPS pollution by researching the NPS pollution in Tianjin Yuqiao reservoir; Zhu Xuan et al. put forward regional runoff – pollution load model based on statistical technology by researching the farmland storm runoff pollution feature and contaminant output law; Chen Xiping etc. put forward the rainfall runoff and runoff water quality sub – model; Wang Hong combined improved water quality model with Non – Point Source pollution model, applied statistical model to calculate contaminant load, established comprehensive water quality model using in river basin optimization management. Li Dingqiang et al. analysed the dynamic changing rules of main Non – Point Source pollutant nitrogen and phosphorus change with rainfall – runoff process in Yangzikeng river basin, established the mathematics statistical model of rainfall – runoff and runoff – contaminant load output; Li Huaien et al. put forward 3 kinds of new method, average density method, land use relation method and pollution load – silt relation method, based on the monitoring of rainfall runoff pollutions in 3 typical river basins and the mensuration of total phosphorus and total nitrogen of soil,; Hong Xiaokang divided the annual runoff into surface water runoff and ground water runoff according to monitoring information, established water quality – quantity correlation model; Zhang Chun – ling et al. studied Non – Point Source pollution loads of Hanjiang river and the Danjiang river applying water quality – quantity correlation method and average density method.

Relatively, in our country, the mechanism model considering rainfall and runoff form process and Non – Point Source pollution transfer route mechanism is studied less, Li Huai – En et al. generalized river basin as river network system, taking contrary Gauss instant unit line model as foundation, established a set of mathematical model of Non – Point Source pollution with mechanism property, which completely include river basin runoff model, conflux model, pollution model and Non – Point Source pollution transfer model, application result shows that this model have better practicality; Zhang Jian – yun, analyzed the major factor that influences soil corrosion process, put forward Non – Point Source pollution model that includes rainfall runoff model, soil corrosion model and livestock pollution model (NPSP) through describing soil corrosion physical process; Hao Fang hua et al used the advantages of statistical experience model and mechanism model, combined the actual condition in investigation of Non – Point Source pollution in our country, aiming at satisfying water resource comprehensive program demand, established the big scale Non – Point Source pollution loads estimation method with Non – Point Source pollution production, move, transfer mechanism; Cheng Hong guang et al. applied the big scale Non – Point Source pollution loads estimation method to estimate and analyze the spatial and temporal distribution features and rules of

Non – Point Source pollution load in the Yellow River basin, set forth the difference of the Non – Point Source pollution type of the Yellow River basin, put forward calculating method of applying model to determine the coefficient of Non – Point Source pollution load flowing into the river.

Moreover, in improving and using overseas models, Cai Ming et al. improved the output coefficient method of Johnes by considering rainfall influence and the loss of contaminant in transfer process, and apply it in estimation of total nitrogen load in Weihe River basin; Hu Yuan an discussed the calculation of hydrology module in progressive simulation Non – Point Source pollution model with the application of distributed Non – Point Source pollution model SWAT; Zhang Zhan bin et al. improved and applied AGNPS and ANSWERS model combined with the reality.

In recent years, along with RS and GIS technology application in Non – Point Source pollution model, relevant scholars in our country has also carried out discussions of this respect. Dong Liang et al. applied GIS to establish the West Lake basin Non – Point Source pollution information database; Wang Yun peng established the Non Point Source information system based on RS and GIS; Wang Shao ping etc. combined imitating test, with GIS technology and Non – Point Source pollution model, discussed the Non – Point Source pollution load and temporal spatial development rule of Suzhou River basin; Wang Ning et al. used GIS in the quantification of river basin runoff contaminant; Shi Zhi hua et al. applied mathematics model and its combination with GIS, studied the agricultural Non – Point Source pollution load and distribution rule of middle and lower reaches of Hanjiang River; Hao Fang hua et al. used RS and GIS technology, imitated, calculated and researched the Non – point source pollution load in different typical hydrological year in Beijing Guan Ting reservoir basin.

4 Conclusions

Making a comprehensive view of domestic and international research progress of Non – Point Source pollution model in more than 30 years, following tendency is presented recently:

(1) Synthesization, considering needs of overall river basin management, giving prominence to the influences of human activities and land use change; Coupling, the major ecosystem and social economy system in river basin are contacted; practicality, big and medium – scaled river basin become research objects; Modernization, modern technologies such as RS and GIS are combined closely.

(2) Model development pay much attention to quantification avaluation of the Non – Point Source pollution control management measures, for examples, AGNPS, ANSWERS model have similar functions.

(3) The early model which only emphasis mechanism and fit small river basin is developed to the large and medium – scaled river basin forecast model with mechanism concept.

(4) Forecasting and avaluating the influence of Non – Point Source pollution to underground water become one of hotspots in recent years studies.

(5) Because there are various inevitable errors in imitating, and the results are also uncertain, adding fuzzy theory, uncertain analysis, risk avaluation and risk management in model research is also a big tendency.

Since1980s, Non Point Source pollution researchin China has made great progress, but model research still exists a lot of deficiency: Experience statistical models are many, mechanism models are few; improving and applying foreign models are many, researching models independently is few; models are dependent on local area data strongly and are difficult to be popularized in large scale. This condition is caused by various reasons, such as weak basic data and insufficient research accumulations. So far, the Non – Point Source pollution has not been brought into routine monitoring in our country, the Non – Point Source pollution research in most regions is still blank. Plenty of lessons and the experiences of domestic and overseas water pollution control practices have proved that in order to solve water environment problems, we must consider point source pollutions and Non – Point source pollutions at the same time. Therefore, according to the actual conditions of present situation of our country, to develop actively non point source pollution models with mechanism foundation and befitting to large and medium – scaled river basin, to develop Non – Point Source pollution load estimation model befitting to areas with lacking or even no data will be urgent tasks for interrelated researchers.

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Application of Information Technology in Water Project Administration

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Abstract: The development of information technology brings significant changes to every sector of the society including water project construction administration. This paper discusses the importance of using information technology in water project construction administration by exploring several IT application stages in water project construction administration and introducing the development and implementation of Yellow River water project construction and administration system.
Key words: information technology, water project, construction Administration

1 Introduction

From the middle of the 20th century, information technology's fast improvement and broad application has deeply influenced the development of global economy and the human society. IT motivates the world – wide adjustment for economy structure and leads human society's changing from industrial society to information society. Until now, information technology has penetrated into every field of Chinese economy and society and had big impacts in many areas. On Jan 9th, 2006, at China Science and Technology Meeting, Chairman Hu Jintao pointed out:" In the 21st century, the world – wide new technology revolution will be more powerful and will bring potential breakthroughs with it. Information technology will become the main motivation for economic development and knowledge transmission and application…" Water project is one of the basic infrastructures and properties of domestic economy, water project administration must take advantage of the advanced information technology to increase informationization level, and attain more prosperous and developed future in the 21st century.

2 What is information technology

Any technology which can be used to expand human's information processing ability is information technology. can make use of electronic computers, network and telecommunication mcasures to collect, store, record, process, transmit and manage nectwork information. It is the most potential new production power in modern society.

3 Three stages of IT application in water project construction administration

3.1 Part usage of information technology

From 1970s to the end of 1980s of last century, water project construction mainly relied on people to manage data. Data were collected manually and were stored, analyzed and processed using paper – based medium. Telephone (later fax) was also used as a medium to transmit information. This led to high requirement, low efficiency and the data process performance was largely limited by people factors. Errors in data transmission and analysis easily happened in this circumstance.

3.2 Integrate computer with telecommunication technology

In 1990s, along with the popularization of computers, fax machines and telecommunication technology, water project operators can use computers, fax machines to collect, convert, store, process, analyze and transmit construction administration data. This strengthens their ability to process and analyze data and in some degree reduces the dependence on paper – based medium, diminishes transmission errors, greatly improves administration quality and work efficiency. Since the computers have had the ability to produce images and graphs, visualization in construction administration is possible.

3.3 Take full advantage of Internet

From 90s until now, internet has penetrated into every industry field, which provides more opportunities for the improvement of water project construction administration. Water resources field begin to set up internet connections, build websites, Intranet, e – govern system, database, project management system and other network systems and data management platforms. These systems and platforms not only can quickly, efficiently and automatically publish, store, modify, search and process large amount of administration data but also can trace the performance of every ring of the whole construction administration chain. The broad usage of digital camera, scanners and other modern electronics enable the visualization of administration information. Various text fonts, electronic spreadsheets, graphs, pictures, video and audio information makes construction administration colorful. Digital data can be transmitted in light speed, copied unlimitedly, stored for long time and shared broadly. Telecommunication technology development benefits water project construction administration by providing wireless connections, short message group sending and other services. These mean that water project administration has entered a "digital" and "informationized" time.

To improve Yellow River water project construction's information administration, enforce communication and cooperation, maximize information sharing and continually increase construction administration level and efficiency, the Yellow River Conservancy Commission of the Ministry of Water Resources developed the Yellow Rive water project administration system in April, 2006. This system combines the Yellow River Conservancy Commission's real working process with innovative management methodology and pushes forward the application of information technology in water project administration for a big stride (Fig. 1).

Fig. 1

4 Development and application of yellow river water project administration

The system which was developed independently by the Yellow River Conservancy Commission includes eleven function modules such as basic information, quality control, schedule management, budget management, contract management, data maintenance and several other sub – modules. Each module applies specific information processing function for a stage of Yellow River water project construction administration. This system can securely and efficiently store, retrieve, analyze, process data and generate charts and tables, and achieve entirely information sharing. Except using data maintenance module, users can easily and quickly use other modules to browse and search needed information after logging in.

This information system adopts modular administration authorization and information classification control. In data maintenance module, the same variables in different sub – modules can substitute each other which prevent users from inputting the same data repeatedly and each authorized user can add, modify and renew certain data based on his authority in the system. In project plan, contract, financing, construction management and other sub – modules, data collection is combined with daily performance by an interactive platform so that employees can finish data collection and input while dealing with daily issues. This platform solves the problem of real – time data collection and updating and ensures the smooth data flow and accuracy, integrity and efficiency of data mining.

Considering system security and liability, user identity recognition technology was used in designing the system. Only authorized user can modify and add related information. Through this system, anyone can acquire the situations of all construction projects finished or under – building. This system improves the transparency of water project administration to a degree that could not be imagined before. The development and application of the system has strongly supported the water project administration and led the further informationization and modernization of Yellow River water project construction administration.

5 Conclusion

The above discussion shows that information technology has influenced every perspective of water project administration and already has impressive outputs, but this is just a beginning. Water project normally contains multiple programs, high responsibility, a lot of paperwork, a large number of attendees and countless information, by taking full use of advanced information technology, managers can optimize the administration process, increase work efficiency and improve the quality of decision – making so as to take water project administration to a new level.

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Towards a Demonstrator of Flash Flood Warning System a Case Study for St. Maarten, the Netherlands

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Abstract: This paper focuses on building a demonstrator of a comprehensive Flash Flood warning system using of the knowledge of modern ICT technologies and Hydrodynamic (HD) Models, such as mobile communication, SMS/MMS messages, GIS, Database, Web, Internet and MIKE 11. Concerning information dissemination, three applications namely: Web – GIS based Flood Information System; SMS/MMS based Flash Flood Warnings System and Mobile – WAP based Integrated Storm Water Management Information System (MW – ISMIS) have been developed on the basis of the case study of St. Maarten.
Key words: FFWS, risk map, hazard level, pre – cooked, MIKE 11, central database, Web – GIS, SMS/MMS, mobile – WAP, J2SE, J2ME, waterRIDE

1 Introduction

Flooding takes many forms, such as river flood, coastal flood, urban flood, ice jam and flash flood, of which two kinds of flash flood can be defined: "flash flood" produced by rain accumulations of typically more than 200 mm during less than 6 hours over natural watersheds ranging in area from 25 to 2,500 km^2 and "urban flood" produced over built – up areas of typically 1 to 100 km^2 by even shorter storms accumulating over 50 mm in less than 1 hour. As for the rainfall duration, the other flooding is a longer term event and may last a week or more. Because flash flood has a very quick speed of water flow, it causes very dangerous disaster.

Neither the structural nor the non – structural approach can solve all the problems by itself. In order to effectively manage impacts from flash floods and control the flood mitigation process, both structural and non – structural measures have to be applied in conjunction. As one of the most important non – structural measures, Flash Flood Warning System (FFWS) has received enormous attention by many researchers over the past decade.

In this paper, the Island Territory of St. Maarten, located in the midway through the chain of islands in the Caribbean, is chosen as a case study area for a demonstrator of FFWS. St Maarten is the smallest island in the world ever to have been partitioned between two different nations Dutch and French for 350 years.

1.1 Problem definition

For a comprehensive flood management system, FFWS as an important part should be integrated into Flood Management Decision Support System (DSS). However, for a smaller area, such as the Dutch side of St. Maarten Island, which encompasses an area of 3,380 ha, FFWS could be set as an operational stand – alone tool.

Essentially, the stand – alone FFWS can be described as a system with three distinctive functionalities: flood forecasting, warning and response. Therefore, when speaking about a demonstrator of the FFWS, such system should be also divided into three parts. In the first part, telemetry (i. e. ,data acquisition) and pre – processing are concerned with the use of meteorological data and simulation of a hydrodynamic (HD) model to predict an upcoming flash flood given the required lead time. In the second part, either the model results are obtained or the pre – prepared library of model results is searched for appropriate information (e. g. , risk maps, safe areas notification, evacuation routes, traffic control etc.). Finally, the third part is concerned with information dissemination. Further to the functionalities of the three main parts, three flood – related problems should be addressed. Firstly, according to the U. S. Bureau of Reclamation statistics, improving lead time to 90 minutes or more appears to reduce fatalities by over 90 percent. Therefore, it is crucial for a FFWS to get available forecasted rainfall data as soon as possible.

Secondly, with the development of weather radar, it is possible to make a relatively accurate forecast of rainfall events with a lead time ranging from 50 minutes to 2 or 3 hours. However, after simulating the HD model with the forecasted input rainfall data, the model outcomes should be both timely and meaningful. A question of what and to whom the model results are going to be displayed should be taken into account? Thirdly, and most importantly is how meaningful warnings to be disseminated to the interested users?

1.2 Objectives of the study

Address a conceptual design framework of a FFWS, which makes use of the combination of modern information technologies such as, mobile communication, GIS, Database, Internet, website, and the application of JAVA in the system.

Provide interested communities (end – users as a client) a client/server solution to get flood information from a Flash Flood Information Centre (as a server) by means of browsing website on a PC or mobile phone/PDA.

Provide a solution to directly disseminate flood warnings to those end – users who are related to the hazardous area, utilizing SMS or MMS dissemination from the Flash Flood Information Centre.

1.3 Methodology

An existing hydrodynamic model and rainfall data for prediction of the upcoming flood by applying the following tools: ArcGIS, MIKE 11.

A Central Database for data storage, applying tools: Microsoft Access.

Processing of model results to generate real – time or pre – cooked flood risks map by applying tools: ArcGIS, waterRIDE, Access.

Warning dissemination processor by applying tools: ArcIMS, ArcGIS, IIS6, J2SE SDK1.6, J2ME WTK25, JBuilder 2006.

SMS/MMS Gateway API provided by commercial organisation such as Clickatell or Bulk, to disseminate SMS/MMS to the end users.

2 Conceptual design framework of FFWS

Conceptually, a design of a FFWS consists of the constructions of data acquisition and model simulation, model results analysis and information dissemination (see Fig. 1).

2.1 Data acquisition and model simulation

With the application of meteorological satellite or radar, the upcoming rainfall event data is available, then the data is fed into a calibrated hydrodynamic model, normally MIKE 11 (for rural or river basin areas) or MOUSE (for urban areas), to produce one dimensional HD result, namely water level, discharge and velocity.

For a flash flood warning system, if HD model simulation period is very long, it is very difficult to accomplish an effective real – time flash flood warning dissemination. So a possible way is to build a Pre – cooked flood library, which means based on floods history records and rainfall events data, running the HD model in advance to generate the corresponding flooding maps.

2.2 Model results analysis

After the HD model simulated, binary results are obtained. However, for an efficient and effective DSS, the 1D model result, if unprocessed, is not very much usable for flood warning purposes. Therefore, a GIS – based software packages, such as waterRIDE, ArcGIS, are used to extract and analyze HD model results and to generate more meaningful maps.

2.3 Information dissemination

This phase addresses aspects of what contents of the warnings should be, to whom the warnings will be send and how to disseminate warnings to the interested communities. This paper mainly focuses on how to disseminate the flood – related information.

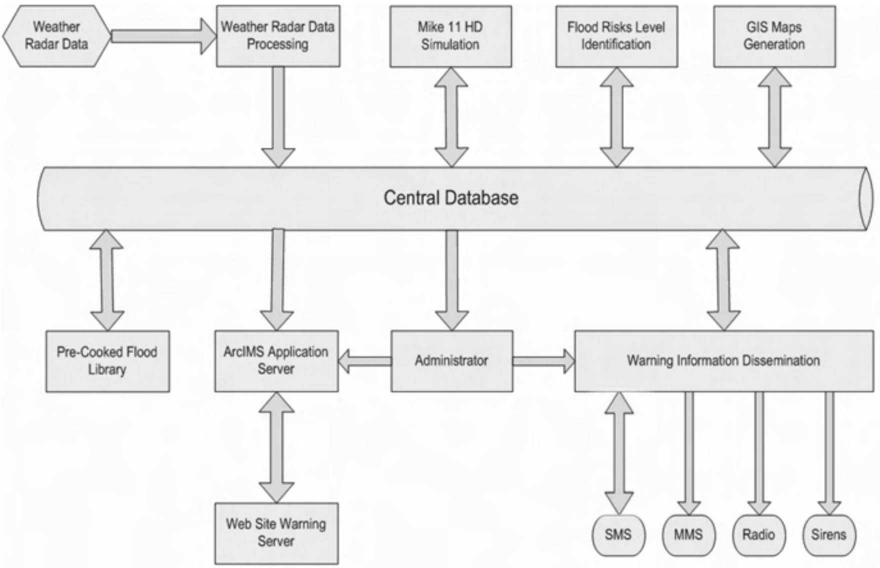

Fig. 1 A conceptual design framework of a FFWS

3 Testing and implementation of a FFWS

Three applications about information dissemination are developed, namely the Web – GIS based Flood Information System the SMS/MMS based Flash Flood Warnings System and the Mobile – WAP based Integrated Storm Water Management Information System (MW – ISMIS). Actually the first part and the second part are integrated into a single Web based application. However, to make each part's function clear, they are described separately. The third part is an application related to end users, a Midlet should be installed in each mobile device.

3.1 Risk map generation

Analyzing a simulated HD model result, given a function of $V \cdot D$, which means a multiplication of velocity and water depth, classifying the values of $V \cdot D$ by some rules and using different colours to render the corresponding hazard levels, a meaningful risk map is generated. The waterRIDE™ software is a very efficient package for the process. Fig. 2 is 900 mm/h risk map.

3.2 Web – GIS based flash flood information system

The system provides a Web – GIS platform for distributing all the flood – related information on

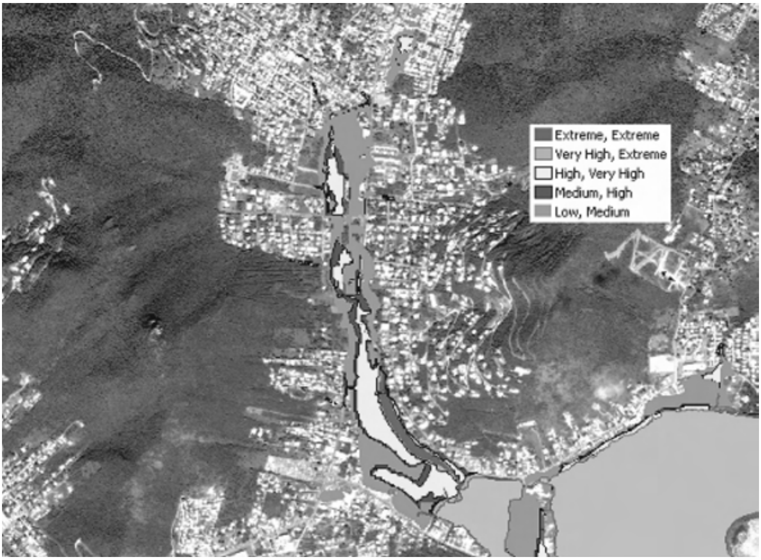

Fig. 2　90 mm/h (50 years ARI) risk map

a website server. It works in a Client/Server pattern, the Client side users with browser and the Internet can access the web server to obtain flood information.

An upcoming rainfall event is forecasted by radar. Then from the Pre – cooked flood library, the record which has similar rainfall intensity is queried. In the case, five different flash floods are recorded in the library. A 90 mm/hour, 50 years ARI rainfall event is chosen as an example to illustrate how to use the Web – GIS based system to browse flood risk map and identify buildings and roads which are under the threaten of a selected hazard level (see Fig. 3).

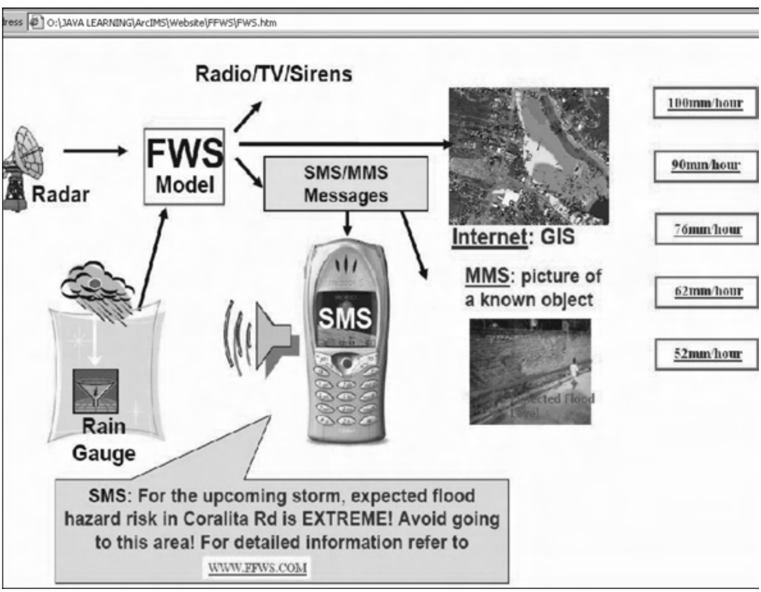

Fig. 3　Web – GIS based flash flood information system

Clicking the query icon, and then input the Query Sting text field with HAZARDMIN = "2. V High", highlighted areas with a hazard level between Very High to Extreme. Similarly appears. The followings show highlighted selection of buildings and roads in the hazard level between Very High to Extreme(see Fig. 4 ~ Fig. 6).

Similarly, maps of hazard level between High to Very High, Medium to High and Low to Medium, High to Very High, Medium to High and Low to Medium can be obtained by the same processes.

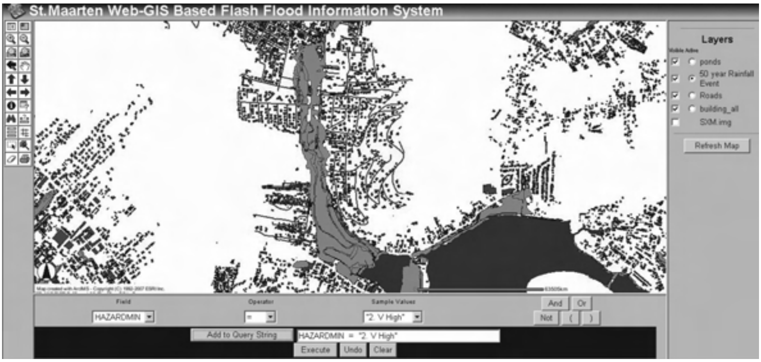

Fig. 4　Risk map of hazard level from Low to Extreme

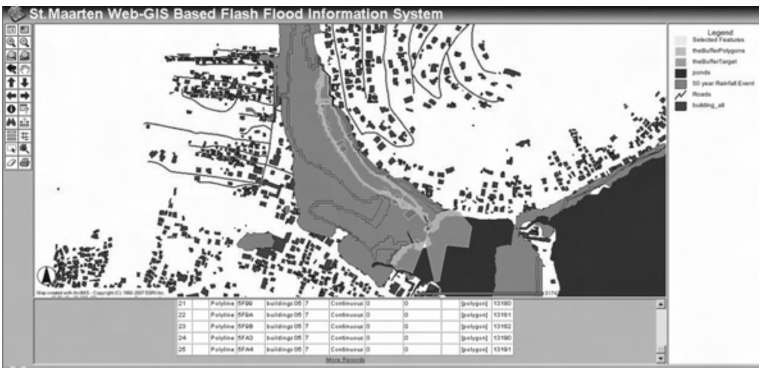

Fig. 5　Buildings with hazard level from Very High to Extreme

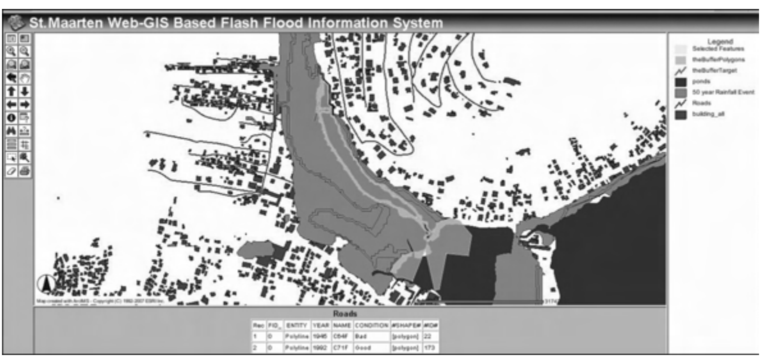

Fig. 6　Roads with hazard level from Very High to Extreme

3.3 SMS/MMS based flash flood warnings system

The system provides a solution to disseminate flood warnings to communities by means of SMS/MMS. It is composed of four panels, namely the SMS/MMS Services Control Centre, Government and Critical Facilities Planning, Data Processing and Testing panel respectively. Just as their names suggest, each panel performs the corresponding function. In the left corner, the comb list offers a selection of different rainfall events from the Central Database. The next comb list provides different hazard level selection. Once selecting a rainfall event and a hazard level, roads and buildings under the selected hazard level will be automatically queried from Central Database and displayed in the table.

Meanwhile, mobile telephone numbers of each of the buildings are input into a telephone number list, which will be used as a SMS/MMS destination.

According to different hazard levels, the corresponding SMS message contents are automatically formulated and displayed on the right text editor panel. The message content is also editable and changed freely (see Fig. 7).

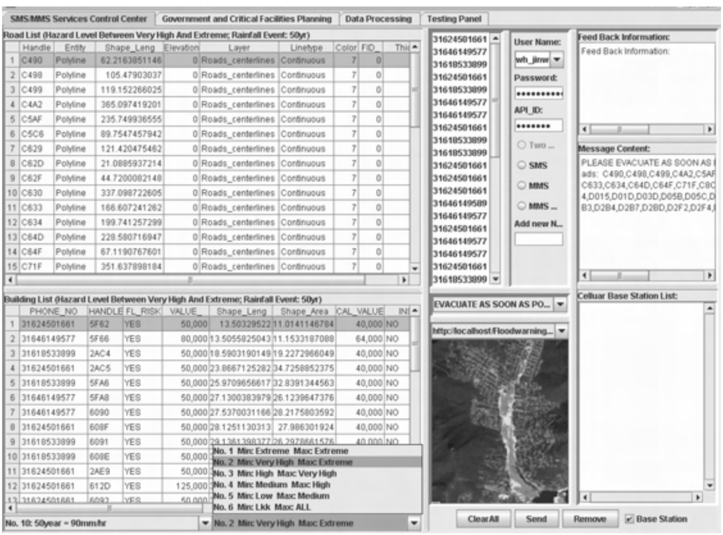

Fig. 7 SMSCC operation of hazard level from Very High to Extreme

In the following figure, the Feed Back Information panel shows a successful SMS sending by invoking an online SMS/MMS Gateway API offered by the Clickatell Company in South Africa. MMS sending is also applicable in this application, but it depends on whether the wireless carriers support the services or not. In the Netherlands, both SMS and MMS are provided by most of the wireless carriers (see Fig. 8 ~ Fig. 10).

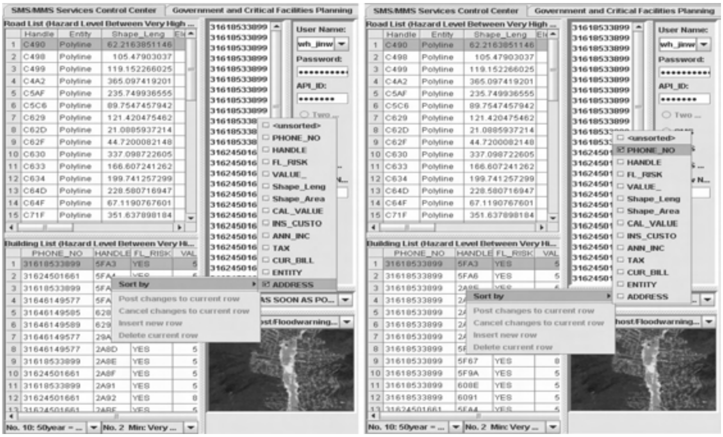

Fig. 8　SMSCC operation of a pop menu in buildings table

Fig. 9　SMSCC operation of SMS message content panel

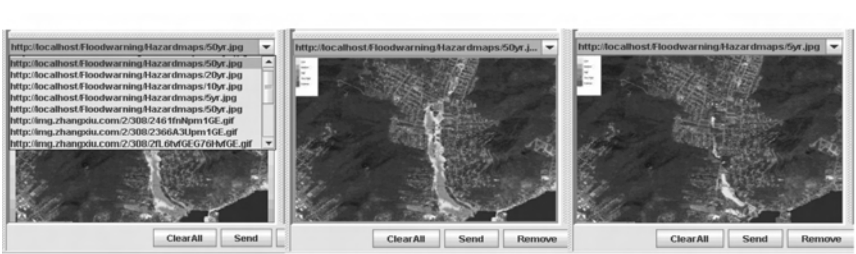

Fig. 10　SMSCC operation of MMS picture selection

In Government and Critical Facilities Planning panel, choosing different rainfall event, the corresponding person of government and critical facilities, who are related to the selected flash flood, are automatically queried from Central Database and displayed on the screen (see Fig. 11 ~ Fig. 12).

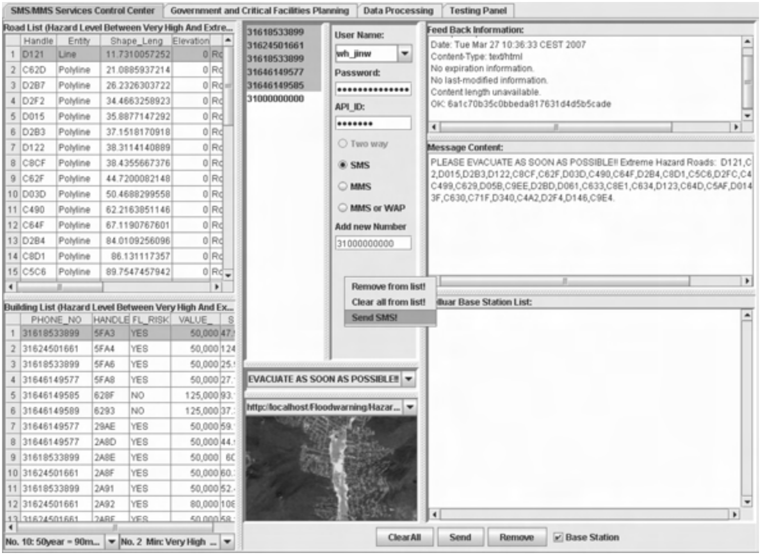

Fig. 11 SMSCC operation of SMS/MMS message sending

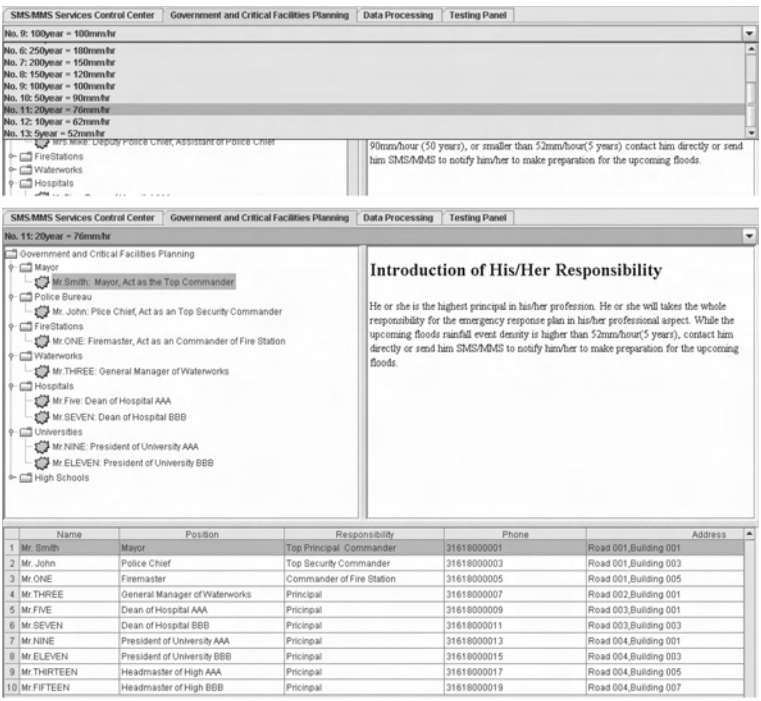

Fig. 12 GCFP operation of 20 years rainfall event

3.4 Mobile – WAP Based Integrated StormWater Management Information System (MW – ISMIS)

MW – ISMIS provides an application for end users utilizing their mobile phone or PDA to actively acquire flood – related information. This application works in a C/S pattern. After an installation of a flash flood warning system (named Midlet) in a mobile phone or PDA, by means of mobile – based Web technology, the end user can send a request to a web server; in the Web Server side, a Servlet automatically deals with the request and sends a response to the end user. Thus, the end users can query their interesting information, and do not need to be confined to the limitation of SMS/MMS.

After being authorized by server, a main screen with several menu items appears (see Fig. 13). Selecting "Flood Warning Information", a screen with a title of Flash Flood Warning and two menu items come into sight. To make the case simple, the following screens after choosing Principle, Flooding_Warning, Hazard_Level, Hazard_Areas, Hazard_Roads, Safe_Areas, Escape_Routes and Other_Information, the linked screen to each of the menu items is simplified by a simple plain text frame with tips. On the bottom of each screen, the www.ISMIS.com provides users a detailed flood information Web server URL (see Fig. 14).

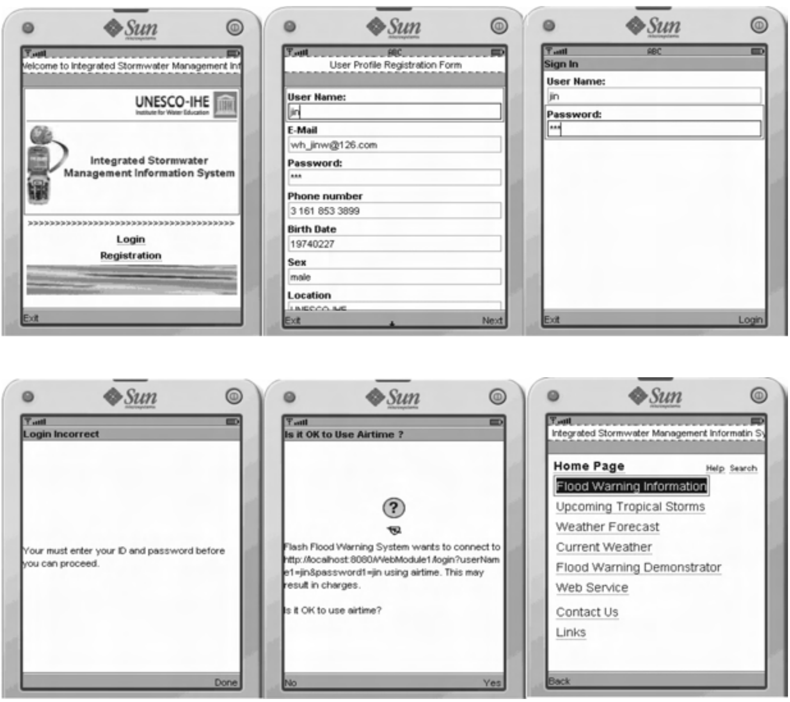

Fig. 13 MW – ISMIS operation of login and registration

Fig. 14 MW – ISMIS operation of flash flood warnings

It should be noted that for the St. Maarten area, the information of Tropical Storms Forecast and Report is not available; New York is chosen to be displayed as an example. The following group figures show the operation of the Weather Forecast(see Fig. 15 ~ Fig. 16).

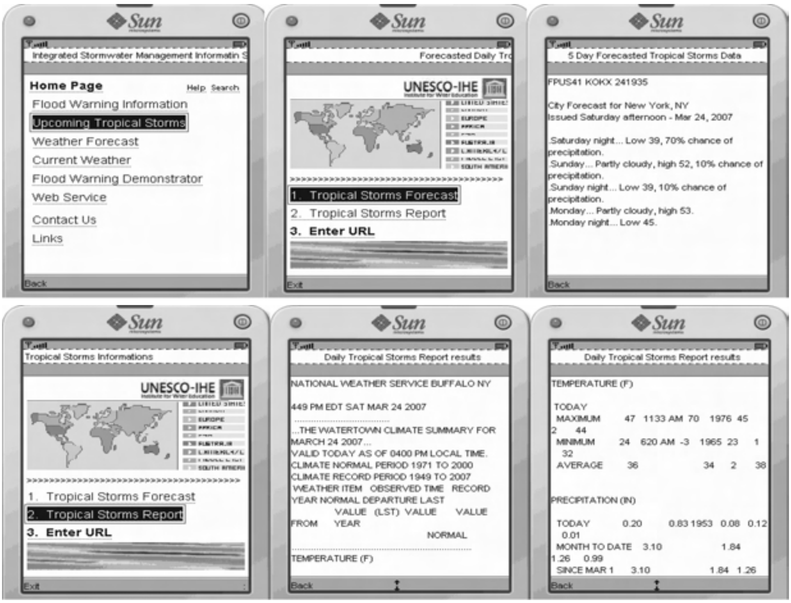

Fig. 15 MW – ISMIS operation of upcoming tropical storm

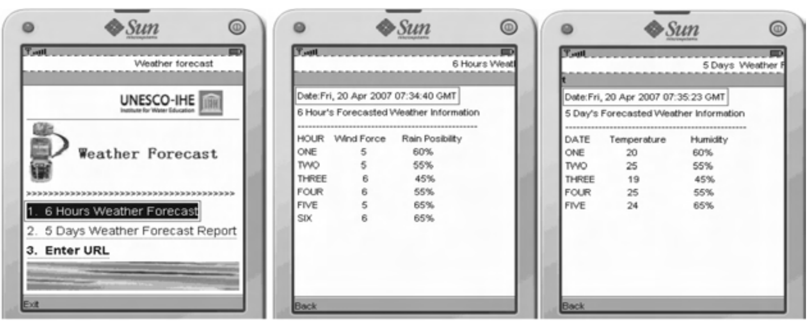

Fig. 16 MW – ISMIS operation of weather forecast

4 Conclusions

(1) From the demonstration described before, it can be seen that in the technical aspect, it is feasible to combine the knowledge of Web – GIS – SMS/MMS – Mobile – WAP in a FFWS.

(2) With the rapid development of Information and communication technologies (ICTs), and the competition in the IT field, the public, not only in developed countries but also in most developing countries, have got the chance to use or own a PC, mobile phone or even a PDA; accessing the Internet is also becoming more and more popular around the world. As a result, to implement such a FFWS is also feasible in respect to the economic cost.

(3) The system provides two directional information transmissions by SMS and the Internet

Web. Such a Web – GIS – SMS/MMS – Mobile – WAP system combining the widely accepted technologies will contribute to the education of flood knowledge education.

(4) To implement such a FFWS, it is recommended to have cooperation among various organisations, governmental agencies, mobile telecommunication companies, water – related companies and expert system, etc.

The Information Building of Reservoir and Riverbed Sedimentation Survey System for the Yellow River

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Abstract: This paper generalized the achievements of the information building of reservoir and riverbed sedimentation survey system for the Yellow River in recent years: including plane/elevation survey, sedimentation section survey, and the information building of the survey data management; Meanwhile, this article introduced the new developing directions of the related information technologies.

Key words: GPS, total – station, triangle elevation survey, cross – section survey, GIS

The sedimentation survey of the reservoir and riverbed for the Yellow River is a regular and important work, it affords important gist for studying the forming, distributing, and changing rule of the reservoir and the riverbed of the Yellow River, it is also the important precondition and guarantee for flood prevention, the reservoir water adjustment, and other works. In recent years, with the development and the abroad application of computer technologies, electronic technologies, 3S technologies, the building and management of the Yellow River riverbed survey system has stride into information process. The Yellow River riverbed sedimentation survey has already introduced and used GPS, total – station, echo sounder, and other advanced data measure instrument, basically realized the auto – measure, auto – dealing for the measured data; the indoor data management work also gradually introduced into GIS software, the data processing and analyzing also went to regulation, automation, and visualization.

1 The information construction for plane control survey technologies

In plane control survey, Since the first introduced GPS (Global Positioning System) in the Yellow River flood preventing and disaster decreasing system project in August, 1995, GPS is popularly used on the Yellow River, because of its full – weather, high – accuracy, real – time, rapid – speed and other excellences. The plane control survey use GPS control network, it needn't open watch between each survey station, only need set the GPS receiver at each station, and observe the satellite data synchronously, the observed data is stored into GPS receiver automatically, the indoor data dealing, network adjustment, and accuracy appraisement is accomplished by special GPS later processing software, and it has unexampled advantages than traditional triangle survey.

In sedimentation survey project of Xiaolangdi reservoir, the plane control survey work of the cross – section stakes is mainly accomplished by GPS. The GPS control network is also built at the Yellow River and its mouth, the work of setting and observing the GPS control network between Yumenkou and the river mouth of the middle and lower Yellow River is also accomplished, the Wangjiazhai reservoir of the middle Yellow River also adopted GPS control survey, GPS plane control survey technology has already broadly applied.

2 The information construction of the elevation control survey technologies

Because of the development of hardware technologies, the introduction of the total station, digital level and so on, the elevation control survey technology has great improvement. Especially the development and use of the total station elevation survey system, solved the elevation survey problem in mountain area better, and had the character of accurate survey results, rapid working speed, and high degree of automation, so we adopted broadly of the total station rapid elevation survey system in Xiaolangdi reservoir, and acquired better benefit.

2.1 The basic principle and survey methods of the total station rapidly survey

Calculate the elevation difference between the two points using the distance and the vertical angle (bow angle or elevation angle) measured by total station, shown as Fig. 1:

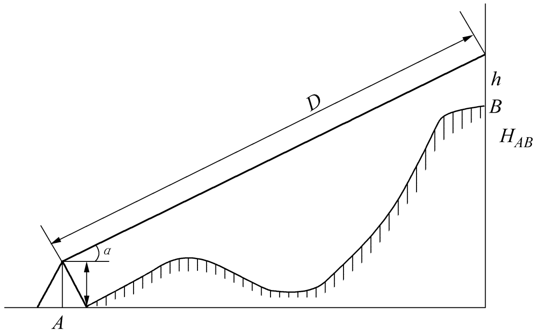

Fig. 1 The sketch map of the elevation difference survey

The elevation difference formula between point A and B is:

$$H_{AB} = D \cdot \sin\alpha + i - h \qquad (1)$$

Considering the influence of the earth curving and atmosphere refraction, the elevation difference formula between point A, B is:

$$H_{AB} = D \cdot \sin\alpha + \frac{1-k}{2R}[D \cdot \cos\alpha]^2 + i - h \qquad (2)$$

In the formula: α is the observed vertical angle; R is the average curving radius of the earth; i is the instrument height; h is the object height; k is the atmosphere refraction coefficient; D is the corrected slope distance; all of the distance parameters above adopted meter as unit.

There are two outside measure method: setting station on alternate point, and setting station on each point. The first method of setting instrument on alternate point set instrument between the two observation targets, survey each station, and the two observation targets progress forward alternately, the working pattern simulated geometry leveling survey. The second method of setting station on each point setting instrument on each point of the restricted distance on the progress route, and it need survey out and home. The observation implemented according to the prompt of the electronic book, the electronic book completed record, calculate, make table, and print result through cable.

2.2 The elevation survey by using digital level

We also introduced into high accurate digital level NA3003, it can be used into accurate level survey, it also can be used into cross – section survey, subside observation and other aspect. The user press down the button, and it can realize auto – collimating the rod, auto – surveying, auto – recording the surveying data into REC modular, and transfer the data into the PC through GIF10 or GIF 12, and deal it using special software.

3 The information construction of sedimentation measurement technologies

The sedimentation survey of the reservoir and the riverbed for the Yellow River adopted cross –

section method, it proceed land and underwater survey by setting a number of fixed cross – section along the reservoir and the riverbed, traditional cross – section survey use angle sextant to locate, use sounding weight and sounding rod to measure depth, this working method need to build survey signal and set baseline on the cross – section, it's expensive, low location accuracy, and low depth accuracy. With the introduction of total station, GPS, echo sounder, the sedimentation cross – section survey technology innovated greatly.

3.1 Cross – section survey with total station

The total station can make accurate distance and angle survey, it have the functions of auto – observe, auto – record etc, it can get the slope distance, horizontal distance, horizontal angle, vertical angle, three – dimension coordinates and other data, the observed data is stored in PCMCIA card, it can be processed indoors using simple program to get cross – section result tables, the total station cross – section survey technology is widely used on the Yellow River because of its high accuracy and efficiency.

3.2 GPS · RTK cross – section survey

GPS working mode in riverbed cross – section survey is RTK (Real – time kinematic), we can navigate accurately to the cross – section location through GPS navigation screen, measure and record the three – dimension coordinates of the observed point precisely, and examine the elevation and the distance between the GPS receiver and the left end point of the cross – section. The biggest tolerant error for RTK survey: 10 mm + $2D \times 10^{-6}$ in plane, 20 mm + $2D \times 10^{-6}$ in vertical direction (D is the length of observed line), we need convert the ellipsoidal height into the normal height when making real – time kinematic location survey using GPS · RTK. It's proved that the normal height calculated by RTK surveyed height difference can reach the fifth class water level accuracy after converted by Bursa model and removed the elevation abnormity by elevation suit, this can meet the accurate requirement of the reservoir and the riverbed survey.

3.3 Water depth measure

In water depth measure, we use echo sounder, the echo sounder is set on the survey ship, working together with GPS, can measure water depth continuously, and can get the three – dimension coordinates of the river floor. We need not observe the water level when surveying the water depth because GPS · RTK can get the real – time three – dimension coordinates. The elevation formula of the observed points of the river floor is:

$$H_i = H_A - (H_E + \Delta H) \tag{3}$$

H_i is the elevation of the river floor, H_A is the elevation of the GPS antenna phase center, H_E is the water depth measured by echo sounder, ΔH is the distance between the transducer probe and the phase center of the GPS antenna.

The new cross – section survey method saved time and power, the observed value was precise, and it's convenient for data management. We accomplished the sedimentation survey of the Xiaolangdi reservoir in 15 days while it need 45 days if we adopted traditional measure methods.

4 The information development in data management and use

4.1 Introduction of GIS

GIS (Geographic Information System) is a new cross subject about describing, storing, analyzing, and outputting space information theory and methods; It based on Geo – spatial Database, adopted analyzing method of geographic model, afforded various space and dynamic geographic information real – timely, it's computer technology system served for geography research and decision – making.

4.2 Software development and use about GIS

With the development of database technology, GIS technology and the related computer application level, we add some new requirement to data management and analyzing, so we cooperated with other unit, developed "the riverbed cross – section analyzing system" and "the hydrology and sediment information management system for Xiaolangdi reservoir".

The two software both used sufficiently of database technology, had the data manipulating functions such as input, edit, inquiry, browse, stat., tab, output, and so on. The object stored in riverbed cross – section analyzing system was data related to the observed cross – section, the software analyzed and calculated the character data of the cross – section, such as the deep slot, the deepest point, the main slot, the position and elevation of the bottomland border. It can calculate the area and width of the cross – section, the area and volume of rush and silt, draw out the cross – section map, and output them through Excel.

The hydrology and sediment information management system for Xiaolangdi reservoir mainly based on 1:10,000 digital topographic map data and the observed cross – section data, the observed sink bank and funnel data, and other topographic data of the reservoir, formed complete space and character database of the reservoir topography. It can calculate and analyze the reservoir volume, rush and silt quantity, the cross – section evolvement, funnel data, sink bank, it can show three – dimension topography map; and it can query hydrologic elements, analyze water and sand gene, calculate water and sand quantity, output reorganized result table, query and analyze other hydrologic information. It afforded automatic, intelligent, and technical desktop for hydrology and sediment information management system for Xiaolangdi reservoir.

5 The information prospects of the Yellow River reservoir and riverbed sedimentation survey system

5.1 The integration of 3S technologies

The combination and integration of 3S technologies (GPS, RS, GIS) will push the information building for hydrology and sedimentation survey system of the reservoir and riverbed. GPS and RS is the important data source and data updating means of GIS, GIS is strong technical guarantee for processing and analyzing data. The 3S integrated system not only have the functions of collecting, processing, and renewing data automatically and real – timely, but also can analyze and use data intelligently, it can afford scientific decision – making and querying for all kinds of applications, and can answer all kinds of complex questions asked by users.

5.2 Tobuild no – slot space database

The space scope afforded by GIS is limited at it's beginning. Nowadays, the no – slot space database that can manage multi – scale, sea – quantity space data, has become emphases of GIS research and application. No – slot space database means the data managed by GIS is not single map any more, but more broaden area, even the whole drainage area. Today, many system depart the space data into block and stored it database, and afford the meet information and method between the map blocks, it assure the space data is continuously in space use, that is to say it's no – slot when used. In order to realize multi – scale zoom, many system adopt the method of storing different scale map data into database independently. The most perfect pattern is storing the biggest scale space data in database, catching space data from space database adaptive to display scale real – timely and automatically, completing the map drawing, and realize the NS – GIS in deed.

5.3 True 3D GIS and TGIS

Traditional GIS can only process two – dimension coordinates X, Y, the space analysis based on two – dimension data too, so it's called 2DGIS. Elevation Z is processed as character data In 2DGIS, it's projected to 2D plane to express, this makes multi character at one place can not be clearly expressed, so it's called 2.5DGIS, it expresses three – dimension content using two – dimension form in fact.

3DGIS should simulate, express, manage, analyze information related to the 3D entity, and afford decision support. The core problem of 3DGIS is the building of three dimensions space data model, the research of all kinds of three dimensions data model is still in theory exploring stage, the ability of description and actually use is still limited.

T – GIS or 4DGIS considers the change of time, it adds time dimension to the original 3DGIS. The key problem of T – GIS is building appropriate united time and space data model——time and space data model, today, having truly usage model is "data models of base state with amendments". The research stress of T – GIS is: Design and build an efficient database structure to store time and space data; analyze data including time consequence and space consequence based on the abundant time sequence data and space data; time and space database management system; time and space data visualization etc.

5.4 VR – GIS

VR – GIS (VR: Virtual Reality), is also called VR space, man – made reality, it's advanced people – machine interactive technology simulating people looking, hearing, and other acts in nature, This stimulation have basic characters of "3I": Immersion – Interaction – Imagination. The integration of VR and GIS can make real – time data query and visualization analysis in interactive virtual scene, the technology integration of VR and GIS transfers GIS information into VR modular mainly through Virtual Reality Modeling Language (VRML). So, VR – GIS is a complex and integrated system. Today, VR – GIS database still adopts traditional GIS database, VR is mainly used to enhance the display function of GIS.

6 Brief summary

Under the influence of information tide development, the building and management of Yellow River riverbed sedimentation survey system has stepped into new stages, it has unexampled advantages compared to traditional measure method. But information building is a continuous and deepening process, we should catch development chance, study and apply advanced technologies of information, and make information technologies exert more social and economic benefits in reservoir and riverbed sedimentation survey work.

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Drought Frequency Analysis Using Percent of Normal Precipitation by L – Moment Method

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Abstract: Droughts effects as destructive and unavoidable they seem in any climate can be controlled and mitigated by applying well – established management procedures. In the present paper percent of normal precipitation obtained from rain gages across Khuzestan province southwest Iran was used to study this phenomenon. Ward clustering method was used to identify the homogenous regions in the province by dividing it into three different areas. By using Hosking and Wallis non – homogeneity index was calculated for three areas and the regional frequently distribution parameters were assessed by using L – moment rates. To determine the best distribution frequency, a goodness – of – fit testing and L – moment diagram were used and a drought index with different return periods was calculated.
Key words: drought, percent of normal precipitation (PN), L – moment, frequency analysis

1 Introduction

Drought is a potentially recurring natural disaster that does not demonstrate impacts clearly until the final stages. There are varying academic definitions for the phenomenon, however, it generally occurs because of low precipitation rate over a long period of time such as long as a season. Drought meteorologically is defined as a period of time characterized by abnormally dry climate that, if continues, will lead to water deficiency and hydrological imbalance in a region over long – run . Palmer suggests that drought most likely occurs during a time in which serious reduction in moisture supply compared to the normal state is observed and, thus, it can affect any kind of region or climate.

Several indices have been proposed in literature based upon precipitation analysis where percent of normal precipitation is a universally acceptable; in which precipitation index to a long – term averaged rainfall value is expressed as a certain percentage. Benefits like simplicity, easy – to – interpret values, applicability to statistical distributions and other calculations have made this index very popular with engineers playing a key role in water resources and development planning.

Due to varieties of climate, geology, soil, vegetation and morphology of the watersheds, different regions will show as many varying hydrological responses to this as possible. By dividing a region with deferring and sometimes conflicting characteristics into homogenous group it is probable to develop more accurate and efficient models for the homogenous divisions than the region as a whole.

From a statistical standpoint, spatial homogeneity occurs when hydrological and meteorological events in a homogenous region display acceptable statistical resemblances and respond almost in the same manner.

2 Percent of normal precipitation index

To study variability of reduction in averaged water resources as an index to express the stability of water resources, an index should be used with the following characteristics:

(1) It should determine the variability of any deficiency in averaged water supply since drought

is generally defined as existing water fluctuations compared to the normal state.

(2) It should be independent from regional mean water supply so that any difference in normal values of different regions does not influence the results of their variability while compared.

Water supply compared to the regional long – term mean precipitation is expressed in percentile and is considered as an appropriate criterion for comparing reducing fluctuations of water supply in the region of mean precipitation. It is determined by:

$$PN_i = \frac{p_i}{\overline{P}} \times 100 \tag{1}$$

in which, PN_i is percent of normal precipitation in a year i, P_i is annual precipitation in year i, $\overline{P}$ is averaged long – term annual precipitation.

3 L – moment

Hosking (1990) has recently defined L – moments which are analogous to conventional moments, and can be expressed in terms of linear combinations of order statistics. L – moments basically are linear functions of probability – weighted moments (PWMs). Similar to conventional moments, the purpose of L – moments and probability – weighted moments is to summarize theoretical distribution and observed samples. Greenwood et al. (1979) summarized the theory of PWM and defined them as:

$$\beta_r = E\{X[F_X(x)]^r\} \tag{2}$$

where: β_r is the rth order PWM and $F_X(x)$ is the cumulative distribution function of X. Unbiased sample estimators (bi) of the first four PWMs are given as

$$\beta_0 = m = \frac{1}{n}\sum_{j=1}^{n} X_j \tag{3}$$

$$\beta_1 = \sum_{j=1}^{n-1}\left[\frac{n-j}{n(n-1)}\right]X_{(j)} \tag{4}$$

$$\beta_2 = \sum_{j=1}^{n-2}\left[\frac{(n-j)(n-j-2)}{n(n-1)(n-2)}\right]X_{(j)} \tag{5}$$

$$\beta_3 = \sum_{j=1}^{n-3}\left[\frac{(n-j)(n-j-1)(n-j-2)}{n(n-1)(n-2)(n-3)}\right]X_{(j)} \tag{6}$$

where: $x(j)$ represents the ranked AMS with $x(1)$ being the highest value and $x(n)$ the lowest value, respectively. The first four L – moments are given as follows:

$$\lambda_1 = \beta_0 \tag{7}$$

$$\lambda_2 = 2\beta_1 - \beta_0 \tag{8}$$

$$\lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0 \tag{9}$$

$$\lambda_4 = 20\beta_3 - 30\beta_2 + 12\beta_1 - \beta_0 \tag{10}$$

Unbiased sample estimators of the first four L – moments are obtained by substituting the PWM sample estimators from Eq. (2) into Eq. (11). The first L – moment λ_0 is equal to the mean value of X.

$$\lambda_{r+1} = (-1)^r \cdot \sum_{k=0}^{r} P_{r,k} \cdot \alpha_k = \sum_{k=0}^{r} P_{r,k}\beta_k \tag{11}$$

Finally, the L – moment ratios are calculated as:

$$L - C_V = \tau_2 = \frac{\lambda_2}{\lambda_1} \tag{12}$$

$$L - \gamma = \tau_3 = \frac{\lambda_3}{\lambda_2} \tag{13}$$

$$L - k = \tau_4 = \frac{\lambda_4}{\lambda_2} \tag{14}$$

4 Case study

The study area of this research located within jurisdiction of Khuzestan Water Affairs Company in south west of Iran. It is confined to Zagros Mountains from north and east, from south to Persian Gulf and from west to the international borders with Iraq. This area was 74,960 km^2. Varieties in elevation and effects of Zagros Mountains on the climatology of region have created relative climatic inconsistencies so that southwestern parts of Khuzestan usually experience a warmer weather with lower rainfall rate while north and northeast Khuzestan have an almost mild to cold climate with higher precipitation.

5 Methodology

Data were collected from raingauge stations within the study area and based on their location, duration of the respective period, randomness test and homogeneity test, 78 indicator stations were selected for a period of 37 years, from 1967 to 2003.

5.1 Identification of homogeneous regions

For identification of homogeneous regions Hosking and Wallis recommended using Ward's method, which is a hierarchical clustering method based on minimizing the Euclidean distance in site characteristics space within each cluster. The site characteristics selected in this study for each station included: latitude (LAT), longitude (LON), altitude (AL) and annul precipitation (AP) of raingage stations.

Based on this method, study area was divided into three homogenous regions. Then, heterogeneity of each region was determined by using Hosking & Wallis heterogeneity criterion. Fig. 1 displays the three homogenous regions.

5.2 Heterogeneity test

Hosking and Wallis (1997) proposed a statistical test based on L-moment ratios for testing the heterogeneity of the proposed regions. The test compares the between-site variation in sample L-CV with the expected variation for a homogeneous region. The method fits a four parameters kappa distribution to the regional average L-moment ratios. The estimated kappa distribution is used to generate 500 homogeneous regions with population parameters equal to the regional average sample L-moment ratios. The properties of the simulated homogeneous region are compared to the sample L-moment ratios as:

$$H = (V_1 - \mu_{V1}) / \sigma_V \tag{15}$$

where: μ_{V1} is the mean of simulated V_1 values, and σ_V is the standard deviation of simulated V values.

For the sample and simulated regions, respectively, V is calculated as

$$V = \left\{ \sum_{i=1}^{N} n_i (t^{(i)} - t^R)^2 / \sum_{i=1}^{N} n_i \right\}^{\frac{1}{2}} \tag{16}$$

where: N is the number of sites, n_i is the record length at site i, $t^{(i)}$ is the sample L-CV at site I, and t^R is the regional average sample L-Cv. If $H < 1$, the region can be regarded as "acceptable homogeneous", $1 \leqslant H < 2$ is "possible homogeneous", and $H \geqslant 2$ is "definitely heterogeneous".

The homogenous values for three regions are shown in Table 1.

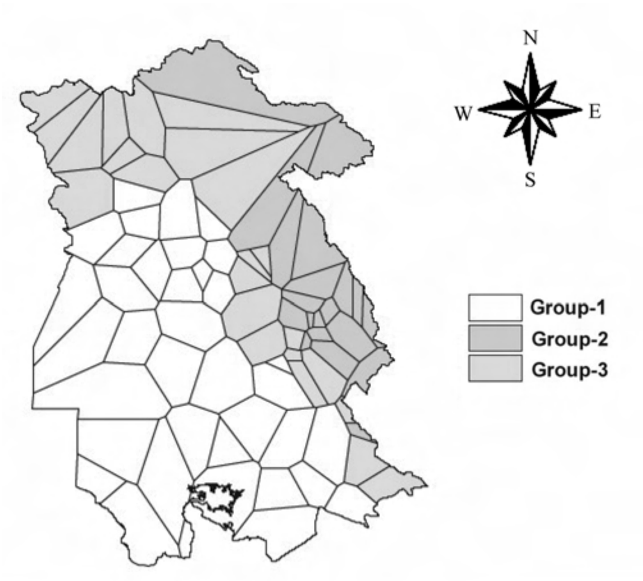

Fig. 1 Regional divisions used in the study

Table 1 Homogenous values for three regions

Region	1	2	3
H	−0.7	−0.4	−0.01

5.3 L – moment ratio diagrams

An L – moment ratio diagram of L – kurtosis versus L – skewness compares sample estimates of the dimensionless ratios with their population counterparts for a range of statistical distributions include General Logistic (GLO), General Extreme Value (GEV), General Normal (GNO), Pearson Type 3 (PE3) and General Pareto (GPA). L – moment diagrams are useful for discerning grouping of sites with similar precipitation frequency behavior, and identifying the statistical distribution likely to adequately describe this behavior. As the sample L – moments are unbiased, the sample points should be distributed above and below the theoretical line of a suitable distribution.

This diagram shows that the GLO distribution fits best the region 1 (see Fig. 2).

5.4 Goodness – of – fit test

The goodness – of – fit test described by Hosking and Wallis (1997) is based on a comparison between sample L – kurtosis and population L – kurtosis for different distributions. The test statistic is termed Z^{DIST} and given as follows

$$Z^{DIST} = (\tau_4^{DIST} - t_4^R + B_4)/\sigma_4 \tag{17}$$

where: $DIST$ refers to a candidate distribution. τ_4^{DIST} is the population L – kurtosis of selected distribution, t_4^R is the regional average sample L – kurtosis, and σ_4 is the standard deviation of regional average sample L – kurtosis. A four – parameter kappa distribution is fitted to the regional average sample L – moment ratios. The kappa distribution is used to simulate 500 regions similar to the observed region, and from these simulations and are estimated. Declare the fit to be adequate if

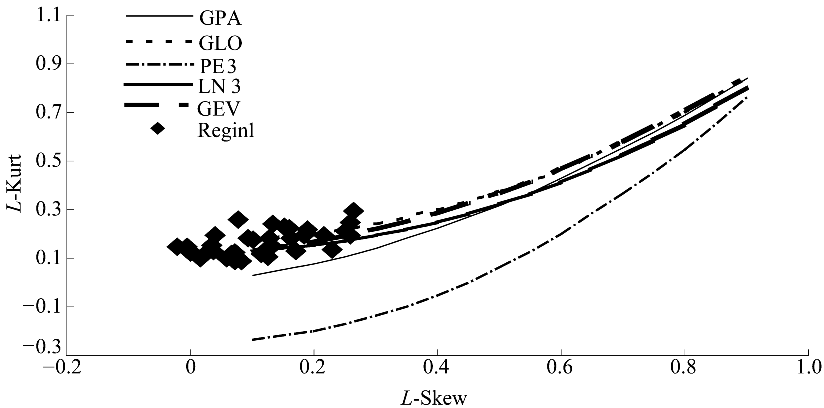

Fig. 2 L – moment ratio diagram for region 1

Z^{DIST} is sufficiently close to zero, a reasonable criterion for selection of suitable being $|Z^{DIST}| \leqslant 1.64$.

5.5 Drought frequency analysis

The PN index was calculated for 2, 5, 10, 20, 50, 100 return periods by applying the best regional probability distribution with a 90% confidence level. Results are shown in Table 2 and Table 3:

Table 2 Goodness – of – fit values of PN for different regions

Distribution	Z		
	Region 1	Region 2	Region 3
GEN. LOGISTIC	−0.43	3.51	3.47
GEN. EXTREME VALUE	−5.27	−0.65	−1
GEN. NORMAL	−4.92	−0.35	−0.65
PEARSON TYPE III	−5.49	−0.83	−1.15
GEN. PARETO	−15	−9.02	−9.96

Table 3 PN values for different return periods

Region	Number of stations	T(Year)					
		2	5	10	20	50	100
1	36	96.34	126.7	146.68	166.71	194.53	217.11
2	19	96.67	124.97	141.94	157.21	175.89	189.28
3	23	96.22	127.26	145.94	162.81	183.49	198.36

6 Results and conclusions

(1) Khuzestan province was divided into three regions using Ward's hierarchical clustering method based on height, latitude, longitude and annual precipitation characteristics.

(2) By calculating the heterogeneity criterion the third region was determined to be the most

homogenous where the station inconsistency is lower than that of the other regions. The lower inconsistence can reduce the heterogeneity criterion.

(3) Using goodness – of – fit and L – moments diagram, generalized logistic distribution for Region 1 and generalized normal distribution for Region 2 and 3 were determined to have the best distribution.

(4) In order to analyze the drought frequency in Khuzestan province the best regional probability distribution for PN index was used to determine the values of the index for return periods of 2, 5, 10, 20 and 50 on annual basis for all regions with a 90% confidence level.

(5) It was also determined that the drought index for the regions under study is a function of regional topography so that it is lower in northeastern mountainous region (Region 2) than in southern low – lay, low – rain region (Region 1) and the intermediate region (Region 3).

(6) The drought index does not vary significantly for short return periods for 3 regions under study; however, variations were higher for 20 – year return period and beyond.

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A Users' Friendly Decision Support Tool to Promote Conjunctive Use in Canal Command

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Abstract: There is hardly any evidence about adoption of conjunctive use practice in India mainly due to tremendous difference in cost of canal water and groundwater. In order to convince farmers about conjunctive use and its economical benefits, a users' friendly decision support tool is developed both in Hindi and English languages using Visual Basic platform. This interactive tool calculates: (i) annual fixed and operational costs of irrigation from tubewell and canal; (ii) yield and total cost of produce; (iii) excess expenditure incurred in tubewell irrigation over canal irrigation; and (iv) required yield increase to compensate additional cost of irrigation from tubewell. The tool was demonstrated among water users for three situations: (i) own tubewell; (ii) renting pumping sets to run tubewells; and (iii) purchasing water from tubewell owners in the command of RP Channel V of Patna Main Canal under Sone Command in India.

The results reveal that conjunctive use option can be propagated provided water users are convinced about yield improvement resulting in economic benefits, which compensate the additional cost of irrigation. Analysis showed that compared to owning tubewell, water purchasing is the most economical option followed by getting only pumping sets on rent basis to run tubewells for irrigation.

Key words: conjunctive use, decision support tool, canal, tubewell irrigation, cost economics

1 Introduction

Survival of the agrarian economy of world largely depends upon the sustainable use of land and water resources. India is perceived to be endowed with large and reasonably good land and water resources, but with alarming increase in population since last 30 to 40 years per capita resource availability is progressively decreasing. On global basis the irrigated agriculture covers only 16% of the total land under cultivation while it contributes about 36% of the total food production. This supports the fact that irrigation is the most potential and effective means of increasing agricultural productivity. It is however realized that water is a scarce resource, which goes into many competing and conflicting processes and requires a comprehensive planning for appropriate utilization. Development of these resources by individuals has not only created unfavorable conditions for crop production and environmental sustainability but also raised the energy uses in agriculture for irrigation. At the same time intensive irrigation in various canal commands has created the problems of water logging and salinity, making the soil unproductive while overexploitation of groundwater in certain parts of the country has resulted in lowering of water tables and causing decline in yield and productivity of wells, saltwater intrusion along the coast, drying of springs and shallow dug wells, increase in cost of lifting etc. Hence, it is advantageous to look water as a single resource irrespective of its source of development, rain, surface or groundwater. Planning for conjunctive use requires basic understanding of the processes and principles involved in water resource management. A well – formulated conjunctive use programme, must consider fulfilling the irrigation requirement of crops during lean period by other sources of water when supply through canal is not enough to meet the irrigation requirement. In addition, it must also take into account the conservation of rainwater along with augmenting the groundwater storage through recharge.

Hence, Conjunctive use management can be defined as the management of multiple water resources in a coordinated operation such that the total water use of the system over a period of time exceeds the sum of water uses of the individual components of the system resulting from uncoordinated operation. This reflects that conjunctive use planning has a major demand in areas, essentially facing a resource management problem and needs a proper planning at farm, project and regional level.

Conjunctive use models developed earlier may be classified as simulation models, dynamic programming models, linear programming models, hierarchical optimization models, nonlinear programming models and others as reported by Vedula et al. (2005). The conjunctive use models developed and employed by various researchers like Bredehoeft and Young (1983), Latif and James (1991), Belaineh et al. (1999), Marino (2001) Barlow et al. (2003), Rao et al. (2004) can be classified under a single or combination of categories mentioned above. Vedula et al. (2005) attempted to model conjunctive use and developed a stable operating policy for optimal allocation of surface and ground waters for irrigating multiple crops in a canal command area.

Lakshminarayana and Rajagopalan (1977) studied the problem of optimal cropping pattern and water releases from canals and tubewells in the Bari Doab basin in India using a linear programming model. The model is deterministic and the dynamic response of ground water aquifer is not considered. In most of the cases of conjunctive use programmes in India, what is being practiced in the country at the moment does not really envisage the optimal use of rain, surface and groundwater resources (Prasad, 1993). None of the states, so far have formulated clear – cut operational plan for conjunctive use in any irrigation projects though bulk of attempts through research and extension agencies have been undertaken and developed technologies have been disseminated in the country. Reviews indicate that no irrigation project, however, has either been planned, or designed and operated, on conjunctive use principles so far, which can incorporate the institutional framework, socio – economic factors of wide range of stakeholders and policy guidelines for development of water resources along with the technical aspects of canal management due to unresolved technological issues, absence of a methodological framework, and certain inhibiting policy and socioeconomic factors. Upadhyaya etal. (2004) developed a conceptual framework for a decision support system based on prevailing constraints faced by farmers and opportunities available to them.

In this paper attempts have been made to present the constraints in conjunctive use identified through survey and interaction with farmers to explore and promote conjunctive use options in the canal command with the help of an interactive decision support tool.

2 Study area

In order to understand the constraints related to conjunctive use and explore possibilities for its promotion RP Channel V distributary of Patna Main Canal under Sone Canal system in Bihar was selected. In this area conjunctive use of rain, surface and ground water is poorly developed, despite the chronic unreliability and shortage of canal water. Tubewell irrigation is practiced mostly at the tail end of RP Channel – V, where canal water supply is poor. Although many wells and tubewells have been created, as shown in Table 1, yet farmers use them rarely.

Table 1 Wells and Pumpsets in RP channel V

Reach	Number of wells			Pump sets	
	Open	Tubewells	Open + Tubewells	Motor	Diesel
Head	57	26	2	—	28
Middle	69	46	4	2	45
Tail	131	101	14	17	98

The cost of tubewell water varies from Rs. 40/ – to Rs. 70/ – per hour depending on location, time and amount of water supply, whereas cost of canal water supply in the command varies from Rs. 217 to Rs 370.50 per ha depending on the crop. (The conversion factor of 1 US \$ = Rs. 45/ – may be considered). The cost of canal water supply is given in Table 2 below.

Table 2 Cost of canal water (Rs/ ha per crop season)

Sl. No.	Crop	1985 ~ 1995	1995 ~ 2001	2001 ~ 2002 till date
1	Rice	89.41	172.9	217.36
2	Wheat	51.13	148.2	185.25
3	Sugarcane and vegetables	157.59	296.4	370.50

Low cost of canal water misleads cultivators into avoiding use of water sources that are more expensive. Hence they avoid the cost of paying for water from wells or tubewells in the belief that this would be unnecessary in the event that canal water becomes available, or rain occurs. Because canal water is inadequate, irregular, untimely and uncertain, many farmers wait to buy water until it is too late and their crops fail.

3 Constraints in conjunctive use based on farmers' survey

Before propagating the concept of utilizing rain, surface and ground water conjunctively in the canal command farmers were interviewed through a questionnaire and their responses towards conjunctive use were analyzed. Major constraints in adoption of conjunctive use as reported by farmers are:

3.1 No land consolidation

55 % farmers in the head reach, 35% farmers in the middle reach and 32 % farmers in the tail reach of RP Channel V distributary reported that small and fragmented land holding and non – existence of land consolidation were the major problems in owning a tubewell and utilizing groundwater along with canal and rain water conjunctively.

3.2 Uneconomical because it needs high initial investment

All the farmers reported that utilization of ground water has become uneconomical because initial investment ranges from Rs. 25,000/ – to Rs. 40,000/ – depending on the selection of pump, engine/motor and other accessories, whereas canal water though irregular and unreliable, but available at much cheaper rate.

3.3 High recurring expenditure due to increase in price of diesel

All the farmers were of the opinion that due to hike in price of diesel recurring expenditure increases and it discourages the farmers to withdrawal ground water and utilize it for crop production.

3.4 Frequent power failure

Power supply in the villages is totally unreliable and there is a frequent failure so electric motors are very limited in use and farmers are compelled to use diesel engine in place of electric motors.

3.5 Lack of awareness about selection of pump, motor/engine as per farmers' requirement

60 % farmers reported that they don't have knowledge about selection of pump, motor or

engine and other accessories and they purchase either on the basis of experience of other farmers or on the advice of supplier. Due to this they don't get the expected output of pump and face problem due to early failure.

3.6 Lack of trained manpower to efficiently operate and timely maintain the pump, engine/motor and other attachment

All the farmers reported that trained and efficient mechanic is not easily available and accessible in affordable price. Due to this repair and maintenance of pumping unit is not done at proper time, which results in frequent loss of time and money.

3.7 Transportation from one place to another is difficult

Some people have boring in their fields but don't have pumping unit, whereas some people have pumping unit but no boring. These people face problem in transportation of pumping unit due to heaviness of whole assembly.

4 Advantages of conjunctive use quoted by farmers

When farmers were asked about the advantages of conjunctive use, they reported that ground water is assured source of water supply and we can use it efficiently and economically as per requirement of the crop. 63 % farmers in the head reach, 60 % farmers in the middle reach, and 95% farmers in the tail reach, who are also using ground water, reported that use of ground water only during nursery period, helped them in attaining higher yield of rice. The farmers requested to demonstrate the concept of conjunctive use and conditions under which it is economically beneficial to them.

This response of farmers inspired for development of a decision support tool in order to analyse the possibility of ground water utilization and promotion of conjunctive use in the canal command.

5 Decision support tool for conjunctive use

An interactive decision support tool in Visual Basic was developed in English and Hindi versions. A pictorial view of English version with example is presented here (see Fig. 1).

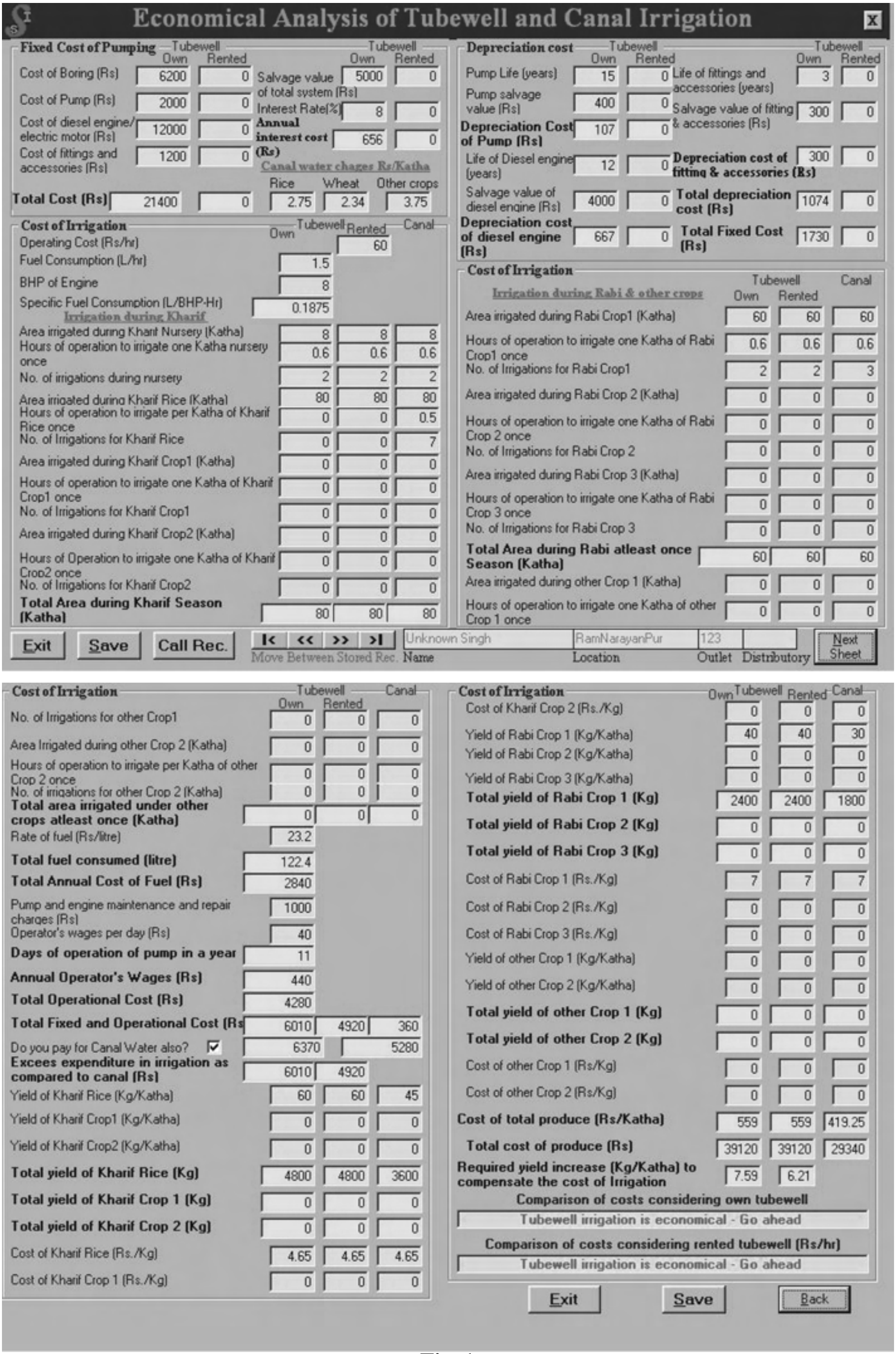
This tool calculates:

- Annual fixed and operational costs of irrigation from tubewells and canal;
- Yield and total cost of produce;
- Excess expenditure incurred in tubewell irrigation over and above the canal water charges;
- The required yield increase needed to compensate for the additional cost of irrigation from tubewells.

The tool was demonstrated to water users and data was collected through the specified format from 150 farmers (50 farmers each at head, middle and tail reaches). The tool was found capable of making the required analyses and of convincing them to use it to make decisions about ground water use under the prevailing constraints they face. Along with canal irrigation the economic viability of tubewell irrigation under three situations were also analysed to understand why conjunctive use is not so popular in this region:

- Own tubewell;
- Renting pumping sets to run tubewells for irrigation;
- Purchasing water from tubewell owners.

Analysis showed that farmers applied 2 to 3 irrigation during rice nursery and 2 to 3 irrigations during Rabi season to irrigate wheat, the required yield increase to compensate the additional cost of irrigation from tubewell in case of the water users owning tubewell varied in the range of 0.069 t/ha to 1.28 t/ha in head, 0.067 t/ha to 1.51 t/ha in middle and 0.13 t/ha to 1.32 t/ha in tail reach



Economical Analysis of Tubewell and Canal Irrigation

Fixed Cost of Pumping

	Tubewell Own	Tubewell Rented
Cost of Boring (Rs)	6200	0
Cost of Pump (Rs)	2000	0
Cost of diesel engine/electric motor (Rs)	12000	0
Cost of fittings and accessories (Rs)	1200	0
Total Cost (Rs)	21400	0
Salvage value of total system (Rs)	5000	0
Interest Rate(%)	8	0
Annual interest cost (Rs)	656	0

Canal water chages Rs/Katha

Rice	Wheat	Other crops
2.75	2.34	3.75

Depreciation cost

	Tubewell Own	Tubewell Rented
Pump Life (years)	15	0
Pump salvage value (Rs)	400	0
Depreciation Cost of Pump (Rs)	107	0
Life of Diesel engine (years)	12	0
Salvage value of diesel engine (Rs)	4000	0
Depreciation cost of diesel engine (Rs)	667	0
Life of fittings and accessories (years)	3	0
Salvage value of fitting & accessories (Rs)	300	0
Depreciation cost of fitting & accessories (Rs)	300	0
Total depreciation cost (Rs)	1074	0
Total Fixed Cost (Rs)	1730	0

Cost of Irrigation

	Tubewell Own	Tubewell Rented	Canal
Operating Cost (Rs/hr)		60	
Fuel Consumption (L/hr)	1.5		
BHP of Engine	8		
Specific Fuel Consumption (L/BHP-Hr)	0.1875		
Irrigation during Kharif			
Area irrigated during Kharif Nursery (Katha)	8	8	8
Hours of operation to irrigate one Katha nursery once	0.6	0.6	0.6
No. of irrigations during nursery	2	2	2
Area irrigated during Kharif Rice (Katha)	80	80	80
Hours of operation to irrigate per Katha of Kharif Rice once	0	0	0.5
No. of Irrigations for Kharif Rice	0	0	7
Area irrigated during Kharif Crop1 (Katha)	0	0	0
Hours of operation to irrigate one Katha of Kharif Crop1 once	0	0	0
No. of Irrigations for Kharif Crop1	0	0	0
Area irrigated during Kharif Crop2 (Katha)	0	0	0
Hours of Operation to irrigate one Katha of Kharif Crop2 once	0	0	0
No. of Irrigations for Kharif Crop2	0	0	0
Total Area during Kharif Season (Katha)	80	80	80

Cost of Irrigation

Irrigation during Rabi & other crops	Tubewell Own	Tubewell Rented	Canal
Area irrigated during Rabi Crop1 (Katha)	60	60	60
Hours of operation to irrigate one Katha of Rabi Crop1 once	0.6	0.6	0.6
No. of Irrigations for Rabi Crop1	2	2	3
Area irrigated during Rabi Crop 2 (Katha)	0	0	0
Hours of operation to irrigate one Katha of Rabi Crop 2 once	0	0	0
No. of Irrigations for Rabi Crop 2	0	0	0
Area irrigated during Rabi Crop 3 (Katha)	0	0	0
Hours of operation to irrigate one Katha of Rabi Crop 3 once	0	0	0
No. of Irrigations for Rabi Crop 3	0	0	0
Total Area during Rabi atleast once Season (Katha)	60	60	60
Area irrigated during other Crop 1 (Katha)	0	0	0
Hours of operation to irrigate one Katha of other Crop 1 once	0	0	0

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Cost of Irrigation

	Tubewell Own	Tubewell Rented	Canal
No. of Irrigations for other Crop1	0	0	0
Area Irrigated during other Crop 2 (Katha)	0	0	0
Hours of operation to irrigate per Katha of other Crop 2 once	0	0	0
No. of irrigations for other Crop 2 (Katha)	0	0	0
Total area irrigated under other crops atleast once (Katha)	0	0	0
Rate of fuel (Rs/litre)	23.2		
Total fuel consumed (litre)	122.4		
Total Annual Cost of Fuel (Rs)	2840		
Pump and engine maintenance and repair charges (Rs)	1000		
Operator's wages per day (Rs)	40		
Days of operation of pump in a year	11		
Annual Operator's Wages (Rs)	440		
Total Operational Cost (Rs)	4280		
Total Fixed and Operational Cost (Rs)	6010	4920	360
Do you pay for Canal Water also? ☑	6370		5280
Excees expenditure in irrigation as compared to canal (Rs)	6010	4920	
Yield of Kharif Rice (Kg/Katha)	60	60	45
Yield of Kharif Crop1 (Kg/Katha)	0	0	0
Yield of Kharif Crop2 (Kg/Katha)	0	0	0
Total yield of Kharif Rice (Kg)	4800	4800	3600
Total yield of Kharif Crop 1 (Kg)	0	0	0
Total yield of Kharif Crop 2 (Kg)	0	0	0
Cost of Kharif Rice (Rs./Kg)	4.65	4.65	4.65
Cost of Kharif Crop 1 (Rs./Kg)	0	0	0

Cost of Irrigation

	Tubewell Own	Tubewell Rented	Canal
Cost of Kharif Crop 2 (Rs./Kg)	0	0	0
Yield of Rabi Crop 1 (Kg/Katha)	40	40	30
Yield of Rabi Crop 2 (Kg/Katha)	0	0	0
Yield of Rabi Crop 3 (Kg/Katha)	0	0	0
Total yield of Rabi Crop 1 (Kg)	2400	2400	1800
Total yield of Rabi Crop 2 (Kg)	0	0	0
Total yield of Rabi Crop 3 (Kg)	0	0	0
Cost of Rabi Crop 1 (Rs./Kg)	7	7	7
Cost of Rabi Crop 2 (Rs./Kg)	0	0	0
Cost of Rabi Crop 3 (Rs./Kg)	0	0	0
Yield of other Crop 1 (Kg/Katha)	0	0	0
Yield of other Crop 2 (Kg/Katha)	0	0	0
Total yield of other Crop 1 (Kg)	0	0	0
Total yield of other Crop 2 (Kg)	0	0	0
Cost of other Crop 1 (Rs/Kg)	0	0	0
Cost of other Crop 2 (Rs/Kg)	0	0	0
Cost of total produce (Rs/Katha)	559	559	419.25
Total cost of produce (Rs)	39120	39120	29340
Required yield increase (Kg/Katha) to compensate the cost of Irrigation	7.59	6.21	

Comparison of costs considering own tubewell

Tubewell irrigation is economical - Go ahead

Comparison of costs considering rented tubewell (Rs/hr)

Tubewell irrigation is economical - Go ahead

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Fig. 1

Note: Katha is smallest local unit of area and 1 hectare = 80 Katha of the canal, whereas for the water users renting pumping sets to run tubewells for irrigation the required yield increase varied in the range of 0.078 t/ha to 0.8 t/ha in head reach, 0.052 t/ha to 0.81 t/ha in middle reach and 0.16 t/ha to 0.78 t/ha in tail reach, and in case of water users purchasing water from tubewell owners it varied in the range of 0.13 t/ha to 0.26 t/ha in head reach, 0.16 t/ha to 0.35 t/ha in the middle reach and 0.18 t/ha to 0.52 t/ha in tail reach of canal. The results reveal that compared to owning tubewell, water purchasing is the most economical option followed by getting only pumping sets on rent basis to run tubewells for irrigation.

6 Conclusions

Conjunctive use is defined as operation of surface and groundwater in such a way, which enhances their combined output. Since long, researchers and planners are trying to recommend the concept of conjunctive use in canal command as well as salt affected areas and many theoretical studies have been conducted in the past, but so far there is hardly any evidence about wide adoption and acceptance of conjunctive use practices among water users due to many constraints and mainly due to tremendous difference in cost of canal water and ground water. Since canal water is available at much cheaper rates, water users don't prefer ground water utilization unless they feel that their production will reduce drastically in the absence of water.

A user interactive decision support tool was developed both in Hindi and English versions using Visual Basic platform and demonstrated among water users in order to create awareness and explore the possibility of conjunctive use in the canal command. Farmers found this tool quite helpful in understanding and analyzing the concept of conjunctive use and taking appropriate decision for its adoption under the prevailing constraints.

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Large – scale Hydrological Modelling for Flow Prediction in the Weihe River Basin

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Abstract: The objective of this study is to develop a capable large – scale hydrological model (LSHM) for flow prediction in Weihe River basin, which is the largest tributary of the Yellow River with an area of 136,000 km^2. The geological formation, hydro – meteorological conditions and human activities are complex and variable in this area. This study was performed based on a distributed catchment modelling system developed at Hydrology core, UNESCO – IHE. The required data include two categories: one is basic data, consisting of digital elevation map, land use data, soil type data, river network and river geometry, the other is time – depending data, consisting of daily rainfall, runoff and actual evapotranspiration.

Data preparation for this study mainly includes catchment schematization, daily areal rainfall and actual evaporation calculation. Catchment schematization consists of DEM derivation, land use and soil type map digitization, cross section schematization and sub – basin delineation. Daily areal rainfall and actual evaporation were calculated based on 1980 ~ 1983 4 years station – measured daily rainfall and monthly pan evaporation data. Specifically, daily rainfall in each 4.5 km × 5.5 km grid cell of the basin was generated by using a spatial interpolation toolkit (Hykit) based on inverse distance weighting method. The daily actual evaporation in each grid cell was derived following sequential steps. Firstly, the potential evaporation was derived from the pan evaporation using proper pan coefficients and seasonally varied crop factors based on the land use map. The monthly actual evaporation was estimated using Thornthwaite – type monthly water – balance model method. Finally, the daily variation of the actual evaporation is achieved by consulting the variation of open water evaporation on sunny day and rainy day based on available data from the year 1980 ~ 1983.

Model parameterization was done by establishing river segment geometry, Manning's roughness, diffusivity and initial water content deficit. Following, 1980 ~ 1983 4 years flow simulation was performed combining with model calibration, performance evaluation shows the present model has high capability for hydrological modelling in large – scale basin. Afterwards, flow prediction for flood season of the year 1983 was implemented on the calibrated model and validated by observed flow. The result indicates that the model is reasonably good for one day flow prediction by combining measured discharge at upstream stations.

Key words: large – scale hydrological model, flow prediction

1 Introduction

This study was carried out in the largest tributary of the Yellow River, Weihe River basin based on the successful application of a distributed catchment modeling system in the Upper Yellow River. The motivation of this study is to further test and improve the model applicability in the Yellow river basin by dealing with a more challenging study area with more significant spatial variability of terrain, soil type and vegetation, temporal variability of temperature, rainfall and evaporation, as well as impact of human activities.

The general objective of this research is to develop a capable large – scale hydrological model (LSHM) for flow prediction in the Weihe River basin. The research was performed following various steps in sequence including Data Collection and Analysis, Catchment Schematization, Areal Rainfall and Evaporation Calculation, Model Parameterization and Calibration, Model Performance Evaluation, Sensitivity Analysis and Assessment of Model Capability.

2 Study Area

The Weihe River basin is located between longitude E 103.5° to 110.5° and latitude N 33.5° to 37.5°, The total length of the main stream is 818 km, the catchment area is 136,000 km^2, enclosing 13 regions 86 counties of Gansu province, Ningxia municipality and Shanxi province. A sketch map of Weihe River basin is shown in Fig. 1.

Fig. 1 Sketch map of Weihe River basin

Weihe River basin belongs to arid – semiarid area and continental monsoonal climate. The mean annual temperature is 6 to 14 ℃, which decreases from east to west as well as from south to north, the mean annual precipitation is 450 to 700 mm, mainly concentrates during July to October, which takes more than 60% of the total annual precipitation; the mean annual runoff is 10.2 billion m^3, more than 60% takes place during August to November, the mean annual open water evaporation is 700 ~ 1,200 mm, the maximum occurs during June.

The general annual land cover types in Weihe River basin are mainly composed of croplands, grasslands, shrubs and forests, which take 49%, 31.6%, 10.2% and 8.5% of the total area respectively. The geology and geomorphology of Weihe River basin is complex, including Qinling mountainous region, Shanbei, Longdong loess plateau and Weihe valley. The topography is higher in west and lower in east with the elevation variation from 330 m to 3,322 m. Most area of Weihe River basin is covered by thick loess, which has the characteristics of loosen texture, high porosity, developed joints, rich in calcium carbonate and easy eroded.

3 Data Preparation

3.1 Required Data and Availability

The required data for this study mainly include two categories, one is basic data, consisting of digital elevation map, land use data, soil type data, river network and river geometry. The other is time – depending hydro – meteorological data, consisting of daily data series of rainfall, runoff and actual evapotranspiration. The available data in study area are 75 cross sections at hydrological stations, 1980 ~ 1983 daily rainfall, daily runoff and monthly pan evaporation at 65 well – distributed rainfall stations, 85 hydrological stations and 39 evaporation stations respectively. The locations of available rainfall and evaporation stations were shown in Fig. 2. All the other basic data were obtained from the work carried out at Hydrology core, UNESCO – IHE as part of a Sino – Dutch project on Yellow River.

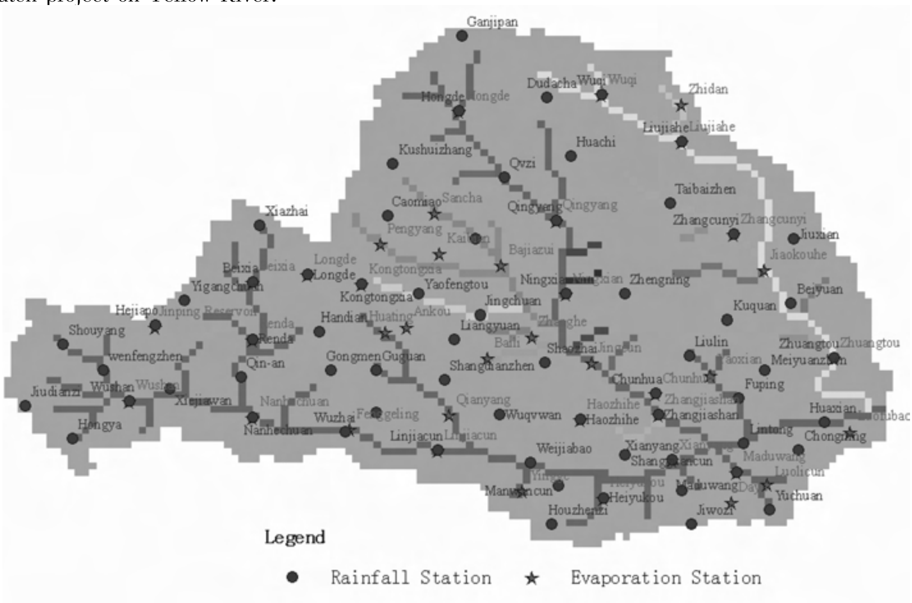

Fig. 2 The locations of available rainfall and evaporation stations in Weihe River basin

3.2 Catchment Schematization

3.2.1 DEM Derivation

The 0.05 degree (G55 grid – aligned) DEM for Weihe River basin was derived from Shuttle Radar Topography Mission elevation data (Farr and Kobrick, 2000), the 30 arc second data set, version 2 (SRTM30), and used to delineate the basin boundary. Some manual corrections are applied on the G55 DEM by visual comparison of the individual pit location surroundings with paper maps to ensure proper drainage connectivity. The derived drainage network of Weihe River basin contains a total of 47 first – order streams and 5,415 grid cells (Venneker and Maskey, 2006).

3.2.2 Land Use and Soil Type Map Digitization

Data of spatial informations on land use and soil type for the entire basin of the Weihe River, the former was acquired from Global International Geosphere – Biosphere Program (IGBP) DISCover Global Land Cover data set (IGBP, April 1992 to March 1993), the latter was obtained from Food and Agriculture Organization of the United Nations Digitized Soil Map of the World data set (FAO/UNESCO, 1995). The acquired data sets were then re – sampled to derive digital maps with 4.5 km × 5.5 km resolution used by the model.

3.2.3 Cross Section Schematization

Stream cross – sections are schematized to a trapezoidal section based on measured cross sections at several river sections. Firstly, the part of schematization was selected based on the maximum water level, then the schematization was performed in spread sheet by using trial and error method and visual comparison of original and schematized cross sections until they fit in both area and shape.

3.2.4 Sub – Basin Delineation

The catchment is divided into five sub – basins. The sub – basins are used to establish the spatial variation in some of the model parameters, such as diffusivity coefficient and initial water content deficit. A map of Weihe River basin with sub – basins and stream networks was shown in Fig. 3.

3.3 Areal Rainfall and Evaporation Calculation

3.3.1 Application of HYKIT Tool

HYKIT tool is a spatial interpolation kit developed at hydrology core group of UNESCO – IHE based on inverse distance weighting method. The procedure of inverse distance method is given by (You et al., 2004)

$$P' = \frac{\sum_{i=1}^{n} W_i P_i}{\sum_{i=1}^{n} W_i} \tag{1}$$

(1) where P' is the estimated value, P_i is the particular measurement at the *ith* surrounding station and the weight function W_i is derived from the inverse of the distance between the target station and the *ith* surrounding station.

$$W_i = \frac{1}{d_i^n} \tag{2}$$

where d_i is the distance between target station and the *ith* surrounding station, n is the power of distance, the most common choice is $n = 2$.

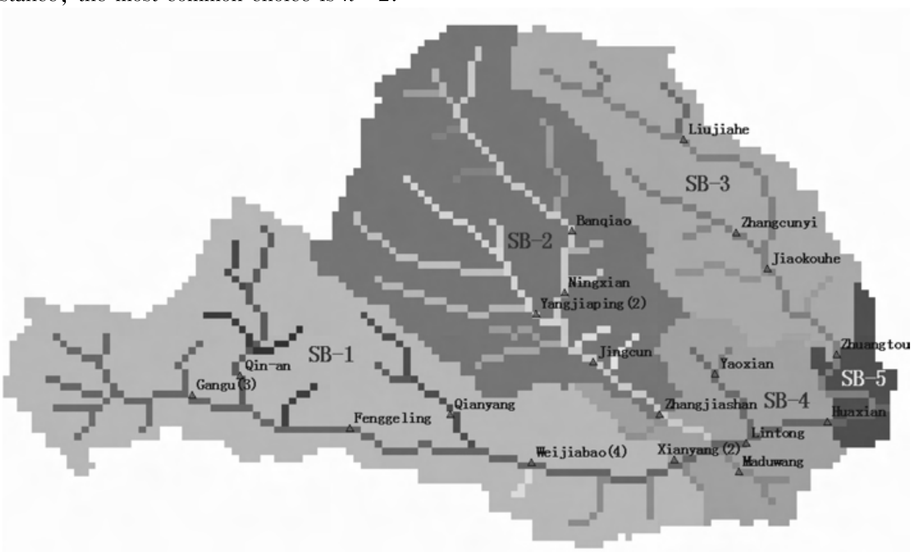

Fig. 3 The Weihe River basin with sub – basins and stream networks

A typical interface of HYKIT was shown in Fig. 4.

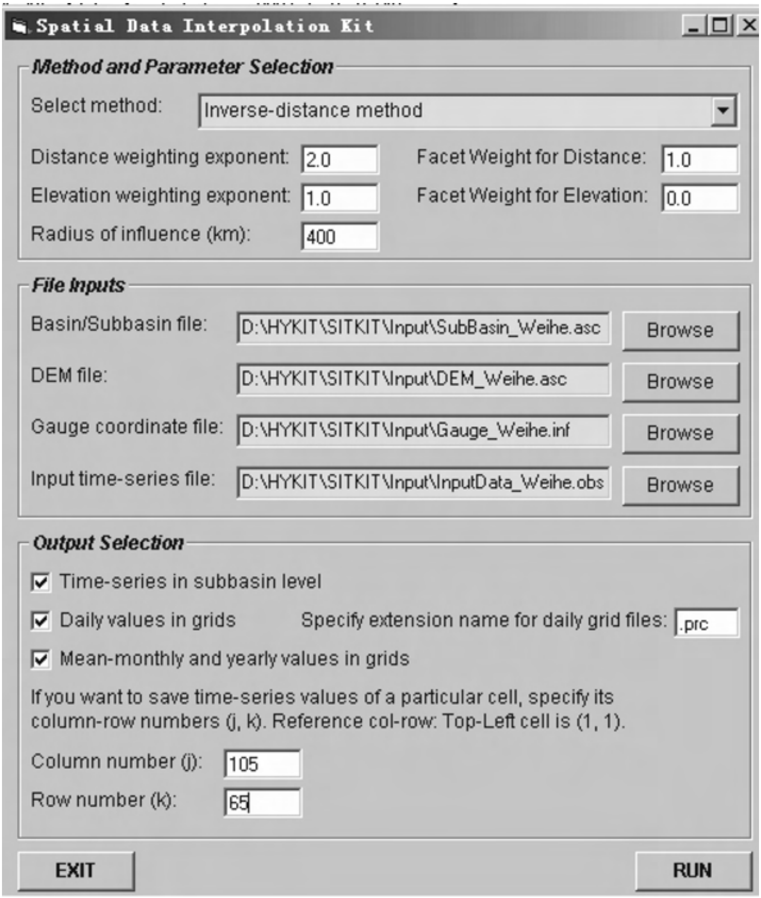

Fig. 4 Interface of HYKIT tool

Distance weighting exponent n and radius of influence should be defined on the interface, for Weihe River basin, these two parameters were determined by validation using precipitation and evaporation maps of the Yellow River basin (YRCC, 1989). Eventually, results showed that $n = 2$, radius = 400 km and $n = 1$, radius = 600 km are preferable for the interpolation of rainfall and evaporation respectively.

4 files in ASCII format are required as the input of HYKIT, they are the basin/sub – basin file, DEM file, the Gauge coordinate (in grid – based columns and rows) file and the time series file. The output provided by HYKIT include time series in sub – basin level, daily, mean monthly and yearly values in grids.

3.3.2 Calculation of Daily Areal Rainfall

Based on measured daily rainfall at 65 stations, daily areal rainfall in each cell (4.536 km × 5.547 km) of the basin was generated by using Hykit tool, which can be used as the model input directly.

3.3.3 Calculation of Daily Areal Actual Evaporation

Based on measured monthly pan evaporation at 39 stations, daily actual evaporation in each cell of the basin was derived following sequential steps:

(1) Calculate Monthly Open water Evaporation

Monthly open water evaporation at each station was calculated by using the formula

$$E_0 = E_{pan} K_{pan} \quad (3)$$

where E_0 is the open water evaporation, E_{pan} is pan evaporation and K_{pan} is pan coefficient.

Then, monthly open water evaporation in each cell of the basin was derived by using Hykit tool.

(2) Calculate Monthly Potential Evaporation

The monthly potential evaporation was calculated in each cell by using formula

$$PET = E_0 K_c \quad (4)$$

where PET is the potential evaporation, and K_c is the crop factor.

(3) Calculate Monthly Actual Evaporation

The monthly actual evaporation in each cell of the basin was calculated by using Thornthwaite – type monthly water – balance model, which are lumped conceptual models that can be used to simulate steady – state seasonal (climatic average) or continuous values of watershed or regional water input, snowpack, soil moisture and evapotranspiration. Input for such models consists of monthly values of precipitation and temperature. Such models typically have a single parameter, the soil – water storage capacity of the soil in the region, $SOIL_{max}$, typically, $SOIL_{max}$ = 100 or 150 mm. All water quantities in the model represent depths (volumes per unit area) of liquid water. All input and outputs are monthly totals and snowpack and soil storage are end – of – month values (Dingman, 2002). The Thornthwaite – type monthly water – balance model was implemented in spreadsheets to compute actual evaporation at each grid.

Step 1. Data input

The monthly precipitation P_m, monthly potential evaporation PET_m generated from formula (4), monthly temperature T_m based on the temperature map of the Yellow River basin (YRCC, 1989), are input into this model.

Step 2. Calculate melt factor F_m

The melt factor used to divide precipitation is computed as follows:

If $$T_m \leqslant 0\ ℃: \quad F_m = 0 \quad (5)$$

If $$0\ ℃ < T_m < 6\ ℃: \quad F_m = 0.167\ T_m \quad (6)$$

If $$T_m \geqslant 6\ ℃: \quad F_m = 1 \quad (7)$$

Step 3. Divide precipitation into rain and snow

Monthly precipitation is divided into rain, $RAIN_m$, and snow, $SNOW_m$, where

$$RAIN_m = F_m P_m \quad (8)$$

$$SNOW_m = (1 - F_m) P_m \quad (9)$$

Step 4. Calculate snowpack $PACK_m$

The snowpack at the end of month m is then computed as

$$PACK_m = (1 - F_m)^2 P_m + (1 - F_m) PACK_{m-1} \quad (10)$$

where $PACK_{m-1}$ is the snowpack water equivalent at the end of month m – 1.

Step 5. Calculate monthly snowmelt $MELT_m$

The monthly snowmelt $MELT_m$ was determined by

$$MELT_m = F_m (PACK_{m-1} + SNOW_m) \quad (11)$$

Step 6. Calculate water input W_m

By definition, the water input W_m is

$$W_m = RAIN_m + MELT_m \quad (12)$$

Step 7. Calculate soil moisture $SOIL_m$

Two cases were considered. Firstly, if $W_m \geqslant PET_m$, the soil moisture should be no larger than the soil – water storage capacity of the soil in the region, $SOIL_{max}$, thus

$$SOIL_m = \min\{[(W_m - PET_m) + SOIL_{m-1}], SOIL_{max}\} \quad (13)$$

Secondly, if $W_m < PET_m$, the decrease in soil storage is modelled via the following conceptualization:

$$SOIL_m = SOIL_{m-1}\exp\left(-\frac{PET_m - W_m}{SOIL_{max}}\right) \tag{14}$$

where $SOIL_m$ and $SOIL_{m-1}$ is the soil moisture at the end of month m and m − 1 respectively.

Step 8. Calculate monthly actual evaporation ET_m

If $W_m \geqslant PET_m$, ET_m take place at the potential rate, that is

$$ET_m = PET_m \tag{15}$$

If $W_m < PET_m$, ET_m is the sum of water input and an increment removed from soil storage, that is

$$ET_m = W_m + SOIL_{m-1} - SOIL_m \tag{16}$$

Finally, the average monthly water surplus, $W_m - ET_m - (SOIL_m - SOIL_{m-1})$ were calculated, this water can be available for recharge and runoff.

(4) Estimate Daily Actual Evaporation

Daily Actual Evaporation was estimated based on two assumptions,

(1) daily actual evaporation is proportional to the daily open water evaporation,

(2) the daily actual evaporation within a certain month is only composed of two magnitudes divided by sunny day and rainy day.

Based on an available 1980 – 1983 monthly data series of mean daily open water evaporation for sunny day and rainy day in Qianhe River sub – basin, as well as the number of sunny days and rainy days for each month counted from daily rainfall data series, the mean daily actual evaporation can thus be calculated by equations (17) and (18).

$$ET_R = \frac{ET_m}{D_R}\left(\frac{E_{OR}D_R}{E_{OR}D_R + E_{OS}D_S}\right) \tag{17}$$

where ET_R is the mean daily actual evaporation during rainy day, ET_m is the monthly actual evaporation, D_R and D_S are the number of rainy days and sunny days for a certain month, E_{OR} and E_{OS} are the referenced mean daily open water evaporation during rainy day and sunny day.

$$ET_R = \frac{ET_m}{D_S}\left(\frac{E_{OS}D_S}{E_{OR}D_R + E_{OS}D_S}\right) \tag{18}$$

where ET_S is the mean daily actual evaporation during sunny day.

So far, the monthly actual evaporation was reasonably distributed into daily actual evaporation in each grid cell, which can be directly used as model input.

4 Model description

The model used in this study is a spatially distributed model with a lumped vertical process representation. It is a compromise modelling approach between a fully distributed physically – based model and a lumped conceptual model, which is used for flow forecasting in a large river basin. A schematic diagram of the modelling system was shown in Fig. 5.

The runoff modeling process is represented by two components:

(1) a land component.

(2) a river component. The land component is structured as a single – layer grid on which the lateral flow is simulated in two dimensions, the transport is simulated as a diffusion process. The one – dimensional river flow component is based on the Muskingum – Cunge routing method (Cunge, 1969) with lateral inflow. more detailed information can consult to A distributed hydrological modelling approach to flow forecasting of a large river basin. (Maskey and Venneker, 2006a).

The model inputs are required as files in ASCII format. The data sets can be classified into three categories:

(1) Basic data.

(2) Time – dependent data.

(3) Simulation control and calibration parameter data. The main outputs produced by the model are simulated time series of discharge at every section of the river segment and defined

stations with observed runoff.

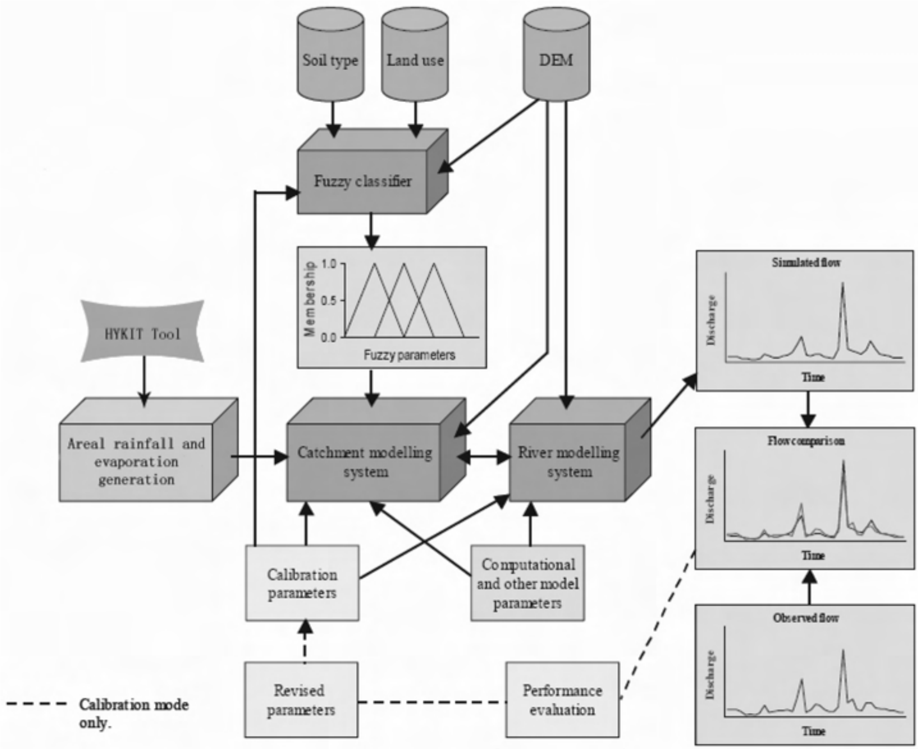

Fig. 5 Schematic diagram of Weihe River basin hydrological modelling system

The general procedure for running the model is

(1) Opening Menu windows.

(2) Defining calibration parameters (optional, can also define in files).

(3) Defining simulation control parameters.

(4) Data preparation of simulation.

(5) Running simulation.

(6) Viewing and saving results. The Menu window of model was shown in Fig. 6, more detailed information can consult to Large – Scale Hydrological Model of the Upper Yellow River Basin, User's Manual Version 2 (Maskey and Venneker, 2006b).

5 Model application

5.1 Model parameterization

(1) River segment geometry input. Based on the schematized trapezoidal cross sections consisting of bottom width, left and right slopes, the geometry of the other cross sections were interpolated, the results was used for model input.

(2) Manning's Roughness Determination. The Manning's roughness at all stream cross sections of river network was estimated by using the available literature for Weihe River basin. Finally, 0.04 and 0.03 two magnitudes were assigned dividing by the elevation of 1,000 m.

(3) Diffusivity Estimation. The diffusivity was qualitatively estimated by using Fuzzy – If – Then rules on soil type (*ST*) and land use (*LU*) of study area, A general form of the Fuzzy – If –

Then rules looks like (Maskey, et al., 2005):

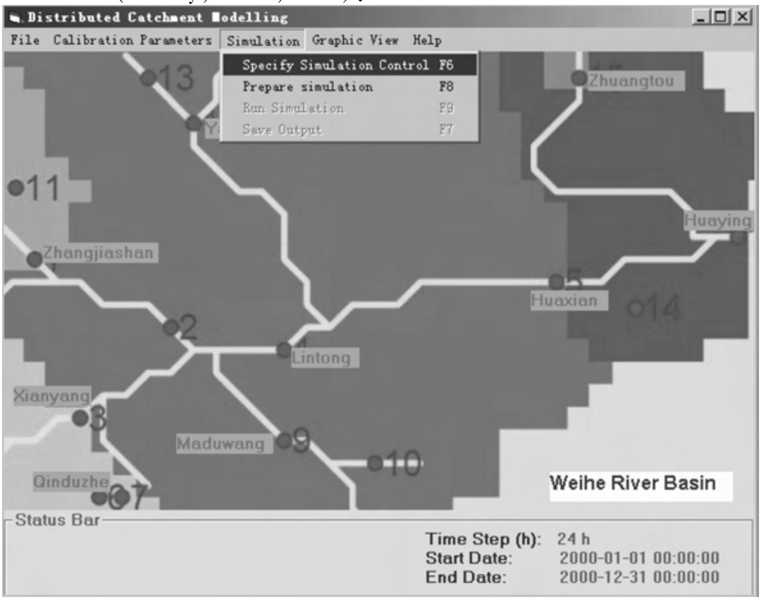

Fig. 6 The menu window of Large – Scale Hydrological Model of Weihe River basin

If Soil Type is ST_i and Land Use is LU_j Then Diffusivity is $D_{0,k}$.

(4) Preliminary Assignment of Dynamic Model Parameters. Initial water content deficit, In_{lw}, modification constant b_1, and antecedent day for rainfall consideration for diffusivity modification, N are the main adjustable parameters during model calibration. Among which, In_{lw} is varied from sub – basins.

5.2 Model Calibration

Because some model parameters are dynamic, in addition, the available time series data are not long enough, model calibration and validation were done conjointly. Model calibration was performed for each sub – basin respectively by evaluating the goodness of fit at the outlet station. During model calibration, root mean square error (*RMSE*), coefficient of Nash – Sutcliffe efficiency (*COE*), mean daily error (e) and relative error on total discharge (E) were conjunctively used to evaluate the goodness of fit. The expression for each criterion was listed as following (Hall, 2001):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Q_{obv_i} - Q_{sim_i})^2} \tag{19}$$

where Q_{obv_i} is the observed daily discharge, Q_{sim_i} is the simulated daily discharge, n is the number of records.

$$COE = 1 - \frac{\sum_{i=1}^{n}(Q_{obv_i} - Q_{sim_i})^2}{\sum_{i=1}^{n}(Q_{obv_i} + \overline{Q}_{obv})^2} \tag{20}$$

where $\overline{Q}_{obv}$ is the mean of observed daily discharge.

$$e = \frac{1}{n}\sum_{i=1}^{n}(Q_{obv_i} - Q_{sim_i}) \tag{21}$$

$$E = \frac{V_{sim} - V_{obv}}{V_{obv}} \times 100\% \tag{22}$$

where V_{sim} is the total simulated volume, V_{obv} is the total observed volume.

5.3 Model Performance Evaluation

According to the calibrated model output, the auto – output RMSE, COE, e and E as well as correlation coefficient R from scatter plot for each outlet station and some main control stations were summarized and listed in Table 1.

Table 1 Statistics of different evaluation Criteria for sub – basin1,2,4

Sub – basin	Stations	*RMSE* (m^3/s)	*e* (m^3/s)	*E* (%)	*COE*	*R*
1	Weijiabao(4)	222.65	76.33	68.75	0.61	0.82
	Xianyang(2)	225.41	59.78	38.03	0.70	0.85
2	Zhangjiashan	58.98	–4.65	–8.21	0.51	0.74
3	Zhuangtou	37.67	0.48	1.73	0.34	0.58
1,2,4	Lintong	272.96	29.19	11.44	0.71	0.85
	Huaxian	255.61	22.20	8.31	0.75	0.87

Intergrated comparison of five evaluation criteria shows that sub – basin 1、2、4 represented by Huaxian station presented the best fit, the joint hyetograph and hydrograph of simulated and observed flow for this sub – basin were shown in Fig. 7.

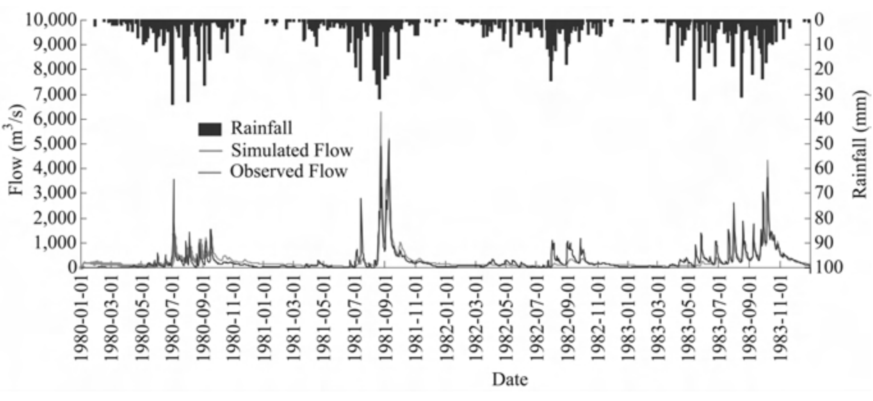

Fig. 7 Comparison of observed and simulated flow in sub – basin 1,2,4

For more precise flow simulation, another scenario was performed by using the observed flow at available upstream stations as forced boundaries (FB). Some basic information of these selected stations was listed in Table 2, the location of these stations can be found on Fig. 3.

Table 3 shows the best fit still presented in Huaxian station based on the improvement of simulation at upstream outlet stations in sub – basin 1 and sub – basin 2, as well as the forced upstream boundaries in sub – basin 4.

The result of present flow simulation at Huaxian station comparing with that under the condition of non – forced upstream boundaries was listed in Table 4.

Table 2 Distance of forced upstream boundaries to the Outlet

Sub – Basin	1		2	3			4	
Outlet Station	Xianyang(2)		Zhangjiashan	Zhuangtou			Huaxian	
Upstream FB Stations	Gangu(3)	Qin – an	Yangjiaping(2)	Liujiahe	Zhangcunyi	Jiaokouhe	Maduwang	Yaoxian
FB Station to Outlet(km)	318	293	110	192	114	81	71	83

Table 3 listed the *RMSE*, *COE*, *e*, *E* and *R* according to the model output under the condition of forced upstream boundaries.

Table 3 Statistics of evaluation criteria with forced upstream boundaries for sub – basin 1,2,4

Sub – basin	Stations	*RMSE* (m^3/s)	*e* (m^3/s)	*E* (%)	*COE*	*R*
1	Weijiabao(4)	180.05	60.00	54.04	0.68	0.85
	Xianyang(2)	189.75	43.39	27.60	0.73	0.86
2	Zhangjiashan	41.85	–1.49	–2.62	–0.74	0.87
3	Zhuangtou	16.75	–4.31	–15.57	0.61	0.81
1、2、4	Lintong	218.78	25.19	9.88	0.78	0.89
	Huaxian	203.66	16.62	6.23	0.81	0.91

Table 4 The improvement of evaluation criteria at Huaxian station after adding forced upstream boundaries

Sub – basin	Stations	*RMSE*(–)	*COE*(+)	*e*(–)	*E*(–)	*R*(+)
1,2,4	Huaxian	20.32%	8.00%	25.14%	25.03%	4.60%

Note: (+) means increase, (–) means decrease.

Table 4 shows that the simulated results at Huaxian station were improved dramatically due to the selected forced upstream boundaries, which can mitigate the influence of intermediate human activities such as water diversion and reservoir regulation.

After applying the forced upstream boundaries, the joint hyetograph and hydrograph of simulated and observed flow for Huaxian station were shown in Fig. 8.

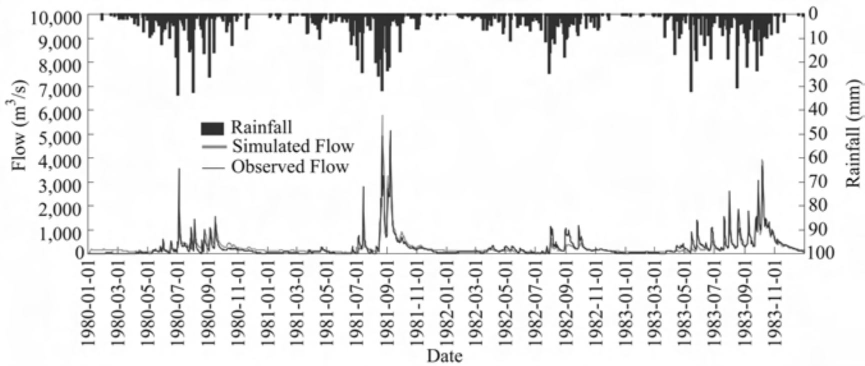

Fig. 8 Comparison of observed and simulated flow in sub – basin 1,2,4

5.4 Sensitivity Analysis

Model uncertainty depends on the model structure, the model parameters and input data. The common method of predicting model uncertainty at present is sensitivity analysis. The simple common method of sensitivity analysis is the disturbance analysis, that is, when the model computes, one of the system parameter has an exiguity of change, while the other parameters are kept unchanged. The ratio of output change rate to the parameter change rate, called as the sensitivity, is expressed as follows (Jia, et al., 2006):

$$I = \frac{\Delta y / y_0}{\Delta x / x_0} = \frac{(y - y_0)/y_0}{(x - x_0)/x_0} \tag{23}$$

where I is the sensitivity, having dimensionless value and a character that the greater the value, the larger the sensitivity, and vice versa, x_0, initial input value of a parameter, x, another input value of the parameter, y and y_0, the corresponding output values of x and x_0 respectively.

Here, a simplified backward method was performed, after decreasing the initial input and model parameters by the same ratio of 5%, the results of performance on calibrated model for each sub – basin were listed in Table 5.

By comparing the absolute value of sensitivity, it can be summarized that model output is very sensitive to both daily rainfall and daily actual evaporation, and daily rainfall is the most sensitive input. For the model parameters, the model output is more sensitive to initial water content deficit than Manning's roughness.

Table 5 The sensitivity of input data and model parameters to model output

Sub – basin	Sub – basin 1	Sub – basin 2	Sub – basin 3	Bub – basin 1,2,4
Daily Rainfall	2.78	2.46	2.48	2.67
Daily Actual Evaporation	–1.66	–1.47	–1.48	–1.60
Initial Water Content Deficit	–0.03	–0.71	–0.81	–0.17
Manning's roughness	–0.003	–0.004	–0.001	–0.003

5.5 Assessment of model capability

5.5.1 Assess capability of flow simulation

For further understanding of the model capacity on flow simulation, the relative simulated error was calculated by:

$$RSE = \left| \frac{Q_{sim} - Q_{obv}}{Q_{obv}} \right| \times 100 \tag{24}$$

where Q_{obv} is the observed daily discharge, Q_{sim} is the simulated daily discharge.

Plot of relative simulated error to observed runoff for Huaxian station was shown in Fig. 9.

Fig. 9 distinctly displays that the extremely large relative simulated error occurred in the range of low flow, but for the high flow, the relative simulated error is relatively quite small and consistent. Based on above analysis, it can be concluded that for the model applied in Weihe River basin, it is more applicable for high flow simulation.

5.5.2 Assess capability of flow prediction

In order to assess the flow prediction capability of the model, two days moving flow prediction for a typical flood season form July, 1983 to October, 1983 was performed. Based on two assumed scenarios: scenario one is assuming the rainfall, evaporation and upstream runoff in the next two days are the same as today, scenario two is assuming the evaporation and upstream runoff are the same as today, but there is no rainfall in the next two days. For scenario one, the validation results of the following one day flow prediction at Huaxian station by using Xianyang(2), Zhangjiashan, Maduwang and Yaoxian four upstream stations as forced boundaries was shown in Fig. 10.

Scenario two acquired a very similar result to scenario one. Based on model output and observed flow data, various criteria for evaluating the goodness of fit were calculated and listed in Table 6.

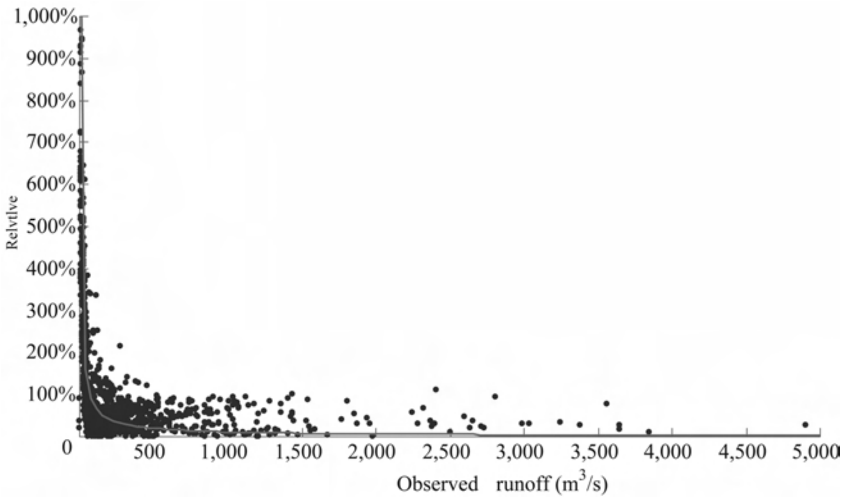

Fig. 9 Plot of relative simulated error to observed runoff for Huaxian station

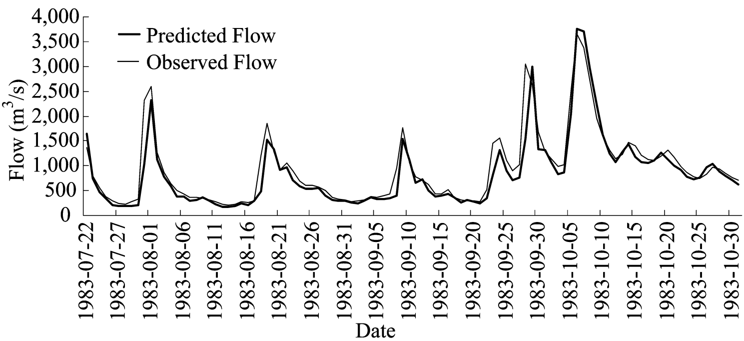

Fig. 10 Comparison of observed and predicted flow at Huaxian station for scenario one

Table 6 The statistics of evaluation criteria for the performance of two scenarios

No	Criteria	Scenario one	Scenario two
1	Mean observed daily discharge(m^3/s)	931.95	931.95
2	Mean predicted daily discharge(m^3/s)	834.21	830.34
3	Coeffi cient of efficiency	0.87	0.86
4	Root mean square error(m^3/s)	260.49	263.09
5	Mean daily error(m^3/s)	97.74	101.61
6	Correlation coefficient	0.942	0.941
7	Relative error on total discharge(%)	−10.72	−11.14

Visual inspection of the joint plot of observed and predicted hydrograph can find they well fit consistently during the whole flood season, all criteria in table 6 indicate that the model performed a well – fit one day flow prediction during the flood season of the year 1983 based on assumed input data.

6 Conclusions and Recommendations

6.1 Based on the research so far, the following conclusions can be drawn

(1) Evaluation on performance of flow simulation shows the results is consistently better in Huaxian station than in other small sub – basins, which indicates the present model is typically suitable for large – scale hydrological modelling.

(2) Under the influence of human activities such as water diversion and reservoir regulation, the model can incorporate such influences into modelling process by using forced upstream boundaries, and improve the accuracy of flow simulation at downstream stations.

(3) The satisfactory performance of flow prediction during flood season shows the model is reasonably capable for flood forecasting in Weihe River basin. It is expected that the potential of the model can be further exerted by improving the technique of hydro – meteorological data forecast and optimizing forecasting network design.

6.2 Further study is suggested to focus on the following aspects

The 1980 ~ 1983 time depending data series applied in this study is not long enough. For the further study, it is better to use longer time series data to establish more appropriate model parameters and initial values.

(2) To further improve the results of hydrological modelling in Weihe river basin, more data and information related to human activities should be collected and combined into the modelling process.

(3) It is necessary to perform further study on the development of flow prediction strategy in Weihe River basin based on data assimilation techniques.

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Briefing on the Development of Hydraulic Works Repairing and Maintenance Budget System

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Abstract: The Hydraulic Works Repairing and Maintenance Budget System, Which has been developed according to Hydraulic Works Repairing and Maintenance Quota Standard (green version), is a kind of automatic financial budget management software for the relative accountants in the water conservancy administrations. Based on establishing hydraulic works databases, maintenance quota standard databases and hydraulic works maintenance budget databases, and by setting up flexible right definition, accurate reliable computing function, abundant and convenient inquiry function, the software can realize electronic automatic budgeting of repairing and maintenance funds.

Key words: repairing and maintenance of hydraulic works, appropriation budget, management system

1 Development necessity

With the economic development and establishment and perfection of the market economy system in China, the existing hydraulic works management system can not adapt to the new situation requests in some aspects. In order to resolve such issues, the Opinion on Implementation of Reform on Management System of Water Conservancy Engineering (hereinafter called the Opinion) was enacted by the State Council on 17th September 2002. In view of some ubiquitous difficulties and key problems of water conservancy administrations, and the requirements for the socialist market economy systems, the Opinion puts forward practical reform goals and policies, which offers the reliable guaranteed policy for strengthening the management, safe operation, benign development in hydraulic works.

The Opinion prescribes all levels of the financial departments should guarantee the authorized funds, which is decided by them, together with the same level of water administration according to maintenance quota standard, to be put in place at full amount in order to make sure the smooth implementation of the reform of water conservancy engineering management system. On July 2004, Repairing and Maintenance Quota Standard of Hydraulic Works (green version) was issued by the Ministry of Water Resources together with the Ministry of Finance (hereafter referred to as Quota Standard). From then on, the repairing and maintenance funds begin to be included in the financial budget at all levels and will be put in place gradually. In order to use the fund more efficiently and make appropriation budget accurately and reasonably, the management of making and using appropriation budget must be strengthened. The scientific methods and hydraulic works data must be gained in order to calculate the appropriation budget properly.

There are many problems in calculating the maintenance funds by hand, according to the Quota Standard, such as large quantity of calculations, long period, statistical analysis difficulty and so on, so it is necessary to base on establishment classificatory hydraulic engineering databases and develop a automated management software with the function of budgeting, auditing, summarizing, approval and inquiry, which can complete the management of making appropriation budget quickly and accurately by the help of computer. Therefore, the Yellow River Flood Control Research Department of YRIHR together with Henan Share Tech Share Future Ltd. according to Quota Standard and Development Specification of Software (GB8567) developed commonly Repairing and Maintenance Fund Budget System of Hydraulic Works (central version) (hereafter referred to as

"System").

2 System design

2.1 System development purpose

(1) The system should possess perfect integrality, suit to the work flow of the maintenance funds budget, and have the function of water conservancy data collection, inquiry, budget, report, auditing, summarizing and approval.

(2) The interface should be friendly, flexible and convenient for financial people at all levels.

(3) The funds should be budgeted simply, swiftly, reliably.

(4) The systematic interface should be designed reasonably to ensure the data can be transmitted rapidly among different modules.

(5) The system must be high practical, and should be secure, expansible, easy to safeguard at the same time.

(6) The conditions in the systematic demand should be fulfilled.

2.2 System development environments

2.2.1 Software environments

(1) Development environments: ①Windows OS. ②ACCESS, MS SQL Server 2000 or above editions. ③Microsoft. NET。

(2) Application environments: Microsoft Windows98/2000/XP, Microsoft SqlServer 2000, Microsoft MSDE 2000.

2.2.2 Hardware environments

PIII or above processors, suggestion 256 MB memory (at least 128 MB), suggestion 1 GB hard disk space (at least 500 MB), true color 800×600 or above display, CD – ROM drive, laser printer and so on.

2.3 System design principles

(1) The system is based on C/S frames.
(2) The system development is based on groupware.
(3) The system is base on the ideas of modularization.
(4) The idea of constituting arbitrarily is used.
(5) The system has high extensibility.

2.4 System function design

The system has the comparatively perfect functions, which mainly includes the following several aspects (Fig. 1):

(1) The system supports large databases such as Oracle, MSS – SqlServer, Sybase etc.

(2) The system supports the single or local area network consumers.

(3) The system allows defining the affiliations of different administrations.

(4) The system has flexible privilege definition functions.

(5) The system has preset the fixed quota standards of correlation projects in order to calculate accurately.

(6) Each kind of hydraulic works data has supposed rights and can be conveniently increased, deleted, and revised by people who has the corresponding rights.

(7) During the calculation, the corresponding fixed quota standards will be called, and the repairing and maintenance funds can be calculated quickly. The computation function transfer, the hydraulic works data may fast budget the correlation funds;

(8) The system has plenty of contents and can be inquired by combination conditions.

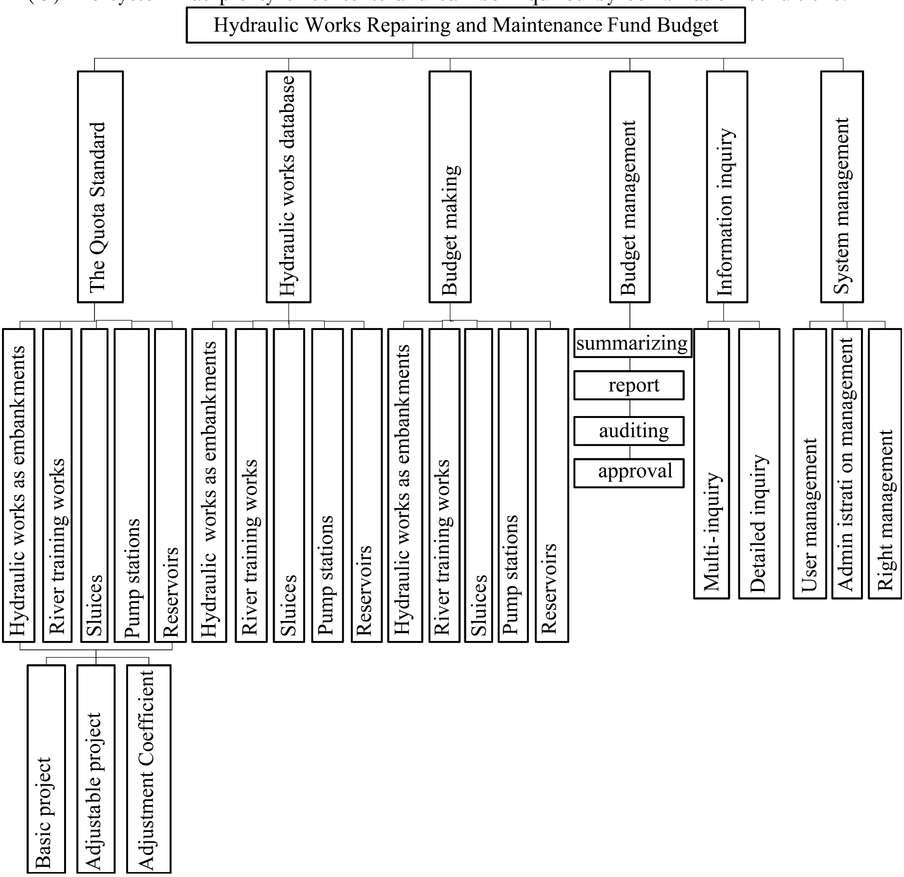

Fig. 1 Hydraulic Works Repairing and Maintenance Fund Budget

3 Main functions of the system

3.1 Inquiry and modification of the Quota Standard

The basic function of the system is to inquiry the details of Quota Standard. Because the Quota Standard is still in the trying out period and may be revised later, the system sets the Quota Standard revise function and right, which belongs to the Ministry of Finance, in order to suit to the future modifying. It also provides a convenient way for the system upgrade.

3.2 Hydraulic works database

The calculation of repairing and maintenance fund depends on the Quota Standard and engineering databases, so establishing the databases is the fundamental works. The database includes five kinds of hydraulic works as embankments, river training works, reservoirs, sluice and pump stations. Except the items in the Quota Standard, each project datasheet also includes the items of budget year and name of the administration and sets up the relative functions such as increment, modification and deletion, etc at the same time. When engineering data are written down, a database will be set up. The engineering database also has a modifying right to be entrusted to the special department who can revise and update. The database can be browsed and queried by its own administration.

3.3 Budget making

Budget making is a main part of the system. When an administration is selected, the system will automatically provide all the engineering information which belongs to that administration, the user can select one kind of engineering to calculate and also can inquiry the calculated result if necessary.

3.4 Budget management

This function comprises report, auditing, summarizing and approval etc. By establishing the budget management function, the system realizes the electronical, automated management, resulting in improvement of the work efficiency.

3.5 Information inquiry

The Information inquiry function divides into the multi – inquiry, the budget detailed inquiry and the project data inquiry. The multi – inquiry is special for modules, the user can flexibly select the combination of the kinds of wanted data according to the project data field information. Budget detailed inquiry mainly aims at the different kinds of budget fund value. Project data inquiry is aimed to the project data information.

3.6 System management

The system management is divided into the user management, the administration management and the right management. The user management mainly aims to maintain the user information. The administration management mainly aims to maintain fundamental information of its own. The right management mainly aims to allocate the management rights to different administration in order to ensure the data to be used accurately and safely.

4 Conclusions

(1) The System can help financial budget people get rid of complicated handing calculation. By the assistant of computer, the management and calculation of hydraulic works repairing and maintenance fund becomes more easy, quick and accurate.

(2) By establishing and integrating hydraulic engineering database, hydraulic engineering quota standard database and hydraulic engineering funds budget database, the System can realize the share of fundamental database and unification of the calculation standard and formulas, which is the basic work of the later budget management.

(3) The System has flexible definition of right, it allocates different rights to different budget making to make their responsibilities clear.

(4) The System has made beneficial exploration for realizing standardization and electronic management of budget business.

The Study and Applications of One – dimensional Unsteady Water Quality Model for the Lower Yellow River

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Abstract: An one – dimensional hydrodynamic numerical model was established for the lower reaches of the Yellow River and coupled one – dimensional water quality model, then the finite volume method was used for the basic equation discretization. The discrete equation was solved by using the forecast – revision of second order in time. This method features good conservation, simple operation, universal application and better practicability in forecasting normal flood and the flood wave evolution of dam – break. At the same time, the sudden pollution accident can be initially simulated in the lower reaches of the Yellow River.

Key words: lower Yellow River, TVD, sudden pollution accident

With the development of society and economy, more and more waste water and pollutant are being discharged into the water system of the Yellow River with each passing day. After the pollutant that is carried by the waste water enters the main river, the pollution level, pollution characteristics, pollution law of water body, pollutant transfer and ascription have a close relation with flow quantity, suspended sediment concentration, flow velocity, the space – time distribution of runoff and hydro – chemical properties of water. Because the water environment chemistry and water environment dynamics are exceptional complex, solving many problems in short duration is impossible, and that the existed findings of water quality model mainly establish the empirical model in steady state, tank model and one – dimension steady flow model. These models can mainly solve some water pollution problems in routine state and don't satisfy the actual demands. Due to the sudden pollution accidents being continually taken place recently, it is essential to simulate and forecast the water environment action of soluble and insoluble poisonous and harmful substance that is instantaneously discharged by the sudden pollution accident, and rapidly forecast the time that the pollutant reaches the lower sensitive target, pollution mass movement process and pollutant concentration distribution, and then it is necessary to establish water quality model based on one – dimension unsteady hydrodynamics so as to meet water quality forecast of the sudden pollution accident. This paper establishes one – dimensional unsteady water quality model for the lower of the Yellow River on the basis of the former findings, and constructs a high – resolution TVD scheme to solve non – homogeneous conservation equation with contaminated source. This model was tested by the flood routing of Baihe – Jiahetan river section during water and sediment regulation in 2006, and based on which, the pollutant transport process of the sudden pollution accident in Baihe – Lijin of the Yellow River is simulated.

1 Control equation and its numerical solving

1.1 Hydrodynamics control equation

The flow in natural channel is disposed according to one – dimensional flow, and the Saint – Venant equation is as follows:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{A} + P\right) = gA(S_0 + S_f) + R \qquad (1)$$

In which,

$$S_f = \frac{n^2 Q|Q|}{A^2 R^{4/3}} \tag{2}$$

$$P = g\int_0^{h(x,t)} (h(x,t) - \zeta) b(\xi, x, t) \mathrm{d}\xi$$

$$R = g\int_0^{h(x,t)} (h(x,t) - \xi) \frac{\partial b(\xi,x,t)}{\partial x} \mathrm{d}\xi \tag{3}$$

where, A is cross – sectional area, m^2; Q is profile average flow m^3/s; S_0 is river bottom gradient; S_f is friction slope; ξ is height relative to bottom, m; b is flow – section weight relative to ξ, m; R is hydraulic radius, m; P is flow – section area moment that relates to water surface elevation; R is projection of unit length river bed reacting on water body in flow direction.

Due to acute change of the lower profiles and very irregular river bottom, the magnitude order of $\frac{\partial h}{\partial x}$ and $\frac{\partial Z_b}{\partial x}$ items is far bigger than $\frac{\partial Z}{\partial z}$ and other items in generalized stream channel. In order to avoid oversized error by equation discretization, and that pressure intensity item and river bed gradient and river bed reaction are merged into water surface gradient. The simplified momentum equation is:

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) = -gA\left(\frac{\partial Z}{\partial x} + S_f\right) \tag{4}$$

1.2 Solving for hydrodynamics finite equation

Equation(1) and equation(4) are written as $\frac{\partial U}{\partial t} + \frac{\partial F}{\partial x} = Sou$, its first difference TVD conservative explicit scheme can be expressed as follows:

$$U_i^{n+1} = U_i^n - \frac{2\Delta t}{\Delta x_{i+1/2} + \Delta x_{i-1/2}}(f_{i+1/2}^n - f_{i-1/2}^n) + Sou_i \Delta t \tag{5}$$

in which, n and $n+1$ is time step; i is profile number; $\Delta x_{i+1/2} = x_{i+1} - x_i$, $\Delta x_{i-1/2} = x_i - x_{x-1}$ is space – time ratio; U is conservative variable; F is physical flux; Sou is source item; $f_{i+1/2}^n$, $f_{i-1/2}^n$ is numerical flux that can be written in the following:

$$f_{i+1/2}^n = \frac{1}{2}\left[F_i + F_{i+1} - P(a_{i+1/2})\Delta_{i+1/2}U\right]$$
$$f_{i-1/2}^n = \frac{1}{2}\left[F_i + F_{i+1} - P(a_{i+1/2})\Delta_{i+1/2}U\right] \tag{6}$$

in which, $F_i = F(U_i)$, $\Delta_{i+1/2}U = U_{i+1} - U_i$, $\Delta_{i-1/2}U = U_i - U_{i-1}$; $P(\cdot)$ is numerical viscosity function, its value is:

$$P(z) = \begin{cases} |z| & |z| \geqslant \varepsilon \\ (z^2 + \varepsilon^2)/2\varepsilon & |z| < \varepsilon \end{cases} \tag{7}$$

z can be $a_{i+1/2}$ or $a_{i-1/2}$, the corresponding calculation method is:

$$a_{i+1/2} = \begin{cases} \frac{F_{i+1} - F_i}{U_{i+1} - U_i} & \Delta_{i+1/2}U \neq 0 \\ \left(\frac{\partial F}{\partial U}\right)_i & \Delta_{i+1/2}U = 0 \end{cases}$$

$$a_{i-1/2} = \begin{cases} \frac{F_i - F_{i-1}}{U_i - U_{i-1}} & \Delta_{i-1/2}U \neq 0 \\ \left(\frac{\partial F}{\partial U}\right)_i & \Delta_{i-1/2}U = 0 \end{cases} \tag{8}$$

The simplest method that extends TVD scheme with second – order precision to solve source item is to firstly consider source item and solve in terms of two steps, which includes forecast and revision. The last step is to revise the forecast result. This method is called MacCormack equation of TVD. The following is typical steps:

$$u_i^{(1)} = u_i^{(n)} - \lambda \delta_x^- f_i^n + \Delta t S_i^n \tag{9}$$

$$u_i^{(2)} = \frac{1}{2}\left(u_i^{(1)} + u_i^{(n)} - \lambda \delta_x^+ f_i^{(1)} + \Delta t S_i^{(1)} \right) \tag{10}$$

$$u_i^{n+1} = u_i^{(2)} + (\phi_{i+\frac{1}{2}}^{(2)} - \phi_{i-\frac{1}{2}}^{(2)}) \tag{11}$$

$$\phi_{i+\frac{1}{2}} = \frac{1}{2}(\Psi(\gamma_{i+\frac{1}{2}}) - \gamma_{i+\frac{1}{2}}^2) \times (\Delta_{i+\frac{1}{2}} - \hat{Q}_{i+\frac{1}{2}}) \tag{12}$$

in which,

$$\gamma = \lambda a,\ \lambda = \frac{\Delta t}{\Delta x},\ \Delta_{i+\frac{1}{2}} = u_{i+1} - u_i \tag{13}$$

$$\hat{Q}_{i+\frac{1}{2}} = \min\ \mathrm{mod}(\Delta_{i+\frac{1}{2}}, \Delta_{i-\frac{1}{2}}) + \min\ \mathrm{mod}(\Delta_{i+\frac{1}{2}}, \Delta_{i+\frac{3}{2}}) + \Delta_{i+\frac{1}{2}} \tag{14}$$

$$\hat{Q}_{i+\frac{1}{2}} = \min\ \mathrm{mod}(\Delta_{i-\frac{1}{2}}, \Delta_{i+\frac{1}{2}}, \Delta_{i+\frac{3}{2}}) \tag{15}$$

$$\hat{Q}_{i+\frac{1}{2}} = \min\ \mathrm{mod}(2\Delta_{i-\frac{1}{2}}, 2\Delta_{i+\frac{1}{2}}, 2\Delta_{i+\frac{3}{2}}, \frac{1}{2}(\Delta_{i-\frac{1}{2}}, \Delta_{i+\frac{1}{2}})) \tag{16}$$

If $Sou = 0$, the equation coefficient is constant and $\phi_{i+\frac{1}{2}}$ is taken on $u^{(n)}$ point instead of $u^{(1)}$ point, and this method is TVD in feature. It is difficult to prove the finding to nonlinear state, but numerical solution really has similar characteristics with TVD.

1.3 Boundary condition disposal of hydrodynamics control equation

One – dimensional unsteady equation set is often expressed as equivalent characteristic form and characteristic scheme is adopted to dispose inlet and outlet boundaries (Fig. 1, Fig. 2).

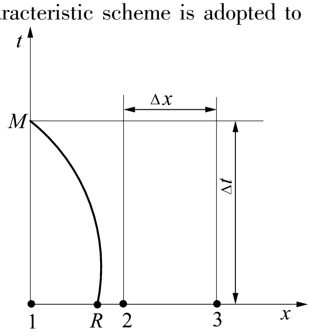

Fig. 1 Computation of inlet boundary condition

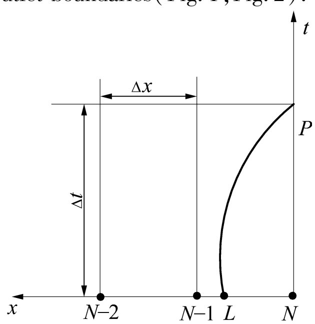

Fig. 2 Computation of outlet boundary condition

$$\begin{cases} \mathrm{d}(u \pm E) = g(S_0 - S_f) \\ \dfrac{\mathrm{d}x}{\mathrm{d}t} = u \pm C \end{cases} \tag{17}$$

in which, $u \pm E = R$ is Riemann constant; E is Escoffier water level variable, $E = \int_0^h \sqrt{g\frac{B(\eta)}{A(\eta)}}\mathrm{d}\eta$, $B(\eta)$ 、$A(\eta)$ respectively is corresponding profile width and flow area of η point. Introduce the water depth formula of $h_E = E^2/4g$, then $R = u \pm 2\sqrt{gh_E}$.

Characteristic line equation is:

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \lambda_{\pm} = u \pm C = u - c \tag{18}$$

In one – dimension open channel the computation method of C is $C = \sqrt{g\frac{A}{B}}$; A is profile area; B is water surface width. The computation formula in unit time is:

$$\omega = \frac{L_R}{L_2} = \frac{\frac{\mathrm{d}x}{\mathrm{d}t} \cdot \Delta t}{\Delta\lambda} = |\lambda_{\pm}| \Delta t/\Delta x \tag{19}$$

$$x_R = x_1 + \omega\Delta x \tag{20}$$

The corresponding hydraulic parameter at R point is:

$$Z_R^n = Z_R^n + \omega(Z_2^n - Z_1^n) \tag{21}$$

$$Q_R^n = Q_R^n + \omega(Q_2^n - Q_1^n)$$

(1) Discharge process of M point in inlet is known, based on this the area of M point can be computeed, then reversely calculate the water level of M point.

$$A_M = \frac{Q_M - Q_R - \Delta t\left[gA(S_0 - S_f)\right]_R}{(u+c)_R} \tag{22}$$

(2)The water level of L can be computed according to the given water level – discharge process of L point in outlet, then computes water level of L point and makes flow iteration.

1.4 Control equation of water quality

If vertical direction and horizontal direction of water body are uniform, one – dimension water quality equation can be:

$$\frac{\partial AC}{\partial At} = -\frac{\partial QC}{\partial x} + \frac{\partial}{\partial x}\left(AE_x \frac{\partial C}{\partial x}\right) + A(S_L + S_B) + AS_K - kC \tag{23}$$

in which, C is water quality concentration, mg/L; E_x is longitudinal dispersion coefficient; S_L directness and scattering load rate; S_B is boundary load rate; S_K is total dynamic response rate; k is degradation coefficient.

The Nitrochlorobenzene is one of major pollutants in the middle and lower Yellow River according to the observation in this river section. This paper takes Nitrochlorobenzene as pollution factor of the sudden pollution accident in the lower of the Yellow River. Because pollution factor characteristics and the time and site of sudden pollution accident emission are uncertain and its instantaneous discharge concentration is bigger, this paper ignores horizontal mix process and the process of sediment adsorbing and releasing pollutant. The equation can be simplified as:

$$\frac{\partial AC}{\partial At} = -\frac{\partial QC}{\partial x} + \frac{\partial}{\partial x}\left(AE_x \frac{\partial C}{\partial x}\right) - kC \tag{24}$$

1.5 Solution for water quality equation and boundary condition

The equation of explicit solution is:

$$(AC)_i^{(n+1)} = (AC)_i^{(n)} - \frac{2\Delta t}{\Delta x_{i+1/2} + \Delta x_{i-1/2}}\left(f_{i+1/2}^{(n)} - f_{i-1/2}^{(n)}\right)_C + \left[AE_x\left(\frac{\partial^2 C}{\partial x^2}\right)_i - k_1 C_i\right]\Delta t \tag{25}$$

The solution method of $f_{i+1/2}^{(n)}$ refers to equation(6):

$$\frac{\partial^2 C}{\partial x^2} = \frac{C_{i+1} - 2C_i + C_{i-1}}{\Delta x^2} \tag{26}$$

E_x and flow velocity and water surface width has the direct ratio, at the same time E_x and water depth has the inverse ratio. Empirical equation is in the following:

$$E_x = \alpha C_0 \theta^2 q \tag{27}$$

in which, $C_0 = c/\sqrt{g}$ is dimensionless Chezy coefficient; c is Chezy coefficient, $\theta = B/h$ is the ratio of width and depth, q is unit discharge, $\alpha = 0.011$ is empirical const.

The outlet boundary condition is:

$$\mathrm{d}C/\mathrm{d}n = 0 \tag{28}$$

1.6 The test example of water quality model

The hydroxybenzene concentration is c_0 = 20 mg/L at the outset profile, the average flow velocity of water is u = 40 km/d, dispersion coefficient is E_x = 1 km^2/d and the attenuation velocity of hydroxybenzene is k = 2/d.

Table 1 shows analytic solution and numerical solution of hydroxybenzene variations along the river reach, and the both basically tallies with each other. Because the biggest error is 0.994%, this water quality model can be used to simulate water environment behavior of channel pollution.

Table 1 Analytic solution and numerical solution comparison of pollutant streamwise variations

Distance(km)	10	20	30	40	50
Analytic solution(mg/L)	12.138,3	7.366,9	4.471,1	2.713,6	1.646,9
Numericalsolution(mg/L)	12.140,7	7.369,6	4.472,8	2.711,7	1.630,5
Error analysis(%)	0.194	0.037	0.039	0.069	0.994

2 The flood flow simulation between Baihe to Jiahetan in the lower of the Yellow River

The flood routing for the section of Baihe and Jiahetan during water and sediment regulation in 2006 is simulated by the one – dimension unsteady numerical model. Fig. 3 is the observed discharge hydrograph of Baihe profile, this hydrograph is the simulated result of the lower flood routing from the Baihe profile during water and sediment regulatios.

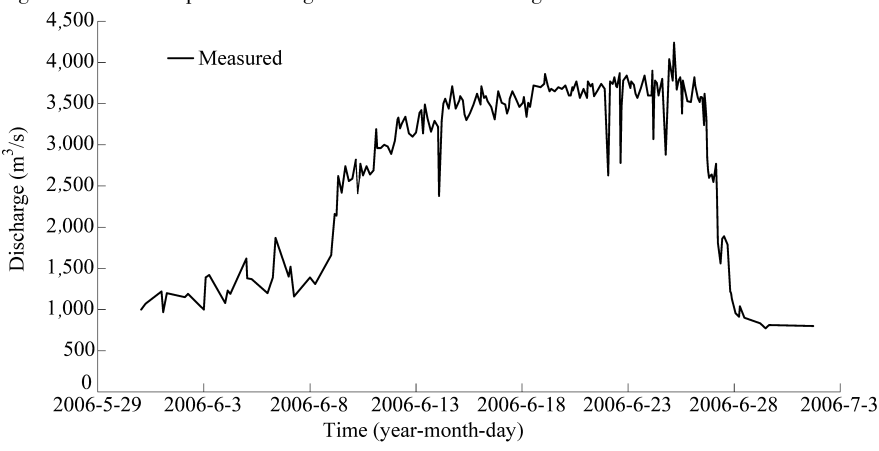

Fig. 3 Discharge hydrograph of Baihe profile

Discharge and water level hydrograph of Huayuankou profile are shown in Fig. 4 and Fig. 5; discharge and stage hydrograph of Jiahetan profile in Fig. 6 and Fig. 7. The test and analysis for discharge and water level show the stage hydrograph and channel travel time are more reasonable.

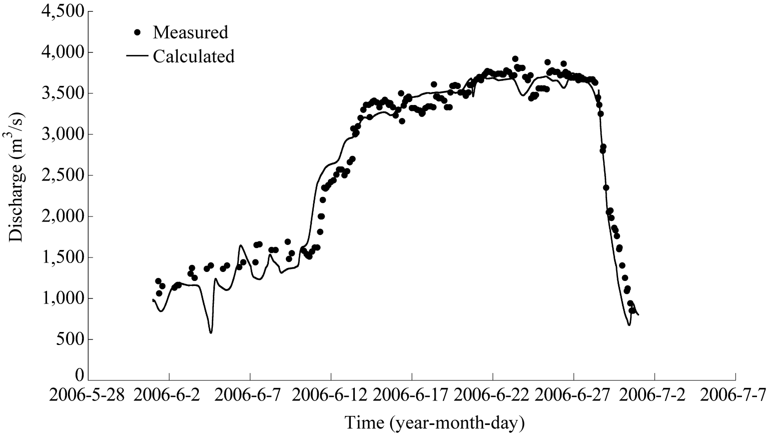

Fig. 4 Streamflow hydrograph of Huayuankou profile

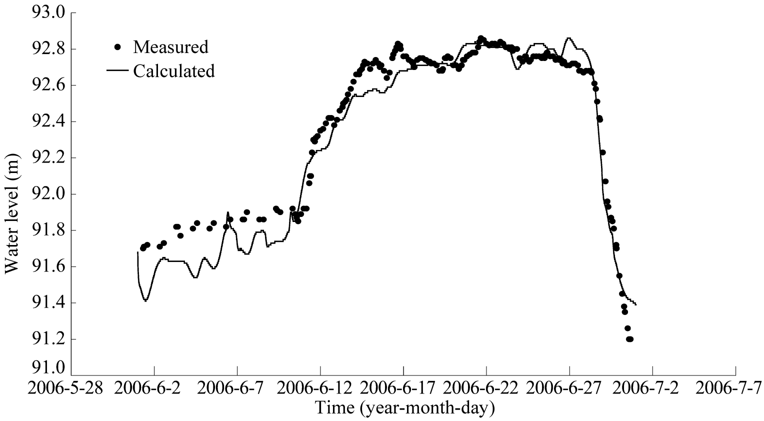

Fig. 5 Water level hydrograph of Huayuankou profile

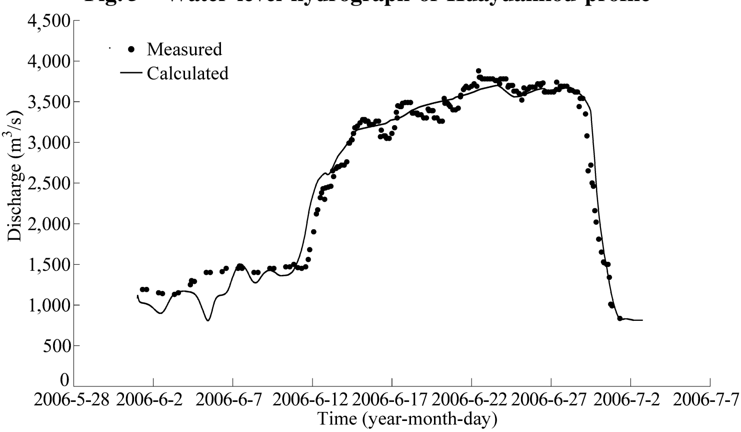

Fig. 6 Streamflow hydrograph of Jiahetan profile

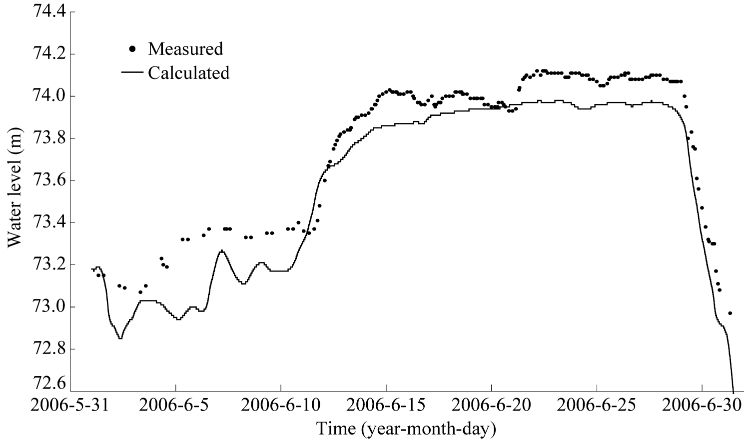

Fig. 7 Water level hydrograph of Jiahetan profile

3 Initial simulation of the sudden pollution accident between Baihe and Lijin

The sudden pollution accident has some significant characteristics such as suddenness, randomness and instantaneous remarkable velocity variation of water quality. Under the condition of no bankfull discharge, initial simulation was made for the sudden pollution accident in the lower Yellow River. The sudden pollution accident arises on the profile of the Yi – luo river – mouth to discharge high concentration solubility pollutant containing Nitryl chlorobenzene, with the duration of one hour and the homogeneously mixture is 260 mg/L on the discharge profile. Regardless of the river natural purification, the degradation coefficient k is equal to 0/d.

The pollutant transport process is shown in Fig. 8. The pollutant peak value arises on the Huayuankou profile after unloading 12 hours; the pollutant peak value arises on the Doumen profile after unloading hours; the pollutant peak value arises on the Shicaiyuan profile after unloading 72 hours. The distance of these three profiles from Baihe is respectively 108. 87km, 156. 57 km and 359. 48 km. The concentration variation process on the Huayuankou and Jiahetan profile is shown in Fig. 9. After loading 3 hours, 12 hours and 43 hours the pollutant concentration is 0. 062,9 mg/L, 17. 686 mg/L and 0. 144 mg/L on Huayuankou profile respectively. After loading 16 hours, 37 hours and 82 hours the pollutant concentration respectively is 0. 119 mg/L, 9. 137 mg/L and 0. 117mg/L on Jiahetan profile, and that the duration process almost finishes.

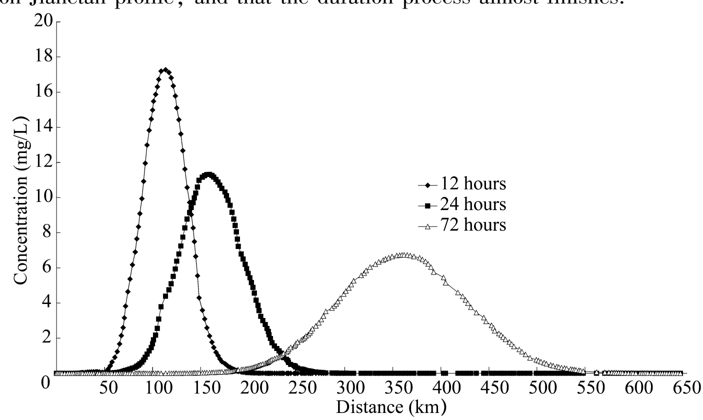

Fig. 8 Concentration variation of pollutant transport process

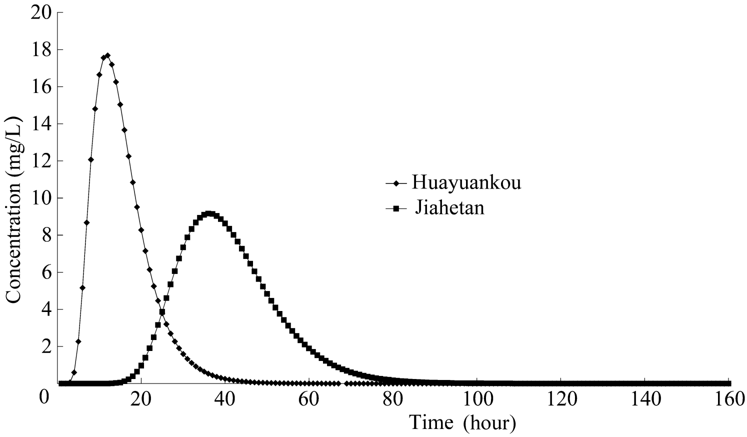

Fig. 9 Pollutant transport process in different profile

Computation and analysis can get the pollutant transfer process along the river, the time that pollutant arrives at every profile and the maximum concentration arrives at profile.

4 Conclusions and discussions

TVD scheme can automatically satisfy jumping condition in the two sides interrupted and effectively dispose the interrupted flow problems. This paper well simulates flood propagation in the lower Yellow River and gets the higher precision.

The pollution mass movement process and pollution concentration distribution of the sudden pollution accident in the lower Yellow River is qualitatively analyzed by the one – dimension water quality model. Because the observation data is less, and especially, the synchronous observation data for the sudden pollution accident, it is more difficult to determine the parameters of water quality model and model calibration.

Moreover, the study on pollution transfer and transform laws need strengthening in the lower Yellow River. The higher sediment concentration in the Yellow River brings tremendous affect to water quality and has remarkable absorption to most pollution. Sediment effects on water quality is important content of river study and many experts and scholars have gained achievements in this field, but the findings have not satisfied with the application demands of production and formed integrated theory system. This paper simulates the sudden pollution accident without considering sediment affects on pollutant, but then the simulation method can ultimately satisfy the need that the sudden pollution accident forecasts in the lower Yellow River and establishes emergency processing mechanism.

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A Conceptual Planning of Zhengzhou Ecological Water System (ZEWS) on GIS

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Abstract: Presently the urban planning, construction, management and service are aimed at well – written plan, quality construction, efficient management and good service. Meanwhile, a sustainable development of the city is strongly insisted on. It requires not merely information support and service but also scientific decision according to information. In the conceptual planning of Zhengzhou ecological water system, according to the present situation of the water system, flood prevention and drainage, water resources planning and water source plan are accepted as the goal and breakthrough point of the planning service. GIS is intended to supply technical support for the water system planning and provides basis for decision – making.
Key words: ecological water system, urban, GIS technology

1 A survey of the Zhengzhou water system

The planning area of ZEWS covers all the urban area and some rivers such as the Jinshui River, the Jialu River, and 12 reservoirs like the Jiangang Lock, the Changzhuang Lock, and 3 lakes including the Longhu Lake, the Longzihu Lake and the Xiliuhu Lake as well as the upper reaches and lower reaches of the connected waters. The total planning area is 1,010 km^2.

2 Problems of the water system

(1) Concretization of the basin underlayer. The quickening pace of urbanization here results in the concretization of the basin underlayer, alters the process of water circulation in the urban basin area, and leads to the 'hot island effect' in the city. As a result, the transformation between surface water and ground water is blockaded, and it is more liable for floods to happen. The ecosystem is thus structurally destroyed.

(2) Deficiency in systematic capability against floods disaster. The rivers in the Zhengzhou urban area can merely boast of a small flood flowing cross – section and a severe deposition. Therefore, the flood control standard is extremely low.

(3) Severe water pollution. Except for a moderately good quality of the drinking water source, the rivers, reservoirs and underground water have been polluted separately with a varying degree. The water quality of the majority of the cross – section surpasses the V kind of water standard.

(4) A deterioration of the diversity of the survival habitat in the rivers and a loss of the aesthetic function of the rivers landscape.

The hardened river bank, the deteriorated water environment of the rivers, and the damaged water ecosystem all together have destroyed or at least lowered the quality of the survival habitat of the living forms. The biodiversity is reduced greatly. Human beings are estranged from water, and the landscape function of rivers vanishes completely.

(5) The management of the Water System waits to be modernized urgently.

3 The planning of the water system and the GIS

Presently the urban planning, construction, management and service are aimed at well - written plan, quality construction, efficient management and good service. Meanwhile, a sustainable development of the city is strongly insisted on. It requires not merely information support and service but also scientific decision according to information.

About 80 per cents of the total information resources in the society are related to spatial locations, and the majority information of water conservancy departments is closely related to spatial locations as well. The GIS and RS technologies enable people to grasp the initiative in gaining a broadened perspective or obtaining necessary spatial information about both inaccessible regions and dangerous regions.

In terms of city GIS, it should be noted that it cannot function well unless it is integrated with its ultimate aim of service. As a sort of particular information management system based on spatial data, the geographic information system relates the attribute data of water conservation topic to the view of spatial locations, carries on a generalized analysis of the spatial data and the attribute data, and provides a powerful technical method for the visual delineation of water conservation information and the highly effective processing analysis.

4 The idea and principle of the planning

The Idea of the ZEWS: Security, Health, Ecology, Harmony.

Planning Principle: In the planning what should be taken into consider - ation first and foremost is the relationship between the overall layout of urban planning and the function of the water system, and then the relationship among city landscape, environmental protection and municipal engineering. Both of them should follow the principle of totality. It is of the same necessity and significance that the ZEWS planning take into consideration the water body, the water front and the shore hydrospace, and this manifests the principle of 'ecology first'. Local history and culture should be fully respected in the planning, which aims at promoting an epochal atmosphere of the 'uprising central China' topic and discloses the regional features by means of efforts such as the molding of urban spatial landscape and an integration of the solid accumulation of the history and culture of central China.

The planning is intended to clean the water of rivers, to revitalize the rivers into a healthy life, and then to bring man and water into harmony, by means of source direction, pollution control, ecological repair, and water saving, finally supplying a powerful support for the sustainable development of the city of Zhengzhou.

5 The planning of the Zhengzhou Ecological Water System

5.1 The present situation of the water system

To the north of Zhengzhou is the Yellow River, to the south of it lies the main channel of the South - to - North Water Transfer, and the Jialu River, the Jinshui River, the Dongfeng Ditch, Xionger River and others run through the city. The GIS is used for a vividly direct - viewing delineation of the water system to ensure an overall knowledge of the formation of the Zhengzhou water system so as to provide a solid foundation for the whole planning.

The planning involves water resources disposition, water pollution preventing and controlling, ecological repair of the river course, government of the Bin River dike, circulation of the water body, construction of an aquatic ecology, and use of rain water, which the ZEWS faces. It also involves water sales commission, water affinity landscape, structure of hydraulic engineering, and the operation of the management system.

5.2 Floods prevention and dispatch control

With the assistance of the powerful function of GIS spatial analysis, a numerical model of the basin ground can be set up to simulate the possible evolution processes of floods of different ranks and to provide a visual display of the possible submergence scope of different regions through the operation of the Rainfall – Runoff Model and both the predicting and actual water rainfall information as well as the surface seepage situation, thus making a comprehensive plan of flood fighting and drainage works and supplying a predetermined plan of dispatch for the decision – making of flood prevention. Meanwhile, with a combination of the disaster situation provided by the remote sensing real – time monitor and the localization information of the GPS, the efficiency and accuracy of the flood prevention dispatch can be enhanced.

Waterlogging Damage Risk District: According to such factors as terrain, water system distribution, and municipal administration construction, the waterlogging damage risk district in Zhengzhou is divided into 3 extremely risky areas, 3 highly risky areas, 7 moderately dangerous areas, and 3 low risky areas. The flood water of the extremely risky areas enters the Dongfeng Ditch mainly through the Jinshui River and Xionger River and finally pours into the Jialu River.

5.3 Water resources disposition planning

The real – time dynamic monitor of water resources is extremely important in hydraulic informationization because only a grasp of the information of water supply and needs of instant change can ensure both dynamic appraisal and active oversight of the environment quality, the possibility of immediate response to thunderbolt of water pollution and a safe supply of water. The monitored content includes water resources information of water volume and water quality as well as water use information including water resources disposition. The "3S" technology will play an extremely important role in the real – time dynamic monitor of water resources information.

5.4 The planning of water source proposal

Under the GIS support, with the remote sensing technology carrying on estimates of the amount of resources of both surface water and ground water, and a combination of the distribution as well as the supply and demand quantity of estimated pilot water volume, the evolution process of water flow can be demonstrated in a direct – viewing way through the evolution of water flow and the dispatching system model, simulating different plans of water volume dispatch and supplying basis of macro – scientific policy – making for the cultivating use of both water conservation and water resources, and dispatches management.

5.5 Aquatic environment protection

Using GIS to carry on the management of the water quality information can help reasonably select out those stands representing the general condition of the quality of the surface (or ground) water of concrete basin (or area) in order to conduct continuously automatic real – time monitor of the water quality and quantity, water volume dispatch and water pollution control.

5.6 Ecological repair of rivers and measurements

The hardened river bed causes a dropping quality of the river water, for it reduces the purification capacity of rivers, and affects greatly the ecological and ornamental values of the river bank. The river bank can also lose the ability of flood resistance and absorption. The ecological repair first has to restore the natural ecology of rivers: rivers wind naturally, river bed pools and riffles alternate, both banks are covered with natural vegetation, the multiplicity of animals and plants comes into being again. Small strips of wetland, which appear to be natural, may also be constructed in the beach to enrich ecological and natural landscape, obtaining the benefit of sustainable development.

Table 1 A Planning List of the Ecological Repair of the Water System in Zhengzhou

Time	Rivers	Planning goals	Measurements
Recent period	Xushui River	Travel and entertainment	Dredging operation, river course of landscape, aquatic contact, corridor rest, forestation of river bank
	Suoxu River	Floods prevention, ecological corridor	Dredging operation, protection of primitive state, local repair, forestation of river bank
	Jialu River: lower reaches	Floods prevention, ecological corridor	Dredging operation, protection of primitive state, local repair, river course extension, forestation of river bank
	Chao River: lower reaches	Floods prevention	River course extension, forestation of river bank, river course of landscape, aquatic contact
Middle period	Jialu River: middle part	Ecological corridor, water source protection	Dredging operation, protection of primitive state, local repair, forestation
	Dongfeng Ditch, Xionger River, Jinshui River, Qili River, Jialu Branch River	Landscape	Direct – to – winding, landscape diversity, aquatic contact

5.7 Engineering management and public participation

The establishment of the GIS system is beneficial to the management of hydraulic engineering maintenance. The management system of hydraulic engineering closely united with the DEM is of great help to flood prevention and decision – making as well as to the benefit appraisal of flood – control works.

The public may gain a knowledge of the plan design proposal and participate in plan examination and approval through the Internet dynamic; moreover, the plan design proposal and achievement manifestation forms are more direct – viewing and vivid because of the use of virtual reality and multimedia technologies, which enables the public to better understand the planner's intention, to conduct a direct dialogue with the planner, managers and other personnel concerned, and to participate more effectively, thus promoting the democratization of the decision – making process.

6 Conclusions

Spatial data acquisition and the GIS technology will gain new and greater advances in the future. Meanwhile, along with the quickening pace of urbanization, the urban GIS technology will obtain new opportunities. Urban GIS will turn further to application from technical impetus, for this side of application will be the life of GIS. In the conceptual planning of Zhengzhou ecological water system, according to the present situation of the water system, flood prevention and drainage, water resources planning and water source plan are accepted as the goal and breakthrough point of the planning service. GIS is intended to supply technical support for the water system planning and provides basis for decision – making.

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Coupled SOBEK and Visual MODFLOW Model for Yellow River Delta Water Resources Interaction Analysis

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Abstract: When using groundwater model to simulate surface water – groundwater interaction, the common method is to input the interpolated surface water levels provided by the local Hydrologic stations. This method fails to work when river bed undulates too large or the location or number of hydrologic stations can't meet the simulating demand. In this paper, SOBEK's one dimensional river level simulation results and estimated two dimensional wetland water level are used as the boundary conditions for Visual MODFLOW. The resulting model is used to simulate the groundwater changes under the influence of surface water in Yellow River Delta (YRD). It is indicated that the coupled model can enhance the reliability and accuracy of the simulated results.

Key words: SOBEK, Visual MODFLOW, Yellow River Delta, Coupled Model

1 Introduction

Surface water leakage is an important component of the general hydrological cycle especially when estimating the ecological water demand. The ecological effects of flooding River courses and wetlands are more significant than that of surface water extents. Moreover the leaking fresh river waters and wetlands water into aquifer travels long distances, dissolving precipitated soil salts, and by action of soil aquifer treatment (SAT) improves the groundwater quality, ultimately providing fresh water to the vegetation.

Groundwater level in YRD is shallow with the depth ranging from 0 to 4 m. The interaction between surface water and groundwater is evident, more so the ecological effect induced by surface water leakage is significant. For example, near the Yellow River course, a large area of silver chain forests grows relying on the river lateral leakage. Because of the stable recharge from Gubei Reservoir, the distribution area of natural vegetation around the reservoir is three times larger than the area of reservoir.

When establishing a groundwater model, often the river is generalized as a constant head boundary where water levels along the river which are normally a result of interpolation of the water levels provided by local hydrologic stations are used. However the accuracy of model depends on the numbers and locations of hydrologic stations.

SOBEK software is developed by Delft Hydraulics jointly with Dutch public institutes and a number of private consultants. It is powerful 1D and 2D software for flood forecasting, drainage systems, irrigation systems, sewer overflow, groundwater level control, river morphology, salt intrusion and water quality modeling and monitoring. The software simulates (easily, accurately and fast) flow in simple or complex channel networks, consisting of thousands of reaches, cross sections and structures.

In this paper, SOBEK has been used to simulate the water level changes within Yellow River course and wetlands under the natural condition and artificial flooding situation in YRD, and the results are used as boundary conditions for the Visual MODFLOW model. It is verified that the combine model can improve the simulating results of the groundwater level distribution around the surface water and the interaction between surface water and groundwater. It is the first time that coupled surface water model (SOBEK) and groundwater model is used in YRD.

2 River Course Model

2.1 Simulation of water levels

There are four hydrologic stations along the downstream of Yellow River after Lijin, viz. Lijin, Yihaoba, Xihekou and Dingzilukou.

First the interpolated river levels from these four stations (Fig. 1) are input into groundwater model as boundary conditions. Because there is no hydrological station below Dingzilukou, the river level at Dingzilukou is used to represent the whole reach below this point, although the river bed changes a lot.

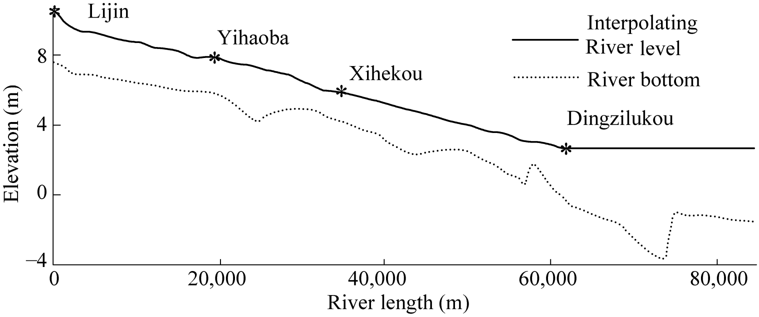

Fig. 1 (a) The interpolated water level profile and river bed level distribution of Yellow River

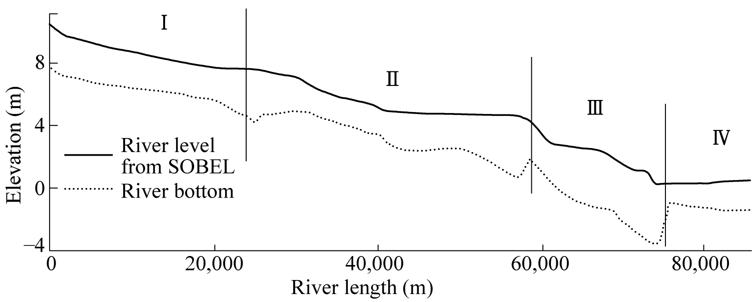

Fig. 1 (b) The SOBEK simulated water level profile and river bed level distribution of Yellow River

Then SOBEK software was used to simulate the river level. SOBEK generalizes Yellow River into a network which is connected by a series of points at 600 m interval. It calculates the water level changes at each point and the flow of each reach using staggered grid method. The profile of river level distribution determined by SOBEK is shown in Fig. 1(b). Comparing the interpolated river stage and SOBEK simulated results, SOBEK's seems to offer a better representation of the true river stage under the condition of lacking hydrological data as it embodies the influence of river bed morphology and the shape of river cross – section. At the joint of river stretch Ⅰ ~ Ⅱ and Ⅱ ~ Ⅲ, river bed levels rise at these two points, surface water level also rise at these points. The joint of river stretch Ⅲ ~ Ⅳ lies on a S – type river bend, with the width of the river course broadening sharply, the area of floodplain increasing largely, river depth and water flow become shallow and gentle respectively.

2.2 Estimation of leakage Volume

Yellow River is generalized as Deterministic Hydraulic Heads boundary in Visual MODFLOW model. The map of SOBEK's network including river stage and river bed level values of each node was exported to Visual MODFLOW. The average river width is 500 meters. The average hydraulic conductivity of sediment at the bottom of Yellow River based on falling head permeate test is 0.016,7 m/d with sediments average thickness of 0.5 m. The groundwater model was run for a total simulating period of 365 days with a time step of 5 days.

There is a strong evidence of the interaction between surface water (river) and groundwater (Fig. 2). When river level exceed groundwater level, the river water recharges (loses) to groundwater, which appears at the 180 day and 245 day. However, when river level is low, the groundwater reversely recharge to the river (gaining), which appears at 55 day and, 210 day.

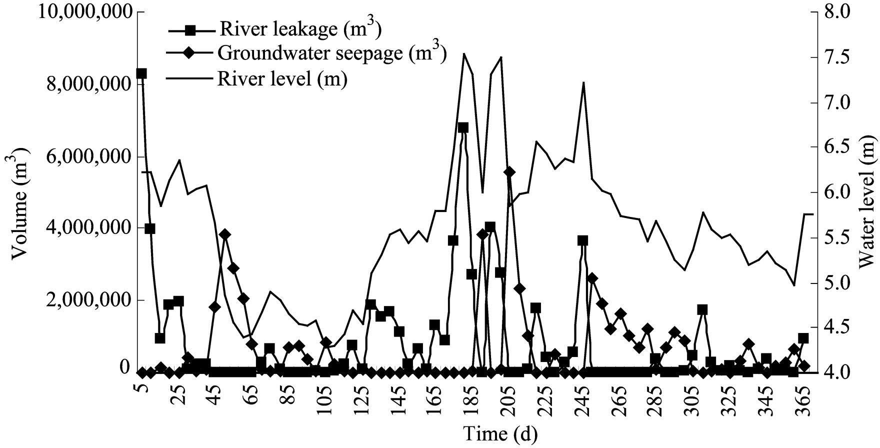

Fig. 2 River leakage and groundwater seepage variation

Spatially, the distribution of groundwater recharge and discharge is well displayed and varies at different river reaches. General, the total amount of river leakage is larger than the amount of groundwater seepage, i.e. the annual net river leakage amount (leakage amount minus groundwater seepage amount) is about $1.6 \times 107\ m^3/a$.

The Yellow River greatly influences groundwater level around the river course especially within 1,500 m where there is a general rises in groundwater level. However the rising height decreases with an increase in distance. Within the buffer zone of the first 100 m around the river, groundwater level rises ranges from 1 m to 3 m; from 100 m to 500 m, the groundwater rise range from 0.5 ~ 1 m; from 500 m to 1,500 m, the groundwater level slightly rise by about 0.1 ~ 0.5 m; and the groundwater level rise is not affected by river leakage in area at distance of more than 1,500 m from the river (Fig. 3). Compared with straight river stretch, meandering rivers can have larger percentage of surface water per unit area hence can more river leakage with a possibility of river leakage water reaching further distance.

3 Wetland Model

3.1 Background on wetlands artificial flooding

Fresh water wetlands in YRD provide the important foraging and breeding site for some rare birds which are endangered in the world. Wetlands lie in the transitional zone between Yellow River and the Bohai Sea. Most of the wetlands are recharged by rainfall and Yellow River. Adequate fresh water is the premise for the quality of wetland ecosystem, the health of plants and animals.

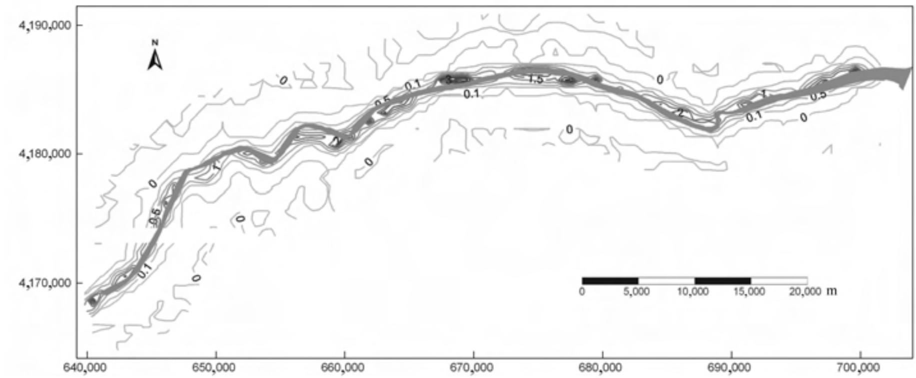

Fig. 3 Groundwater level elevating contour under the influence of Yellow River

In recent years, the amount of fresh water flow into YRD has decreased sharply due to the drought, agriculture and industry water use and especially irrigation. Soil erosion and the seawater intrusion have accelerated the decrease of the area and quality of wetland, and the shrinkage of bio – species and bio – quantity. The intrusion of seawater into the aquifer, have also salinized groundwater, and accelerated soil salinity, which has degraded large area of natural vegetation. To restore and protect wetland ecosystem, improve the wetland quantity, promote the better cycle and eco – function of wetland, a wetland artificial flooding plan has been proposed. The plan entails a project which will be implemented by constructing a dyke, irrigating and restoring water from the Yellow River.

3.2 Distribution and subdivision of artificial flooding zone

When nature reserve was found by the State in 1992, the total area of wetland exceeded 320 km^2. Taking the standard of this year as the wetlands recovering goal, the surface water area will not exceed 320 km^2 after artificial flooding. The preferred protected vegetation type is reeds marsh, which is the typical site for a number of wild animals. Typically the surface water depth for reeds should not exceed 0.3 m, with a maximum water depth of less than 1.5 m. Hence the designed water depth for artificial flooding should be less than 1.5 m in order to protect as large area of reeds marsh as possible.

The location and extent of wetland recovering zones are designed based on fresh water availability and terrain conditions. For the 57 km^2 wetlands in the north nature reserve, the Gubei reservoir can provide fresh water for its recovery. On the other hand, the 263 km^2 wetlands in south nature reserve which lie near both sides of Yellow River can draw its water from the river. Based on the undulating terrain and water storage ability, the whole area is divided into 24 subdivisions (Fig.4). Some civil structures will be set to separate the subdivisions to facilitate controlled zonal water levels.

The 2 – D SOBEK software overland flow module was used to estimate the water depth, inundation area and duration for every subdivided area. The average water depth for each subdivided area as an output of the SOBEK is shown in Table 1.

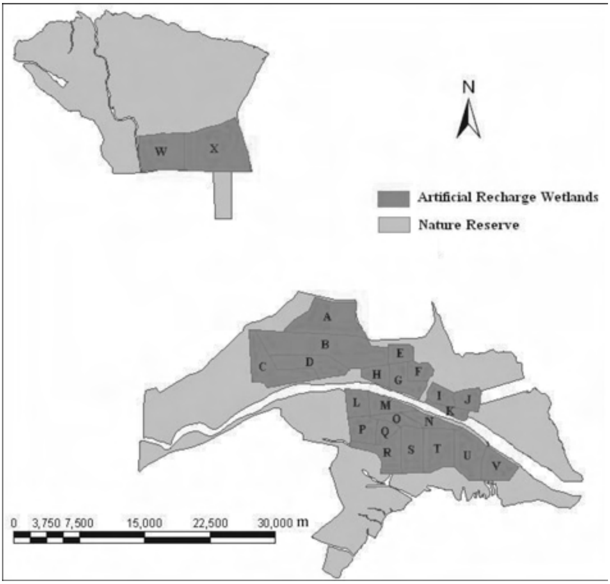

Fig. 4 Extent and subdivision of artificial wetland flooding areas

Table 1 Estimated monthly average water depth for each zone **Unit: m**

Subdivided area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A	0.19	0.36	0.39	0.63	0.68	0.68	0.64	0.37	0.36	0.28	0.27	0.18
B	0.22	0.55	0.51	0.68	0.71	0.66	0.64	0.41	0.29	0.21	0.20	0.13
C	0.13	0.28	0.35	0.61	0.60	0.59	0.55	0.28	0.29	0.18	0.20	0.10
D	0.20	0.37	0.36	0.63	0.65	0.65	0.61	0.33	0.33	0.24	0.23	0.16
E	0.18	0.92	0.88	1.01	1.06	0.90	0.85	0.86	0.61	0.02	0.02	0.02
G	0.13	0.32	0.40	0.51	0.65	0.51	0.39	0.38	0.31	0.22	0.20	0.16
H	0.09	0.25	0.28	0.45	0.50	0.45	0.40	0.19	0.10	0.09	0.09	0.09
I	0.13	0.10	0.38	0.82	0.88	0.71	0.83	0.90	0.80	0.54	0.50	0.26
J	0.13	0.08	0.37	0.82	0.88	0.71	0.83	0.90	0.80	0.53	0.50	0.26
K	0.03	0.06	1.36	1.07	0.89	0.53	1.81	0.90	0.54	0.28	0.21	0.09
L	0.23	0.35	2.20	2.07	1.87	1.32	2.84	1.97	1.43	1.00	0.85	0.54
M	0.27	0.38	2.36	2.23	2.03	1.45	3.05	2.13	1.57	1.11	0.94	0.60
N	0.13	0.30	0.31	0.57	0.60	0.60	0.55	0.25	0.27	0.19	0.18	0.07
O	0.13	0.30	0.32	0.57	0.60	0.60	0.55	0.25	0.27	0.19	0.18	0.07
P	0.13	0.30	0.34	0.60	0.60	0.60	0.55	0.25	0.28	0.19	0.18	0.07
Q	0.13	0.30	0.31	0.57	0.60	0.60	0.55	0.25	0.27	0.19	0.18	0.07
R	0.13	0.10	0.38	0.82	0.88	0.71	0.83	0.90	0.80	0.54	0.50	0.26
S	0.11	0.28	0.32	0.54	0.62	0.62	0.58	0.27	0.24	0.20	0.20	0.10
T	0.11	0.26	0.31	0.52	0.61	0.61	0.56	0.26	0.23	0.18	0.17	0.09
U	0.11	0.26	0.31	0.52	0.61	0.61	0.56	0.26	0.23	0.18	0.17	0.09
V	0.06	0.21	0.26	0.46	0.56	0.56	0.51	0.21	0.18	0.13	0.12	0.04
W	0.22	0.48	0.51	0.74	0.81	0.81	0.76	0.43	0.38	0.10	0.10	0.11
X	0.11	0.29	0.32	0.50	0.59	0.58	0.55	0.30	0.25	0.16	0.16	0.08

3.3 Wetland leakage amount and groundwater response

Taking the SOBEK estimated water level fluctuation of each zone under the condition of wetland artificial flooding to be relatively accurate; the water levels were used as the boundary condition to simulate wetland in Visual MODFLOW by use of RIVER module. The wetland bottom level of each zone was determined from digital elevation model (DEM) average values; the sediment hydraulic conductivity was set to be 0.016,7 m/d, with the thickness of 0.5 m. Simulation was carried with a period of 365 days, and time step of 5 days.

The coupled model shows annual fresh water recharging from wetlands to aquifer of 9×10^7 m^3/a, this accounts for the rise of the groundwater level rise around the wetland. Within the buffer zone i.e. the first 200 m and 200 to 1,000 m around the wetland, the groundwater level rise is more than 1 m and 0.1 ~ 1 m respectively (Fig. 5). However for distances more than 1,000 m, the groundwater level does not rise significantly. It is inferred that wetland flooding project can also recharge the groundwater within 1.0 km around the wetland. This part of fresh water can dilute the high – saline groundwater, and add the available fresh water to natural vegetation. If measures are taken to recover the natural vegetation of this area when wetland artificial recharge plan is implemented, the biodiversity of wetlands will be greatly improved.

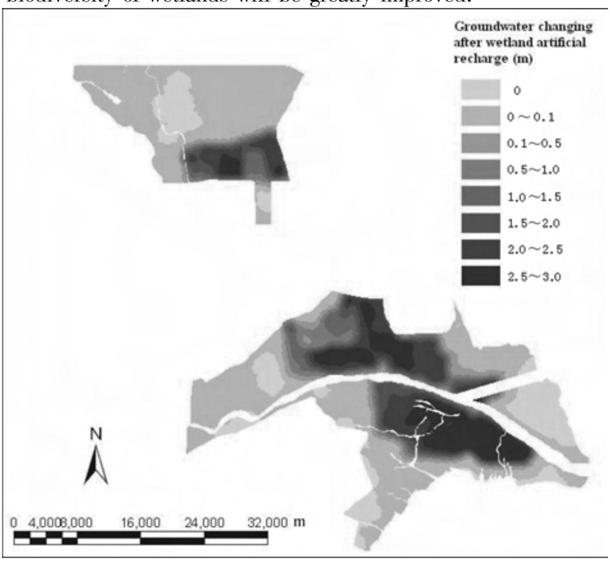

Fig. 5 Groundwater level changes after wetlands artificial flooding

4 Conclusions

In this paper, surface water model SOBEK's 1D and 2D simulating results are used as boundary condition for Visual MODFLOW model. The coupled model is used in Yellow River Delta to study the interaction between surface water and groundwater. This study indicates that there is a strong interaction between the Yellow River and groundwater both in space and time, in the form of leakage and seepage. However the River leakage amount is larger than groundwater seepage amount with the net annual leakage amount of about 16×10^6 m^3/a. Generally, the groundwater level within the 1.5 km distance from the river is influenced by the river itself.

It is estimated that there will be 9×10^7 m^3/a fresh water recharge to the groundwater after wetland artificial recharge plan is implemented. This will have a significant impact on groundwater quantity within the 1 km distance from the river with improved groundwater quality. This study reinforces the belief that wetlands artificial recharge will improve and develop the biodiversity not only within the wetland areas but also around the wetland.

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Modeling the Hydraulic Condition of the YRD Wetlands Using A 1D – 2D Integrated Hydraulic Model

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Abstract: It is a key to a 1D – 2D integrated hydraulic model of Yellow River Delta (YRD) that correctly modeling the hydraulic condition. Based on hydrology and hydraulics, and according to the wetted parts of cross sections, discharge of the river, the skeleton of model was built firstly, then we schematized the lateral flow, ground water seepage, precipitation, evaporation, etc., and ran and verified it. After modifying the value of coefficient, calibrating the water level process several times in simulation period, the result shows that the final model has a good agreement. So the overland model in YRD was built on the channel model and simulated the flow in wetlands after pumping from YR. Then the channel model and overland model make up the YRD wetlands 1D – 2D integrated hydraulic model.

Key words: Yellow River Delta (YRD), SOBEK, R2

1 Background

The Yellow River Delta (YRD), normally refering to the sector zone with Ninghai culmination, from Taoer estuary to Zhimai estuary, is the youngest land in China, with a total area of about 6,000 km^2, 350 km – long coastline.

The unique water and sediment resources are the main reasons for the high biodiversity in YRD because of the high nutriment in YR and fecundity of the new lands. Many salt plants grow in offing with the tide, but the freshwater plants subject to the river with the supplement of the freshwater. Meanwhile unique environment of the YR estuary has become the paradise for birds. According to the survey, the YRD have about 393 plants species, about 1,524 animal species (Xi Song, 2006). And in 1992, the YRD national Nature Reserve of a total area of more than 150,000 hectares was establishment in the YRD.

However, due to less rainfall in YR basin in recent years and the production and living water soaring, Water and Sand Lijin cross section of the Yellow River of continued to decline, and the YRD ecosystem quality declined with the significant reduction of a natural wetland area. Such as the YRD Nature Reserve, according to the satellite image of 1992 to 2004, natural wetland area has decreased by nearly 28% from 39% to 11% of the total area. Table 1 shows the YRD wetland area statistics in 1992 and 2004.

Table 1 YRD Nature Reserve wetland area statistics in 1992 and 2004 **Unit: hm^2**

Regions	1992		2004	
	Reed	Shrub	Reed	Shrub
Yiqianer	4,155	12,180	3,689	7,087
YR estuary	14,769	9,086	4,416.12	—
Dawenliu	13,848	5,003	2,087.22	—
Total	32,772	26,269	10,192.34	7,087

2 Introduction

From 1970 ~ 2002, with the Yellow River into the dry season, water volume declined year – on – year. After 2002, the Yellow River water was controlled by unified manner, and became stable and regularity, Fig. 1 shows the Yellow River runoff changes in nearly 35 years at Lijin hydrologic station. Fig. 2 shows the Yellow River discharge process of Lijin hydrologic station in 2004.

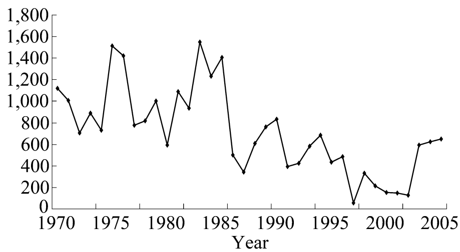

Fig. 1 Runoff change of YR in nearly 35 years

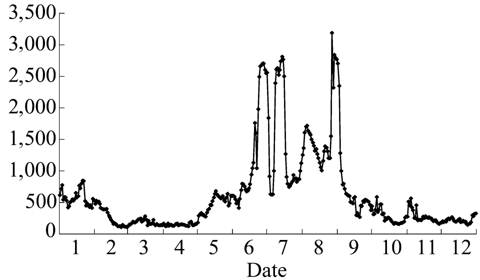

Fig. 2 Discharge process of Lijin in 2004

The flow of LiJin section in Nov. – Jun is smaller than in Jul. – Oct, generally between 50 ~ 200 m^3/s and after the water and sediment regulation, there will be one or two sharply water increasing.

Affected by YR, the YRD topography is unique, lying on the YR for a high titled to the side, physiognomy was made up of hillock, slope and billabong. The terrain of the Nature Reserve is relatively flat, but has been fragmented into many patches by the roads and dykes.

According to the Yellow River integrated planning, the current flow path, Qingshui ditch water flow path, would be remained unchanged for 50 years. With the little variation rainfall in the Yellow River Basin and the Yellow River water regulation, water and sand from the Yellow River are expected relatively stable and modest changes in the same period. And now the extension of the estuary lies in a stable condition.

According to statistics, from 1976 to 1996, the Qingshui ditch water flow path totally extended 38 km to the sea, 1.9 km/a in average; and from 1996 when the Yellow River flow changed to the new flow path, extension to sea is 3 km to 1998, then after 1998 the YR basically no longer extended. The speed of erosion of the original flow path has been gradually declining, and by 2000 the rate of erosion was about 0.2 ~ 0.3 km/a. But corresponding with this, the annual loss rate of the abandon riverway, Diaokouhe, is about 0.4 ~ 0.5 km/a. So far, the coastline has been advanced to the Yiqianer station site, and it still continues(Yan Pu, 2006) (see Table 2).

Table 2 Changes of the Coastline since the 1976 **Unit: km**

Date	Qingshui ditch	Current flow path	Abandon riverway
1976 ~ 1996	+38	—	–7
1996 ~ 2000	–2.2	+12	–2

3 The hydraulic models of YRD wetland

With the aim of restoring the YRD wetland to level of 1993 in the YRD environmental flow study, considering the Yellow River water supply during more than 30 years and the Nature Reserve status and practice, the 23,614 hm^2 land was planned the restoration of vegetation in the Nature Reserve. According to the Nature Reserve ground elevation changes in 1993, it is divided into 9 areas, and its distribution is showed in Fig. 3.

Fig. 3 The distribution of restoration zones

To evaluate different water amount effect on YRD wetland, the YRD wetland 1D – 2D integrated model was built based on the hydrological information being used to analyze the movement and residence time of the flow in wetlands. 1D network of the model includes Lijin part of the YR and the channels schematization, primarily on the basis of the Lijin discharge, the cross section's shape, elevation and locations, the constructions along the river, tide, etc. 2D part simulates the flooding process in wetlands while 1D network is correct. Both parts of model are connected to Visual MODFLOW to deduce the volume of the groundwater infiltration.

3.1 Principles of the numerical model

The water flow is computed by solving the complete De Saint Venant equations. For one dimensional flow the following equations are used.

Momentum equation 1D:

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A_f}\right)+g\cdot A_f\cdot\frac{\partial h}{\partial x}+\frac{gQ\,|\,Q\,|}{C^2RA_f}-W_f\frac{\tau_{wi}}{\rho_w}=0 \quad (1)$$

Continuity equation 1D:

$$\frac{\partial A_f}{\partial t}+\frac{\partial Q}{\partial x}=q_{lat} \quad (2)$$

For two dimensional flow, three equations are used:

Momentum equation 2D for the $x-$ and $y-$ direction:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+g\frac{\partial \zeta}{\partial x}+g\frac{u\,|\,V\,|}{C^2h}+au\,|\,u\,|=0$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+g\frac{\partial \zeta}{\partial y}+g\frac{v\,|\,V\,|}{C^2h}+av\,|\,v\,|=0$$

Continuity equation 2D:

$$\frac{\partial \zeta}{\partial t} + \frac{\partial (uh)}{\partial x} + \frac{\partial (vh)}{\partial y} = 0$$

The combination of 1D and 2D:

Fig. 4 shows the combination of 1D and 2D. Using the connected point (red point in figure), the 2D flooding module can simulate the overland of flow from 1D network.

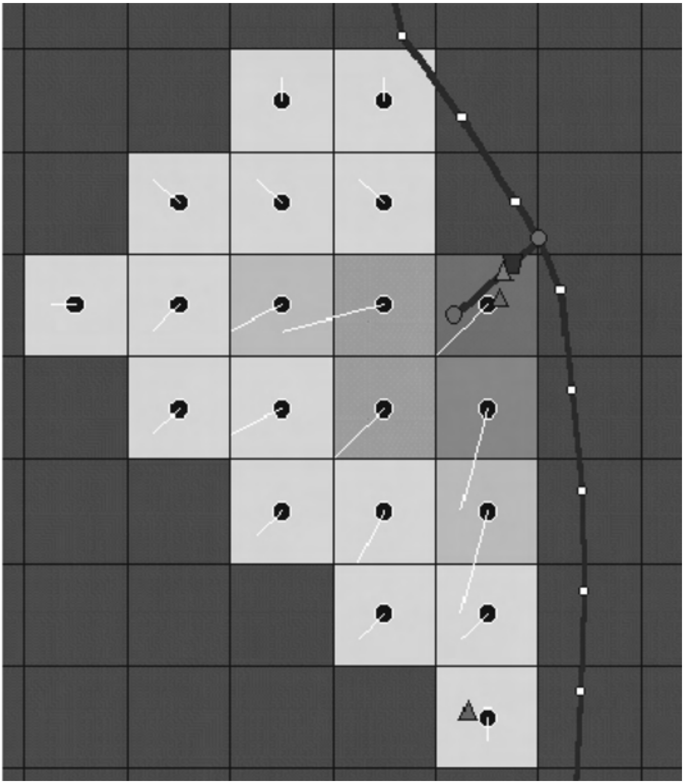

Fig. 4 The combination of 1D and 2D

The joint construction of 1D and 2D let model closer to the nature state. In order to simulate it more accurately, we added the roads, dykes, reservoirs, cofferdam and so on to the restore region according to the plan the Nature Reserve and water conservancy layout.

3.2 Modeling the hydraulic conditions

The water conservancy facilities and hydraulic parameters were built in model and 1990 is the typical year among 1970 ~ 2002 after calculating. So we let Lijin hydrologic station measured discharge process and tidal changes be the boundary, and then modified the model by Lijin, Yihaoba, Shibagongli, Xihekou water level data as verification data.

3.2.1 Manning parameters

The Manning coefficient reflects the effect of the roughness of riverbed to flow. The nature river' Manning coefficient changes between 0.2 ~ 0.01. But the Manning coefficient of downstream of YR is often smaller than 0.01, even smaller than the glass sink's. We would not discuss with the reason of it, and just use the Manning formula to calculate the value.

The Manning formula reads follow:

$$n = \frac{1}{V} R^{2/3} S^{1/2}$$

So after simulaed and verifyed by SOBEK, the Manning value of the section from Lijin to the Estuary changes between 0.01 ~ 0.008 s/$m^{1/3}$, and the best value equals to 0.008,3.

Due to the lack of observed data and test data, and changes of delta landscape, it is difficult to calculate the Manning values of wetlands, so we obtained those from "Manning coefficient table" according to the land use map and vegetation map of YRD wetlands.

3.2.2 Cross sections

The sections are the basis of the model. We selected 13 sections as the model framework, such as Lijin, Qianzuo, Yihaoba, Yuwa etc., which were locdated by the coordinates in the SOPT5 imag. The model would calculate the interpolation. It is noteworthy that the YR riverbed changes constantly. Fig. 5 shows the wetted section shape of the Yihaoba in 1983, May 1990, October 1990, and May 2001. From the figure we can see the riverbed constantly rises, and the flow swings. Affected by it, the calibrated 1D module would certainly have an error while applying to another years.

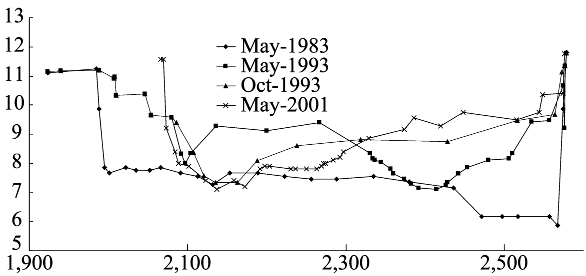

Fig. 5 The shapes of Yihaoba section in 1983, May 1990, Oct. 1990 and May 2001

3.2.3 Meteorological data

It is important for model to calculate the evaporation in wetlands because the value of evaporation in average year is about 3.5 times than precipitation. So the meteorological data in 1990 (Fig. 6) are used, then the meteorological statistics data of 20 years would be the simulation condition which includes the precipitation, evaporation, wind speed, etc.

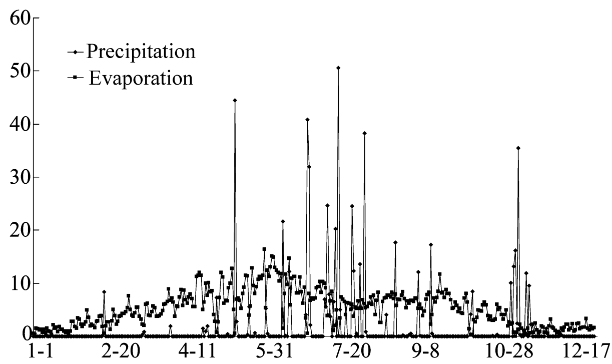

Fig. 6 Meteorological data of Dongying station in 1990

3.2.4 Seepage

Due to the leakage of surface water, Visual MODFLOW was used to simulate the infiltration.

First, we got the total water amount using formula: water amount = leakage + evaporation + water depth with average infiltration value of 20 years. Then SOBEK simulated the water level of wetlands in run time, and linked to VM which would compute the surface water leakage. Third, water amount would be checked. It did several times till the water amount became stable.

The leakage would be deduced by the calculation points with storage and lateral flow in 1D network and by the connection nodes with storage and lateral flow.

3.2.5 Lateral flow

Lijin station is the last standing measure station along YR whose discharge is regarded as the one into the sea. However, they are not same because of the leakage and branches for production and life of Dongying municipality. According to statistics, there are currently 26 outlets down the Liyin. So we replaced the lateral flow in the corresponding locations instead of the outlets with average discharge daily to balance the flow of YR. It is helpful to both predigest the model structure and decrease the run time.

3.2.6 Restore zones

The DEM of restore region is the foundation of model which is split into 9 zones according to DEM of YRD in 2005, digital vegetation map, water conservancy distribution map, traffic map of YRD ,SPOT image and YRD wetlands planning, etc. The distribution of zones shows in Fig. 3. And Table 3 listed the areas of every zone.

Table 3 The area of restoration zones **Unit: hm^2**

	Yiqianer	YR Estuary						Dawenliu	
	A	B	C	D	E	F	G	H	I
Area	3,671	2,557	2,216	1,328	1,241	1,471	1,213	2,687	7,230

3.2.7 Supply and drainage system

Water supply system consists of three methods: pumping from reservoir, from YR and flooding of YR. The main method is pumping from YR. The drainage system is designed based on the water depth every month, and also have two methods: pumping and cofferdam. The last one was taken up to maintain the water depth of zones. Fig 7 shows the schematization.

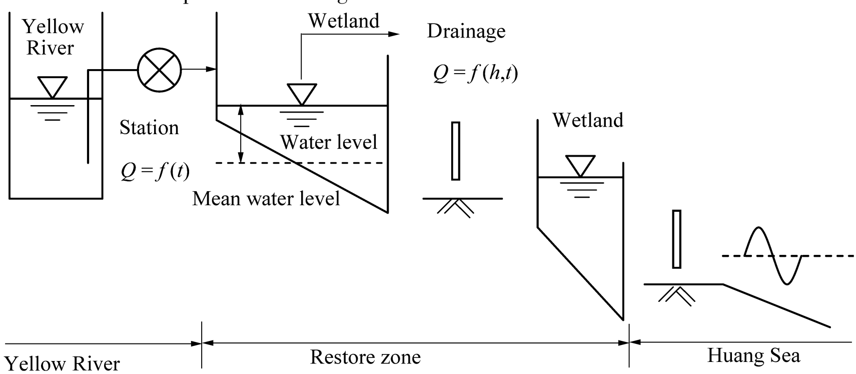

Fig. 7 The schematization of supply and drainage system

4 Set up of model

The SOBEK is linked to the Visual MODFLOW model by a feedback interchange of data. Water level and flow width of the 1D river and channel network as well as the 2D wetlands are computed in SOBEK and transferred to MODFLOW. Ther MODFLOW feedback seepage losses to SOBEK. Both models supply data to LEDESS for performing an overall analysis on landscape and ecology. Fig. 8 shows the relationship bmong SOBEK and Visual MODFLOW and LEDESS.

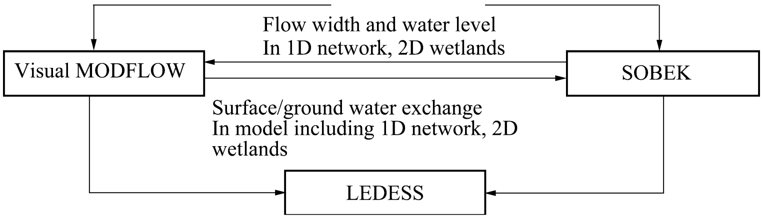

Fig. 8

The diversion channels was designed basedon current channel, whose width could be measured according to SPOT5 2.5m image. The section was assumed as typical trapezoidal cross section. The elevation was decided by the DEM. The water was supplied from the YR, and discharge was calculated by the average water depth of every zones. Fig. 9 shows the topology of the model.

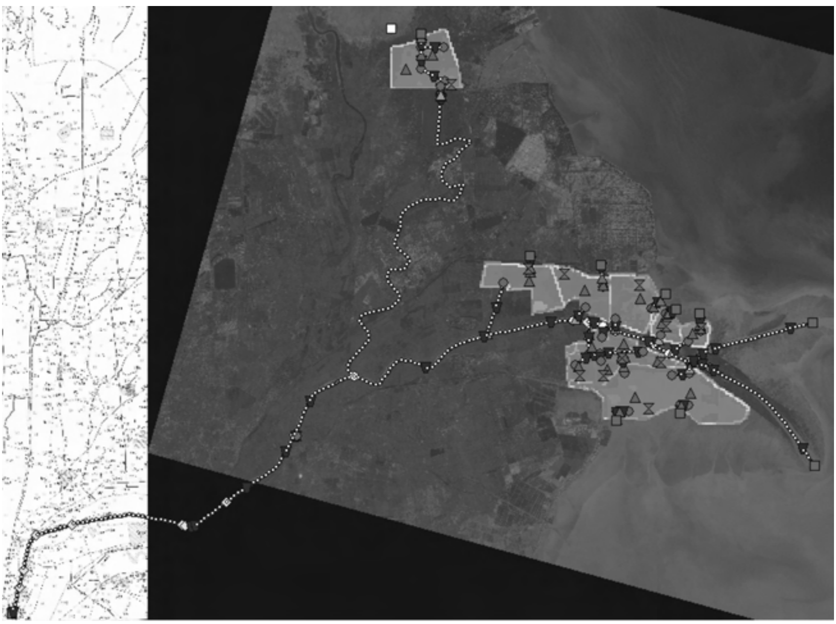

Fig. 9　The topology of the model

5　Simulation of the model

The model simulated the flooding process firstly in order to get more precision in calculation, aiming to water level. And after repeating verifying river roughness coefficient, the model would have a good agreement while $n = 0.0083\ \mathrm{s/m^{1/3}}$, and R^2 (nash Sutcliff efficiency) equal to 0.991,3. Fig. 10 shows comparison of measure and simulation data at Lijin section.

Then the model rau with flow discharge of the whole 1990 year and wetted sections of every section measured in May 1990 and calibrated. Fig. 11 shows the differences of measured and simulated water level of Lijin, Yihaoba, Xihekou and Shibagongli. The biggest difference in the figure from Jan – Feb was caused by the ice because of weather. The results includ bias, standard

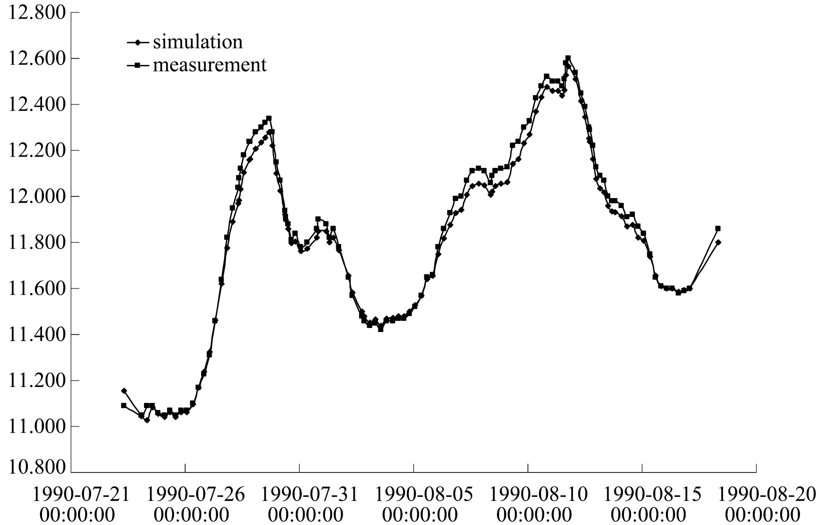

Fig. 10 Comparison of measure and simulation data at Lijin section

deviation and nash - sutcliff coefficient listed in Table 4. The indicators show a good model agreement.

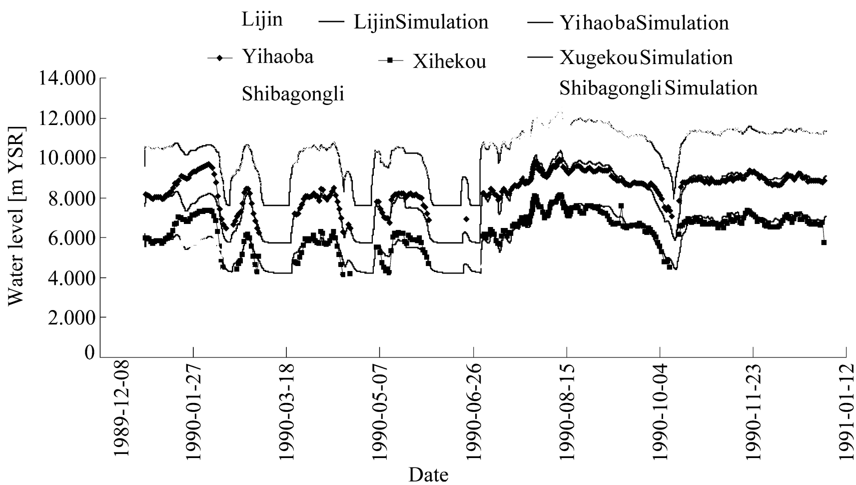

Fig. 11 The difference of measured and simulated data of Lijin, Yihaoba, Xihekou and Shibagongli

Table 4 Summary of bias, standard deviation, nash - sutcliff coefficient

	Lijin	Yihaoba	Xihekou	Shibagongli
R^2	0.84	0.61	0.76	0.65
R^2 (except 16 - 1 till 8 - 2)	0.96	0.85	0.89	0.86

However, affected by the riverbed elevation decreasing, the model would have an error in recent future years' simulation, for example in 2005 (see Fig. 12), the figure shows that the water level of actual flow decrease at the same discharge because of the regulation of the water and sediment, so the model need to be modified. But the model still could get a good agreement after cutting down the average value of the cross sections. In fact the 2D overland module wouldn't be affected by the water level because of the dyke of YR and supply method.

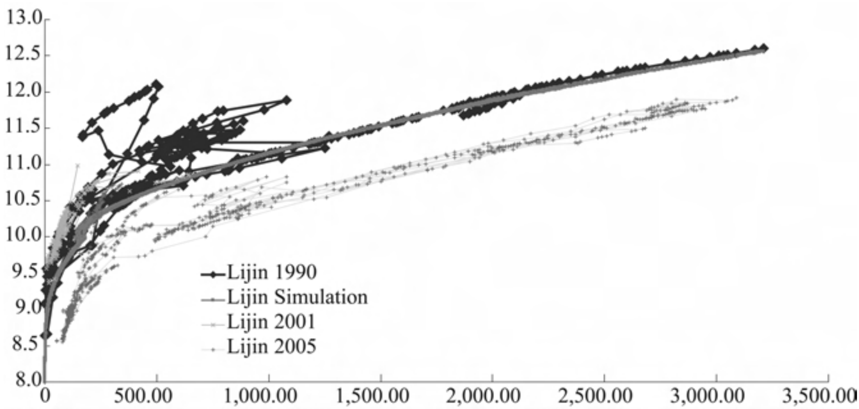

Fig. 12 Water level and discharge

So based on the 1D network, we worked out the water amount and simulated the flooding in wetlands. The Fig. 13 shows the flow distribution on two days in simulation period. It is a problem that we can't verify and calibrate the 2D model because of the lack of the obsenred data in wetlands of YRD, so we could not directly evaluate the result of 2D module. But since model has an authentic hydraulic basis and successful application in other countries, we think it could be meaningful.

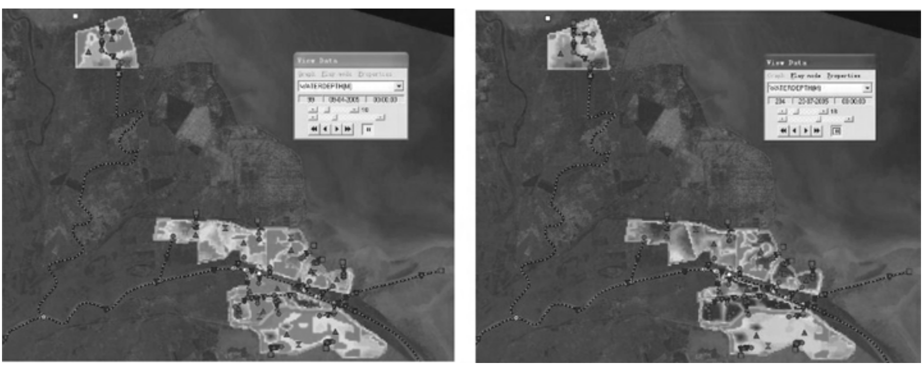

Fig. 13 Comparison of flow distribution in two different days by SOBEK

6 Results and conclusion

The model of the hydraulic condition in YRD was set up by the SOBEK and Visual MODFLOW, and is divided into two parts: 1D network and 2D overland. The 1D part includes the YR and channels; the 2D part includes the wetlands in the Nature Reserve.

We found the model would have a high precision in short simulation period, but the precision would be down with lengthening the simulation period, so we selected one year, 1990, as the simulation period.

The precision of the 2D module could not be authoritativeh verified due to the limit of the observed data.

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The Construction and Application of Sluice Remote Supervision Control System of Shandong Yellow River

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Abstract: The tasks of water resources consolidated regulation and assurance of the Yellow River not to be blocked are rather arduous for Yellow River Shangdong Bureau, the administrator department of Yellow River Shandong section. This paper introduces the necessity to construct sluice remote supervision control system in Yellow River Shangdong section and summarizes the significance of system construction and the role in integrated water regulation.

Key words: sluices, remote supervision control, water regulation

1 General overview

1.1 Water resources survey of Yellow River Shandong section

Shandong Province is one of the most serious water shortage provinces in China, and the province's utilization of water resources is only 30.8 billion m^3 on average in many years. The water consumption of burden and per capita is only about one – sixth of the national average level. Yellow River flows through the Heze, Jining, Tai'an, Liaocheng, Dezhou, Jinan, Zibo, Binzhou and Dongying nine cities in Shandong province, 25 counties (cities, districts) and disembogues into the Bohai Sea in Kenli County, and the length of watercourse is 628 km. Yellow River water is the main objective of water resource in Shandong Province, and is developed and made use of since the last 1950 s. It has been successively built 73 Yellow River irrigation district offices, has 63 block culverts existing of which design water capacity is 2,423 m^3/s. Shandong Yellow River water use is increasing after the 1970 s and the irrigated area continues to grow. In the 1970 s, the average annual water amount is 4.8 billion m^3, and the irrigation area is 11 million mu (1ha = 15mu). In the 1980s, it is 7.6 billion m^3 on average, and the irrigation area is 20 million mu. The average in the 1990s is 7.3 billion m^3, and the irrigation areas are more than 25.8 million mu. In the late 1990s, the irrigation areas have been exceeded more than 30 million mu. The Yellow River water diversion and areas account 40% of the total in terms of the province's total water consumption and irrigated areas. Now, 11 cities and 68 counties (districts) of the province are using water from the Yellow River. The Yellow River water diversion irrigated areas along the Yellow River play a significant role in Shandong's economic and social development.

1.2 The Yellow River dry conditions

The Yellow River water carrying capacity is limited. With the development of industrial and agricultural production of the provinces along the Yellow River Basin, regions and the water consumption increases in the cities industry and life. Yellow River water consumption is increasing in the provinces of the upper and middle reaches, so the Yellow River water entered in Shandong Province decline in the volume. Since 1972, the Yellow River in Shandong started to dry up, especially after the 1990s, the situation of drying is increasing seriously in the Yellow River, and it has become a truely serious impact and harm, leading to agricultural output decline, the industrial damage, water crisis of life of urban and rural residents, and the rivers silt is aggravating due to the Yellow River drainage capacity is much lower.

1.3 The regulation of the Yellow River water resources

The Yellow River's aggravating has caused great concern to stop the Yellow River drying in the government and all sectors of society. It is appealed to take measures to solve the problem of the Yellow River drying up by 163 academicians of the Chinese aggrement of the Academy of Sciences and Academy of Engineering by solemnly signing. In December 1998, by the State Council "the Yellow River annual allocation of water and the river water regulation plans"" and the "the management measures of the Yellow River water regulation" were jointly issued by The State Development Planning Commission and the Ministry of Water Resources and the Yellow River Conservancy Commission (YRCC) is authorized to be responsible for the management of the Yellow River water regulation. it is clear to be responsible for the management of water resources regulation by Shandong Yellow River Bureau in Shandong Province. In March 1999, it is beginning to introduce the unified management of the Yellow River water regulation Lower – dischage events have been solved many times by the united regulation of YRCC, thus no dry up has been guaranteed basically.

2 The construction of the sluice gate remote monitor and control system

2.1 Necessity

According to state authority, Yellow River Shandong Bureau has taken charge of the Shandong Yellow River water for the unified management and scheduling work since the March 1999. Due to the obvious contradiction between supply and demand in the Yellow River water, and in Shandong the river is long, the sluice gates are more. Scheduling and supervising the implementation of the program of work is very difficult. The backward measurement the sluice gate monitoring can't satisfy the requirements of the river water balance calculation; it increases the difficulty of water regulation. That the sluice gate gets more water and reports less or doesn't report often happen, it makes a serious influence to the scheduling a science and rational distribution of water. It will give threats on the efforts to ensure the YellowRiver not drying up. But every levels river works department lack of effective and reliable technology to control the sluice gate and prevent the Yellow River drying up. It is difficult to ensure that the Yellow River doesn't dry up in the emergency. When the water is scarce, the river works department had to send the officer to every sluice gates and limit the sluice gate get more water by locking the pump house. This measurement wastes a lot of human and material resources and it is easy to trigger contradiction between the Yellow River management and the local people. So, it is very necessary and urgent to strengthen the supervision and management of water sluice gate by the modern technology.

2.2 Feasibility

It is necessary and feasible to construct the sluice gate remote monitor and control system of Yellow River by using the technology of sensor, electronic, network and communications those are modern and mature. By this system, we can get the information of every sluice gate in time. The every levels river works department can monitor and control the situation of every sluice gate in real time. It can help the river works management to schedule the water resource of Yellow River by science to ensure that Yellow River doesn't dry up. At the same time, we can keep the Yellow river healthy, promoting sustainable economic and social development of the region which crosses the Yellow River in Shandong and improving the level of modern management of the project – Yellow River sluice gate.

2.3 The system construction

In 2000, the River Works Department of Shandong constructed the sluice gate remote monitor and control system in Weishan sluice gate, the system was the first on the Yellow River and it achieved good results. In 2002, the River Works Department of Shandong constructed two sluice gate monitor systems in Xingjiadu sluice gate and Lijia'an sluice gate, and YRCC constructed seven sluice gate monitor systems in Yantan, New(old) Xiezhai, Shengli, Mawan, Gongjia and Hantun sluice gates. In 2003, thirty sluice gate monitor systems were constructed in Gaocun sluice gate etc. In 2004, twelve sluice gate monitor systems were constructed in Suge sluice gate etc. Up to now, there are 51 sluice gate monitor systems have been constructed in Shandong Bureau, 81% of the 63 sluice gates overall, more than 95% of the water of the Yellow River has been controlled. Through years of constantly improving to the system, the system is getting better and better.

3 Functions and application

According to "the Yellow River Technical Specification of Culvert Remote Monitoring System (proposed regulation)" (SZHH01 – 2002) and "design report of Remote Monitoring System downstream of the Yellow River culvert design" and "the Sluice Gate Design", after the completion and operation of Culvert Remote Monitoring System, the qualification of technical get excellent, the specifications and standards meet the design requirements.

3.1 Function of the system

3.1.1 Real – time

Culvert response capability meet the data acquisition and control systems, man – machine communications, control systems and communications function of the time requirements. Digital acquisition cycle is <1 s, analog acquisition cycle: electricity capacity <2 s, non – consumption $<$ 10 s. Sequence of events are $\leqslant 5$ ms resolution, real – time database update cycle <2 s. Control orders response time to answer is <1 s and accept orders to be implemented to control the implementation of the response time <1 s.

3.1.2 Reliability

Culvert and equipment control system can adapt to the working environment, a good anti – jamming capability reliable and long – term stable operation. Gate controls monitoring computer (including HD) is $>16,000$ h, ground control equipment PLC $>30,000$ h.

3.1.3 Maintainability

The hardware and software of system is easy to facilitate maintenance, testing and maintenance. Self – diagnostic equipment with functions, is used to facilitate the continuous testing and fault isolation, with a special installation tool inserted dumping. Wear failure to reduce preventive maintenance so that the exchange of documents and the exchange of documents can not guarantee identification. The software can be easily revised and increased.

3.1.4 System security

Each operating functions are checked by the function that any errors are found when alerted or removed, information can be reported to ensure the mistakes will not lead to critical system failure. Water dispatch center, a higher level of communication and monitoring system is to control information includes, certainly responding to a clear system of feedback. System has these functions including power failure protection, self – identification capability, alarming in automatic fault detection. Any failure will not jeopardize the hardware and software system to improve and personal security, system failures will not cause any individual components of the production equipment malfunction.

3.1.5 Expansiveness

Backup point is not less than 20% of point – of – use equipment, control is more than 40% of computer memory capacity margin, having now expanded to the control unit, communications equipment or systems of the external interface allows sufficient margin channel utilization, channel utilization rate was less than 50% , and have a drawer of equipment to expand the space.

3.1.6 Software performance

Operating system software, database software such as Microsoft ´s popular software used Windows 2000 Server, SQL Server.

Application software system contains the complete monitoring system and the application software source code and development, maintenance of equipment. With high efficiency, high reliability, maintainability and modular design, these are easy expansion and modification. Certain software modules or functional modules to the integrity and independence, software environment is designed to enable security personnel to achieve operating software supplements and amendments.

Video surveillance software is installed in the front of the video system software in local sluice gate, including image compression data acquisition software data transmission system control software and network software. At the scene and the camera can pan and tilt control, but also to carry out water regulation and control video equipment orders issued by the center.

3.2 The role of system

Currently, the culvert remote monitoring system has completed a full functional design, video clear, flexible control; reasonably accurate monitoring data; remote hoist operation is safe and reliable; culvert hoist room and control room touch screen control system practical convenience; lightning, power and other facilities, equipment intact; work in a clean and tidy environment. The overall functions of the system are in good working condition.

The system will use, the control room staff in every water levels can drill holes through the culvert opened and the gates opened height of the monitor, immediately understand the state of real – time acquisition culvert downstream water level changes. Through curves culvert out formula, according to the culvert site acquisition parameters, the instantaneous water flow to projected culvert. Video can be observed through the gate before the culvert downstream river flow, the flow into the culvert. Video can be observed through the gate after the culvert outflow, headworks near water changes. Video can also be accomplished through observation room hoist operations, operating environment. The system realizes the Yellow River Management Committee, Provincial Director, Council and county offices, five gates are extremely according to the law governing control gradually reducing the authority from top to bottom, it is absolutely superior to the lower right of control. Remote scheduling department can be accomplished at all levels of water culvert, the culvert surveillance operation, monitoring data, which Scheduling and management of water resources departments at all levels of water management needs can be readily accomplished culvert under surveillance culvert operation, Scheduling order to reduce water gradually notice after the previous operation time and improve the effectiveness of water management directives, enhance the effectiveness of water management, give full play to the supervisory role of the diversion, effective and standardized the order of diversion. Basically eliminated the diversion reporting and draw fewer phenomenons. Meanwhile, the water management department at all levels, culvert special management unit is a culvert through the system daily accomplished management automation, greatly reduced the labor intensity, to improve the modernization level of the culvert management.

Along with the management of water resources and water management efforts to step up the construction and operation are the remote monitoring system culvert. 2000 to 2005 was a continuous flow for six years in a row, meanwhile meet basic water and industrial and agricultural production of regions along the Yellow River water for urban and rural residents into the sea constantly increased. The water of Lijin station flow into the sea in 2002 to 4.189 billion m^3, into the sea in 2003 to 19.13 billion m^3, into the sea in 2004 to 19.88 billion m^3 2005 to 20.82 billion m^3 into the sea. Wetland along the Yellow River region and the continuous improvement of the ecological environment are gradually restoring river drainage capacity. Achieved significant social, economic and ecological benefit, the central leadership's praise is "This is the kind of song green, Deserving writing home about."

4 Questions and suggestions

4.1 The management of the system

Shandong Yellow River Flood Culvert related to the management, utilization, water management, project management, water supply and other departments and units. As more departments involved in the management culvert, the main uncertainty caused management to passive management work. Proposed to set up a special regulatory body, which is equipped with full - time staff, the city, county offices, gate tube pipe system where the monitoring system should be clearly specialized management positions, specifically responsible for the management of remote monitoring system after the handover.

4.2 Equipment

According to years of observation for the operation, in the course of operation for some equipments that require manual reduction, some equipments often damaged, are there is the need for timely replacement. Equipment proposed to conduct a comprehensive inspection system, the replacement of the quality that do not meet the requirements, the models do not match the accessories, purchase some spare parts, to the timely replacement of damaged equipment operation.

4.3 System operating circumstance

Yellow River embankment wind sand, summer is the summer, a cold winter, seasonal temperature and impact of the operation of outdoor equipment installation; another rural power grid voltage is not stable enough, and frequent power outages caused UPS often lacking electricity, a normal start. Proposed to open the place for the necessary protective equipment, increased rain, lightning, heat ventilation facilities; culvert impetus for the transformation of individual circuits, the poor quality of some electricity. a great impact on the stability of the system, increasing the culvert transformers, surge protection device equipment the system power supply to maintain a reasonable range.

4.4 Maintenance of operating

Culvert remote monitoring systems and equipment used for electronic products, high sensitivity, easy loss, vulnerability to the external environment such as temperature, affected by factors such as humidity, the constant need for equipment maintenance. Due to the limitations of specialized knowledge and deficient training, the staff of grass roots can only operate the system. It is difficult for them to diagnose and elimitate system troubles. So the stable operation of system is affected sometimes by glitches. Recommended the establishment of a sound maintenance system, in accordance with the principle of separation of custody and establish the professional Maintenance Company, Maintenance clear system, the sources of funds, professional team responsible for the maintenance, According to the contents of the management and maintenance requirements for a clear separation of management and maintenance division to ensure the normal operation, Yellow River water to play a greater role in scheduling.

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Using Arc GIS to Develop and Research Soil – Retaining Dam Planning System on Small Watershed

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Abstract: The soil – retaining dam system planning must use the information system method based on the GIS technique to enhance efficiency. Using the planning system, it could obviously raise the level of soil – retaining dam system planning and decision. The system has the remarkable benefits in ecological and economic, and has a broad market extension and application.
Key words: soil – retaining dam system planning, GIS, system design

1 Introduction

The soil – retaining dam – system planning requires advanced technology, feasible measures, regular management and typical demonstration. To this end, plenty of attribute data, spatial data and image need to visual description and expression. GIS is the information technology to combine data management and graphics management, being of great advantage to perform these data. With Geospatial spatial analysis, the system can get the information for decision – making which is difficult to be got with conventional methods. It is more accurate, efficient and scientific than artificial methods. With GIS, naturally occurring or thinking planning dynamic process can be actualized in the data model to accurate forecast future trends, to guide the soil – retaining dam system planning and bring about the optimal program.

2 The status of the soil – retaining dam planning system research

2.1 Methods of soil – retaining dam – system planning

Currently used methods of soil – retaining dam – system planning can basically be divided into two kinds: First, the overall – balance method; Second, the system planning method (the nonlinear planning method is mostly applied now). The nonlinear planning method achieved certain results in soil – retaining dam system planning, however, the method has some limits: Firstly, variables shouldn't be too many; Secondly, if the Studied objects are different, the mathematical models will be also different and difficult to use and promote.

Additionally, "3S" is mainly applied in the monitoring and assessment of floods and drought, soil erosion, water and soil conservation, the underwater topographic survey of reservoirs or lakes or estuaries, forecast of debris flow, analysis of water resources in arid areas, the water reservoir resettlement environmental analysis and environmental impact assessment capacity of the river, coast evolution analysis. But in soil – retaining dam system planning, the "3S" application are still in blank.

The soil – retaining dam planning system research will focus on the disadvantages of existing methods, take advantage of "3S" technologies, and combine the remote sensing technology and simulation technology with the overall – balance method. The application of comprehensive methods is much better than the single application of overall – balance method or nonlinear planning method, exclude artificial factors at a certain extent, and get actual optimization against a more complex model. In addition, the application of remote sensing technology in vast areas can help you get comprehensive, objective, accurate and dynamic first – hand information quickly. This is much better than the traditional means with high input, long period of and low efficiency. It's more applicable, easy to be researched and popularized, and can be applied areas of different natural conditions.

2.2 The soil – retaining dam planning system

The research and software development of soil – retaining dam planning system has passed through the "Eighth Five – Year Plan" and the "Ninth Five – Year Plan" two stages, and has developed a number of software modules, having a more profound understanding of mathematical model and calculation method. The system has been applied in a few valleys, and yielded some results. Judging from the current application, there are still some issues that have manifested in: First, previous researches focused on the theory more, neglected the practicability, haven't formed integral software system, can't be applied in large scale. The production of software development in general is procedural modules. Second, the testing of software modules is not final completed and lack of understanding of the core technology. If the user is not very familiar with the staff of the process, the system is difficult to operate. Third, it is not modular, without the design of structured procedures, and lack of very important input, output interface and friendly user interface, so unable to meet the request to modern software. The research and software development will be fully absorbed with previous research results to practical application as the basic requirements, pay attention to the operating interface design and software functional design.

3 The programming idea of soil – retaining dam planning system

In the traditional mode of operation, the data Acquisition of soil – retaining dam system planning is based on manual paper records and inefficient, due to the manual processing of the data is likely to have errors. It is much undated to the informationization and modernization of water conservancy. The soil – retaining dam planning system will apply remote sensing techniques on the acquisition of watershed basic data; apply geographic information systems, computer graphics technology, database technology, virtual reality technology on data processing. Meanwhile on the Windows platform, by the object – oriented method, three – dimensional visualization technology, Pyramid virtual reality technology, imaging technology and other advanced technology, two – dimensional data model will be extended to three – dimensional. The GIS system models dispose digital orthophotos, digital elevation models, digital map as comprehensive objects. The research aims at how to lay projects on the topographic map, or cut sections to make clear the relationships between the dam – capacity, dam – alluvial area, dam – project loads and the spatial relationships between the dams.

4 The flow and method of soil – retaining dam planning system designing

The soil – retaining dam – system planning has combined remote sensing technology, the overall – balance method and dynamics simulation methods. Its design flow is as following (see Fig. 1):

(1) Adequately realize and grasp basic information of the small watershed, which including socio – economic conditions, channel characteristics, types of soil erosion, the status quo of land utilization, the operating status quo and maintaining experience of ravine project, and the existing problems of them.

(2) Utilize remote sensing images, digital elevation models to get 1/10,000 or 1/5,000 digital topographic maps.

(3) Set primary locations of dams in 1/10,000 or 1/5,000 digital topographic maps.

(4) Survey the primary locations of dams on the spot, realize the basic information such as the geological conditions and channel slope, etc.

(5) Analysis and comparison in the way of man – machine conversation, establish two above

dam – system plan, determine the type and scheduling of building

(6) Use GeoMedia Grid or ERDAS to calculate technical indicators including the curve of dam – capacity, dam – alluvial area, dam – project loads of each project.

(7) Carry through dynamic simulation for each kind of dam – system planning layout.

(8) Confirm the optimal plan by dynamic simulation. The comparison is in areas such as the comparison of water and sediment control, blocking sediment, water storage capacity, ensuring harvest capacity, alluvial capacity and the benefit of dam – system operating, etc.

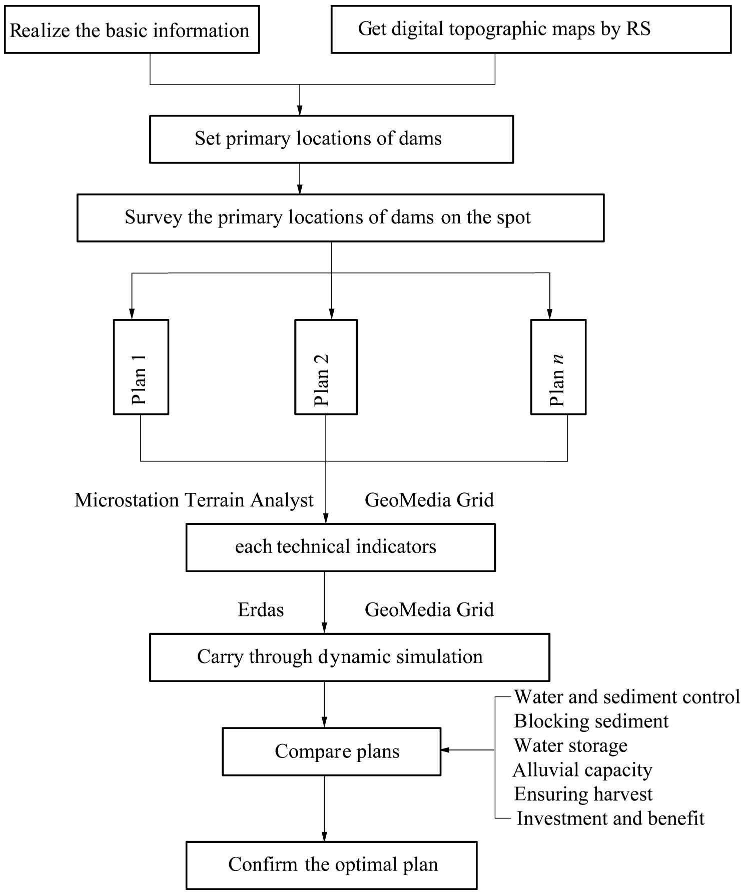

Fig. 1 The design flow chart and method of soil – retaining dam planning system

5 The establishment of the system database

5.1 Collecting the data

The data sources required by the soil – retaining dam planning system include all attribute data and graphics data. The database of attribute data indicated that the actual location or the statistical data of non – location relationships of features:

The general situation of small watershed includes geographical location, administrative divisions, topography, meteorology and hydrology, soil vegetation, soil erosion, economic and social, agricultural production and the development and utilization of water resources, etc;

The economic development plan and requirements (mainly agricultural) of the region, watershed, province and county;

Construction status, operating status quo, experience, and question of the projects in the watershed;

The planning documents, technical specifications, procedures, standards, etc.

Specific region (such as mine) Information.

The required graphic data is the 1:10,000 digital vector maps of the Small Watershed.

5.2 Processing the data

Extract the grooves and ridges from DEM, number and save. Vectorize the border of the ravine. The generated dam – cells map will be basis maps of the database. The natural or socio – economic statistics will be directly inputted when they are attributes of thematic maps, will be linked when natural or socio – economic database is to be built.

5.3 Design of the database

Database design is one of the core technologies in systems development and construction. Database design means building the optimal database model for a given application environment, establishing databases and applications, being able to effectively store data, meeting the needs of various users (requests for information and processing requirements). The database structure is shown in Fig. 2. Following the principle of combining the database design and applied systems in the process of designing, the designer will take (data) design and conduct (treatment) design close together. The main steps are as following:

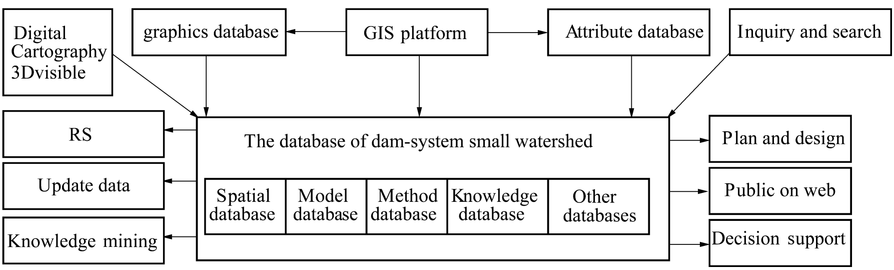

Fig. 2 Structure of the database of dam – system on small watershed

(1) Firstly, structure the database, after which the data processing is dividing layers or blocks of diagrams and coding data. Establish the database, classify the collected data, and establish a series of database structure.

(2) The input of attribute data: link attribute data of an entity with the corresponding set goals, establish the relationship between attributes and graphics, to the effect that graphics and attributes could inquiry and visit with each other.

(3) The input and editing of Graphic data: use ArcView3.2 to vectorize topographic maps after coordinate conversion and data format conversion.

(4) The integration of database: Use the "connect external data table" function of the system, export gathered data into graphics data. Because there are inquiring links exist among layers, the layers will form an organic, available, a complete spatial database after these relations are integrated.

6 Analysis of system functions

The system is composed by six functional modules: recognizing dam – location, calculating project characteristic curve, calculating the flood in dam – system, calculating alluvial capacity, comparing plans, three – dimensional display.

6.1 The selection of dam – location

There may be a certain number of tributaries or several adjacent dams upstream of a dam. In the process of optimizing plan, whether a dam is there or not will have a direct impact on the calculation of dams downstream. It is necessary to build a recognizing dam – location module. The module is to solve the problem if the dam – location is reasonable.

6.2 Calculating project characteristic curve

In general, project characteristic curve is multimode. The planer should establish the curves of dam – capacity, dam – alluvial area, dam – project loads.

6.3 Calculating the flood in dam – system

Calculating the flood in dam – system is an important question in the soil – retaining dam – system planning. After the dam – location is recognized, the planer should establish the module of calculating the flood in dam – system to solve the question of safety and rationality in operation

6.4 Calculating alluvial capacity

If there is no storing sediment dam upstream of the dam being calculated, all the sediment will be counted into the capacity of the dam being calculated; If there is a dam upstream, then the situation will change in terms of silting of the dam, the planer should establish calculating alluvial capacity, Layout planning system to solve the question of safety and rationality in operation.

6.5 Comparing solution

The main functions of the module are calculating benefit and analyzing economic indicators. Calculating benefit includes four areas: basic benefit, cost – effective, eco – benefit, social benefit. The effective period of calculating benefit is based on key dam project, divided into two phases. First, the comprehensive benefits of the dam – system after the key dam projects are built; second, the comprehensive benefits of the dam – system after the key dam projects are filled. Based on Comparative analysis of the economic indicators, the planer confirms the optimal plan.

6.6 Three – dimensional display

Realize the inquiry on 3 – D solid models: the entities such as key dams and soil – retaining dams, Realize the real – time browsing and tabulation output on water protection project information (dam highness, water storage capacity, alluvial area), see Fig. 3.

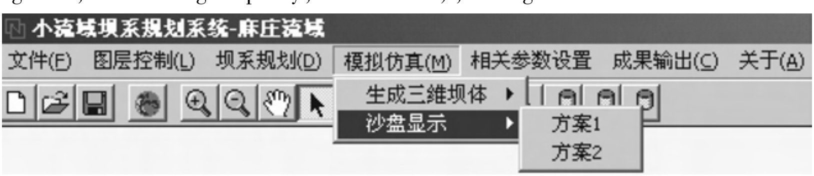

Fig. 3 The interface of soil – retaining dam – system planning system

7 The status of apply

After the research in the 24 dam – system small watersheds such as Nianzhuanggou, Fansiyao and Xiheidaigou, Leiguchuan small watershed in Yan'an, Shaanxi was chosen to be the model to finish dam system planning firstly by the soil – retaining dam planning system. In the small watershed, the system is used to choose the location of dams, build the substance of dams on the 3D topographical map, query information of all kinds, simulate the flow of water and sands. The result display the veracity of information gotten by the soil – retaining dam planning system meet the require in the phase of feasibility researching. In addition, the efficiency of soil – retaining dam planning system is much higher than traditional means. The soil – retaining dam planning system is being applied in small watersheds in different types of soil erosion region and taking out marked effect。

8 Conclusions

Building soil – retaining dam planning system on small watersheds and researching overall layout mode of dam – system in small watersheds in different types of soil erosion region in the Loess Plateau will help planer know and master the principium of blocking, storing and adjusting water and sediment by the soil – retaining dam in small watersheds, analyze the relationships and influence of the slope erosion and ravine erosion, reveal ecological, economic and social benefits of dam – system construction, and provide strong technical support for dam – system construction in large – scale in the Loess Plateau.

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Research on Wetland Vegetation Succession in Yellow River Delta Based on LEDESS Model

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Abstract: This paper analyzes the habitat features of different wetland vegetations in Yellow River Delta, identifies water and salt conditions of vegetation succession and explores the rules of vegetation succession. Based on the model LEDESS, integrates a great number of expert knowledge of relevant subjects, such as ecology, plant physiology, geography, hydraulic and agrology, couples the hydraulic model and underground water model, quantificationally simulates vegetation succession series under different ecological water supplement situations, shows the results with visual and spatial expression. Analysis LEDESS model simulation results: ① After ecological water supplement, vegetation succession positive development, barren land, alkaline land, tidal flat decreases, while area of wetland marsh, ordinary meadow, and shrub increases. ② Indicator species habitat suitability area increases, bird habitat quality improved significantly. Using LEDESS model to simulate vegetation succession under the situation of ecological water, to the image - makers to "see" the vegetation succession tendency and ecological effect after carrying out ecological water supplement measures, and provide the technical support for the ecological water supplement, wetland protection and rehabilitation in Yellow River Delta wetland.

Key words: The Yellow River Delta, wetland vegetation succession, LEDESS model

Vegetation succession is significant theoretical foundation of the protection and restoration of the wetland. With the rapid development of the research on ecology of wetland renewing, people gradually concerned on wetland vegetation succession. Yellow River Delta is the fastest soil - forming river - mouth delta in the world. Here, wetland has the features of young and natural succession and with relatively less human interruption, the creation, development and succession of all kinds of plant resources largely proceeds under natural situation, which gives it typical representatives. Therefore, many scholars and experts began to focus on vegetation succession in Yellow River wetland and gained plentiful results which lay the foundation for protecting Yellow River wetland. However, because vegetation succession need a relatively long time, past research had some limitation on the time and always analyzed vegetation succession by space taking place of time, there are some limitations. Thus, vegetation succession basis on LEDESS model is very good simulation and reproducible function. It provided excellent technical support and theoretical basis for exploring the rules of wetland vegetation succession, mastering the relative relations between vegetation succession and habitat conditions, and protecting, renewing and managing the ecological system in wetland.

1 Site condition of typical vegetation in Yellow River Delta wetland

1.1 Wetland vegetation

1.1.1 Reed

Reed can adjust themselves to a rather wide ecological range. The typical habitat is the river beach which collects water all the year round, low lands and mud alluvial lands in the Yellow River estuary. Reed is relatively alkaline tolerant. Among all the ecological factors that affect the growth of the reed, water is the main restricted factor and the requirement for other factors is not very strict.

Habitats of reed in Yellow River Delta wetland can be divided into three kinds. ① It is to live in the water depth of 30 ~ 50 cm, where is always flooded by the Yellow River with marsh soil, low salinity and fine vegetation growth conditions. ② It is to live in the districts where collect water all year round or seasonally with high salinity in the soil and lower growth ability of reed. ③ It is to live on the offshore tidal flat with higher salinity in the soil and lower growth ability of reed .

1.1.2 Purple osier(willow)

Purple osier is a kind of photophilous and hygrophilous vegetation with slightly alkaline tolerant, and mostly lives in low – lying grassland and sand beach with high river level on the riverside. It also can form community on the shore salty where underground water level is 1.0 ~ 1.5 cm, soil layer 10 ~ 15 cm with salinity of 0.38 ~ 1.17% and pH 7.5 ~ 8.0.

1.2 Saline vegetation

1.2.1 Seablite

Seablite is the dominate vegetation in sludge tidal flat and high alkaline land, whose habitat is generally low – lying. There underground water depth is 0.5 ~ 3.0 m or there always has seasonal water log, and the soil is mostly shore salty land. The growth of seablite is limited to the salt in the soil. Once the salt in the soil decreases, such vegetation would lose its growth ability and would be taken place by reed or tamarisk, etc. Coverage degree of seablite community varies due to the change of the salinity in the soil and underground water depth. In tidal flat and light saline soil environment, it will distribute scattered with coverage less than 5% , while in the environment with higher salinity it will form seablite pure community with coverage of 100% .

1.2.2 Tamarisk

Tamarisk has the features of draught, water logging, barren, cold, alkaline and sand tolerance. Tamarisk community mainly distributes in the shore tidal flat above the average sea – tide line with smooth topography, sludge salty soil, underground water depth of 1.5 ~ 2.5 m, and soil salinity of 0.25% ~ 2.76%. It is vegetation type developed based on the saline seablite with complex or interleaving distribution among seablite community and reed community.

1.3 Ordinary meadow vegetation

Ordinary meadow vegetation is in respect to the saline meadow vegetation. Ordinary meadow vegetation in Yellow River Delta is mainly lalang meadow formation. Lalang community is a kind of light saline tolerant vegetation, mainly distributing in the old Yellow River course, new silting area by recent Yellow River flood, isolated farmland and badlands with a height of 4 m above the sea level and salinity below 0.3% .

2 Rules of vegetation succession in Yellow River Delta Wetland

2.1 Factors influencing the wetland vegetation succession

There are many factors influencing the current vegetation succession in newly wetland in Yellow River Delta, including Yellow River water and sand resources, natural disasters and humane activities.

(1) Yellow River sand and water resources are the fundamental driving force of the straightforward development of vegetation succession in delta wetland as well as the leading factor in

forming and maintaining the water resource in the area. Yellow River plays a predominant role in the wetland vegetation succession.

(2) The tide attack would lead to the converse development of the wetland vegetation from ordinary meadow to saline, even leading to the leap backing of the vegetation types.

(3) As the deepening of the exploration of the Yellow River Delta, humane factors such as petroleum exploitation and unreasonable cultivation have more and more influences on vegetation succession in Yellow River Delta.

2.2 Rules of wetland vegetation succession

According to the analysis on the influencing factors of wetland vegetation succession and wetland vegetation habitat, the research results of comprehensive experts showed that vegetation succession in Yellow River Delta wetland can be briefly generalized as the succession approaches combined by Tolerance Model and Promotion Model. There also forms two succession series – one is saline vegetation succession sequence and the other is meadow wet – vegetation succession sequence. See Fig. 1.

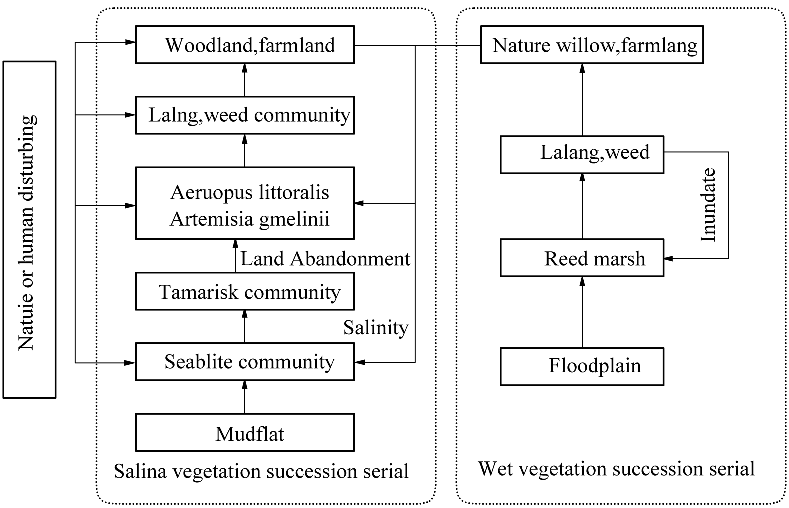


Fig. 1 Yellow River Delta Wetland Vegetation Succession Series

Among them, saline vegetation succession sequence is: mudflat, tamarsik – seablite community, aeluropus littoralis – wormwood community, lalang community, farmland or residential. Wet – vegetation succession sequence is taking the Yellow River bed as the axle, from river bed to flood land, sequence is: floodplain, reed community, aeluropus littoralis + lalang community, natural swallow community and drought farmland.

These two ecological series are interleaved and distributed in time and space, under condition that no human activities affect, and its directions of succession rules are all straightforwardness succession. But participation of human activities complicate direction of local vegetation succession, and especially unreasonable human disturbance (such as over reclamation and graze) makes vegetation succession converse and disturbs vegetation succession rules under natural state.

3 YRD wetland vegetation succession simulation based on LEDESS model

LEDESS model (landscape ecological decision – making and evaluation support system) is an expert model based on knowledge base, which can be applied to estimate ecological effect of vegetation and animal community under artificial water supplement scheme. Meanwhile, LEDESS model is a typical space clarification model, through which ecology knowledge related to space information can be used systematically and result can be expressed spatially and visibly, making decision maker " see " vividly trend of vegetation succession after putting ecological water supplement into practice and therefore improving the scientificalness of decision – making.

3.1 Highlight of simulation

Yellow River plays a dominant role in vegetation succession of wetland, but in recent years, as Yellow River resources of water and sand decrease, area of wetland vegetation and ordinary meadow decrease, and freshwater wetland degenerates increasingly. Therefore, artificial ecological water supplement is in bad need to protect and renew wetland marsh and ordinary meadow. To provide technical support for wetland ecological water supplement better, this paper simulates wetland vegetation succession sequence under implementation of ecological water supplement scheme.

3.2 Selection of simulation region

State – level nature reserve of Yellow River Delta is important component of Yellow River Delta, which has the most complete, broadest, youngest wetland ecosystem conserved in warm temperate zone, and is highlight of this paper.

According to each wetland protection value of nature reserve, protection degree in urgent need and feasibility of water supplement, considering reality of Yellow River water resource, this paper simulates wetland vegetation succession that has important ecology value, needs to be protected and has water supplement conditions in nature reserve (Fig. 2).

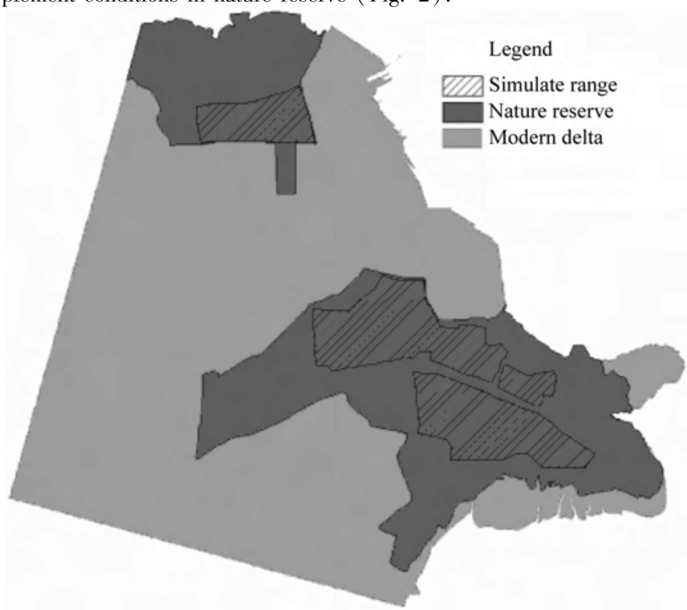


Fig. 2 Simulation scope of wetland vegetation succession

3.3 Vegetation Succession Simulation Based on LEDESS Model

3.3.1 General idea

Combining with hydraulic flood model and underground water model, underground water level, number of days of flood and flood scope are calculated after implementation of ecological water supplement. Integrating with vegetation succession expert knowledge, vegetation habitat expert knowledge, GIS drawing, LEDESS model is used to simulate vegetation succession sequence under different habitat conditions, supplying technical support for wetland renew (Fig. 3).

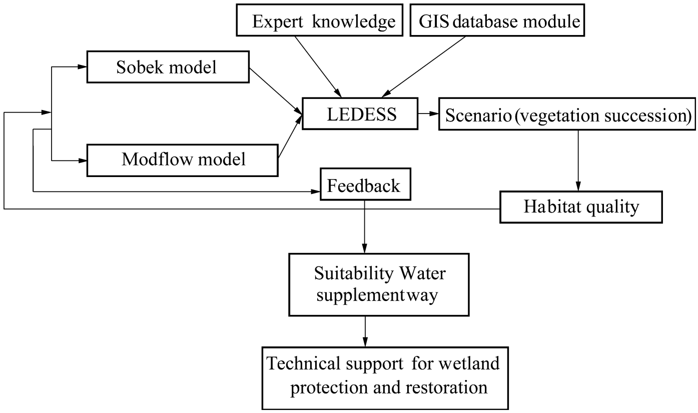


Fig. 3 General idea of vegetation succession simulation based on LEDESS model

3.3.2 Model structure

Main body structures of LEDESS model based on vegetation succession are two succession modules—site succession module and vegetation succession module, in addition including assistant module – habitat quality module (Fig. 4). Three modules need input of expert knowledge system and space graph data defined by user in according reality of Yellow River Delta, and propose of project research respectively.

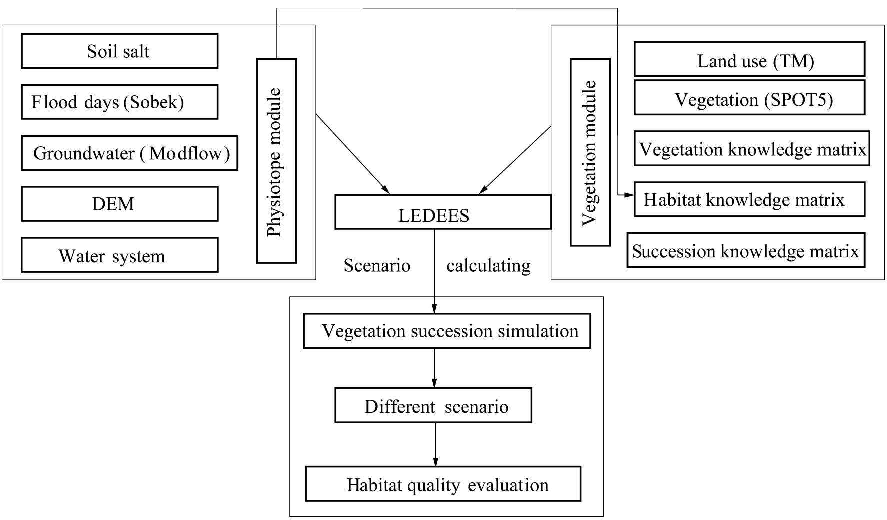


Fig. 4 LEDESS model structure based on vegetation succession

Site module: site module decides succession situation of vegetation and habitat directly, and can be used to describe, analyze the dynamic influence to succession situation of vegetation and habitat situation. This project considers the effect of surface water, underground water and salinity of soil on vegetation succession after implementation of ecological water supplement.

Vegetation succession module: vegetation type is determined according to main vegetation type of Yellow River Delta, SPOT image interpretation result and vegetation succession sequence, building contact among vegetation type, underground water, surface water and species habitat.

Habitat quality module: that is evaluation module; vegetation succession sequence is evaluated simply by means of superior or inferior of habitat quality.

3.3.3 Model structure

(1) Grading of Site ConditionAccording to site condition analysis of Yellow River Delta wetland vegetation, combining water – salt feature of Yellow River Delta, salinity of soil, underground water level and number of days of flood are graded as follows: (Table 1).

Table 1 Grading of Site Condition of Vegetation

Class	Flooding (d/a)	Groundwater (m/a)	Soil salt (%)	
1	0	0 ~ 0.5	0 ~ 0.2	Low salinity
2	0 ~ 30	0.5 ~ 1.0	0.2 ~ 0.4	Medium salinity
3	30 ~ 120	1 ~ 2	0.4 ~ 0.8	
4	> 120	> 2	0.8 ~ 3.0	High salinity
5			> 3.0	Salina

(2) Building vegetation habitat knowledge table. According to hereinbefore typical vegetation habitat analysis result, referring related research, combining result of actual investigation (Yellow River Delta vegetation habitat investigation work held by China Academy of Sciences in October, 2003), typical vegetation habitat knowledge table is built (Table 2), and changing it into knowledge matrix of LEDESS model.

Table 2 Yellow River Delta typical vegetation habitat knowledge table

Vegetation		Reed marsh	Reed meadow	Willow	Seablite	Tamarisk	Lalang
Root depth (m)		0.5 ~ 1.5	0.5 ~ 1.5	1.0 ~ 2.0	0.2 ~ 0.3	0.5 ~ 2.0	0.1 ~ 0.2
groundwater (m/a)	Low	—	0.1	0	0	0.5	0.1
	Suitability	—	0.3 ~ 0.8	2 ~ 3	0.3 ~ 0.5	1 ~ 1.5	0.3 ~ 0.5
	high	—	3.0	4 ~ 5	1.0	2.0	1.0
Surface water depth (m/a)	Low	0.1	0	0	0	—	0
	Suitability	0.5	0.1	0	0 ~ 0.1	—	0
	high	2.0	0.3	1.5	0.30	—	0.5
Flooding (d/a)	suitability	365	60	60	1	3	0
	high	365	90	365	2	30	10
Soil salt (%)	Low	0.1	0.1	0	0.9	1.0	—
	suitability	0.5	0.5	0.1	1.0 ~ 1.5	1.5	0.0 ~ 0.3
	high	2.0	2.0	1.2	3.0	2.8	0.3

Note: Surface water level and number of days of flood in table indicates situation of surface water and underground water under artificial water supplement scheme, without considering influence of natural rainfall to vegetation habitat.

(3) Building vegetation succession knowledge table. According to wetland vegetation habitat knowledge table (Table 2) and wetland vegetation succession rules (Fig. 1), based on current vegetation, vegetation succession knowledge table (Table 3) after 5 years is built under different water – salt conditions (Table 1), and changing it into knowledge matrix of LEDESS model.

Table 3 Yellow River delta vegetation succession knowledge table (five years)

Vegetation	Soil salt	0 d/a				0 ~ 30 d/a				30 ~ 120 d/a				>120 d/a			
		0 ~ 0.5 m	0.5 ~ 1 m	1 ~ 2 m	>2 m	0 ~ 0.5 m	0.5 ~ 1 m	1 ~ 2 m	>2 m	0 ~ 0.5 m	0.5 ~ 1 m	1 ~ 2 m	>2 m	0 ~ 0.5 m	0.5 ~ 1 m	1 ~ 2 m	2 m
Forest	Low	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow
	medium	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow	willow
	High	seablite	tamarisk, seablite	tamarisk	tamarisk	tamarisk, seablite	tamarisk, seablite	tamarisk	tamarisk	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	bare land	bare land	bare land	bare land	seablite	seablite	bareland	bareland	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed march	reed march	reed march	reed arch
Farmland	Low	farmland	farmland	farmland	farmland	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	S – T – R	tamarisk – reed	tamarisk – reed	tamarisk	S – T – R	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	seablite	tamarisk, seablite	tamarisk	tamarisk	tamarisk, seablite	tamarisk, seablite	tamarisk	tamarisk	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	bare land	bare land	bare land	bare land	seablite	seablite	bareland	bareland	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
Paddy – field	Low	lalang	lalang	lalang	lalang	lalang	lalang	lalang	lalang	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field
	medium	S – T – R	tamarisk – reed	tamarisk – reed	tamarisk	S – T – R	tamarisk – reed	tamarisk – reed	tamarisk	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field	paddy field
	High	seablite	tamarisk, seablite	tamarisk	tamarisk	tamarisk, seablite	tamarisk, seablite	tamarisk	tamarisk	tamarisk_reed	tamarisk_reed	tamarisk_reed	tamarisk_reed	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	bare land	bare land	bare land	bare land	seablite	seablite	bareland	bareland	seablite – tamarisk	seablite – tamarisk	seablite – tamarisk	seablite – tamarisk	reed marsh	reed marsh	reed marsh	reed marsh
Reed – marsh	Low	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	reed meadow	reed meadow	reed meadow	bareland	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
lalang	Low	lalang	lalang	lalang	lalang	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	T – R – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	Bare land	Bare land	Bare land	Bare land	seablite	seablite	bareland	bareland	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed – tamarisk	reed marsh	reed marsh	reed marsh	reed marsh
reed meadow	Low	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	S – T – R	S – T – R	S – T – R	S – T – R	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh

Continued to Table 3

Vegetation	Soil salt	0 d/a				0~30 d/a				30~120 d/a				>120 d/a			
		0~0.5 m	0.5~1 m	1~2 m	>2 m	0~0.5 m	0.5~1 m	1~2 m	>2 m	0~0.5 m	0.5~1 m	1~2 m	>2 m	0~0.5 m	0.5~1 m	1~2 m	2 m
tamarisk – reed	Low	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	tamarisk	tamarisk	tamarisk	tamarisk	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	tamarisk	tamarisk	tamarisk	tamarisk	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
tamarisk	Low	tamarisk	tamarisk	tamarisk	tamarisk	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	tamarisk	tamarisk	tamarisk	tamarisk	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	T – R – S	T – R – S	T – R – S	T – R – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
tamarisk – seablite	Low	T – R – S	T – R – S	T – R – S	T – R – S	tamarisk – reed	tamarisk – reed	tamarisk – reed	tamarisk – reed	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	T – R – S	T – R – S	T – R – S	T – R – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	T – R – S	T – R – S	T – R – S	T – R – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	tamarisk – seablite	T – R – S	T – R – S	T – R – S	T – R – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
seablite	Low	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed meadow	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	medium	seablite	seablite	seablite	seablite	R – T – S	R – T – S	R – T – S	R – T – S	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	High	seablite	seablite	seablite	seablite	reed – seablite	reed – seablite	reed – seablite	reed – seablite	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh
	Salina	seablite	seablite	bareland	bareland	seablite	seablite	bareland	bareland	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh	reed marsh

Note: T – R – S = tamarisk – reed – seablite; S – T – R = seablite – tamarisk – reed, R – T – S = reed – tamarisk – seablite.

(4) Building connection between LEDESS model and hydraulic model, underground water model. According to grading of site conditions and knowledge table of vegetation habitat analysis, making use of "Avenve script" function of LEDESS model, connection between LEDESS model and hydraulics model, underground water model is built.

3.3.4 Vegetation succession simulation

(1) Making water supplement scheme. According to simulation emphases and simulation scope determined, considering ecological value, urgency degree for protection and water supplement conditions of each part of nature reserve, combining with reality of Yellow River water resource, following ecological water supplement schemes are made (Table 4).

Table 4 Ecological water supplement schemes of Yellow River delta wetland

Water supplement strategy	Water supplement bound	Water supplement area	Water supplement
Reference strategy	Keep current situation		0.00×10^8 m^3
Perfect strategy	Nature reserve (South + north)	263.8 km^2 $+ 57.7$ km^2	4.93×10^8 m^3
Practical strategy	Nature reserve (South + north)	199.4 km^2 $+ 36.7$ km^2	3.46×10^8 m^3

(2) Simulating hydrology condition change under conditions of ecological water supplement. Combining with hydraulic model (SOBEK) and underground water model (MODFLOW), stimulate wetland hydrology condition change under ecological water supplement, calculate ecological water supplement scope, surface water flood time, water depth of flood, flood scope and underground water level in scope of ecological water supplement influence, etc. (Fig. 5) to provide input condition for LEDESS model simulation.

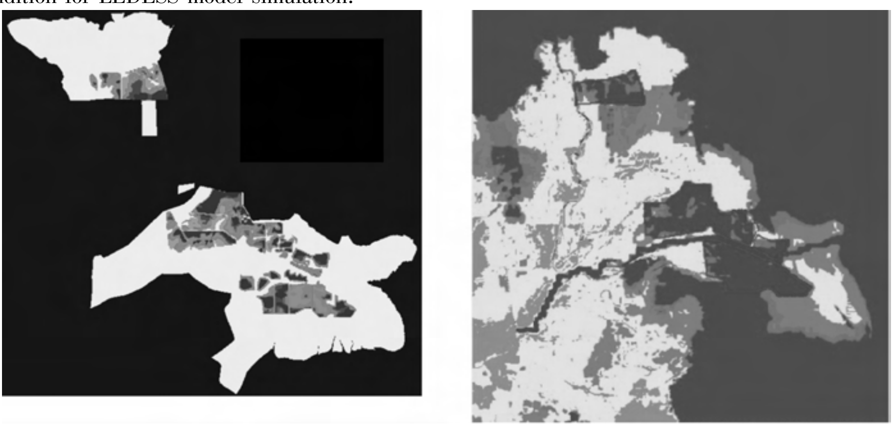
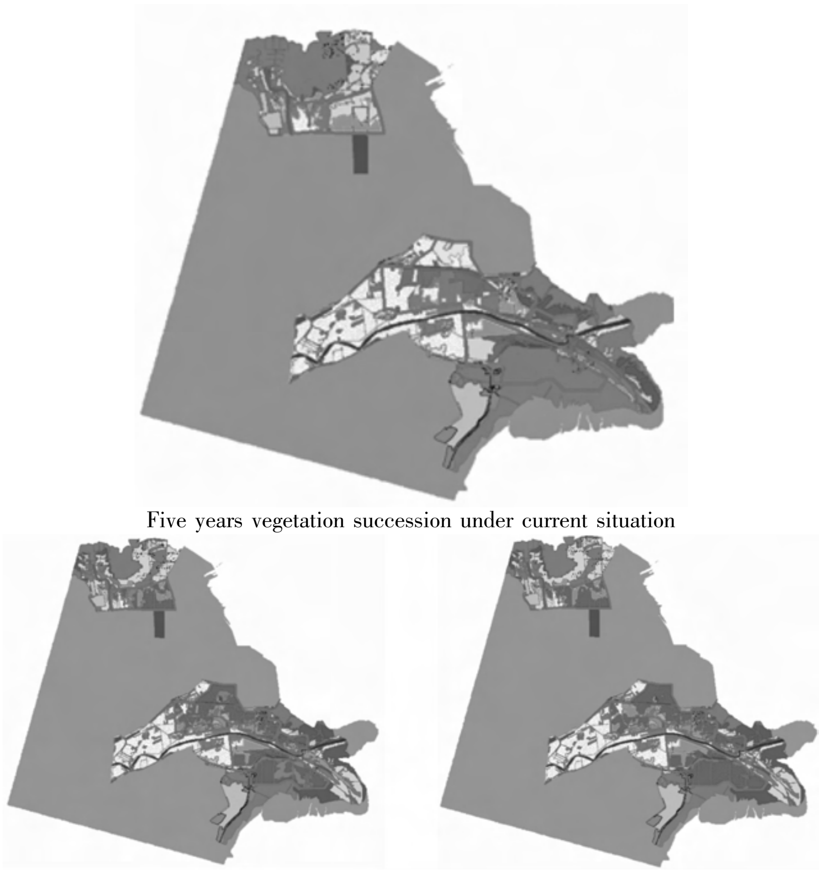


Fig. 5 Output result of hydraulic model, underground water model

(3) Vegetation succession simulation. Based on LEDESS model, integrating a amount of expert knowledge of related subjects such as ecology, vegetation physiology, geography, water power, hydrology and water resources etc, knowledge matrix is built; Coupling with hydraulic model, underground water model, vegetation succession under different ecological water allocation scheme is simulated through a mount of complicated scene calculation; simulation result is exported in spatially explicit way by means of geographic information system technology (Fig. 6).

(4) Calculation of Simulation Result. According to simulation result, under support of Arcgis, area of different vegetation type in different vegetation succession sequence is calculated (show in Table 5). From table, after implementation of ecological water supplement, saline vegetation succession series and wetland succession series are straightforwardness succession. Areas of barren land, saline lands and tidal flat decrease and areas of wetland marsh, ordinary meadow and shrub increase. To some degree, ecological water supplement is conducive to wetland vegetation natural succession, to the wetland ecosystem in a virtuous circle.



Five years vegetation succession under current situation

Five years vegetation succession under ecological water supplement

Ten years vegetation succession under ecological water supplement

Fig. 6 Vegetation succession result under ecological water supplement

Table 5 Different vegetation succession sequence area

Vegetation	Area(km^2)		
	Nature succession (5years)	Succession under ecologic water supplement (5years)	Succession under ecologic water supplement (10years)
Mudflat	295.42	126.33	125.00
Seablite	39.38	90.93	92.34
Tamarisk - seablite	48.91	7.06	8.14
Tamarisk - reed	52.72	111.31	116.35
Tamarisk	27.28	42.68	42.44
Reed meadow	55.98	107.41	76.76
Reed marsh	53.75	144.27	168.97
Lalang	—	6.24	6.24
Willow	63.28	54.00	54.00
Farmland	177.67	139.2	139.02
Paddy field	1.29	—	—
Bare land + Salina	28.01	14.53	14.52

4 Evaluation on the ecological effect of vegetation succession

4.1 Analysis on habitat suitability of indicator species

Wetland vegetation decides habitat type of species and suitability grade of the habitat to some extent. To make a further quantitative introduction to the effect of vegetation succession after ecological water supplement, this paper evaluates the ecological effect of vegetation succession in light of the change of habitat suitability area for indicator species.

According to protection grade and international importance of the avifauna in the nature reserve and fully considering the species' representativeness, red – crowned crane, sauder′s gull, oriental stork, siberian crane, are taken as the indicator species. Based on instructions species habitat habits, breeding habits and feeding habits and ecological preferences, reference related research results, determine indicator species habitat suitability.

Table 6 Habitat suitability grade of different vegetation types for indicator species in Yellow River Delta

Vegetation	Habitat suitability			
	Red – crowned crane	Sauder's gull	Oriental stork	Siberian crane
Mudflat	+	+	+	+
Seablite		+ + +		+ + +
Tamarisk – seablite		+ +		+
Tamarisk – reed	+ +	+	+ +	+ +
Tamarisk				
Reed meadow	+ +		+ +	+ +
Reed marsh	+ + +	+	+ + +	+ + +
Lalang				
Willow	+ +			
Farmland	+ +			

Note: ① " + " indicates the suitability grade is 10% ;" + + " indicates the suitability grade is 50% ;" + + + " indicates the suitability grade is 100% .
② Tidal flat shown in the table indicates bare tidal flat.
③ The determination of suitability grade for indicator species′habitat only considers the types of vegetation, regardless of the other natural conditions.

4.2 Evaluation on the results of vegetation succession

According to simulation results on the vegetation succession (Table 5, Fig. 6) and the grade division of species habitat (Table 6), calculate the suitable habitat area of each indicator species of vegetation types with different succession sequence (Table 7, Fig. 7). Shown from the results, after ecological water supplement, with the straightforward development of the vegetation succession, the suitable habitat area of species increases remarkably, rising by 1.6 times of that from 700 km^2 to 1,134 km^2, and the quality of habitat increases distinctly.

Table 7 Suitable habitat area of different vegetation types for indicator species

Unit: km^2

Vegetation		mudflat	Seablite	Tamarisk – seablite	Tamarisk – reed	Tama – risk	Reed meadow	Reed marsh	willow	farmland	total
Nature succession 5years	Red – crowned crane	30			26		28	54	32	89	258
	Sauder's gull	30	39	24	5			5			104
	Oriental stork	30			26		28	54			138
	Siberian crane	30	39	5	26		28	54		18	200
Succession under ecologic water supplement (5years)	Red – crowned crane	13			56		54	144	27	70	363
	Sauder's gull	13	91	4	11			14			133
	Oriental stork	13			56		54	144			266
	Siberian crane	13	91	1	56		54	144		14	372
Succession under ecologic water supplement (10years)	Red – crowned crane	13			58		38	169	27	70	375
	Sauder's gull	13	92	4	12			17			137
	Oriental stork	13			58		38	169			278
	Siberian crane	13	92	1	58		38	169		14	385

Note: Suitable habitat area of each vegetation type = Area of each vegetation type × Habitat suitability grade of indicator Species.

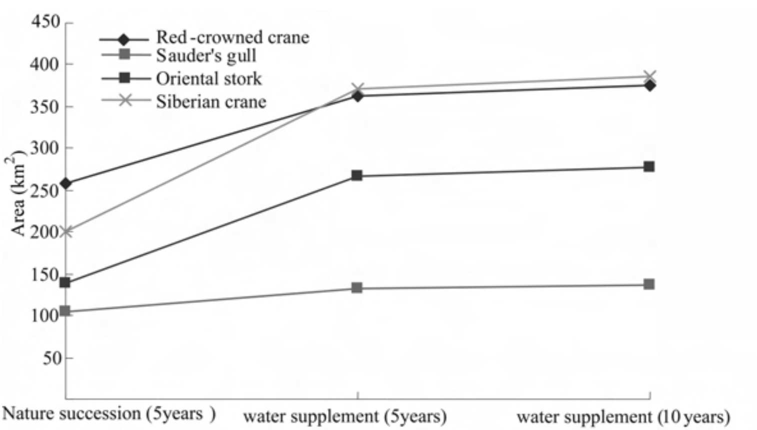


Fig. 7 Suitable habitat area change graph of different indicator species in different vegetation succession sequence

5 Conclusions and discussions

(1) LEDESS model is a model based on the expert knowledge, which could well simulate the succession condition under the scheme of artificial water supplement and express the results in spatially explicit and quantitative way. The model makes up the time and spatial restriction and qualitative description of the former study on vegetation succession to make the policy – makers visualize the vegetation succession trend after ecological water supplement and provide excellent technological support for establishing wetland water supplement scheme and carrying out the protection and renewal on wetland ecology.

(2) According to the simulation results of LEDESS, after conducting ecological water supplement, both saline vegetation succession series and wet vegetation succession series of Yellow River delta are straightforward succession. The area of barren land, alkali land, tidal flat decreases, while area of wetland marsh, ordinary meadow and bush wood increases. With the straightforward development of the vegetation succession, the suitable habitat area of indicator species is increasing remarkably, and the quality of avifauna habitat improves distinctly.

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Study on Method of Water Recycling – based Environmental Monitoring for Estuarine Wetland of the Yellow River

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Abstract: The Yellow River estuarine wetland is the most typical one in home and abroad. In order to effectively protect its ecological environment, to perform all – round environmental monitoring is necessay. This text puts forward the method on how to monitor the Yellow River estuarine wetland and the scheme on how to lay out the net of stations on the basis of water recycling, hence effectively monitor the environmental variety rules and provide the basis to protect thereof.

Key words: water recycling, the Yellow River, estuarine wetland, environmental monitoring

1 Necessity

1.1 General situation of the Yellow River estuarine wetland

The Yellow River estuarine wetland came into being on the low – lying land, river course and the shoal in the process of advancing of delta to sea area and swing of the tail multifarious in the delta . In addition, the artificial reservoirs and pit pools for water supply to oil – fields and cities alsp contribute to the hydrological ecological system. Currently, the Yellow River estuarine wetland area mainly includes three parts: wetland area (around 890 km^2) composed of the Yellow River estuary (now left bank of the Yellow River main stream) and the Dawenliu (now right bank of the Yellow River estuary); the land wet area (about 370 km^2) of the Yiqianer Yellow River old way; the shallow sea (over −3 m)area in between of the above mentioned two areas.

The wet landform is directly influenced by the modern Yellow River delta ´s formation and evolvement, complicated in shape and multiple in type. The landforms mainly are river – derived highland, less inclined flat ground, doline, estuarine spit, etc.. The land geography appearance mainly has river highland, tiny and inclined flat ground, marsh land, the river estuary sand spit and etc. The tide shoal geography has the high tide shoal and the littoral, its geography has the accumulated of the shell and the chips, the river estuary sand spit type dam, the tide water ditch fasten the littoral diffluent river way and river estuary sand spit etc. Sub – littoral zone geography divided into current Yellow River estuary submerged delta and abandon river estuary submarine crag – slope.

1.2 The necessary of the Yellow River estuary wetland environment monitor

The Yellow River estuarine wetland is a new – born wetland, with annual increase of 20 km^2 in area. It is the most complete, vastest and youngest wetland conserved in warm temperate zone up to now; It is the best typical model in our country, even the world, and is the best place to study the engenderer and evolvement regulation of the estuarine wetland.

In the last decades, In addition, the exploration of the old field directly or indirectly destroyed the wetland, deterorating the ecological environment of the wet land. Therefore, through monitoring of the wet land environment, to grasp the dynamic variety rule is necessary to protect the natual and complete wetland ecological system, promote the sustainable development of the wetland resources and wet land environment, maintain a healthy, safe and integral ecological system.

(1) Through monitoring the wetland environment, we can observe the human activities

(include the agriculture herding, fishery production, the ecosystem tour and various engineering construction and the other human activity) ,find out the influencing degree of the Yellow River and the dynamic state variety regulation that the other brook flow into the wetland to the natural sanctuary in time and the space, as well as the various factors related to the wetland's geologic change and draw up the wetland management plan to realize the scientific management of the Yellow River estuary.

(2) After many years' construction, the Yellow River estuarine wetland protection area, many management organizations have been deployed, the management system have already been initially formatted, but the research monitoring system construction is relatively delayed. Especially the water environment monitoring system belongs to the foundation of the estuarine wetland studies, it will play an important role in promoting research level on the wetland.

2 Monitoring basis and target for the estuarine wetland

2.1 Monitoring basis

The monitoring basis of the wetland is water recycling; it means to monitor each link of quantity and quality, in order to meet the reqirements of unit water quantity and water balance calculation.

The water balance calculation based on water recycling of the estuarine wetland, is the one of the important contents of the Yellow Rriver estuarine wetland for measurement and report, it is the only way to study the Yellow River estuarine wetland dry and wet regulation and to calculate an input and output nutritious material from the wetland, the other chemical material quantity and the amount of water of the wetland ecosystem and etc. The water balance equation of the Yellow River estuary wetland can be written as follows:

$$\Delta V = P + R_i + G_i + H_i - E - Q_0 - G_0 \pm e$$

In the formula:

ΔV——change of water storage;

P——rainfall;

R_i——run – of – inflow;

G_i——underground inflow;

H_i——sea water into the wetland;

E——evapored water from the wetland;

Q_0——run – of – flow out of the wetland;

G_0——underground flow out of the wetland;

e——error.

The monitor of river estuary wetland contents must meet the water balance calculation request under the river estuary wetland water recycling condition and the water quantity calculation condition basis on the water balance.

2.2 Targets of monitoring

The Yellow River wetland environment monitor based on the water recycling should realize the target as follows:

(1) Through constructing the integral monitor system of the Yellow River estuary wetland, building the all – round monitoring network, accumulating all – directions and systematically observation information of the Yellow River estuarine wetland ecosystem environment, hydrology situation, the geography... etc, all can provide a high – quality service for the management and the ecosystem development of the river estuarine wetland.

(2) It will be realized to service for ecosystem quantity of water operation of the Yellow River water resources . The ecology quantity of water of the Yellow River downstream mainly is the water consumption to maintain river estuary wetland ecosystem to benign develop. in the determinate time, it is a determinate number , but the ecology quantity of water of the river estuary wetland will

be changed along with the change of the wetland area, earth surface appearance, precipitation and evaporate, the sea water encroachment condition and the animal and plant distributions etc.

None but build up the perfect monitor system the of the Yellow River estuary wetland , it can actually real time control the variety regulation of these main factors and provide the science reference gist for the operation of the Yellow River ecosystem quantity of water.

(3) It can realize real time monitor that the mankind activity (oil – field development ect.) influent the river estuary wetland ecosystem environment. The Yellow River delta industry and the development of the city advance by leaps and bounds in recent years, the town construction, the quick increment of the farmland irrigation ,the hydraulic engineering work ,the highway ,the plain reservoir and various dam all have brought greatly influence to the river estuary wetland original ecosystem system . Although the development construction of the oil – field brought delta the prosperity on the economy, the bane from the breakage of the plant cover and the pollution of the environment to the river estuary wetland also causes similarly death. Therefore it is necessary that construct the wetland environment monitor system to realize inspecting of the wetland pollution and the breakage degree, it can well service for the Yellow River delta economic development.

3 Choice of monitoring items

The choice of the Yellow River estuary wetland monitor contents and the item , should consider change of the wetland hydrology circulation, basis on the Yellow River estuary wetland quality of water equation and the monitor target . It must reflect the variety of the wetland area and the hydrology situation , meet to the water quantity calculation request, reflect the dynamic state variety of the pollution condition to the wetland and the variety characteristics of the small wetland environment weather.

It is divided into 3 types according to the contents and method of the requested monitor items. They are general gauging item, tour gauging item and intermittent gauging item.

3.1 The general gauging item

(1) Wetland earth surface accumulate stage gauging. The wetland earth surface accumulate stage is the most basal hydrology main factor, its variety reflect directly wetland ground water measure of increase or decrease process, it is also indispensable water to quantity balance calculation .

(2) The wetland groundwater level gauging. The river estuary wetland groundwater, the earth surface accumulate water and the ocean water quantity are always placed in the dynamic state commutation process, the wetland groundwater either is the main source of the humidity wetland, also is one of the excretion districts of the humidity wetland.

(3) The sea area tide level observation of the wetland face the sea. The environment of the river estuary wetland is influenced by the ocean condition greatly, particularly to the change of the wetland earth surface; the groundwater salt degree and the area of sea breach . It will influent directly to the distribution of the animal and plant. Yet the change of the sea area tide level of the wetland face the sea related to the area of sea breach size and the influence degree of the sea water to the wetland groundwater.

(4) The hydrology main factor observation of the Yellow River steam wetland reach. The Yellow River is the mainly supply water river of the Yellow River estuary wetland. The water come from the Yellow River steam is the mainly survival condition of the river estuary wetland. Its hydrology factor variety at first hand influent the variety regulation of the river estuary wetland ecosystem environment. So, it is necessary that hydrology main factor observation of this the Yellow River steam wetland reach.

(5) The weather and the main weather factor of the wetland. The river estuary wetland weather and the weather condition is one of the main influence factors of the wetland natural geography variety process, in the same time the variety of the wetland also have bigly influence to

environment. It is the indispensability of important contents to gauging the wetland temperature, precipitation, wind velocity direction of wind, air degree of humidity, wetland evaporation, day shoot, sunshine etc.

3.2 Tour gauging item

The wetland water quality monitor should adopt tour gauging. the water quality condition of the Yellow River estuary wetland on different position and different time can reflect variety regulation of the wetland environment condition. The water quality item need to be monitor should include: Mercury, arsenic, copper, lead, cadmium , zinc, six price chromes, vaporize aerobic quantity, ammonia nitrogen, second nitrate nitrogen, pH, salt degree, electric conductivity rate, chloride, vitriol, total degree of hardness etc. phenol, water temperature, chemistry ; The water body of monitor should include: the wetland earth surface water accumulation , wetland groundwater , sea district(−3 ms is above), the Yellow River steam wetland river reach, the wetland other supply water river and the wetland depletion.

3.3 Investigate item

3.3.1 The investigation of the influent and depletion road

The influent and depletion road of the Yellow River estuary wetland influenced by the Yellow River flood greatly. Each time flood later on, the wetland original influent and depletion road will be changed greatly . The influent and depletion road of the wetland is inseparable towards to change of the wetland evolvement and the landform. It required obtain periodically the on - site inspection data of the influent and depletion road.

3.3.2 The investigation and gauging of the wetland landform change

The Yellow River estuary wetland landform is in opposite stability in the certain period, but be influenced to the deposition continent - making , sea tides corrosion and the Yellow River flood scour and silting , the landform variety influences to the variety of the wetland hydrology characteristic. The distributing condition of plant and the animal swill also take place to correspond. Therefore when the wetland landform has bigger variety, it needs the necessity investigation and gauging

3.3.3 The investigation of living creature category distributes

The living creature diversity is the most important index sign of the Yellow River estuary wetland environment and also is the basic purpose of protect the wetland. The investigation of the wetland living creature's distributing is the important aspect to the wetland monitors. These work need be completed by the unit and section engaged in the animal and plant profession.

4 The monitoring way and method

4.1 Monitoring system

The Yellow River estuarine wetland is composed of three parts: the Yellow River estuary (now left bank of the Yellow River main stream) and the Dawenliu (now right bank of the Yellow River estuary); the land wet area of the Yiqianer Yellow River old way; the shallow sea (over −3 m) area in between of the above mentioned two areas. According to the defined monitoring items, a complete system for monitoring should include the following 9 parts diagramed as below: GPS control station net, the Yellow River main stream station particular for wetland, flow measuring station net, water level observation station net, water quality observation station net, rainfall evaporation and meteorological observation station net, tide level observation station net closer to the sea, and monitoring administration center.

4.2 Arrangement of monitoring net

4.2.1 Layout of plane and elevation nets

Arrangement of the plane and elevation control nets are based on the environment monitoring platform for the Yellow River estuarine wetland, which should be suitable for measurement of the wet landform, sea – water encroachment, influent and depletion flow way investigation, water compiling level station, underground water level station, tidal level station and other monitoring items. The first plane control net can be Grade D with GPS, and the first elevation control net can be Grade 3.

4.2.2 Monitoring on river reach

The Lijin hydrology station, as a basis station to control the Yellow River water to the sea, should be treated as the basis monitoring station, for it is the nearest and the most standard station. The Dingzilukou hydrology station (well done), located at the mid and lower reaches of the wetland, was specially set up to harness the Yellow River estuary.

4.2.3 Measuring of inflow and outflow water

Inflow and outflow water are divided into two types in respect of their tracks, i. e. fixed and unfixed tracks. Thus temporary section measurement is used for unfixed water way while fixed section one for fixed water way.

4.2.4 Monitoring of water level

The wetland pounding water level station net should control the all change course of the wetland pounding water level; reflect the variety regulation of the surface pounding water level and the relation of the amount of water of the Yellow River stream flow. The wetland pounding water level station net mainly assigned in the wetland region of land of the Yellow River estuary and the Dawenliu and the Yiqianer Yellow River old way.

The location of the pounding stage station should be according to the geography and pounding water area and the submerged frequency. The place of the big pounding water area and the high submerged frequency should be insured to establish station observe, the other can equally establish station. The initial programming is each 50 km^2 stations to established, the Yellow River estuary and the Dawenliu region can established 18 stations, they are equally distributed in the Yellow River two banks (right and left); the Yiqianer Yellow River old way region can established 8 stations. It is total 26 pounding water level observation stations.

4.2.5 The observation of the wetland groundwater water level

The shallow layer groundwater influence highly to wetland ecosystem environment , so we mainly monitor the water level variety of the shallow layer groundwater . the groundwater water level observation net should establish according to the groundwater flow direction. If according to each 100 km^2 a stations to established, the Yellow River and Dawenliu region can be established 9 stations, they are equally distributed in the two bank of the Yellow River steam; The Yiqianer Yellow River old way region can be established 4 stations . Total they are established 13 groundwater water level observation stations.

4.2.6 The tides of the wetland face the sea observation

The tides of the wetland face the sea observation should monitor the course of the sea tide to rise and to fall and its influence degree to the wetland. Especially it can incarnate the relations that the tide and sea water invade scope and the wetland earth surface with the groundwater quality. it can be established a tidal station on the Yiqianer Yellow River old way wetland facing sea area above −3 m . it also can be established a tidal station on the Yellow River estuary and Dawenliu facing sea area above −3 m, which will be meet the basic demands.

4.2.7 The establishment of the monitor station net

The water quality monitor is divided into three parts: the earth surface water quality monitor, the groundwater quality monitor and the water quality facing sea –3 m above monitor.

The establishment of the wetland earth surface pounding water quality monitor station should control the time space distribute and change regulation of the water quality condition of the wetland area and should consider the transportation condition and the water body's area size. If established with each 200 km^2 a stations, it can be established 4 stations on the Yellow River estuary and Dawenliu, it also can be established 2 stations on the Yiqianer Yellow River old way wetland.

The established location of the groundwater monitor station should be same as the earth surface pounding water monitor station . It is conveniences that compare analysis the monitor result.

These area should be established 2 water quality monitor stations, one should be located on the sea area wetland on the land of Yiqianer Yellow River old way; The another should be located the wetland land area to face the sea of the Yellow River estuary and Dawenliu, it is also the nearby waters of the current the Yellow River estuary door nearby the waters.

4.2.8 The small environment weather main factor monitor

The Yellow River estuary wetland observation station net of precipitation can according to the average principle to established . it can be each 150 km^2 cloths to established 1 station, Total can be established 8 to decline the amount of precipitation observation stations.

Moreover, in consideration of the geography of the river estuary wetland is not influencing greatly upon the weather main factor , at the wetland of the Yiqianer Yellow River old way region and the Yellow River estuary and Dawenliu wetland region each also be established 1 evaporation and weather observation station.

5 Remarks

Study on method of water recycling – based environmental monitoring for estuarine wetland of the Yellow River is the basis of wetland environment study, also a very important part of the Yellow River ecological environmental monitoring system, supporting the scientific resolution method to protect and make good use of the Yellow River estuarine wetland. To develop this study is meaningful to maintain the balancing ecology of the Yellow River, protect the diversity of living creatures, promote sustainable development of the Yellow River estuarine wetland, safeguarding the local and adjacent regions' healthy and safe ecological system. Hence a complete environment monitoring system for the Yellow River estuarine wetland should be established with due expedition.

Study on Fast Assessment of Watershed Surface Erosion Susceptibility Using Decision Tree Method Based on GIS and Remote Sensing Technology

—A Case Study of Jiuyuangou Watershed on the Loess Plateau

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Abstract: Based on GIS and Remote Sensing Technology, the procedure of fast assessment to watershed surface erosion susceptibility by use of decision trees method in the Jiuyuangou watershed on the Loess Plateau was presented. Obtaining the influence factors of soil erosion, the rule of soil erosion classes and calculation of results were included in the detailed procedures . The research shows that this method is simple and versatile and be suitable for the poor data areas.
Key words: decision tree, GIS, remote sensing image, soil and water loss, jiuyuangou watershed

Fast and accurate assessment of watershed surface erosion susceptibility can help management organizations to scientifically and rationally make decisions. Meanwhile, it can improve the work efficiency of planning and design companies, and ensure the final results having good quality. At present, USLE as a soil erosion model was broadly applied in China, which can scientifically predict and analyse the watershed surface soil erosion. But this model need huge basic information to support its running and it is very difficulty to apply under the poor data. The investigation of soil and water loss mainly is based on the soil erosion module, finally finish the soil erosion quantitative assessment by field investigate, aerophotography, and air images judgement. Its shortcomings are that these methods need long time; accuracy of the research results has big difference, and difficult to catch the dynamics change of soil loss.

This report presents the procedure of fast assessment to watershed surface erosion susceptibility by use of decision trees method in the Jiuyuangou watershed on the Loess Plateau.

1 Description of Jiuyuangou watershed

Jiuyuangou watershed is located in Suide county of Shaanxi Province in the northern part of the Loess Plateau. The total area is about 74.72 km^2. There are many gullies and hills in the research area, soil erosion is very serious, and the average soil loss is 15,000 t/(km^2 · a). The climate is temperate monsoon; the annual precipitation is 475.1 mm with a distinct dry and a distinct wet season, Annual rainfall falls during the rainy season (July to September), takes up 64.4 % of the annual rainfall. Most of the rainfall comes from a few heavy rains, which lead to huge damage to local people. Annual transported sediment is 0.59 million tons.

2 What is decision tree method and how to implement it

Decision tree method shows an intuitionistic information and decision clusters by use of tree framework. It is a high efficient classifying tool. This method makes full use of the information and combines of all kinds of influence factors and finally obtains the results which can meet the end condition. This paper presents the procedure of fast assessment to watershed surface erosion susceptibility using decision trees method. On the Loess Plateau, soil loss is mainly decided by land use type, vegetation coverage and topography. Therefore, the first step is to obtain the land use map and vegetation coverage map by Remote Sensing images, and combining the slope degree map from the DEM; then based on the above information we analyze and assess the watershed surface soil erosion susceptibility; finally a watershed surface soil erosion susceptibility map can be gotten.

3 Implement procedures

3.1 Obtaining the related factors affecting soil erosion

The factors which influence surface soil erosion includes vegetation coverage, topography and land use type. On the basis of the remote sensing images, which time is 21 – 11 – 2002 and 29 – 06 – 2000, respectively, Jiuyuangou watershed land use map and vegetation coverage map were obtained by use of satellite images interpret software, combination with field investigate and remote sensing images judgement. The land use within the study area is classified into four groups: water area, agricultural land, grass land, and bare land and construction land. Vegetation coverage is classified into four classes: very poor coverage, poor coverage, good coverage and very good coverage based on the Ndvi value.

The slope map was derived from the digital elevation model (DEM) by using the Arc – Info software. The slope gradient was classified into five domains: 0° ~ 8°, 8° ~ 15°, 15° ~ 25°, 25° ~ 35° and > 35° in accordance to the Chinese method of soil erosion risk estimation.

3.2 The rule of soil erosion classes from the decision tree method

Based on the Loess Plateau soil erosion characteristic, Table 1 shows the details of the decision rules applied.

Table 1 Decision trees method for assessing surface erosion susceptibility

Land use	Vegetation cover	Slope (degrees)				
		0° ~ 8°	8° ~ 15°	15° ~ 25°	25° ~ 35°	> 35°
Water	no influence for cover indicator	0	0	0	0	0
Bare land		1	2	3	4	5
Agricultural land		1	1	2	3	4
Grass land	very good cover	1	1	1	2	2
	good cover	1	1	2	2	3
	poor cover	1	2	2	3	4
	very poor cover	2	2	3	4	5

Note: 0 for no erosion; 1 for very low erosion; 2 for low erosion; 3 for moderate erosion; 4 for high erosion; 5 for very high erosion.

On the Loess Plateau, many experts think that soil loss can not occur under water body area which is located in the gullies. Therefore, all of areas which are covered by water were given 0 values, meaning no soil loss. In this research, about bare land and agricultural land soil loss, we only take into account the influence of slope degree and ignore the vegetation coverage influence. When assess grass land soil loss, vegetation coverage and slope degree were both discussed.

3.3 Calculation of results

By use of Arc – Info software, the erosion classes can be calculated by overlapping all of the lays, then based on the rules of soil erosion classes, a surface soil erosion map can be obtained. In this research, this procedure can be automated using script file, which allow this calculation to be done easily once the script is created.

In the GIS environment, we can get the area of different soil erosion classes by calculate the number of their plots. Based on the above method, areas of surface erosion susceptibility in Jiuyuangou watershed are showed in Fig. 1 and Table 2.

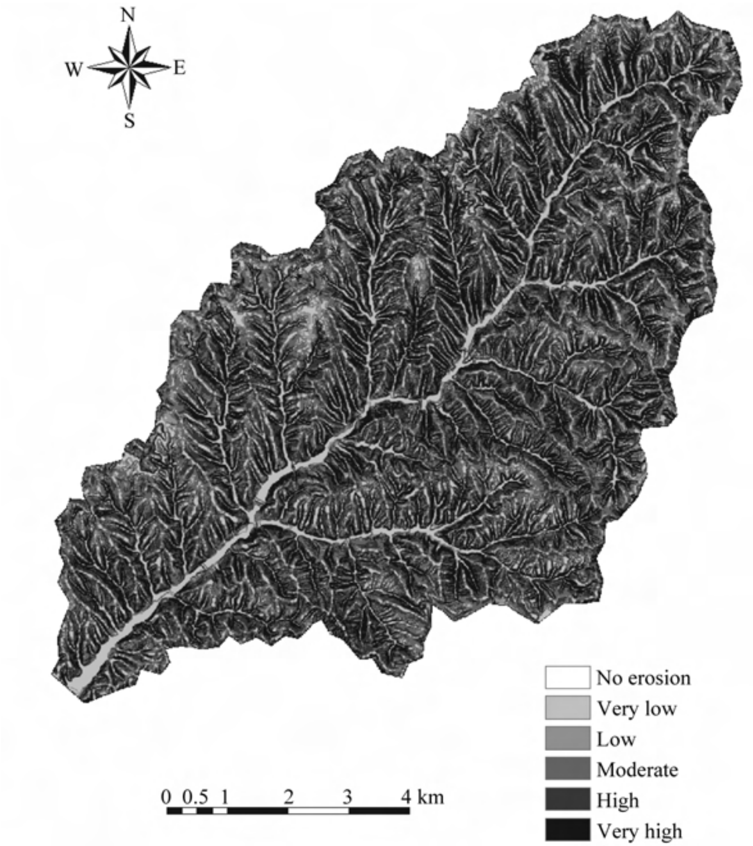

Fig. 1 Surface erosion susceptibility map in Jiuyuangou watershed

Table 2 Area of surface erosion susceptibility in Jiuyuangou watershed

Surface erosion class	No erosion	Very low	Low	Moderate	High	Very high	Total
Area of each class (km^2)	6.45	4.26	11.69	20.04	22.40	9.88	74.72

4 Conclusions

Based on GIS and Remote Sensing Technology, this research presented the procedure of quick assessment to watershed surface erosion susceptibility by use of decision trees method. This is a simple and versatile method that can nevertheless give useful information, especially in the data-poor areas. Meanwhile, this method not only quickly obtains the information which influence surface soil erosion, but also asses the attribute of map unit, for example area etc.

This method shows the watershed soil loss space distribution by watershed soil erosion map which can provide a visual view for management organizations and planning and design companies. Especially, it can help the plan and design companies to rationally select control measures to decrease the soil loss. The main limitations of the current method are as follows.

First, using this method it is very difficult to obtain the rates of surface erosion. It is only a qualitative assessment method to surface soil erosion. Second, rainfall was also not taken into account in the decision tree. This is the reason why erosion rates could not be quantified. Finally, whether this method has good effect depends on the rules of surface soil erosion classes. How to reasonably obtain the rules, an important point is the experts who make rules need good soil erosion professional knowledge and fully know the research area soil erosion characteristic.

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Flood Forecasting Methods for Sanmenxia Reservoir area in Yellow River and its Development Direction

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Abstract: These years, the silt deposition is very serious in sanmenxia reservoir area in Yellow river, the carrying capacity of flood channel is universally lower and the flood routing principle is changing. According to the channel characteristic and flood routing principle, flood forecasting methods for different reaches in Sanmenxia Reservoir area were reviewed and improved, later on, the flood forecasting accuracy was greatly improved. The automatization of hydrological information collecting and transmitting will improve modernization of flood forecasting.

Key words: flood forecasting methods, development direction, Sanmenxia reservoir area

1 Introduction

Sanmenxia reservoir area is located in the middle reaches of the Yellow River, where part of the main river channel below Longmen station and the lower reaches of Weihe River and Beiluohe River are involved. It's the controlled area of flood source from the upstream Sanmenxia. The flood forecasting is very important to flood control scheduling of Sanmenxia reservoir and flood prevention in the lower Yellow River.

These years, the sediment deposition is very serious in Sanmenxia reservoir area in Yellow river, the flood carrying capacity in river channel is universally lower, and flood routing principle has been changed. We developed the new flood forecasting scheme of Longmen, Tongguan, Huaxian and Sanmenxia hydrological stations, and greatly improved the flood forecasting accuracy. With the accomplishment of the water information sub – center of national flood control command system, automatically hydrological information collecting and transmitting will improve modernization of flood forecasting.

2 Combined – discharge forecasting method for upper reaches

The flood at Longmen station comes from upper tributaries and valley between Shannxi and Shanxi provinces with characteristics of high sediment concentration and flood rapidly rising and falling. We used the Muskingum routing method to combine the corresponding discharge in main stream and distributaries, calibrate the parameters of K, and X according to the maximum combined discharge, and continually forecast flood at Longmen station with that at Wubao station. This method was also used for reaches from Fugu station to Wubao station. Therefore, the continually forecasting scheme for reaches from Fugu to Longmen station with length of 517 km was established. And the leading time is more 27 hours. Moreover, we build the corresponding flood peak forecasting method and the rainfall – runoff forecasting method. Now, the leading time is more 13 hours than before and the average forecasting accuracy of flood peak is about 92%, which is higher than that of 86% before 2 000.

3 Muskingum layered routing method

It's compound channel in lower Weihe River, the width of main channel is about 200 m, while the total channel width is 2,000 ~ 3,000 m. These years, the sediment deposition is very serious in the lower Weihe River, the flood carrying capacity in river channel is universally lower. The bankful discharge has been decreased from 4,500 m^3/s in 1985 to 1,500 m^3/s in 2003. Currently, the flood often overflows, the flood peak has been reduced and the routing time become longer. The flood peak is 5,100 m^3/s at Lintong station on Aug. 31, 2003, and the corresponding discharge at Huaxian station is 3,540 m^3/s. The routing time was 12 hours more than the normal while the flood peak has decreased by 31%. Considering the different flood characteristic and routing principle after overflowing, we use Muskingum layered routing method, and calibrate the parameters for different main channel. The average forecasting accuracy was improved from 76% to 87%. In autumn flood in 2005, the flood peak at Huaxian station is 4,880 m^3/s on Oct 4,2005. And the forecasting accuracy was about 92%. We also built the corresponding flood peak forecasting method according to the rainfall, peak – shape coefficient, etc.

4 Overbank flood forecasting method in Xiaobeiganliu stream in Yellow River

The reaches of Xiaobeiganliu stream in Yellow River (from Longmen to Tongguan station) is wandering reach. After 1985, the channel was shrunk seriously, the bankful discharge has decreased from 11,000 m^3/s (before flood season in 1985) to 4,200 m^3/s (before flood season in 2005). And routing time of overbank flow has become longer. We build the subsection storage – discharge relationship and use reservoir storage curve method to forecast continually according to the observed data of sediment cross – section and stage gauging station. We build the real – time updating model. This method improved the overbank flow forecasting accuracy from 70% to 85%.

5 United regulating flood forecasting method in Sanmenxia reservoir

5.1 United regulating flood forecasting method

After the flood of "92 · 8", Sanmenxia reservoir has been dropping the storage – waterlevel and limited stage before flood season. The operational mode is sluicing sediment and releasing flood in flood season. It is normal channel in upper stream from Tongguan station to Dayudu station and reservoir in downstream from Duyudu station to sanmenxia dam. We use the Muskingum routing method in upper stream and reservoir storage curve method in downstream. This method can calibrate parameters and forecast the water lever and discharge process, maximum and appearing time continually.

5.2 Real – time updating of reservoir storage

Considering the change of storage for deposition and erosion, we build the real – time updating model for reservoir storage according to sediment. The model can improve the forecasting accuracy.

After developing the forecasting system in 2001, the forecasting accuracy of the maximum outflow discharge and stage and flood process in Sanmenxia reservoir has been improved from 81% to 90% .

6 Development direction of flood forecasting method for Sanmenxia reservoir area

Automatically collecting and transmitting hydrological information will improve modernization of flood forecasting with radar and satellite.

6.1 Developing the rainfall – runoff forecasting model to enlarge the leading time

The Sanmenxia water information subcenter was completely accomplished and was put into operation in May 2006. We can collect and transmit the real – time precipitation, which is necessary for rainfall – runoff forecasting. The rainfall – runoff model can forecast the flood in non –

controlled area in the reaches of Xiaobeiganliu and Nanshan distributaries in lower Weihe River, improve the forecasting accuracy and leading time.

6.2 Studying the forecasting scheme based on the new forecasting methods and models

With the operation of remote sensing and new forecasting methods, such as interactive model, and ANN etc., we will study the flood forecasting system according to the meteorological, hydrologic and flood characteristics in Sanmenxia reservoir area.

6.3 developing runoff, sediment and water quality forecasting

Now we have not formally forecasted the sediment, medium and long – term runoff and water quality. With the sustaining development of industry and agriculture, the water resourse are shorter and the river is polluted. It is very necessary to develop the medium and long – term runoff and water quality forecasting and to provide the basis for water resources scheduling and water supply scheduling. During the water and sediment regulation and sediment deposit test in Xiaobeiganliu stream, it's important to forecast the sediment.

6.4 Building the real – time updating model to improve the forecasting accuracy

With the accomplishment of the Sanmenxia water information subcenter, it's possible to offer continuas forecast and real – time revise.

The continual flood routing method is used in the Fugu – Longmen reach in yellow river and Xianyang – Huaxian reach in Weihe River, and the leading time is about 27 hours. During the leading time, we can continually revise the forecasting value. We will build the real – time revisal model by using the Kalmen filter algorithm and CRC filter algorithm to improve the forecasting accuracy and service for flood prevention better.

7 Summary

The paper summarizes the new flood forecasting methods according to the channel characteristic and flood routing principle after changing the deposition and erosion and Sanmenxia reservoir operational mode. These methods is practical and reliable, but mainly by experience, only forecast the flood peak discharge. The leading time is not long. With the Sanmenxia water information subcenter accomplishing, collecting and transmiting the hydrological information automatically (especially the application of the radar, satellite and remote sensing technique) will improve modernization of flood forecasting and make basis for developing sediment, medium and long – term runoff and water quality forecasting and improving the flood forecasting accuracy and science and technology content.

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Feasibility Analysis of Setting up Groundwater Monitoring System in Riverhead Area of the Yellow River

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Abstract: The general situation of riverhead district of the Yellow River is introduced. The necessity of setting up groundwater monitoring system of riverhead district is put forward by analyzing the current situation of groundwater monitoring and the characteristics of hydrological situation change in recent years. The feasibility of the groundwater monitoring system establishment of riverhead district is discussed with the analysis, assessment and investigation of the aspects such as technology, engineering, economy, social benefit etc.. Construction of this system is important in strengthening development and utilization of water resources, studying on the transformation rules of precipitation, groundwater and surface water of riverhead district, preventing natural calamity scientifically, strengthening the constructions of ecological environment, and promoting regional economy and society development.

Key words: Yellow River riverhead district, groundwater monitoring system, feasibility analysis

1 General situation of Yellow River riverhead district

Yellow River riverhead district refers to Yellow River main stream area upwards from Longyangxia reservoir. with Drainage area of 120,000 km^2. Mean annual discharge is 20,470 million m^3 which accounts for 35.3 percent of the total Yellow River yearly discharge. Because of its high elevation, cold weather, serious efflorescence and broken rock in the basin, which is good for infiltration, groundwater is abundant. Two big tributaries of Heihe River and Baihe River originated from Ruoergai meadow marsh in the west of Sichuan province. Enormous water yield and strong regulation ability of the two rivers play important roles in stabilizing the water yield of the upper reaches of Yellow River. More than 40 glaciers distributed in the mountain of Animaqing. The area of glaciers is 120.57 km^2. It is the natural solid reservoir. Qushianhe river and Qiemuqu originated from glaciers is the main water source between Jungong and Tangnaihai.

The average altitude here is above 3,000 m. It belongs to a plateau continental climate, which is in high position, cold weather and oxygen deficiency, strong temperature variation, long winter and short summer, no clearly four seasons, climate zone distribution differently, obvious vertical change, obvious precipitation distribution and seasons difference. The riverhead district of the Yellow River crosses over three provinces of Qinghai, Sichuan, Gansu province, limited by natural and economy environment, population distribution is not even, average density of population in most areas is only 7 people /km^2. Industry and agricultural foundation is weak, husbandry is the main economy source.

2 Groundwater monitoring situation

Climate change and influence of human economic activity in recent years lead to the fact that the snow line of source district of the Yellow River rises, the glacier goes backwards, numerous lake areas shrink and basify. Degradation of meadow, desertification and soil erosion are serious day by day. Obvious change has taken place in groundwater resources circulation condition, quantity, quality and rule of distributing, etc., which influences the form, development and utilization of the groundwater resources seriously, influences people´s health, water supply safety and ecological environmental security, and becomes the restriction factor of comprehensive, coordinated and sustainable development of economy and society of our country. According to the data of Maduo hydrology station of YRCC, water level of Zhaling lake, Eling lake has dropped continuously in recent years. The groundwater level has a downward trend in other basins, the Ruoergai wetland disappears progressively, which is incorporate of groundwater level dropping continuously. The riverhead district has not launched the groundwater monitoring yet at present.

3 Feasibility analysis of setting up Yellow River riverhead district groundwater monitoring system

3.1 Necessity of setting up Yellow River riverhead district groundwater monitoring system

Water resource is irreplaceable resource of human survival and development. Groundwater resources amount is about 5.36 billion m^3 in the riverhead district of the Yellow River which accounts for 26.8% of the total amount of water resource. Because of regional maldistribution, big yearly changeable , especially after 1990s, annual precipitation of Jiuzhi, Maqin, Maqu, Henan, Zeku, Tongde Tangnahai drops continuously which makes discharge of Tangnaihai hydrology station be in dry period, and aggravates pressure of downstream water resource. Meanwhile, temperature rising leads to the fact that freeze soil layer melts in the basin, aeration zone becomes thick, water infiltration increases, new shallow layers of groundwater bury condition growes. Some phenomena occurred, like groundwater water level dropping continuously, lake coverage shrinking and salinizing meadow degenerating, soil desertification. In addition, human activity and mouse harm etc. caused the condition of the lower cushion in the basin change, not only produced influence greatly on the forming of the surface water, but also brought out a lot of ecological environment problems. These questions have close contacts with the change of the groundwater water level. So, it has important realistic meanings on preventing natural calamity and protecting the environment to build groundwater network of monitoring station scientifically, economically, and rationally, monitor the dynamic change of groundwater, explore the groundwater buries condition in source district, analyze changing process of groundwater, confirm the hydrology and geological parameter, probe into the groundwater resources estimation method, and research precipitation, surface water, groundwater "three water" transformation rule and relation between groundwater bury depth and ecological environment. combining the new situation of environment change of the district, studying water resource change of source district and strengthening the work of ecological environmental protection.

3.2 Feasibility of setting up groundwater monitoring system of riverhead district of the Yellow River

With the implementation of national west development strategy, change of economy, traffic, living condition in the riverhead district of the Yellow River created the condition for the network construction of underground well progressively and groundwater monitoring. In the project of new "*Yellow River Basin Integrated Planning*" development use and conservation planning of the Yellow River Basin groundwater, based on groundwater exploitation and protection requirements, put forward groundwater monitoring system framework and content, make overall implementation suggestions. The project of "Yellow River basin Longyangxia upward integrated planning", combined with the economic and social development planning, gives full consideration to water save and life and ecological water demand, brings forward the river ecology base flow and runoff control index. It is necessary and feasible to establish groundwater monitoring system of the Yellow River source region from the view of Yellow River management plan.

4 Main contents of setting up Yellow River riverhead district groundwater monitoring system

4.1 Construction objective

According to the Yellow River riverhead actual conditions and relevant important national groundwater observation well distribution principles, construction aim is to set up groundwater observation well network with the density of 1 ~ 2 wells each 1,000 km^2 in the basin of Ruoergai, Xinghai – Tongde – Zeku, Yueguzhonglie three basins, to build the automatic monitoring system of monitoring groundwater water level, water temperature, water quality regularly, to realize transmit real time information to responsible department, to analyze and forecast groundwater accurately and dynamically, and reach the level of the same period of developed country basically.

(1) Prospective: To predict the demands on the groundwater monitoring due to environment change and socio – economic development.

(2) Advance: To follow the latest international development of groundwater monitoring technology closely, adopt advanced means and apparatus, improve the level of monitoring science and technology.

(3) Stress emphases: To construct according to the principle and objective of constructing national – level key groundwater observation well.

(4) Suit measures to local conditions: To establish groundwater monitoring station network which is reliable, economical, practical and compatible with national water conservancy development plan with the villages or residential area as the well position.

4.2 Monitoring center and sub – center site selecting

According to the detailed conditions of the source district, 3 sub – centers of groundwater monitoring management should be set up in 3 basins respectively. In view of the local special geographical position and easy to monitor, the sub – center of Ruoergai basin can be set up in the hydrometric station of Maqu, that of Xingde – Tongde – Zeku basin can be set up in the hydrometric station of Tangnahai, that of yuekuzhonglie basin can be set up in the hydrometric station of Huangheyan. Center of monitoring can be set up in the Lanzhou city which is responsible for groundwater monitoring management of the whole riverhead district.

4.3 Groundwater observation well network layout

Groundwater of riverhead district is not exploited and utilized dramatically. Decline of the groundwater water level mainly results from the reason of temperature rising and precipitation reduction. It is analyzed that the distribution of groundwater water level drops is even. So, according to the density of key observation well in our country, considering actual traffic conditions, living condition and villages distribution of every basin, setting up well network near the villages can basically meet the requirements of considering both upstream and downstream, left and right bank, and uniform distribution, can satisfy the purpose of analyzing and researching change of groundwater. On the basis of surveying and studying on the spot, through comprehensive analysis, 19 wells can be lay in the basin of Ruoergai, 17 wells lay in the basin of Xingde – Tongde – Zeku, 18 wells lay in the yueguzhonglie basin. There are 54 wells altogether, which can meet demands of the system construction basically.

4.4 Construction of groundwater observation wells and rooms of well

4.4.1 Observation wells

Design of the groundwater monitoring station (well) structure should be based on the geologic map of hydrogeological. Structural design accords with the automatic observation of the water level, reaches the requirement of installing automatic monitoring instruments and water level gathering, and accords with the demands of national – level key groundwater monitoring station operating for no less than 20 years.

4.4.2 Rooms of monitoring station(well)

Rooms should be designed according to nobody on duty, firm and practical standard. It is used as a site of protection and management for groundwater observation wells, monitoring instrument and information gathering and transmitting equipments.

4.5 Groundwater monitoring information system

4.5.1 Data collection, transmission, receiving, processing system

Type chosen of instrument equipment and auxiliary facility should follow the practical, reliable, advanced principle, realizing water level monitored automatically, monitoring message can be gathered, transmitted, received and processed remotely. Four levels operation management include State Information Center, Lanzhou center, sub – center (Maqu, Tangnahai, Maduo), groundwater monitoring stations. On this basis, groundwater monitoring information syntheses process application database system should be built up adopting advanced means and technical equipments.

After the system is built up, it can be guaranteed that the information gathering station sends groundwater information to sub – center, monitoring center and relevant administrative departments of higher level on the same day through automatic monitoring instruments. Transmission means can choose wired or wireless according to the possession condition. Wire transmission means rely on Internet or LAN. Satellite (like no. 2 Feng Yun) communication should be chosen by wireless.

The structural frame of syntheses process and analysis assessment system can be divided into three levels: Man – machine interface, system operation layer and system support layer. System operation layer intercource with decision analyzing personnel and policymaker through man – machine interface. Under the support of databases, model, method, knowledge, figure, picture of system support layer and analysis function of system operation layer, information demands of each stage are analyzed. At present, it is possible that information function comes true for ripe communication and computer network technology . System operation layer is the core, which provides various necessary functions such as technological analysis, information receive process, database administration. Systematic information supports layer stores and manages all data of every sub – systems in the whole system.

4.5.2 Information database system

Groundwater monitoring information database contains groundwater monitoring information storage, information processing, output and operation service. The detailed content includes: groundwater real – time data and historical data accepting; information processing automatically; Setting up the modification, inquiry ,statistics, output system; Setting up the groundwater model base to calculate groundwater parameters and resource amount of various hydrogeological unit; improving the management software of database constantly, finishing the construction of the groundwater model and put into operation to offer support for appraisal of water resource, management and science decision – making.

4.5.3 Application service system

Application service system constantly will be improved after construction. to raise the scientific and technological level according to scientific development and demand. Applying geographical information system and network technology, the groundwater application service system of riverhead district will be developed, realizing inquires and analysis function visually. The system can predict and forecast, groundwater development and utilization situation, and offer the overall, high – quality service for water resource management of riverhead district and constructions of ecological environment.

5 Analysis of social and economic benefits

5.1 Social benefits analysis

The implementation of the project can improve the modernization level of groundwater monitoring of the Yellow River riverhead district. Setting up scientific management and multiple functional groundwater observation well network and information collection, transmission, process and prediction system offer dynamic information of groundwater for the related departments and reliable supports for researching hydrogeological environment change and transformation rules of precipitation, groundwater and surface water, ecological environment change of riverhead district. Implementation of this project will make groundwater well network construction of riverhead district distribute in a large scale and lay a good foundation for investigating the amount of groundwater resources in the future, for improving water resource appraisal, management, protection, and ecological environmental protection.

5.2 Economic benefits analysis

Implementation of this project will produce enormous economic benefits for water resource management of riverhead district, water conservancy engineering construction, environment geological calamity prevention, ecological environmental protection, groundwater development utilization, scientific research etc. It has the signification for managing surface water and groundwater, water quantity and water quality unifiedly; carrying on investigation appraisal, plan, water quantity regulation; making long term water supply plan, applying water – taking permit system; promoting the comprehensive development and utilization of water resource according to law, applying unified supervision and management on developing, utilizing and protecting; coordinating contradiction; supervising water – saving, and monitoring and limiting environment geological calamity and ecological environment deterioration caused by water level dropping.

6 Conclusions

The construction of the groundwater monitoring system of the Yellow River riverhead district will fill the blank of no groundwater monitoring in the riverhead district of the Yellow River, improve the modernation level of the groundwater monitoring. Monitoring and transmitting automatically of items such as water level, water temperature, water quality will improve the transmission ability of the real – time information of groundwater. It also establishes a good foundation for science and technological study in such fields as meteorology, hydrology, geology, environment, ecology, etc. It is important for "maintaining health life of the Yellow River".

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3D Graphics and Virtual Reality Applications in Decision Support System

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Abstract: This paper discusses the procedures of generating a 3D terrain visualization system which includes a basic GIS inquiry function, a navigation function and a dynamic change function. By using the WINDOWS XP system and Visual C + + 6.0, a pilot system has been established. The system can transform the DEM data into the 3D version in the screen and use aerial photographs or image data from the analysis procedure as a texture file in order to show photo – realistic details about the area. Through the control of transparency between two images, a dynamic change function can be realized. The 3Ds MAX software is used to make an active movie about the dynamic change. As a case study, the Yellow River Delta is used as the study area in order to show the past and present situation of the area and simulate the change due to regulation of the area in the time.

Key words: DEM, 3D terrain, OpenGL, 3D coordinates query

1 Introduction

"Magnanimous" and "Real Time" are characteristic for dealing with data in the hydraulics domain (Haixia Xin. 2005). These data provide the basis for the decision maker on flood control or catchment management and so on areas. How to show the physical phenomena, which correspond with the data, play an important role in making the right decision. The 3D (often 4D when time variation is involved) graphic model is an effective way for solving such problem. Till now, the real time tracking of results from the water resources analysis are represented by figures and 2D maps, but this way lacks direct and integral observations. Using time continuity of the 3D simulation system, the decision maker will be given the inspiration so that the time of making a decision will be reduced. Especially, the application to flood emergency has its superiority, obviously. The 3D model is the first step for the 3D simulation system. The model can give people the feeling of walking into the real world that can supply the different versions of the critical area. The objective of the DSS in the Yellow River Delta is to help the decision maker understand the effect of regulation on the change of the area and try to explain what will happen in the future when some kind of measures are applied to the area. If in the system, the decision maker can see the changes in the distribution of landuse and know the reason why these changes happen, their mind will be clearer when they make a decision in the area. Because they will know what will be good for the area and what is bad for the area. The DSS for the Yellow River Delta has to let the decision maker have a clear and direct impression of the history of the critical areas so that they can make a right decision for the future. The 3D terrain visualization system is developed from the basic layer using VC + + as its developing language combined with the OpenGL. This system combined with geographic information system (GIS), visualization, information search, and simulation together with 3D virtual reality (VR) can service the decision support. By using the digital elevation model (DEM), the system can show the 3D virtual environment on the screen. Users can navigate through the virtual landscape freely to view their world from different vantage points.

2 Data description

2.1 DEM

If we want to model some natural landscape, we should have the elevation data of each point in the coordination of this area. Because these points include the basic geographic information, using these data we can model a critical area without distortion. But, in reality, we can not simulate every point of the area, so the points' selection is important in this part. The normal method is to select points by using grid and select a point every 1 m, 10 m or 1,000 m. According to these points, we can simulate the area easily. The ASCII version of the DEM data is very simple and is editable with any text editor. A file starts with a short header describing the location and the size of the grid. Following the header, elevation values read from left to right, starting with the northernmost row. The following six lines form a valid header:

```
ncols        10
nrows         8
xllcorner 637,500.000
yllcorner 206,000.000
cellsize 500.000
NODATA_value  -9,999
```

The first two lines ("ncols" and "nrows") specify the size of the grid. The third and the fourth lines specify the horizontal ("xllcorner") and vertical ("yllcorner") coordinates of the lower left corner of the grid. "cellsize" is the distance between two adjacent rows or columns. The last row ("NODATA_value") is optional and specifies a value considered as "not valid". This kind of format is the form that can be read into the 3D terrain simulation system. The DEM data can be prepared into this format by using ArcGIS. DEMs consist of a sampled array of elevations for a number of ground positions at regularly spaced intervals. In the system, the DEM data use the regular grid model, i. e. arrays in the X and Y direction and the space between the two points is the same. The value in the Z direction means the elevation of the terrain, so that a matrix of the elevation can be generated. The elevation of the points in the matrix can be calculated by the number of columns, rows and the head file as be mentioned before.

2.2 Texture file

The texture file contains the image which is used to map on the surface of the virtual 3D terrain. It is more or less like pasting the image onto the surface. In the 3D terrain visualization system, there are two methods to achieve the texture files.

2.2.1 The analysis data texture file

The analysis data means contains the 2D images which are exported from the model running, for example, the landuse maps which prepared from the ArcGIS, and the analysis images from the remote sensing process. Any kinds of 2D images can become the texture files and then pasted on the surface of the virtual terrain.

2.2.2 The elevation based texture file

In the system, the elevation data of each point in the DEM data has been saved in the cache of the computer. By the function of the depth testing, every point's elevation data will be classified so that the user can give the different ranges of elevation the different kinds of texture file materials. For example, the 20% of the maximum elevation is water; we can paste the water picture onto the surface of the virtual landscape. Therefore, the elevation below 20% of the maximum elevation will be given as the water layer. The method can be used into simulate the process of flood routing.

3 System structure

As the flow chart (Fig. 1) shows, firstly, the DEM data has to be prepared then transformed to the 3D version of the landscape. The different texture files mean the images of the different periods about the area have to be prepared too. Secondly, the texture files should be pasted onto the 3D virtual landscape surface in order to generate the different scenarios for the area. Then, the navigation part should be added to the different scenarios which mean that the users can control the landscape by using keyboard and mouse in order to realize the translation, zoom in/out and rotation of the landscape. At last, the different scenarios can be shown in a dynamic change by using the technique named image morphing.

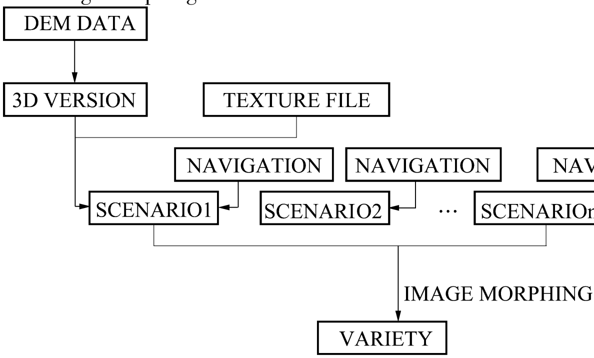

Fig. 1　System structure

3.1　Data input

This part corresponds to the function of input the DEM data into the system. As mentioned before, the input data has to be prepared into the terrain matrix format. The Fig. 2 is shown below.

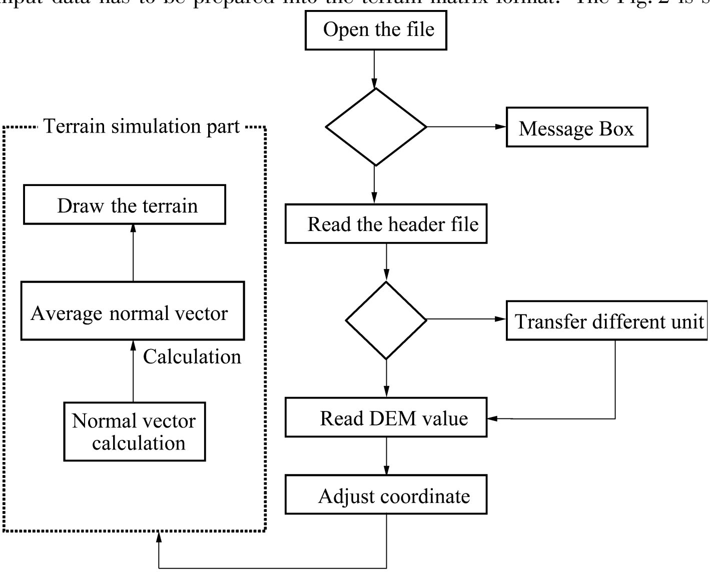

Fig. 2　Data input

(1) The procedure "Read the header file" means read the header file as been mentioned in the DEM data preparation part.

(2) The procedure "Transfer different unit" means unify the different coordinate unit into meter. For example, if the DEM data has the unit of degree, they should be changed into meter in

this procedure. So, in this system, if the unit of the original data is not meter, we have to give the cellsize the value less than 1.0. The transformation is not very accuracy, so the DEM data should better use the projection that has the linear unit meter.

(3)The procedure "Adjust coordinate" means that move the 3D terrain model into the center of the screen. This step is finished in the circulation of reading DEM value.

3.2 Terrain simulation

This part is including 3 parts: normal vector calculation, average vector calculation and draw the terrain. The first two steps are used to adjust the right reflection reaction of the light point in order to generate the correct shadow for the 3D version feeling. In the terrain simulation part, the system uses the OpenGL function to draw the terrain. The system uses the function GL_TRIANGLE_STRIP to draws a connected group of triangles. It uses the algorithm to connect the vertex of the triangle in an anti-clockwise way, and when the next point has been identified, the algorithm will be drawing the other triangle automatically. This mechanism will save a lot of time. In the system, the function is realized in the double circulation which covers the whole matrix of the surface, the steps are shown below(Fig.3).

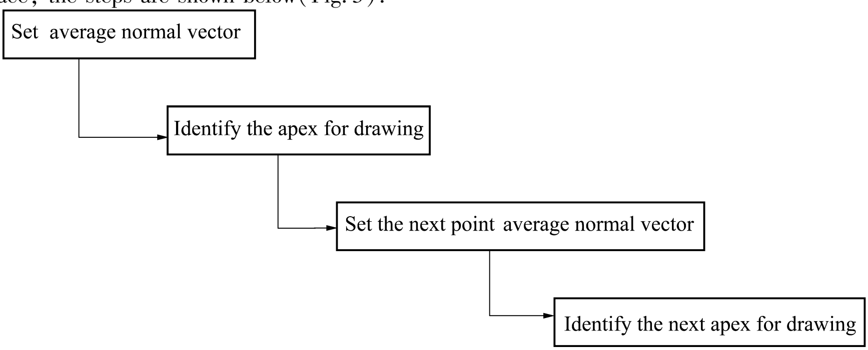

Fig.3 Terrain simulation

After that the triangles which approach the curve surface can be drawn, the illustration below shows the situation in the 3D space(Fig.4).

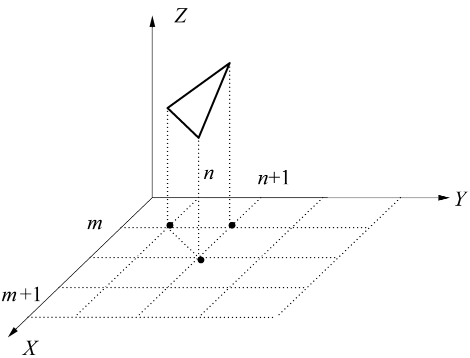

Fig.4 Triangle in 3D space

3.3 Texture mapping

The key point of transferring the normal image file into the texture files which can be accepted by the computer is to identify the kinds of the image (luminance, RGB RGBA), the width, height of the image, what kind of texture file it is and the coordination of the texture file. The procedure of the texture mapping in OpenGL is includes 4 steps.

3.3.1 Identify the texture files

The attribution of the texture files have to be identified, for example, the texture files are 1D or 2D image and the width, height of the texture files and so on. There are 6 kinds of image format can be loaded into the system: TGA, TIF, BMP, GIF, PCX, PNG. In this step, the attribution of the images, such as the width, height, colour format have to be achieve in this part.

3.3.2 Texture filtering

Generally, the texture files have the shape of rectangle or square. However, when these kinds of shape mapping on a curved surface or a polygon objective and transfer the coordination into the screen coordination, the texels (pixels of the texture) is difficult to match the pixel of the image on the screen. Texture filtering is the method used to determine the texture color for a texture mapped pixel, using the colors of nearby texels (pixels of the texture). In short it blends the texture pixels together by breaking them up into tinier pixels.

3.3.3 Mapping method identification

In this step, the method for the texture files blending with the colour of the objectives has to be identified in order to get the correct colour result of the texture mapping.

3.3.4 Draw the scene

Identify the texture coordination and the objective coordination in order to paste the texture file to the accuracy position and then draw the scene to see the objective with the texture files.

3.4 GIS inquiry

The key point of this part is to locate the object that is chose by the mouse click. The function can be achieved by the OpenGL select mechanism. The function named gluPickMatrix(GLdouble x, GLdouble y, GLdouble del$x$, GLdouble del y, GLint * viewport) is in charge of selecting areas. x, y Specify the center of a picking region in window coordinates. del x, del y Specify the width and height, respectively, of the picking region in window coordinates. *viewport* Specifies the current viewport.

For example, when the mouse click down, on small area will be selected around the click point, and if one point which includes the GIS information, it will be selected and saved the information in the memory. According to the mouse clicking, the system should find the responding DEM data and then export the coordination data. The effect is like the Fig. 5 showing: when the point has been identified, the coordination of the point can be export in the message box.

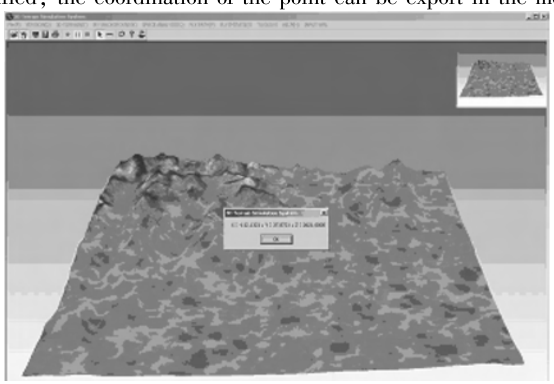

Fig. 5 Coordination inquiry

The distance between two points can be generated from the system, the mouse click twice and saved the two records of the points, then use the formula like below to calculate the distance two points.

$$d_{i,i+1} = \sqrt{[(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2 + (z_i - z_{i+1})^2]^2}$$

$d_{i,i+1}$ means the distance from the i point to the $i+1$ point. The effect is like the Fig. 6 showing:

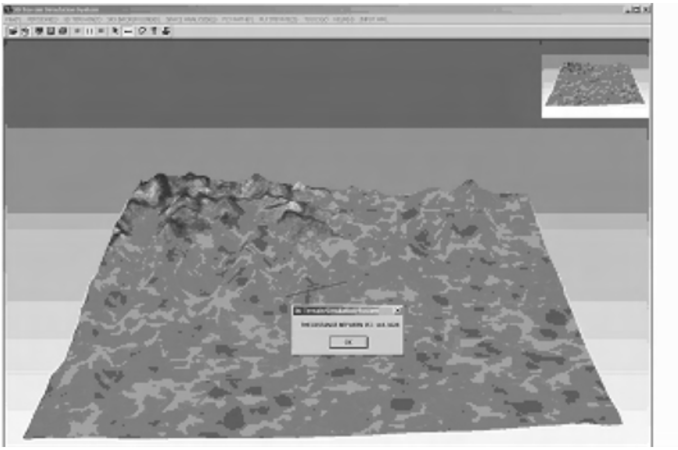

Fig. 6 Distance inquiry

3.5 Dynamic demonstration

The purpose of this part is to show the different scenarios of the critical area and show the changes in a dynamic way so that the users can see the changes during the period. This function can help the decision makers to realize the area in the coordinate of time. Therefore, they can understand the changes in a more direct way. With the help of the analysis part, the decision makers can have a clear idea about the reason why the changes will happen. It will help them to make a right decision to manage the area. This function of image morphing is finished with the help of Visual Basic. Due to the convenience of the function AlphaBlend which help to control the transparency of the images, the function of dynamic change has been support.

3.6 Human – computer interaction

This function helps the users to check the virtual 3D terrain from the different angles of view. The OpenGL supports the viewpoint conversion, projection conversion and viewport conversion functions in order to realize the movement on the terrain, for example, the translation, rotation and zoom in/out and so on. The users can use their keyboard and mouse to active the relevant movements in order to realize the human – computer interaction.

4 Case study

4.1 Study area

The Yellow River delta means that the Yellow River silt up for many years in the estuary extends(Fig. 7), swinging, changes course then made a fan – shaped region. It is located between north of the Shandong Province which named the Laizhou Gulf, and Bohai Gulf. Its scope approximates from east longitude 118°10′ to 119°15′ and from north latitude 37°15′ to 38°10′. In the custom, according to the difference of the age and the concrete geography condition, the delta has been divides into the old delta and the new delta. In the thesis, the system will focus on the new delta. The new delta refers take the Yuwa as an apex, north from the river mouth, south to the Songcun Ronggou, that forms the ditch fan – shaped region, area approximately 2,400 km^2. Mainly, this area is manmade to change the direction of the Yellow River in order to help the development of the river mouth economy, protect the agriculture and control the flood.

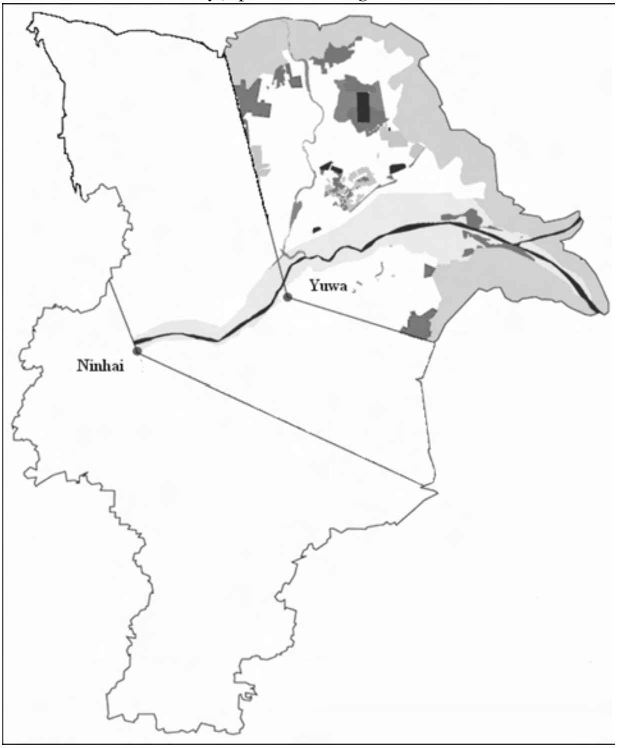

Fig. 7 The Yellow River delta

4.2 Input Data

The input data has been distinguished into two parts: DEM data and texture file.

4.2.1 DEM data

The data has been collected from the Yellow River Committee, the general description of the DEM data is like below(Table 1, Fig. 8).

Table 1 Yellow River Delta DEM Data

Coordination System		WGS_1984_UTM_ZONE_50N
Resolution		90 m
Coordination		NO DATA
ASCII	Column	2,401
	Row	1,841

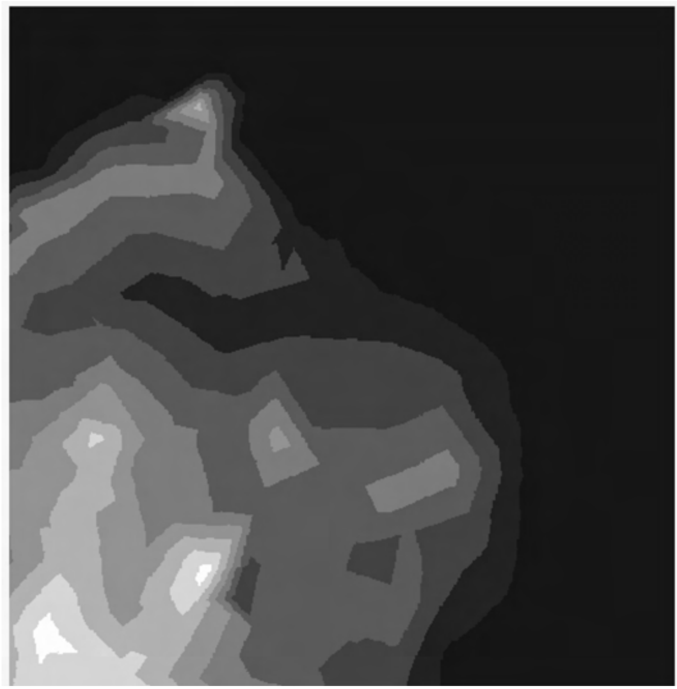

Fig. 8 Yellow River Delta DEM Data

4.2.2 Texture file data

The texture files used into the system is the landuse maps (Hui Ma, 2007), they are the years for 1986, 1996, 2001 and the future. The future map is predicting base on two kinds of situations: Drought and Regular flood. According to the regulation that the Yellow River Committee formulate, the discharge for the yellow river delta will be adjust to about 20 billion cubic meters (Wu Dong, 2007), if the discharge is less than 16 billion m^3, we identify the year is drought. By check the yearly discharge, we found that the discharge of the 1986 is a little bit higher than 16 billion m^3, and the yearly discharge for the 1996 is 19 billion cubic meters. Base on the two years landuse map, we generate the prediction for the future landuse maps in the drought and regular flood year. The maps focus on the change of the forest and the vegetation along the outlet of the delta. The maps are like below(Fig. 9 ~ Fig. 11)

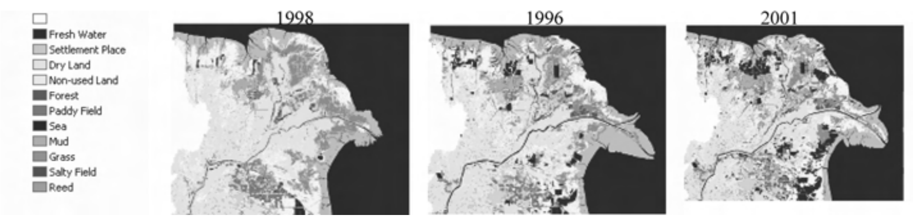

Fig. 9 Texture files

(1) Future, Drought:

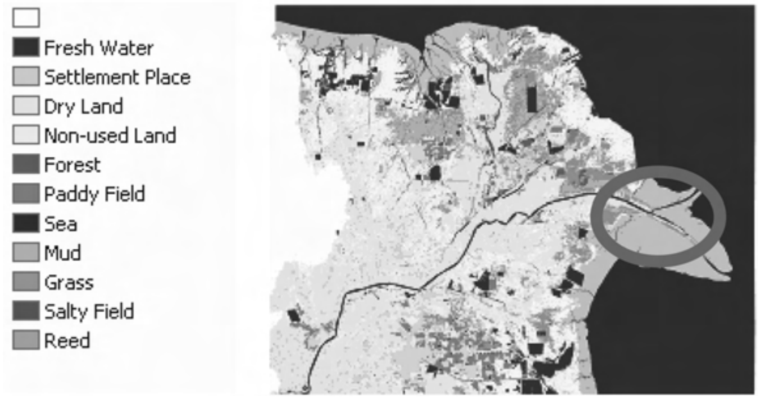

Fig. 10　Future landuse map

(2) Regular flood:

Fig. 11　Future landuse map

4.3　Results

With the help of the Movie Maker, a short animation can be generated. The animation is constructed by the different scenarios' images which include the change of the landuse maps from the 1986 to the future that is separated the drought and regular flood periods. From the animation, the users can see the changes for the different scenarios clearly. The animation can be paste as the texture files on the 3D surface. By the texture mapping technique in the 3DS MAX the animation texture can register the 3D landscape perfectly and can be export as the AVI file in order to have a more active impact to the users. By checking the dynamic change, the users can make assumption of the reason why the change happened. In this case, due to the yellow river flood, the fresh water can be supported to the delta, so, when the regular flood happened, the fresh water can be transformed to the vegetation, especially the plant grown near the riverbed. Therefore, the forest and the reed near the river, which represented by the dark green and the pink, can be extended in the maps. However, when the drought year comes, the fresh water is not enough for the vegetation in the delta so that the area of the forest and the reed will be reduced in this year.

The graph below (Fig. 12) shows the 3D virtual landscape with the texture file of the aerial photograph of the Yellow River Delta. From the result, we can see the 3D view of the area and with the function of navigation; the users can control the virtual landscape by the keyboard and the mouse.

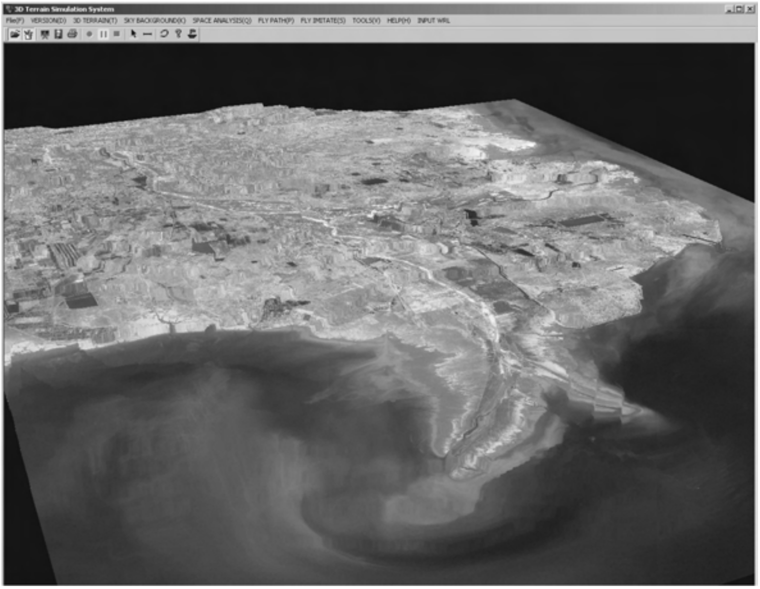

Fig. 12 3D Virtual landscape of the Yellow River Delta

5 Conclusions

(1) The application of computer graphics in the water related area can help the scientist to visualize the result from a complex simulation model. By data visualization, the decision makers will understand the results more clearly and directly. It will help the people to digest the information from the model simulation and transform them into knowledge layers for generating a better understanding of the physical world. This application can also show the data in a 4D version, which can display the change for every time frame. It will help people to see backwards into the history and for exploring measures order to predict what the future could be like.

(2) The function of the OpenGL library can realize the GIS inquiry in a 3D space, which means that the 3D space analysis can be done in the virtual terrain. The basic information of the 3D space, for example, the coordinates, the distance, the slope can help the scientist to do the research work in the virtual environment.

(3) The interaction with people is the most important part in scientific visualization. In the 3D terrain simulation system, the interaction means to zoom in/out, rotate, translate and scale changes in the virtual terrain, which can help people to understand the area. However, the interaction with people can be extended to more aspect. For instance, changing parameters in the model and then visualize the simulation results is very important for people to understand the sensitivity and action of the parameter, which also is a kind of interaction with the people. The field of hydroinformatics is very much into data visualization in order to represent the complex physical features in a more active way so that people can understand and "develop a feel" for model results.

(4) Virtual Reality is a powerful tool in data visualization; it gives a whole new way for people checking 3D space and getting information. It enhances the feeling of vision which will motivate the people to learn the world. By the interaction technique in virtual reality, people will be the core in the environment; they can change the virtual physical world and check the result of the actions. Moreover, if the affection is lethal, they can get the feedback in the virtual environment, not worrying the bad consequence in the real world.

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Applications of GIS in Two – dimensional Water – sediment Mathematical Model

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Abstract: The two – dimensional water – sediment mathematical model is an important tool in the area of water dynamics simulation and sediment changes in space – time factors. Based on the lower reaches of the Yellow River Huayuankou to Lijin,the GIS applications in data acquisition ,data analysis and visualization of calculated result are described in this paper in detail. As an result, GIS technology offers geographical information data for 2D water – sediment mathematical model, such as lines and DEMs, etc. , it has also offered the abundant symbol and played up tools for the calculated result. In addition, the integration of mathematical model becomes possible in the use of Visual Basic and COM – GIS technology.

Key words: GIS, water – sediment, mathematical model, integration

1 Introduction

Mathematical model of two – dimensional water and sediment uses hydrodynamic methods to simulate water and sediment movement of water flow field. In addition to its core – method of calculation, border data entry and expression of calculated results is an important part of the model. And the model is also concerned on data acquisition, data analysis, data management, visualization of scientific computing and other fields.

GIS as the effective means that integrated GIS data collection, management and analysis can meet requirements of water and sediment mathematical model in the data input and output. It is outstanding in more accurate geographical positioning, more powerful spatial data analysis and the more traditional mathematical model of water and sediment data management. The following on these applications were discussed.

2 Applications

2.1 Geographic data collection

Geographic data collection in two – dimensional water and sediment mathematical models includes terrain, features and regional border of calculation area. Terrain means underwater topography and land elevation, while mainly refers to Regarding Production, spatial information of embankment and vegetation, building time, land – use type, etc. And borders mainly refer to water lines, island borders,embankments, Lake dam border. These data is an important basis for judging the border information in mathematical models of water and sediment and is one of the most indispensable tasks which ensure the accurate simulation of the actual physical process by mathematical models.

GIS utilizes satellite image s , GPS data , CAD or paper map collect data. The image data of the satellite can reflect the land use pattern and river tendency change in time. GPS provides more accurate data for the three – dimensional coordinates in space information. CAD and paper map are the control guidance project of obscure time changes and the main data sources of training works and embankments.

In addition, the geographical data with different source often adopt different coordinate system or scale, if these digital maps are used in the same project, must carry on the projection again , namely change from different systems of coordinates into the same system of coordinates.

2.2 Geographic data management and analysis

Geographic data management analysis includes attribute data management and spatial data analysis.

2.2.1 Attribute data management

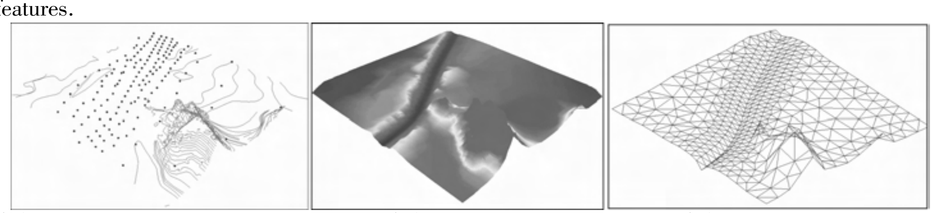
The attribute data in GIS usually use relational database management, which is composed of representatives from a number of mutually independent tables, associated with their counterparts of spatial data to facilitate data entry, query, retrieval, and output operations. For example, a land – use attribute table with ID, type, size field, elect to participate in land area more than 10 m^2, thereby simplifying the model and improve efficiency; or under different types of land use with different roughness. These are the important applications in attribute data management in the water – sediment mathematical models.

2.2.2 Spatial data analysis

The spatial data analysis in the calculation of 2D water – sediment mathematical model includes spatial data interpolation, line profile analysis, aspect analysis of the surface curvature and slope analysis.

The mathematical model of two – dimensional water – sediment data sources are elevation points or contour lines. How to calculate the whole terrain and acquire elevation information from is an important application in spatial data analysis in two – dimensional water – sediment mathematical model. Spatial interpolation methods are as follows: Construction of Triangulation, Inverse Distance Weighted Interpolation, Thin – plate Spline and Kriging Interpolation, etc. Different methods are suitable for different data sources and requirements.

Fig. 1 demonstrates the process of the two – dimensional computational grid from contour lines or terrain elevation data using the triangular irregular network method which have the advantages over the flexible input data sources , such as points, contour lines even with the area elevation information elements. In addition, it also allows the user to focus on the dramatic changes in terrain features.



(a) Contour lines and elevation points (b) Digital Elevation Model (c) Two – dimensional grid

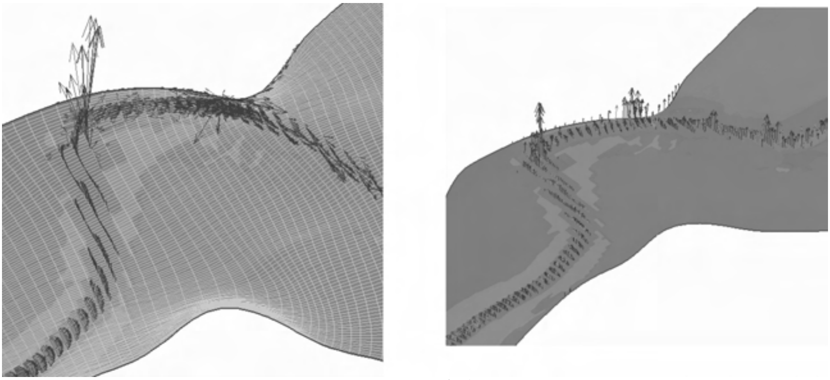
Fig. 1 Spatial data analysis

Compared with the triangular irregular network data, irregular grid in surface analysis can reach higher efficiency, which are widely used in extracting water network.

2.3 Scientific visualization

The result visualization plays an important role in project analysis. For example, the visualization technology is used to simulate the flow, similaring, it can be also used in the Large Scale prolonged flood.

According to the data types, calculated results can be divided into scalar and vector; depending on the type of distribution, calculated results can be divided into two – dimensional and three – dimensional data. 2D vector field usually have two components (V_x, V_y), indicating the direction and size with different angles and the length of the arrows. Fig. 2 show the state of flow in 2D and 3D view.



(a) Two – dimensional velocity field view (b) Three – dimensional Velocity field view

Fig. 2 Two – dimensional and three – dimensional velocity field view

2.4 System integration of the two – dimension water – sediment mathematical model

The purpose of mathematics model integration is to offer a friendly interfaces to users, including database management, data analysis and the integration of model calculation.

Traditionally, the fore and after handling and model calculation of two – dimensional water – sediment mathematical model used to employ different procedures and different software, causing much inconvenience to the user. For example, use of CAD data acquisition software, professional output data visualization software, and the model is used Fortran procedures. Therefore, the use of existing Com – GIS (ArcObjects ,MapObjects, MapX) , and the visual programming tools (Visual Basic,Visual C + + , etc.) in integration of mathematical model is very necessary and effective.

Fig. 3 is the development of the visual system using Visual Basic 6.0, which has integrated Fortran95 development of two – dimensional water – sediment calculation module, and combined with geographical information technology.

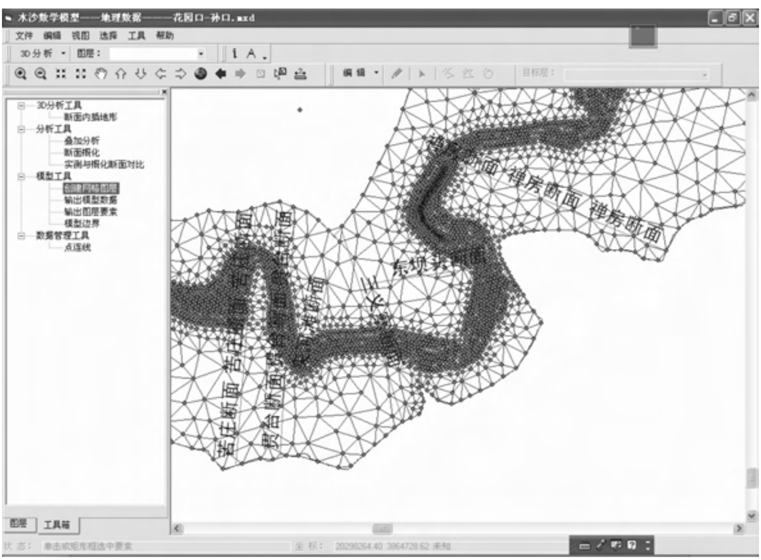


Fig. 3 Integrated mathematical model of water and sediment Visualization System

3 Conclusions

Input and output data of the traditional two – dimensional water – sediment mathematical model often adopt text files ,both data editing and visualization are require substantial manual. After the introduction of GIS, data visualization and editing of boundary lines become more convenient ; Secondly ,the spatial data analysis tools offered by GIS products make the spatial data interpolation become more efficient and reliable; Moreover, GIS offers the abundant symbol, rendering and 3D visualization utilities for scientific calculated results, establishing a good platform foundation for the propaganda of mathematics model.

Most of two – dimensional water – sediment mathematical model programs use Fortran compiler, However, because of the difficulties in integration with the extensive use of the Visual Basic, Visual C + + or other object – oriented programming language, therefore, the applications of Com – GIS in the integration of water – sediment mathematical model have a better balance between the calculation efficiency of Fortran language and the predominance of object – oriented language in the visualization interface. Certainly, the integration of two – dimensional water – sediment mathematical and GIS, involving database , software engineering , Component object Model, and other fields, it will need to do a large number of work to achieve a real sense of "seamless" integration.

Application of the Xin'an River Model Combining with Snowmelt Runoff Model in the Source Area of the Yellow River

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Abstract: In view of the characters of the source area, the method is to combine Xin'an River model with snowmelt runoff model and apply to the basin of Bai River. The basin is divided into several sub-basins. Firstly, distinguishing snowfall from rainfall by temperature in every sub – basin, then combine model is carried on the rainfall – runoff calculation. Using the Muskingum method performs channel routing. Thus, the method is viable.

Key words: Xin'an River model, snowmelt runoff model, source area of the Yellow River, BaiRiver basin

1 Preface

Snow occupies a very important position in the water resources and the water environment in our country cold area. In spring even summer, snowmelt runoff is main part for runoff of the area. The accumulated snow overlays specially ground so that producing and routing characteristics of snow is very greatly distinct normal regulation of the region, and influence factor is also different. So, for this area, the result simulated by only one hydrology model is invisible. This paper will combine Xin'an River model with snowmelt runoff model to study the hydrology simulation of the cold area, take the Bai River basin in source area of the Yellow River as an example.

2 The model introduction

2.1 Xin'an River model

Xin'an River model is from professor ZhaoRenjun etc[1]. in Hohai university. It has got a widespread application in the local forecast flood.

Each parameters of Xin'an River model contain certain physical meaning and math expression type, but it is not strict mathematics, as a result it discriminates mathematics and physical model.

Considering to ununiformity of rainfall and basin, the model is dispersion. The whole basin is divided into some sub-basins and calculate runoff process of every sub-basin, then gets runoff process of the whole basin by add runoff of every sub-basin.

The sub-basin hydrology simulation:

(1) Evaporation is divided into three layers: up, lower and deep.

(2) Repletion of storage.

(3) Surface, soil and underground runoff.

(4) Surface and river – net routing.

2.2 Snowmelt runoff model

The calculation model is a snowmelt model which is established to meet the local condition according to the snowmelt character. It is built up base on the basic snowmelt runoff model theory.

2.2.1 Basic data input

This model's principle and form are simple, the parameters are rather few, and the require about data is rather low, the data which need to input are only precipitation and air temperature. The average air temperature and precipitation data are the measured value and the calculated value which obtained from the anterior inquiring formula.

2.2.2 The partition of rainfall and snowfall

Precipitation can arrive the underlying surface by rainfall, snowfall, mixed rain and snow form and so on. There are close relations between precipitation form and air temperature, the two critical air temperature T_1 and T_2 which is used to differentiate the precipitation form can be got by analyzing the air temperature and the other related precipitation data; the precipitation form of each sub – river is judged by critical air temperature; when the air temperature $T(t) < T_1$, the precipitation form is snowfall; when $T(t) > t_2$, the form is rainfall; when $T_1 \leqslant T(t) \leqslant T_2$, the form is mixed rain and snow. For the calculation model on daily period, who based on the general condition and reference values, the values of T are +4 ℃ and −4 ℃ respectively in this paper. Then, the snowfall $P_s(t)$ in the period can be ensured by different air temperature condition:

$$P_S(t) = \begin{cases} 0 & T(t) > T_2 \\ \dfrac{T_2 - T(t)}{T_2 - T_1} \times P(t) & T_1 \leqslant T(t) \leqslant T_2 \\ P(t) & T(t) < T_1 \end{cases} \tag{1}$$

in which, $P(t)$ is the precipitation in a period with a unit of mm.

Then the precipitation forms of the reference station in the sub – river are snowfall, it is need to do rainfall correction, and let the corrected precipitation as the actual datum. The correction formula as follows:

$$P'(t) = P(t) - P_S(t) \tag{2}$$

where, $P'(t)$ is corrected rainfall, mm; $P(t)$ is measured precipitation (uncorrected precipitation), mm; $P_S(t)$ is deduced snowfall, mm.

The snow cover in basin in period of time $S(t)$ is:

$$S(t) = S(t-1) + P_S(t) \tag{3}$$

where, $S(t-1)$ is prophase snow cover in river basin, mm.

2.2.3 The calculation of snowmelt

The snowmelt is divided into two forms by the different heat source of the snow absorbed: high temperature snowmelt and rainfall snowmelt. The high temperature snowmelt is the snowmelt caused by the raise of the air temperature, the rainfall snowmelt is the snowmelt caused by the heat come from the raining.

$$M = M_t + M_p \tag{4}$$

where, M is total snowmelt, mm/d; M_t is high temperature snowmelt, mm/d; M_p is rainfall snowmelt, mm/d.

The high temperature snowmelt M1 in the (4) formula is deduced by daily method:

$$\begin{aligned} M_t &= R_a \cdot (T(t) - T_K) \qquad T(t) > T_K \\ M_t &= 0 \qquad\qquad\qquad\quad\;\; T(t) < T_K \end{aligned} \tag{5}$$

where, R_a is gene of daily method, mm/(℃ · d); T_K is temperature of snow surface, ℃, it is preferred constant generally.

The rainfall snowmelt M_p is deduced by the follow formula:

$$M_p = 0.1(T(t) - T_K) \times P(t) \qquad T(t) > T_K \tag{6}$$

where, $P(t)$ is corrected precipitation, mm.

$P'(t)$ is deduced by consult corrected precipitation, is the actual precipitation; R_a is the model parameter; $T(t)$ is the average air temperature of the counted area, , its unit is ℃, it is can deduced by the air temperature of the reference station; T_K can take the constant $T_K = 0$; the other signs are same as before. The supposition of that the rainwater temperature equal to the air temperature implied in formula actually. Furthermore, M_t and M_p are the possible maximum snowmelt, which depends on the snow condition.

2.2.4 The calculation of the available snowmelt

The available snowmelt is the actual snowmelt. It is calculated by different condition: if the river basin snowmelt less than the possible total snowmelt M, the snow melt entirely, the available snowmelt equal to the river basin snowmelt ; if the river basin snow can content the total snowmelt M, the snow melt available snowmelt partly equal to M; the calculation formula is as follows:

$$M_S(t)\begin{cases} S(t) & S(t) < M \\ M & S(t) \geqslant M \end{cases} \tag{7}$$

where, $S(t)$ is river basin (desire to calculate area) snow, mm;

$M_S(t)$ is available (actual) snowmelt, mm.

The snow quantity take change after the available snowmelt is calculated. Known from before, when the river basin snow is less than the total possible snowmelt, the river basin snow is melt entirely; or, the snow will deduct the possible snowmelt. The remain snow is:

$$S(t)\begin{cases} 0 & S(t) < M \\ S(t) - M & S(t) \geqslant M \end{cases} \tag{8}$$

2.2.5 The calculation of outflow

The outflow is calculated by the characteristic of snow, the snowmelt run into snow cover in the form of liquid water. At first, it is supply the liquid water storage of snow cover. When the water storage content water – holding capacity of the snow cover, the last snowmelt is discharged under the effect of weight, and become the snowmelt outflow, it is the runoff yield.

Like the water – holding capacity of the soil, the water – holding capacity of snow is not equality, it is relate to the density of snow, the water – holding capacity of the relax new snow is big, and the water – holding capacity of the granular old snow is small, in this text, according to the snow condition of the river basin and the proportion of the snowmelt runoff to the total runoff, in the condition of not influence the precision, in order to simplified calculation, take the snowmelt is 0, it means don't consider the water – holding capacity of snow. Then the ability snowmelt is the runoff

$$R_S = M_S \tag{9}$$

where, R_S is snowmelt runoff in period, mm.

3 Model application and result analysis

Baihe is one primary – branch of the source area of the Yellow River between JiMai and MaQu, it flows through HongYuan and Nuoergai country in Sichuan Province from South to North , then joins in the mainstream of the Yellow Rive in TangKe countryside, it is about 269.9km long and 537 km^2, locating between north latitude 32°10′ ~ 33°28′, east longitude 102°08′ ~ 102°58′. TangKe station is hydrological control station of Bai River in the downstream, about 6.3km from exsit of Bai River.

In this paper, author adopts hydrological modulet of ArcView to divide sub – basin, and chooses measure day flux data from 1981 to 1991 (lack 1985).

3.1 Model application

Exit runoff of TangKe station is made up of snowmelt and rainfall runoff, Snowfall is about from October to March or April of the next year, sometimes being May or June. Because of the inaccuracy of day air temperature data, which is convert of average month air temperature, so in model calculation, the time of snowfall will be centralized from November to May of the next year. The simulation method in this paper is: in each sub – basin, it adopts snowmelt runoff model and snowmelt – quantity is net storage when basin is snow, while it adopts Xinanjiang model when being rainfall. Then performing channel routing to exit of Baihe basin.

In Bai River basin measures oneself is so inaccurate, station is again so little, that adopting day data in model simulation and verification. There is ten years day data of the Bai River basin in all.

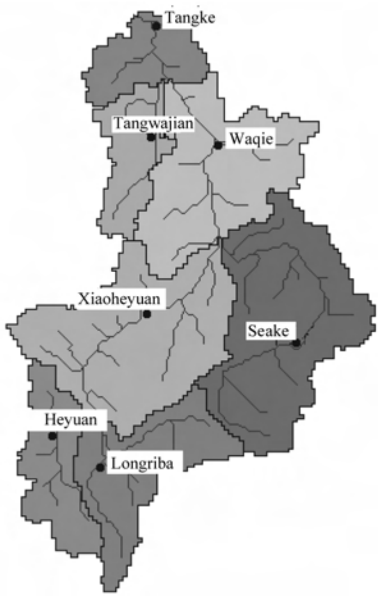

Fig. 1 sketch map for the Bai River basin **Fig. 2 Sketch map for sub – basins of the Bai River basin**

According to the requirement, it is better to choose six years database as the model simulation data, the other four years as the model verification data. The results of simulation and verification see Table 1. Table 1 shows that: among six times flood simulation, the error range of runoff is 0.69% ~ 15.5% and less than 20%; the relative error absolute value of flood peak is 0.1% ~ 18.4%, deterministic coefficient is between 0.76 and 0.9. and five times simulation is above 0.8.; among four flood verification, the range of relative error absolute value of runoff depth is 6.16% ~ 19.14%, which is a little bigger, and the flood peak is 3.9% ~ 8%, deterministic coefficient is between 0.72 and 0.85, and one verification is above 0.8. Both simulation results and verification results are quite satisfactory.

Table 1 Model simulation and verify result statistics

	Year	Measured runoff (mm)	Calculated runoff (mm)	Runoff relative error margin(%)	Measured flood peak (m^3/s)	Calculated flood peak (m^3/s)	Runoff relative error margin (%)	Deterministic encoefficient
Model simulation	1986	16.025,1	17.427,2	−8.75	378	327.4	13.3	0.76
	1987	17.358,9	18.643	−7.4	387	334	13.6	0.84
	1988	17.588,2	17.708,14	−0.69	299	298.6	0.1	0.90
	1989	26.549,8	25.479,3	4.03	466	379.8	18.4	0.86
	1990	23.357,8	20.334,6	12.96	467	402.4	13.8	0.89
	1991	16.926,7	14.301,6	15.5	201	194	3.4	0.81
Model verification	1981	23.804,8	25.270,3	−6.16	583	635.2	8	0.72
	1982	24.832	21.430,5	13.69	300	288	3.9	0.85
	1983	36.248,4	29.309,4	19.14	554	505.5	8.7	0.79
	1984	24.405,2	22.198,6	9.09	420	448.2	−6.8	0.74

3.2 Applied result analysis

It can seen from the model results, runoff is basic consistent but total have a little to be partial to small, and the flood peak is widespread to be partial to small. The reasons are as follows:

3.2.1 Data problem

The data problem is the main reason that produces an error margin in this paper. In Baihe basin measures oneself isn't so strict, station is again so little, that the data is rough, for example day – runoff data has only one list in the some whole month, and there is no any measureing hydrology data in percent 62.5 areas, a effective method is to get hydrologic data of none – data regions from other regions with data by the law of elevation. It is strictly linear without time change and space change. Obviously this method increased uncertain of data.

Worthy of pay attention to air temperature data here, here is only data of month, because of having no air temperature data of day, the paper applies converted data, so this will affact caculation of snowmelt runoff, that results in runoff small in beginning months of every year. Influence the accuracy of the certain coefficient.

Correlative temperature gene is change with time and space, but because of lacking data gene is not change, data is same in whole course. This is one part to impact accuracy.

3.2.2 Model structure

The model is general predigestion to the realistic course, turning process will exist a certain error margin. The model that gathers a total type or a distribute type regardless, just is the different degree turns all just on the space. In the paper the whole basin area is 5 374 km^2, only divided into 7 sub – basins, the general predigestion turns rough, this may also be cause the result deviation.

4 Conclusions

It considers to difference and commonness of rainfall-runoffand snowfall – runoff in Xin' an River model with snowmelt runoff model. Rain and snow are also water but their characters are different, then runoff causees are also no same. Air temperature is an important facter to affect runoff type and crucial facter for snowmelt runoff. Thus, the paper adopts the mixed model which can be applicable for caculatating not only rainfall – runoff but also snowmelt runoff. Of course, this paper mainly studies cold area where the problem of lack of hydrologic data and exists, and this basin commonly has not weather data ,such as radiancy, wind speed etc.. So the model doesn't consider these factors at inside except air temperature. Although the result exists an error margin, the model is suitable for day data simulation. It shows that this mixed model is visible.

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Assessing the Ecological Environment around the Yellow River Delta Area by RS and GIS

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Abstract: As one of the most active regions with changing land and sea boundaries, the Yellow River Delta has a rapid and complicated evolution of its ecological environment. So it is very important to evaluate the ecological environment in the Yellow River Delta.

In this paper, Remote Sensing (RS) and Geographic Information Systems (GIS) are used to build the factors index system for ecological environment synthetic evaluation. The ecological environment synthetic evaluation (EESE) model was applied to analyze the conditions and spatial differences of the ecological environment in the Yellow River Delta.

The research results have shown that dramatic spatial differences of ecological environmental conditions occurred in the Yellow River Delta. By comparing the status of 1986, 1996, and 2001, the trends in ecological environmental quality seem to have been better and more stable in the inland study area, but poorer along the coastal area because of the inappropriate land use, less water from the Yellow River and increasing industrial activity along shore.

Key words: ecological environment synthetic evaluation, the Yellow River Delta, remote sensing(RS), geographical information system (GIS)

1 Introduction

1.1 Description of the study area

The Yellow River Delta (YRD) lies between the south shore of Bohai bay and west shore of Laizhou bay, which mainly distributes the churchyard of Dongying city and Bingzhou city in Shandong province, with an onshore area of about 3,000 km^2. The longitude is between 117°31′ and 119°18′ E, the latitude between 36°55′ and 38°16 N. The latter – day YRD, caused by a dike burst of the Yellow River(YR) in 1855, is from Taoer river western to Zhimaigou river southern, like a fan with Ninghai as its center. The present – day Delta has been forming since 1934 with Yuwa as its center, from Tiaoer river western to Songchunrong river southern. As the YRD has abundant land resources which increase rapidly and great mineral resources, it has become an important land resource in China.

During the research, we not only want to evaluate the ecological environment for YRD, but to focus on the correlation between incoming water quantity from YR and the Delta area. However, there are many long dikes built along the river and less water quantity alongshore from the YR in recent years, which is called a channelized delta plain. This implies that the YR has not more influence on the latter – day Delta. Combined with real conditions, we selected part of the present – day Delta, which, with Yuwa as its center, reaches from Diaokou river West to Songchunrong river South, with an area of about 2,000 km^2.

1.2 Main characters of natural ecological environment

The YRD has abundant land resources. The national land area is 0.47 hectare per person in the central city of Dongying. The rich crude oil and natural gas resources are most famous. The predicted petroleum resources of the Shengli Oil field, are about 7.5 billion tons, and about 80% of the resources are in the area of the YRD and the shallow sea. The annual quantity of water resources in the YRD amounts to 14.7 billion m^3, as well as annual mean of 13.3 billion m^3 from the Yellow River in recent years (1986 ~ 2002), being the most important water resources for the Delta. The YRD has about 4,000 km^2 of wetland, mostly concentrating near the estuary.

1.3 Main problems exsting of natural ecological environment

Firstly, the YR water is the primary fresh water resources of the delta. The situation of zero – flow in the channel is becoming more and more serious since the first drying – up happened in 1972. In recent years, through the integrated regulation and allocation of the water resources zero – flow never happens again, but the incoming water of the river tends to reduce successively. ? Secondly, Because of the higher underground water table contributing to sea water of Bohai filtering in. And the water in the delta becomes salty, so that such arbor trees with developed roots extending deeply into the ground can not grow in most area of delta. Thirdly, Due to the young age, short – period evolution, and unsteady situation, the original wetland in the delta is too vulnerable to hold any destroy. In current several years the ecological system of the original wetland in the delta is facing serious threat of deterioration, and it becomes awfully urgent to protect the original wetland. Lastly, the obvious drop of the YR runoff and construction of the training dikes, the environment pollution, and ravening exploitation of human being has made biology species deceased.

1.4 Utilization of RS and GIS for ecological environment

Usually, the evaluation factor and model are emphases in the evaluation of ecological environment. Furthermore, whether can obtain the accurate and timely data or not is key for the evaluation. As the macroscopic monitoring method, RS, can provide timely, exact, and large scale image information. Meanwhile, GIS is an integrated computer system with storage, management, analysis, and displaying geography information. The combination of the RS and GIS will have advantages in the research of the monitoring, evaluating, forecasting of the ecological environment from the standpoint of the macroscopic.

1.5 Study objectives

Based on the remote sensing image, spatial data and observed data, by the RS technology and GIS, we will extract the required information from RS images to generate the factor system for EESE. Furthermore, we will utilize the integrated model to evaluate the ecological environment for each pixel. That is significant to make a scientific plan for sustainable development in study area.

2 Methodology

2.1 Factors system of ecological environment evaluation

The chosen factors

Landscape diversity index provide important information about rarity and commonness of species in a community. The Shannon diversity index (H) is index that is commonly used to characterize species diversity in a community. Shannon´s index accounts for both abundance and evenness of the species present.

$$H = -\sum_{i=1}^{n} P_i \ln(P_i) \quad (i = 1, 2, \cdots, n) \tag{1}$$

where, H is Shannon diversity index to characterize species diversity in a community; P_i is Proportion of species i relative to the total number of species; $\ln(P_i)$ is Natural logarithm of this proportion

The Normalized Difference Vegetation Index (NDVI): $\frac{\rho NIR - \rho Red}{\rho NIR + \rho Red}$, and that is the most commonly used index for satellite imagery. The fresh wetland index has the function with conserving water resources, cleaning water quality, regulating inundation, groundwater, even climate comfort and protecting the shore. The salinization index showed the degree of soil salt, and is the main negative factor to affect the ecological environment. The water quantity index is very important factor in evaluation of ecological environment.

2.2 Analytic Hierarchy Process (AHP) model

2.2.1 Introduction of the AHP method

AHP provides a proven, effective means to deal with complex decision making and can assist with identifying and weighting selection criteria, analyzing the data collected for the criteria and expediting the decision – making process. AHP is especially suitable for complex decisions which involve the comparison of decision elements which are difficult to quantify.

2.2.2 The procedure of AHP

(1) To build the evaluating factors system. In order to evaluate the ecological environment, we should know which factor we will choose. Moreover, we have to define the relation between the different factors. That means to decide that which one is more important than the other.

(2) To build the matrix for judgement. According to the defined rule, we can build the matrix by the relation above concerned. This is the key to the AHP model. The scale has been listed as follows (Table 1).

Table 1 The compare standard of two elements

scale	meanings
1	if the two objectives are equal in importance
3	if O_i is weakly more important than O_j
5	if O_i is strongly more important than O_j
7	if O_i is very strongly more important than O_j
9	if O_i is absolutely more important than O_j
2,4,6,8	The mean value above the closer result
Count backwards	$O_{ji} = 1/ O_{ij}$

Form a pairwise comparison matrix A, where the number in the i th row and j th column gives the relative importance of O_i as compared with O_j.

(3) To calculate the weights. The method to get the weight can be turned to calculate the eigenvalue and eigenvector of matrix, and the procedure can be also described as follows:

The first step is to compute the average value of each row and use them as the weights in the Objective Hierarchy.

$$\overline{w}_i = \sqrt[n]{a_{i1}a_{i2}\cdots a_{in}} \quad (i = 1, 2, \cdots, n) \tag{2}$$

The second step is to normalize the weights, which means compute the sum of all weights and then divide each weight by the sum.

$$w_i = \overline{w}_i / \sum_{i=1}^{n} \overline{w}_i \quad (i = 1, 2, \cdots, n) \tag{3}$$

The weights would be:

$$W = (w_1, w_2, \cdots, w_n)^T \tag{4}$$

The third is to calculate the maximum latent root.

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{w_i} \tag{5}$$

The last step is to check the coherence, and that means to judge whether the matrix has the coherence or not.

$$CI = (\lambda_{\max} - n)/(n-1) \tag{6}$$

According to the table (Table 2), the coherence index (RI) will be calculated, even to get the CR

$$CR = CI/RI \tag{7}$$

when the value of CR is less than 0.1, we regard the judgement matrix as eligibility, otherwise, we have to change the contents of matrix.

Table 2 The average random identical index

Matrix exponent number	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

(4) To get the synthetic evaluation result based on raster. Multiply the weigh of every factor with corresponding index, add together, and we will get the synthetic result.

$$EI = \sum_{i=1}^{n} W_i \times C_i \tag{8}$$

where, EI is synthetic value of ecological environment to every pixel; C_i is the i index value; W_i is the weight of i factor.

3 Data preparation

3.1 Remote Sensing image pretreatment

The procedure of image pre – treatment includes Geometric rectification of imagery and Image registration (Fig. 1 ~ Fig. 3).

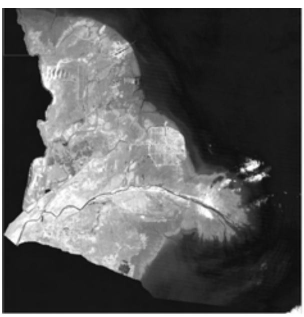

Fig. 1 1986 Landsat TM

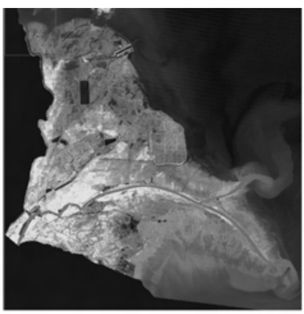

Fig. 2 1996 Landsat TM

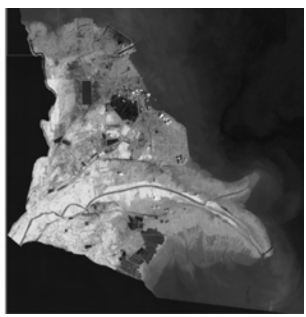

Fig. 3 2001 Landsat ETM +

3.2 Information extraction by GIS

3.2.1 Extraction of landscape diversity index

As the foundational data to generate the landscape diversity index, landuse interpretation will be carried out here. During the interpretation, land use mapping will be made up of inhabitation, agricultural landscape, grassplot, etc. Under the image pretreatment methods, such as supervised classification, unsupervised classification, man – machine Interaction and so on. (Table 3, Fig. 4).

Using the Fragatsts, spatial pattern analysis program for quantifying lands cape structure, the value of H can be gotten as follows:

Table 3 Landscape diversity index of every ecological function sections

Number	Ecological subarea	H	Number	Ecological subarea	H
1	I_1	1.8	2	IV_1	1.71
3	VI_4	1.89	4	II_1	1.71
5	VI_6	1.71	6	VI_7	1.35
7	V_1	1.44	8	II_2	1.44

3.2.2 Extraction of vegetation index

The NDVI can be treated as vegetation coverage. In this research, it can be gotten by the ENVI for 1986 The conclusion concerned that the value of NDVI is between −0.952 and 0.832 (Fig. 5).

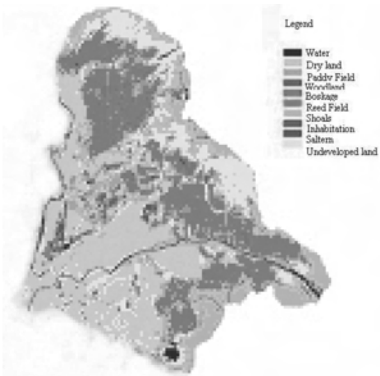

Fig. 4 Classification map of the YRD in 1986, Liu gaohuan

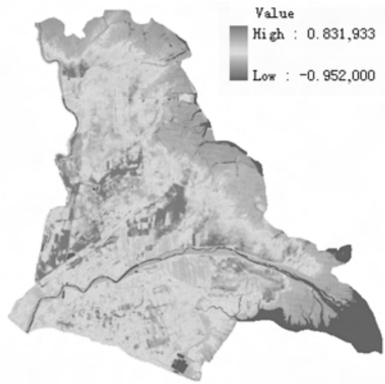

Fig. 5 Vegetation index, 1986

3.2.3 Extraction of fresh wetland index

There are three characters to the wetland, with water above the ground, with the aquifer under the ground, and with the hygrophyte among the ground. The spectral value of TM5, TM4 and TM3 are representing the hygrophytic vegetation and aquifer in wetland respectively. According to the research concerned above, we can use spectral synthesis to extract the information of wetland(Fig. 6).

3.2.4 Extraction of salinization index

The salinization has been the main negative factor to prevent the farmer from richness. Meanwhile, the interpretation of image about salinization is due to visual interpretation, with the strong subjectivity. Therefore, we have to combine the field soil type survey and image in order to fulfill the local area salinization investigation and dynamic detection (Fig. 7).

3.2.5 Extraction of the water quantity index from YR

On behalf of calculating the water quantity from YR, we regard the observed data at Lijin hydrology station as the incoming water quantity. Failure to the abundant water resource from the source of YR in decade year, the incoming water quantity from YR is not stable. In this study, as the important factor, we will take up with the proportion of water quantity within three research year.

3.3 The normalization of index

3.3.1 The range standardization

According to the influence of factors and character of ecological environment, if the influence

Fig. 6 Fresh wetland in 1986

Fig. 7 Salinization index in1986

provided by factor is positive, then the formula is expressed as follows (9). To the value excess the dramatic range, we will treat them with the maximum or the minimum.

$$F_i = (X_i - X_{min}) / (X_{max} - X_{min}) \times 100 \quad (9)$$

If the influence provided by factor is negative, for example, the higher the salinization index is, the worse the ecological environment turn, then the formula is expressed as follows.

$$F_i = 100 - (X_i - X_{min})/(X_{max} - X_{min}) \times 100 \quad (10)$$

where, F_i is the normalized result of i factor; X_i is the actual value; X_{min} is the minimum value; X_{max} is the maximum value.

For this method, we can evaluate the actual value in the range with 0 and 100 to the raster map or sub area. That means the every pixel in the raster map or sub area will be assigned with the range of 0 and 100(see Fig. 8 ~ Fig. 10).

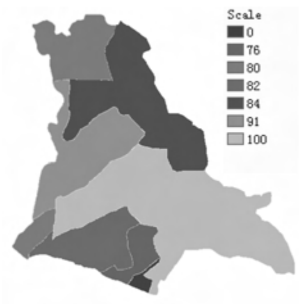

Fig. 8 Landscape index normalization

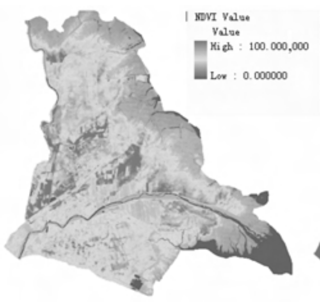

Fig. 9 Vegetation index normalization

Fig. 10 Wetland index normalization

3.3.2 Rules – of – thumb techniques

The essence of rules – of – thumb techniques is depending on the experience of experts, which means to be assigned the mark by the experiential researchers. In addition to the remote sensing image, there are some observed points distributed among the study area for getting the actual value to correct the data from the image. Depending on the survey data and experience, we can get the classification of soil salinity in study area (Table 4). That will be the standards we normalize the salinization index (Fig. 5).

Table 4 The classification of soil salinity

Range	90	70	50	30	10
Soil salinity(%)	<0.1	0.1 ~0.2	0.2 ~0.4	0.4 ~0.8	>0.8

3.3.3 Percentage method

It has been concerned above that the percentage of incoming water quantity from the YR in 1986 is 44% in the three research year. The way we normalized the water quantity index is to assign the mark with 44 to every pixel in the study area (see Fig. 11 ~ Fig. 12).

Fig. 11 The normalization of salinization index in1986

Fig. 12 The normalization of water quantity index in1986

4 Model building

4.1 The calculation of the weights

According to the method we concerned above, we can count the weight for every factor based on the Analytic Hierarchy Process method. First of all, the judgment matrix should be constructed. we can construct the matrix as following (Table 5). In fact, the table showed the correlation, in which the one is much more or less important than another in all factors.

Table 5 Judgment matrix of Ecological Environment (E) and its corresponding index

A(*EI*)	E1	E2	E3	E4	E5
E1	1	3	4	2	1/2
E2	1/3	1	2	1/3	1/5
E3	1/4	1/2	1	1/3	1/6
E4	1/2	3	3	1	1/5
E5	2	5	6	5	1

Reference with the method concerned above, the weights can be computed as follows (Table 6).

Table 6 Remote sensing image data

Number	Factor	Weight
E1	Landscape diversity index	0.247
E2	Vegetation index	0.081
E3	Wetland index	0.056
E4	Salinization index	0.147
E5	Water quantity index	0.470

4.2 The synthetic assessment

4.2.1 About the model

After getting the weights and normalized index of all factors in the system of the synthetic ecological environment assessment for the YRD, we can calculate the synthetic ecological environment assessment value based on the pixel in the study area. The result will be determined by the formula as following (11).

$$EI = \sum_{i=1}^{n} W_i \times C_i \tag{11}$$

where, EI is The synthetic ecological environment assessment index; C_i is the normalized index of factor i to all pixel; W_i is the weight of factor i. See Table 7.

Table 7 The classification of ecology and environment status in the Yellow River Delta

Classification criterion	0 ~ 20	20 ~ 35	35 ~ 50	50 ~ 70	70 ~ 90	90 ~ 100
EE remarks	Bad	Poor	Moderate	Good	Better	High

4.2.2 Assessment of Ecological Environment based on grid pixel

According to the result calculated through the formula 4, Ecological environment synthetic evaluation index in the YRD based on raster in 1986 is as following: the maximum with 71.11, the minimum with 25.92, and the mean value with 0.005,8. The result can be also shown like as follows (Fig. 13, Table 8).

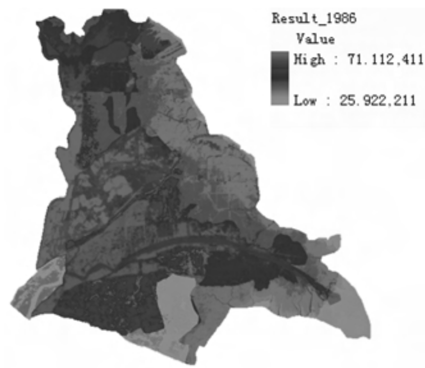

Fig. 13 Ecological environment synthetic evaluation map in the YRD based on raster, 1986

Table 8 Ecological environment synthetic evaluation area proportion statistics in the YRD based on raster, 1986

Ecological environment classification	Area (km^2)	Area proportion (%)
High	0	0
Better	0.62	0.03
Good	913.16	48.06
Moderate	939.20	49.43
Poor	47.22	2.49
Bad	0	0

There is 97.51% above moderate about ecological environment quality around the study area with 1,900 km^2. And the area with above good is 48.09%. With reference to the historical record, it has shown that the ecological environment quality in the YRD had been stable and optimum with the abundant water quantity from the Yellow River and little mankind active before 1986.

Using the same method, we can get the other two years result see Figs. 14 ~ 15, Tables 9 ~ 10.

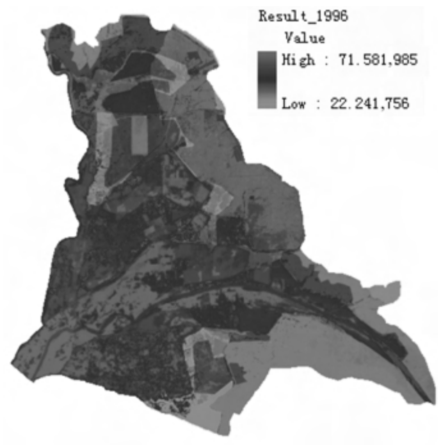

Fig. 14 EESE synthetic evaluation map, 1996

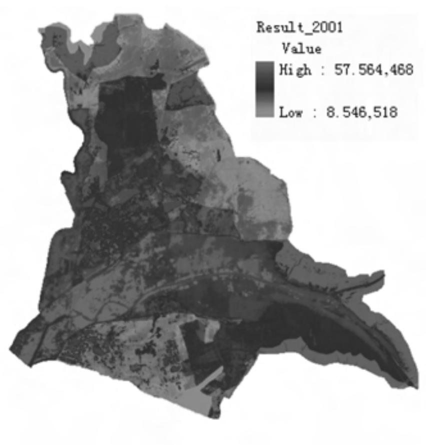

Fig. 15 EESE synthetic evaluation map, 2001

Table 9 Ecology and environment synthetic evaluation area proportion statistics in the YRD based on rasters 1996

Ecological environment classification	Area(km^2)	Area proportion(%)
High	0	0
Better	27.51	1.45
Good	1,174.29	61.8
Moderate	681.96	35.89
Bad	16.43	0.86
Worse	0	0

Table 10 Ecology and environment synthetic evaluation statistics in the YRD based on rasters

Ecological environment classification	Area(km^2)	Area proportion(%)
High	0	0
Better	0	0
Good	136.39	7.18
Moderate	1,330.45	70.02
Bad	417.17	21.95
Worse	16.18	0.85

4.3 The analysis

As shown as Table 11 below, the synthetic evaluation rank is divided into 6 parts. From 0 to 20, it presented the quality of ecological environment with Bad, and from 20 to 35, 35 to 50, 50 to 70, 70 to 90, and 90 to 100, it implied that quality of ecological environment with the Poor, Moderate, Good, Better, and High respectively.

Table 11 Ecological environment synthetic evaluation area proportion distribution in the YRD for three years

Classification rank		0 ~ 20	20 ~ 35	35 ~ 50	50 ~ 70	70 ~ 90	90 ~ 100
Criterion		Worse	Bad	Moderate	Good	Better	High
Area proportion (%)	1986	0	2.49	49.43	48.06	0.03	0
	1996	0	0.86	35.89	61.8	1.45	0
	2001	0.85	21.95	70.02	7.18	0	0

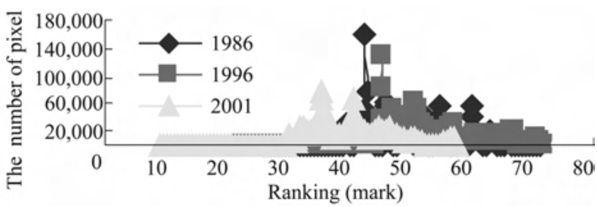

Fig. 16 Ecological environment synthetic evaluation pixels distribution in the YRD for three years

From the Fig. 16 by analyzing the ecological environment synthetic evaluation in the YRD based on raster, it has shown that the change of ecological environment is remarkable in spatial dimension. The classifications are in the Bad, Poor, Moderate, Good, and Better. Moreover, the pixels value with Moderate and good are much more than others in the whole rank, with bad tendency in 2001. The research result has shown that there are dramatic spatial differences of ecological environment conditions in the YRD. That is, the level is lower in coastal regions and higher in inner land. It is rising gradually from coastal regions to inner land (from Fig. 13 ~ Fig. 15). The ecological environment in the YR channel and surroundings is better than that in other place.

5 Conclusions

This research has shown that it is feasible and significant to evaluate the ecological environment by applying present day information technologies, notably RS and GIS. These also provid a method to assess the ecological environment quality in the following quantitative way:

- A suitable factor index system was built for the YRD, based on ecological landscape diversity, vegetation coverage, wetland area, salinization, and fresh water availability.
- Using image processing techniques for multi – temporal and multi – spectral remote sensing images in a GIS environment, it has become possible to interprete information on a macrostructure level as well as obtain insight into the changes in land use; by applying range standarzation, all factors were non – dimensionalised in order to get a synthetic value for every raster cell.
- The weights for the corresponding factor were calculated by the Analytic Hierarchy Process method, and a model for assessment of the ecological environment was built within a GIS framework. Furthermore, the proper reasons were found based on the analysis of the developed factor system.

The research results have shown that there are dramatic spatial differences in ecological environment conditions in the YRD. That is, the level is lower in coastal regions and higher inland, rising gradually from coastal regions to inland. The analysis results of 1986, 1996, and 2001 have shown that the trends in ecological environment quality have been better and more stable in the inland part of study area, but poorer along the coastal area. Furthermore, the ecological environment quality in 2001 can be regarded as poor because of faulty landuse and growing economic infrastructure, severe salinization, and less water coming from the YR.

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Application of One Finite Volume Method in Dam – break Simulation *

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Abstract: The unstructured triangular mesh is suitable for complex irregular boundary. Based on this, adopting finite volume method to disperse shallow water equation and combining with the finite difference method, this paper has developed a new discrete format that could cause the interface flux to reach second – order precision. Through simulating and calculating typical example, this format can not also well measure the wave advance of dam – break wave but also has strong ability of simulating gap. Furthermore, it can get satisfactory results in simulating the discontinuous shape and location of flood wave of dam – break.
Key words: finite volume method (FVM), dam – break, second – order precision, shallow water wave equation

Due to tremendous damage caused by dam – break induced wave in flood detention area and lower dam, evolution process of dam – break flood wave mainly basing on the wave research is always a concerned issue. The flood wave caused by dam – break is a kind of long forward wave with strong nonlinear characteristic. Dam – break calculation is the basis of engineering design, forecast and prediction and management and maintenance. It is a process of describing the changing of features of the flood wave with time, which includes the propagation velocity, the shape, the height of the wave, the water level, the flux, etc. Both the domestic and abroad scholars have made many researches in the field of dam – break. At early stage, the studies were usually started on theoretic solution by the Saint – Veran equation, however, this method has a great limitation. Owing to complexity of the problem, there has no any document about analytical solution of 2D dam – break flow problem. With the development of computer industry and numerical method, numerical derivation for the solution of dam – break problem is gradually becoming a major method for this kind of problems.

Finite volume method divides calculation area into a series of control volume without repetition, and calculates the integral of the unsolved differential equation by every control volume. There are many discrete forms of FVM, and the primary difference is that disposal of nodes and discharge of the control volume differs from each other. In this paper we put the unit nodes in the grid nodes, and try to calculate the interface flux to reach second – order precision by means of FVM. By Comparing the results, we evaluate its feasibility for simulating the dam – break flow.

1 Mathematic model

The 2D shallow – water equations can be described by:

$$\frac{\partial h}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0 \tag{1a}$$

$$\frac{\partial U}{\partial t} + \frac{\partial}{\partial x}\left(\frac{U^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{UV}{h}\right) = -\frac{\partial}{\partial x}\left(\frac{gh^2}{2}\right) - ghS_{0x} - ghS_{fx} + v\left(\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}\right) \tag{1b}$$

* National natural scientific fund item: comprehensive analysis, evaluation theory and application on profiled risk of flood disaster (50579019).

$$\frac{\partial V}{\partial t}+\frac{\partial}{\partial x}\left(\frac{UV}{h}\right)+\frac{\partial}{\partial y}\left(\frac{V^2}{h}\right)=-\frac{\partial}{\partial y}\left(\frac{gh^2}{2}\right)-ghS_{Oy}-ghS_{fy}+v\left(\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}\right) \quad (1c)$$

$$U=hu, V=hv$$

where, u and v are the velocities in the x, y directions respectively, g is the gravity acceleration, (S_{Ox}, S_{Oy}) is sloping effective terms of stream channel, x, y subscripts mean differential, (S_{fx}, S_{fy}) is the friction terms of base slope in the x, y directions.

The 2D shallow – water equations are advection – diffusion equations, which can be written with the following formats:

$$G_t+\nabla\cdot F=S \quad (2)$$

$$G=(u_1,u_2,u_3)^{\mathrm{T}}, F=(f^{\mathrm{I}}-vf^{\mathrm{II}}, g^{\mathrm{I}}-vg^{\mathrm{II}})^{\mathrm{T}}, f^{\mathrm{II}}=f^{\mathrm{II}}(G_x), g^{\mathrm{II}}=g^{\mathrm{II}}(G_y).$$

$$G=\begin{pmatrix}h\\U\\V\end{pmatrix}, f^{\mathrm{I}}=\begin{pmatrix}U\\ \frac{U^2}{h}\\ \frac{UV}{h}\end{pmatrix}, g^{\mathrm{I}}=\begin{pmatrix}U\\ \frac{UV}{h}\\ \frac{V^2}{h}\end{pmatrix}, f^{\mathrm{II}}=\begin{pmatrix}0\\U_x\\V_x\end{pmatrix}, g^{\mathrm{II}}=\begin{pmatrix}0\\U_y\\V_y\end{pmatrix}, S=\begin{pmatrix}0\\ -\frac{1}{2}gh^2-gh(S_{fk}+S_{Ox})\\ -\frac{1}{2}gh^2-gh(S_{fy}+S_{Oy})\end{pmatrix}$$

2 Numerical methods

In equation (1), there is a discrete derivation by FVM, grid is any triangular and node is the top point of grid, so that the FVM can be adapted to problems of great complexity and unusual geometry flow field. If the thickness of control volume is taken as one, it can be governed by the following equation:

$$\int_V G_t+\int_V \nabla\cdot F=\int_V S \quad (3)$$

F includes advection term (f^{I}) and viscosity diffusion term (f^{II}), S is the source term.

2.1 Dispersion of the time term

In this paper we take the explicit format for dispersion, so the partial derivative, velocity versus time, can be expressed in the following formulation:

$$\int_V \frac{\partial G}{\partial t}\mathrm{d}V=Vol_i\frac{\partial G_i}{\partial t}+O(\Delta x^2,\Delta y^2)=Vol_i\frac{G_i^n-G_i^{n-1}}{\Delta t}+O(\Delta t,\Delta x^2,\Delta y^2) \quad (4)$$

where, Vol is the volume of control volume, subscript i is the unit number of control volume, $g=(h,U,V)$.

2.2 Dispersion of the advection term

The calculation of the numerical flux on the surface of control volume plays a key role in the procedure of advection disperse. In the different discrete form, the most difference is the advection term proceeding. This article adopts the following method to control the numerical flux across the surface of control volume (control volume of advection term, see Fig. 1, is in the range of area drawn by imaginary line):

$$flux_{c_1c_2}=(Un_x\Delta s)_{c_1c_2}+(Vn_y\Delta s)_{c_1c_2}=(U\Delta y)c_1c_2-(V\Delta x)_{c_1c_2} \quad (5)$$

In the equation (5), $\Delta y_{c_1c_2}=y_{c_2}-y_{c_1}$, $\Delta x_{c_1c_2}=x_{c_2}-x_{c_1}$. If the numerical flux across the interface is decomposed into positive flux plus negative flux, we can get the following equation:

$$flux_{c_1c_2}=F^+-F^- \quad (6)$$

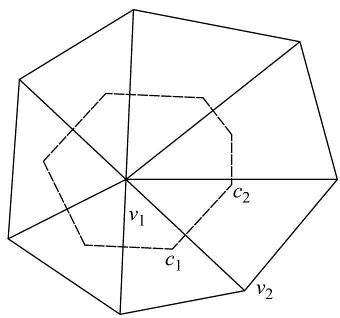

Fig. 1 Control volume of advection term

In the equation (6), $F^+ = \frac{1}{2}(flux_{c_1c_2} + |flux_{c_1c_2}|)$, $F^- = \frac{1}{2}(|flux_{c_1c_2}| - flux_{c_1c_2})$.

In order to assure the upwind characteristic and precision of format, we expand the physical quantity U on the interface by means of Tailor formulation, we get the following equation:

$$U^+ = U_{V_1} + \left(\frac{\partial U}{\partial x}\right)^+ \Delta x_{SV_1} + \left(\frac{\partial U}{\partial y}\right)^+ \Delta y_{SV_1} + \cdots \tag{7}$$

$$U^- = U_{V_2} + \left(\frac{\partial U}{\partial x}\right)^- \Delta x_{SV_2} + \left(\frac{\partial U}{\partial y}\right)^- \Delta y_{SV_2} + \cdots \tag{8}$$

where, $\Delta x_{SV_1} = x_s - x_{V_1}$, $\Delta y_{SV_1} = y_s - y_{V_1}$, $\Delta x_{sV_2} = x_s - x_{V_2}$, $\Delta y_{sV_2} = y_s - y_{V_2}$, (x_s, y_s) is the coordinate of central point on the interface. In the equations (6) and (7), gradient variable is the minor of absolute values, which calculate the arithmetic mean of one – edge gradient and two – edge gradient. This method has introduced the merit of NDD format. The specific calculations of gradient formula are:

$$(\overline{U_x})^+ = \min\bmod\{(U_x)_{V_1}, 0.5[(U_x)_{V_1} + (U_x)_{V_2}]\} \tag{9a}$$

$$(\overline{U_y})^+ = \min\bmod\{(U_y)_{V_1}, 0.5[(U_y)_{V_1} + (U_y)_{V_2}]\} \tag{9b}$$

$$(\overline{U_x})^- = \min\bmod\{(U_x)_{V_2}, 0.5[(U_x)_{V_1} + (U_x)_{V_2}]\} \tag{9c}$$

$$(\overline{U_y})^- = \min\bmod\{(U_y)_{V_2}, 0.5[(U_y)_{V_1} + (U_y)_{V_2}]\} \tag{9d}$$

In the above equations, function "min mod" is defined as the following formulations:

$$\min\bmod(U_1, U_2) = \frac{1}{2}[sign(U_1) + sign(U_2)]\min(|U_1|, |U_2|) \tag{10}$$

where, U_1 and U_2 are two optional variables.

Due to the influence of first – order gradient term, precision in calculation is of second – order. If put the results of equations (6) ~ (9) into equation of advection term (5), we can get the following formulation that calculates the second – order upwind advection term:

$$F^+ [U_{V_1} + (\overline{U_x})^+ \Delta x_{SV_1} + (\overline{U_y})^+ \Delta y_{SV_1}]/h_{v1} - F^- [U_{V_2} + (\overline{U_x})^- \Delta x_{SV_2} + (\overline{U_y})^- \Delta y_{SV_2}]/h_{v2} \tag{11}$$

2.3 Dispersion of the viscosity term

In the non – structured grid, diffusion term is far more complex than that in the orthogonal structured grid. The purpose, we make diffusion term discrete over the cell, lies in getting an algebraic expression between and adjacent nodes under diffusion influence. In order to calculate the partial derivative of velocity in the diffusion term, we introduce the auxiliary control volume $v_1c_1v_2c_2$ (Fig. 2) with the hypothesis that partial derivative is constant in the control volume. So we can get the following formulation:

$$\frac{\partial \Phi}{\partial x} = \frac{1}{VolA}\int_{\partial\Omega} \Phi n_x \mathrm{d}s \tag{12}$$

$$\frac{\partial \Phi}{\partial y} = \frac{1}{VolA}\int_{\partial\Omega} \Phi n_y \mathrm{d}s \tag{13}$$

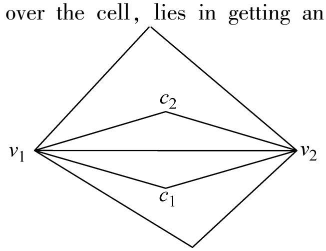

Fig. 2 Auxiliary control volume

where, $VolA$ is the volume of auxiliary control volume, $\Phi = (U, V)$

With respect to the 2D plane, we get the following:

$$\frac{\partial \Phi}{\partial x} = \frac{1}{2VolA}[(\Phi_{v2} + \Phi_{v1})(y_{c_2} - y_{c_1}) + (\Phi_{c_2} + \Phi_{c_1})(y_{v_1} - y_{v_2})] \tag{14a}$$

$$\frac{\partial \Phi}{\partial y} = \frac{1}{2VolA}[(\Phi_{v2} + \Phi_{v1})(x_{c_2} - x_{c_1}) + (\Phi_{c_2} + \Phi_{c_1})(x_{v_1} - x_{v_2})] \tag{14b}$$

Substitute the equation (11)、(14a)、(14b) for the 2D shallow water equation (1b), (1c), and simplify the representation, we can get the following second – order form of advection term:

$$\alpha_i U_{v_1} = U_{v_1}^{n-1} Vol_{v_1}/\Delta t + \sum_{j=1}^{ie} \alpha_{ij} U_{v_2} + S_U \tag{15a}$$

$$\alpha_i U_{v_1} = U_{v_1}^{n-1} Vol_{v_1}/\Delta t + \sum_{j=1}^{ie} \alpha_{ij} U_{v_2} + S_V \tag{15b}$$

In the above equations:

$$\alpha_i = Vol_{v_1}/\Delta t + \sum_{j=1}^{ie} F^+ / h_{v_1} + \sum_{j=1}^{ie} v \frac{1}{2} VolA_{v1} (\Delta x_{c1c2} + \Delta y_{c_1c_2}{}^2)$$

$$\alpha_{ij} = F^- / h_{v_2} + v \frac{1}{2} VolA_{v_1} + (\Delta x_{c_1c_2}{}^2 + \Delta y_{c_1c_2}{}^2)$$

$$S_U = - \sum_{j=1}^{ie} \frac{1}{2} gh^2 \Delta y_{c_1c_2} + \sum_{j=1}^{ie} v \frac{1}{2VolA_{v_1}} (U_{c_2} - U_{c_1}) \Delta y_{v_1v_2} \Delta y_{c_1c_2} + \sum_{j=1}^{ie} v \frac{1}{2VolA_{v_1}} (U_{c_2} - U_{c_1}) \Delta x_{v_2v_1} \Delta x_{c_2c_1} + \sum_{j=1}^{ie} ghS_{0x} + \sum_{j=1}^{ie} ghS_{fx} - \sum_{j=1}^{ie} \frac{F^+}{h_{v_1}} [(\overline{U_{v1x}})^+ \Delta x_{sv_1} + (\overline{U_{v1y}})^+ \Delta y_{sv_1}] + \sum_{j=1}^{ie} \frac{F^-}{h_{v_2}} [(\overline{U_{v_2x}})^- \Delta x_{sv_2} + (\overline{U_{v_2y}})^- \Delta y_{sv_2}]$$

$$S_V = \sum_{j=1}^{ie} \frac{1}{2} gh^2 \Delta x_{c_1c_2} + \sum_{j=1}^{ie} v \frac{1}{2VolA_{v_1}} (V_{c_2} - V_{c_1}) \Delta y_{v_1v_2} \Delta y_{c_1c_2} + \sum_{j=1}^{ie} v \frac{1}{2VolA_{v_1}} (V_{c_1} - V_{c_2}) \Delta x_{v_2v_1} \Delta x_{c_2c_1} + \sum_{j=1}^{ie} ghS_{0y} + \sum_{j=1}^{ie} ghS_{fy} - \sum_{j=1}^{ie} \frac{F^+}{h_{v_1}} [(\overline{V_{v_1x}})^+ \Delta x_{sv_1} + (\overline{V_{v_1y}})^+ \Delta y_{sv_1}] + \sum_{j=1}^{ie} \frac{F^-}{h_{v_2}} [(\overline{V_{v_2x}})^- \Delta x_{sv_2} + (\overline{V_{v_2y}})^- \Delta y_{sv_2}]$$

3 Boundary conditions

Generally, boundary condition can be divided into two types: water boundary condition and solid boundary condition.

3.1 Water boundary condition

As regards inflow boundary, water level (or velocity) varied with time should be given; as regards outflow boundary, when supercritical flow emerges, outlet cross – section accounts the gradients of water level and velocity as zero in flow direction; when subcritical flow emerges, downstream water level should be given.

3.2 solid boundary condition

As regards water level of solid wall, we approximate it by assuming normal gradient is zero; as regards velocity of solid wall, according to viscosity of water, we adopt non – slip boundary or slip boundary respectively. For the latter, normal velocity is zero, the tangential should use finite difference method to deal with.

4 Computational example

4.1 Rectangle complete dam – break problem

The channel used has a rectangular flat bottom of 10 m width. Initially, upstream water level is 10 m , and downstream is dry river . In the following figures, dam is within 20 m distance to the upstream cross – section. Permissible error is not more than 0.000,01.

Results obtained by means of adopting the algorithm presented by this paper, which can be seen in the Fig. 3. It shows the water level after dam break at time of 0.1 s, 0.5 s, 1 s. Comparison between water surface curve of the river central line and result of analysis can be seen in the Fig. 4. On the basis of result, we can find there is no numerical oscillation nearby the discontinuous wave. The forward distance of water surface curve and discontinuous wave is coincided with the result of analytic solution.

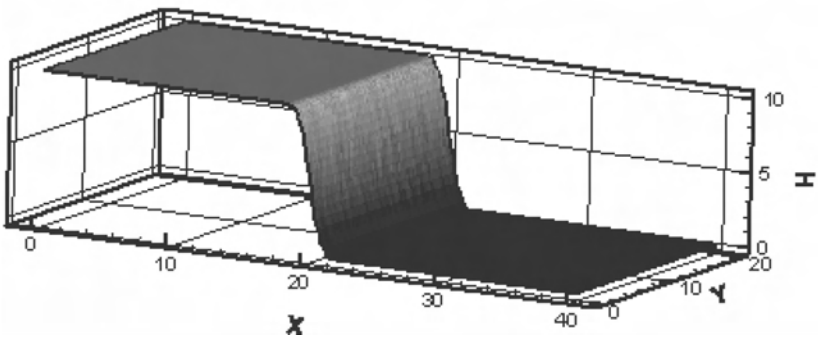

Fig 3(a) Dam-break's water level($t=0.1$ s)

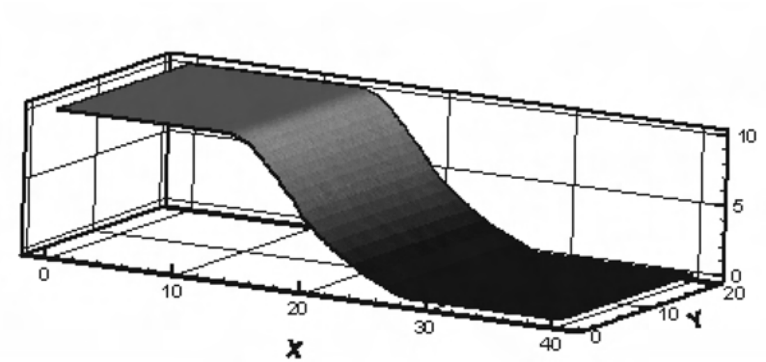

Fig 3(b) Dam-break's water level($t=0.5$ s)

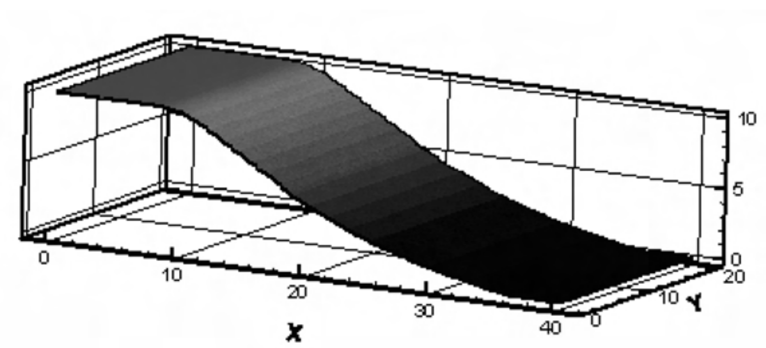

Fig 3(c) Dam-break's water level($t=1$ s)

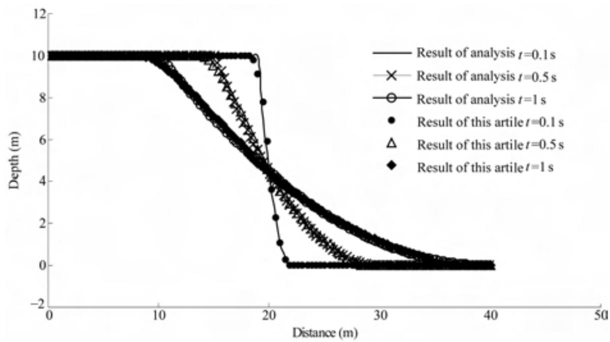

Fig. 4 Comparison between water surface curve of the rive central line and result of analysis

4.2 Asymmetry partial dam – break problem

Flat bottom and non – friction 2D asymmetry partial dam – break is simulated with the following model: area 200 m × 200 m, dam thickness 2m, breach orifice 75 m, initial upstream water level 10m, downstream water level 5 m (In the Fig. 5), Fig. 6 shows the grid applied. There is 17,647 points, 34,766 cells in the grid. After the instantaneous breach of dam body, negative wave spreads upstream, while positive wave spreads downstream. The compression wave is a kind of discontinuous wave.

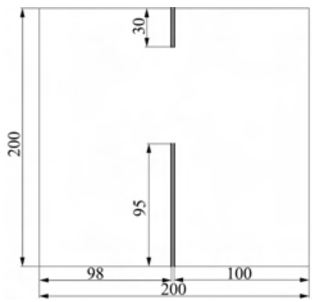

Fig. 5 Diagrammatic sketch and dimensional drawing of dam-break model

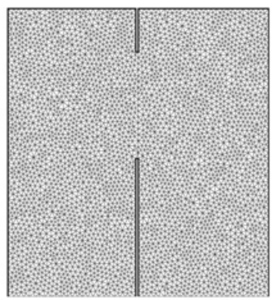

Fig. 6 Graticule of dam-break model calculation

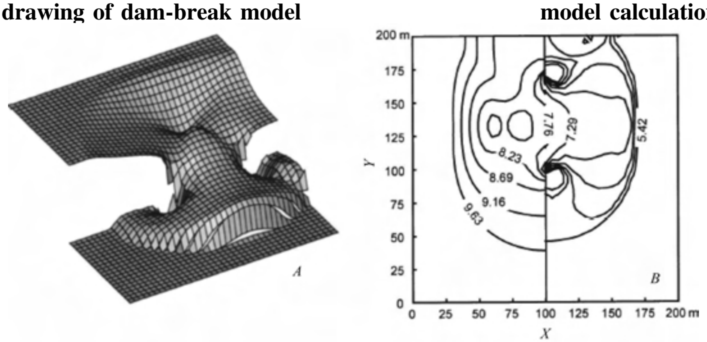

Fig. 7 Sergio Fagherazzi result of calculation (*A* water level, *B* equipotential water level graph)

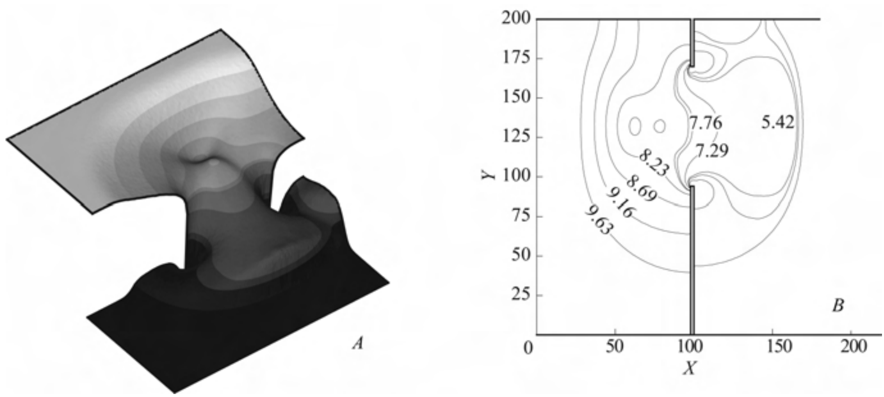

Fig. 8 This article calculates result
(*A*: water level, *B*: equipotential water level graph)

In the Fig. 7, it is derived from the discontinuous Glairing method used by Sergio Fagherazzi. While in the Fig. 8, data is figured out by means of method presented by this article. As you can see, results of these two methods are very close. Therefore, we can infer that the model introduced has a high resolution for gap. It can keep the solution steep within the range of discontinuous, and its reaction to peak valley is quite timely.

5 Conclusions

Through above instances, we can find that the figures, with finite volume method we introduce, indicate features of automatic upwind, good stability, fast convergence. Capturing discontinuous wave plays a key role in dam – break calculating. The FVM used has a good performance on the respect of having high resolution of discontinuous. It keeps the solution steep within the range of discontinuous and can capture the reflected wave when flood wave encounters obstacles as well. In conclusion, the method we present can simulate not only the evolution process of instantaneous 2D complete and partial dam – break but also the characteristics of current motion .

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Risk Assessment on Limit Water Level Based on Flood Forecast and Wind Wave

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Abstract: This paper carries out stochastic analysis and overtoping risk assessment on limit water level in flood season by using the first order second moment method and theoretic distribution to describe stochastic distribution of parameters, considering stochastic process of flood forecast and wind wave with fix frequency to combine them. The outcomes of case calculation show that an important the increased height of water level mostly comes from flood, over – flood level causes overtopping easily, and wind waves can increases overtopping risk obviously at critical water level when it is sensitive.

Key words: limit water level, flood forecast, wind wave, stochastic analysis, overtopping risk

1 Introduction

In reservoir regulation, limit water level is an important and sensitive indictor, If it is reasonable and can solve the contradiction well between flood control and beneficial operation, this condition needs to combine the watershed and reservoir circumstance to evaluate and adjust limit water level afresh to exert the comprehensive performance. The overtopping is that an important part of hydraulic engineering risk crash, relating to reservoir flood control and safety directly, and is basis to evaluate limit water level reasonable or not. There are so many uncertain factors such as flood forecast system, hydrology, hydraulic performance, decision and management, wave etc., so can enlarge or cause risk crash. Overtopping risk includes many content, scholars have developed a great deal of researches including risk analysis on flood regulation、stochastic analysis of hydrology and hydraulics、risk assessment on hydrological safety, risk loss etc., overtopping risk theories gradually mature on these foundation, still need a further thorough research. This article mainly considers flood forecast and wind wave to make overtopping risk assessment on limit water level, so rationally adjust limit water level to make full use of flood resource based on the flood safety.

2 Stochastic analysis on flood routing process

The basic method inquiring limit water level is to make flood routing on various frequencies' design floods by flood rule, distinguish the calculation result with various standards, and so can synchronously satisfy flood control and beneficial operation. Accompanying with a great deal of indetermination factors in this process, the regulation process is random which can be simulated by Markov process, and wanders around synthetical average process. Water level can be considered to be the most penetrating discriminance standard inside flood's influence to reservoir, and the variety of water level comes from the variety of storage capacity, water level's stochastic distribution can be acquired by storage capacity's.

2.1 Stochastic discrete analysis on water level – storage capacity

According to water balance principle and relation between water level and storage capacity, supposed each parameter is discrete, so reservoir storage capacity and water level are as follows:

$$V_i = V_0 + \sum Q_i \Delta t - \sum q_i \Delta t - E + \varepsilon_V, h_i = H(V_i) + \varepsilon_h \tag{1}$$

In formula(1): V_0 is initial storage capacity; Q_i is inflow flood; q_i is outflow flood; Δt is time section; E is evaporation; ε_V is storage capacity's uncertain amounts arouse by water temperature、seepage、piping etc.; ε_h is storage capacity's uncertain amounts, mainly including uncertain amounts of function between storage capacity and water level. During the flood period, E、ε_V、ε_h have a very small impact on water level and storage capacity , not consider this part effect.

In formula(1), the stochastic discreteness is mainly restricted by V_0, Q_i and q_i, the triple are not independent variables but affected reciprocally, here regard them as independent variables for simpleness. Value of time section Δt affects calculation accuracy, which usually takes 1h or 2h to calculate. According to numerical statistics relation, get formula as follows:

$$\sigma_{V_i}^2 = \sigma_{V_0}^2 + \sum(\sigma_{Q_i}^2 \Delta t^2) + \sum(\sigma_{q_i}^2 \Delta t^2) \tag{2}$$

Because usually lack various statistical data, therefore some parameter's stochastic distribution only can be replaced with relevant theoretic distribution, some articles suggest to take normal distribution as the foundation of error analysis on hydrology forecasts. Supposed each parameter's stochastic distribution obeys normal distribution, discreteness degree can be reflected by the frequency factors φ with relevant distribution's frequency p, the u_{V_i} is the expectant value at i moment as follows:

$$V_i = u_{V_i} + \varphi_i \sigma_{V_i} \tag{3}$$

2.2 Analysis on stochastic error

The actual regulation is on the basis of flood forecast, because of subjective and objective factors such as the hydrology test error、forecast method error and sampling error etc.. hydrology forecast error is exists inevitably, stochastic error's source as follows:

(1) Initial storage capacity V_0: When water level is about to arrive at limit water level, our consciousness on flood control is very sensitive and control strictly water level under limit water level, so initial water level's stochastic discreteness is very small, mainly from uncertain function between storage capacity and water level、data error (artificial observation error、instrument etc.)、forecast error etc..

(2) Inflow flood Q: Forecast inflow flood is the end ownership of reservoir basin's flood forecast system, is also one target that flood forecast system builds. Errors are mainly from: ① Data error: information collecting error such as water level, rainfall, evaporation, which are restricted by artificial observation, instrument, record error etc.). ② Forecast error: runoff model and concentration model, the key place of flood forecast, are complex process, which are influenced by rainfall, land surface, regulation of river network and slope and etc. Its error mainly comes from difference of hydrologic model selection、parameter calibration、standard judgment etc.. Above every error belongs to flood forecast error, and just calculate comprehensive error from the statistical error of actual measure flood and forecast flood with forecast accuracy.

(3) Outflow flood q: In actual regulation, we take forecast flood as the actual flood to control outflow flood, errors are mainly from: ① error of hydraulic and flow building: Because of construction error、overflow building distortion、hydraulic parameters indetermination, makes outflow to have indetermination. The indetermination of the structure size is small, which influence is also small, considered as a certain parameter to calculate, the relative error of hydraulic and building size takes 1.5% for simplification. ② regulation error: Subjected to indetermination of information collects and deliver、management and control operation etc., the actual regulation will have certain degree of deviation, takes 5% for simplification.

2.3 Stochastic error calculation

2.3.1 Stochastic deviation

The stochastic error can be reflected by sample's mean square deviation, while sample's statistics parameters are hard to get, so it can combines allowable error with the confidence and use qualification rate to place the confidence, then obtain statistic parameters according to numerical statistics.

Sample variable $x \sim N(u_x, \sigma_x^2)$, error $\varepsilon = x - u_x$, confidence $\alpha = P(-\Delta < \varepsilon < \Delta)$, and often take relative error r to reflect allowable error, $\Delta = ru_x$, $r = (x - u_x)/u_x$. According to normal distribution knowledge, mean – square deviation:

$$\sigma_x = \Delta/\Phi_{(0.5+\alpha/2)} = ru_x/\Phi_{(0.5+\alpha/2)} \tag{4}$$

In above formula: u_x is sample expectation; σ_x is sample mean – square deviation; Φ_p is standard normal coefficient from mean.

2.3.2 Error synthesize

function $y = f(x_1, x_2, \ldots)$, the whole error comes from every factor's effect, and often make some supposition and simplification because of complexity in flood routing and uncertainties of factors. Then total mean – square deviation:

$$\sigma = \sqrt{\sum \left(\frac{\partial f}{\partial x_i}\sigma_i\right)^2 + 2\sum \rho_{ij}\frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j}\sigma_i\sigma_j} \tag{5}$$

Suppose each change quantity as independent, and take every error dissemination coefficient $\frac{\partial f}{\partial x_i}$ as 1, then total mean – square deviation:

$$\sigma = \sqrt{\sum \sigma_i^2} \tag{6}$$

Each change quantity's error all takes same confidence α, and approximatively take all u_{xi} as u, then total relative error:

$$r = \sqrt{\sum r_i^2} \tag{7}$$

3 Wind wave influence analysis

3.1 Wind wave calculation

Wind wave can strikes slope surface while breaking up dam body, the fluctuation flow rises and drops on slope back and forth, and increases water level in certain degree, which has very strong breakage function to surface, it can cause increased height:

$$\Delta z_p = R_p + e_p \tag{8}$$

In formula(8): R_p is wave run – up; e_p is wind banked – up height.

When shed area has wind data more than 20 years, design wave factors can carry on frequency analysis (normal distribution、lognormal distribution、Pierson Ⅲ distribution、rayleigh distribution etc.), by adopting some accumulation frequency to confirm. When shed area has no long period data or length of wind region isn't long, design wave factors can adopt prediction method to calculate. Wind wave process is complicated, and also restrict by measure data、locale circumstance, current method is mainly experience method、half theory and experience method, which often needs to make some assumption and simplification. Wind speed and wind direction are key factors affecting wind waves parameters, wind wave can not cause overtopping risk under general circumstance, but combined with flood function in flood season, can cause wreck. So can take the biggest valid wind speed in flood season to calculate. According to shed area's characteristic, select relevant different formula, each parameter calculates with expectation value of design condition, and then get value of cumulation frequency with correspond distribution, criterion's formula as follows:

$$\overline{H} = AV^2/g \cdot \text{th}[0.001, 8(gF/V^2)^{0.45}/A], A = 0.13\text{th}[0.7(gD/V^2)^{0.7}] \tag{9}$$

$$e_p = KV^2F/(2gD) \cdot K_p\cos\beta \tag{10}$$

$$R_p = K_\Delta K_V K_p R_0 K_\beta \overline{H}, (m \leqslant 1.25) \tag{11}$$

V is design wind speed; F is wind region length; D is water depth of wind region; β is wind direction angle; K is comprehensive friction coefficient; m is slope coefficient; K_Δ is roughness; K_V

is coefficient contact with wind speed; R_0 is wave run – up on slippy slope without wind; K_p is conversion coefficient of cumulation frequency p; K_β is wave direction reduce coefficient.

3.2 Combination of wind wave and flood

The parameters of wind wave are restricted by shed area characteristic (shape、water depth、slope etc.), wind conditions (wind speed、direction, barometric regiment etc.) etc. but parameters of floods are restricted by watershed characteristic (geomorphic、river network、area etc.), rainfall (humidity, temperature, cold and warm atmosphere), and the difference between them is obvious. It has certain relativity between them, for example, typhoon often causes big flood and strong wind wave simultaneously, we should analyse the relativity, but this relativity is often not obvious so that the relativity of these increased heights is also small. overtopping risk is mainly from flood, however the risk from wind wave is little, so can regard increased height from flood、increased height from wind as independent random variables, and these combination as random combination process. In fact only valid wind that blows toward dam body can affect overtopping, but wind direction is indetermination, so combination between wind direction and other parameters including wind speed is somewhat random.

Owing to the complexity、random of flood and wind wave, combination between them takes fix frequency to combine, each frequency design flood combines respectively with three frequency wind wave 2%, 1%, 0.1% to calculate.

4 Overtopping risk assessment

Limit water level, affecting obviously dam's stabilization, overtopping etc., is a very impressionable factor toward failure risk, and its change will cause variety of reservoir movement factor and can increase the crash risk, so need to evaluate operation benefit and possible disaster lose. This text mainly considers overtopping risk from flood regulation and wind wave under certain limit water level, and assesses it with tolerance risk standard.

4.1 Tolerance risk analysis on overtopping

4.1.1 Overtopping and dam – break

Dam – break is mainly aroused by overtopping, piping, seepage, crack, landslide and earthquake etc., and overtopping mainly results from over – level flood, poor discharge capacity. overtopping doesn't equal with dam – break, whether brings failure depends on hydraulic condition、erosion time、operating condition and management of dam etc. But overtopping flood easily erodes dam foundation and bank, and result in failure because of structural instability. Concrete dam and masonry dam, which rarely destroy by overtopping, can resist flood overtopping better than earth – rock dam, partial concrete dams can allow wave overtopping and dam – crest freeboard without failure. Average annual rate of dam – break in the World is about 2.0×10^{-4}, and in America is about 2.5×10^{-4} in the last decade, and about 1/3 of them result from overtopping, so average rate of overtopping is about 0.7×10^{-4}. In China, average annual rate of dam – break is about 8.761×10^{-4}, but because China has reinforce our country safety management since 1981, average rate of dam – break is about 2.54×10^{-4} in the last 20 years, and about 1/2 of them result from overtopping, so average rate of overtopping is about 1.27×10^{-4}.

4.1.2 Probability of risk events

Risk probability itself has fuzzy indetermination; many scholars put forward to measuring it with risk magnitude order, not reach a consensus to the acceptable failure risk. As Chinese rule, probability in range of (0.01 ~ 0.000,1) means that event basically doesn't happen on the whole, and probability in range of (0.000,1 ~ 0.000,001) means that event never happen; Australian guidelines on risk assessment suggest that magnitude order 10^{-4} is very seldom possible, magnitude order 10^{-5} is very impossible, and magnitude order 10^{-6} is nearly impossible; Some scholars think that probability 10^{-4} means that event hasn't record happening, and will not have a similar circumstance event happening under condition at present. Synthesizing above various risk probability, magnitude order of tolerance risk of overtopping is about 10^{-4}.

4.1.3 Tolerance risk standard

Method of tolerance risk analysis is popular in dam safety decision – making at present, which directly touch failure consequences C with failure risk probability P_f, then tolerance risk standard $R^* = C \cdot P_f$. Some departments in America and Canada take 0.001 person/(year · dam), Holland suggests to take 0.1 ~ 0.001person/(year · dam), Germany suggests to take 0.02 ~ 0.001person/(year · dam). According to international experience, $R^* = US\$7120/$ (year · dam), namely $R^* = 0.001$person/ (year · dam), which is acceptable widespread. But because of big population、falling behind economy in our country, average annual rate of dam – break in our country is about 4.4 times than that in world, so tolerance risk standard in our country can take 0.004,4 ~ 0.001 person/(year · dam). Estimate failure loss by magnitude order[15] for simplification, large reservoir takes billion RMB, then tolerance risk probability of large reservoir is about $3.133 \times 10^{-4} \sim 0.712 \times 10^{-4}$, overtopping accounts for 1/2 in all dam failure and magnitude order of risk probability is 10^{-4}, so tolerance overtopping risk probability of large reservoir is about $1.57 \times 10^{-4} \sim 0.36 \times 10^{-4}$.

4.2 Over water level risk probability calculation

The change of water level is aroused by trigger event A such as from flood、wind wave etc., risk probability P_f is the probability that highest water level H_{max} exceeds dam crest elevation Z_c:

$$P_f = P(H_{max} \geqslant z_c) = P(H_{Lmax} + \Delta z_p \geqslant z_c) \tag{12}$$

(1) Not take account of randomicity, calculate routing process with expectational mean of parameter, given limit water level h_0, the smaller trigger event's frequency is, the taller routing level $h_{max}(h_0)$ is, and supposed probability distribution P_A, risk probability:

$$P_f(h_0) = P_A(H_{max}(h_0) \geqslant z_c) \tag{13}$$

(2) Take account of randomicity, given limit water level h_0, taller routing level with trigger event of frequency P_{Ai} has stochastic distribution, and supposed discrete distribution p_i, the risk probability that highest level H_{max} (P_{Ai}, h_0) exceeds z_c under event P_{Ai} is conditional risk probability:

$$P_{f/Ai}(h_0) = p_i((H_{max}(P_{Ai}, h_0) \geqslant z_c)) \tag{14}$$

All probability event P_{Ai} compose whole probability S, take trapezoidal interpolation to calculate frequency interval S_i, the risk probability that highest level exceeds Z_c in all frequencies is whole – probability risk or cumulative probability risk, as follows:

$$P_f(h_0) = \sum_{i=1}^{n} (P_{f/Ai}(h_0) \cdot S_i) \tag{15}$$

Dam's ability of resisting flood is limited, only be able to resist some maximum frequency flood, regard risk aroused by over – level flood as natural risk, and supposed exceptional frequency P_e is critical over – level frequency, then risk probability that highest level exceeds Z in frequency range $P_A \in [0, P_e]$ is cumulative probability of over – level flood.

5 Example calculation

MianHuatan Reservoir is a synthetical large reservoir, take generating electricity as the first place. The normal level is 173 m, dam crest elevation is 179.0 m, and has another 0.6 m high entity wave wall in upper stream. Limit water level is 168.74 m in the main flood season (5 ~ 6 months), for satisfying needs including water supply、power supply etc., draw up to increase limit water level to 169.80 m under condition of satisfying flood prevention, then apply above method to analyse its feasibility.

Mainly analyse flood peak, flood volume, flood process and flood happened time, and synthetical accuracy is 84% which is near to 85%, the first grade level and compute with the first grade level.

5.1 Stochastic analysis and calculation on flood routing

(1) Initial storage capacity V_0: The ability in observation and forecast toward water level is all right, and can control error within ±0.10 m range, considering wind banked – up height to take 0.15 m, take confidence 85%, and get $\sigma_{V_0} = 0.057,3 \times 10^8 m^3$ based on relation of water level – storage capacity.

(2) Forecast inflow flood $Q(t)$: Calculate with relative error of every moment, take 20% of the biggest variable amplitude inside forecast period as allowable error[22], Calculate biggest variable amplitude with continuous 6 – hour flood process, the measuring flood's biggest average variable rate is 0.517/6 h; the design flood's is 0.547/6 h, so then take 0.6 to calculate, get $\Delta_Q = 0.12Q(t)$, $\sigma_{Q(t)} = 0.083,7Q(t)$.

(3) Inflow flood $q(t)$: Take approximately 5% as the operation error, 1.5% as error of hydraulic and building size, then the total relation error is 5.22% by formula(5), then $\sigma_{q(t)} = 0.036,2q(t)$.

(4) Reach the total mean – square deviation of storage capacity as follows: While water level is lower than 173 m, the regulation is a process affected synthetically by above – mentioned stochastic errors, the total mean – square deviation:

$$\sigma_V = \sqrt{(0.057,3 \times 10^8)^2 + \sum[(0.083,7Q(t))^2 + (0.036,2q(t))^2] \times 7,200^2}$$

While water level is not lower than 173 m, the regulation is free process with all gate and bottom hole open, relation error is 5.22% only influenced by error of hydraulic and building size, the total mean – square deviation: $\sigma_V = \sqrt{\sigma_{173}^2 + \sum(0.010,4q(t) \times 7,200)^2}$

Select kinds frequency design floods, make routing with regulation rule and different stochastic discrete frequency, then get highest water level which has stochastic distribute, as Table 1 (partial data).

Table 1 Stochastic distribution of highest level adjusted by design floods with limit water level of 169.8 m

Design flood P (%)	Discrete frequency p (%)									
	99.9	99	95	80	50	20	5	1	0.1	0.02
0.01	174.00	174.53	175.32	176.24	177.19	178.30	179.21	180.11	181.14	181.76
0.02	173.63	173.88	174.61	175.49	176.54	177.42	178.41	179.26	180.07	180.64
0.2	173.15	173.08	173.64	173.72	174.48	175.24	176.10	176.65	177.44	177.92
0.1	173.03	173.10	173.12	173.70	173.71	174.38	175.03	175.70	176.43	176.71
0.5	171.40	172.77	173.18	173.13	173.25	173.58	173.93	174.37	174.89	175.29
1	169.80	171.22	172.32	173.15	173.28	173.28	173.67	173.56	173.84	174.21
2	169.80	169.80	170.77	171.79	172.98	173.13	173.17	173.34	173.63	173.71

5.2 Calculation of wind wave

According to statistics data in Shanghang Station, motionless wind without direction takes first place, and northwest wind takes second, average annual wind speed is 2. 3 m/s, the measured quickest wind speed is 25 m/s (June 16, 1971) and direction is southeast, and the quickest and valid wind speed is about in range 5 ~ 6 grade(8 ~ 14 m/s). The annual maximum floods happened in 4 ~ 6 months account for 76%, but typhoons that land in 5 ~ 6 months account for 12%, and land in 7 ~ 9 months, which is important period for typhoon, account for 70%, so most typhoon flood could not reach maximum grade of flood. Average maximum design wind speed approximatively takes 14 m/s, 20 m/s, wind direction angle approximatively takes 30°. use formula (9, 10, 11), parameters as follows: $D = 25$ m; $F = 3.3$ km; $\beta = 30°$; $K = 3.6 \times 10^{-6}$; $K_\Delta = 0.85$; $K_V = 1.02$; K_p = 2.11(2%), 2.28(1%), 2.73(0.1%); $m = 0.1$; $R_0 = 1.346$; $K_\beta = 0.92(30°)$. as Table 2.

Table 2 Calculation results of wind wave parameters

P (%)	ΔZ_{Flood}	Wind wave $V = 14$ m/s				Wind wave $V = 20$ m/s				N_2
		e_p	R_p	ΔZ_p	N_1	e_p	R_p	ΔZ_p	N_1	
2	3.182	0.009	0.784	0.793	4.0	0.017	1.159	1.176	2.7	1.5
1	3.478	0.009	0.848	0.857	4.1	0.019	1.252	1.271	2.7	1.5
0.1	4.675	0.011	1.015	1.026	4.6	0.022	1.500	1.522	3.1	1.5

Note: N_1, ratio between ΔZ_{Flood} and ΔZ_p; N_2, ratio between ΔZ_p of speed 20 m/s and 14 m/s.

5.3 Risk probability of overtopping

Each frequency design flood combines respectively with wind wave of three frequency, 2%, 1%, 0.1%, and calculate by two projects, one is only considering certain process, namely without stochastic (Pro Ⅰ), another is considering stochastic process of parameters (Pro Ⅱ), which calculate by expectation of stochastic process (stochastic frequency $p = 50\%$), use formula (12) with trapezoidal interpolation to calculate data in Table 1 (6th columns); Synchronously ascertain whole – probability of overtopping and cumulation probability of overtopping beyond exceptional flood,. The resulte shows in Table 3.

Table 3 Risk probability of overtopping with limit water level of 169.8 m (10^{-4})

Flood	Cal – Project	No wind	With wind ($V = 14$ m/s)				With wind ($V = 20$ m/s)				N_4
			2%	1%	0.1%	N_3	2%	1%	0.1%	N_3	
Whole –	Pro Ⅰ	0.056	0.145	0.156	0.191	2.9	0.229	0.256	0.346	4.9	1.7
probability	Pro Ⅱ	0.143	0.338	0.367	0.441	2.7	0.508	0.587	0.850	4.5	1.7
Except –	Pro Ⅰ	0.012	0.064	0.068	0.082	5.9	0.097	0.115	0.168	10.5	1.8
ional	Pro Ⅱ	0.031	0.149	0.160	0.189	5.4	0.215	0.265	0.412	9.7	1.8
Over –	Pro Ⅰ	0.044	0.081	0.088	0.109	2.1	0.132	0.141	0.178	3.4	1.6
level	Pro Ⅱ	0.112	0.190	0.207	0.252	1.9	0.293	0.323	0.438	3.1	1.6

Note: N_3, ratio between average risk probability with wind wave and without wind wave; N_4, ratio between average risk probability with speed 20 m/s and 14 m/s.

5.4 Results analysis

The height increased by flood is bigger than that by wind wave, and the contrast with big flood is more obvious; From reasoning formula in wind wave and calculation example can see that wind speed is key factor and sensitive for increasing height. Risk probability without wind wave is 0.056×10^{-4} (calculation without stochastic), with wind wave is 0.346×10^{-4} (calculation without stochastic), function of wind wave is sensitive at critical water level, the relevant overtopping risk is obviously bigger, and can result in risk crash. With stochastic process calculation, risk probability is 0.85×10^{-4}, bigger than without stochastic process 0.346×10^{-4}; The probability of over – level flood is extreme small, but overtopping risk is so big which accounts for 51.9%. Tolerance overtopping risk critical probability is about $1.57\times10^{-4}\sim0.356\times10^{-4}$, maximum overtopping risk with stochastic process and wind wave is $0.816, 9\times10^{-4}$, which is in range of safety. So taking 169.80 m as limit water level to control reservoir can satisfy overtopping risk standard.

6 Conclusions

(1) Flood regulation process is synthetically subjected to lots of indetermination factors. This work mainly considers stochastic process of flood forecast and wind wave by taking fix frequency to combine them, carries out stochastic analysis and assess the risk on limit water level in flood season by using the first order second moment method and theoretic distribution to describe stochastic distribution of parameters.

(2) The outcomes of case calculation show that the increased height of water level mostly comes from flood, over – level flood causes overtopping very easily, the influence of wind wave is small relatively, and wind waves can increase overtopping risk obviously at critical water level when it is sensitive.

(3) Overtopping risk assessment on operation of reservoir is helpful and useful to determine the limit water level in flood season for performance reservoir's benefit well under condition of flood prevention satisfy.

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