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

Volume Ⅰ

Yellow River Conservancy Press

The 3rd International Yellow River Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance

Organizer

Yellow River Conservancy Commission (YRCC), Ministry of Water Resources, P. R. China

Co – Organizer

Dongying Municipal Government of Shandong Province, P. R. China
Shengli Petroleum Administrative Bureau, P. R. China
Yellow River Shandong Bureau, YRCC

Sponsors

EU – China River Basin Management Program
Ministry of Environment, Spain
WWF (World Wide Fund for Nature)
Department for International Development (DFID)
World Bank (WB)
Asian Development Bank (ADB)
Global Water Partnership (GWP)
Challenge Program on Water and Food (CPWF)
International Network of Basin Organizations (INBO)
World Conservation Union (IUCN)
Asia Scientific Regional Office of Global Water System Program (GWSP)
National Natural Science Foundation of China (NSFC)
Tsinghua University (TU)
Center for Water Resources Research, Chinese Academy of Sciences (CAS)
China Institute of Water Resources and Hydropower Research (IWHR)
Nanjing Hydraulic Research Institute (NHRI)
Yellow River Water & Hydropower Development Corporation (YRWHDC)
International Economic Technical Cooperation and Exchange Centre, MWR (IETCEC, MWR)

Advisory Committee

Honorary Chairmen

Qian Zhengying, Former Vice Chairwoman of Consultant Committee of People's Republic of China; Academician of Chinese Academy of Engineering
Yang Zhenhuai, Former Minister of Ministry of Water Resources of China; President

of Chinese Society of Water and Soil Conservation; Honorary Chairman of GWP China
Wang Shucheng, Former Minister of Ministry of Water Resources of China

Chairmen

Hu Siyi, Vice Minister of Ministry of Water Resources, China
Jia Wanzhi, Vice Governor of Shandong Province, China

Vice Chairmen

Zhu Erming, Former Chief Engineer of Ministry of Water Resources of China
Gao Anze, President of Chinese Hydraulic Engineering Society (CHES)
Xu Qianqing, Academician of Chinese Academy of Engineering
Dong Zheren, Chairman of GWP China
Huang Ziqiang, Vice Chairman of Technical Committee of Yellow River Conservancy Commission (YRCC), MWR, China; Chairman of GWP China (Yellow River)
Zhang Jianhua, Mayor of Dongying Municipal Government of Shandong Province, China
Serge Abou, Ambassador of the Delegation of EC to China
Loïc Fauchon, President of World Water Council, France
Dermot O'Gorman, WWF China Representative
Paul Ching – Wu Chu, President of the Hong Kong University of Science and Technology

Members

Cao Zelin, Director General of Academy of Chinese Economics Limited, China
Christopher George, Executive Director of International Association of Hydraulic Engineering and Research, Spain
Dai Dingzhong, Professor of Chinese Hydraulic Engineering Society (CHES)
Des Walling, Professor of Department of Geography, School of Geography, Archaeology and Earth Resources, UK
Don Blackmore, Academician of Australian Academy of Science; Former Chief Executive of Murray – Darling Basin Commission (MDBC), Australia
Feng Guobin, Director of Henan Hydropower Engineering Society, professor, China
Gaetan Paternostre, General Manager of National Company of Rhone River, France
Gong Shiyang, Former Commissioner and Professor of Yellow River Conservancy Commission, MWR, China
Jacky COTTET, President of Rhône River Agency, France; President of the European International Network for Basin Organizations (Euro – INBO)
Khalid Mohtadullah, Senior Advisor of Global Water Partnership (GWP), Pakistan
Kuang Shangfu, Director General of Institute of Water Resources and Hydropower Research (IWHR), China
Liu Weimin, Director General of Qinhai Provincial Water Resources Bureau
Liu Zhiguang, Deputy Director General of Department of International Cooperation, Science and Technology, MWR, China
Pan Junfeng, Director General of Shanxi Provincial Water Resources Bureau
Pierre ROUSSEL, Head of the French General Inspection for Environment; Presidency

of the French "Scientific and Technical Association of Environmental Engineering"
Shao Xinmin, Deputy Counsel of Henan Provincial Water Resources Bureau
Tan Cewu, Director General of Shaanxi Provincial Water Resources Bureau
Wu Yiqun, Deputy Director General of Shandong Provincial Water Resources Bureau
Xu Wenhai, Director General of Gansu Provincial Water Resources Bureau
Wu Hongxiang, Director General of Ninxia Autonomous Regional Water Resources Bureau
Yves Caristan, Executive President of French Geological Survey Bureau (BRGM)
Zhang Jianyun, Director General of Nanjing Hydraulic Research Institute, China

Organizing Committee

Honorary Chairman

Chen Lei, Minister of Ministry of Water Resources, China

Chairman

Li Guoying, Commissioner of Yellow River Conservancy Commission, MWR, China

Vice Chairmen

Gao Bo, Director General of Department of International Cooperation, Science and Technology, MWR, China
Wang Wenke, Director General of Bureau of Comprehensive Development, MWR, China
Xu Cheng, Vice Commissioner of Yellow River Conservancy Commission, MWR, China
Yin Baohe, Director General of Xiaolangdi Multi – purpose Project Administrative Bureau, MWR, China
Yuan Chongren, Director General of Yellow River Shandong Bureau, YRCC
Gao Hongbo, Deputy Director of the Administration Office, Shandong Provincial People's Government, China
Lv Xueping, Deputy Mayor of Dongying Municipal Government of Shandong Province, China
Li Zhongshu, Deputy Director General of Shengli Petroleum Administrative Bureau, China
Emillio Gabbrielli, Executive Secretary of GWP Secretariat, Sweden
Andras Szollosi – Nagy, Deputy Assistant Director General of UNESCO
Kunhamboo Kannan, Director of Agriculture, Environment & Natural Resources Division, East and Central Asia Department, ADB

Members

An Xindai, Director General of Department of Water Resources Management and Regulation, YRCC
A. W. A. Oosterbaan, Senior Expert of International Affairs of Directorate of Sciences and Technology, Ministry of Transport, Public Works and Water Management, the Netherlands

Bjorn Guterstam, Network Officer of GWP Secretariat, Sweden
Bryan Lohmar, Economist of Economic Research Service, USDA
Chen Yiyong, Deputy Director General of Xiaolangdi Multi – purpose Project Administrative Bureau
Chen Yinlu, Deputy Secretary General of Dongying Municipal Government of Shandong Province, China
Du Zhenkun, Coordinator of GWP China
Guo Guoshun, Chairman of Labor Union and Director General of Administration Office, YRCC
G. H (Gordon) Huang, Professor of Canada Regina University, Canada
Hou Quanliang, Deputy Director General of Administration Office, YRCC
Huub Lavooij, First Secretary of the Royal Netherlands Embassy in Beijing
Jia Jinsheng, Deputy Director of Institute of Water Resources and Hydropower Research, China
Jonathan Woolley, Coordinator of Challenge Program on Water and Food (CPWF), Sri Lanka
Joop L. G. de Schutter, Dean of Department of Water Engineering, UNESCO – IHE, the Netherlands
Li Guifen, Professor of China Institute of Water Resources and Hydropower Research (IWHR), Council Member of IAHR
Li Jingzong, Director General of Office of Chief Engineer, YRCC
Li Xinmin, Director General of Department of Personnel, Labour and Education, YRCC
Li Ming, Professor of National Natural Science Foundation of China
Liu Shuanming, Director General of Department of Construction and Management, YRCC
Liu Xiaoyan, Deputy Chief Engineer, YRCC
Luo Xiangxin, Director General of Press & Publication Center, YRCC
Ma Chaode, Freshwater Programme Officer, WWF China
Paul van Hofwegen, Senior Expert on Water Management of World Water Council, France
Paul van Meel, TAT TL EU – China RBMP
Stephen Beare, Research Director of Australian Bureau of Agriculture and Resource Economics, Australia
Tan Guangming, Dean and Professor of College of Water Resources and Hydropower, Wuhan University, China
Wang Changci, Deputy Director General of Yellow River Shandong Bureau, YRCC
Wang Guangqian, Professor of Tsinghua University, China
Wang Jianzhong, Director General of Department of Water Policy, YRCC
Wang Xijun, Director General of Department of Water and Soil Conservation, YRCC
Wang Xuelu, Y. R. Wanjiazhai Water Multi – Purpose Dam Project Co. , Ltd
Wouter T. Lincklaen Arriens, Lead Water Resources Specialist of Asian Development Bank (ADB)
Wu Baosheng, Professor of Tsinghua University, China
Xia Minghai, Director General of Department of Financial Affairs, YRCC

Xu Zongxue, Leading Professor and Deputy Dean, College of Water Sciences, Beijing Normal University, China
Yan Tongsheng, Deputy Division Chief of Shengli Petroleum Administrative Bureau
Yao Zijing, Director General of Office of Administration, YRCC
Yu Xingjun, Director General of International Economic Technical Cooperation and Exchange Centre, MWR, China
Zhang Hongshan, Deputy Chief Engineer of Shengli Petroleum Administrative Bureau
Zhang Jinliang, Director General of Office of Flood Control, YRCC
Zhang Junfeng, Director General of Department of Plan and Programming, YRCC
Zhang Yongqian, Professor of Academy of Chinese Economics Limited, China

Secretary General

Shang Hongqi, Director General of Department of International Cooperation Science and Technology, YRCC

Technical Committee

Chairman

Xue Songgui, Chief Engineer of YRCC

Members

Anders Berntell, Executive Director of Stockholm International Water Institute (SIWI), Secretary General of Stockholm World Water Week, Sweden
Bart Schultz, Senior advisor of Civil Engineering Division, Directorate General for Public Works and Water Management, Utrecht, Professor of UNESCO – IHE, the Netherlands
Bas Pedroli, Professor of Alterra Wageningen University, the Netherlands
Chen Jiyu, Academician of Chinese Academy of Sciences (CAS), Professor of Institute of Estuary and Seacoast Research, East China Normal University
Chen Xiaoguo, Chairman of Technical Committee, YRCC, MWR
Chen Zhikai, Academician of Chinese Academy of Engineering, Professor of China Institute of Water Resources and Hydropower Research (IWHR)
Cheng Chaojun, Deputy Chief Editor of Academy of Chinese Economics Limited, China
Cheng Xiaotao, Professor of China Institute of Water Resources and Hydropower Research (IWHR), China
Chih Ted Yang, Professor of Bureau of Reclamation, USA
Chin – Lien Yen, Professor of Taiwan University, Taipei, China
David Molden, Theme Leader of IWMI, Sri Lanka
Ding Dewen, Academician of Chinese Academy of Sciences (CAS), the First Institute of Oceanography, State Oceanic Administration, China
Dou Xiping, Chief Engineer of Nanjing Hydraulic Research Institute, China
Eelco van Beek, Professor of WL | Delft Hydraulics, the Netherlands
Gao Jun, Academician of Chinese Academy of Sciences (CAS)
Hongyuan Lee, Professor of Taiwan University, Taipei, China

Hu Angang, Senior Advisor of State Council, Professor of Tsinghua University, China
Hu Chunhong, Deputy Director of Institute of Water Resources and Hydropower Research, China
Hu Dunxin, Academician of Chinese Academy of Sciences (CAS), Professor of Institute of Marine Research, Chinese Academy of Sciences (CAS)
Huib J. de Vriend, President of WL | Delft Hydraulics, the Netherlands
Jean – Francois Donzier, Permanent Technical Secretary of International Network of Basin Organizations (INBO), General Manager of the International Office for Water
Ji Changming, Director of Graduate – student Institute of North China Electric Power University
Ji Chunlou, Deputy Director General of Chongqing Municipal Water Resources Bureau
Jinn – Chuang Yang, Professor of Chiao Tung University, Taipei, China
Joseph H. W. Lee, Professor of Hong Kong University
Kuniyoshi Takeuchi, Professor of Yamanashi University, Japan; Director of International Center for Water Hazard and Risk Management (ICHARM) under the Auspices of UNESCO
Laszlo Iritz, Vice President of COWI, Denmark
Lee Yee Cheong, Academician Dato'Ir, President Elect WFEO, Malaysia
Lei Tingwu, Professor of Northwest China Institute of Soil and Water Conservation Research, CAS
Li Jiayang, Vice Director & Academician of Chinese Academy of Sciences (CAS)
Li Lifeng, Director of Freshwater Programme Officer, WWF China
Li Wanhong, Professor of National Natural Science Foundation of Chinese
Li Wenxue, President of Yellow River Engineering Consulting Co., Ltd
Li Zhuofen, Vice President of the University of Hong Kong, Academician of Chinese Academy of Engineering, Academician of Canada Academy of Engineering, Director of Hong Kong Academy of Engineering and Science
Lin Binwen, Professor of Yellow River Conservancy Commission
Liu Bin, Deputy Director General of Gansu Provincial Water Resources Bureau
Liu Changming, Academician of Chinese Academy of Sciences (CAS), Professor of Beijing Normal University, China
Lu Yongjun, Deputy Director of River and Harbor Department, Nanjing Hydraulic Research Institute, China
Lu Youmei, Academician of Chinese Academy of Engineering (CAE)
Ma Jiming, Professor of Tsinghua University, China
Mao Zhi, Academician of Chinese Academy of Engineering (CAE), Wuhan University, China
Mohamed Nor bin Mohamed Desa, Director of Malaysia UNESCO Regional Humid Tropic Hydrology Center (HTC), Malaysia
Ni Jinren, Professor of Peking University, China
Peng Jing, Professor of Institute of Water Resources and Hydropower Research, China
Peter A. Michel, Head of Water Protection and Fisheries Division, Switzerland
Peter Rogers, Member of Technical Advisory Committee of GWP, Professor of Harvard University, USA
Ren Liliang, Dean of Water Resources and Hydropower Engineering College, Hohai

University
Richard Hardiman, Project Officer, Delegation of EC to China
Shi Changxing, Professor of Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Stefan Agne, First Secretary, Delegation of EC to China
Sun Honglie, Academician of Chinese Academy of Sciences (CAS)
Sun Ping'an, Chief Engineer of Shaanxi Provincial Water Resources Bureau
Tian Zhen, Director General of Inner Mongolia Water Resources and Hydropower Engineering Reconnaissance and Design Institute
Volkhard Wetzel, Director of Federal Institute of Hydrology (BFG), Germany
Wang Bingchen, Senior Advisor of State Council, Professor of Tsinghua University, China
Wang Hao, Academician of Chinese Academy of Engineering, Director of Water Resources Research Department of IWHR, Secretary General of GWP China
Wang Jiayao, Academician of Chinese Academy of Engineering, Professor of Science and Information Engineering University, China
Wang Jiyang, Academician of Chinese Academy of Sciences (CAS)
Wang Xianzhang, Chief Engineer of Henan Provincial Water Resources Bureau
Wang Yadong, Chief Engineer of Inner Mongolia Water Resources and Hydropower Engineering Reconnaissance and Design Institute
Wang Zhaoyin, Professor of Tsinghua University, China
William Bouffard, Head of the Coordination and Quality Unit for the Rhône River Basin Agency, France
Wu Bingfang, Professor of Institute of Remote Sensing Applications, Chinese Academy of Sciences
Xia Jun, Professor of Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences; Vice Chairman of IAHS and IWRA
Xue Saiguang, Chief Engineer of Ningxia Autonomous Regional Water Resources Bureau
Y. Cheng, Chairman of Sinotech Foundation for Research & Development of Engineering Sciences & Technologies, Taipei, China
Yan Dakao, Director General and Professor of North China University of Water Conservancy and Electric Power, China
Yang Guowei, Vice Chairman of the China Technical Advisory Committee (TAC), GWP – China
Zeng Guangming, Director of College of Environmental Science & Engineering, Hunan University, China
Zhang Baishan, Deputy Director General of Yellow River Shandong Bureau, YRCC
Zhang Hongwu, Professor of Tsinghua University, China; Deputy Chief Engineer of YRCC
Zhang Qiangyan, Chief Engineer of Sichuan Provincial Water Resources Bureau
Zhang Ren, Professor of Tsinghua University, China
Zhang Renduo, Professor of Ohio University, USA
Zhou Jianjun, Professor of Tsinghua University, China
Zhu Qingping, General Manager of China Water International Engineering Consulting Co. Ltd., MWR, China

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

图书在版编目(CIP)数据

第三届黄河国际论坛论文集 = Proceedings of the 3rd International Yellow River Forum/尚宏琦,骆向新主编. —郑州:黄河水利出版社,2007. 10
ISBN 978 - 7 - 80734 - 296 - 0

Ⅰ. 第…　Ⅱ. ①尚…②骆…　Ⅲ. 黄河 - 河道整治 - 国际学术会议 - 文集 - 英文　Ⅳ. TV882. 1 - 53

中国版本图书馆 CIP 数据核字(2007)第 150063 号

出 版 社:黄河水利出版社
地址:河南省郑州市金水路 11 号　　邮政编码:450003
发行单位:黄河水利出版社
发行部电话:0371 - 66026940　　传真:0371 - 66022620
E - mail:hhslcbs@ 126. com
承印单位:河南省瑞光印务股份有限公司
开本:787 mm × 1 092 mm　1/16
印张:151. 50
印数:1—1 000
版次:2007 年 10 月第 1 版　　印次:2007 年 10 月第 1 次印刷

书号:ISBN 978 - 7 - 80734 - 296 - 0/TV · 525　定价(全六册):1 200. 00 元(US $ 160. 00)

Contents

Sustainable Water Resources Management and Basin Ecosystem Construction

Sustainable Water Resources Management and Basin Ecosystem Construction

The Theory, Methodologies and Practice of Water Resources Assessment Based on Ecosystem *

Wang Hao, ***Wang Jianhua***, ***Qin Dayong***, ***Jia Yangwen*** and ***Qiu Yaqin***

China Institute of Hydropower and Water Resources Research, Beijing, 100044

Abstract: The water resources assessment based on ecosystem is one of the basic problems to realize water resources sustainable development and promote the harmonious development between economic and ecological system. This paper summarizes the developments state and tendency of water resources assessment in contents and methodology in the research of this area, and analyzed their faced challenge. Furthermore, this paper presents the concept of water resources based on ecosystem and a dynamic hierarchical methodology of water resources assessment, that is, regional precipitation is considered as the whole flux of water resources. The resources structure of precipitation is analyzed systematically according to three principles of effectiveness, controllability and recoverability in water resources assessment in order to realize the hierarchical assessment including general water resources, special water resources and available water resources for national economy. In measure, the dualistic water resources assessment model jointing distributed hydrological model with physical mechanism and lumped water resources allocation model is applied to realize dynamic hierarchical assessment of water resources with changed underlying conditions and water use conditions as model variable.

Key words: human activities, water resources, assessment methodology, dualistic hydrological cycle, distributed hydrological model

Water resources are basic natural resources and stratagemical economical resources. The shortage of water resources has restricted the economical society development to different extent, meanwhile, the ecological and environmental problem caused by water shortage exert serious influence on economical development. Thus, dealing with relationship between the economy and ecosystem and promoting the sustainable development have become the key urgent research problem in present. Facing new national demand, it need to understand and assess rightly the water resources to rationally plan water resources and guarantee the sustainable development of water resources.

1 The development of water resources assessment in the world

Water resources assessment, an important fundamental work for water resources planning, exploitation, utilization, protection and management, is a completely analysis and evaluation course of water resources quantitative, qualitative, temporal and spatial distribution, and exploitation and utilization condition in river basin or regional scale, whose results will be a vital fundamental evidence for water events and decision – make.

Practical demand is source drive to promote development of applied science theory and technology. Water scarcity is the main drive to impel technological method development of water resources assessment. Before the mid of 20th century, the scarcity of water resources was not very obviously compared with water demand in economy and society. Although the primarily method of water resources assessment was formed based on the works about hydrological data collection and water amount statistics in Unite State and former USSR, the concrete techniques and method researches were still in vacancy. Since the mid of 20th century, increased utilization and drainage of

* The study got financial supports from the project of the national basic research program (2006CB403404).

water resources in the process of production and living had caused a series of water resources problem including water shortage in different degree, ecosystem degeneration and serious water contamination in many countries with rapidly growth of population and development of economy. Thus, many countries began to search practical way of promoting water resources sustainable utilization and pay great attention to water resources assessment which is an important fundamental work of water resources planning and management. Unite States implemented two national water resources assessments in 1968 and 1978, respectively. The first assessments mainly focused on base state evaluation of natural water resources, and developed subarea division work in river basin. The second assessment mainly focused on development and utilization assessment of water resources and water supply and demand forecast. The two assessments preliminarily formed the methodologies and technology of water resources assessment mainly based on statistics. Successively, west Europe, Japan and Indian and the other states put forward their water resources assessment in 1975. Due to more and more intensive water resources situation, an agreement was gradually made about important of water resources assessment in international. The world water meeting in Argentina in 1977 requested nations to increase fund invest into activities of water resources assessment. In 1988, UNESCO and WMO jointly formulated "the activity of water resources assessment – the national assessment handbook" based on experiments programs implemented in Australia, German, Ghana, Malaysia, Panama, and Rumania, Sweden, etc., and expert approval performed in Africa, Asia and Latin America to promote uniform water assessment methods in different countries, and course of water resources assessment. With increased demand for water resources assessment and management, UNESCO and WMO revised "the activity of water resources assessment – the national assessment handbook", and published "the water resources assessment the national capability evaluation handbook".

According to national demand of agricultural natural resources investigation and agricultural zone division, first national water resources assessment, started in China in 1980, mainly draw on the experience of assessment methods put forward and applied in Unite State and combined with practical situation in China, including the concept and assessment method of groundwater not – overlapped surface resources. The results, covering "initial water resources assessment in China" and "water resources assessment in China", clearly assessed Chinese essential water resources condition. Moreover, groundwater resources were evaluated by Ministry of Geology and Mineral. After then, due to serious water resources problem in north China, water resources assessment and some related water problems were studied specially in Eighth and Ninth five – years, Research plan. In 1999, as a standard in water industry, "the guide of water resources assessment" (SL/T238—1999) was issued by Ministry of Water Resources, which explicit prescribed the assessment contents and methods. In 2000, project of national water resources comprehensive planning was jointly developed by State Development and Reform Commission and the Ministry of Water Resources. In its technological outline and detailed rules, the technology and methods of water resources assessment were further modified and improved.

2 Challenge of technology and methodology of water resources assessment at present

The hydrological cycle, formulation and evolution basis of water resources, is a main cycle process in five surface material cycles. Water in different form exist everywhere and transform by each other, which make the sophistically systemic water resources assessment itself faces immense challenge. The faced challenges in water resources assessment technology under present environment are caused by evolution of subject and change of object demand.

(1) A challenge from intensive evolution of water resources due to human activities. With rapidly growth of economy and population, natural hydrological cycle in surface of earth has been deeply disturbed by human activities, and, formulation and evolution of water resources in basin is affected. These effects mainly concentrate in the following three sides: (a) Effect of water use. Due to large – scale utilization of water, artificial water cycle with basic structure of "abstration – water supply – water use – water consumption – water discharge" process was formed coupling with

natural "slope – river course" water cycle process. In most areas of north of China, the flux in artificial water cycle process were far greater than the observed flux in natural water cycle process. (b) Effect of underlying surface condition. Human activities such as exploitation of water body, alteration of local micro – topography and land use, as well as construction of building completely changed the underlying condition, and then affect the hydrological characteristic of infiltration, runoff, evapotranspiration and conflux, which need more demands to be satisfied for water resources assessment. (c) Effect of extensive discharge of greenhouse gas. This resulted in change of precipitation and energy condition in natural water cycle process and difference between basic condition at present and historic process of water resources, which bring difficulty for water resources assessment.

(2) A challenge from improved society development requirements to traditional water resources assessment method. Development of society and economy resulted in change of water resources exploitation and utilization situation, which need improvement in technology and methodology of water resources assessment. These obviously appear in three sides: (a) With serious shortage of surface water resources and groundwater resources, effective water such as soil water resources have paid great attention in rational allocation and effective utilization of special water resources, which demand extension of water resources assessment contents to realize unified allocation of different water resources. (b) With more extrusive of resources scarcity, high effective utilization of water resources should be strongly emphasized. This get a require for technology of water resources effective assessment, including methodologies and technologies of distinguished criterion of effective and ineffective water resources, united measurement between ecological avail and socio – economy avail, and quantification of high effective and low effective. (c) Water resources is united between quantity and quality. With popularization of the idea of regarding people as basis and harmonious society, requirement of exploitation and utilization of water resources cannot only stayed in the stage that there have water which can be used, but in the stage that there have water which meet quality criterion. Therefore, both of water environment criterion and water used quality criterion need united assessment between water quantity and quality.

Therefore, facing the challenge, the traditional water resources assessment need to be extended in the following aspects: the first is to extend from the aspect of resources, that is, contents of traditional water resources should to be extended from runoff water resources to general water resource, including effective utilization of precipitation, surface water and groundwater to atmosphere water, surface water, groundwater and soil water; the second is to extend from the view of system, that is, the hydrological cycle system should be extended to complex system coupling water cycle system and eco – economical and society system.

3 Theory, methodologies and model of water resources assessment based on ecosystem

3.1 Theory of water resources assessment based on ecosystem

The processes of atmospheric, surface, soil and underground in the whole natural hydrological cycle process have been altered due to extensive human activities including agricultural production, urbanization, ecological protection and process of water abstraction, water use, water consumption and water discharge, resulting that hydrological cycle gradually become the system which coupled the economical system with hydrological system. This tendency will become more and more intense. Thus, compared with traditional method, the water resources assessment based on ecosystem should at least have three characteristics. The first is that, in the view of assessment, human activities should be considered as intrinsic force in water resources evolution, but not as a "eliminating" items to obtain the natural actual hydrological series through the measure of "reverting". The second is that, in assessment process, maintaining dynamic coupled relation between natural and artificial water cycle, influence of human activities could be reflected sufficiently. The third is that, assessed contents and productions should serve both ecology construction in different level and environment protection and social economy development. In general, water resources assessment based on ecosystem should follow rules below:

(1) Water resources assessment, starting from general hydrological cycle flux in basin, consider the definition of water cycle flux with different characteristics and availability as the basis.

(2) "Usefulness" is primary attribution of natural resources. Therefore, the second important content in water resources assessment is to further distinguish and measure avail of water under the general water cycle flux.

(3) "Usable" is another important attribution after "usefulness" attribution of natural resources. Therefore, the third is to further distinguish usefulness of water according to the principle of controllability.

(4) Conception of resources based on ecosystem is pu relative to eco – environment system and socio – economy system. Thus, it is still needed to further distinguish the national economy permitted exploitation among the controllable water resources.

(5) The water resources assessment under present environment should be able to clearly describe effect of human activities on water resources evolution. The above five aspects together constitute basic thought of water resources assessment based on ecosystem.

Of course, for the whole of theories and methodologies of water resources assessment, besides quantity of water resources should be assessed, unified utilization efficiency, quantity and quality of water resources should be further assessed.

3.2 Hierarchical dynamic methodologies of water resources assessment

According to above theory of water resources assessment base on ecosystem, hierarchical dynamic methodologies of water resources assessment is put forward which is adapted to present and can meet the practical demand of water use in socio – economy and eco – environment.

3.2.1 Full calibers assessment

The full calibers water resources assessment is that, with all the input fluxes of hydrological cycle as basic calibers of water resources assessment, the water fluxes in different form is systemically analyzed, on the basis of which systematic assessment of water resources is realized. From the general point of precipitation, it contains two kinds of forms, namely vertical and horizontal precipitation. The vertical precipitation mainly refer to a phenomenon that moisture in cloud fall to ground as liquid or solid state, including rain, snow, sleet, rice snow, frost, hail, ice grain, ice pin, etc. The horizontal precipitation mainly refer to a phenomenon that fogdrop in air is intercepted by the some medium, such as leaves of vegetation to form bigger water drop. The horizontal and vertical precipitation differ with each other in intrinsic mechanisms. The vertical precipitation was mainly studied in this paper with four layers structure from top to bottom shown in Fig. 1. ① canopy interception; ② land interception or named depression storage; ③ infiltration to soil; ④ recharge of ground water. It can be seen that water resources assessment with precipitation as all input fluxes should systematically, definitely and quantitatively assess canopy interception, surface depression, surface water, soil water and ground water one by one, so that the hierarchical dynamic assessment of water resources in river basin can be realized.

3.2.2 Hierarchical assessment

As above statement, only available and usable water, as one of natural resources, can be considered as special water resources. To realize matching of natural distribution and social demands of water resources in space and time, artificially regulation of water resources is needed through construction of many kinds of hydraulic engineering. Thus, controllability of water resources will directly affect usefulness degree and extension of resources. Moreover, cycle character of water decides that water resources has the recoverability character different from one – off natural resources, but this character is not firm. It is necessary for maintenance of water resources

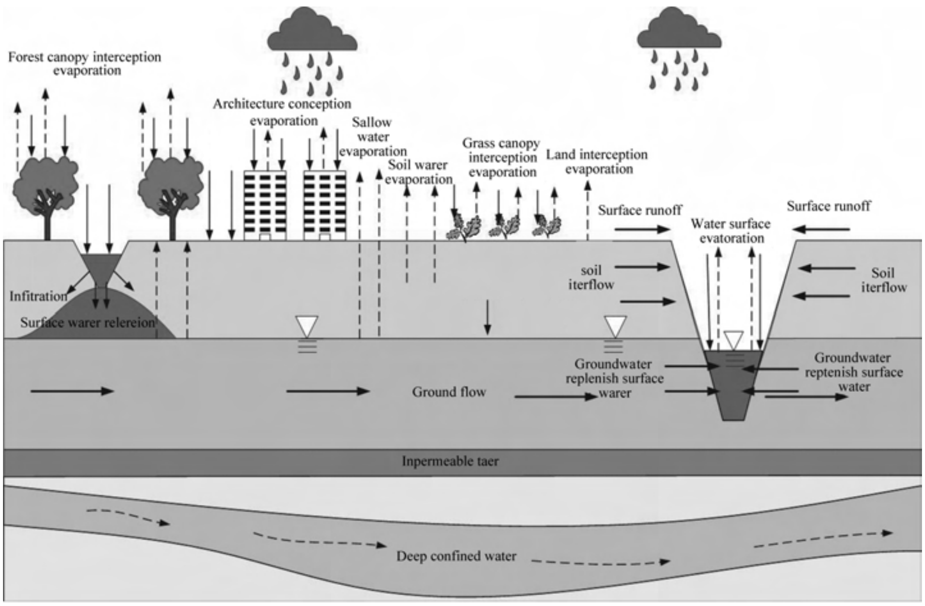


Fig. 1 Vertical structure of precipitation

sustainable utilization to instruct exploitation, utilization and regulation of in basin. Base on above analysis, three basic principles including effectiveness, controllability and recoverability (Wang, etc. 2003) are put forward in this paper.

Based on the three principles, resources structure of precipitation fluxes is analyzed. According to effectiveness principle, general water resources are divided into invalid evapotranspiration and general water resources. The general water resources can be further divided into runoff water resources and non – runoff water resources base on the controllability principle. The runoff water resources can be further divided into national economic available water and eco – environment demand water. In the general water resources, the main identification of valid and invalid water is that whether it exerts effectiveness on ecology or economy in transforming process. So identification of valid precipitation means judgement of output items. According to water balance, the relationship between water input flux and output flux in basin could be expressed as following:

$$P = R + E + \Delta V \tag{1}$$

where: P is precipitation flux; R is actually observed runoff flux; E is evapotraspiration flux; ΔV is storage variable.

In right item of Eq. (1), runoff water resources are complete valid undoubtedly, evaptransporation flux contains valid and invalid parts. Soil water storage variable can be considered as constant in long time series, while it need take its evaptransporation process into account in short time series. Thus, the important point of special water resources evaluation is valid evaluation of evaptranspration flux (E).

In vertical items of precipitation flux, canopy evaporation can reduce the temperature of vegetation or human resident environment, which is beneficial to maintenance of biology normal physiology. Meanwhile, it can substitute part of valid evaporation of vegetation. Thus, the canopy interception can be considered as valid and as a part of special water resources. Land use is divided systematically into plowland, woodland, grass land, water area, urban and rural resident area and hard use land according to national related standard. The interception evaporation from resident area, crop and forest and grass special area have direct environmental avail to human being and eco – environment. Interception evaporation from hard use land (swamp land belongs to water area) and sparse grassland space evaporation (according to cover degree) can be considered as invalid evaporation. The evapotranspiration from soil directly participate biological production, being valid water. Evaporation from resident area, crop, forest, and grass space has direct environmental avail to human being and environmental. Evaporation from soil in barely land, sparse grassland space evaporation can be considered as invalid water.

Base on above analysis, the total quantity of special water resources can be expressed as the Eq. (2):

$$W_s = (R_s + R_g) + E_p + E_{ss} + E_{es} \tag{2}$$

where: W_s is general water resources; R_s is surface water resources; R_g is ground water resources no – overlapped with surface water resources; E_p is valid canopy interception evaporation; E_{es} is valid soil water evaporation no – overlapped with surface water and ground water.

The calibers of special water resources assessment are consistent with that of traditional calibers. It is only needed to definitude the "area water" and "cross section water", that is, "cross section water" refers to "area water" minus the loss during river conflux process.

In order to serve rational development and utilization practice of water resources, it is needed to distinguish national economic available water and ecological water demand in special water resources. The national economic available water outside river is equal to river flow quantity minus ecological water demand inside river. Because of multi – function property of water, different ecological water demands maybe overlap with uncontrolled flood. Calculation of annual water demand is to select the largest water quantity process as river water demand process of this period. Calculated equation is following if the annual water demand process is calculated based on month. The groundwater resources was controlled ecologic mainly through ground water level.

$$W_{en} = \max(W_{1xs1}, \cdots, W_{1xsj}) + \max(W_{2xs1}, \cdots, W_{2xsj}) + \cdots + \max(W_{12xs1}, \cdots, W_{12xsj}) \tag{3}$$

where: W_{en} is annual eco – environment water demand; W_{ixsj} is ecological water demand in j th item of ith month in a year.

3.2.3 Dynamic assessment

Water resources in river basin are always in evolution process due to influence of human activities. Thus, any static evaluation method that tries to revert water resources to a time section is unscientific, while dynamic assessment reflecting real state should be applied. The main human activities affecting water resources evolution in river basin contains global climate changing, underlying changing and water use. Because of large changed in spatial and temporal impact scale on water resources in river basin and uncertainty in quantity, global climate change is not considered in water resources assessment for planning. The effect of underlying changing (mainly land coverage changing) and water use are considered in quantity assessment.

$$R_t = f(P, L_t, W_t) \tag{4}$$

where: R_t is water resources in cross section at time t; P is precipitation; L_t is underlying condition in cross section at time t; W_t is water use in cross section at time t.

Aimed at the two effects aspects of human activities, the effect of underlying condition and water use in different stage are considered as model variables of water resources assessment in this study to realize multi – scenario dynamic scientific assessment of "reverted" quantity, "current" quantity and "future" quantity of water resources in river basin, and the dynamic assessment of water resources in river basin. The assessed water amount is "real value" of water resources.

3.3 Distributed water resources assessment model with physical mechanism

Hydrological cycle, fundament of water resources forming and transforming, must be precisely simulated in whole process in order to realize dynamic hierarchical water resources assessment in river basin. According to dualistic structure of water cycle in present environment, model construction thought coupling distributed hydrological simulation model with lumped water resources allocation model is put forward. The distributed model simulates "slope and river course" process of four – water transforming process under natural water cycle, and provides water information for lumped water resources allocation modal. Meanwhile, lumped model simulates artificial water cycle of abstraction, transportation, utilization, consumption and discharge, and provides input and output water information in the process of runoff for distributed model. The basic framework of dualistic water resources evolution model is shown in Fig. 2.

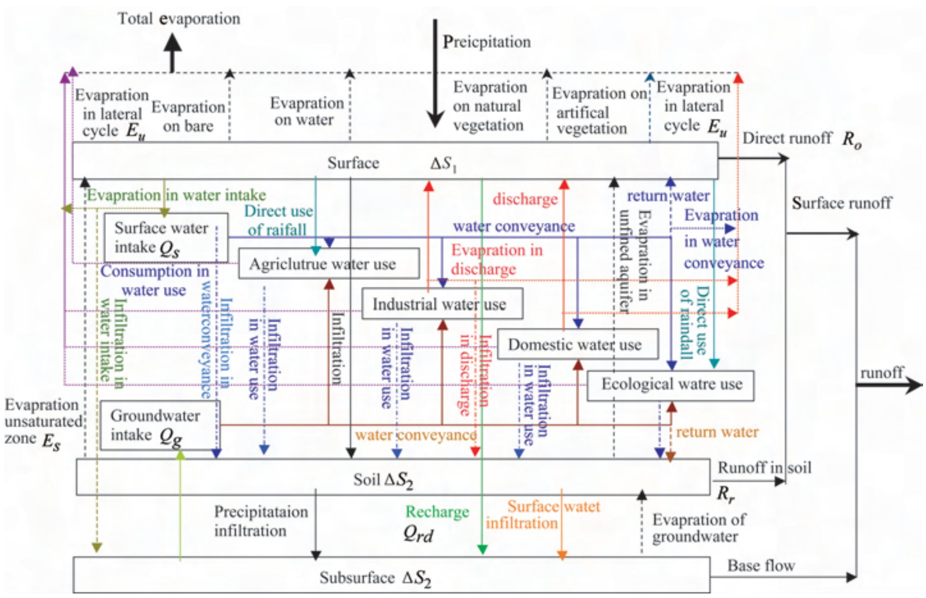
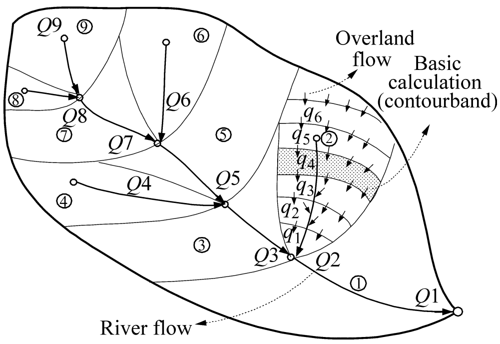


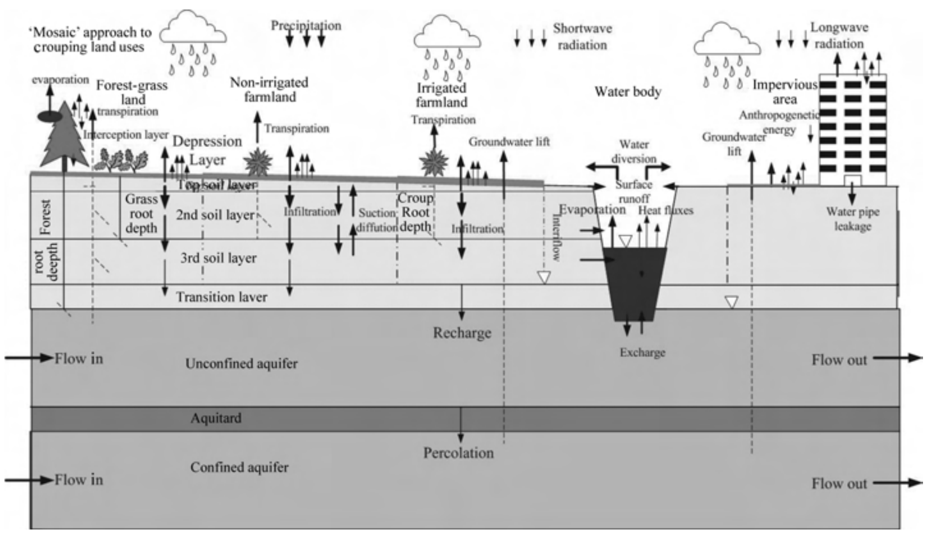
Fig. 2 Basic framework of dualistic water resources evolution in basin

In practice, main problem affecting coupling between distributed hydrological cycle model and centralized water resources allocation model is amalgamation of distributed and lumped information in spatial and temporal scale. Two amalgamation patterns are used: the first is that, the output information from lumped model is dispersed downwards in space and time to the scale which is suitable to distributed time step and spatial unit for the distributed model; the second is that, distributed simulation information is integrated upwards in space and time to realize matching of temporal and spatial scale needed in lumped model. After then, systemic coupling is performed. For example, daily runoff in river courses integrated into month or year scale is a basic input in year process of water resources allocation.

According to the model construction thought above stated, the author constituted a distributed hydrological model with physical mechanism in Yellow River Basin (WEP – L) in National Basic Research Program (973) and Research for tenth Five – Years' plan (Jia, 2005) to simulate the process of water/energy cycle. In the model, simulated objects include natural main hydrological cycle process with "slope and river course" and artificial hydrological cycle process with supply, utilization, consumption and discharge as basic process. The two models are coupled through water balance and hydraulic relation among cycle elements. The horizontal and vertical structures are shown in Fig. 3 (Jia, 2005).



(a) The horizontal structure



(b) The vertical structure

Fig. 3 The basic structure in WEP – L model

The lumped water resources allocation model includes two model, that is, water resources rational allocation model and water resources regulation model. Given system structure, parameters and running rules, the water resources allocation model first optimally regulate water resources system time by time, and then obtains the results of supply and demand balance in the system with intrinsic decision mechanisms in allocation process mainly including water balance society justices, market economy and eco – environment. The water regulation model may select precise model with "real time regulation and scroll modification" characteristic or simple model based on rules.

The simulated periods in the lumped model includes historic and future process. The simulation of historic process, historic recurrence, is realized through revert of lumped water use information in space and time in the water resources allocation and regulation model. The simulation of historic process, sceneries simulation of hydrological cycle process under planning condition, is realized through constructing rational allocations model of water resources based on rules.

3.4 Characteristics of water resources assessment based on ecosystem

Compared with the traditional water resources assessment, dynamic hierarchical methodologies of water resources assessment have unique characteristic in four aspects of pattern, scope, profundity and measure of assessment.

Assessment pattern means dualistic pattern. The traditional water resources assessments are all based on statistic assessment pattern of "Observer – naturalization – model establish – regulate and control", which deal with human activities in "eliminate" style. This pattern can meet the need in areas with little human activities. While with strengthened of human activity, the "water supply – water use – water consumption – water discharge" process has become the process that can not be neglected in the hydrological cycle, so that this statistic pattern can not be used in practice. Therefore, disturbance of high intensity human activities on hydrological cycle need the view of water assessment turn to the dualistic pattern of "Observer – separation – coupling – model establish – regulate and control".

Assessment scope means extension of assessment subjects. The objectives of assessments before were centralized mainly on surface water and groundwater. Soil water has been paid great attention by the academes and correlation departments due to its more and more important effects on agriculture development and ecological and environment establish ment. Food and Agriculture Organization of United Nations had considered "green water", evaporation in production process of vegetation, as the important contents of research. Full calibers assessment put forward in this paper, considering all the input fluxes as basic caliber of assessment, systematically analyze the water flux with different shape, on the basis of which, subject of water resources assessment are greatly extended through defined and quantitative evaluated assessment of interception of vegetation and ground, surface water, soil water and groundwater.

Assessment profundity means that assessment pay attention to not only water resources, but also influence of eco – environment and economic society on water resources, The influence of human activities on water resources considered in this paper include two aspects: ① effect of water used; ② effect of changed underlying condition.

Assessment measure refers to application of distributed hydrological model. In early stage, statistics method is the main methods of water resources assessment. Since 1980s, the methodologies of water resources assessment general became water balance method in river basin (Igor A. etc. 2003). To promote integrated methods of water resources assessment, FAO further put forwards water balance model based on GIS. In China, water resources assessment method extensively used in practice is water balance method. Each items of water balance is very clear through 20 years' development, and the concrete technique way is "observation – naturalization – collection – calibration". During the period, distributed hydrological models developed quickly. This paper applies this model to improve calculation precision of water resource assessment (Yang etc. 2005; Wang etc. 2000).

4 Case study

4.1 Introduction to the Yellow River Basin

The Yellow River, flowing through 7 provincial administrative including Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shanxi, Shaanxi, Henan and Shandong, flows into Bohai with length 5,464 kilometers. The riverhead is Tuoketuo reach, middle reach is from Tuoketuo to Taohuayu and lower reach is downstream of Taohuayu. The total river basin is located from 96°E to 119°E and 32°N to 42°N with area 794,712 square kilometers.

The distribution of precipitation in Yellow River Basin is uneven, raininess in southeast and drought in northwest, more in plain and less in altiplano, more in hilly than less in pan. the tendency of precipitation is decrease from southeast to northwest.

4.2 Hierarchical assessment

In order to assessment water resources in Yellow River Basin under present underlying surface, 2000 underlying surface condition and water allocation pattern were used in model. Hydrological data from 1956 to 2000 were applied in model according to data condition and representative. Coupled pattern between natural hydrological cycle and water use was applied in order to reflect water use process in river basin.

4.2.1 General water resources

It can be seen from Table 1 that the normal annual precipitation in 1956 ~ 2000 is $3,563 \times 10^8$ m^3, the general water resources under present underlying surface and water use condition is $2,756.6 \times 10^8$ m^3, 77.4% of precipitation, in which, the effective utilization of precipitation is $2,080.1 \times 10^8$ m^3, 3.1 times of special water resources. This means that the effective utilization of precipitation existing in the state such as soil water and others have play great action to economic and ecological system. In each second river basin, the Sanmenxia—Huayuankou has the greatest proportion of general water resources to precipitation, being 94.7%, while the Neiliuqu has the lowest proportion, only 54.2%.

Table 1 Result of general water resources under present condition in the Yellow River Basin **Unit: 10^8 m^3**

Subarea of water resources	Precipitation	Special Water resources	Effective utilization of precipitation				General water resources
			Evaporation from farmand①	Evaporation from forest and grass②	Evaporation from residential area③	total	
Whole Basin	3,563.0	676.4	890.9	1,173.3	15.9	2,080.1	2,756.6
Upstream Longyangxia	632.3	212.1	5.5	227.2	0.1	232.8	444.9
Longyangxia—Lanzhou	433.0	116.1	48.5	182.9	1.0	232.4	348.4
Lanzhou—Hekouzhen	427.6	53.7	119.6	116.7	2.9	239.2	292.9
Hekouzhen—Longmen	480.2	49.2	144.6	143.0	0.6	288.2	337.5
Longmen—Sanmenxia	1,038.8	143.5	386.8	330.1	6.7	723.6	867.1
Sanmenxia—Huayuankou	274.7	50.3	89.6	118.5	1.6	209.7	260.0
Downstream of Huayuankou	157.8	32.0	85.8	20.8	2.9	109.5	141.5
Internal flow ared	118.6	19.5	10.5	34.1	0.1	44.7	64.3

Note: ①Evaporation from farmland includes interception evaporation from crop canopy and canopy special area, transpiration from crop, and evaporation from soil, excluding evaporation from aquifer.

②Evaporation from forest and land include interception evaporation from crop canopy and part of canopy special area, transpiration from vegetation, and evaporation from soil, excluding evaporation from aquifer.

③residential areas refer to land use of urban, rural and other construction. The Evaporation from residential areas means Evaporation from interception form these areas and evapotranspiration from soil.

4.2.2 Special water resources

It can be seen from Table 2 that the special water resources under 2000 underlying surface and real water use condition is 676.3×10^8 m^3, in which, the surface water is 548.7×10^8 m^3, and groundwater is 404.2×10^8 m^3 with groundwater 127.6×10^8 m^3 not - overlapped with surface water.

Table 2 Result of special water resources under present condition in the Yellow River Basin **Unit: 10^8 m^3**

Subarea of water resources	Surfacewater	Groundwater		Total quantity of water resources
		groundwater	Not - overlapped with surface water	
Whole basin	548.7	404.2	127.6	676.3
Upstream Longyangxia	210.1	65.3	1.9	212.0
Longyangxia—Lanzhou	112.8	37.0	3.4	116.2
Lanzhou—Hekouzhen	18.5	58.6	35.2	53.7
Hekouzhen—Longmen	42.3	40.0	6.9	49.2
Longmen—Sanmenxia	104.5	125.1	39.0	143.5
Sanmenxia—Huayuankou	39.2	35.1	11.0	50.2
Downstream of Huayuankou	18.0	23.6	14.0	32.0
Internal flow area	3.3	19.5	16.2	19.5

4.3 Dynamic assessment

In order to instruct the future planning of water resources in river basin, the scenes in 2020 in Yellow River Basin are simulated and forecasted based on dualistic model. The scene of water use is simulated according to the result of lumped model, and underlying surface condition is received from GIS based on 2000 underlying surface and correlative special planning in each provincial administrative and analysis result of evolvement rule of history and future. Although the effect degree of human activities on climate system and the change tendency of future climate have been paid great attention, the uncertainty of climate change bring great difficult to forecast and long series simulation. The influence of changed climate on precipitation in future needs to be studied further. Thus, precipitation series is from 1956 to 2000 in this paper, not taking into account the change in future.

Table 3 show the result of general water resources in 2020 in Yellow River Basin. Under the scene of 2020 underlying surface and water supply and use, the general water is $2,763.2 \times 10^8$ m^3, while ineffective evaporation is 799.8×10^8 m^3. Compared with that in 2000, the effective utilization of precipitation increase about 7.0×10^8 m^3.

Table 4 show the result of special water resources in 2020 in Yellow River Basin. Under the scene of 2020 underlying surface and water supply and use, the special water resources is 670.7×10^8 m^3 with 554.2×10^8 m^3 surface water and 116.5×10^8 m^3 groundwater not - overlapped with surface water, and the groundwater is 392.7×10^8 m^3. Compared with that in 2000, the total quantity of special water resources change little, only reducing 5.7×10^8 m^3, but the structure of water resources evolve further, that is, the base flow increase due to control of groundwater overtake, and then the surface water increase, and the groundwater not - overlapped with the surface water have the tendency of decrease. The underlying conditions in 2020 change a little compared with that in 2020, and play little action on the evolvement of water resources.

Table 3 Result of general water resources in 2020 evolvement scene in the Yellow River Basin **Unit: 10^8 m^3**

Subarea of water resources	Precipitation	General water resources			Ineffective evaporation
		Special water resources	Effective evaporation①	General water resources	
Upstream Longyangxia	632.3	210.8	238.8	449.6	182.7
Longyangxia—Lanzhou	433.0	114.9	235.0	349.9	83.1
Lanzhou—Hekouzhen	427.6	53.8	244.5	298.3	129.3
Hekouzhen—Longmen	480.2	49.6	288.2	337.8	142.4
Longmen—Sanmenxia	1,038.8	139.4	726.0	865.4	173.4
Sanmenxia—Huayuankou	274.7	50.6	203.0	253.6	21.1
Downstream of Huayuankou	157.8	32.1	111.2	143.3	14.5
Internal flow area	118.6	19.5	45.8	65.3	53.3
Whole basin	3,563.0	670.7	2,092.5	2,763.2	799.8

Note: ①The effective evaporation, effective utilization of precipitation, includes evaporation from farmland, forest and grass and residential areas, excluding the evaporation from groundwater, which have been calculated in special water resources.

Table 4 Result of special water resources in 2020 evolvement scene in the Yellow River Basin **Unit: 10^8 m^3**

Subarea of water resources	Surfacewater	Groundwater	Groundwater not – overlapped with surface water	Total quantity of water resources
Upstream Longyangxia	208.8	65.8	2.0	210.8
Longyangxia—Lanzhou	111.8	37.1	3.1	114.9
Lanzhou—Hekouzhen	19.3	58.0	34.5	53.8
Hekouzhen—Longmen	42.6	40.8	7.0	49.6
Longmen—Sanmenxia	106.5	116.7	32.8	139.3
Sanmenxia—Huayuankou	41.8	35.8	8.8	50.6
Downstream of Huayuankou	20.0	19.5	12.1	32.1
Internal flow area	3.4	19.0	16.2	19.6
Whole Basin	554.2	392.7	116.5	670.7

5 Conclusions

The water resources assessment based on ecological, a new exploring, extends the view of traditional water resources assessment. In the view of research, it need take into account the comprehensive demand of ecology, economy and society with hydrological cycle as the main process; moreover, the method need to be innovated. The dynamic hierarchical methodologies of water resources assessment put forward in the paper, facing the demands of different economy and society construction and ecology protection, provide a basic theory of water resources assessment in river basin with intensive human activities. This method may be probably formed a new generation methodologies of water resources assessment suiting for shortage water areas with frequent human activities.

However, the water resources assessment based on ecosystem is a long process of research. It needs new scientific ideas to be added into the traditional study to improve and perfect the theory and method.

References

Wang Hao, Chen Minjian, Qin Dayong, et al. Study on carrying capability and national allocation of water resources in north – west China[M]. Zhengzhou: Yellow waterpower press. 2003.

Wang Hao, Wang Jianhua, Qin Dayong, et al. Study on Methodology of Water Resources Assessment in River Basin under Present Environment[J]. Hydrology, Vol (25), 2006(3), 18 – 21.

Jia Yangwen, Wang Hao, Wang Jianhua, et al. Development and Verification of a Distributed Hydrologic Model for the Yellow River Basin[J]. Journal of Natural Resources. 2005,20(2): 300 – 308.

Jia Yangwen. Development and Application of WEP Model. Advance in Water Resources, 2003,14 (supplement): 50 – 56.

Jia Yangwen, Tsuyoshi Kinouchi and Junichi Yoshitani. Distributed hydrologic modeling in a partially urbanized agricultural watershed using WEP model. Journal of Hydrologic Engineering, ASCE, 10(4): 253 – 263, 2005.

Jia Yangwen, Tsuyoshi Kinouchi and Junichi Yoshitani. Distributed hydrological modelling in the Yata watershed using the WEP model and propagation of rainfall estimation error Weather Radar Information and Distributed Hydrological Modelling, Proc. of 7th IAHS Congress, Sapporo, Japan, IAHS Redbook (No. 282), 121 – 129, 2003.

Jia Yangwen, Ni Guangheng, Junichi Yoshitani, et al. Coupling Simulation of Water and Energy Budgets and Analysis of Urban Development Impact. Journal of Hydrologic Engineering, ASCE,7(4): 302 – 311, 2002.

Jia Yangwen, Ni Guangheng, Yoshihisa Kawahara, et al. Development of WEP Model and Its Application to an Urban Watershed. Hydrological Processes, John Wiley & Sons, 15(11), 2175 – 2194, 2001.

Jiang Dabang, Wang Huijun, Lang Xianmei, et al. Multimodel ensemble prediction for climate change trend of china under sresa2 scenario[J], Chinese journal of geophysics,2004,47(5): 776 – 784.

Igor A. Shiklomanov, John C. Rodda. World Water Resources at the Beginning of the Twenty – First Century[M]. United Kingdom: the Press Syndicate of the University of Cambridge, 2003.

Towards a New Integrated Management of Water Resources at Basin Level, Example in Europe

—Implementation of the European Water Framework Directive 2000 ~ 2015

Jean – François DONZIER

Permanent Technical Secretary of the International Network of Basin Organizations (INBO),
General Manager of the International Office for Water
21, rue de Madrid 75008 PARIS (FRANCE)

Abstract: The Directive of 23 October 2000 intends proposing to the water community policy and to the Member States "a Transparent, Effective and Consistent Legislative Framework".

The Directive confirms the principles of integrated management and planning at the level of river basins, introduces obligations of results and proposes an overall approach, with a precise timetable, methods and a progressive development of the tools. It defines an objective of "Good Status" for the aquatic environments before 2015, gives the natural environments their place in the European water policy and preserves the future.

The Framework Directive asks for the establishment of hydrological districts in large basins. It recognizes that the search for solutions for better water resources management must pass through an integrated and holistic approach, organized at the relevant level of basins of rivers, lakes and aquifers, either local, national or transboundary.

The Directive strengthens transboundary basin management.

It introduces the concept of "International Basin Districts" for which the riparian Member States will have to comply with the same obligations as for the strictly national basins.

Key words: Integrated Water Resources Management, European Water Framework Directive

1 Introduction: The European Water Framework Directive

The European Water Framework Directive of 23 October 2000 demands that, from now on, the twenty seven Member States, and the two candidates countries to accession to the European Union, delimit "Hydrological Districts", in which a "Good Ecological Status" will have to be achieved before 2015 and lead to a harmonization of practices and to the improvement of management tools between the European countries.

For the first time in history, twenty – nine Countries are committed to jointly manage all their freshwater resources on a basin scale.

This Directive of 23 October 2000 sets "A transparent, Effective and Consistent Legislative Framework" for the community water policy.

In Europe, the Community Directives are imposed to the Member States, which must not only transcribe them into their national law, but also apply them within prescribed times, unless they will face the risk of being prosecuted by the European Commission at the Court of Justice of the Union for lack of conformity and be condemned to very heavy financial obligations.

At the same time, the European Union passed to 27 Member States Member States in 2007, and maybe 29 later, with the accession of new Eastern European and Mediterranean Countries.

2 A very ambitious objective

The Framework Directive objective for 2015 is the long term protection of the aquatic environments and water resources, to secure drinking water supply for the population and meet the economic needs in a sustainable manner.

Therefore, the objectives are both simple and very ambitious:

—stopping the deterioration of water resources,

—reducing the discharges of substances,

—and achieving a "Good Status" for water and aquatic environments.

But as everything is related at the basin level, the Directive cannot limit itself to the only issues of quality and conservation of the environments and must take simultaneously all the aspects of water and land management into account, navigation, flood and drought prevention, water transfers or hydropower production in particular, etc.

Basin management policy is not only water policy!

The linkage to other policy areas becomes even more important as concepts such as "living with rivers" or "giving space to rivers" gets greater weight.

3 A common method and principles for action

The preamble of the Directive proposes several main principles to the Member States:

—the need for integrated water policy;

—a river basin approach;

—the principles of precaution and preventive action;

—the principle of remedial measures at the source of the threats to the environment;

—the polluter - pays principle and the principle of the recovery of costs linked to water use "Including Environmental and Resource Costs";

—decision making "at a level as close as possible to the sites of water use and degradation";

—a "Combined Approach Setting Emission Limit Values and Environmental Quality Standards";

—involvement of the public as a condition for success.

The Directive proposes an overall approach, with a precise timetable, common methods and a progressive development of new tools.

4 The relevant scale for the river basin

The Framework Directive plans for the establishment of hydrological districts in large basins.

It introduces new territorial concepts such as:

—"Sub - basins", in which particular issues can be dealt with,

—the 《water bodies》, which are entities corresponding to homogeneous ecosystems where the obtained results will be evaluated and compared,

—"Heavily Modified Water Bodies", for which exemptions could be obtained by the Member States, by reasons of disproportionate cost, by too long delays in the building of infrastructures or pollutant migration or by existing uses, which cannot be suppressed.

Europe is the continent where there is the greatest number of transboundary basins shared between at least two countries or more.

The Directive strengthens transboundary basin management.

It introduces the concept of "International Districts", for which the riparian Member States will have to comply with the same obligations as for the strictly national basins

The existing International Commissions will be consolidated, new ones will be created.

In Europe, most of these International Commissions have a similar organization which is based on the plenary assembly of the international commission itself which makes the decisions committing the Member States, its permanent secretariat, and on many official geographical, sectoral or technical Working Groups which are the places where the decisions are prepared, the plans and programs developed or the common tools designed for observation, monitoring or warning in particular.

Here are some examples of International Commissions on various cases of European transboundary basins.

In each of these International Districts, a common characterization and a master plan for the monitoring of the basin have already been established, and the following will have to be prepared: an overall management plan and a program of measures to achieve the objectives of the Directive.

Remember that there are two hundred and sixty three rivers or lakes and hundreds of aquifers over the world, the basins of which are shared by at least two or more (up to eighteen) riparian countries.

Their specific situation should be better taken into account in the debates and bi – national and multilateral agreements on a new governance of water resources.

Many agreements were signed in the past centuries between riparian countries of Transboundary Rivers to ensure:

—free navigation,

—more rarely the share of river flows or the prevention of floods,

—and, since the end of the nineteen century, the building of hydropower dams.

But, today, there are still too few agreements, conventions or treaties dealing with pollution control, aquifer management and, a fortiori, the integrated management of shared river basins.

However, in cooperation with international organizations and programs, several countries have already established, for a long time for some of them, a real basin organization and a large number are considering doing so.

The United Nations Convention on uses other than navigation in international river basins will take more than a decade to be ratified.

This is the reason why the International Network of Basin Organizations has had, for twelve years, the objective of strengthening and developing effective basin organizations over the world, especially for Transboundary Rivers, lakes and aquifers.

Indeed, river basins are the relevant territories in which water runs on the soil or in the sub – soil, whatever are the national administrative limits or international boundaries crossed!

In such a context, the European Water Framework Directive of 23 October 2000, especially demands that the twenty seven Member States and the two candidates countries to accession to the European Union delimit "International Districts", in which a "Good Ecological Status" will have to be achieved before 2015 and lead to the harmonization of practices and to the improvement of management tools between the riparian countries of Transboundary waters, including with the neighboring countries of our new borders, in the Balkans and in Eastern Europe!

5 The new directive has significant innovations

It concerns all the environments: rivers, lakes, groundwater, coastal water, are interdependent and must achieve the good status objectives.

The Directive introduces a socioeconomic approach and firstly requires the identification of water uses and the assessment of the economic impact of these uses.

The Directive requires the establishment of a common frame of references for assessment, allowing real analyses of the situations and strategies of the Member States. It is also a guarantee for transparency.

Today, the systems for assessing water quality and for formulating the objectives to achieve vary considerably from one country to another within the European Union.

Quality indicators and reference values will then be defined for each type of "Water Body" allowing, for example, exchanges of data and comparisons between countries.

The development of this European frame of references will take place up to 2006.

Inter – calibration procedures are also planned for to calibrate the data provided by the Member

States.

The Directive requires a report on the recovery of the costs of services linked to water uses.

It introduces into the economic calculation not only the traditional investment and operating costs, but also newer approaches, such as the calculation of opportunity costs between various uses of the resources and of the costs of the damage caused to the environment.

6 A demanding planning

For each District, "Management Plans", defining the objectives to be achieved, and "Programs of Measures", defining the necessary actions, must be formulated before 2009 at the latest.

The Directive provides an interesting methodology for developing these management tools: characterization of the current situation in the basins, an assessment of the pressures and their impacts and the identification of significant sensitive areas have been just carried out and will be used as a basis for the establishment of different baseline scenarios before 2015.

An iterative approach of the programs of measures will permit assessing: if the mere continuation of the current actions is sufficient to achieve the objectives, or if additional actions must be considered and if their financial or social cost is acceptable, or in the negative option, if exemptions are appropriate, whose justification will have to be made public and subjected to possible discussion.

7 Public consultation: a participative working method

The Directive clearly stipulates that the water stakeholders must actively participate in all the steps of the management plan formulation.

The reference documents will be available to the public, the latter being consulted during the formulation of the management plan.

The methods for information, consultation, the gathering and processing of the comments of the public will be based on a concern for transparency of the costs, the assigned objectives and granted derogation, the evaluation and publication of results.

Consultations of the general public are required at the different steps of the process.

8 An obligation of result

The Directive imposes to the Member States to achieve the "good status" objective for water bodies before 2015, for all those which will not have benefited from of an exemption, because too heavily modified.

The obtained results will be evaluated and made public.

9 A precise timetable for implementation

The Directive sets out a precise timetable for its implementation:

2003: laws for transposition of the Directive into the national legislations

December 2004: characterization of the situation in the basins

December 2006: setting up of networks for monitoring water quality

December 2009:

- definition of the objectives and justification for derogation, the district management plans;
- formulation of the first action plans, the programs of measures;
- December 2015:

Reporting on the achievement of objectives + new updating of the management plans + second action plans.

We are thus committed from now on to carry out the process with the obligation to succeed.

10 Conclusions

The European experiment shows that, indeed, a suitable and constraining integrated management of the resources in the basins of rivers, lakes or aquifers is today necessary and can be considered with real ambitions.

The first results obtained are positive and stimulating.

Clearly, nowhere else in the world, we may see, officially and for twenty nine countries, a so high care of water resources management.

This does not mean that the European Water Framework Directive can be "exported" as an all other countries. The Directive itself is not universal. But its key elements are, such as securing public participation, forming basin councils, making basin plans, setting time – bound, measurable targets, establishing appropriate monitoring and enforcement, introducing cost recovery mechanisms, etc. The important thing to "export" is the process of establishing an IWRM framework – the final shape varies from country to country.

Thus, obviously, the implementation of the European Water Framework Directive in the 27 countries of the enlarged European Union, and in the Countries applying for accession, seems a major fact for the dissemination of the good governance principles recommended within the Associated Program implemented jointly by the International Network of Basin Organizations and the Global Water Partnership, which make it a priority topic for the mobilization of their members, not only in Europe, but in all the Countries which would be interested.

INBO Recommendations for Better Water Resources Management

Jean – François DONZIER

Permanent Technical Secretary of the International Network of Basin Organizations (INBO), General Manager of the International Office for Water
21, rue de Madrid 75008 PARIS (FRANCE)

Abstract: Freshwater resources are limited and threatened all over the world and their better governance, respectful of the environment, is one of the main keys to sustainable development.

Global warming cannot now be avoided. Fresh water resources will be directly affected in the coming years. The demographic, economic and ecological consequences are likely to be very significant.

It is necessary to increase the thinking about and prospective on the consequences of the climate change, which is likely to increase the frequency of extreme events, such as floods and droughts.

It is thus essential to adapt water resources management policies, by taking into account the new elements of the climate change.

In this respect, anticipation measures for these changes should be planned at the level of each river basin for the coming years, by developing adapted research programs, within basin management plans or master plans and of programs of measures.

Climate change, pollution, wastage, destruction of ecosystems: the seriousness of the situation in many countries requires comprehensive, integrated and consistent management of water resources, respecting the aquatic ecosystems and territories.

Integrated and sound water resources management at the level of river basins is obviously essential worldwide!

Key words: integrated water resources management, climate change, urban sanitation, users' participation

1 Integrated water resources management at the level of river basins

Freshwater resources are limited and threatened all over the world and their better governance, respectful of the environment, is one of the main keys to sustainable development: freshwater is essential to sustain life on our planet and ensure the health, peace and socioeconomic progress of our societies.

However, findings are alarming over the world: 1.3 billion human beings have no access to safe water, 2.6 billion human beings have no basic sanitation. 85% of the anthropogenic pollution is discharged into inland, coastal and marine natural environments, without any treatment.

Climate change, pollution, wastage, destruction of ecosystems: the seriousness of the situation in many countries requires that comprehensive, integrated and consistent management of water resources, respecting the aquatic ecosystems and territories is implemented to preserve the future and the human heritage.

The Millennium Goals for drinking water supply and sanitation can only be achieved with significant and simultaneous progress made to introduce Integrated Water Resources Management (IWRM), organized on the relevant scale of basins of rivers, lakes and aquifers, either local, national or transboundary.

Integrated and sound water resources management at the level of river basins is obviously essential worldwide!

The basins of rivers, lakes and aquifers are the relevant natural geographical territories in which to organize this integrated and sound management.

Indeed, river basins are the natural territories in which water runs on the soil or in the sub soil, whatever are the national or administrative boundaries or limits crossed.

Significant progress has already been made since the 1990s:

River basin management experienced a quick development in many countries, which made it the basis of their national legislation on water or experimented it in national or transboundary pilot basins.

The Helsinki Convention of 17 March 1992 gives a European cooperation framework in this field.

Although the United Nations Convention of 21 May 1997, on the uses other than navigation on the international rivers, did not come into effect, its principles are now more and more recognized as a basis for relations among the riparian States concerned.

In addition, the European Water Framework Directive of 2000 (WFD) lays down an objective of good status in the national or international river basin districts of the 27 current Member States and the Countries applying for accession to the European Union.

The gained experience allows now to say that integrated water resources management at the level of river basins is a real advantage for governance.

It is now widely recognized that water resources management should be organized and the subject matter of debates and decisions at the level of the geographical area where the problems occur, i. e.:

(1) On the scale of local, national or transboundary basins of rivers, lakes and aquifers;

(2) Based on integrated information systems, allowing knowledge on resources and their uses, polluting pressures, ecosystems and their functioning, the follow – up of their evolutions and risk assessment. These information systems will have to be used as an objective basis for dialogue, negotiation, decision – making and evaluation of undertaken actions, as well as coordination of financing from the various donors;

(3) Based on management plans or master plans that define the medium and long – term objectives to be achieved;

(4) Through the development of Programs of Measures and successive multiyear priority investments;

(5) With the mobilization of specific financial resources, based on the "polluter – pays" principle and "user – pays" systems;

(6) With the participation in decision – making of the concerned Governmental Administrations and local Authorities, the representatives of different categories of users and associations for environmental protection or of public interest. Indeed, this concerted participation will ensure the social and economic acceptability of decisions taking into account the real needs, the provisions to be acted upon and the contribution capabilities of the stakeholders in social and economic life. Decentralization is the basis for effectiveness in water policies.

2 Legal and institutional frameworks

Legal and institutional frameworks should allow the application of these six principles.

It is especially necessary to take into account the particular situation of the 263 rivers or lakes and hundreds of aquifers, the basins of which are shared by at least two riparian countries or sometimes more (up to 18).

Water has no national or administrative boundary: jointly managing the resources shared between several bordering States of the 263 rivers and lakes and hundreds of transboundary aquifers over the world is strategic and a priority. This reality should be taken into account and organization should be on the scale of the basins of these transboundary rivers, lakes and aquifers.

For several centuries, many agreements have certainly been signed between riparian countries to ensure freedom of navigation or sometimes the sharing of flows or the prevention of floods, and, since the end of the 19th century, for the building of hydropower dams. But, today, there are still not enough agreements, conventions or treaties on pollution control, environmental protection and integrated management of these shared basins.

The G8 Heads of State and Government, who met in Evian in 2003, retained the stakes of better governance of transboundary basins, among their priorities for future actions in the water sector.

Cooperation agreements need to be initiated or signed between the riparian countries of transboundary river basins to achieve indispensable common cause at the basin level.

It seems necessary to support the creation of International Commissions or similar organizations and to strengthen those already existing.

Such international commissions, authorities or organizations allow better dialogue, the exchange of useful information, the solving of possible conflicts and the sharing of benefits from better joint management and the strengthening of transboundary cooperation.

Agreements for transboundary aquifer management should be developed in particular, taking into account their fragility, especially that of trapped groundwater, and the time needed for restoring degraded situations, from the quantitative and qualitative viewpoint.

It is also necessary to take adequate measures to prevent the introduction and dissemination of invasive aquatic species.

To this institutional system should be added the richness of the personal and informal exchanges maintained by international and regional networks such as those of "INBO family".

3 Adaptation of water management to climate change is needed

Global warming cannot now be avoided. Fresh water resources will be directly affected in the coming years, with announced consequences:

(1) increase of extreme hydrological phenomena, such as droughts and floods, with the risk of human losses, destructions and catastrophic economic damage,

(2) melting of glaciers, reduction of the snow cover in mountains, which then will not be able to play their irreplaceable part of "Water Towers of the Planet", by ensuring flow regulation in the large rivers which are born there,

(3) modification of the plant species and soil cover, which will result in increased erosion,

(4) increase of sea and ocean level, which is likely to drown not only the coral islands of the Indian and Pacific Oceans, but also coastal lowlands, especially the polders areas, as well as river deltas and mouths, the flow of which will be modified. Very wide areas of human and economic life will be seriously threatened,

(5) inland salt water intrusion, such as salted water wedge in coastal aquifers,

(6) significant move of populations.

The demographic, economic and ecological consequences are likely to be very significant. It is thus essential to adapt water resources management policies, by taking into account the new elements of the climate change. It is especially necessary to quickly evaluate the hydrological consequences of this change, according to various scenarios.

In this respect, anticipation measures for these changes should be planned at the level of each river basin for the coming years, by developing adapted research programs, within the framework, in particular, of basin management plans or master plans recommended above and of programs of measures for the practical implementation of their objectives.

It is necessary to increase the thinking about and prospective on the consequences of the climate change, which is likely to increase the frequency of extreme events, such as floods and droughts:

3.1 With regard to floods

(1) It is first necessary to make the "Upstream – downstream" common cause a main item of consistent management on the scale of basins and sub – basins.

(2) In the transboundary basins in particular, cooperation between riparian States for jointly

looking for coordinated solutions and for sharing responsibilities should be promoted.

(3) Protection against floods must pass through a coordinated approach, combining the protection of people and properties, the reduction of vulnerabilities, the restoration of the open flows of rivers, the conservation and the re – building of the natural flood storage areas, the forecasting of events, the identification of zones at risk, the publication of "Atlases" of easily flooded zones, the control of urbanization, warning and education.

(4) International circles of exchanges on flood management are useful platforms to improve our common knowledge.

3.2 With regard to droughts

(1) The availability of fresh water, in sufficient quantity and quality, may become, in a generation from now, one of the main limiting factors of the economic and social development in many countries.

(2) The prevention of recurring droughts can no more be done on a case – by – case basis but must be planned in the long term, by solving the structural problems which occur in order to prevent, in the best possible way, their effects and to avoid the total degradation of water resources.

(3) Mobilizing new resources should only be planned for when they are ecologically acceptable and economically reasonable.

(4) Plans for the Management of Water Scarcity should prioritize drinking water supply as compared to the other uses, making sure that water is equitably and soundly shared between the various uses, ensuring a better optimization of water and avoiding wastages.

(5) They must ensure a better optimization of existing water and resources before planning the launching of projects for the mobilization of new resources.

(6) Water saving, leak detection, recycling, the reuse of treated water, groundwater recharge, the desalination of sea water, research on low – consumption uses must become priorities.

It is essential to very quickly strengthen, on a worldwide scale, the actions necessary to ensure a true integrated water resources management.

4 A priority: to make up for lost time as regards urban sanitation

85% of the anthropogenic pollution is discharged into inland, coastal and marine natural environments, without any treatment. The telluric discharges are the main causes of ocean and marine pollution.

The discharges are often made upstream of water intakes for human or animal consumption, making more difficult the efforts to ensure the populations' access to safe water, etc.

If, of course, rural sanitation is essential, it should be reminded that more than half of the world population now lives in cities, in larger and larger cities, and in particular in their underprivileged suburban districts. 320 cities have already more than one million inhabitants, and, within one century, 2/3 of the human population will live in cities.

The effects on human health and hygiene, on economic development and degradation of natural environments are very significant and will worsen with the lack of sufficient measures.

Eutrophication of the environments and the disappearance of aquatic life are the direct consequences, as well as the reduction of fishing activities, the first resource for food of many populations.

The time lost with sanitation is extremely alarming and will require urgent reforms, several decades of constant effort and huge financial resources. It is necessary to orientate research towards the development of new techniques, with an acceptable economic and social cost.

It should be reminded (and convince the people in charge) that the economic benefits of sanitation are indeed higher than the costs of the necessary investments and maintenance.

The renewal, maintenance, operation and management of installations are also a challenge to meet to ensure full effectiveness of the existing or planned investments. Their costs will be higher and higher and recurring. Vocational training of the employees of the sector is still almost non – existent and will have to be organized on a large scale.

The United Nations have declared 2008 "International Year for Sanitation". Indeed, it is necessary to start a long – term mobilization over several decades for an essential and practical implementation of sustainable development.

The reduction of non – point pollution is a prerequisite to maintain or recover good water status.

For this reason, INBO recommends that agricultural practices be adapted to limit pollution risks, either at the level of fertilizers or of pesticides.

INBO also recommends a better control of the marketing and use of substances dangerous for human health and the aquatic environments.

5 Users' participation should be organized for a real mobilization of partners

INBO recommends that this participation be organized in Basin Committees or Councils.

These Basin Committees should be involved in the decision – making related to water policy in the basin, within procedures that clearly define their role in preparing the decisions to be made by the relevant public Authorities. In particular, they should be associated to the formulation of long – term objectives and to the preparation of Management Plans or master plans, to the selection of development and equipment priorities and to the implementation of Programs of Measures and multiyear priority investment programs, as well as to the setting of financing principles and to the calculation of water taxes that concern them.

Their role should be facilitated by the setting – up of integrated water information systems as objective basis for dialogue, negotiation and decision – making.

The transfers of research findings to water managers and decision makers, as regards socioeconomics in particular and prospective analyses, must be improved and be the basis for decision – making.

Finally, significant means should be devoted to raise awareness among the public, and especially women and young people, and enable their participation, and to the training of their representatives regarding decision – making.

The investments necessary for the sustainable management, conservation and control of water resources and ecosystems and for the exploitation, maintenance and rehabilitation of public utilities require huge financial resources.

Therefore, it is necessary to set up everywhere complementary financing systems that are based on the users' participation and common cause.

It is thus necessary to consider specific financial resources complementary to each other by combining national or local administrative taxes, the pricing of community services and taxes specific to objectives retained through dialogue.

This arrangement should be an incentive to limiting wastage, to controlling pollution and to reducing discharges, to change the users' behavior.

INBO recommends the progressive and wide use of the cost recovery principle, through the establishment of basin water taxes, which have shown their efficiency everywhere they have been applied.

Such arrangements enable improving resources and environments, favoring access of everyone to water supply and sanitation, while ensuring common cause between the categories of water users, between upstream and downstream, and between generations and have an interactive effect on consumption reduction and pollution control.

These water taxes enable the use of the "polluter – pays" and "user – pays" principles.

6 Improving knowledge of water resources, aquatic environments and of their uses is essential to allow decision – making

It is recommended to the Public Authorities concerned and to the bi – and multilateral cooperation organizations which support projects related to the management and use of water resources to consider the setting – up of comprehensive information systems, as a preliminary obligation, and to promote the creation of observatories of water resources and of their uses at the level of each basin, either national or transboundary, and the organization of national information systems, consistent with these basin observatories.

Systems for warning against floods, droughts and pollution should be developed and coordinated for better facing the natural disasters caused by water and for protecting human lives and properties.

It is essential to specify the institutions responsible for the organization and the permanent operation of such systems and to guarantee not only sufficient means for the corresponding investments, but also, and in an imperative way, financial mechanisms allowing their continuous operation on the long term.

It is necessary to promote the emergence in this field of means and competences for specific engineering and to support any work aiming at defining common standards and nomenclatures for data administration in order to allow exchanges, comparisons and syntheses of information between partners at all the relevant levels of observation.

The islands are systems which offer a wide range of biodiversity. The island ecosystems and socioeconomic entities are usually fragile; management of freshwater and coastal areas is a complex issue which requires special attention, a specific legal framework and adapted means.

INBO recommends that the concerned multilateral institutions and national Authorities take into account the specificity of water and environmental management in insular environments.
Cooperation between the islands in relation to this matter should be strengthened.

7 Conclusions

Integrated and sound water resources management is more than ever a priority if we do not want this scarce resource to become one of the limiting factors for sustainable development in many countries of the world.

Organizing this management on the basin scale seems efficient.

However, the time lost becomes worrying and unprecedented mobilization becomes essential so that humanity wins the water battle and prepares the future.

It is necessary to support the creation and strengthening of Basin Organizations over the world!

Climate Change Influence on a Water Policy

—Why a Water Policy should be Coping with a Possible Climate Change

Jacky COTTET

Rhone River Basin Agency France (Euro RIOB network)

Abstract: In this day and age, climate change is a concern shared by many. Its impact on water management is certain and worrying. Even though we do not know how to foresee with certainty the exact nature of the steps to be taken, it is possible to already initiate a reorientation in the water management policy. The Rhone – Mediterranean and Corsica River Basin Agency has already taken several measures to face that effect and is introducing this requirement in its intervention programs. These measures deal equally with a prediction of the scarcity of the resource and a forecast of extraordinary floods. In order to face scarcity, measures towards the security of water supplies call for widespread water transfers and their interconnection, the reduction of waste, and the improvement of the performance of equipment, with regard to irrigation in particular. As regards the fight against floods, the task is more modest at this stage, since the objective is to combine spatial planning (land occupation), existing urbanization, and the optimized management of drainage flows. The provision of areas allowing rising river flow to expand is a concept enjoying a strong development. Prospective research needs to be encouraged in these different fields.
Key words: climate change, climate – water, climate – water policy impact, water scarcity, flood plain

The occurrence of the climate change phenomenon as a consequence of the increase in the concentration of greenhouse gases has been almost unanimously accepted in the last few years: at global level, i. e. all over the planet, the average temperature of the earth surface may increase by 1.5℃ to 5℃ by 2100; the increase in evaporation would then produce a rise in average precipitations all around the globe (Leblois et al., 2005).

However, the extent of the variations in precipitations in terms of space and time is still open to much speculation, in particular when trying to study the possible incidences of this global phenomenon on regional territories (such as Europe, or all the more, certain specific "regions" in Europe). In spite of everything, the most likely scenarios conclude on trends towards increasingly contrasted hydrological regimes, entailing higher flood risks in the winter and drought risks in the summer.

As a result, these phenomena cannot be ignored when developing management plans and other water development master plans whose ambition is to allow for a sustainable use of the water resource, while respecting natural equilibriums.

1 What do we really know

Research programs have been initiated at national level, specifically via the programs launched by the French Ministry of Ecology and Sustainable Development over the past ten years.

These take as a working hypothesis that levels of atmospheric CO_2 will double by 2050 and attempt to adapt to local levels those scenarios resulting from the global models. Despite strong uncertainties, it is possible to identify a number of phenomena.

The most definite conclusions predict, in France (which nowadays enjoys a temperate climate under a mainly oceanic influence):

—a decrease in the snow coverage, both in terms of quantity and spatial cover and with regard to the duration of the snow coverage;

—an increase in winter flows, with a decrease of spring and summer flow;

—a more noticeable drying out of land.

With regard to the biology of aquatic ecosystems, this evolution may strengthen the overall regression of fish species in flowing water.

Furthermore, climate change may impact agricultural production, irrigated farming in particular, with for instance a decrease in the yield of maize, knowing that simultaneously, the requirement for irrigation water to sustain the crops would rise and would therefore intensify the local situation of water deficit.

In short, there is still a great deal of uncertainties. These are the subject of specific research work aimed at solving them. However, it has already been possible to identify various phenomena which are used as a basis for drawing up possible scenarios in terms of availability of resource or evolution of the ecosystems. These components are sufficient to already mobilize operators in order for them to integrate these elements in forecast planning, which goes hand in hand with carrying out the water policy.

Let's take the example of the Rhone River Basin, for which the management policy of water resources is coordinated by the Rhone – Mediterranean and Corsica River Basin Agency. In the case of this basin, if the total available resources generally exceed the needs, both in terms of surface water and groundwater, problems may occur locally over some sectors, and in certain seasons. In fact, the annual water balance is positive – with 68 billion m^3 flowing through the water network while 16 billion m^3 are abstracted each year (11 of which to cool down nuclear power plants, 3 to 4 to supply irrigation schemes and approximately 2.5 billion to be used by local communities and industry). However, the basin features a great diversity of geographical, geological or climatic factors, which explains why deficit situations may be observed locally or temporarily. The potential impact of climate change would therefore exacerbate these phenomena and must therefore be addressed with care.

On this point, the actions carried out by the Rhone River Basin Agency already anticipate on the risks of deficit:

- The Agency maintains close ties with the scientific community in order to share knowledge on this subject and include the impact of climate change into the definition of management plans.
- It incorporates, within the Water Development and Management Master Plan (WDMMP), a draft prospective study covering the whole Basin area, which is thus used to create development scenarios linked to climate change, focusing in particular on activities and uses.
- Extensive water systems have been put in place in the southern regions where the rainfall deficit in the summer must be offset by water transfers: crop irrigation and tourism drain the water resources while these have reached their lowest level. Large canals (from 30 m to 80 km long, with a flow rate of several tens of m^3/s) were built to promote irrigation, but also increasingly to secure the water supply of large cities (such as Nice, Toulon, Marseilles, etc.)
- At the same time in the Alps, the developers of skiing resorts acquire machines for the production of artificial snow in order to secure their investments. This strong increase in the use of water resources in the winter (right when high altitude resources are at a low level because of the frost) is not sanctioned by the Water Agency. The Agency is concerned about the impact of the widespread use of artificial snow, which contributes to even lower water levels, while competing with the water use linked to the influx of tourists.

2 The balance management of the resource: an even bigger challenge

It seems plausible that climate change is intensifying the existing water deficit, in the summer in particular when demand is at its peak (irrigated crops, household needs, leisure activities, etc.).

It is therefore paramount to equip ourselves with a forward – looking vision with regard to the management of the resource, and extend the selection of good practices in this respect. There are various courses of action: water savings, both at the level of individual households and of socioeconomic actors, availability of new resources through the creation of reservoirs, new pumping into the aquifers or transfers between river basins, etc.

The water policy can call upon two major principles which coexist and fit into each other

• that of a policy based on supply: build the infrastructure required to meet the foreseeable needs and therefore promote these needs.

• and a demand – based policy: intervene to reduce water demand while promoting savings, with crops relying on less water.

Taking account of the climate change in the balanced management of the resource implies that preventive actions should be favored.

In this respect, it is indeed the second principle listed above, i. e. the management of water demand, which intends to become an integral part of the integrated management of water resources, given the resource restrictions and the costs linked to supply policies (the construction of large projects is often more costly than practicing savings and a strict management of uses, and even recycling). This is all the more true that climate change contributes to a level of uncertainty regarding the sustainability of both the natural resource and the alternative solutions implemented.

The above – mentioned impacts of climate change require from operators that they adopt a sustainable development policy with regard to the quantitative management of water. This entails:

• a remedial attitude facilitated by a better management of available resources: evolution of consumer habits and non – viable crops on the one hand.

• and a policy based on prevention: sustainable protection and management of natural resources aimed at ensuring the socioeconomic development on the other hand.

The management of water demand meets these objectives maybe more so than management through supply. It intends to reduce losses and improper uses, optimize water uses while ensuring a logical allocation of the resource among the various consumers, promote recycling while having regard to the needs of the ecosystems and taking into account the requirements which are necessary for the renewal of this resource.

Furthermore, this approach may be used to anticipate and avoid the crises announced via the above – described trend scenarios. Not only do the uncertainties linked to climate changes become impossible to control, but they are also difficult to predict, while the management of demand is within the operators' scope and can be adjusted by them. The idea in this case is to moderate the pressures exerted on the resources by limiting and stopping unsustainable practices, such as overexploitations, or the use of non – renewable resources (mainly deep underground resources).

In this respect, the River Basin Agency has initiated preventive measures:

Even though thirty years ago, the spatial development policy had encouraged this institution to support the development of large water supply infrastructures, such as large dams, and major water transfer systems, a very strong trend towards increased efforts towards prevention and the sustainable management of available resources has recently been adopted. Year – to – year storage reservoirs were no longer able to cope with prolonged droughts.

There are many preventive actions:

(1) In its Intervention Program, the Agency provides for the funding of water savings through the implementation of irrigation technologies (sprinkling and drip irrigation) and industrial processes using less water, the search for leaks in the city pipe networks…

(2) It grants financial aid to reservoir operators in order to establish a support system to guarantee the minimum water flow for the benefit of the aquatic life.

(3) It promotes the global vision of the quantitative management of water though the implementation of diagrams showing the resource allocation, including a state of play, the definition of objectives which are common to the various users and setting sharing rules; as a consequence farmers coordinate in order to stop pumping for irrigation when even the flow of the river happen to be to low: a comprehensive management is adopted and therefore set by the users alone without necessity of a law enforcement.

(4) The Agency may also contribute financially to the installation of additional equipment for the supply or transfer of the resource, but while stressing the necessity to set up diagrams showing how the resource is shared out and a water saving policy; whatever the case, the solutions implemented will have to fit into a rationale of sustainable development, i. e. be economically viable and environmentally acceptable.

(5) It draws on agreements in order to promote, with local stakeholders, a concerted management of the use of the water resource (sample framework agreement signed by the users of irrigation of the Drome river area).

(6) It intervenes in the restoration and conservation of wetlands, which play a part in ensuring the minimum level of water courses.

In addition, legal mechanisms are now available to manage crisis situations at the level of departments (i. e. districts), by defining the priority uses that can be maintained where there is a water deficit and, as a result, the restricted uses.

3 Prevent risks linked to floods

The scenarios envisaged by scientists concur in stating that the hydrology would be more varied as a result of climate change, which leads us to think that phenomena of river floods will become more frequent or more significant, or even both.

These conclusions from the research work require from operators that they incorporate without delay the problems inherent to the rise in river levels and flooding into the implementation of their policies, both in terms of water management (abstractions, discharges, management of run – offs) and spatial development.

The preservation of a flood plain for rising waters therefore becomes an even bigger and current challenge. Keeping these areas and their buffer effect thus seems like an inexpensive solution for the community, where this is planned as a preventive step.

When there is little leeway to allow for the expansion of rising waters, a number of protection systems may be considered, either by isolating the river bed through the construction of dykes, or by leveling floods thanks to a system of dry retaining walls.

The River Basin Agency is becoming more involved on this point:

Although this area used to be the responsibility of the State, French River Basin Agencies are becoming more and more involved in concertation with the national actions planned within the framework of a plan for risk prevention which is benefiting from exceptional funds.

In its program, the Agency is planning to finance risk and vulnerability studies linked to floods; It provides financial support to the reclamation work applied to the flood plain and major bed.

4 Take into account the artificial heating of waters

The research carried out by scientists on the impact of climate change puts great emphasis on hydrological impacts, considering what is at stake there in terms of resources or risk management in relation to rising waters. Similarly, the repercussions caused more specifically by the artificial heating of waters are also of concern to operators.

First off, from the ecological standpoint, it seems plausible that aquatic populations could evolve. With regard to water management, this type of trend has a direct influence on the notion of reference concerning the ecological status under the terms of the European Water Framework Directive and thus of a quality objective.

In more practical terms, it is possible for the objectives that are set currently and on which management plans are based will no longer be attainable in the long term due to waters heating up, provided the biological system has evolved. The question is already valid in the case of large stretches of water where the effect of the waters heating up seems to manifest itself by changing the mixing phenomenon, a structuralizing stage of the lake ecosystem.

The establishment at national level of a network of sites considered as a reference and on which elements of physico – chemical and biological properties are measured and recorded would be a way of integrating such a development. By monitoring this network in a sustained way, the evolution of the biological system will be defined where appropriate.

The fact that waters are heating up creates a new strain on the management of nuclear plants whose operators are forced to apply for exemptions concerning the discharge temperature of their cooling waters. Such situations, which are becoming an increasingly frequent occurrence in France in the previous years, along the Rhone River in particular, set electricity generators against environmentalists. In actual fact, the River Basin Agency recently asked the Scientific Council of its River Basin Committee to draft a position paper on the potential impact of such exemptions on the ecosystem. On one hand nuclear electricity does not develop greenhouse gas and so can be considered as a possible solution, on the other hand it remains a problem for heating rivers. The requirements with regard to the quality of the environment remain firm, while the constraints imposed to operators are becoming tougher.

5 The water management policy must both: develop prospective approaches, anticipate changes through reorientations of its policy

Whereas knowledge regarding the possible impact of climate change is still open to speculation, it seems however that foreseeable scenarios with regard to hydrology or modified ecosystems are sufficiently plausible to allow operators to make them their own and incorporate here and now the necessary provisions into their management plans.

It seems very relevant to adopt preventive policies. This supports a number of messages, which the Rhone River Basin Agency had delivered to its partners and which find their expression in its own Water Development and Management Master Plan (WDMMP) in particular.

Simultaneously, the Rhone River Basin Agency will monitor closely the scientific research on the subject, whose scope of investigation goes well beyond the field of water. It may, in some cases, develop partnerships with certain research institutions in order to make progress in accounting for these phenomena in the definition of future management plans.

References

Eaux de Rhone – Mediterranee – Corse. 1991. Rhone – Mediterranean – Corsica River Basin Agency, 331pp.

Leblois et al.. 2005. Etude des impacts potentiels du changement climatique sur le bassin versant du Rhone en vue de leur gestion – deuxieme phase – Management and Impacts of Climate Change (GICC) project – Rhone, final report, abridged version, 24 pp.

Panoramique 2000: Tableau de Bord du SDAGE Rhone – Mediterranee – Corse. Rhone – Mediterranean & Corsica River Basin Committee, 137 pp.

European Water Framework Directive

—How a River Basin Agency Got Involved in a Common Implementation of a Recent "Water Framework Directive"

Jacky COTTET

President of Rhone River Basin Agency France
(also President of Euro RIOB network)

Abstract: The European Water Framework Directive applies to all the 27 States of the Union. The objective set therein is to achieve good status for all the water bodies by 2015; in situations where this goal cannot be reached by 2015, extensions to the deadline may be granted provided they are justified. The transposal of this Directive in France has been launched with a strong involvement on the part of River Basin Agencies. These are in actual fact the kingpins in the implementation of the various stages which were put forward by the Directive to achieve the agreed goal: issue of a state of play, definition of important issues, selection of remedial actions, economical assessment of the feasibility of such measures, public consultations, planning of actions ... reporting. The Rhone – Mediterranean and Corsica River Basin Agency is widely involved in this work.

This presentation summarizes some of the key points of this major project. It stresses the impact of such work on the Water Development and Management Master Plan which is in effect at the time. The new Intervention Program (2007 ~ 2012) run by the Rhone River Basin Agency is also highly dependent on these directions: as a result, the approach followed is now based on targets and results to be attained, rather than in terms of equipment to be installed. Whereas the River Basin Agency used to depend mainly on a standard list of equipment for which funding was provided, it now sets itself the task of checking that the funding which is the subject of the aid is likely to efficiently contribute to the planned environmental benefit. If not, funding can be unavailable. In this approach, financial aid can vary widely depending on the areas: a given equipment may be inefficient here (which means it is no longer subsidized), while it is highly effective elsewhere (which leads to maximum rate for aid). In short, financial interventions can now be bound to a particular area and conditioned by the targeted goals.

Key words: European Water Framework Directive (EWFD), transposal, French Water Agencies, selective aid, water funding

On 2000 October 20th the EUROPEAN UNION enacted a European Framework Directive for Water which sets a new approach in water management in all the 27 Member States of the Union. This Directive, which applies to each and every one of the States, aims at the implementation of a strict and structured approach of the policy for the preservation of water resources. Even though some countries such as France have already implemented a sophisticated policy for the preservation of their resources, the Water Framework Directive heralds a strong development in the water policy of each Member State. As a case in point here, we shall mention France, which even though it had set up a river basin management structure some forty years ago, was forced to carry out a lengthy diagnosis process, followed by remedial actions, in order to comply with this Directive.

1 The main principles of the directive in brief

This Directive sets, for each Member State, the following objectives which need to be reached by 2015 for each of the water bodies.

—Non – degradation of waters;

—Achievement of good status or good ecological potential;

—Removal of hazardous substances;

—Observance of the goals of the areas which are already the subject of Community commitments (UWW Directive, nitrates, NATURA 2000, potential drinking water, bathing waters).

Obviously, there is room for some adjustments: either extensions to deadlines may be granted provided these are suitably justified, or some water bodies may, due to their very nature, be considered as validating derogatory measures (case of highly modified waters). Postponements may then be granted. The Directive also allows for an implementation schedule which respects the following stages (detailed hereunder):

—Carrying out of diagnosis as soon as 2005;

—Public consultation in 2006 and 2008;

—Provision of evidence that measures have been implemented that are suitable to achieve good status by 2009;

—Ensure constant reporting on the efforts made in this respect.

As a result, this Directive presents an approach which is based on seeking results and no longer on merely setting up practical means. Whereas the targeted goals used to be the installation of the equipment deemed necessary, the new approach implies that one should set goals to be achieved within a certain timeframe. Therefore, the thinking process now focuses mainly on the goal to be achieved, since equipment no longer constitutes a prerequisite but rather the tool which may be required to attain this objective.

This organization provides for a management based on river basin districts corresponding to the watersheds of the large hydrographic units. Each of the self – contained water bodies will have to be identified inside those districts. The purpose of this structuring is not only to standardize the approach, but also to rationalize it. It is modeled on the organization which is already in place in France. Having regard to transboundary rivers however, transnational districts should be considered.

A river basin management

The Directive requires from Member States to identify the river basin districts by 2003, i. e. groups of river basins, while ensuring the coherence of the delimitations in the case of cross – border basins.

Planning and scheduling

A state of play shall be carried out in each district by the end of 2004, in order to report on the various uses of water and their impact on the status of water. This characterization of the district takes into account the initiatives launched in the area of water and the spatial planning policies, in order to identify the water bodies for which the environmental objectives of the Directive may not be carried out by 2015.

In addition, the Directive requested, also by the end of 2004, that a register of protected areas be set up in order to identify all the areas subject to special protective measures (abstraction of water intended for human consumption, areas of bathing waters, protection of habitats,).

In real terms, for the Rhone – Mediterranean and Corsica Basin, this state of play has shown that:

—46% of lakes, 58% of underground water bodies, and 32% of water courses should reach good status by 2015;

—for 8% of water courses and 11% of groundwaters, there is a very strong possibility that good status may not be achieved;

—the fate of 21% of water courses and 31% of groundwaters remains undecided;

—39% of water courses need to be dealt with on a case – by – case basis because of their respective infrastructure (for navigation, hydroelectricity generation,) and will be the subject of reduced objectives.

By the end of 2006 Member States were required to set up water status monitoring networks. Complemented with a type classification of surface waters and a rating of the methods used to assess water status, this system will allow for a comparison between the qualities of aquatic environments among Member States.

By 2009, a "management plan" shall define the objectives that need to be reached by 2015, and the "program of measures" identify the actions required for their achievement. Such measures, which are essentially legal in nature (control of waste discharges, authorizations, etc.), may also include financial incentives, as well as voluntary agreements.

An economical analysis

The Directive requires the terms for water – pricing and the application of the principle for the recovery of the costs of water services to be stated, including environmental costs, taking account of the application of the "polluter – pays" principle. The contributions by the various water users need to be identified, disaggregated into at least households, industry and agriculture. The Directive uses water – pricing as a measure to be implemented in order to contribute to its environmental objectives.

Public consultation

The Directive encourages the active participation of the water stakeholders and the public in the development of the management plan, allowing in particular for public consultations on the work program, the identification of the main issues with which water management is faced in the district and, finally, on the draft management plan. By publishing the technical and economic data on water uses, the Directive therefore seeks to reinforce the transparency of the water policy.

2 Initiation of transposal into French Law

The Directive renews, at European level, the principles of a large river basin management, of balance management and planning as defined in France in the 1964 and 1992 Acts.

The river basins that are currently defined in France shall therefore make up the implementation standard for the Directive. The River Basin Committees of mainland France and the French overseas departments (districts) shall be entrusted with the definition of the environmental objectives within the framework of the update of Water Development and Management Master Plans (WDMMP), and shall carry out the necessary consultations to that effect. The prefect in charge of coordinating the river basin shall have to sanction the program of measures which are needed to achieve the environmental objectives.

Thanks to the state of play, major problems were brought to light

Upon completion of the state of play on the district (new word used by the EWFD for "river basin"), several major problems were identified that hamper the achievement of the environmental objectives of the Directive, and expressed in the form of major issues, in accordance with the provisions of this document. These major issues represent the conditions for the success of the four objectives. Non – degradation of waters, achievement of good status or good ecological potential, removal of hazardous substances, observance of the goals of the areas which are already the subject of Community commitments (UWW Directive, nitrates, NATURA 2000, potential drinking water, bathing waters).

At the stage of the state of play, the major issues give a review of the water bodies for which the risk of not being able to reach the objectives is confirmed or remains open (doubt). After forecasting elements based on trends and feedbacks, these offer broad guidelines for future action, illustrated by several lines of actions.

Among the selected options for the organization of works in 2005 – 2006, the relevance in maintaining a multi – disciplinary working method based on studies at river basin level was confirmed. This work includes two components.

The first component consists in identifying the relevant measures used to remove the obstacles to achieving good status.

A second, more forward – looking component consists in carrying out a strategic approach for the implementation of the measures throughout the district while identifying challenging areas, providing an overall financial assessment and the evaluation of the delay in achieving the objectives.

To that effect, several working groups were set up that focused on the problems raised in the major issues. They were entrusted with the task of developing proposals in relation to both identified components.

For the Rhone River Basin, the work was entrusted to working groups bringing together a great number of multi – disciplinary skills:

The brief of these working groups was based on two components.

(1) Develop a series of relevant measures for each of the problems raised in the 13 selected major issues. This set of measures had to be founded on the National Thesaurus in particular; it should include information on the cost of the measures, their effectiveness and their interest.

This first component must produce a directory of measures for the district, which will be used as a tool by local work teams. This work is the opportunity not only to list and/or recall the measures which are "traditionally" used to solve this or that problem, but also and above all to stress the measures, whatever their type, that are the most efficient (based on the cost/efficiency ratio), the most interesting in terms of social and economic repercussions, with the possibility of using tools outside the area of water and, for some of them, are typical of a certain level of innovation.

(2) Derive the main directions for the implementation of these measures at the level of the whole district: challenging areas, possible development in activities and pressure, overall cost approach, prospects of reaching the objectives and possible hypothesis for derogations or geographical selectivity.

For instance, these are a few of the selected major issues for the Rhone River Basin:

—Water and spatial planning can not be disconnected from each other;

—Hydroelectricity generation is faced with the double objective of a renewable energy and the protection of aquatic ecosystems;

—The problem of pesticides will not be solved without a significant effort on the subject of farming practices;

—Water and public health must combine prevention and risk management;

—Are the action strategies which are usually implemented still the most effective?

Adjusting the brief to the various themes was necessary:

Each working group leader rejected the standard brief order to adapt to the issue at hand. Debates on local management, pesticides or financial tools for instance did not proceed in the same way, even though the format of the expected result needed to be standardized. In addition, the composition of the groups was modified to suit the components under review, with the work being more technical for the first component and more strategic for the second because of the economical approach.

As regards the "environments" groups (NGO), with the exception of "wetlands", only the first component was dealt with, since the purpose of the work was to fuel the reflection on major issues and pinpoint the vital measures to be submitted to this reflection.

In addition to these "Major Issues" and "Environments" groups, a group had to assess more specifically the legal measures which support the other groups. In particular, it had to ensure that legal measures which are useful in the "Good Status" reflection are not forgotten because of the "major issue" filter.

Such groups were made up of representatives from various Government departments with prerogatives in the subject of water. The composition of the working groups was set in accordance with the following principle:

—A leader identified among experts on the issues raised within the State services or River Basin Agency concerned;

—A rather limited number of participants (approx. 12 individuals) including technicians of the same services, a few representatives of the interested socio – professional sectors, and of municipalities;

—The role of these representatives was to ensure the handover within their network at the right times in the work.

This work needed to be integrated into other on – going projects

The European Directive comes into effect as national measures are being implemented. In the case of France, this applies to the Water Development and Management Master Plans for each of the six large river basins of the national territory. It was therefore crucial for consistency to be maintained between this Directive and the WDMMPs in effect.

Furthermore, while other public policies are complemented with their own set of measures (agri – environmental measures, national rural development plan), some are about to enter a phase of regional definition (national environment – health plan). In the areas under consideration, it is worth seeking synergies or even economies of scale, in the organization of the working groups for instance, where applicable when the schedule and the objectives are common for the most part.

Finally, the results of these working groups largely contributed to the development of a new intervention program (2007 ~ 2012) by each of the River Basin Agencies, and which had been drafted at the same time.

The administrative division (territory of several "departements" (districts) and regions) can be covered by several water districts. In the course of the institutional consultation, these stressed the need to have consistent measures on each side of the groundwater divide. It will therefore be vital to consider a standardization of measures whenever possible.

This work led to the preparation of two executive summaries:

one on the major objectives put forward to deal with the problems raised, including a summary table of the selected measures, combined with a detailed list of measures; the other on the challenging areas, including an overall cost simulation, an assessment as to the possibility of reaching the objectives and, if applicable, an exemption proposal.

It was asked, during this project component, to gather, for each measure, information concerning positive and negative repercussions on the uses, the possible consistency of the measures with other actions dealing with the risk of flooding, possible disproportionate costs, or technical or financial difficulties.

Public consultation produced constructive remarks

The public consultation process was organized by each River Basin Agency at the level of the large river basins. It drew from the facilities offered by new information technologies (Internet), while allowing for the consultation of the documents in public locations (prefectures, sub – prefectures, River Basin Agencies).

In the period from May to November 2005 in mainland France, 300,000 citizens submitted their opinion through questionnaires, during public debates, via written contributions addressed to the presidents of Basin Committees, or in the course of the various assemblies which were consulted in 2004. This is the result of a widespread action on the part of public bodies, associations and water stakeholders.

From the first interpretations of the views thus expressed it appears among other things that prevention needs to be reinforced. Many of our fellow citizens wish to have a better knowledge of the actions which they can carry out at their level to prevent pollutions. When defining the steps required achieving the objectives of the WDMMP, the feasibility of preventive measures should be studied. Thus the July 2007 ban on phosphates in detergents is in line therewith.

The consultation also emphasized the public's expectation to obtain information on water quality, its availability, and whether it is in sufficient amount to ensure the various intended uses. In this respect, local information needs to be intensified. To this end, the French Ministry of Ecology and Sustainable Development has initiated the revision of the water information system. As a result of a recent Act on water (enacted in 2006) data dissemination will be developed, thanks to the creation of the French National Office of Water and Aquatic Environment (ONEMA).

An improved knowledge of costs is also sought. By acting as an observer of public water supply and sanitation services, the ONEMA will therefore meet this concern expressed by water consumers.

A new public consultation is planned for 2008. The institutions involved in the area of water will also be consulted in parallel.

The economic assessment of the remedial actions is initiated.

In order to determine if the cost of the recommended remedial actions is economically acceptable, a detailed analysis is initiated for each water body. It takes into account the estimated cost of all the actions which were recommended during the previous stage for each water body and assesses whether or not it is disproportionate with regard to the corresponding realistic funding options.

This on – going work requires the input of a great deal of expertise and faces the added difficulty of dealing with projects which are often still at the drafting stage. Provisional results indicate that it will be possible to identify excessively costly measures.

The next stage will deal with examining the repercussions of these measures on water – pricing. It has not been started to date.

3 The transposal shall be accompanied by provisions which are in the process of being drafted

In addition to the reporting process provided for in the Law, legal provisions should supply answers to outstanding questions:

—Complete the standardization of the approach among the various Member States;

—Decide on whether both groundwaters and surface waters should be jointly taken into consideration;

—Coordination of the approach initiated with regard to toxic substances (in the case of pesticides, but many other toxic products as well);

—Ensure the consistency of the European Urban Wasted Water Directive (which is currently in effect and sets requirements with regard to the equipment in public wastewater treatment plants based on size) and the Framework Directive;

—Remedy the inconsistencies in the intervention applied to agriculture and search for solutions which are compatible with the qualitative and quantitative preservation of the water resource;

—Control of flooding risk;

—Full integration with the public policies of each Member State.

These actions shall be maintained while the results of the respective states of play, studies carried out, selected recommendations; work initiated and finally of the first outcome observed by each of the Member States reach the services. When taking into account the current diversity existing between the policies implemented by each State (many did not yet enjoy a structure based on river basins), it can therefore be expected that the process will still undergo many changes. The need for adaptability ensures a genuine pragmatism and real efficiency.

Defining a Water Policy French River Basin Agencies Reach a New Step with a New 6 Years Implementation Programm

Jacky COTTET and ***Willam BOUFFARD***

Rhone River Basin Agency, France

Abstract: The Rhone – Mediterranean and Corsica River Basin Agency involves the water stakeholders in its catchment area within the framework of a multiannual "Intervention Programme". The 9th Programme covers the period running from 2007 to 2012 and entails: environmental results – oriented objectives consistent with national or European requirements; an actions policy aimed at fighting pollution, conserving and managing water resources, promoting the knowledge and concerted management of aquatic ecosystems, this in harmony with the environmental objectives; considerable financial resources: 3 billion Euros over 6 years earmarked for this actions policy, to be allocated in the form of financial aid to the projects, but which are generated by charges (polluter – pays principle).

Not only does the Article describe in detail the contents of the 9th Programme, but also the way in which the river basin authorities have developed it, through successive adjustments between the environmental expectations, the cost of the actions planned, the territorial priorities, as well as the capacity to contribute shown by the water stakeholders, municipalities, entrepreneurs and farmers.

Key words: Integrated Management of Water Resources (IMWR), European Water Framework Directive (EWFD), river basin organisations, charges, financial aid

1 Introduction

The Rhone – Mediterranean and Corsica River Basin Agency is a public body which involves all the water stakeholders (municipalities, entrepreneurs, farmers, etc.) from the catchment area in a policy of integrated management of water resources. To that end, it acts by raising monies on the basis of the polluter – pays (or taker – pays) principle and reallocates these funds in the form of financial aid to pollution abatement (or water resource management) projects (see Fig. 1).

Characteristics of the RhoneMediterranean & Corsica Basin

Surface area 135,000 km²

Run off: 68 billion m³ per year

Population: 15 million inhabitants

20% of France's industrial and agricultural activities

50% of France's tourism activity

50% of its territory in mountain area

Fig. 1

Ever since its inception, some forty years ago, the River Basin Agency has been working on the basis of an "intervention programme" which usually runs over a five – year period. This is a planning document which not only defines the water policy and the targeted objectives for the aquatic ecosystems within the river basin, but also the levels of charges as well as the types of operations that the Agency will help fund. Based on assumptions regarding the projects that the water stakeholders in the area will develop, this is combined with an estimated balance between income and expenditure over five years. This balance must be respected, since this body is financially independent and does not receive any subsidies from the State.

This intervention programme constitutes the action plan for the first years of a longer term planning scheme called Water Development and Management Master Plan (WDMMP), which covers a broader scope than that of the Agency. For instance, the efforts of the Agency include the fight against pollution, the conservation of resources, the restoration of aquatic environments and monitoring water quality, whereas the WDMMP covers other actions to which the Agency does not contribute (floods, and water police in particular).

The Water Framework Directive provides this pre – existing French method of operation with a kind of "European legitimacy" if one considers that the WDMMP corresponds to the editable "management plan" contained in the Directive, and that the intervention programme is part of its "programme of measures" over 6 years (this explains why the 9 th Programme will cover 6 years as well, instead of formerly 5 years: 2007 ~ 2012).

2 What the 9 th Programme Implies

As a result of the drafting process, which is described at length in the next Section, the following is what the Intervention Programme of the Rhone – Mediterranean and Corsica Agency is actually planning for the period 2007 to 2012.

2.1 Preserve or restore the status of aquatic ecosystems

The state of playing which was carried out in 2004 pursuant to the European Water Framework Directive shows that surface waters, in a proportion of 30% to 40% depending on pollution parameters, are currently not in a good ecological status; by 2015, the status of waters will improve, but some 15% to 30% of water bodies, depending on parameters, may not achieve a good status by then.

Contributing to the environmental objectives of the WDMMP ranks as a top priority within the strategic guidelines selected for the Agency's Intervention Programme. This is complemented with its participation in the implementation of European directives or national programmes in the area of water and the establishment of a technical and financial solidarity among the water stakeholders of the Rhone – Mediterranean and Corsica river basins within the context of sustainable development.

The WDMMP will only be sanctioned definitely at the end of 2008; however, its first draft, which was being developed in the course of 2006, has already outlined fundamental guidelines and good status objectives per water body. The final WDMMP will include the timescales by which these objectives should be reached, i. e. generally 2015, which corresponds to the end of the first management plan. For some water bodies however, the deadlines shall be postponed to 2021 or 2027, including reduced environmental requirements where applicable.

This results – based on rationale initiated by the Water Framework Directive naturally lead to differing objectives, depending on the local problems of each area (sub – basins in catchment area, aquifers, coastal waters) while prioritising those environments for which results can be obtained in the least possible time, either because related costs are lower, or because more stakeholders are involved therein. This is the "territorialisation" approach (see Fig. 2).

2.2 Intervention through charges and premiums

Almost the entire revenue is made up of the charges collected annually by the River Basin Agency; loans or advances repayments granted the previous years represent approximately 13% of the overall revenue.

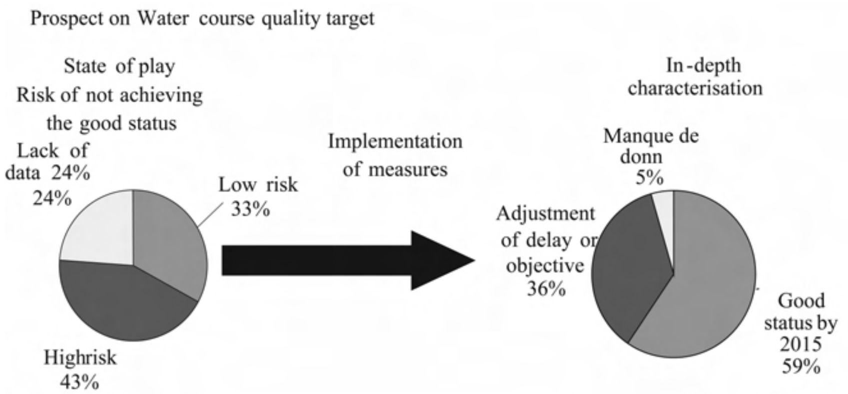


Fig. 2

The 9 th Programme of the Rhone – Mediterranean and Corsica Agency stands out in that it had anticipated the promulgation of the French Law on Water and the Aquatic Environments ("LEMA"), which entails a thorough reform of charges levied by River Basin agencies. Even though the bill had not been passed at the time when the Intervention Programme was approved, its content, (which was going backwards and forwards in Parliament), was known to a large extent. The Agency therefore based its estimated revenue on the current system applied to charges in 2007 and the new post – LEMA charges, for the years 2008 to 2012. The promulgation of LEMA at the very beginning of the year confirmed the relevance of these provisions.

The new system expands the scope whereby charges and premiums can be applied: there will be new charges, such as the charge applied to distributors of plant protection products (pesticides) or to owners of obstacles (dams, derivations) in river beds. However, changes will also affect existing charges, which will require the participation of some actors who until then had been exempt of such charges. This concerns for instance some users of irrigation networks abstracting less than 10,000 m^3/year, waste discharges of small municipalities of less than 400 inhabitants, or the owners of hydro power dams located on water courses. Finally, water treatment premiums will be able to include further criteria for efficient operation and shall be extended to non collective sanitation.

Another new aspect is the fact that charges are no longer exclusively aimed at generating financial revenue: their purpose is also to influence water stakeholders, in order for them to reduce their pressure on water resources (discharges, abstractions, etc.). The incentive character of charges shall be the result of a targeted communication, addressed in particular to taxpayers living in the sub – basins where environmental problems are relatively widespread: the increase in charges in those sub – basins will be explained and justified against the status of the aquatic ecosystems.

Here are the aggregate amounts (in Euros) for the period 2007 to 2012 that the various charges and premiums should generate(see Fig. 3).

2.3 Intervention through financial aid and technical advices

The River Basin Agency intervenes by providing financial aid to those developers who invest in projects for the protection of the water resource or for pollution abatement. Yet, the role of the Agency is also visible in the directions it may give upstream of projects by arranging the concertation among local stakeholders which is specifically based on the knowledge of aquatic environments (a water information system, the development of which is shared between the Agency and other public entities, whereas the cost is mainly its responsibility).

The themes of the actions requiring aid are multiple, but the following can be emphasised:

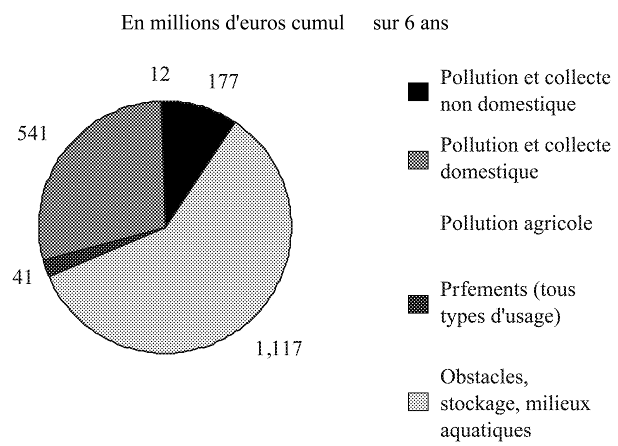


Fig. 3

(1) The compliance of sewage systems with regard to the European Urban Waste Water (UWW) Directive. Despite the fact that very costly investments have already been made, several years of sustained effort are still necessary to meet the requirements of this regulation dating back to 1994.

(2) The restoration and exploitation of aquatic environments. The efforts towards local concertation have led to an ever increasing number of projects, which are bound to play a major part in the good ecological status of water courses.

(3) The reduction in toxic and hazardous substances. Pesticides and some priority molecules have become the main environmental problem in many aquatic ecosystems.

(4) The sustainable use of some water resources or "quantitative balance". Some groundwater or surface water resources are overexploited, or increasingly present an insufficient low – water level. This situation is not widespread thanks to the major water supply systems (transfer with large canals) in the South of the Basin and the abundant water resource in the mountains, but climate change threatens to pose a long – term risk.

(5) Rural water supply and sanitation systems lag behind compared to urban schemes, and investments often cost more per beneficiary. This concerns Corsica Island in particular, but also many other areas which are scarcely populated.

Following the assessment of the previous Intervention Programme, due to the context referred to in the Introduction and the state of play, the framework system for subsidies is changing towards increased contractualisation with contracting authorities or other financing entities, such as the departements ("districts") or regions, and towards more territorialisation: a number of subsidies are not granted over the whole RM&C district, but targeted for specific sub – basins or aquifers. This applies to Corsica in particular, which enjoys a special autonomy pursuant to the decentralisation laws. It therefore has a specific River Basin Committee and benefits from specific aid. The practical actions required reaching the objectives set in the Water Framework Directive or the WDMMP are emphasised in the form of "Main Goals of the 9 th Programme".

In the case of the Rhone – Mediterranean Basin for instance, the main goals to be mentioned are listed below:

(1) Fight against pollution. Compliance of 100% of waste water treatment plants of over 2,000 Equivalent Inhabitants; start up 45 collective initiatives aimed at reducing scattered pollution originating from industries; initiate actions for the reduction of toxic discharges over 60 priority dispersed sites.

(2) Conservation and management of water resource: initiate the physical restoration of 40 priority basins; draw management plans aimed at the resource and low – water levels over 100% of

the priority areas and have a third of the plans approved; implement a programme for the reduction of direct abstractions over 20 priority areas by acting on both supply and demand; restore and/or conserve 10,000 hm^2 of wetlands, protect the strategic underground resources for drinking water supply by delimiting 100% of such resources and supporting the first operational action plans; restore the quality of raw waters in at least 40 public water supply basins affected by diffuse pollution sources; within the specific framework of the resources granted to rural boroughs, dedicate one third of aid to the back fitting work (even upgrading) on run – down waterworks.

(3) Promotion of knowledge and concerted management of aquatic environments: implement the operational control network for the water bodies which may not achieve good status and equip 100% of priority basins with systems to monitor the water resource; set up, in each region, an environment education platform for Sustainable Development; promote the creation of at least 40 local management initiatives on the priority orphan territories; start up 25 new contractual procedures over priority areas.

At the financial level, the programme authorisations which are planned for the period 2007 to 2012 are shown on the opposite chart (in euros for 6 years) (see Fig. 4).

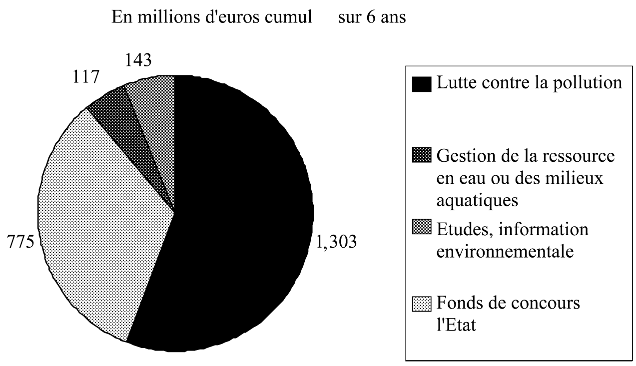


Fig. 4

3 Drafting the 9th Programme

3.1 The design process

Drafting an intervention programme is a delicate exercise in dialogue between the water stakeholders over a whole district: public authorities (elected citizens like mayors), state servants, private entrepreneurs, farmer representatives, environmental NGO debate together. The organisation along major river basins existing in France is based on "basin authorities": on the one hand the River Basin Committee which guides the water policy, since it approves the WDMMP for instance, but which, also, decides on charges; on the other hand the River Basin Agency Management Board, which defines the objectives and priorities for action, the terms for implementing financial subsidies or charges, and decides whether projects are granted aid.

1/3 more or less of the members of these authorities are from territorial communities, 1/3 are representatives from the private sector (industry, farming, …) and 1/3 are State representatives. As a result, none of these groups is able to alone impose its will to the other two (with the exception of the right to veto that the relevant Ministry for Ecology may exercise in some cases). The water stakeholders are therefore bound to agree and this is exactly what happens during the design phase of an intervention programme: over 2 years, the River Basin authorities, have held some thirty successive meetings around various configurations (BC, MB, committees or plenary sessions, etc.) in order to study and amend the proposals submitted by the staff of the River Basin Agency.

These proposals consist in starting from the assessment of the previous programme, the state of play and the objectives of the aquatic environments to envisage a series of projects, and estimate the total cost thereof, as well as the volume of requested financial aid. This corresponds to a precise level of charges and premiums, since the Agency is an independent body and must balance its revenue and expenditure over the duration of a programme. As a rule, the net borrowing requirements of the projects which were initially envisioned lead to a level of charges that is significantly higher than the current contributions; it may prove necessary as a result to take into account the realistic investment capacities of the water stakeholders by means of a series of successive iterations which involve different adjustment tools:

(1) technical adjustment tools such as e. g. the cancellation of certain types of aid which are less efficient than others, selectivity by restricting some subsidies to the areas where they will have more impact;

(2) financial adjustment tools such as e. g. the rates of aid, the levels of charges, and advance payments.

The result is therefore an intervention programme as described in the previous Section.

3.2 A conflict situation

In the case of the 9th Programme for the RM&C river basins, the actors represented on the Basin authorities were actually faced with contradictory reasonings, which can be summarised (and simplified) as follows (Fig. 5).

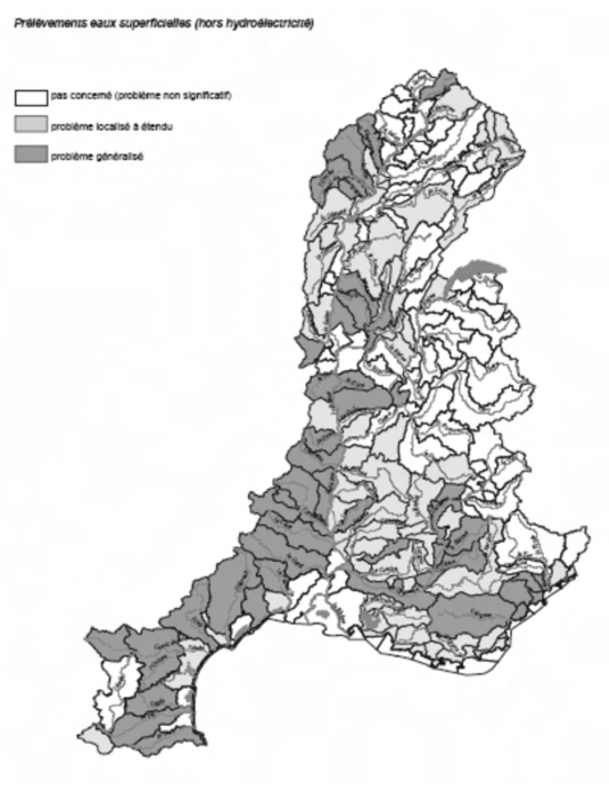


Fig. 5

(1) The economic stakeholders, whether in the industry, electricity generation or agriculture,

were very eager not to increase the burden of current charges. All this in a context of general stability of the economic activity which is the result, in fact, of very different situations: Development of some sectors (hospitality and tourism activities for instance), crisis in other economic areas (textile, bulk chemicals surface treatment, etc.).

(2) Local communities both willing to control the price of water (with charges accounting for approximately 15%) and aware of the need to invest in order to meet legal requirements and achieve good ecological status.

(3) State representatives, concerned at the possibility of litigation (European penalties for delays in implementing the UWW Directive), and keen to promote national policies such as the drought action plans or the solidarity financing initiative in favour of rural municipalities.

(4) Unanimous on this point, the stakeholders are very watchful of the fact that this or that category does not benefit from an increase in subsidies or a drop in charges at the expense of another category.

Some meetings were marred by many interruptions and negative votes, or positive votes but with a very small majority.

3.3 The solutions

The situation might have seemed even more complex because of the many new factors that had to be taken into account in a completely uncertain future. These include:

(1) the good ecological status objectives which have yet to be precisely defined, as well as the forthcoming priorities of the WDMMP.

(2) the solidarity with rural municipalities which falls under the Agency's responsibility but at a financial level that was only revealed at the end of 2006.

(3) the risks of incurring penalties under the UWW Directive (not taken into consideration to date).

(4) subsidies deemed as anti – competitive by European Union (in the agricultural sector in particular).

(5) the new Law on Water and the Aquatic Environments ("LEMA") which utterly changes all the assessments of charges and creates new ones, but whose fate in Parliament had yet to be sealed up until December 2006.

In the end, the solution came partly from these new factors, which were used to offer new consensual principles and eventually secure a clear majority in favour of the programme, the "No" votes being shared equally between those who thought the proposals lacked ambition and those who found these too ambitious. These principles are the following:

(6) The priority results – based objectives (main goals described under § 2.3).

(7) On – going ecological taxes: the stakeholders or structures which give rise to charges under the current legal system (which will remain effective until the end of 2007) will collectively contribute to the same financial level once the LEMA enters into force; however, all the new contributors will bring a new revenue which will add an extra 6% to the 2006 net level of contribution.

(8) The balance between categories of contributors (increase in the net contribution by farmers from 1 to 3% in total, allowing for a slight drop in that of inhabitants and economic activities) and between the fields of intervention (similar level between aid and charges on the same theme: for instance the rates of "collection" charges have been brought down in order to be more on a par with the amounts of aid granted to sewage systems).

References

B. Kaczmarek. Un nouveau role pour les agences de l'eau? Essai pour une politique franco – europeenne de l'eau renovee" Published by Johanet.

Document downloadable on: http// www.eaurmc.fr.

Long – term Trend for Major Climate Variables and its Impact on Eco – environment in the Upper Yellow River Basin*

Xu Zongxue, ***Huang Junxiong*** and ***Zhao Fangfang***

Key Laboratory of Water and Sediment Sciences, Ministry of Education College of Water Sciences, Beijing Normal University, Beijing, 100875, China

Abstract: On the basis of the mean air temperature and precipitation from 23 meteorological stations in the upper Yellow River basin from 1960 to 2001, the long – term trend for major climatic variables has been investigated in this paper. The possible trends of annual and monthly climatic time series are detected by using a non – parametric Mann – Kendall method. The results showed that the annual mean temperature has increased by 0.8 ℃ in the upper Yellow River basin during the past 42 years. The warmest center was located in the northern part of the basin. The nonlinear tendency for annual precipitation was negative during the same period. The declining center in annual precipitation was located in the eastern part and the center of the basin. The variation of annual precipitation in the upper Yellow River basin during the past 42 years exhibited an increasing tendency from 1972 to 1989 and a decreasing tendency from 1990 to 2001. This may result from possible climate change or the effect from human activities. At the same time, climate variability resulted in the problems of eco – environment such as decreasing of the stream flows, shrinking of the lakes, melting of the iceberg, degenerating of the pastures, deserting and losing of water and soil as well. During the past 42 years, the climate of study area becomes drier and warmer, and its variability increases, i. e. increasing of temperature and decreasing of precipitation. Therefore, climate change is considered as a basic driving factor to the deterioration of eco – environment.

Key words: climate change, trend, ecology, Yellow River, Lanzhou

During the past several decades, some problems such as climate change, human activity and deterioration of eco – environment have appeared in the upper Yellow River basin. There are some investigations on the runoff change and its impact factors in headwater of the Yellow River basin (Wang et al., 2004; Bao et al., 2000; Wang et al., 2005; Zhang et al., 2000; Han et al., 2004), but few studies on climate change and its impact on eco – environment in the upper Yellow River basin have been done. Studies on the long – term trend of major climate variables and its impact on eco – environment are very important to the sustainable development of society and economics in the upper Yellow River basin.

The climate system has typical characteristics of multi – scale in space, multilayer in configuration, nonlinearity in nature, with very complex mutual connection and effect (Li, 2001). Many researchers investigated the trend of climate variables and the characteristics of the climate abrupt changes, for example, the climate variations, tendencies and climate jumps in Xinjiang Province (Yang, 2003), etc. However, few studies on the climate tendencies and its impact on eco – environment in the upper Yellow River basin have been done, although Yang and Li (2004b) have analyzed the abrupt and periodic changes of the precipitation and runoff in this area with EOF method and Mann – Kendall method. Therefore, further study should be conducted. In addition, the scarcity of water resources in the Yellow River basin has been paid much attention to by national and international experts in recent years. Headwater catchment of the Yellow River basin is the "water

* Supported by "Jingshi Scholar" Leading Professor Program, Beijing Normal University and the National Basic Research Program (973) of China under Grant No. 1999043601.

tower" of the whole basin, in which the streamflow has reduced, and the water level in the lakes has declined. Whether it resulted from climate change or human activities should be further studied.

Therefore, on the basis of monthly mean air temperature and precipitation from 23 meteorological stations and naturalized runoff at Lanzhou station in the upper Yellow River basin from 1960 to 2001, the feasibility of using hypothesis test techniques to detect the long – term trend for major climate variables has been investigated during the past 42 years. At the same time, the impact of climate changes on eco – environment also has been discussed in the study area.

1 Study area description

The Yellow River basin is located in the semi – dry and semi – humid region with severe water scarcity, in which the annual mean precipitation is about 200 ~ 600 mm, and the naturalized streamflow is about 58 billion. The drainage area at upstrem of Lanzhou station is about 222,551 km^2. The climate belongs to the Qinghai – Tibetan plateau climate system. In cold seasons, the basin climate has the characteristics of typical continental climate, which is controlled by the high pressure of Qinghai – Tibetan plateau, lasting for about seven months. In warm seasons, the climate is affected by southwest monsoon, producing heat low pressure, with abundant water vapor and much precipitation, thus forms plateau semi – tropical humid monsoon climate. The whole climate characteristics of the study area are as follows: long winter without summer, spring immediately after autumn, low heat, little annual temperature difference, large daily temperature range, long sunshine duration, intensive solar radiation, big windy storm, and short growth periods. The average air temperature is 2.68 ℃, with 2,554.7 h for sunshine duration, 1,428.9 mm for evapotranspiration, and 446 mm for precipitation. The average precipitation shows an increasing trend from northwest to southeast. The precipitation from June to September accounts for 75% of the annual value. The water resources of the upper Yellow River basin account for 57.5% of the whole Yellow River basin (1951 ~ 1998), in which the spatio – temporal variation of water resources are very important for the whole Yellow River basin (Li, 2003). The variation of climate variables is the main reasons for the water resources change. Therefore, it is very important to investigate the spatio – temporal variation of the climate variables in the upper Yellow River basin in order to identify the evolvement of the water resources and the safety of ecological system in the whole Yellow River basin.

2 Data and methodology

There are 23 meteorological stations selected in the upper Yellow River basin. These stations are spatially well distributed, which can reflect the characteristics of regional climate. The data of monthly mean air temperature and precipitation are from China Meteorological Administration (and have been checked by the primary quality control). Considering the reliability and integrality, the observed data from 1960 to 2001 are selected in this study. At the same time, in order to ensure the integrality of the time series, the absent data are interpolated by using the data from near stations. From the statistical meaning, it is credible using so long time series to get the credible results. The location of the study area and the meteorological stations selected are shown in Fig. 1.

Considering the unique climate characteristics in the upper Yellow River basin, the seasons are determined as follows: March – April – May for spring, June – July – August for summer, September – October – November for autumn, and December – January – February (the following year) for winter. In order to reduce the unilateralism of single station record, the regional series are calculated by the spatial average of all the stations in the whole area. In this study, the climate tendencies in the study area are analyzed by using nonparametric Mann – Kendall method, the periodic changes are analyzed by using departure curve method.

3 Climate change analysis

During the past 20 years, many researchers have investigated the regional climate

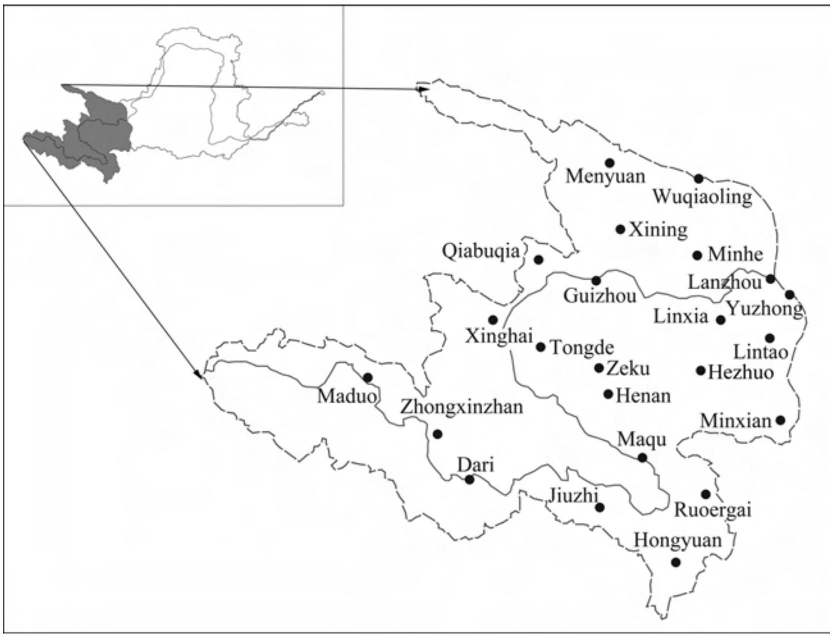


Fig. 1 Location of the study area and the meteorological stations selected

characteristics at different time scales in China. These results provide favorable basis and direction to exactly grasp the climate characteristics at large scale and further understand the regional climate change. Nonparametric Mann – Kendall method is widely used to analyze the trends of the environmental time series, which is recommended by World Meteorological Organization (WMO) (Liu and Zheng, 2003; 2004; Yu et al., 2002). It is also an efficient tool to examine the monotonic trend of hydro – meteorological series (Xu et al., 2002; 2003). In this study, the climate trends of climate variables from 23 gauging stations in the upper Yellow River basin for 42 years are detected at the 95% level of significance in this study. At the same time, the magnitude of long – term trend for climate variables (Kendall slope) from different gauging stations are spatially interpolated in the whole basin by using Kriging method.

3.1 Temperature

Fig. 2(a) shows the spatial distribution of nonlinear tendency for the mean air temperature in the upper Yellow River basin. It shows an increasing trend in most part of the study area. The Kendall slopes at 21 gauging stations are positive, only 2 stations (Zhongxin station and Henan station) are negative. Two warm centers are showed in the whole basin, one is near Qiabuqia station in the north, the other is near Lanzhou station in the east, in which the Kendall slopes are 0.48 ℃/10 a and 0.44 ℃/10 a, respectively. The average Kendall slope for the whole basin is 0.18 ℃/10 a, i. e., the mean air temperature has increased 0.76 ℃ in the upper Yellow River basin during the past 42 years.

Fig. 2(b) shows the departure curves of the mean air temperature in the upper Yellow River basin. Departure is the difference of climate variables for 42 years. It showed in Fig. 2(b) that there are two obvious periods in the study area for past 42 years. One is the cold period of 1960 ~ 1986, in which the negative departure accounts for more than 80%, and the abnormal cold years are 1967, 1977 and 1983, respectively. The other is the short warm period of 1987 ~ 2001, in which the mean air temperature is 3.1 ℃, 0.46 ℃ higher than the average of the whole basin. In warm period, the negative departures account for more than 87%, in which the highest temperature for 42 years happened in this period, and the temperature in 1998 is 1.7 ℃ higher than that of the whole basin. The temperature change has obvious seasonal difference. Comparing the departure curves, winter temperature has major contribution to the annual mean temperature.

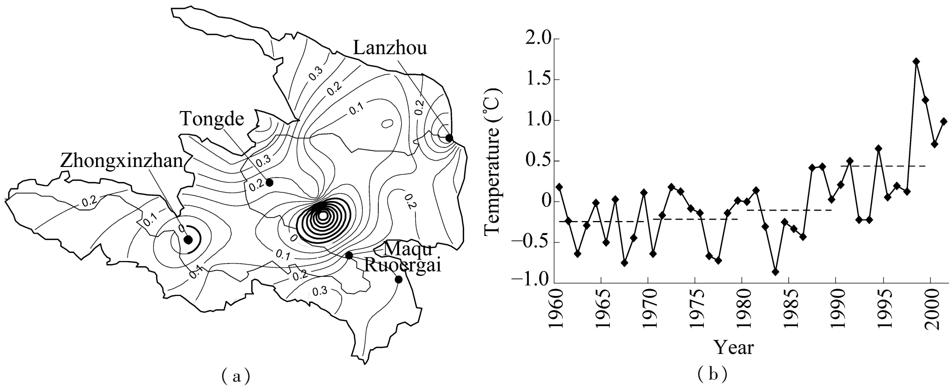


Fig. 2 Distribution of nonlinear tendency for temperature spatial distribution departure curves

3.2 Precipitation

Fig. 3(a) shows the distribution of nonlinear tendency for precipitation in the upper Yellow River basin. It shows decreasing trend in most part of the basin. The Kendall slopes at 17 gauging stations are negative. There are two decreasing centers located near Lintao station and Henan station along the main stream, in which the Kendall slopes are −28.63 mm/10 a and −28.83 mm/10 a, respectively. The average Kendall slope for the whole basin is −4.26 mm/10 a. Therefore, there is a little dry trend in the upper Yellow River basin since 1960.

Fig. 3(b) shows the departure curve of the precipitation in the upper Yellow River basin. It showed that the departure curve fluctuates significantly, with the characteristics of three significant increasing/ decreasing jumps in the 1960s. The more precipitation period of 1970 ~ 1989 lasts for long time, in which the mean precipitation is 11.7 mm higher than that of the whole basin. The less precipitation period is from 1990 to 2001, in which the mean precipitation is 18.6 mm lower than that of the whole basin. The seasonal departure curves show that autumn precipitation has the greatest contribution to the annual total.

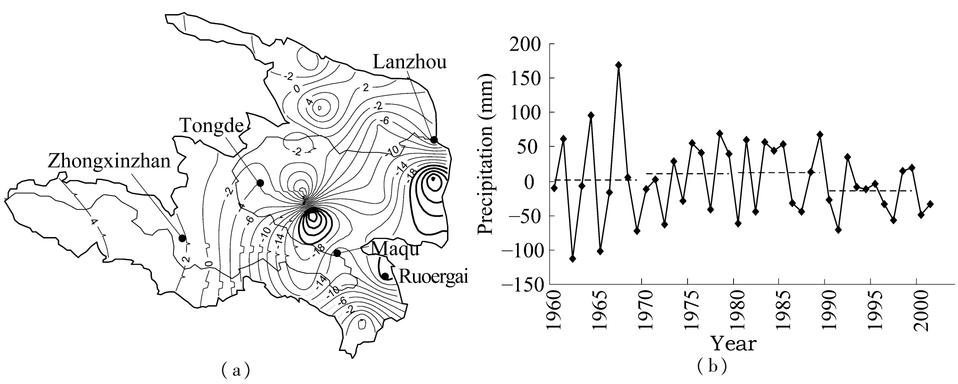


Fig. 3 Distribution of nonlinear tendency for precipitation spatial distribution departure curves

3.3 Variation of major climate factors

The inter – decadal variations for the departure time series of mean air temperature and precipitation are shown in Fig. 2(b) and Fig. 3(b) with broken lines. It showed in Fig. 2(b) and Fig. 3(b) that the temperatures in the 1960s and 1980s are increasing, and the precipitation is increasing from the 1960s to 1980s, but deceasing in the 1990s. The relationship between precipitation and temperature is weak, i. e. the precipitation may be high or low when the temperature is high. The result is similar with that obtained by Shi (1996), i. e. the change of temperature is not the direct reason for the change of precipitation. Therefore, variations of precipitation in the future should be further investigated.

It is the basis to qualitatively analyze the relationship between temperature and precipitation for understanding the change of eco – environment in the study area. It can help to reasonably predict the future climate change and to take corresponding countermeasures. Some conclusions can be obtained by analyzing the climate data in the upper Yellow River basin from 1960 to 2001 as follows:

(1) Mean air temperature: There are two increasing centers in the study area, one is near Qiabuqia station in the north, and the other is near Lanzhou station in the east. The Kendall slope of the mean air temperature is 0.18 ℃/10 a in the whole area, increasing 0.76 ℃ for 42 years. The winter temperature has the greatest contribution to the annual total. The results show that there is an obvious abrupt warming occurred in the late 1980s.

(2) Precipitation: The climate exhibits a dry tendency in the upper Yellow River basin since the 1960s. The mean Kendall slope of precipitation is −4.26 mm/10 a for the whole basin. The autumn precipitation has the greatest contribution to the annual total. The results show that there is one obvious abrupt change for precipitation in the mid 1980s, changing from wetter to drier.

In conclusion, there is a warm and dry tendency in the upper Yellow River basin during the past 42, i. e. increasing of temperature and decreasing of precipitation.

4 Problems of eco – environment in the upper Yellow River basin

4.1 Decreasing of the streamflow in the upper Yellow River

The streamflow in the upper Yellow River has reduced by 13% annually since the last 1980s, especially in 2002, during which the streamflow reduced by 46%. Fig. 4 shows the tendency of naturalized annual runoff in Lanzhou station from 1960 to 2001. The results indicate the similar trend for both naturalized annual runoff and precipitation, which shows the downward tendency as a whole and is in the low flow period since 1990.

The naturalized annual runoff in Lanzhou station shows a significant monotonic trend by using nonparametric Mann – Kendall method. The slope of Kendall is -0.02×10^8 $m^3/10$ a and explains that the naturalized annual runoff showed a declining trend.

The naturalized annual runoff in Lanzhou station is negative related with the regional annual average air temperature, while it is significant positive related with the precipitation, especially in flood seasons (from July to September). In this period, the precipitation is the main factor causing the change of the annual streamflow, which thus explains that the climate change may be the main reason for the change of annual runoff. The reduction of streamflow not only restricts the development of regional economy, reduces the level of residential living and production, but also increases the frequency of drought downstream, influences the development of economy downstream at the same time.

4.2 Shrinking of lakes, ablation of glacier and increasing of depth for frozen soil

Recently, water table declined, volume of groundwater decreased, lakes shrank, and area of lakes decreased in the upper Yellow River basin. There were 4,077 lakes in Maduo county in the

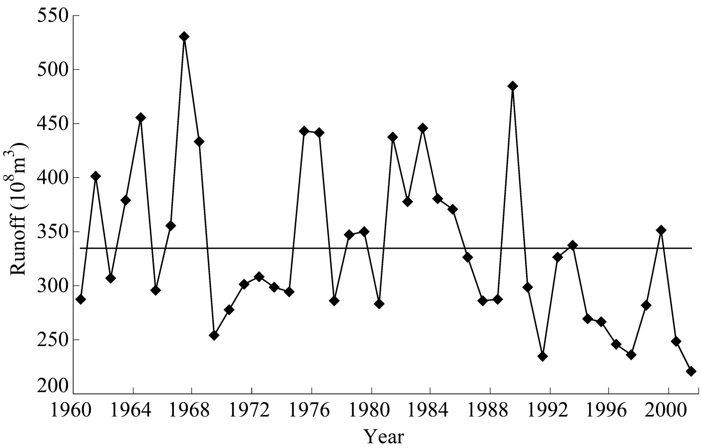


Fig. 4 Tendency curve of annual mean runoff in Lanzhou station

early 1990s, but only less than 2,000 lakes remained presently. Compared to 1976, the area of swamps and lakes in 2000 decreased nearly by 3,000 km^2. Most of the modern glaciers are shrinking in recent 30 years. According to the investigation, the area of glaciers decreased by 17% compared to 1970 in A'nimaqing mountainous region, headwater catchment of the Yellow River basin. The greatest shrinking speed of glacier reached 57.4 m annually.

Most part of the upper Yellow River basin belongs to the high – frigid regions in Tibetan Plateau. Permafrost layer exists in the ground, which is impermeable and can prevent the infiltration of surface water successfully. Since climate becomes warmer, permafrost layer degenerated rapidly and the capability of separating from surface water will descend on a large scale, which result in a losses of surface water infiltrate into ground. As a result, the evolvement of surface runoff will be affected.

4.3 Degradation of pastures, desertification of land, and loss of water and soil

The pasture ecosystem is the most important ecology in the upper Yellow River basin. Degradation of pastures does not only reflect reduction of vegetation cover ratio, but also embody deteriorating of pasture ecology such as evolvement of dominant species, variety of structure and descending of productivity, and so on. In the study area, the deserting and baring of soil are dominating. The desertification in the study area is dominating in the high – frigid grassland, and degradation of pastures in the high – frigid meadows embody in "black soil beach" and desiccation of swamp meadow. At the same time, the degradation and desertification brings serious calamity of rat which accelerate the degradation of pastures as well.

The losses of water and soil resulted in degradation of pastures, calamity of rat and degradation of land is serious in the upper Yellow River basin. At present, the desertification area is about 0.37 million hm^2 in the headwater catchment of the Yellow River basin, and the losing area reached up to 4.17 million hm^2, of which the area of serious erosion is about 225 hm^2 and account for 18% of the total area.

Accordingly, the ability to hold water and adjustment capability become smaller, which is accompanied by abnormal climate, drought, snow damage, hail and sand storm. As a result, the land capability is descendent and water quality becomes bad, which further resulted in the increase of sediment concentration and yield in the upper Yellow River basin.

5 Analysis for the change of eco – environmental system

In the upper Yellow River basin, the deterioration of the eco – environment affected the domestic life and production seriously, and also brought more pressure to ecological protection. The natural factors especially the climate change is the most important factors for the change of eco – environment.

The present study results demonstrated that the climate change in the upper Yellow River has affected the water quantity. Since the 1990s, the temperature has increased, the increasing trend of the precipitation is apparent. Especially the runoff in spring and autumn showed positive correlation with contemporaneous precipitation, decreasing of precipitation in flood seasons has serious effect on the water resources of the Yellow River basin (Wang et al., 2004; Zhu and Zhang, 1999; Li et al., 2004). The effects from the change of temperature in the earth and climate change usually occur in the environment sensitive zones, such as sunspot action and greenhouse effect to geophysical change. As a sensitive zone in the earth, Qinghai – Tibet Plateau is called "Third Pole". The upper Yellow River is in the third pole zone, so the deterioration of its eco – environment is the response of the geophysical change.

The change of water resources in the upper Yellow River basin is controlled by climate factors. The effects are embodied in two directions: first, the condition of climate itself (especially temperature and precipitation) has changed; secondly, it is the change of the underlying surface. This paper analyzed the regional climate change and the effect to the regional eco – environment.

(1) The impact of air temperature on the surface water resource: As a heat index, the temperature can affect the flux in several directions: first, it can affect the ablation of the glacier and snow cover; secondly, it affects the total evapotranspiration of the basins; thirdly, it can change the precipitation style in the mountainous area; fourthly, it can change the temperature difference between the underlying surface of the basin and near – surface soil, thus forms the basin climate. The average temperature in this area shows an increasing trend, the change directly caused the decreasing of the surface runoff into the Yellow River. The increase of temperature enhanced the evaporation, resulted in increasing of surface temperature and the surface tended to become drought. It brought ablation of glacier, melting of underground frozen soil, thus more surface water infiltrated into the soil layer. As a result, the surface runoff decreased largely. At the same time, it also change high – frigid swamp meadow to meadow steppe, and brought the decrease of vegetation cover, expansion of bare land, and desertification of land in the study area.

(2) The variation of precipitation affects the hydrologic system and eco – environment. Precipitation is the main factor of hydrological system and ecosystem. The ecological process in the study area depends on the hydrological process, and the change of precipitation plays an important role for this change. The precipitation in the study area distributes unevenly. The decrease of precipitation directly resulted in the decrease of streamflow, and the evolution of hydrologic regime in the study area, thus it accelerated the deterioration of eco – environment.

In a word, the change of eco – environment change in the upper Yellow River may mainly resulted from climate change such as the change of precipitation and temperature. The effect from human activities such as overgrazing and road construction also plays very important role for this change. The warm climate may be one of the basic driving factors to the deterioration of eco – environment in the study area. But how to distinguish the effect of climate change from human activities need to be further investigated in the future.

References

Bao Weimin, Hu Jinhu. Analysis on runoff resource and its conceivable variation trend over the upper reaches of the Yellow River[J]. Bulletin of Soil and Water Conservation (in Chinese), 2000, 20(2): 15 – 18.

Han Tianding, Ye Baisheng, Ding Yongjian. Study on the change of streamflow in the upper reaches of the Yellow River in recent 40 years[J]. Arid Land Geography (in Chinese), 2004, 27(4): 553 – 557.

Li Chunhui. The reproducible evaluation of the surface water resources in the Yellow River basin [J]. Beijing Normal University (in Chinese), 2003, 7.

Li Lin, Wang Qingchun, Zhang Guosheng, et al., The Influence of Climate Change on Surface Water in the Upper Yellow River[J]. Acta Geographica Sinica (in Chinese), 2004, 59(5): 716 – 722.

Li Yueqing. A phase space EOF method and its application to climate diagnosis[J]. Plateau Meteorology (in Chinese), 2001, 20(1): 88 – 93.

Liu Changming, Zheng Hongxing. Changes in components of the hydrological cycle in the Yellow River basin during the second half of the 20th century[J]. Hydrological Process, 2004, 18: 2337 – 2345.

Liu Changming, Zheng Hongxing. Trend analysis of hydrological components in the Yellow River basin[J]. Journal of Natural Resources (in Chinese), 2003, 18(2): 129 – 135.

Shi Yafeng. Chinese historical climatic changes[M]. Jinan: Shandong Science & Technology Press, 1996. 443 – 467.

Wang Jinhua, Kang Lingling, Yu Hui, et al. Analysis on the Effects of Climate Change on Natural Runoff Volume in the Upper Reaches of the Yellow River[J]. Arid Land Geography (in Chinese), 2005, 28 (3): 288 – 291.

Wang Yunzhang, Kang Lingling, Wang Guoqing. Precipitation variation happened in the upper reaches of the Yellow River and effects on its runoff in the last 50 years[J]. Yellow River (in Chinese), 2004, 26(2): 5 – 7.

Xu Z X, Takeuchi K, Ishidaira, H. Long – term trends of annual temperature and precipitation time series in Japan[J]. Journal of Hydroscience and Hydraulic Engineering, 2002, 20(2): 11 – 26.

Xu Z X, Takeuchi K, Ishidaira, H. Monotonic trend and step changes in Japanese precipitation [J]. Journal of Hydrology, 2003, 279: 144 – 150.

Yang Lianmei. Climate change of extreme precipitation in Xinjiang[J]. Acta Geographica Sinica (in Chinese), 2003, 58(4): 577 – 583.

Yang Zhifeng, Li Chunhui. The spatial and temporal structure of precipitation in the Yellow River basin[J]. Progress in Geography (in Chinese), 2004, 23(2): 27 – 33.

Yu, P S, Yang, T C, Wu, C K. Impact of climate change on water resources in southern Taiwan [J]. Journal of Hydrology, 2002, 260, 161 – 175.

Zhang Guosheng, Li Lin, Shi Xinghe, et al. Climatic changes over the upper reaches of the Yellow River and its effects on water resources[J]. Advances in Hydrologic Science (in Chinese), 2000, 11(3): 277 – 283.

Zhu Xiaoyuan, Zhang Xuecheng. A Study on the Changes of Water Resources in Yellow River (in Chinese)[M]. Zhengzhou: Yellow River Conservancy Press, 1999.

Historical Changes of the Lower Yellow River and its Influence on the Rise and Fall of Chinese Nation

Yang Yuzhen

Yellow River Mouth Sediment Research Institute of Dongying City, Shandong, 257091

Abstract: Great Rivers are always the cradle of humankind's civilization, the gestation and development of prehistoric Yellow River has formed the civilization groundwork of Chinese nation. By analyzing geological reason of the five main watercourses' change of Yellow River in this article, it provides a theory basis for long – term stabilization of the current watercourse. When it argues that the change of Yellow River has brought influences on the rise and fall of Chinese nation, it also points out that a position switch has happened quietly between natural force that is represented by present Yellow River and social productivity, and only to ensure the balanced development between social productivity and natural sustaining capacity including the life of Yellow River, can great revival of Chinese nation with a harmonious relationship between human being and the nature be realized.

Key words: Yellow River, historical vicissitude, geological base, nation's rise and fall, healthy life of Yellow River

Influence of great rivers on the growth of peoples living in their basins is all along admirable in the eyes of historians and sociologists. For instance, Nile has fostered the ancient Egypt; The Euphrates and Tigris that has raised "the Fertile Crescent" have once successively raised nations of Sumerian, Akkadian, Phoenicia, Hebrew and so on; Indus and Ganges nurtured the civilization of ancient India and Aryan, etc. Chinese nation was mainly developed in the two big basins of Yellow River and Yangtze River, hereinto, Yellow River demonstrated a magnificent history of national prosperity and decline. Therefore, it has significant realistic meanings to study the influence of Yellow River's change on Chinese nation's development from the multi – angles of geology, ecology, sociology and so on, which can spark something for the more – scientific modern management plan to realize the harmoniouse coexistence between human and the River.

1 Prehistoric Yellow River and the development of Chinese civilization

As for the frame and venation of Chinese ancient history, Professor Su Bingqi, a renowned archaeologist, once generalized as that "it includes more than one million years' great cultural foundation, ten thousand years' civilization growth, and five thousand years' old nation and two thousand years Chinese entity." (Shi Shi, 1999) In recent years, through inspecting the historical change of Yellow River, it was proved that the gestation and development of Yellow River which was known as the cradle of Chinese nation was generally tallying with this judgment. According to the inference of some geologists, Yellow River was gestated in the late Early Pleistocene (from 1.5 million to 1.15million years ago), born and grown in the long – term Mid Pleistocene (from 1.15 million to 100,000 years ago), however, it took only 10,000 years for Yellow River to be shaped into a huge unified river.

In the extremely long geological age, topography of the earth took huge changes in the result that innumerable ancient watercourses, delta and swamp lands have been buried in the very depth of stratum or uplifted to the peak, which was described poetically in The Book of Songs. In the Tertiary and Quaternary of early Pleistocene, there were many ancient lake basins in the ancient Talimu landmass of North China, which were the destination of rivers. In the Quaternary period, uplift of the western plateau enlarged the elevation differences between West and East of the mainland, forming the obvious terrain of the three steps of the high, the middle and the lower level.

In West China, the climate has become dry and cold, lakes gradually silted and shrank, and rivers started to erode headward and to be connected.

In the late Early Pleistocene, ancient Yellow River has not yet connected as a whole river, in the upper reaches, which flowed from east to the ancient Ruoergai Lake from the adjoining area of Eling Lake and Zaling Lake, running south from Hequ County into Fenwei lake basin through a series of small lakes in the middle reaches, but not connecting with the ancient lake in North China Plain because of obstruction of mountains. Then each lake basin became the cradle of local river system, some of them gradually extended into the embryonic form of large river, which was known as the fetation period of large river (Hongjie Li etc. , 1992). The 1. 05 million – year Mid Pleistocene was a very important transitional period in the growing history of ancient Yellow River in which the independent ancient lake basin systems gradually developed into an unified river, just when the Beijing ape man has taken activities in Zhoukoudian about 2 to 7 million years ago, the big river was linked from west to east (Wutong Chen and Mingjie Chen, 2001), known as Yellow River' s growth period. (Fig. 1)

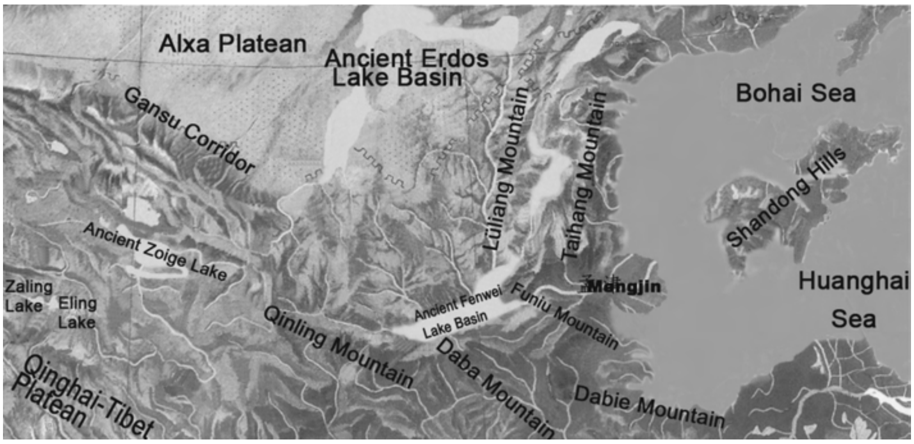


Fig. 1 Lake basins of Yellow River Vally in early and mid Pleistocene as well as modern water system of the River (Drawn according to Yingsheng Dai)

In the late Pleistocene from 100,000 years to 10,000 years ago, the ancient water system took place historical transition in the vally of large river, the ancient rivers continued to erode headward, and finally connected together, forming a large river with huge runoff and boundless vigor and emptying to the sea area on the east of Taihang Mountain. It ran through mountains and lake basins, pouring into the low plain or the vast ocean and flowing out of the mouth of Jinyu Gorge (Shanxi and Henan Gorge), namely the mouth of ancient Yellow River, where it silted up the first alluvial fan in the Mengjin County. However, it was unable to pass through the opposite Shandong Hills but detour from its two sides (Hou Renzhi, 1994) . Therefore, Yellow River has already changed its course between North China Plain and Xu Huai Plain in prehistoric time. Up north to the ancient Haihe River system and down south to the ancient Huaihe River, Yellow River' s waving silted up the great Huanghuaihai Plain, namely the ancient Yellow River delta. In the recent remote sensing picture of the North of China, the entire Huanghuaihai Plain is surrounded by Yanshan Mountain, Taihang Mountain, Funiu Mountain, Dabie Mountain, Taiyi Mountain, Yellow Sea and Bohai Sea, shaping a huge basin where it can be clearly seen the geological relic of Yellow River's waving and sediment (Fig. 2).

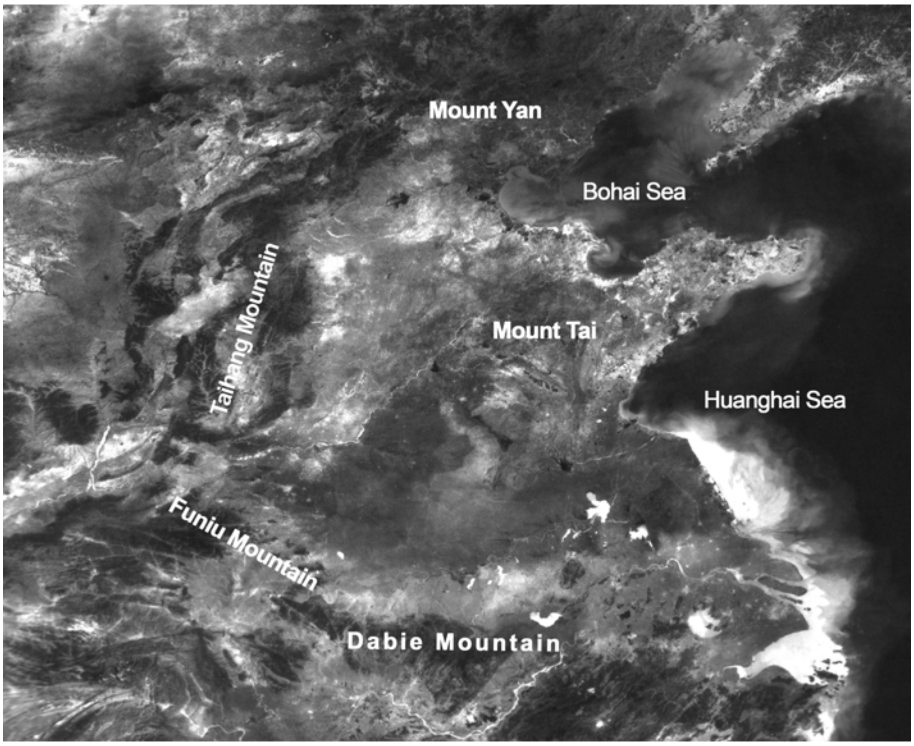


Fig. 2 Geological relic of Yellow River's sediment area in the remote sensing picture of the North of China (Supplied by Lei Wang, Earth View Image Inc.)

During the forming and developing of the Yellow River, it has linked branches and lakes, forming a huge river system and numerous delta alluvial fans, becoming the source of Chinese ancestor's development and providing special favorable conditions for their early time hunting and fishing, picking and even agriculture cultivation as well as suitable geographical environment for the cultural foundation's establishment of Chinese nation, for instance, Tangyu Dynasty Civilization originated from a branch of Yellow River, Fenshui River; Civilization of Xia Dynasty came of the South of Shanxi Province and extended to the vally of Yishui River and Luoshui River; Shang Civilization started from Zhangshui River and Huanshui River as well as Weishui River's Zhou Civilization, etc. The speedy extension of alluvial fan of Yellow River has shaped Central Plains where orient Yi tribe has been connected with other tribes of the South (Yuzhen Yang, 1995). Finally the rise and development of Xia, Shang and Zhou Dynasty established the first prosperous period in the history of Chinese nation.

2 The change of Yellow River course in regard of the geological foundation

Water not only has created geography environment and civilization groundwork for human being's existence and development through erosion and sedimentation, but also brought some grave disasters to humanity because of its violent character.

The ancient Yellow River system got her great growth in the early and middle Holocene of 10,000 ~ 3,000 years B. P., the torrential flood scene in ancient history of China recorded by THE BOOK OF HISTORY: YAO'S STORY should belong to this period. Recently, Mr. Mo Luo wrote an article according to Mr. Jiang Linchang's analysis of the reason why Shun emperor killed Guan but used his son Yu to control flood, and guessed that ancient Yellow River at that time was undergoing profound watercourse changes running to north from Xuhuai watercourse (Luo Mo, 2007). However, the author found that the guess is greatly in concordance with the flood story recorded in many ancient books, the great River watercourse's changes always ended up with flood disasters in Huaishan(present Jiaozhuo city in Henan province) and Xiangling (present Linfen city in Shanxi province). In order to prevent central Plains and North China from grave flood disaster, Guan built water wall which is three Ren high to block flood from former Xuhuai watercourse, however, the natural tendency of Yellow River running to north was irresistible, which crashed Guan's defence completely. Appointed at the time of crisis, Yu gave up his father Guan's strategy, dredging the stagnation, using the natural tendency of water flowing from high place to lower spot. Thus he restricted the overflowing water by introducing flood into dredged river way, marsh land or lake, and finally emptying to Bohai Sea, consequently made the stabilization of Yellow River with thousand - year history.

In the Warring States Period (475 ~ 221B. C.), people started to construct embankment along the lower reaches of yellow River and achieved a suitable scale quickly. Yellow River embankment's appearance reduced the frequency of flood disaster, which was a great progress in the history of our country's river management. However, embankment can also bring harm in that the long - term running water in its dike made Yellow River become an aboveground river and its bed and sandbank unceasingly silted up higher, once washed away, it would become a Gordian knot and finally had to change its watercourse. As a heavy - sediment concentrated river, Yellow River is famous for "be apt to deposition and levee break and shift". During the long - distance history before modern society, natural force was in powerful position which can be seen on Yellow River, her wild nature of torrential flood disasters exercised the will and wisdom of Chinese nation time and time again. Ancestors of Chinese nation rose up against under the underdeveloped social productivity, whose deeds against natural force were above all praise in the eyes of later generations.

During the 4,000 - year history from 2,000 B. C. until now, evolvement of Lower Yellow River mainly located in two zones, of which the first one is located in North China Plain where the watercourse lasted for over 3,000 years from Yu Dynasty to Warring States, Qinhan and Tangsong Dynasties, finally entered to Bohai Sea. The successive one is located in Huanghuai Plain (the present vally area of Yellow River and Huaihe River) where the waterway lasted more than 700 years from Northern Song Dynasty (960 ~ 1127) to 1855 (She changed her way at Tongwaxiang County) (Xu Fuling, 1986). It was counted that the Lower of Yellow River burst 1,590 times during 2,540 years from 602B. C. to 1938, which was known as "twice levee break in three years, once watercourse change in a century." However, as for how many times great watercourse shift happened in the Lower of Yellow River, there were many different answers. Nevertheless, many scholars put forward various opinions according to Yellow River's evolvement situation in different historic period. For instance, Hu Wei pointed in his Research on Yu Gong (Yu Gong, an ancient geography book before Qin Dynasty) that Yellow River experienced five times changes during the period from Yu Dynasty to Ming Dynasty. In the late Qing Dynasty, Liu E drew the six times changes of Yellow River in Diagram Research on Yellow River Changes of Past Dynasties. In Collections of Deng Zihui published after the establishment of new China, it pointed out that along the Lower of Yellow River there were 1500 times flooding and levee break, 26 times important waterway change including 9 times vital watercourse change. And in Landform of the lower Yellow River published by Science Press in 1990 it also pointed that there were 7 times great change of lower Yellow River in all.

Why did Yellow River change so often in its history? What made the difference of watercourse's service life? This study takes the point that river is one short - lived geological phenomenon from the angle of geology, thus it is clearer to survey the whole process of river's life and easier to reach the essence from the foundational geological characteristic to research the watercourse's evolution rule. Therefore, this article wants to analyze the basic reason of Yellow River's migration according (Xu Fuling, 1996) to the book, written by Fuling Xu, On the Security of Yellow River, which recorded the course switch of five times (Fig. 3).

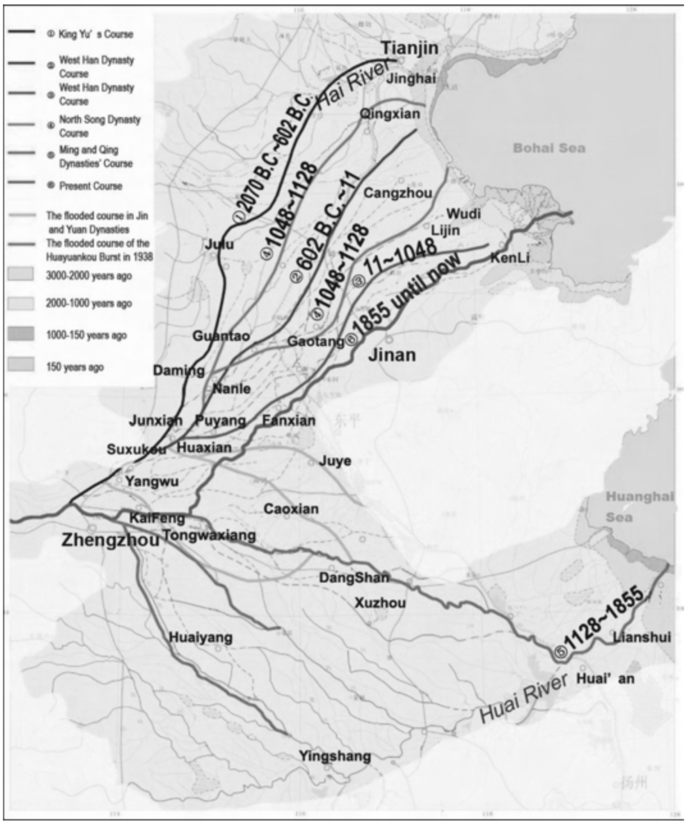


Fig. 3 The main watercourses of Yellow River to the sea in the past dynasties (protracted by Yang Yuzhen and Liu Peng)

According to the correlated experts' analysis of the endogenic geological function on Yellow River course changing, the positional arrangement of large watercourse's migration by and large rolls from north to south since the beginning of recorded history (Dai Yingsheng, 1996). As Fig. 3 shown, ① the earliest route was the waterway excavated by Da Yu in 2070 B. C., which flowed through Raoyang rift valley, emptying to the sea after crossing the north of Hebei Plain to Tianjin. This waterway sustained for more than 1,000 years fully utilizing its advantages of numerous lake basin along the way and the consuming capacity of silt. ② In the fifth year of Zhou Ding's reign (602B. C.), the waterway of Yellow River seized its new course at Suxukou entering the course of Luochuan River, through rift valley of Huanghua to Changzhou, and finally into the sea, which was the first time great watercourse change since the beginning of recorded history, shorter in its length than the latter – day watercourse of Da Yu, unchanging for over 600 years without big project governing. ③ At the junction of Western Han and Eastern Han Dynasty (11A. D.), the main waterway of Yellow River separated from the rift valley of Huanghua at Wei County, crossing through the middle of fault – uplift zone of Haihe into the rift valley of Jiyang, achieving her second time great change, namely the ancient Lijin watercourse which had similar advantages of the two former ones. The rift valley zone is characterized by great range of earth crust subsidence and multitudinous large – scale rift valley lake in its boundary, suitable for big river running water. In Han Dynasty (206B. C. – 220A. D.), Wang Jing took the advantage of lowland in the rift valley zone and the great water – containing capacity of neighboring marshland to regulate Yellow River, whose measures were to set up some water gates to warp the silty water into the lowland along both banks and let the silt – precipitated water back in order to flush the river course, the nature – abiding method had obtained twice effect with half effort. ④In 1048, Yellow River burst in Shanghu running to north, passed through Guangtao and Qing County and finally emptied to the sea from the south of Tianjin city, achieving the third great change, which was recorded as "Northward Current" in Song Dynasty. In the fifth year of Jiayou's reign, Yellow River's watercourse was divided a new branch in the east of Wei County, which passed Gaotang and Leling, emptying to the sea in Wudi County, known as "Eastward Current". Firstly, Yellow River ran water through the two branches, but later it flowed back to the "Northward Current", this period Yellow River was at chaos with many flood disasters. Actually, the two watercourses were still in the rift valley of Haihuang in terms of their geological condition, however, they brought grave disasters to people of Song Dynasty in that governors utilized Yellow River to defense southward attacks from the kingdoms of Liao and Jin in the second year of Jianyan's reign, which ended up with the misfortune of Yellow River's southward removal. ⑤In 1128 the forth time great watercourse change occurred, Yellow River flowed into the waterway of Xuhuai formed by man – made crevasse, which is unfavorable for large river running water in terms of its geological function of endogenic force, because the fault of Huanghuaihai is primarily characterized by vertical movement, and on its north, the fault – uplift zone of Tongxu stretched in an unbroken chain, forming a structure barrier, which became the headstream of north – side rivers. Originally, there were always flood disasters in the vally of Huaihe River; aggravatingly, Yellow River's coming surpassed the capacity of Huaihe River, therefore, the difficulty of controlling increases. For this contemporary geologist Dai Yingsheng gives the explanation that "the subsiding plain rift valley river, once it breaks away from rift valley to uplift zone, can not be kept in long – term peace and security even though people take sparely no effort(Dai Yingsheng 1996)." Although there were some great flood controll masters such as Pan Jixun, Jin Fu and Chen Huang, etc. , they were like running downward in an upward moving elevator in that underlying surface's uplift by siltation counteracted human being's effort of river controlling. Therefore, the 700 – year history of Xuhuai waterway became the most frequent happening period of crevasse disaster in the Yellow River's history. ⑥In 1855, the levee broke at Tongwaxiang which has made Yellow River flow into the north of rift valley of Huanghua and out from east, through the uplift northwest side of Mountain Tai entering the rift valley zone of Jiyang, then crossing Lijin and finally emptying to the Bohai sea from the rift valley trough of Dongying. The present Lijin waterway, the result of the fifth time great watercourse change, is also the last rift valley river as the most southern line in North China subsidence zone, which reaches the same place by different route comparing with Lijin waterway in Eastern Dynasty. However, river's stabilization doesn't only lie in the favorable topography condition. For instance, during the period from the last years of Qing Dynasty to the Republic of China, the flood disasters frequently haunted Lijin watercourse since the political corruption and declining river affair. Until the establishment of the People's Republic of China in 1949, Yellow River entered the historical period containing all kinds of advantages of the nature and human being. Lijin watercourse has become the natural end – result in the process of historic evolvement in terms of Yellow River's long – term stabilization which has great tie with Chinese nation's revival(Li Diankui,2007).

3 Historical changes of Yellow River concerns the rise and fall of Chinese Nation

Is there direct relation between the stabilization of Yellow River and the prosperity of Chinese nation? This article points out that Yellow River doesn't have the will or intention of bringing fortune or misfortune to human being in advance although it objectively plays an important role of life source and power in human being's progress and civilization, the key is human being's idea and wisdom in terms of the control of Yellow River bringing the final result either fortune or misfortune. In the history of China, the political groups with good administration were always able to select the worthy and employ the able, realizing the long – term stabilization of Yellow River with the supports of the public and utilization of the leaders' wisdom and ability. For instance, the watercourse made by Da Yu was in peace for thousand years, which established Chinese Nation's rise and development groundwork; in Han Dynasty (206B. C. – 220A. D.), Wang Jing who kept Yellow River's watercourse entering the sea in the region of Lijin for about thousands years long, which went through the multicultural surfy times of Wei Jin Dynasty as well as Northern and Southern Dynasty (220A. D. – 420A. D.) and the epic cultural times of Sui and Tang Dynasties (581A. D. – 907A. D.), made the longest stabilization of Yellow river after Yu, the king successfully controlled the River. In this prosperous state, everywhere was hustling with effective strength (Feng Tianyu etc., 1990). The cultural spirit shining with vigorous and creative light was like Yellow River pouring into newborn vigor for China and reached the development peak in Chinese nation's feudalism period. However, in the great turbulent society, lose control of Yellow River brought serious disasters to Chinese, so long as where there are turbulence, political corruption or emaciation of nation strength, there will be frequent disasters with Yellow River, moreover, some political powers who bullied Yellow River to take attack, caused extreme tragedy to the public in the history. After the liberation of China, owing to the effect coming from both the superior system of socialism and the great achievement of people's empowerment, the stabilization of Yellow River supplied the indispensable water source and environment support for the high – speed economy development in new China, especially after the reform and opening in China. The continuous control of Yellow River, Yangtze River and other national river systems changes the old situation of frequent flood occurrence to a great extent, especially uprooting the disasters brought by watercourse changing of Yellow River which has the same long history with China, made a great improvement of socialism construction's environment condition.

Large – scale projects of water conservancy and overconsumption of water resource reduced the probability of flood in the Lower Yellow River and even brought the predicament of breaking. Dam system built in the vally of Yellow River stands lofty and firm, which sometimes can contain the total water of Yellow River. Under this circumstances, the exploitation and utilization ratio of Yellow River water resource rose from 21.4% of 1950s to 84.2% in the beginning of this century, which is head and shoulders above the international alarm line of 40%. Besides exhaustation of the water resource, Yellow River is still facing the threat of aggravating pollution. It was estimated that the total waste water discharge of the whole vally area was 2.17 billion tons a year in 1980s, but it has reached 4.15 billion tons a year in 2003, increased by 90% (Li Guoying, 2005). Human being's pursuit of economic indice has hit the base line of Yellow River's ecological balance time and time again, which gradually brought the position switch between natural force and social productivity: On the one hand, Gross Domestic Product, as the important indicator of social productivity, grew swiftly since the establishment of the country, especially after the reform and opening – up. In 2004, its GDP had reached 1,365.15 billion Yuan, ranking the 5th in the world. In conformance with the comprehensive national strength, Chinese people's control capacity of natural force increased tremendously. On the other hand, the load of natural force is ceaselessly aggravated because China is in the period of economic transition characterized by exagerated consumption of energy, water and raw materials as well as pollution discharge, etc. As for the consumption of water resource, China is one of the water scarcity countries, the per capita water resource in China is only 25% of the world average, and in 2004 the water consumption per 10,000 yuan GDP was 399 m^3, which four times of the world average, 8 times of the developed countries. Yellow River, locating in the relative water scarcity area of North, plays an important role in the construction of national economy at the cost of providing the water that is two times of the world alarm water consumption number, gradually degenerated from a grand untamed mighty torrent to a tamed trickle in dry seasons (Fig. 4). The change actually reveals the sharp declination of natural ecological environment's sustainable support ability for the society's economic development. If putting the line of the tendency of the runoff of Lijin watercourse (a part of Lower Yellow River) symbolizing the natural force and the the line of GDP which symbolizes the social productivity together, we can find a surprising "scissor difference", reflecting the position switch between natural force and social productivity (Fig. 5).

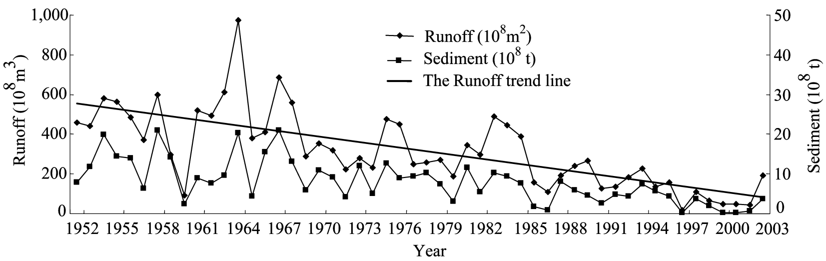


Fig. 4 The change and tendency of Yellow River's capacity of water – running and silt discharge in the past years

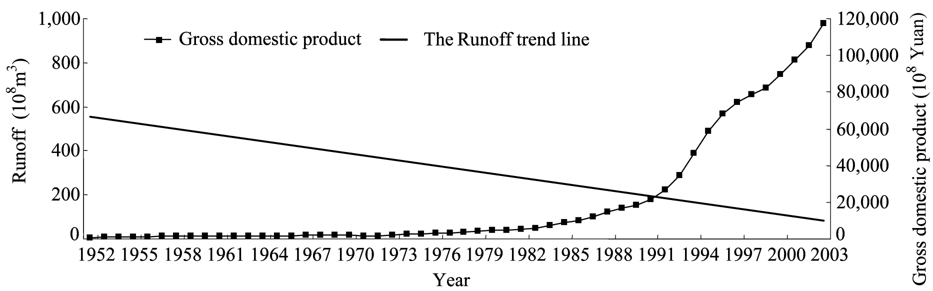


Fig. 5 The sketch map about the position switch between natural forces and social productivity

The influence brought by the reduction of water in the lower reach has attracted great attention and consideration of the all walks of the socity and relevant organizations. From 1991 to 2000, the average runoff in Lijin section is 12 billion m^3, which has decreased by 36 billion m^3 comparing with the 1950s, and this has come up with the zero runoff or water reduction in the lower reaches of Yellow River, the shrinkage of beach area and the delta swamp of Yellow River, and the damage of offshore biodiversity. In fact the present Yellow River has lost foretime power of overflowing and natural waving because of human being's plundering consumption of Yellow River's water source and huge water conservancy projects' influence. However, people's worry about the Yellow River's prospect will be no longer the natural waving occurrence but the crisis of its life and ecological environment. For that, in January of 1998, 163 academicians of CAS (Chinese Academy of Sciences) and CAE (Chinese Academy of Engineering) seriously signed their names on the an appeal of "taking actions to save the River" against the double crisis of water zero – runoff and serious pollution. The essence of the widespread attention is not merely a problem of break and pollution, but the crisis of a big ecological environment related to the entire life of Yellow River. In the new situation, under the guidance of scientific development outlook, the relevant department of Yellow River Management promptly adjusted the traditional thoughts of Yellow River control, arising the idea of maintaining the stable life of Yellow River in order to ensure the River's sustainable support for the human's survival and development and finally realize the harmonious coexistence between human and the River. The right approach to protect the Yellow River is to protect the River's sources and the wetland ecosystem along its watercourse. Besides the implementation of energy and water saving strategy as well as reducing consumption and waste discharge in the social production field, it is also necessary to make various plans and measures of water – increasing in Yellow River in order to meet its ecological water demand and bed – building discharge. Therefore, when the ecological regions of the upper and middle reaches such as the Three Rivers' Source and waterhead of vally basin are kept in good protection, it is also very important to steadfastly set up the faith of long – term stabilization of Yellow River's ocean – entering waterway. On the entire Yellow

River's lower reaches and its ocean outfall area, once the watercourse chooses a new position to empty into the sea, there will be massive water of life wasted and lost, which equals to bring one misfortune after another to the frail life of Yellow River, and there will be nothing left for the wetland ecosystem in the former lower reaches and ocean outfall area. Therefore, keeping the long – term stabilization of the estuary course via all kinds of project measures is vital to the maintenance of the entire Yellow River's healthy life. And only to ensure the balanced development between social productivity and natural sustaining capacity including the life of Yellow River, can the great revival of the Chinese nation with a harmonious relationship between human being and the nature be realized in the new historical period.

References

Li, D iankui Yang Yuzhen, Cheng Yijie, et al. 2007. Technology Research on the Construction of Yellow River Mouth Double Guide Jetty with Sediment Transport by Skillful Use of Marine Dynamics[M]. Zhengzhou: Yellow River Water Resources Press, 47 – 90.

Xu Fuling. 1986. Summerization on The Historic Vicissitude of Yellow River's Lower Reaches[C]. The newsroom of People's Yellow River. Yellow River's Research and Practice. Beijing: Water Conservancy and Electric Power Press, 44 – 48.

Xu Fuling. 1996. Five Times' Route – changing of Yellow River's Lower Reaches[C]. Yisan Hu, Flood Control of Yellow River. Zhengzhou: Yellow River Water Resources Press, 58 – 72.

Li Guoying, 2005. Maintain the Stable Life of Yellow River[M]. Zhengzhou: Yellow River Water Resources Press. 70 – 86.

Li Hongjie, Ren Decun, Hou Quanliang et al. 1992. Yellow River[M]. Beijing, Science Popularization Press, 54 – 73.

Mo Luo. 2007. The Guess of Gun and Yu's Success or Failure Reason of Flood Control[J]. Study. 338(5): 159.

Hou Renzhi. 1994. Yellow River Culture[M]. Beijing: Chinese Art Press, 21 – 40.

Shi Shi, 1999. Five Thousands Years or Ten Thousands Years[J]. New China's Tabloid. 249 (9): 68 – 71.

Feng Tianyu, He Xiaoming, Zhou Jiming, 1990. The History of Chinese Civilization[M]. Shanghai: Shanghai People Press, 559 – 633.

Chen Wutong, Chen Mingjie. 2001. Yellow River Commentary[M]. Baoding: Hebei University Press, 1 – 98.

Dai Yingsheng. 1986. The Brief History of Yellow River's Growth[C]. The Newsroom of People's Yellow River. Yellow River's Research and Practice. Beijing: Water Conservancy and Electric Power Press, 17 – 26.

Dai Yingsheng. 1996. The Geological Characteristics and Ancient Geography Environment of Yellow River's Lower Reaches[C]. Hu Yisan, Flood Control of Yellow River. Zhenzhou: Yellow River Water Resources Press, 32 – 57.

Yang Yuzhen. 1995. The Research on Strategy of Developing Yellow River Delta[M]. Beijing: Ocean Press, 14 – 23.

Groundwater Information for Integrated Water Resources Management

Zhou Yangxiao

UNESCO – IHE Institute for Water Education
Westvest 7, P. O. Box 3015, 2601 DA Delft, The Netherlands

Abstract: Because of its wide availability, good quality and cost – effective for the development, groundwater has been an important source of water supply in the world. Groundwater accounts for more than half of the total water supply and provides important source of irrigation water during dry period in North China. Aquifer storage and enhanced recharge will become an effective method in coping with water scarcity and climate variability. Although it is widely accepted that integrated water resources management should integrate surface water and groundwater as a single resource in the planning and development, it is not commonly applied in practice. One of technical reasons is the lack of reliable groundwater information for decision making by water managers. This paper describes the requirements of groundwater information for integrated water resources management and methods to collect this information by a regional groundwater monitoring network. The Urumqi River Basin case study is presented as an example.

Key words: groundwater, information requirements, monitoring, Urumqi River Basin

1 Introduction

Groundwater is an important component of the hydrological cycle. It is a crucial source of water for nature and for water supply. Groundwater has historically provided a locally available low – cost source of water for public supply and domestic use. As groundwater is generally of good quality and requires less treatment, groundwater is increasingly being exploited in preference to surface water for drinking water supply. In Austria, Denmark, Portugal, Iceland and Switzerland over 75% of the water for public water supply is abstracted from groundwater. Groundwater accounts for 50% to 75% of drinking water supply in Belgium, Finland, France, Germany, Ireland, Luxembourg and the Netherlands (EEA, 1999). Groundwater is also an important source for water supply in China. Around two – thirds of cities depend on groundwater for urban water supply and groundwater for irrigation amounts to 80% of total groundwater abstraction in China (China's Agenda 21, 1994). Especially in North China, groundwater accounts for more than half of the total water supply and 70% of urban water supply in North China Plain (Han, 1998). In semi – arid Northwest China characterized with water scarcity, aquifers play an important role in meeting water demand, not only because of its superior quality and large quantity but also because of its availability in any location and at any time. Groundwater in aquifers provides an efficient natural solution to water scarcity. In northwest inland basins, aquifers cover extensive areas and contain large groundwater reserves. Tube wells provide effective water supplies to urban and rural water consumption and irrigation water use. Large scale groundwater development started in 1960's in North China has stimulated rapid socio – economic development in grain production, farming employment, rural poverty alleviation, industrialisation and urbanisation.

However, water shortage has become a bottleneck for further social and economical development in North China. Although more than 44% of the population and 58% of the cultivated land are in North China, North China has only 15% of the total water resources (surface runoff and groundwater) of the country. Climate change observed in recent decades has adverse impacts on the availability of water resources in North China. Observations during the past 40 years have shown that the runoff of the major rivers in China has decreased. There has been a continuous drought in the

North China Plain since the 1980s and has worsened since 1999. The assessments on the impacts of climate change (China National Communication on Climate Change, 2004) predicted a future hot and drier climate and a further decrease of runoff in North China. Climate change will most likely intensify water shortage in North China. Aquifer storage and enhanced recharge will become an effective method in coping with water scarcity and climate variability.

To sustain intensive groundwater development in North China constitutes one of the world's greatest water resources management challenges. Over – exploitation of groundwater resources has occurred with a rate of decline of shallow water tables at 1m per year and deep groundwater levels up to 5m per year (Foster, et. al., 2004). This has caused aquifer depletion, land subsidence and salt water intrusion problems. Although it is widely accepted that integrated water resources management should integrate surface water and groundwater as a single resource in planning and development, it is not commonly applied in practice. Natural river flow has almost completely ceased because of diversions to urban, industrial and agricultural uses. Over – utilisation of river flows in inland basins of Northwest China has substantially reduced natural recharge to groundwater, which results in lowering groundwater levels and affecting fragile ecosystems in downstream basins. These problems may be caused by a combination of multiple reasons: legal system, institutional arrangement, investment mechanism and sectoral approach. One of technical reasons is the lack of reliable groundwater information for decision making by water managers.

A Sino – Dutch cooperation project on capacity building of a China Groundwater Information Centre aims at improving the situation. The objectives of the project are:

- To establish and strengthen the capacity of the China Groundwater Information Centre;
- To increase the efficiency and effectiveness of groundwater monitoring, data processing and analysis, and information dissemination;
- To train a large number of specialists for groundwater information management;
- To raise awareness of public and decision – makers for groundwater resources protection;
- To optimise groundwater monitoring networks with automatic recorders;
- To develop a GIS – based China Groundwater Information System;
- To develop regional groundwater models for supporting decision – making in groundwater resources management;
- To implement 3 pilot studies: Urumqi River Basin, Beijing Plain, and Jinan Karstic Spring Catchment.

Since 2003, the China Groundwater Information Centre has coordinated national groundwater monitoring, developed GIS – based regional groundwater information systems and set – up regional groundwater models. Three pilot areas were selected for the implementation: Beijing Plain, Jinan Karstic Spring Catchment and Urumqi River Basin. For each pilot area, groundwater monitoring networks were optimised, observation wells were cleaned and protected, automatic groundwater level recorders were installed, GIS – based regional groundwater information systems were established and regional groundwater models are under construction. The spatial and temporal variations of groundwater quantity and quality are presented in easily – understandable maps to be disseminated to publics, water users and decision – makers for better management and protection of groundwater resources. This paper presents the methodology of groundwater monitoring and demonstrated with the case study of the Urumqi River Basin.

2 Groundwater information requirements for integrated water resources management

Integrated water resources management should unit all components (rainfall, surface water, soil water and groundwater) and all aspects (quantity and quality) of the hydrological cycle at river basin scale and consider interactions and impacts among human system, water system and environmental system. Availability of reliable and homogeneous data on all water components is essential for water managers to make the informed decision.

Decision makers require information about the status of groundwater quantity and quality, pressures and impacts on groundwater status and consequences of the implementation of river basin water resources management plan on groundwater (Fig. 1). The natural characteristics of a river basin determine the groundwater system and its intrinsic vulnerability to pressures. Under natural conditions, the baseline status of groundwater quantity and quality depends on the groundwater system structure (defined by geomorphology and hydrogeology) and natural stresses (climate, hydrology and ecosystems). Nowadays, pressures from anthropogenic interferences have had profound effects on groundwater system: such as aquifer depletion caused by groundwater over – exploitation and/or reduction of groundwater recharge; groundwater pollution from agricultural sources and/or (solid and liquid) waste disposals. These negative effects in turn have large impacts on socio – economical development and environment. The well – known examples are degradation of groundwater – fed wetlands and torrential ecosystems and increase of costs of groundwater development. Many of the human pressures on groundwater are on a river basin scale, and thus these problems concerning groundwater quality and quantity can only be solved at the river basin level.

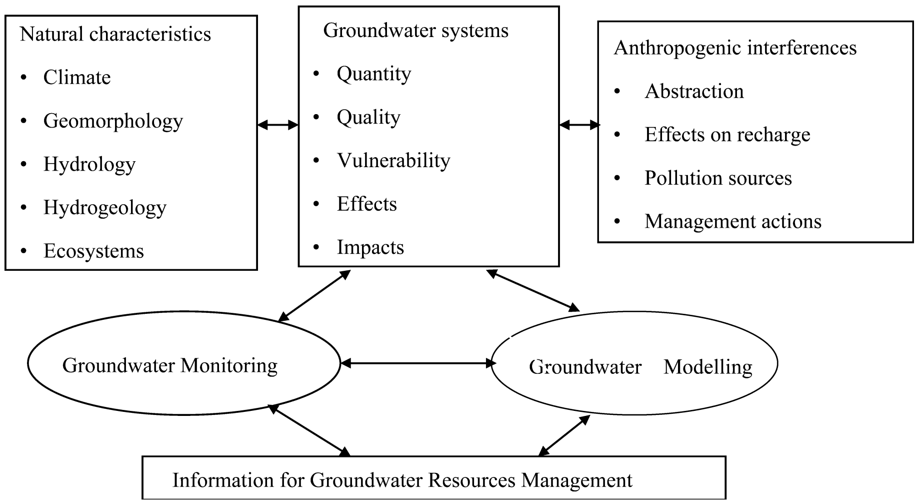


Fig. 1 Information on groundwater status, pressures and impacts

In China, groundwater and surface water historically belonged to the jurisdictions of different ministries. In recent years, the Ministry of Water Resources (MWR) is assigned the responsibility of the integrated water resources management for the whole country. However, the MWR faces great challenges concerning the groundwater information:

- lack of base – line data, statistics, quantitative information to assess groundwater status and trends;
- lack of quantitative data on human interventions and influences on the groundwater systems;
- available information is often not processed or presented in a suitable form for potential water users, water managers, and general public.

Groundwater monitoring is the only direct method to assess the status of groundwater quality and quantity. Information from a monitoring network is essential for detecting the impacts of climate changes and human activities on groundwater quantity and quality. A network can also be used for monitoring the consequences of water resources management actions on the groundwater system and environment. Effective and efficient acquisition of groundwater quantity and quality data for various purposes can be achieved by an optimally designed monitoring network.

Groundwater modelling provides an alternative method to assess groundwater quantity and quality status. Furthermore, groundwater models are often used to predict impacts of pressures on the groundwater system and to evaluate management scenarios. Groundwater models play an important role in the development and management of groundwater resources. Groundwater models are used as:

- supporting tools for planning field investigation;
- predictive tools for predicting future conditions or impacts of human activities;
- screening tools for evaluating the groundwater restoration alternatives;
- interpretative tools for studying groundwater system dynamics and understanding the physical, chemical and biological processes;
- management tools for identifying optimal strategies for groundwater resources development and protection.

The combined use of a groundwater monitoring network and a groundwater model is the best effective way to provide adequate information for integrated water resources management. Measurements from the monitoring network are necessary to calibrate and validate a groundwater model, and thus reduce the uncertainty in model predictions. Simulation results from a groundwater model can be used to determine the best locations to install groundwater monitoring wells for various monitoring objectives.

3 Regional groundwater monitoring

3.1 Classification and objectives of groundwater level monitoring

A clear specification of monitoring objectives and required information is crucial for the design of a monitoring network. The experiences have showed that the cost of monitoring can be significantly reduced if the objectives are well defined and the network is tuned to the specific objectives. Objectives of groundwater level monitoring may be defined as the following:

- Characterization of groundwater systems

— Identification of aquifer parameters
— Assessment of groundwater resources
— Determination of spatial pattern and temporal trends
— Quantification of relations with surface water
— Determination of infiltration and seepage areas

- Development of groundwater resources

— Optimization of groundwater abstraction
— Determination of the cone of depression
— Quantification of effects of groundwater development

- Integrated water resources management

— Optimum control of groundwater levels
— Protection of nature reserves
— Restoration of wetlands
— Quantification of effects of water management measures
— Quantification of transboundary flow

Two main types of groundwater level monitoring networks can be distinguished: strategic (primary or background) monitoring networks and operational (secondary or specific) monitoring networks.

Strategic monitoring networks are large scale regional or national monitoring networks designed for groundwater resources assessment and management. Their characteristics are:

- Covering independent groundwater basins or a complete country;
- Monitoring regional groundwater regime and overall impacts;
- Observation wells are installed in major aquifers at relatively large distances;
- Observations are taken with low frequency for long – term.

Operational monitoring networks are local scale monitoring networks designed for monitoring of operations of groundwater systems for water supply or other specific purposes. Their characteristics are:

- Focusing on local problems, for example, monitoring water table decline around pumping well fields, monitoring effects of irrigation schemes, monitoring the groundwater levels in nature conservation areas;

- Network density is sufficiently high to quantify effects;
- Observation frequency is sufficiently high to identify short term trends.

Strategic and operational monitoring networks are usually combined to form an integrated monitoring network. In this integrated monitoring network, strategic monitoring wells provide reference conditions to assess local impacts observed by operational monitoring network. Regional low density strategic wells serve the overall objectives while superimposed local high density wells focus on specific objectives. The classification of strategic and operational networks may also be used to divide the responsibility for monitoring between governmental organizations responsible for overall water management, and organizations with operation of specific water systems.

3.2 Methods for designing regional groundwater level monitoring networks

A regional groundwater monitoring network can be designed with the following procedures:

- Characterizing the monitoring area
- Defining objectives of groundwater monitoring
- Conceptualizing hydrogeological systems
- Assessing the existing monitoring network
- Designing an optimal groundwater monitoring network

The geographical scope of the monitoring area should include a complete groundwater basin bounded by physical hydrogeological boundaries. Data on climate and hydrology, topography, land use, social - economical activities and water resources development are collected and analyzed to characterize the monitoring area. Objectives of monitoring regional groundwater levels are aimed at reliable assessment of quantitative status of the groundwater system and impacts on base flow and terrestrial ecosystems (EU, 2003). A conceptual model of hydrogeological systems should be established to understand how the groundwater system is believed to behave. It serves the basis for the groundwater regime zone mapping, to design the monitoring network and to interpret the monitoring results to assess the quantitative status of the groundwater system. In most cases, groundwater levels are being observed using observation wells or production wells. It is a necessary step to assess the existing monitoring network including the inventory of well conditions, assessment of the spatial distribution of the wells and observation frequency, and inspection of data management and information dissemination. Whenever it is possible, existing observation wells should be incorporated into the regional monitoring network.

Quantitative design of groundwater level monitoring networks is usually based on geostatistical methods, and requires the estimation of the spatial and temporal correlation structure using the actual measurements (Zhou, 1994, 1996). When available measurements are not sufficient to use geostatistical methods, hydrogeological approach is necessary. Groundwater regime zone mapping provides a useful method to set - up a regional groundwater monitoring network (Zhou, 2006).

3.3 Design of a groundwater level monitoring network for the Urumqi River Basin

3.3.1 Characteristics of the Urumqi River Basin

The Urumqi River Basin, located in the Xinjiang Uigur Autonomous Region in Northwest China, is a typical arid inland river basin. It covers an area of 11,440 km^2. The Urumqi River itself originates from the snow peaks of the Tianshan Mountains in the south, passes through the intermountain Chaiwopu Basin, and finally enters the desert of the Jugger Basin in the north. Urumqi City, the capital of the Xinjiang, lies in the Urumqi Valley (Fig. 2).

The catchment area of the Urumqi River can be divided into 5 distinct topographic zones: the Tianshan Mountains (South, East and West), the Chaiwopu Basin, the Urumqi Valley, the River Plain and the Gurbantonggute Desert. The Tianshan Mountains are mainly composed of sedimentary rocks with elevation changes from 1,700 m to 4,483 m above mean sea level. Permanent snow and glaciers present over 3,500 m. The Chaiwopu Basin is an intermountain basin inside the Tianshan Mountains with an elevation between 1,075 m and 1,700 m above mean sea level. The basin consists of gravel and sand with a thickness of several hundred meters. Most parts of this basin are also referred to as 'Gobi'. The Urumqi Valley is a narrow intermountain pass between the East and West Tianshan Mountains. The width of the Valley is in between 2 to 5 km. The Valley consists of alluvial deposits. The River Plain, with an elevation between 416 m and 750 m, consists of several alluvial fans and plains of the Urumqi River and other small streams. The Urumqi River Plain is connected with the Sangong River Plain in the east and the Toutun River Plain in the west. Finally, the Gurbantonggute Desert with elevations below 400 m mainly consists of sand dunes, which stretch out towards the centre of the Jugger Basin.

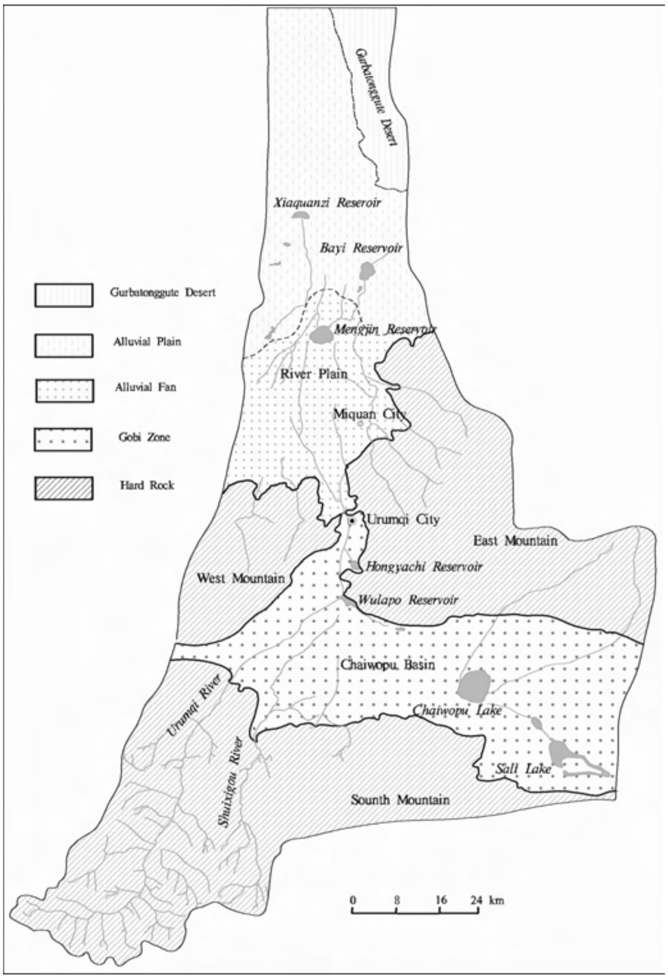


Fig. 2 Sketch map of the Urumqi River Basin in Northwest China

3.3.2 Groundwater regime zone map

The hydrogeological zones map was created using the geomorphologic map, geological map and hydrogeological map of scale 1∶250,000. A total of 14 distinct geomorphologic units were identified in the geomorphologic map; 23 hydrogeological units were defined according to aquifer media and hydraulic conductivity. The superposition of the 14 geomorphologic units and 23 hydrogological units results in 47 distinct hydrogeological zones: 18 in the Chaiwopu Basin, 8 in the Valley and 21 in the Plain.

The unsaturated zones map was created by superposition of the unsaturated zone media (10 distinct units) and depth to water table (7 depth classes).

Groundwater recharge zones map was made according to the sources of groundwater recharge: river linkage, irrigation return flow, precipitation infiltration and lateral inflow. In total 12 distinct recharge zones were identified.

The influencing zones map included lakes, reservoirs, well fields, groundwater irrigation zones, Spring discharge zones, and evapotranspiration zones.

The superposition of the above 4 thematic maps resulted in the groundwater regime zone map (Fig. 3). There are in total 178 regime zones: 62 in the Chaiwopu Basin, 44 in the Valley and 72 in the River Plain. Each regime zone is a distinct combination of hydrogeological zone, unsaturated zone, recharge zone and influencing zone and expected to exhibit different behaviour of groundwater level variation.

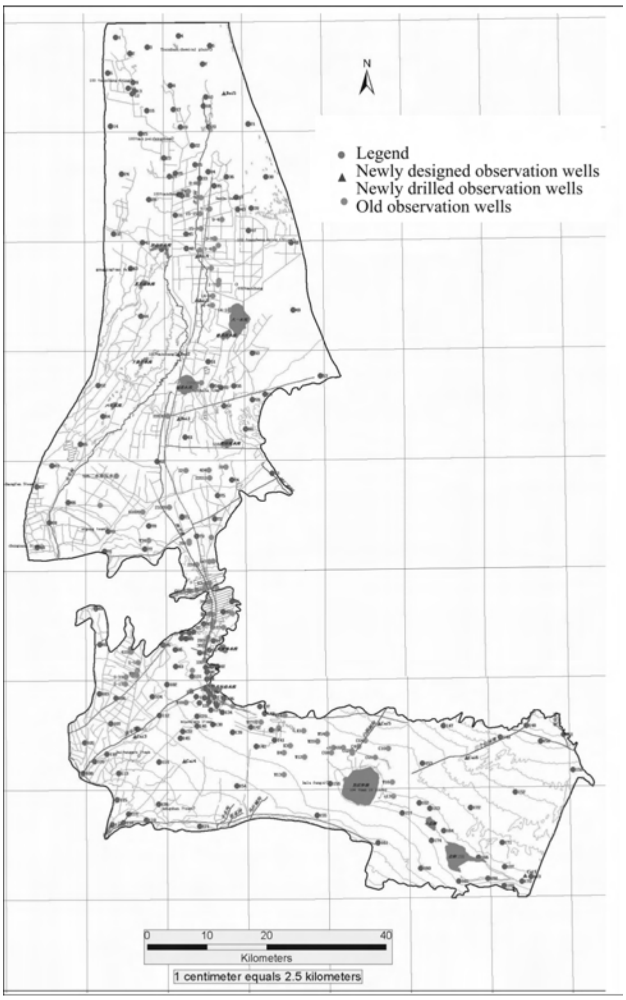


Fig. 3 Layout of the regional groundwater level monitoring network in the Urumqi River Basin

3.3.3 Design of a regional groundwater level monitoring network

Based on the principle of one observation well per groundwater regime zone, a total 178 observation wells is necessary to monitor regional groundwater regime in the Urumqi River Basin. The existing monitoring wells can cover 73 regime zones, 105 new observation wells are required: 48 in the Chaiwopu Basin, 4 in the Valley and 53 in the River plain. The actual locations of the observation wells were placed by taking the aforementioned considerations (Fig. 3). The newly designed observation wells will help to monitoring:

- Interaction between rivers and groundwater;
- Interactions between lakes and reservoirs and groundwater;
- Spring discharges;
- Evapotranspiration in the shallow groundwater areas;
- Groundwater irrigation zones;
- Groundwater depletion in the downstream areas.

3.3.4 Implementation

In 2005 eleven new observation wells were drilled in the recharge areas of the Chaiwopu Basin and the irrigation areas of the River Plain to monitor groundwater recharge from river leakage and effects of irrigation on groundwater. All existing observation wells were cleaned and protected with a special well cover. Thirty one automatic groundwater recorders (called Divers) were installed. The Divers were programmed with hourly measuring frequency and each reading includes time, temperature and water pressure. Once a month, measurements stored in Divers were transferred to a laptop computer and water pressures were converted into groundwater levels. Afterwards, measured time series were uploaded into a GIS – based regional groundwater information system. Fig. 4 shows the comparison of Divers records with the hand measurements. It is clear that automatic groundwater recorders review small scale variations in groundwater levels.

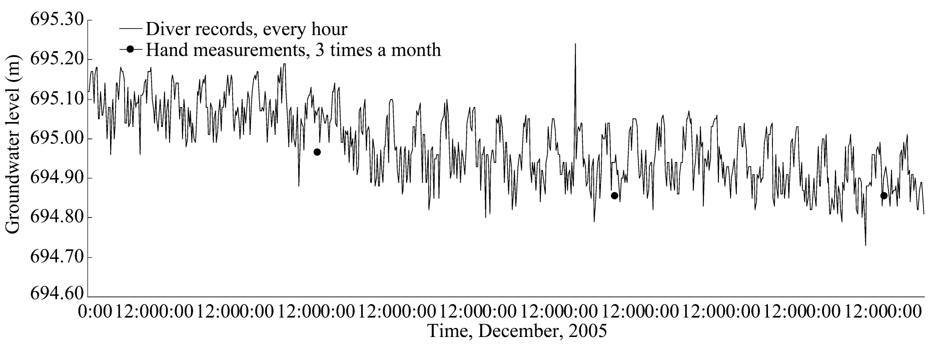


Fig. 4 Measured groundwater levels in an observation well in the Urumqi River Basin

4 Conclusions

Regional groundwater monitoring provides important information on groundwater quantity and quality status. Adequate information can be obtained from an optimally designed monitoring network. Groundwater level monitoring in China is still problem – oriented monitoring concentrated mainly on well fields and urban areas. It is time to upgrade the networks to regional groundwater level monitoring network with the objective to provide information for the integrated water resources management. Groundwater regime zone mapping can identify distinct areas where groundwater level may have unique spatiotemporal characteristics. Therefore, groundwater regime zones can be used to locate groundwater level observation wells. Automatic groundwater recorders provide accurate and reliable monitoring of groundwater levels with high frequency. They are particularly useful in remote areas where measuring groundwater level by observers is too costly and difficult to maintain.

Acknowledgements

The project is co – financed by the Chinese and Dutch government and is implemented in cooperation with the Netherlands Institute of Applied Geosciences, Van Essen Instruments and China Institute of Geo – environmental Monitoring. The maps of the Urumqi River Basin were prepared by the Xinjiang Geo – environmental Monitoring Station.

References

China's Agenda 21, white paper on China's population, environment, and development in the 21st century, Beijing, 1994, China Environmental Science Press.

European Environment Agency, 1999, Environmental assessment report No 1: Sustainable water use in Europe, Part 1: Sectoral use of water, Prepared by: W. Krinner, C. Lallana and T. Estrela, S. Nixon, T. Zabel, L. Laffon, G. Rees and G. Cole.

European Union Water Framework Directive, Working Group 2.7 (2003) Guidance on monitoring for the Water Framework Directive. http://forum.europa.eu.int/Public/irc/env/wfd/library.

Foster S. S. D., H. Garduno, R. Evans, D. Olson, Y. Tian, W. Zhang, Z. Han, 2004, Quaternary aquifer of the North China Plain – assessing and achieving groundwater resources sustainability, Hydrogeology Journal, 12(1): 81 – 93.

Han Z., 1998, Groundwater for urban water supplies in northern China – An overview, Hydrogeology Journal, 6(3): 416 – 420.

The People's Republic of China, Initial National Communication on Climate Change, Executive Summary, 2004, http://www.ipcc.cma.gov.cn/

Zhou Y., 1994, Objectives, criteria and methodologies for the design of primary groundwater monitoring networks, Proceedings of the Helsinki conference, Future Groundwater Resources at Risk, IAHS publication no. 222.

Zhou Y., 1996, Sampling frequency for monitoring the actual state of groundwater systems, Journal of Hydrology 180: 301 – 318.

Zhou Y., 2006, Groundwater regime zoning as a tool to design regional groundwater level monitoring networks, Proceedings of the 34th conference of International Association of Hydrogeologists, Beijing, China.

Estimating Peak Discharges in Arid Regions: The Importance of Measurements and the Effect of Climate Variability/Change

Pieter J. M. de Laat[1] and ***Issa Al – Nsour***[2]

1. UNESCO – IHE Institute for Water Education, P. O. Box 3015, 2601 DA Delft, The Netherlands
2. Ministry of Water and Irrigation, Amman, Jordan

Abstract: For the design of small retention dams in the desert area of Jordan, rainfall and runoff were measured in a catchment of 37 km^2. In a period of two years eight runoff events were recorded from which a relation could be derived between rainfall intensity and runoff coefficient. Statistical analysis of time series of almost 60 years of daily rainfall values of stations in the vicinity of the catchment showed a significant downward trend of the annual daily extreme precipitation. In this study extreme rainfall events for various return periods were estimated from the last 30 years, which time series was stationary. The relation between rainfall intensity and runoff coefficient was then used the estimate peak runoff from extreme rainfall events.

A similar study was carried out in the 1990s in the same region based on a ten year shorter time series of rainfall data and in the absence of runoff measurements. Peak runoff was then estimated with the use of the Soil Conservation Service – Curve Number (CN) method from the extreme rainfall data derived from the shorter time series. Large differences in the predicted extreme discharges were found between the two methods. The estimated peak runoff for a 50 – year event appears almost seven times larger than found in this study. It is shown that the difference may predominantly be attributed to the use of a non – stationary time series, which is caused by a variation or change in the climate.

Key words: climate variability/change, extreme discharge, curve number method, statistical analysis

1 Background

Since 1994 a Working Group on Water Resources consisting of Israeli, Jordanian and Palestinian water professionals (the Core Parties) operates under the name EXACT (Executive Action Team) with financial support from a. o. the USA, EU, UK, and The Netherlands. The aim of the working group is to enhance cooperation among the Core Parties in the field of water. The Netherlands government finances under EXACT the project Small – scale water treatment facilities for domestic use and artificial recharge with surface water, which started in 2002. Part of this project is a pilot study on artificial recharge with surface water in the desert, some 25 km northeast of Amman (Jordan). In the 1990s a feasibility study on artificial recharge was carried out in this region by Chehata & Dal Santo (1997), which focused on the wadi's Madoneh and Butum. In another report Chehata et al. (1997) present a detailed design of a series of retention dams and related structures, based on a hydrological study of the area. This study was later summarized by Abu – Taleb (2003).

UNESCO – IHE who was asked to execute the Dutch contribution to EXACT, selected Wadi Madoneh for a pilot study on artificial recharge with surface water. The study started in 2003 and is carried out in close cooperation with the Ministry of Water and Irrigation (MWI) of Jordan.

2 Objectives

To retain flood water in Wadi Madoneh for artificial infiltration, six small dams will be constructed in 2007. The design criteria (height of the dam and capacity of the spillway) have to be derived from a hydrological study in the area. The objective of this research is to compare the derived design criteria with the outcome of an earlier study carried out by Chehata et al. (1997) in the 1990s. The basic difference between the two methods is that the study in the 1990s is based on the Curve Number (CN) method, where the runoff coefficient in this study is based on hydrometeorological measurements in the catchment. Moreover, for statistical analyses of rainfall data use could be made of a ten year longer time series.

3 Data collection and processing

In 2003 the catchment was equipped with two tipping bucket raingauges (Fig. 1), one inside the catchment on the roof of a small factory and one 2 km downstream on the roof of a school. The instruments have been collecting data for the two winter seasons 2003 ~ 2004 and 2004 ~ 2005. In this period eight storm events that produced runoff were recorded.

For a statistical analysis of precipitation data, use had to be made of rainfall stations outside the catchment (Fig. 1). From six rainfall stations long time series of daily values are available, some of which start already in 1937. For station A0052 only annual data exist. The data were carefully screened and missing values were filled in (Dhakal, 2006). The quality of the data appeared to be good. In this study annual data refer to the hydrological year, which runs from 1 September to 31 August. Based on the seven stations isohyets of average annual precipitation for the period 1975 ~ 2005 were computed (Fig. 1). Since annual rainfall totals decrease rapidly from west to east, daily rainfall values for Wadi Madoneh were computed as a weighted average from the rainfall stations AL0016 and CD 0003 as follows.

$$P_a(t) = \left[\frac{\overline{P_a}}{\overline{P_3}} P_3(t) + \frac{\overline{P_a}}{\overline{P_{16}}} P_{16}(t) \right] \qquad (1)$$

where: $\overline{P}$ is the 30 - year average precipitation; $P(t)$ the daily precipitation and the subscripts a, 3 and 16 refer to, respectively areal precipitation, and the stations CD0003 and AL0016.

In a rather straight section at the outlet of the catchment a traditional stilling well was built, which was not only equipped with a Steven's recorder, but also with a Diver. Divers are small instruments (length 12 cm, diameter 2 cm) for measuring pressure and temperature. The instrument in the stilling well was programmed to record the outside pressure every 10 minutes. The pressure recorded is in general the atmospheric pressure, except during a flood. In the observation hut where the Steven's recorder is housed, another so - called Baro - Diver is located, which was used to correct the Diver that measured the flood for the barometric pressure. About 80 m downstream of the stilling well, in the straight section of the wadi, a steel pipe (length 1 m) on a concrete base was constructed in the middle of the wadi bed. Inside the steel pipe another Diver was mounted to measure the pressure at exactly the same time as the Diver in the stilling well upstream. Water level measurements with the two Divers showed very similar results and appeared far superior to the traditional way of measuring. There are various reasons why preference should be given to a Diver above a Steven's recorder. The traditional method uses a float, which needs a minimal water level before it starts moving and is thus not accurate for the first 5 to 10 cm water level in the wadi. The float may get stuck in the mud during a dry period and may then not measure the water level of the next flood properly. The paper recordings have to be read out manually, which is time consuming and subject to errors, where the Divers are readout digitally with the aid of a laptop.

The cross section of the wadi was surveyed at both stilling wells and at three more locations in between. For each cross section the relations between water level (H) and wetted area (A), and water level and wetted perimeter were developed, which were then used to derive the relation between water level and hydraulic radius (R) for the average cross section. Given the slope (S) between the two stilling wells the discharge could then be computed for each water level with the

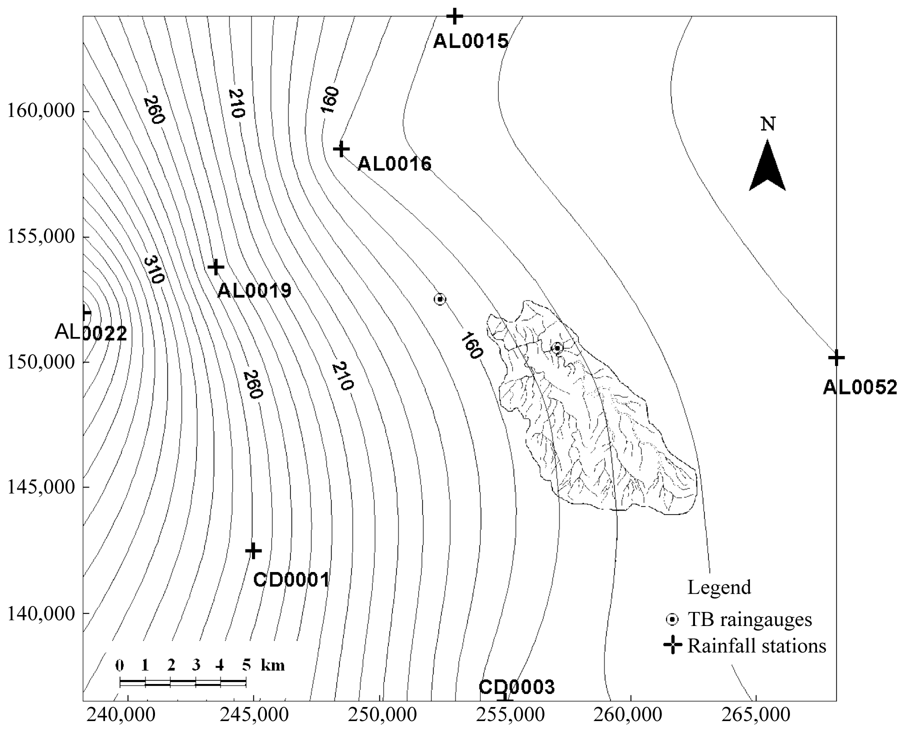


Fig. 1 Wadi Madoned, the location of the TB raingauger and isohyets based on seven rainfall stations for the period 1875 ~ 2005

equation of Manning

$$Q = A\frac{1}{n}R^{\frac{2}{3}}S^{\frac{1}{2}} \tag{2}$$

where the roughness coefficient (n) was computed from the equation of Jarrett (1992)

$$n = 0.32S^{0.38}R^{-0.16} \tag{3}$$

With this equation the roughness coefficient was found to range between 0.050 and 0.031 for water levels varying from 0.1 to 1.4 m respectively. These values were considered realistic in view of the size of the material found in the wadi bed. The resulting rating curve was then used to compute for the eight runoff events the discharge from the observed water levels.

4 Statistical analyses of rainfall data

An analysis of 68 years (1937 ~ 2004) of annual areal rainfall totals as derived for Wadi Madoneh shows a downward linear trend, although Spearman's rank correlation test is just not significant at 5 % significance level. The average annual precipitation over the entire period is 161.4 mm. Because of the downward trend, isohyets in Fig. 1 are based on the last 30 years of record, which time series does not show a trend and has for Wadi Madoneh an average annual total of 145.7 mm.

The annual daily maximum series of 57 hydrological years (1948 ~ 2005) shows a significant linear trend (Fig. 2) and is therefore unsuitable for the derivation of an extreme value distribution. The same series covering the last 30 hydrological years (1975 ~ 2005) is stationary, it does not show a trend, no jumps and the mean is stable. For this shorter series the Gumbel distribution was derived which is depicted in Fig. 3. In table 1 estimates of extreme rainfall for various return periods are compared with those obtained from a Gumbel distribution using the full (non - stationary) series and the values found by Chehata et al. (1997).

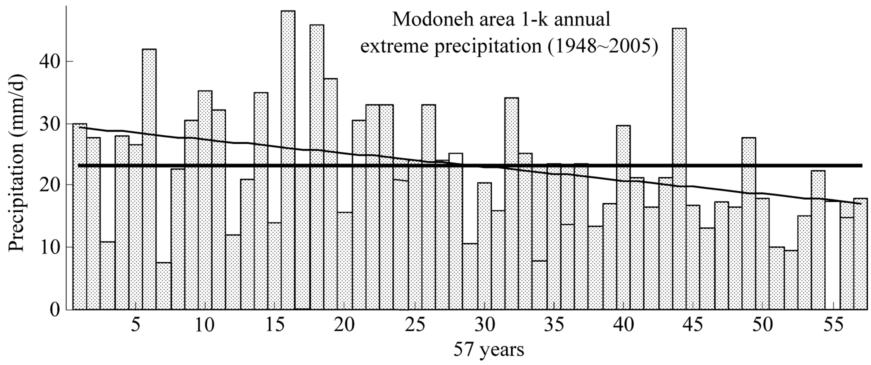


Fig. 2 Annual daily maximum series of 57 years of areal rainfall data for Wadi Madoned

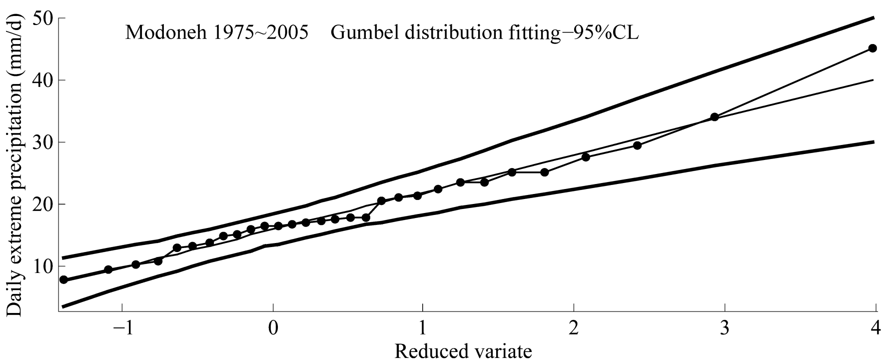


Fig. 3 Gumbel distribution of annual maximum daily areal rainfall for Wadi Madoneh, based on the period 1975 ~ 2005

The significant downward trend in annual daily extreme rainfall in Wadi Madoneh leads to significant higher estimates of extreme rainfall for various return periods if the entire series is used. The values published by Chehata et al. (1997) are much larger than found in this study. There are three reasons for this difference. First the way the areal rainfall of Wadi Madoneh is computed. In the study of Chehata et al. (1997) Wadi Madoneh includes also the tributary Wadi Ishshe, covering a total area of 57 km^2. The area of Wadi Ishshe (20 km^2) is adjacent to the west of Wadi Madoneh, where there is slightly more rainfall (see Fig. 1). The second reason is that areal rainfall was computed from Thiesssen polygons based on the rainfall stations AL0016, AL0019 and CD0003. Since there is no compensation for the decreasing rainfall in eastern direction, the inclusion of AL0019 leads to higher areal rainfall estimates. The third reason is the use of all rainfall data prior to 1997, which contains larger extremes than in more recent years.

5 Estimation of the runoff coefficient

In the two hydrological years, covering the period 2003 ~ 2005, eight runoff events occurred.

For each storm the total rainfall (P) and direct runoff (Q) , but also the rainfall amount (P_i) and duration (D) prior to the peak discharge are tabulated. The rainfall intensity (i) is defined as the ratio of P_i over D. All values are shown in Table 2, including the Runoff Coefficient (C) , which is defined as Q/P. Runoff coefficients of the eight storms vary from less than 1 % to more than 11%. Plotting the rainfall intensity against the runoff coefficient yields a graph with two outliers. These outliers may be explained after plotting the rainfall totals of the two TB raingauges against each other (Fig. 4). This shows that the rainfall during the storm events 3 and 6 was unevenly distributed. The relation between rainfall intensity and runoff coefficient is plotted in Fig. 5, omitting the storm events 3 and 6. This shows that for Wadi Madoneh the runoff coefficient may as follows be estimated from the rainfall intensity

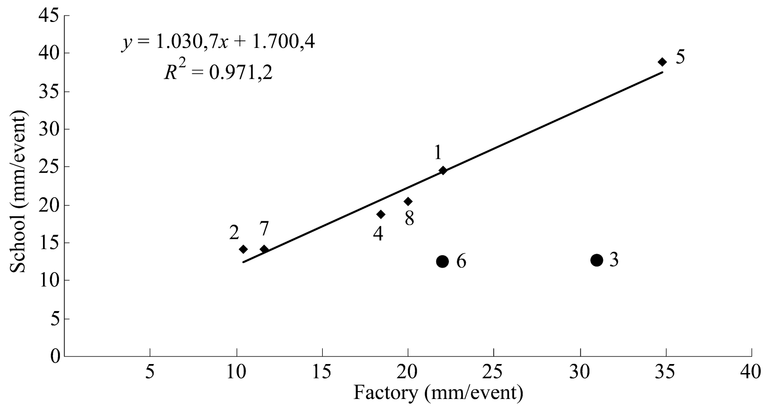


Fig. 4 Comparison of observed rainfall for the eight storm at the school and the factory

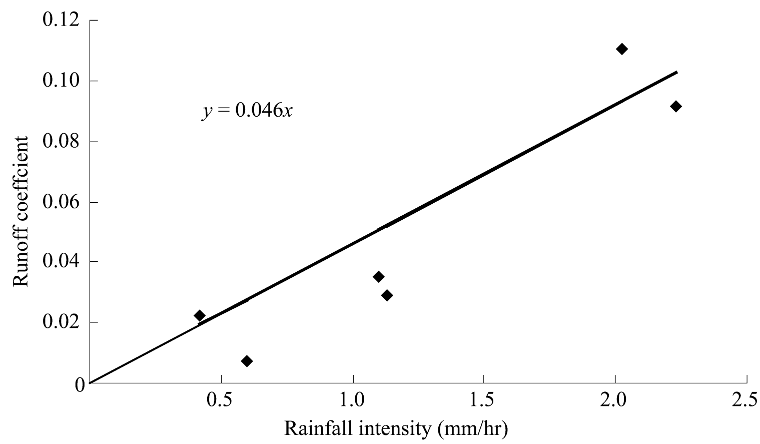


Fig. 5 Relation bwtweem rainfall intensity and runoff coefficinet, based on six strorm events

$$C = 0.46i \quad (4)$$

For extreme rainfall events the runoff coefficient may now be computed with (4). This requires that the rainfall intensity has to be specified. For return periods $T = 2$, 10 and 50 years daily rainfall extremes were derived (Table 1). The duration of the rainfall is not necessarily 24 hours. From the data observed in the period 2003 ~ 2005 it was found that durations can be much less (Table 2). For the computation of the rainfall intensity of daily extremes the duration was taken (rather arbitrarily) equal to 12 hours. The resulting runoff coefficients for various return periods are tabulated together with the extreme rainfall and the runoff (mm). These data are compared in Table 3 with the results presented by Chehata et al. (1997). This shows that the direct runoff from the 1990s study is approximately three to seven times larger than estimated in this study. This is partly due to the larger extreme rainfall as discussed above but also due to the much larger runoff coefficients that were used by Chehata et al. (1997).

Table 1 Annual daily extremes for various return period based on time series of different length and as found by Chehata et al(1997)

Return Period	30 years (1975 ~ 2005)	57 years (1948 ~ 2005)	Chehata et al. (1997)
2	18	22	27
10	29	36	48
50	40	49	85

Table 2 Data of eight storms recored in Wadi Madoned in the period 2003 ~ 2005. The data are explained in the text

Event	Date	P(mm)	Q(mm)	P_i intensity (mm)	D Duration (h)	Intensity $i = P_i/D$ (mm/h)	Runoff Coeff. $C = Q/P$
1	3 ~ 5 Dec 03	22.6	0.66	15.8	14.00	1.13	0.029
2	14 ~ 16 Dec 03	12.3	1.36	8.10	4.00	2.03	0.111
3	18 ~ 20 Dec 03	24.4	0.78	22.80	17.00	1.34	0.032
4	15 ~ 16 Feb 04	18.3	0.64	17.60	16.00	1.10	0.035
5	22 ~ 24 Nov 04	38.2	3.50	27.90	12.50	2.23	0.092
6	27 ~ 28 Nov 04	17.2	1.91	17.00	22.50	0.76	0.111
7	8 ~ 9 Feb 05	12.6	0.28	12.40	29.50	0.42	0.022
8	10 ~ 11 Mar 05	20.1	0.15	19.10	32.00	0.60	0.007

Table 3 Comparison of estimated values for extreme rainfall (P), runoff coefficient (C) and direct runoff (Q) for three different return periods (T)

	This study			Chehata et al. (1997)		
T	P	C	Q	P	C	Q
2	18	0.07	1.2	27	0.13	3.5
10	29	0.11	3.2	48	0.30	14.4
50	40	015	6.1	85	0.49	41.7

6 Curve umber method

The Soil Conservation Service – Curve Number (CN) method is developed for urban areas and small watersheds (SCS, 1986). It is an empirical method based on observations of rainfall and runoff in small catchments in the USA. The method is rather popular for the design of urban drainage systems, in the absence of measured discharges. Since a situation where runoff values are lacking occurs frequently, the method is often applied, also to situations for which it was not developed. The method is based on the following two equations

$$S = 25.4\left(\frac{1,000}{CN} - 10\right) \tag{5}$$

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \tag{6}$$

where: S is the subsurface storage capacity in mm, CN the curve number, P the rainfall amount in mm and Q the estimated direct runoff in mm. The Curve Number is an empirical parameter depending on the land use, type of soil and initial wetness. The values for arid and semi – arid rangelands are presented in Table 4.

For the computation of the runoff coefficient, Chehata et al. (1997) used $CN = 82$. This value led to rather large runoff coefficients as compared to the values found in this study. For storm events 1, 5 and 8 the CN value for Wadi Madoneh was optimized using Eqs. (5) and (6). Only those three events could be used, since the method requires a minimum amount of rainfall and events 3 and 6 were already discarded. The optimized CN value was found to equal 73.

Table 4 Curve Numbers for arid and semi – arid rangelands (source: SCS, 1986)

Runoff curve numbers for arid and semi – arid rangelands					
Ground cover	Runoff potential	Low*	Moderate	High	Very high
	< 30%	63	77	85	88
Desert shrub	30% ~ 70%	55	72	81	86
	> 70%	49	68	79	84

Note: * was specially developed for desert shrub.

7 Discussions of results

Chehata et al. (1997) have estimated a runoff volume for a 50 year rainfall event which is almost seven times larger than found in this study. The discrepancy is mainly caused by a difference in the way extreme rainfall was estimated. This study shows that the annual extreme rainfall in the region is affected by climate change/variability. The 50 – year annual maximum extreme rainfall based on the last thirty years is only 40 mm, where Chehata et al. (1997) found more than double this amount (85 mm) using a longer time series without the last ten years (see Fig. 2). Another reason for the difference is the runoff coefficient (Table 3), for which Chehata et al. (1997) used a value, which is, for a 50 – year runoff event, more than three times larger than used in this study. In Table 5 a comparison is made for various return periods between the extreme runoff computed for the CN value used by Chehata et al. (1997), the CN value based on the observed rainfall – runoff events and for the derived relation between rainfall intensity and runoff coefficient (this study). The differences between the various methods are much smaller than shown in Table 3, because the CN methods leads, for lower extreme rainfall values, to lower runoff coefficients. Hence, the large difference between Chehata et al. (1997) and this study is predominantly caused by ignoring climate variability/change in the time series of extreme daily rainfall.

Table 5 Comparison of estimated extreme runoff (Q) for extreme rainfall events (P) and runoff coefficients (C) found from three different methods as disscussed in the text. The return period (T) is given in years and Q and P are in mm

		This study		$CN = 73$		Chehata: $CN = 82$	
T	P	C	Q	C	Q	C	Q
2	18	0.07	1.2	0.00	0.0	0.04	0.7
10	29	0.11	3.2	0.03	1.0	0.15	4.3
50	40	0.15	6.1	0.10	3.9	0.25	9.8

References

Abu – Taleb, M. F. (2003) Recharge of groundwater through multi – stage reservoirs in a desert basin, Environmental Geology 44:379 – 390.

Chehata, M. and Dal Santo, D. (1997). Feasibility study of artificial recharge in Jordan; Case of Wadi Madoneh and Wadi Butum, Water Quality Improvement and Conservation Project, Ministry of Water and Irrigation, Amman, Jordan.

Chehata, M., Livnat, A. and Thorpe, P. (1997). Groundwater artificial recharge pilot project at Wadi Madoneh, Water Quality Improvement and Conservation Project, Ministry of Water and Irrigation, Amman, Jordan.

Dhakal, B. (2003). Development of design criteria for the construction of retention dams in Wadi Madoneh, Jordan, MSc thesis WSE – Hy. 06. 01, UNESCO – IHE, Delft.

Jarrett, R. D. (1992). Hydraulics of mountain rivers. (In: Yen, B. C., eds., Channel Flow Resistance: Centennial of Manning's and Kuichling's Rational Formula: Littleton, Colorado, Water Resources Publications, p. 287 – 298.

SCS (1986). Urban Hydrology for Small Watersheds, USDA – SCS Publication 210 – VI – TR – 55, Second Edition, June 1986.

A Study on Water Cycle and Groundwater Formation at Chabagou Catchment, Loess Plateau, China

Song Xianfang[1], ***Liu Xin***[1,2], ***Xia Jun***[1] and ***Zhang Xuecheng***[3]

1. Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Science and Natural Resources Research, CAS, Beijing, 100101, China
2. Graduate University of CAS, Beijing, 100049, China
3. Institute of Hydrology and Water Resources, YRCC, Zhengzhou, 450004, China

Abstract: In the past decades, runoff in the Yellow River has decreased sharply, with the mainstream drying up at times in recent years. At the Loess Plateau locating at the middle reaches of Yellow River Basin, people have constructed widespread silt arresters and terraces to conserve soil and water resources. However, for lack of systematic observation on water cycle, how does climate change and human activities as silt arresters and terraces affect local water cycle mechanism, what extent do they affect, and origin of local groundwater, is still under dispute. These call for a detailed study of interactions between precipitation, surface water and groundwater in Loess Plateau, which needs systematical observation on water cycle. In the study area Chabgou Catchment, typical Loess Plateau Ravine Region with great human activities, Chabagou Catchment and Caoping Xigou Experimental Watershed have been chosen to perform systematic hydrological and climatic observation, and to collect water samples periodically and instantaneously for isotopic and hydrochemical analysis. At Caoping Xigou Experimental Watershed, artificial rain also has been carried out to study the processes of runoff yield and precipitation infiltration. In combination with isotopic compositions and hydrochemistry of different waters, the hydrological study will provide reliable data foundation, and then to give some suggestions to reconstruction of local environment and ecology.

Key words: water cycle, groundwater, environmental isotopes, chabagou catchment, Loess Plateau

1 Introduction

Nowadays, land use\cover change affected by human activities, as well as global change, has produced great influence on underlying surface in some direct or indirect form, and then to local hydrology from precipitation amount to yield of surface water, groundwater and so on, which has been a critical challenge to local development, including water resources utilization, living conditions of residents and ecological reconstruction in vulnerable areas. As the second largest river in China, Yellow River is of great significance to the nation's sustainable development of social economy. Nevertheless, the yield of runoff has decreased sharply, and the down reaches even dry up for a long time in recent year. Similarly, the runoff of branches at Loess Plateau has decreased by a large degree. As a result of the incompact characteristic of loess, loess loosen by human trample or reclamation were washed away in mass during the first storms, and in the next several months' rainy season, the eroded sediment will be carried out. So, serious soil and water loss occurred in Loess Plateau, and widespread soil and water conservation projects, such as silt arresters, have been constructed since 1960s, which has brought great influence to hydrological cycle. For lack of long – term observation, how does the global change and human activities affect hydrological cycle and what extent do they impact, is still unknown. Moreover, the groundwater renewability and/or its origin in the Hilly and Gully Ravine Region is still kept a dispute. All these require a systematic observation for hydrological and climatic features in Loess Plateau.

Systematic observation of water cycle features and hydrological experiments are prerequisite and important tool for water cycle mechanism study. In combination with isotopic compositions and hydrochemistry of different waters, the observation & experiment can provide information to identify interactions between water cycle features, to quantify origins of water, to calculate evapotranspiration and water balance, and then to quantify change of water cycle mechanism. In addition, systematic hydrological and climatic observation is essential foundation to developing and validating hydrological model. However, in China, this systematic and high dissolution observation in catchment scale is still underway, especially for the long – term observation.

Up to now, water related studies in Loess Plateau are mainly about flood prediction, water – sand relationship, effect of soil and water conservation measures on hydrological processes. And the observation mostly refers to some single features. In the late 1980s, the workgroup for Loess Plateau Study of Chinese Academy of Sciences, has presided some studies such as natural environment and water resources investigation. These studies have already provided precious suggestions for vegetation construction, soil and water conservation, but few of them considered the water cycle features in the arid and semi – arid area as a whole.

Chabagou Watershed is an ideal study area under vulnerable environments for its vast soil and water conservation projects such as silt arresters and terrace constructed since 1960 – 70s. Moreover, there are 11 years' observation & field experiments during 1959 ~ 1969, when there is relatively mild human activities; and since then, over 30 years' regular observation was recorded. For such, comparing observation in new conditions with that of 1960s, and by integrated applications of hydrogen and oxygen isotopes, hydrological experiments and hydrochemistry, it is feasible to reveal the law of water cycle mechanism and groundwater formation in the Hilly and Gully Raverine Region, Loess Plateau.

2 Description of the study area

Chabagou watershed, is a fourth tributary of Yellow River at Loess Breck Ravine Region with a total area of 205 km^2, and 187 km^2 above the outlet station Caoping Hydrologial Station (CHS), locating at about 37°40′N, 109°55′E. The elevation is 900 ~ 1,292 m, and descents from northwest to southeast (Fig. 1).

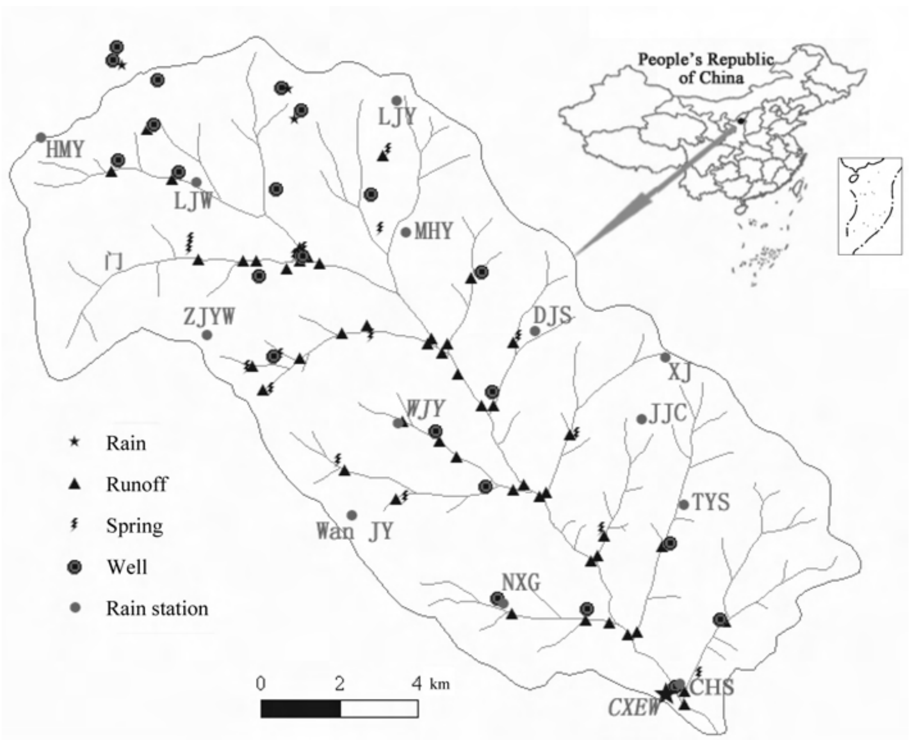


Fig. 1 Location of Chabagou Catchment, rain gauge stations and instantaneous sampling sites for surface water and groundwater in August, 2005

The study area belongs to the semi – arid climate, and precipitation penetrates unevenly both in spatial and temporal aspects. The average annual rainfall during 1959 ~ 2001 is 430. 8 mm, maximum 749.4 mm (in 1961) and minimum 253.4 mm (in 1965), about 60% of which precipitate from June to August as rainstorms with short duration and great spatial variation. The average air temperature is 8 ℃, maximum 38 ℃ and minimum −27 ℃, with annual evaporation capacity about 1,200 mm and frost period near 180 days.

Loess layers from tens of meters covering the watershed is a typical characteristic of the study area, and at the upper reaches it can reach nearly 100 m. Under the complicated influences of water erosion, gravity erosion and human activities, there are ditches highly developed all around, and at upper reaches, the slope of most erosion escarpments can even exceed 60°. Consequently, it becomes more severe for recharge of groundwater, which is mainly incompact pore water in the form of loess water with small water supply. Most wells can give groundwater less than 10 m^3 per day, which can only provide water for residential use.

Tilth land with no ribbing and grassland are the dominant land use in the study area, and exploitation of tilth is too high. As a result of the vast silt arresters built since 1970s, the total storage capacity is still as much as 33.12 million m^3 by June 2001.

3 Experiment desigh and data obtained

In order for a better study of water cycle features, Chabagou Catchment and Caoping Xigou Experimental Watershed (CXEW, 0.1 km^2) were chosen to monitor hydrological and climatic features, and to collect samples of precipitation, surface water, soil water and groundwater systematically in different spatio-temporal scales during 2004 ~ 2006. Moreover, simulation rain with different duration and intensity were performed to quantify the precipitation infiltration and runoff generating processes in the Loess Plateau. Still, to study relationships between surface water and groundwater in different periods of a year, instantaneous sampling for surface water and groundwater were conducted at Chabagou Catchment, with electric conductivity, pH values and water temperature being tested in situ. All the samples were analyzed using isotope spectrometer Finnigan MAT253 in Laboratory of Environmental Isotopes, Institute of Geographic Science and Natural Resources Research (IGSNRR), with precision ±2‰, ±0.3‰ for δD and $\delta^{18}O$ by VSMOW standard. Herein, the main observation & experiment items will be introduced by watersheds.

3.1 Chabagou Catchment

3.1.1 Rain gauge and sampling

In order to study the spatio-temporal variation of both precipitation and its environmental isotopes, 12 rain gauge stations were chosen to monitor rainfall during May and October automatically, using the JDZ-1 rain gauge data collector made by Nanjing Automation Institute of Water Conservancy and Hydrology, PRC. The observation interval is 5 minutes, and the daily rainfall is calculated from 8:00 am. Precipitation samples were collected once in a month, with one sample collected when all the rains collected into one collector and being mixed up completely.

3.1.2 Surface runoff observation and periodic sampling

In order to study the runoff process and its environmental isotopes of Chabagou Catchment, the surface runoff, as well as the sediment content in the mainstream, was observed at the outlet station CHS. During typical flood events, surface water was sampled at five main points, i.e., beginning to rise, on the rise, peak, on the decline and comeback. All the samples were collected in 100 ml airproof plastic bottles.

3.1.3 Groundwater investigation and periodic sampling

A detailed investigation of wells including domestic wells and power operated wells was performed in 2004. Since 2005, groundwater near 12 rain gauge stations and CHS were sampled routinely from May to October in step with that of monthly precipitation. As most of the domestic wells are drilled into loess layers and there is no obvious delamination, it is deemed to be representative for groundwater sampling.

3.1.4 Instantaneous sampling of surface water & groundwater

To study relationships between surface water and groundwater in different periods of Chabagou Catchment, two trips of instantaneous sampling for surface water and groundwater were conducted in June and August of 2005. Totally 22 samples were collected along the mainstream during the June 2005 trip; while during the August trip, 89 samples were obtained at all 12 of main ditches, with electric conductivity, pH values and water temperature tested in situ using WM22EP EC/pH meter (Japan). In 24 September 2005, 16 samples were collected in both Chabagou Catchment and its senior watershed Wudinghe River, and some of the spots were review of the former samplings. Surface water were collected from flowing surface runoff in mainstream, and groundwater from domestic loess wells or fissure spring. Surface water and groundwater were collected correspondingly in spatial distribution. All the samples were sealed up in 50 mL or 100 mL plastic bottles. Fig. 2 has exactly shown the sampling spots during August 2005.

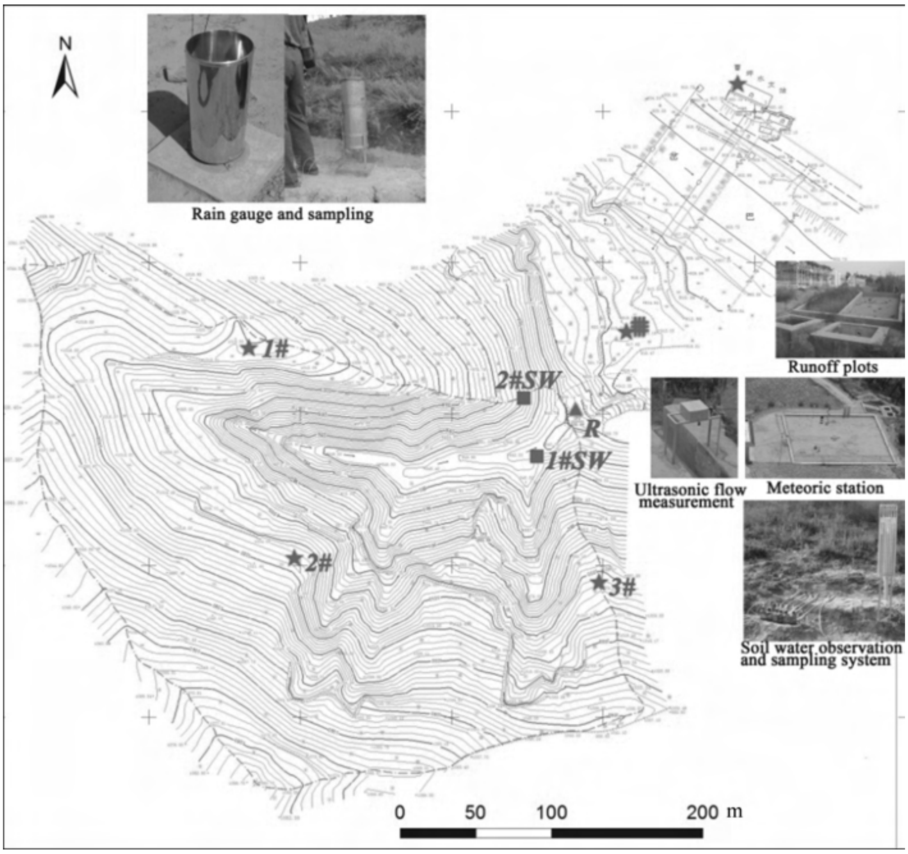


Fig. 2 Observation & Experiment Items at Caoping Xigou Experimental Watershed

3.2 Caoping Xigou Experimental Watershed

Since 2004, hydrological and climatic features as precipitation, surface runoff and soil water content were observed at CXEW constructed by IGSNRR and Hydrology Bureau of YRCC (See Fig. 2).

3.2.1 Weather observation

In the weather station of CXEW, climatic information as air temperature, pressure, velocity, direction, humidity, and rainfall, soil temperature of land surface, 5 cm, 15 cm and 30 cm underground, and soil moisture of layers 10 cm, 20 cm, 30 cm, and 50 cm below surface, was observed every ten minutes. Still, the evaporation from water surface was tested using E601 evaporation pan, being tested once 8:00 and 17:00.

3.2.2 Rain gauge and sampling

For a detailed study of rainfall and its environmental isotopes at small watershed, rainfall information in 5 spots, including 3 rain gauge stations at CXEW, weather station and CHS, were observed using JDZ – 1 rain gauge data collector, and rain events heavier 5 mm were sampled shortly after the rain stopped.

3.2.3 Surface runoff observation and sampling

In the outlet trough of CXEW, surface runoff processes was monitored in real time using ultrasonic water level gauge recorder, which measures the water head running through the trough. Still, we measure the runoff process by manual measurement, every 3 minutes on the rise stage, and every 6 minutes if there is little change in water level, by which to calculate the water level – runoff curve. Similar to the design at Chabagou Catchment, surface water was sampled in five main points, i. e. , beginning to rise, on the rise, peak, on the decline and comeback in typical flood events.

3.2.4 Soil water content observation and sampling

In order to study the infiltration of precipitation at slopes with different covers, grassland and tilth land, soil water content at four depths, i. e. , 10 cm, 20 cm, 30 cm and 50 cm, were monitored every 10 minutes using SWR sensor made by China Agriculture University. Additionally, soil water suction of 6 layers, two more layers than SWR, 70 cm and 100 cm, were gained using mercury tensiometer made by IGSNRR, through two – stage measurement at 8:00 and 17:00, respectively. Meanwhile, soil water in the six layers were abstracted to analyze environmental isotopes.

3.2.5 Simulation rain at runoff spots

To make up for the lack of natural rain for concentrated research in the study area, totally 16 simulation rains of different intensity and duration were performed in the bare land and grassland runoff spots during September 2005, with water suction of surficial 50 cm layer, i. e. , 5 cm, 10 cm, 20 cm, 30 cm, 50 cm, and runoff processes being observed. Soil water suction and runoff processes were observed using mercury tensiometer (IGSNRR) and data collector HOBO (USA), respectively. Combined with the soil water content under natural rains, this can help to identify the responses of land use, land cover and rainfall types to precipitation infiltration and surface runoff generating processes.

3.3 Data obtained

Since 2004, three years' systematic and continuous hydrological & climatic observation has been carried out, and a great deal of water samples were obtained for environmental isotopes and hydrochemistry analysis, which has provided qualified information to a further study of hydrological cycle. Table 1 shows the main data obtained during the study.

Table 1 Hydrological and climatic data and samples obtained at Chabagou Catchment during 2004 ~ 2006

No.	Items	Features	Sites	Data			Remark
				2004	2005	2006	
1	Hydro logy	Water level	Outlet trough of CXEW	70	13	200	
2		Runoff flux		6		200	
3		Sediment content			3	24	
4							
5		Stage standard		10			
6		Soil moisture	Grassland	32,616	102,740	98,484	
			Tilth land	32,616	102,740	98,484	

No.	Items	Features	Sites	Data 2004	2005	2006	Remark
7		Evaporation	Weather Station	184	392	368	
8		T、P、V、D、T_s、		8,188	26,602	26,628	
9			Weather Station	8,188	26,602	26,628	
10	Climate		1# Rain Gauge Station	193	151	180	
11		Rainfall	2# Rain Gauge Station	182	157	180	
12			3# Rain Gauge Station	197	159	180	
13			Weather Station		22	21	
14			1# Rain Gauge Station		22	21	
15		Rain samples	2# Rain Gauge Station	64	22	21	
16			3# Rain Gauge Station		22	21	
17			CHS		22	21	
18	Isotopes sampling		12 Rain Gauge Stations	49	72	72 + 6	
19			13 Rain Gauge Stations		64	78	
20		Groundwater samples	Instantaneous sampling at CC		52		EC – pH – T
21			CXEW	3	3	30	
22		Surface water samples	CHS	9	16	24	
23			Instantaneous sampling at CC		76		EC – pH – T
24		Soil water samples	CXEW		62	18	

4 Preliminary results

4.1 Characteristic of water cycle features

4.1.1 Precipitation

Fig. 3 demonstrates the variation of monthly rainfall during 2004 ~ 2006 at Caoping Hydrological Station. There is obvious inter – annual change for rainfall, 351.4 mm, 356 mm and 519.5 mm for the three years, among which the rainfall during July and August occupies 51%, 42% and 57% of the annual rainfall, respectively; while it is 90%, 93% and 91% for rainfall during May to September. The rainfall during September to April of the next year also has an obvious variation, from 14.6 mm in normal year(2004) to 47.3 mm in wet year(2006). From the variation of daily rainfall during May to October observed at CXEW shown in Fig. 4, the rainy days and daily rainfall differ greatly. From May to October, there were totally 66 rainy days in 2005, with the maximum rainfall 42.3 mm; while in 2006, it reached 89 days and the maximum rainfall 51.6 mm, among which 40 days' rainfall exceeded that of 2005. In the two years, there were 7 and 9 days raining heavier than 15 mm, and amounted to 45% and 51% of the total rainfall from May to

October. Notably, most of these rain events penetrate in 2 ~ 4 hours.

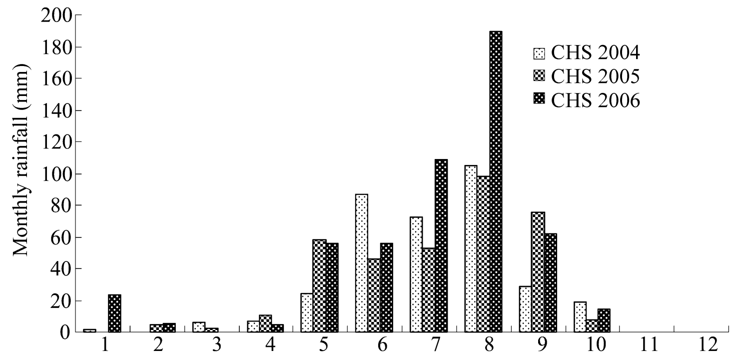


Fig. 3 Monthly rainfall at Caoping Hydrological Station during 2004 ~ 2006

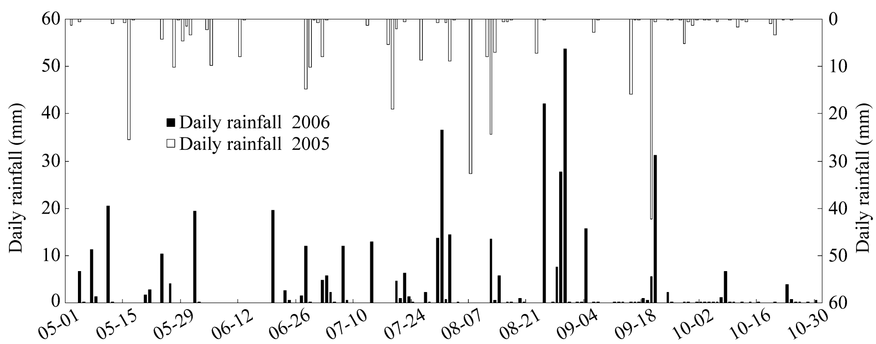


Fig. 4 Comparison of Daily Rainfall at Caoping Xigou Experimental Watershed during May to October in 2005 and 2006

The study also observed spatial variation of rainfall at Chabgou Catchment. Fig. 5 is an example of spatial distribution of daily rainfall, monthly rainfall and total rainfall during May and October. In 7 August 2005 rain event, the maximum point rainfall was 76 mm and appeared at the Zhujiayangwan Station, while the minimum rainfall was only 27.2 mm (Jijiacen Station). During the observation period, the maximum point rainfalls all exceed 60 mm and mainly penetrate in August, with spatial variation minishing when the annual rainfall increases.

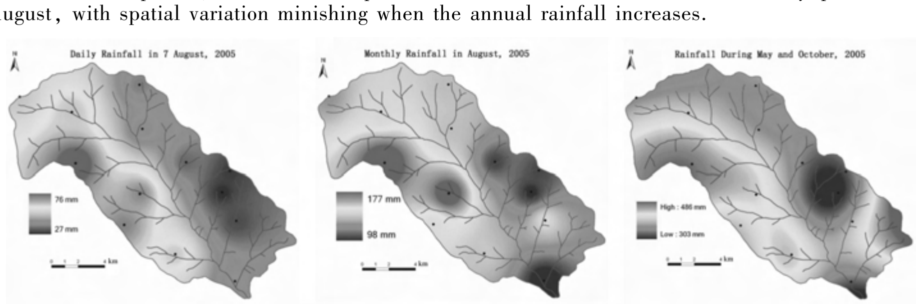


Fig. 5 Spatial distribution of rainfall at Chabagou Catchment

4.1.2 Surface runoff

As a result of characteristic of loess, vegetation cover and topography in the study area, flood only appears after widespread heavy rain or rainstorm and the duration is very short. The runoff process mainly lasts only 12 ~ 24 hours, and lasts 48 hours only after widespread and long duration rainstorm. Immediately floods recede, surface runoff gets recharge from groundwater discharge and returns back to nearly or lower than 0.05 m^3/s. At May, the baseflow falls to 0.01 m^3/s or the stream even dries up. Fig. 6 shows the dominant runoff processes at Caoping Station during May and August 2005, with maximum 49.6m^3/s and duration approximately 12 hours, and in most flood processes, the runoff flux is less than 0.2 m^3/s.

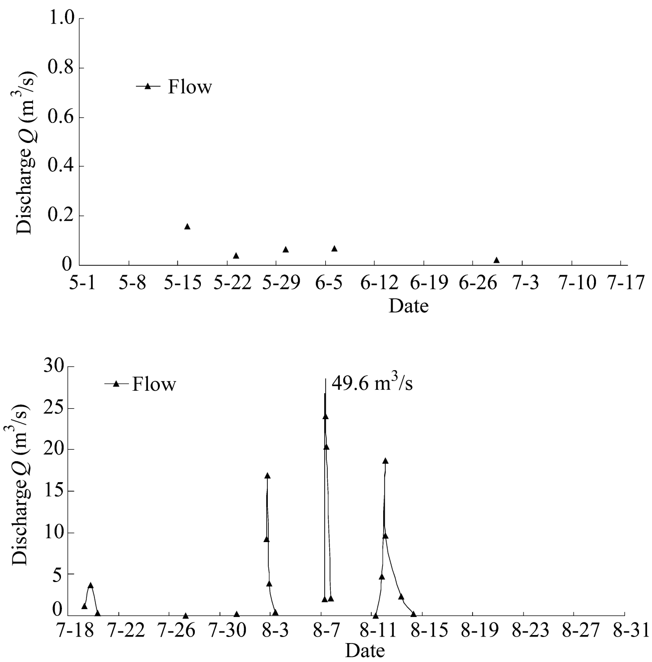


Fig. 6 The process of surface flow at Caoping Station from May to Auguest in 2005

4.1.3 Soil water

Fig. 7 shows the soil moisture change of the upper 50cm in 20°slope of tilth land and grassland in 2005. From the three yeas' comparison, we can see that the 50cm loess layers can only get limited recharge from the precipitation infiltration, and only rain events heavier than 50mm can reach to this layer. The surficial 20cm should be the active zone for soil water. the isotopic composition of soil water and soil moisture monitoring, can help to identify the process of rain infiltration and rain events recharging groundwater. In combination with the anta soil water moisture, the land cover rate and detailed rainfall information, it will be possible to mark out the weight of recharge for distinguished factors.

4.2 Preliminary discussion on groundwater formation

By analyzing isotopic compositions δD and $\delta^{18}O$ of rains in 2004 ~ 2005, the study discussed the amount effect, seasonal effect, spatial distribution of δ values for monthly precipitation at upper, middle and lower reaches of Chabagou Catchment, and for event precipitations at CXEW; preliminarily discussed water vapor origin, and got the local meteoric water line of Chabagou Catchment $\delta D = 7.41\delta^{18}O + 2.9$ (see Fig. 8). At Chabagou Catchment, isotopic compositions for monthly precipitation show obvious spatio - temporal variation, with an altitude effect of approximately −3.35‰ per 100 m for rainfall weighted average δD (see Fig. 9).

As shown in Fig. 10, routinely collected groundwater at Chabagou Catchment has relatively stable isotopic composition with a weak correspondence to the obvious seasonal variation of both

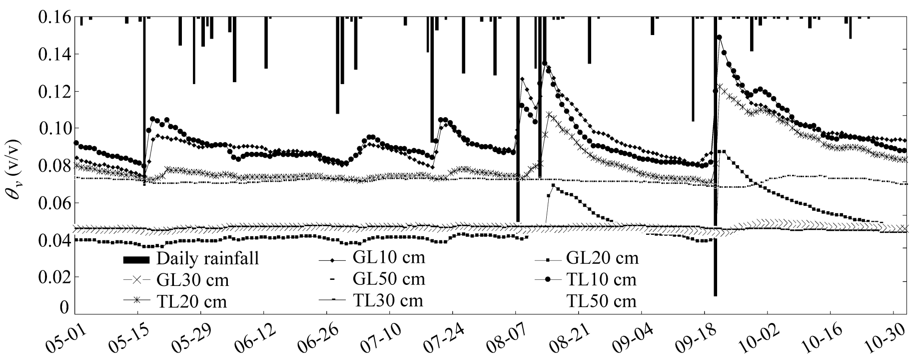


Fig. 7 Variation of soil water content for slopes of grassland and tilth Land during May and October, 2005

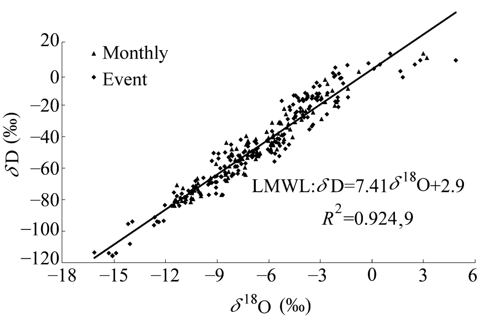


Fig. 8 Local meteoric water line

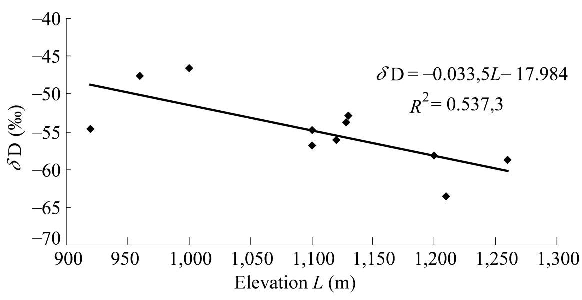


Fig. 9 Altitude effect of monthly precipitation at Chabagou Catchment

rainfall and its isotopic composition, and the $\delta D - \delta^{18}O$ relationship for groundwater is $\delta D = 3.41\delta^{18}O - 36.3$ (see Fig. 11). Isotopic composition of groundwater indicates that, groundwater is a mixture of only some rain events with heavy rainfall but low δ value, but not the average of all rains in a year. ; groundwater experiences a slow and adequate mixing process at the zone of aeration. Isotopic variation of the stations also demonstrates that groundwater near Mahuyan Station mainly origins from precipitation of high elevation through passages underground, while groundwater in some spots such as Wanjiayan Station, Caoping Hydrological Station and Jijiacen Station, has multiple origins. Wholly speaking, the renewability of local groundwater is not optimistic.

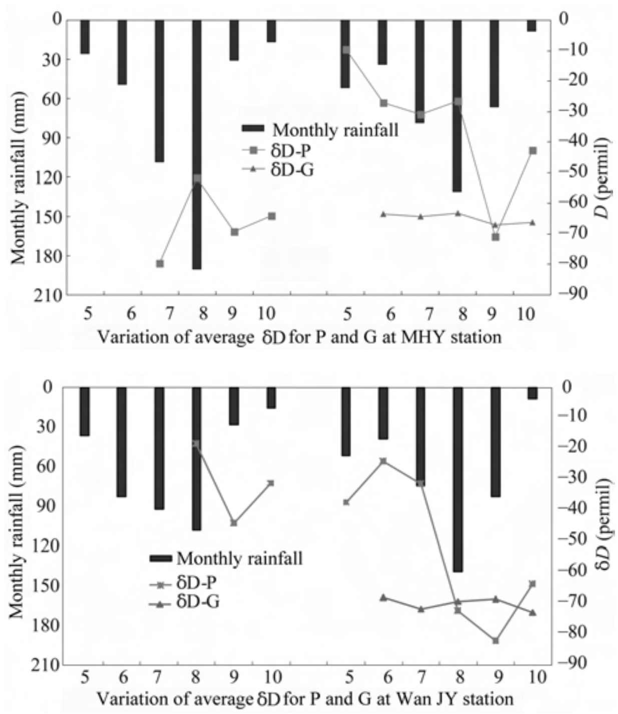


Fig. 10 **Variation of δD for Precipitation (P) and Groundwater (G) at Chabagou Catchment**

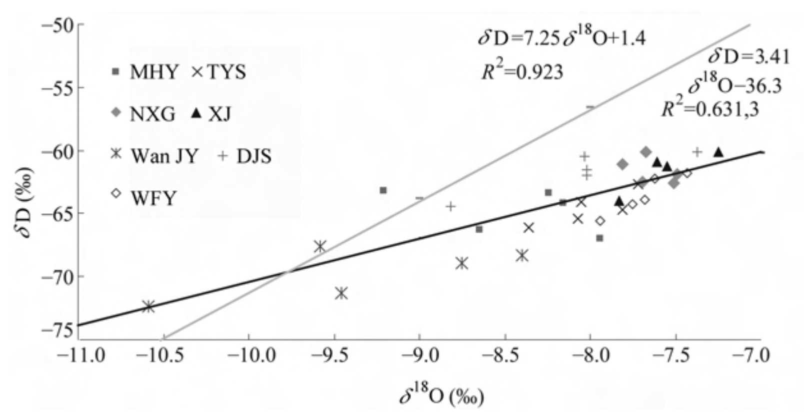


Fig. 11 **$\delta D - \delta^{18}O$ relationship for periodically sampled groundwater at Chabagou Catchment**

5 Conclusions

According to the observation & experiment mentioned above, some preliminary conclusions have been deduced.

(1) The annual and spatial distribution of precipitation is remarkably uneven at Chabagou Catchment, over 90% of rainfall falls from May to September, most of which is in the form of

intense rainstorm of about 60 ~ 100 mm in 2 ~ 4 hours. In August, the maximum point rainfall can be twice of the minimum point rainfall. At the Chabagou Catchment, isotopic composition for monthly precipitation shows obvious spatio – temporal variation, with altitude effect of about – 3.35‰ per 100m for rainfall weighted average δD. Based on isotopic analysis of precipitation in 2004 ~ 2005, a series of meteoric water lines including the local meteoric water line, were obtained.

(2) At CXEW, the runoff coefficient varies from 0.12% ~ 7.78%, half of which is less than 2%, and over 90% of precipitation went back to the atmosphere by evapotranspiration. At Chabagou Catchment, most of flood yield generates in regions with steep slope or at loess layers with low coverage. The flood processes occur after rainstorm events and only several times a year. High peak discharge, extremely short duration as to 12 ~ 24 hours, and streamflow quickly receding to lower than 0.05 m^3/s after flood, are main characteristics of local surface runoff. The annual runoff coefficient of the whole catchment is around 10%. In most periods of a year, the baseflow is recharged by groundwater discharge from fissure spring and loess spring, and there is hardly any soil water recession process.

(3) At 20° slope, only rainfall larger than 40mm or rainstorm can infiltrate to layers as deeper than 50cm, and annual recharge is limited as a result of short rainfall duration and fine loess particles. Isotopic composition of groundwater is a reflection of some rain events with heavy rainfall but low δ value, not the average of all rains in a year, and it experiences a slow and adequate mixing process at the zone of aeration. The renewability of groundwater in the study area is not remarkable.

References

Li Fadong. 2005. Hydrological cycle research based on environmental isotopes and integrated hydrological experiments—Case study in a representative catchment, Taihang Mountain[D]. Doctoral dissertation in graduate school of Chinese Academy of Sciences.

Yang Cong. 2006. Experiments of water cycle process in typical catchment, mountainous area, North China—Case study in Dongtaigou Catchment[D]. Doctoral dissertation in graduate school of Chinese Academy of Sciences.

Hu Kun. 2006. Experiment and Mathematical Simulation Study on Slope Hydrological Processes in Lithoid Mountainous Areas in North China——Case Study at Chongling Catchment[D]. Master dissertation in graduate school of Chinese Academy of Sciences.

Yang Cong, Yu Jingjie, Song Xianfang, et al.. 2004. Reference Crop Evapotranspiration Calculation in Short Interval of Mountainous Area in North China. Progress In Geography[J] (in Chinese), 6:72 – 81.

Yang Cong, Yu Jingjie, Liu Changming. Experimental Study on Slope Runoff Generation Process in North China Mountainous Area, Acta Geographical Sinica[J] (in Chinese). 2005. 60(6): 1021 – 1028.

Li Fadong, Song Xianfang, Tang Changyuan. et al.. 2007. Tracing infiltration and recharge using stable isotope in Taihang Mt, North China. Environmental Geology[J]. DOI: 10, 1007/S00254 – 007 – 0683 – 040.

Song Xianfang, Li Fadong, Liu Changming, et al.. 2007. Water Cycle in Taihang Mt. and Its Recharg to Groundwater in North China Plain, Journal of Natural Resources[J] (in Chinese). 22(3):398 – 408.

Song Xianfang, Li Fadong, Yu Jingjie, et al.. 2007. Characteristics of groundwater cycle using deuterium, oxygen – 18 and hydrochemistry in Chaobai River Basin. Geographical Research [J] (in Chinese). 26(1):11 – 21.

Yu Jingjie, Song Xianfang, Liu Xiangchao, et al.. 2007. A Study of groundwater cycle in Yongding River Basin by using δD, $\delta^{18}O$ and hydrochemical data. Journal of Natural Resources[J] (in Chinese). 22(3):415 – 423.

Song Xifang, Liu Xiangchao, Xia Jun, et al.. 2006. A study of interaction between surface water and groundwater using environmental isotopes in Huaisha River basin. Science in China Series D, 49(12):1299 – 1310.

Liu Changming, Hong Baoxin, Zeng Mingxuan. 1965. Cinese Science Bulletin[J] (in Chinese). 2(2): 158 – 161.

Liu Changming, Zhong Junxiang. 1978. Preliminary analysis of the effect of forest on annual runoff. Acta Geographica Sinica[J] (in Chinese). 33(2).

Huang Mingbin, Kang Shaozhong, Li Yushan. 1999. A comparison of hydrological behaviors of forest and grassland watersheds in gully region of the Loess Plateau[J]. Journal of Natural Resources[J] (in Chinese). 14(3) :226 ~ 231.

Li Peicheng, Liu Junmin, Wei Xiaomei. 1999. Study on mechanism of "three waters" conversion and the adjusting and controlling function[M] . Shaanxi : Shaanxi Science and Technology Press.

Zhao Hongyan, Wu Qinxiao, Liu Guobin. 2001. Mechanism on soil and water conservation of forest vegetation on the Loess Plateau. Scientia Silvae Sinicae[J] (in Chinese). 37(5):140 – 144.

Li Yushan. 2001. Effects of forest on water circle on the Loess Plateau. Journal of Natural Resources[J] (in Chinese). 16(5):427 – 432.

Wang Hongshan, Huang Mingbin, Zhang Lu. 2004. Impacts of re – vegetation on water cycle in a small watershed of the Loess Plateau. Journal of Natural Resources[J] (in Chinese). 19(3):344 – 350.

Li Yuyuan, Shao Ming'an. 2004. Experimental study on characteristics of water transformation on slope land, Journal of Hydraulic Engineering[J] (in Chinese). 4:48 – 53.

Team for Groundwater series of Loess Plateau Investigation, CAS. 1990. Reasonable Utilization of Groundwater in Loess Plateau[M]. Beijing. Academy Press.

Liu Suxia, Zhang Shifeng, Liu Changming. 2001. Advances on the research into the mechanism of hydrological cycle in Yellow River catchment. Geographical Research[J] (in Chinese). 2001, 20(3): 257 – 265.

Liu Xin, Song Xianfang, Xia Jun, et al.. 2007. Characteristics of Hydrogen and Oxygen Isotopes and Preliminary Analysis of Vapor Origin for Precipitation at Chabagou Catchment, Loess Plateau. Resources Science[J] (in Chinese). 29(3):59 – 66.

Water Resources Management in the Yellow River Basin

Tetsuya KUSUDA[1], ***Masahiro MATSUSITA***[2] and ***Yang Dawen***[3]

1. The University of Kitakyushu, 1 – 1 Hibikino, Wakamatsu – ku, Kitakyushu 808 – 0135 Japan
2. Tokyokensetsu Consultants Company, 5 – 6 – 20 Nakasu, Hakata – ku, Fukuoka 810 – 0801 Japan
3. Department of Hydraulic Engineering ,Tsinghua University, Beijing 100084, China

Abstract: The Yellow River Basin is the largest river in north west and north China, covering 753 thousand km^2 and accounting for 8% of the area of China. The annual precipitation ranges from 200 mm to 800mm. The basin is characterized by arid and semi – arid climate, the Loess Plateau, and industrially developing and highly cultivated area. This basin has been suffering from water shortage. Appropriate allocation of water resources would bring better ecosystem, higher sustainability, and more vivid economy with wise water use, efficient water reuse, and discharge of wastewater after appropriate treatment.

Allocation of water resources to the sectors; agriculture, industry, daily lives, and ecosystem, is a matter of policy and economy. In order to get more appropriate allocation, the evaluation of scenarios considered with conditions on food production, economy and employment is inevitable.

In this study, several scenarios on development are discussed under water supply and social constraints with an integrated water quantity and quality model newly developed. It was found that there are several measures for further development, such as water saving irrigation, water reuse in industry, and wise use in daily life and excess water by appropriate water use is available for enlargement of irrigated farmlands.

Key words: Yellow River, water, management, wise use, irrigation

1 Introduction

The Yellow River basin originates from the Tibetan plateau, flows through the northern semiarid region, crosses the loess plateau, passes through the eastern plain, and finally goes into the Bohai Gulf. The Yellow River flows about 5,500 km in distance in the main course and accumulates 753,000 km^2 of drainage area. The area of the river is 8.3% of the total Chinese area. From the origins to the river mouth, the Yellow River has three typical landforms, the Tibet plateau with elevations from 2,000 m to 5,000 m, the loess plateau and midstream tributaries with elevations from 500 m to 2,000 m, and the alluvial plain in the eastern part. The precipitation ranges from 200 mm to 800 mm in the basin. The mean annual precipitation is 452 mm. Rainfall of the Yellow river basin occurs in 7 monsoon months (April to October) and more than 60% of the annual precipitation arrives during June – September.

According to the statistics in 2000, a population of 110 million settled in the basin, 8.7% of the total nation number. The ratio of rural population to the total has been declining gradually, from around 73% in 1990 to 63% in 2001 (WDI, 2003). Urbanization and concentration of population to urban areas demand more water with increasing living standards.

The cultivated land is 11.93 million ha, forest and forage lands are 10.20 million ha and 27.93 million ha, respectively. The increasing total irrigated area in 1949 was about 0.80 million ha in the basin and 7.1 million ha in 1990. The area of 5.1 million ha received surface water and that of 2.0 million ha was supplied by well irrigation in 1900. The rest is rain – fed. All areas of farmland needs much water from the river. The income of farmers depends on the amount on water supplied.

A number of newly built industrial bases and cities have been set up in the basin. According to the strategy layout of Chinese economy development in the beginning of the 21st century, there are four special economic centers in the Yellow River basin: Lanzhou, Xi'an, the midstream region such as the southern Shanxi, and the down stream part. Industry in the basin, especially these four centers, has been developing and they need more water than they are.

In the Yellow River basin: all sectors: agriculture, industry, daily life, and ecosystem need more water for better work and life. Therefore, water resources management is the key to construct a sustainable Yellow River basin where is scarce of water resources with high water demand and strong stress to ecosystem as well as China herself. Wise water use, efficient water reuse, and discharge of wastewater after proper treatment would bring better environment for human and ecosystem (see Fig. 1).

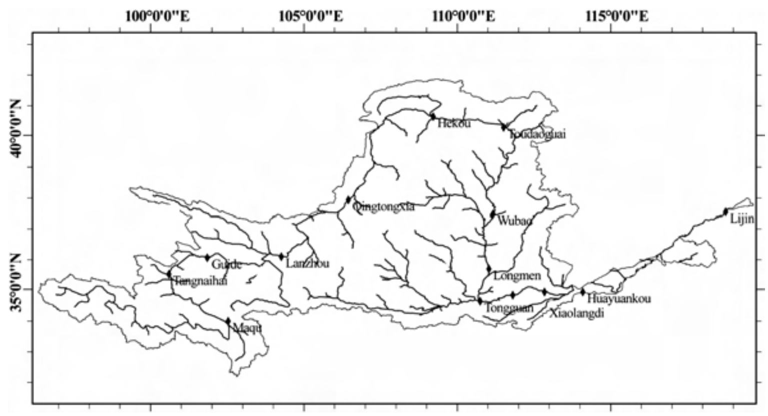


Fig. 1 The Yellow River basin

Allocation of water resources to the sectors are matters of policy and economy with science knowledge base. In order to obtain appropriate allocation from the scientific base, the construction of an integrated model on water quality and quantity followed by simulation of future figures is important.

In this study, for increasing income in the basin, several appropriate scenarios are developed with the allocation of water resources, water use and reuse, and water saving by using an integrated model of water quantity and quality.

2 A coupled model on water quantity and quality

A coupled model on water quantity and quality which is based on the hydrological module; the Geomorphology – Based Hydrological Model (GBHM) and the water quality module; the Streeter – Phelps equation was used to analyze the hydrological phenomena in the Yellow River basin. In the model, the hydrological module is composed chiefly of hill – slope and river components. In each component, natural and artificial water cycles are calculated. Each grid cell in the model is 10 km × 10 km in area, and the sub – basin is divided into two layers with an aggregate of grid cells, i. e., surface and unconfined aquifers, to allow the calculation of soil water movement.

The water quality module is based on a one – dimensional advection – dispersion equation. This module uses flow rate calculated by using the hydrological module and pollutant discharge from point and non – point sources in the basin. Pollutant load from point sources was calculated with basic units, and pollutant load from non – point sources was derived by using the Soil and Water Integrated Model (SWIM). This model can calculate suspended solids (SS), BOD_5, dissolved oxygen (DO), ammonium nitrogen ($NH_4^+ - N$), and nitrate nitrogen ($NO_3^- - N$). The structure and conditions are presented in Table 1.

Table 1 The structure and conditions of the model

Model characteristic		
Temporal - spatial division of the object basin	Basin confines	Yellow River Basin
	Subdivision of the basin	Pfafstetter method (137 basins)
	Grid units	10 km × 10 km
	Number of grid cells	182 × 266 = 47,866 cells
	Unit of calculation	1 hour
Basic equations	River discharge	Kinematic wave method, Manning equation
	Soil water	Richards equation, Ven Genuchten equation, Darcy equation
	Groundwater movement	Darcy equation
Input data	Meteorology	Precipitation, snow, temperature, wind speed, sunshine hours, evapo - transpiration
	Artificial water use	Population size, factories, domestic water use and discharge, industrial water use and discharge, treatment water, reservoirs, irrigation area
	Grid cells	Elevation, land use, slope, slope length, soil characteristics, ground thickness, NDVI, border
	Other	Sub - basin, river, vegetation, and soil parameters
Output data	River	Discharge, evapo - transpiration
	Grid cells	Soil water, groundwater level, evapo - transpiration

3 Possibility of water reallocation

Wise reallocation of water resources needs excess ones. Since sixty percent of water is consumed in the agricultural sector in the Yellow River basin, water saving on irrigation is plausible and reasonable. Water budget in the Hetao irrigation area is presented in Fig. 2 by Shi Haibin. Due to these figures, only 34% of intake water reaches the irrigation area and 60 % of intake evapo - transpires. This means that the reduction of leakage in the canal and of evapo - transpiration bring more water resources in the basin. As far as investment for the repair of canals and the reduction of irrigation such as drop irrigation is valued, there are possibilities to improve them more than 50%. The other irrigation areas seem to be in similar conditions, so that when the industrial sector, the urban sector or/and the central government, as a policy, are able to share the repair cost, the shortage of water in the basin would be improved.

4 Estimation of allocation of water resources in the future

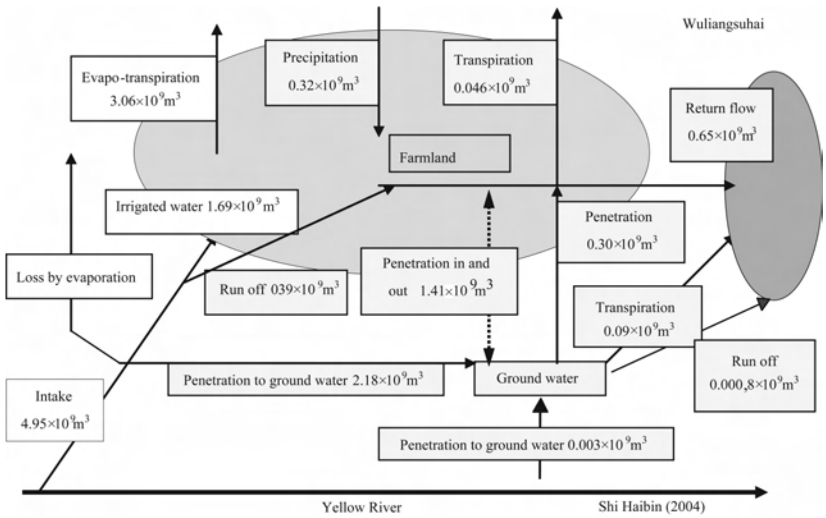


Fig. 2 Water budget in the Hetao irrigation area

4.1 Conditions for estimation

It is necessary to set internal and external conditions on meteorology, human activities, etc and scenarios on the development of society to consider future water supply and management in the Yellow River basin.

4.2 Meteorological conditions

4.2.1 Basic distributions of meteorological data

Meteorological data used in the coupled model for water quantity and quality, are precipitation, temperature, wind speed, and sunshine hours. These data for past years were analyzed to find characteristics of their distributions. The results are summarized in Table 2.

Table 2 Characteristics of meteorological data

Meteorological item	Item	Distribution function
Precipitation	Annual and monthly precipitation	Log – normal
	Numbers of rainy and snowy days in a month	Poisson
Sunshine hours	Annual and monthly mean sunshine hours	Log – normal
	Daily sunshine hoursp	Binomial
	The number of short and long sunshine	Binomial
Wind speed	Daily average wind – speed	Weibull
Temperature	Annual highest and lowest temperature	Log – normal
	Daily mean temperature	Sine

4.2.2 Spatial distributions of meteorological data

The basin was divided into 7 regions based on the results of correlation analyses of meteorological data at 120 stations in the past 20 years, from 1981 to 2000 (see Fig. 3).

Meteorological data were reproduced for estimation with certain procedures, that is, regarding precipitation, probabilistic determinations of an annual precipitation, monthly precipitation, and daily precipitation in the order by use of distribution functions in Table 2. Sunshine hours, temperature, and wind velocity were also reproduced with similar procedures.

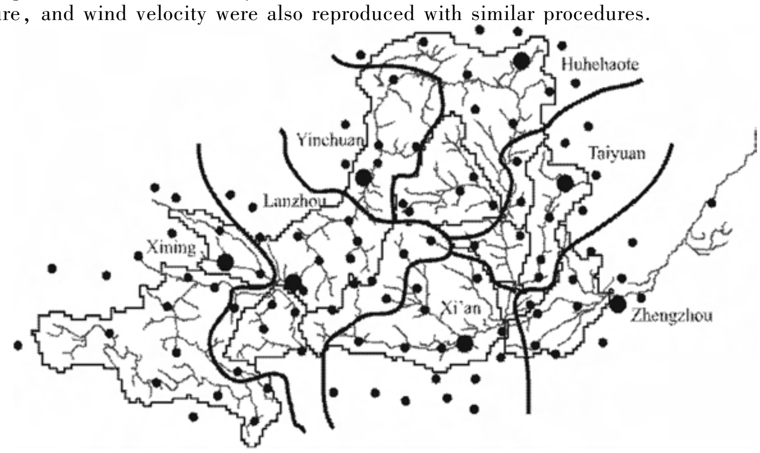


Fig. 3 Division of the basin estimation

4.3 Human activities

4.3.1 Population and production

Distributions of population and production in cities, towns, and villages of each province were calculated by use of statistical year books of province.

4.3.2 Water consumption

Water consumptions in cities, towns, and villages of each province were calculated by use of statistical year books of the provinces in the basin, Yellow River books and China water resources publicity.

4.3.3 Distribution and volume of reservoirs

Characteristics of reservoirs were obtained published data from administration.

4.4 Socioeconomic scenarios on development

4.4.1 Division of the basin

The basin was divided into five areas, the upstream, the middle stream, the Fenhe basin, the Weihe basin, and the downstream, depending on the stage of development and regional characteristics for estimation in future as shown in Fig. 4.

4.4.2 Population

The population in China reaches 1.3 billions in 2005 and has been increasing, the increasing rate of which is 5.89%. It is estimated to hit a peak in the middle of the 21 century and then decrease(see Fig. 5). Population increase in each region is estimated as presented in Fig. 6 due to the 11th five year Plan.

4.4.3 Water consumption

Basic units on domestic water use in each prefecture were calculated by dividing the amount of domestic water use by population. Basic units on industrial water use are also calculated with the amount of industrial water use and factories in a similar way. On the estimation in the future, the water supply on new requirement is assumed to be kept at the present level.

4.4.4 Socio – economic scenarios

Development in the society means several items, such as maximization of the basin benefit,

Fig. 4 Division of the basin for secenario setting

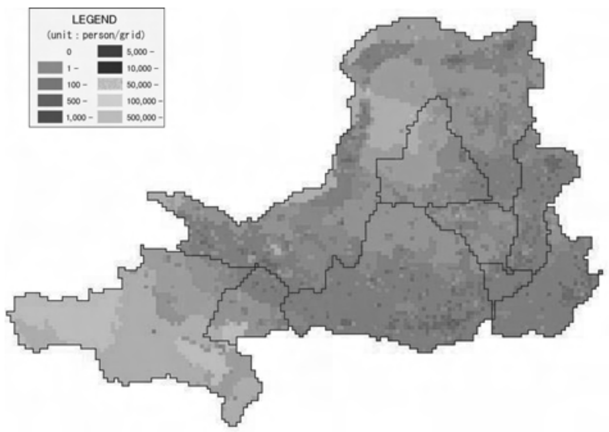


Fig. 5 Spatial distrbution of population

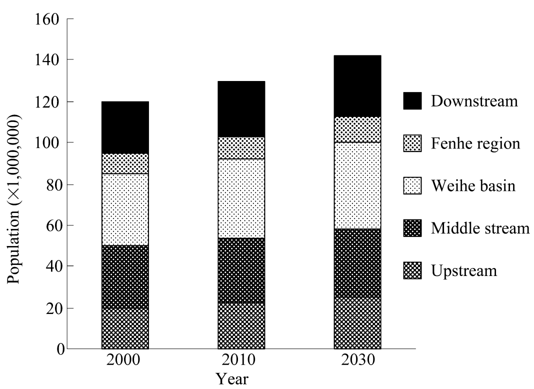


Fig. 6 Increase in population

rising of labour costs (= increasing of income), expanding of job opportunities, food security, ecological soundness, and reducing of sediments. One process to determine scenarios is shown in Fig. 7. Based on the process, several scenarios are adopted as presented in Table 3 and Table 4.

Table 3 Set conditions for secnarios

Secnario		1	2	3	4	5	6	7
Food production	Decrease	○	○					
	No change			○	○			
	Increase					○	○	○
Irrigation area	Reduction	○	○					
	No change			○	○			
	Expansion					○	○	○
Irrigation efficiency	No change	○	○					
	Development			○	○	○	○	○
Ratio of wastewater treated	No change	○		○		○		
	Development		○		○		○	○
Proportion of wastewater reused	No change	○		○		○		
	Development		○		○		○	○
Grain for green	No change	○	○	○	○	○	○	
	Promotion							○

Table 4 Conditions in each scenarion

	Present	2010	2030	2050	Applicable Scenario
Reduction ratio of the cultivated area	—	10%	20%	30%	1,2,7
Development of irrigation efficiency	40%	50%	60%	70%	3,4,5,6,7
Irrigation area ratio of the cultivated area	52%	70%	80%	90	5,6
		70%	85%	100%	7
Treatment ratio of domectic wastewater in uran area	20%	50%	70%	90%	
Introduction ratio of the water rcuse in urban area	0%	10%	20%	30%	2,4,6,7 Others are the present conditions
Treatment ratio of industrial wastewater	20%	50%	70%	90%	
Reuse ratio of industrial wastewater	33%	50%	60%	70%	

5 Simulation and estimation results

5.1 Simulation of water flow rate

Water flow rate was calculated with the coupled model for water quantity and quality. Fig. 8 indicates the observed and estimated annual mean flow rates in 1997 in the Yellow River. The calculated value of "GBHM + artificial" agrees well with the observed.

5.2 Estimation methods

Scenario evaluation was carried out on the benefit base. The net increasing benefit is the total

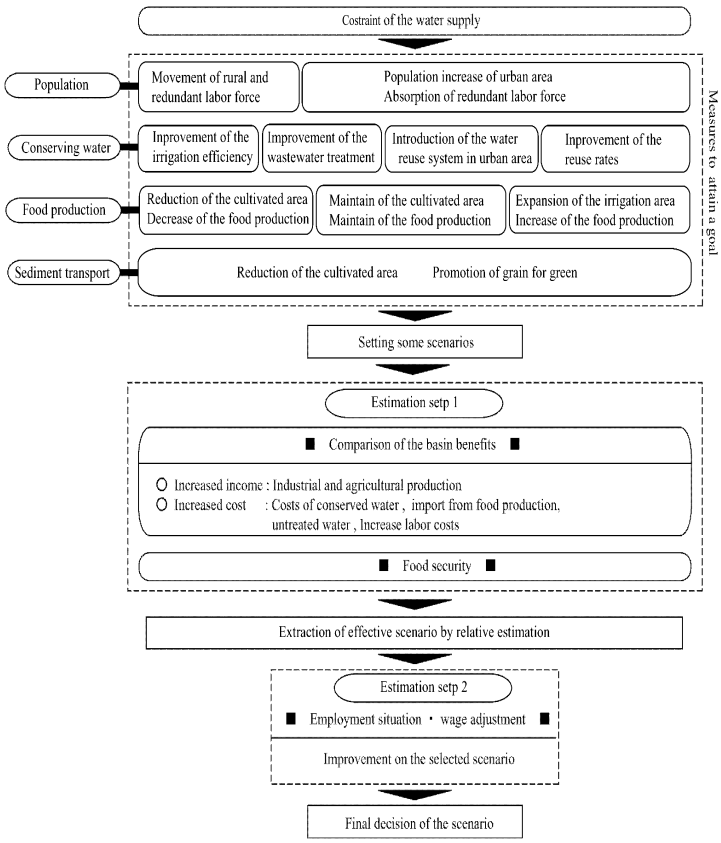


Fig. 7 The process to determine scenarios

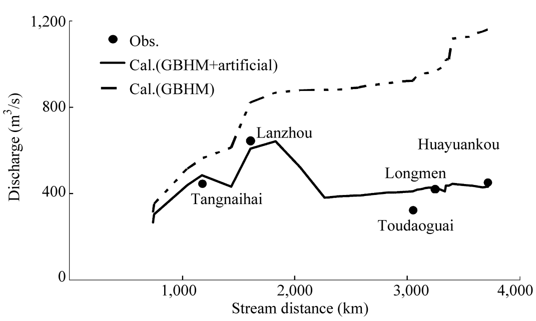


Fig. 8

increasing benefit subtracted by the total increasing costs.

The assumptions on this calculation are as follows.

5.2.1 Regarding reallocation of water resources

(1) Excess water in the agricultural sector is transferred to other sectors;
(2) Excess water in the industrial and daily life sectors is used inside their own sectors;
(3) Water resources are not conveyed to other basins.

5.2.2 Regarding production rates

(1) Productions in the agricultural and industrial sectors increase in proportional to water supply;

(2) The self - sufficient rate on food is 100% at the moment.

5.2.3 Regarding basic units

(1) The basic units of irrigation, daily lives in rural area, daily lives in urban area, and flash toilet at present is 4,279 t/hm^2, 41.5 L/(capita · day), 136.9 L/(capita · d), and 50 L/(capita · d), respectively.

5.2.4 Regarding economics

(1) The price of commodity and basic units of water utilization do not rise;

(2) Excess labor force in the agricultural sector is absorbed in the industrial sector with the same production efficiency and the rest is absorbed into the service sector;

(3) The labor cost in the urban area is kept steady and the labor cost from the agricultural sector to other sectors is also kept constant from the standpoint of development economics;

(4) The initial investment on domestic wastewater treatment, industrial wastewater, water - saving irrigation, expansion of irrigation facility, and forestation is 4.20 RMB/m^3,. 4.46 RMB/m^3, 5.28 RMB/m^3, 19,000 RMB/hm^2, and 0.23 RMB/hm^2, respectively;

(5) The maintenance cost on domestic wastewater treatment, industrial wastewater, water - saving irrigation, expansion of irrigation facility, and forestation is 0.46 RMB/(m^3 · a),. 0.43 RMB/(m^3 · a), 0.528 RMB/(m^3 · a), and 1,900 RMB/(hm^2 · a), respectively;

(6) The crop production is 0.13t/capita on maize and 0.14 ton/capita on wheat;

(7) The prices of maize and wheat imported are 804 and 1,523 RMB/t;

(8) Additional cost of treatment of untreated wastewater for drinking water is 1.5 RMB/ m^3;

(9) The difference of the production rates between rain - fed and irrigated cultivation is 3.69 t/(hm^2 · a).

5.3 Estimation results

Expansion of wastewater treatment and reuse of treated wastewater are able to make water resources, because polluted water does not work as water resources. The scenarios 6 and 7 are much better than the rest. The food security on Scenario 6 is best and the second best is Scenario 7. The food self - sufficiency in 2050 on Scenario 6 is 100% and 80 % on Scenario 7(see Fig.9).

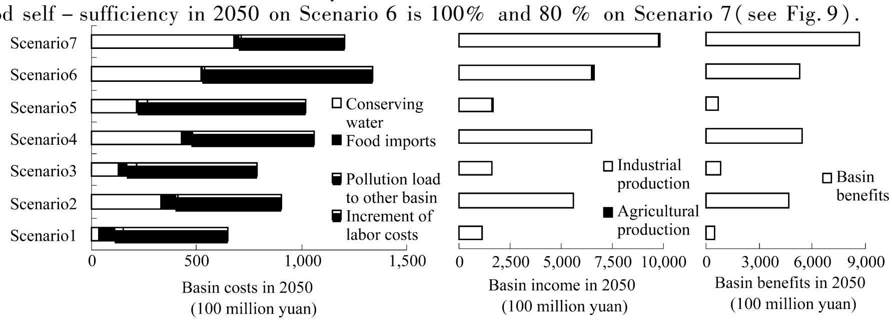


Fig.9 Income and benefit on each scenario(100 million RMB:2050)

As a further assumption, Scenarios 6 - 2, 6 - 3 and 7 - 2 were newly introduced and the values of which on cultivation area per capita in 2050 were set as 1.5, 3 and 3 times large as the present, respectively. The increase in cultivation area per capita leads to excess labour force from the agricultural sector to the others, so that increase in labour power in the service sector may cause the increase in cultivation area per capita.

Figs. 10 and 11 show the increases of farmers' wage and the total profit in the basin on each scenario. Firstly, on Scenario 6 - 3, the farmers' wage gets highest, which exceeds the wage of urban laborer, whereas the unemployment rate is high and the profit in the basin is the lowest. Scenarios 6 and 7 are better with profit in the basin, however the total output of industry per laborer rises compared to the present. Scenario 6 - 2 gives the highest priority to the food security and Scenario 7 - 2 does the maximum profit.

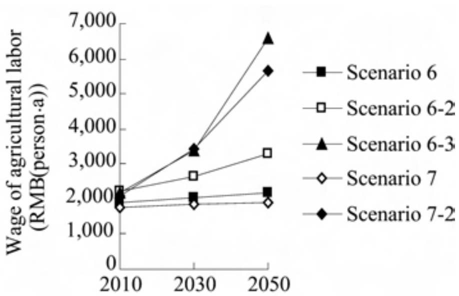


Fig. 10 Wage increase of farmers

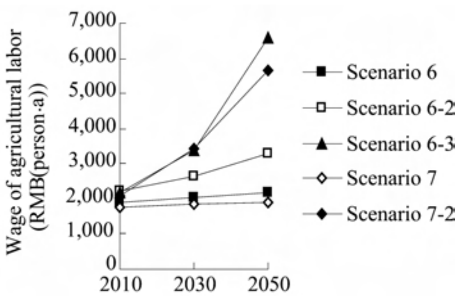


Fig. 11 The total profit in the basin

6 Discussions

In order to get to an optimal solution, several solutions are considered.

(1) Expansion of the labor power demand in the urban area due to massive investment. Although the number of laborer in the urban area in Scenario 6 – 3 is the same as that in Scenario 7 – 2, the employment rate in Scenario 7 – 2 is better than that in Scenario 6 – 3. Compared with the cost in order to obtain water resources in 2050, Scenario 7 – 2 (65 billion RMB) is bigger than Scenario 6 – 3 (48 billion RMB)

(2) Improvement of productivity in both rural and urban areas. The employment stability of Scenario 7 – 2 in 2010 and 2030 is both high. The total outputs of the industrial sector in 2010 and 2030 are about 240 billion RMB and 490 billion RMB, respectively, and the total outputs of the agriculture sector in 2010 and 2030 are about 4 billion RMB and 5.5 billion RMB, respectively. Therefore, the increase in productivity in both sectors brings the increase in the unemployment rate due to population growth.

(3) Restriction of migration. The farm land per capita in Scenario 6 – 2 in 2050 is 1.5 times as large as the present whereas that in Scenario 6 – 3 is 3 times as large as the present. In Scenario 6 – 3, the unemployment rate in the urban area becomes high; on the other hand, the employment rate in Scenario 6 – 2 is kept high. Therefore, the number of unemployment can be controlled by the restriction of migration.

7 Conclusions

(1) Development of a coupled model for water quantity and quality. A coupled model for water quantity and quality of the Yellow River was developed. The simulation results of water quantity and quality agreed well with observation data, and it was proved that the model has high reproducibility.

(2) Future meteorological conditions as external conditions in estimation were set with several types of statistical functions. Appropriate spatial distribution data on meteorology were obtained.

(3) Since there is no net increase in water resources, practical increase in water resources should be achieved with the conversion from irrigation water, saving water and reuse.

(4) Increase in the efficiency of water use in the Yellow River basin is possible by means of step – by – step urbanization and the conversion from irrigation water into other sectors, reduction in irrigated areas and augmentation of saving – water irrigation.

(5) Because the future scenarios assumes the increase in industrial production. It is necessary to validate the possibility of expanding the market including exports.

(6) The selection of a scenario applicable to a practical purpose is a matter of policy.

Reference

Katou, H. 1997: China's economic development and pre – eminence of the market – verification of the reform and opening – up period. Japan: The University of Nagoya Press.

Study of Measures for Sustainable Water Resource Utilization and Sound Eco – environmental Maintaining of the Weihe River Basin

Zhang Mei and ***Gong Hua***

Yellow River Engineering Consulting Co. Ltd. , Zhengzhou, 450003, China

Abstract: The Wei River is the largest tributary of the Yellow River, which runs through Gansu, Ningxia and Shaanxi provinces (autonomous region), across the rich Guanzhong Plain, and plays an important role in the Yellow River management and regional economic development. The river basin has inadequate total volume of water resources, and with rapid development of economy and society, conflicts between water demand and supply are increasingly acute, and water shortage has become an important factor restricting sustainable utilization of water resources and sound maintaining of ecological system of the basin. Under the conditions of intensive water saving and efficient utilization of existing water resources, implementation of the trans – basin water diversion project is the important approach to resolving water shortage, promoting economic and social development of the basin and maintaining the basic function of the river channel.

Key words: water resources, eco – environment, countermeasure, the Wei River Basin

1 Water – sediment feature and status of water utilization of the Wei River

Total mean annual volume of water resources of the Wei River basin is 11.072 billion m^3, mean annual natural sediment is 0.609 billion t, and catchment area, water and sediment volume are respectively 17%, 17.3% and 35% compared to the total of the Yellow river. Inflow and sediment of the basin are characteristic of different sources, uneven distribution in the year and large variation by year, particularly since 1990s, the flow at Huaxian Station on the Wei River averages 3.71 billion m^3 and sediment is 0.246 billion t, being less by 53.8% and 40.1% compared to the averages before 1990s. The fall of water volume is larger than that of sediment, which tends to create a more unfavorable water – sediment relation.

The channel runoff of the basin has declined to a big extent mainly due to rapid increase of water consumption by national economy. Total water use by national economy was 6.38 billion m^3 in 2000, being 57.6% of the total water resources; total water consumption was 4.48 billion m^3 at a rate of 40.5%. Increase of water consumption mainly proves with respect to the large increase of groundwater consumption, and overexploitation of groundwater has affected surface runoff, becoming one of the reasons for decreasing of surface runoff. From 1990 to 2000, water utilization by national economy in the basin increased by 1.71 billion m^3 at an annual rate of 3.2%, being much higher than 0.3% of the Yellow River, Huai and Hai rivers and 1.1% of the national average.

2 Outstanding problems in sustainable utilization of water resources and sound maintaining of ecologic system of the river

As the total volume of water resources of the basin is inadequate, and bearing capacity is limited, with rapid development of economy and society, a series of problems of acute conflicts between water demand and supply, degradation of water environment, sedimentation and narrowing of the lower channel and flood control have occurred, leading to the situation of "less water in upper reach, black water in middle reach and sedimentation in lower reach", and threatening the sustainable utilization of water resources and sound maintaining of ecologic system of the river basin.

2.1 Inadequate total volume of water resources being difficult to support sustainable economic and social development of the basin

Runoff per capita and per mu in the basin is respectively 293 m^3 and 125 m^3, being 12% of the national value per capita, 7% of the national value per mu, and equivalent to half of those in the Yellow River Basin. Total water volume is inadequate and arid disasters occur frequently. As recorded, there were 35 large arid disasters in the years of 1949 to 2000 at a frequency of 70%. Particularly in recent years, with rapid economic and social development, water use has been increasing largely, and it is difficult to coordinate water demand among all sectors. Since 1990s, 50% of the irrigation area has not been irrigated in time and adequately, and 29.7% of the irrigation area was not irrigated in 2000, and the conflict between water demand and supply becomes very sharp. Meanwhile, because of insufficient water source and water pollution, water has been short in many cities and counties, and water use by industry and life is in serious situation. At present, overexploitation has occurred in quite a few cities and well – irrigation areas, groundwater table has dropped in Guanzhong area with the hopper extent enlarging year by year, and yearly overexploitation has reached around 0.5 billion m^3. The situation is more serious in Xi'an, Xianyang and Baoji, the largest hopper area is over 400 km^2, with maximum settlement of 2.3 m, 11 exposed ground cracks in a length of 64.6 km, causing many environ – geological problems.

The basin is one of the economically developed areas in China, and at present, also one of the grain, cotton and oil crop production areas and industrial production areas. Quite a few of old – line large and medium – scale irrigation areas are distributed in the area, and mechanical, aviation, electronic, power, coal, chemical, building materials and non – ferrous metal industries form the development base in northwest region. In recent years, high – technology industries have developed rapidly, and have formed a development zone from Baoji in west to Weinan in East. The Tongchuan – based coal mine is located on the north bank of the Wei River, well known as "black waistband"; an industrial development belt prominently with energy industry has formed in Qingyang of Gansu Province. The total population was 31.55 million in 2000, GDP value was 150.5 billion yuan, and GDP per capita was 4,770 yuan. The Guanzhong area, so called as "800 – li Qin Plain", has developed economy, convenient communications, rich tourism resources, advanced education facilities, and possesses an important position in national economy in the basin. GDP value was 121.4 billion yuan in 2000, being 81.6% of the whole basin. Meanwhile, the basin is in the frontier of the west region, plays an important role in the development strategy of the region. Water demand by economic and social development in the future will further increase, and the present water resource situation will be difficult to support the sustainable development in he basin.

2.2 Difficulties in coordination of water resources and overall degrading tendency of ecological system of the river

2.2.1 Flow break – off, riverbed narrowing and "secondary suspended river"

With increase of water use in national economy, the volume for channel eco – environment has been largely occupied, and the inflow to the Yellow River has reduced very much. As sediment – transporting flows are far from enough, a great deal of sediment deposits in the lower channel, sedimentation in the riverbed becomes serious, and flood disasters increase. Since 1990s, sediment has accumulated for 0.26 billion m^3 with over 60% in the main channel, causing narrowing of the riverbed. Flow – conveying capacity of the main channel reduces from 3,000 m^3/s before 1990s to around 1,000 m^3/s, raising flood levels for the same discharge and resulting in frequent disasters. The floods of "92 · 8", "96 · 7" and "2000 · 10" all caused calamities in the lower reaches. Flood peak discharge at Xianyang, Lintong and Huaxian stations was respectively 5,340 m^3/s, 5,100 m^3/s and 3,570 m^3/s in 2003, recording the highest flood levels in history correspondingly. In particular, water level of 342.76 m at Huaxian Station is higher by 0.51 m than that in 1996 (flood peak discharge at the station is 3,500 m^3/s), breaching happens at one location of the stem dyke in the lower reaches, and 10 locations at Nanshan tributary, leading to serious harm to Linwei District of Weinan City, Huaxian County and Huayin, and direct economic loss is 2.8 billion yuan.

2.2.2 Increasingly aggregating of water pollution, endangering existence of human beings

Discharge of wastewater and sewage in the basin doubled in 2000 compared to the volume in 1982, concentrating in Baoji, Xianyang and Xi'an along the river. In the evaluated reaches of 2,600 km in the stem Wei River and important ranges of major tributaries, 24.2% of the length is of grade Ⅳ water, 53.8% of the length is of grade V and below, including 50.6% of the stem river length in grade V and below, and the water quality downstream Xianyang is below grade V around the year, losing its basic function.

Because of infiltration of polluted water and eluvial waste solids, groundwater pollution has become serious in important towns and industrial zones in the basin, groundwater is affected in Baoji, Xianyang and Xi'an. Groundwater pollution covers an area of 470 km^2 in Xi'an, and sewage water is used for irrigation in some areas, polluting not only groundwater but also soil and crops. Water pollution is increasingly serious, leading to pollution of water sources for living and agricultural water, and industrial water quality is not guaranteed, and water environment downstream Tongguan of the Yellow River is seriously affected.

3 Analysis of water demand by economic and social development and maintaining of ecological system of the river

In accordance with the requirements for the comprehensive planning of national water resources, prediction of water demand in the basin for different level years is carried out with respect to production, life and ecology out of channel and ecology in channel.

3.1 Water demand by economic and social development

As a production base of grain, cotton and oil crops and industry, the river basin, particularly the Guanzhong area, is the frontier of west development strategy, and future development is in great potential. The prediction of the water resource planning of the Yellow River shows, under the condition of fully considering the transfer of industrial structure and water – saving of all sectors, and strict controlling the growth of water demand, the demand for national economy in the basin is respectively 7.63 billion m^3, 8.77 billion m^3 and 9.12 billion m^3 in 2000, 2020 and 2030. Water demand in the Guanzhong area is respectively 5.67 billion m^3, 6.39 billion m^3 and 6.55 billion m^3, being 71.8% to 74.3% of the total in the basin.

3.2 Water demand by ecological system of the river

The Wei River is highly laden with sediment, and sound maintaining of ecological system of the river requires flows for sediment transport, and base flows for ecology in non – flood season.

With consideration of over – channel flow in different periods and variation of the river channel, river training works and standards of flood control expansion works, discharge with medium flows in the lower channel is set to be 3,000 m^3/s. Based on the scouring characteristics of over 100 floods since 1974, the relationship of sediment – transport flows and sediment, and channel scour and pattern is established, and the situation of inflow and sediment in different level years is predicted for the basin, and for the years of 2000, 2020 and 2030, sediment – transport water volume for maintaining medium channel flows in the lower channel is set to be respectively 5.81 billion m^3, 5.07 billion m^3 and 4.75 billion m^3. With the requirements of maintaining the basic channel pattern, a certain diluting and self – cleaning capacity, water use by ecological landscape in the channel section through the city and recharge to groundwater, minimum ecological flow demand in channel is 0.613 billion m^3 in non – flood season (November to next May). Flow demand for maintaining ecological system in channel is respectively 6.46 billion m^3, 5.77 billion m^3 and 5.48 billion m^3 for the level years of 2000, 2020 and 2030.

Above all, for the level years of 2000, 2020 and 2030, water volume for maintaining economic and social development and ecological system of the river basin will be 14.05 billion m^3, 14.46 billion m^3 and 144.58 m^3. Water demand prediction for all the level years is shown in Table 1.

Table 1 Summary of water demand prediction results for all level years of the basin

Unit: $10^8 m^3$

Level year	Life			Production			Ecology			Subtotal of out-of-channel	Total
	Town	Agri-culture	Sub-total	Secondary, tertiary industries	Agri-culture	Sub-total	Out of channel	Channel	Sub-total		
2000	3.6	3.6	7.2	14.8	53.9	68.8	0.33	64.2	64.6	76.3	140.5
2020	8.0	4.3	12.3	24.4	50.1	74.5	0.87	56.8	57.7	87.7	144.6
2030	10.4	4.3	14.7	25.3	50.0	75.3	1.16	53.6	54.8	91.2	144.8

As predicted, with gradual implementation of soil and water conservation, gradual reduction of sediment yielding in the level years is found, and corresponding sediment-transport flows in channel is reduced from 5.81 billion m^3 in the present level year to 4.75 billion m^3 in the level year of 2030. With economic development, population growth and improvement of living standard, water demand for national economy increases from 7.63 billion m^3 in the present level year to 9.12 billion m^3 in 2030 at an annual rate of 0.6%.

3.3 Supply and demand situation of future water resources

With the basic requirement for maintaining the healthy life of the river and the principle of sustainable utilization of water resources, and under the condition of satisfying domestic water use for municipal and rural residents, ecological water demand for the lower limit is considered, and the remaining volume is distributed for all production sectors out of channel. Supply and demand balance of water resources for all level years in the basin is given in Table 2.

Table 2 Supply and demand situation of water resources for all level years

Unit: 10^8 m^3

Region	Level year	Out-of-channel			Channel				Total of shortage
					June to Oct.		Nov. to May		
		Water demand	Water supply	Water shortage	Water demand	Water shortage	Lower limit	Water shortage	
Wei River	2000	76.3	62.9	13.4	58.1	16.3	6.13	0	29.6
	2020	87.7	71.5	16.2	50.7	8.7	6.13	0	24.9
	2030	91.2	73.2	17.9	47.5	7.59	6.13	0	25.5
Zhuang-zhong	2000	56.9	45.8	11.1	58.1	16.3	6.13	0	27.4
	2020	64.2	51.4	12.9	50.7	8.7	6.13	0	21.5
	2030	65.8	51.3	14.6	47.5	7.6	6.13	0	22.1

As shown in Table 2, under the condition of strict controlling the enlargement of farmland area, popularization of water-saving measures and enhancing of pollution prevention, water shortage is respectively 2.96 billion m^3, 2.49 billion m^3 and 2.55 billion m^3 in the level years of 2000, 2020 and 2030. Water shortage mainly concentrates in Guanzhong area, being 86.5% to 92.3% of the total shortage in the basin. Agriculture is the sector with the largest shortage out of channel, and the second is water use for sediment transport; the period of shortage concentrates in June to October when sediment transport is required, and March and April when agricultural water demand is relatively high.

4 Measures

4.1 Overall arrangement of water use for life, production and eco – environment, and optimized distribution of water resources

In accordance with the basic requirement for maintaining the healthy life of the river and the principle of sustainable water resource utilization, water use for life, production and eco – environment in the river basin is overall arranged. For water resource distribution, water use for municipal and rural domestic life is firstly satisfied, and also the lowest demand for eco – environment, with the remaining allocated to all sectors out of the channel. Water resource distribution of the river basin is given in Table 3.

By the level year of 2010, with implementation of all water – saving measures, national economic water demand is 9.09 billion m^3, and relevant water consumption is 6.81 billion m^3; with the practical and feasible scheme, the water diversion works including the phase I from the Tao River to the Wei River, from the Qianyou River to the Shibianyu River and from the Hongyan River to the Shitou River are actively arranged to increase water diversion of 0.53 billion m^3. With the first priority of eco – environmental water demand out of channel for 0.46 billion m^3, the lower limit of eco – environmental water demand in channel for 5.11 billion m^3 and unusable water consumption of 0.54 billion m^3, consumable water allocated for production and life is 5.46 billion m^3, with water shortage of 1.34 billion m^3 at a rate of 10.4%.

Table 3 Water Resource Distribution of the Wei River Basin Unit: 10^8 m^3

Total water resource			Water resource demand				
In the basin	Water diversion out of basin	Total	Lower limit of eco – environ mental water demand	Unusable water consumption	Water consumption for production and life	Total	Water shortage
110.6	5.3	115.8	55.8	5.4	68.1	129.2	13.4

4.2 Reasonable controlling of discharge at main sections on the stem river ensuring basic water requirement for sound eco – environmental maintenance

The basic requirements for maintaining sound eco – environment of the river rest with water provision for sediment transport and ecological base flows in non – flood season. The main controlling sections of Linjiacun, Huaxian and Zhuangtou are selected, for which the requirement for the lower limit of eco – environment, water resource equilibrium in the basin, soil and water conservation, consumable volume for production and life and water diversion is considered, discharge indexes at all sections with normal flows by the level year of 2010 are then put forward; with mean annual inflows, discharge at Lingjiacun, Zhuangtou and Huaxian is respectively 1.51 billion m^3, 0.54 billion m^3 and 4.58 billion m^3 as shown in Table 4.

Table 4 Controlling discharge indexes at main sections in normal – flow year Unit: 10^8 m^3

Section	Linjiacun	Huaxian	Zhuangtou	Inflow to Yellow River
Mean annual water volume	15.1	45.7	5.4	51.1

4.3 Building of society with economic water use and efficient use of local water resources

Among all the national economic sectors of the basin, agricultural irrigation and industrial water use take 76% , being the main water – saving part. The analysis of water – saving potential in the basin indicates the mean irrigation quota is 310 m^3/s in 2000, and with implementation of water – saving measures and adjustment of cropping structure, the quota is lowered to respectively 272 m^3/s and 261 m^3/s in 2020 and 2030. With the development tendency of urbanization and industrialization, industrial water use will increasingly rise, but with water – saving measures and adjustment of industrial structure, industry has a certain potential of water reduction. Industrial production value added per thousand yuan takes water of 264 m^3 in 2000, and respectively 54 m^3 and 28 m^3 per thousand yuan in 2020 and 2030. The volume in U. S. , France, South Korea and Germany is respectively 164 m^3, 77 m^3, 60 m^3 and 43 m^3. The level of economic water use in industry for the Wei River basin will be nearly the same as the standard of developed countries.

The engineering and non – engineering measures and fully tapping of water – saving potential will to some extent alleviate water shortage. But because the total volume of water resources is short, even with full implementation of water – saving measures, by the level years of 2020 and 2030, water shortage of the Wei River basin in the normal – flow year will still be 2. 49 billion m^3 and 2. 55 billion m^3, and even more in the low – flow year. If water – saving measures are not executed, the water – shortage situation will become severer. For such an area being severely short of water, the conflict of water demand and supply shall be resolved not only by water saving, but also by undertaking the trans – basin diversion works at the proper time so as to efficiently increase water resources in the Yellow River basin, which is the important approach to alleviation of water shortage.

4.4 Undertaking of trans – basin diversion works basically resolving water shortage in the Wei River Basin

For alleviating of water shortage in the Wei River basin, the early engineering work is being undertaken for water diversion from the Hanjiang to the Wei River, and the west line south – to – north water diversion project, and preliminary study is being made for the Xiaojiang diversion scheme in recent years.

The Han – to – Wei diversion scheme is from the Hanjiang to the Hei River, a tributary of the Wei River on the right bank, and then to the stem river with a route of 79. 2 km, pumping head of 210 m and annual diversion of 1. 5 billion m^3. Water supply by the west line south – to – north diversion project is to divert water from Maqu County the upper stem Yellow River to the upper Tao River, and then from the middle to the upper Wei River, by the two routes of the Yellow River to the Tao River and then to the Wei River. The total diversion length is 74. 6 km, including the two routes of 51. 1 km and 23. 5 km respectively by gravity flow.

The Han – to – Wei diversion scheme is in a short distance with relatively small engineering scale, short construction period, simple social problems induced and easy implementation, but being limited by the water resource conditions of the Hanjiang, diversion volume is only 1. 5 billion m^3, and the confluence to the Wei River is at a low elevation, only resolving the water shortage of production and life in Guanzhong area, not the whole river. The west line diversion project by supplying water of 2 billion m^3 to the Wei River source will overall resolve the water – shortage problem of national economy of the Wei River basin, and also water flow entering the Wei River is properly reduced, and together with the Han – to – Wei diversion scheme, water shortage of the Wei River will be resolved.

Recently, the Xiaojiang diversion scheme from Three – gorge Reservoir to the Wei River is being undertaken. The works divert water from Three – gorge Reservoir to the Wei River near Xi'an with a length of 453. 3 km, pumping head of 378 m and annual diversion of 4. 01 billion to 10. 29 billion m^3. The works are of a large scale, and the diversion concentrates in June to September (or May to October) to resolve sedimentation in the lower reaches of the Wei River, and further more the reaches downstream of Tongguan on the Yellow River. With high pumping head and high operating cost, and because of the requirement of regulating and storage works for sediment reduction, the engineering scheme needs further study.

5 Conclusions

The Wei River basin has deficient total volume of water resources, and by fully considering of water – saving measures, water shortage by the level years of 2020 and 2030 is still around 2.55 billion m^3, including 1.62 billion to 1.79 billion m^3 for national economy out of channel, being 65% to 70% of the total shortage. With reference to water sources, construction conditions and water shortage of the Wei River basin, recently the preliminary works for the Han – to – Wei diversion scheme and the west line south – to – north diversion project shall be urgently implemented to quickly resolve the problem of the basin, to support the sustainable social and economic development by sustainable utilization of water resources. Meanwhile, the study for the Xiaojiang diversion scheme shall further proceed to realize sedimentation reduction and creation of the river channel for medium flows and sound maintaining of the ecological river system.

Impacts of Climate Change on Water Resources in the Yellow River Basin *

Jia Yangwen[1], ***Qiu Yaqin***[1], ***Gao Hui***[1], ***Niu Cunwen***[1], ***Shen Suhui***[1], ***Peng Hui***[1] and ***Liu Weigang***[2]

1. Department of Water resources, Institute of Water resources & Hydropower Research (IWHR), 20 Chegongzhuang West Road, Beijing, 100044, China
2. Cold and Arid Regions Environment and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, 730000, China

Abstract: Climate change is one of the main reasons of water resources decrease and ecological deterioration in the Yellow River basin in recent years. The WEP – L distributed hydrological model was applied in this paper to analyze the influence of climate change on water resources during the past fifty years, and analyze the response of water resources to the main climate factors such as precipitation and air temperature in the headwater area of the Yellow River basin and the sub – basin of Yiluo river, a tributary in middle reaches of the Yellow River as studied area. The results demonstrated that under the impacts of climate change, the change of water resource from 1980 to 2000 compared with that from 1956 to 1979 were as follows: surface water resources decreased 3.03 billion m^3, groundwater resources decreased 2.50 billion m^3 with 380 million m^3 decrease of the groundwater non – overlapped with surface water, and the total water resources decreased 3.42 billion m^3. With increase of air temperature, the total water resources decreased with the decrease of surface water resources and groundwater, and the groundwater non – overlapped with surface water changed little. The tendency of total water resources and its composition was the same as change of precipitation. The responses of monthly runoff to air temperature varied with seasons. The responses of monthly runoff to precipitation change could be divided into three phases, the dry season phase, the wet season phase, and the transitionary season phase.

Key words: impact, climate change, water resources, the Yellow River, distributed hydrologic model

1 Introduction

Due to the rapid increase of the world's population and the quick economic development, a great amount of greenhouse gas was released and some climate conditions such as precipitation and temperature were changed, which result in change of water resources situation and water resources and environmental problems.

Although the United States National Research Association (USNA) hold a conference discussing the relationship between climate, climate change and water supply early in the 1977, the research about how climate change influences water resources hadn't drawn great attentions of the international hydrology group until middle of 1980s. In China, special researches have been performed in the Seventh, Eighth, Ninth "Five – Year" programs and GAME program since 1980s (Jiang Tao, 2003).

There are many uncertainties in the research of climate change. These uncertainties are caused by three factors, including released amount of greenhouse gas, response of climate system and changeability of nature (Metoffice, 2002). Study on change of climate on evolvement of hydrology

* This study is financially supported by the Special Project of Institute of Water Resources and Hydropower Research (JIZI – KF0701) and the National 973 Project (2006CB403404).

cycle and water resources will play great influence, and has important academic and realistic significances for future planning and designing, development and utilization, and management of water resources system.

2 Change tendency of climate in the Yellow River basin in the past 50 years

Since the 20 th century, the increment of CO_2 and other greenhouse gas in the atmosphere have resulted in the tendency of global warming. In the Yellow River basin, the tendency of climate was fluctuate warming. Fig. 1 shows the temperature and precipitation change from 1956 to 2000 in the Yellow River basin. Table 1 and Table 2 show the temperature and precipitation change from1956 to 2000 in 8 sub – basins of the Yellow River Basin.

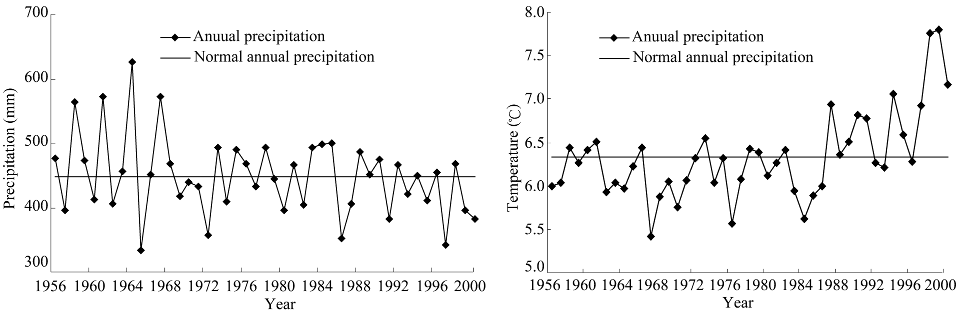


Fig. 1 Change of air temperature and precipitation from 1956 to 2000 in the Yellow River Basin

Table 1 Change of air temperature from 1956 to 2000 in the Yellow River basin and 8 sub – basins

Unit: ℃

River basin	1956 ~ 1959	1960 ~ 1969	1970 ~ 1979	1980 ~ 1989	1990 ~ 2000	1956 ~ 1979	1980 ~ 2000
Whole Basin	6.2	6.1	6.2	6.2	6.9	6.1	6.6
Upstream Longyangxia	–1.5	–2.5	–2.4	–2.2	–1.9	–2.3	–2.1
Longyangxia—Lanzhou	1.7	1.3	1.4	1.5	2.3	1.4	1.9
Lanzhou—Hekouzhen	6.6	6.8	6.9	7.1	8.0	6.8	7.6
Hekouzhen—Longmen	8.2	8.3	8.3	8.3	9.3	8.3	8.8
Longmen—Sanmenxia	9.6	9.7	9.7	9.7	10.4	9.7	10.1
Sanmenxia—Huayuankou	12.6	12.9	12.9	12.7	12.5	12.8	12.6
Downstream of Huayuankou	12.2	12.6	12.5	12.5	12.1	12.5	12.3
Neiliuqu	7.2	7.4	7.5	7.6	8.4	7.4	8.1

The above show that, the general tendency of air temperature in the Yellow River basin, although still with some differences in the process, is increasing, which is consistent with the global warming to some extents. The air temperature changed largest in the headwater area. Precipitation shows a fluctuated decline tendency. These changes will bring new challenge to development and utilization of water resources in the Yellow River basin.

Table 2 Change of precipitation from 1956 to 2000 in the Yellow River Basin and 8 sub – basins

Unit: mm

River basin	1956 ~ 1959	1960 ~ 1969	1970 ~ 1979	1980 ~ 1989	1990 ~ 2000	1956 ~ 1979	1980 ~ 2000
Whole Basin	477.0	471.3	446.1	445.4	422.7	461.8	433.5
Upstream Longyangxia	460.4	494.2	482.0	507.2	468.8	483.5	487.1
Longyangxia—Lanzhou	476.3	491.6	487.3	480.4	459.7	487.3	469.6
Lanzhou—Hekouzhen	288.9	277.3	269.5	243.3	262.2	276.0	253.2
Hekouzhen—Longmen	510.6	463.6	427.9	415.6	397.3	456.6	406.0
Longmen—Sanmenxia	585.4	578.4	532.7	553.6	492.3	560.5	521.5
Sanmenxia—Huayuankou	738.5	685.0	639.9	671.7	606.1	675.1	637.4
Downstream of Huayuankou	697.2	680.3	645.7	564.4	660.0	668.7	614.5
Neiliuqu	287.3	305.2	274.1	251.5	251.8	289.2	251.7

3 Climate change impacts on water resources in the Yellow River Basin

3.1 Analysis methodology

Many different hydrological models have been put forward by lots of scholars to study the influence of climate change on hydrological cycle and water resources. These models mainly include statistical models, conceptual models and distributed hydrological models. Through analyzing historical data such as meteorological factors (precipitation and air temperature) and hydrological factors (runoff and flood frequency, etc.), the statistical models construct the statistical relationship between each factors model, based on which the impact of climate change on water resources can be analyzed. Conceptual hydrological models simulate runoff processes under the assumed climate scenarios and analyze the impact of the climate change on runoff, evaporation, flood peak discharge, flood peak time and distribution of hydrological parameters. Distributed hydrological models couple global or regional climate models with distributed hydrological models or take the output of climate model as its input in offline pattern to study the impact of climate change on runoff in macro – scale areas (Kite et al., 1999).

The distributed hydrological models can overcome the insufficiencies of statistical and conceptual models such as the problems that it is difficult to describe the difference of land surface process under changed environment (impact assessment of land use and climate change), and the parameters in model is inclined to be impacted by the dependence and uncertainty of historical data.

WEP – L distributed hydrological model is applied in this paper to analyze the impact of climate change on water resources in the Yellow River basin.

3.2 Distributed hydrological model

3.2.1 Model introduction

WEP – L (Water and Energy transfer Processes in Large river basins) model (Jia et al, 2006; Jia Yangwen et al, 2005) was developed as a distributed hydrological model in large scale river basin in the Project of National Key Fundamental Development Research (National 973 Project). The WEP – L model is constructed based on the grid – based WEP model (Jia Yangwen et al., 2006; Jia et al., 2001).

To adapt to the super basin like the Yellow River basin, and to avoid calculation disasters with fine grids as well as distorted calculation with "coarse grids of large area", the calculation unit of "contour strip within sub – basin" was applied in the WEP – L model. Furthermore, the attribute information such as terrain, river system, vegetation, soil and land use in each calculation unit were based on spatial data in 1 km grid cells. According to the 1 km DEM and vector graph of observed river system and GIS technique, the Yellow River basin was divided into 8,485 sub – basins containing spatial topological information and every sub – basin is divided into 1 ~ 10 counter strips. Thus, the Yellow River basin is divided into 38,720 counter strips. Faced with large amount of calculation units and data, improved Pfafstetter rule is put forward in order to construct river system, basin partition and coding system containing spatial topological information. Each sub – basins and their corresponding river is coded and then arranged while contour strips in each sub – areas are calculated from high strips to low strips.

Detailed information about this model was introduced in the following references (Jia et al., 2006; Jia. et al., 2005; Jia et al., 2001). In WEP – L model, variation of temperature and precipitation along with terrain, simulation of snow melt runoff and temperature influence on water movement in frost were taken into account. The variety of temperature and precipitation along terrain was interposed based on their respective lapse rate along elevation and DEM (Zhou et al., 2004). Snow melt runoff is simulated by degree – day parameter (Maidment 1992), while hydraulic conduction coefficient of frozen earth affected by temperature can be described as the following equation:

$$k_f = \begin{cases} k_0 & T_a \geqslant T_c \\ k_0 e^{a(T_a + b)} & T_a < T_c \end{cases} \tag{1}$$

in which, k_f is hydraulic conduction coefficient of frozen earth; k_0 is hydraulic conduction coefficient when frozen earth melts absolutely; T_a is daily average temperature; T_c is critical temperature between freezing and melting; a and b are constant. The identifications of T_c, a and b are based on runoff process. $T_c = -5$ ℃, $a = 0.05$, $b = 0.25$ in the Yellow River basin. Research indicated that in upper reaches of the Yellow River runoff process in dry season is difficult to correspond to that of observed value in hydrology station, if the impact of temperature on frozen earth waterpower conduction coefficient is not taken into account.

3.2.2 Model validation

Appling the varied time step (that is, when rainfall intensity is above 10 mm, time step of 1 hour is applied in infiltration and runoff process and time step of 6 hour is applied in conflux process of sloping field and river. While the time step of 1 day is applied in other situation.), the hydrological process of 38,729 calculation unit and 8,485 river from 1956 to 2000 are simulated. In which, the 21 years from 1980 to 2000 is model calibration period. The main calibrated parameters include saturated hydraulic conductivity, conductivity of river bed materials, Manning roughness, maximum depression storage of land surface, and the conduction coefficients and storage coefficients of aquifer. The initial conditions of state variables such as runoff in river, groundwater level, soil moisture content, depression storage of land surface and snow depth are assumed initially, and then replaced by simulated values after continuous 45 years simulation.

The calibration rules are: ① the error of annual average runoff is as small as possible; ② Nash – Sutcliffe efficiency is as large as possible; ③ the correlation coefficient between the simulated runoff and the observed ones is as large as possible. After calibration of the model, all parameters is kept invariable, simulation results of runoff from 1956 to 2000 is validated by comparing the simulated daily or monthly runoff with the observed ones of 23 main hydrological stations in 45 years. The validated results of hydrological station in main section are in Table 3.

3.3 Response of water resource to climate change in the Yellow River basin

In this paper, the distributed hydrological model is applied to simulate the natural hydrological process under the 1956 ~ 2000 meteorological condition in the Yellow River basin. In order to remove the interference of surface conditions, the underlying surface condition in 2000 is applied.

Comparing the quantity of water resources under different meteorological conditions, the response of water resources to climate change in the Yellow River basin can be worked out.

Table 4 is the simulated water resources from 1956 to 1979 in sub – basins of the Yellow River basin. Table 5 is the simulated water resources from 1979 to 2000 in sub – basins of the Yellow River Basin.

Table 3 Model validation results of natural runoff

Hydrological station	Annual average natural runoff ($10^8 m^3$)	Annual average simulated runoff ($10^8 m^3$)	Relative error (%)	Nash – sutcliffe efficiency of monthly runoff
Tangnaihai (in main reach)	204.0	198.0	–2.9	0.819
Guide (in main reach)	212.0	216.3	2.0	0.826
Lanzhou (in main reach)	333.0	333.7	0.2	0.857
Sanmenxia (in main reach)	503.9	498.7	–1.0	0.718
Huayuankou (in main reach)	564.0	546.7	–3.1	0.758
Huaxian (in Weihe river)	85.8	81.7	–4.9	0.722

Table 4 Quantity of water resources from 1956 to 1979 in the Yellow River Basin

Units: 10^8 m^3

Sub – baisn	Surface water resources	Groundwater resources		Total water resources
		Total	Non – overlapped with surface water	
Whole Basin	597.01	393.94	102.83	699.88
Upstream Longyangxia	210.05	64.40	1.85	211.90
Longyangxia—Lanzhou	118.03	35.39	0.65	118.68
Lanzhou—Hekouzhen	22.04	51.41	27.39	49.43
Hekouzhen—Longmen	46.78	50.70	11.98	58.77
Longmen—Sanmenxia	124.12	122.45	29.6	153.73
Sanmenxia—Huayuankou	47.53	31.53	1.37	48.90
Downstream of Huayuankou	24.90	14.62	9.09	33.99
Neiliuqu	3.55	23.43	20.9	24.45

Table 5 Quantity of water resources from 1980 to 2000 in the Yellow River Basin

Units: 10^8 m^3

Sub – baisn	Surface water resources	Groundwater resources		Total water resources
		Total	Non – overlapped with surface water	
Whole Basin	566.68	368.93	98.99	665.72
Upstream Longyangxia	212.79	65.33	1.92	214.71
Longyangxia—Lanzhou	109.92	35.37	0.66	110.58
Lanzhou—Hekouzhen	16.42	43.64	31.27	47.69
Hekouzhen—Longmen	39.40	43.94	8.94	48.34
Longmen—Sanmenxia	114.57	117.38	28.23	142.80
Sanmenxia—Huayuankou	47.82	30.44	1.21	49.03
Downstream of Huayuankou	22.73	13.35	8.67	31.40
Neiliuqu	3.04	19.46	18.08	21.12

It can be seen from the calculation results that the annual – averaged air temperature from 1980 to 2000 increase 0. 5 degree but the precipitation decrease 28 mm in the Yellow River basin, compared with those from 1956 to 1979. Decrease of precipitation results in decrease of water resources. While increase of air temperature results in increase of radiation near the surface, latent heat, sensible heat and thermal conduction, thereby increase evaporation, and a corresponding reduction of surface water and groundwater recharge quantity. Under the action of these two main factors, the change of water resources is that, surface water resources decrease 3. 03 billion m^3, groundwater resources decrease 2. 5 billion m^3 with 380 million m^3 decrease of groundwater non – overlapped with surface water, and the total water resources (defined as the sum of surface water resources and groundwater resources non – overlapped with surface water resources) decrease 3. 42 billion m^3.

The changes of water resources in 8 sub – basins differ from one another due to the different changes of precipitation and temperature.

4 The response of water resources to changes of different climate factors

There are three methodologies to evaluate the impacts of climate change: impact, interaction and integration method (IPCC, 1994). Impact method is mainly applied in the research about impacts of climate change on regional hydrological cycle and water resources, that is, What – if pattern: if the climate changes, how every hydrological cycle would change (Jiang, 2002).

Two climate scenarios are mainly applied in the study on climate change impacts in China. One is given artificially according to the possibility of climate change, such as it assumed that the temperature increases 0. 5 ℃, 1 ℃ or 2 ℃, and the precipitation increases or decreases 10%, 20%. The discretional combinations make up of the imaginary scenarios. The other one is given on the base of the outputs of GCMs (GCMs: general circulation models). Generally, seven forecast values of GCMs by Zongci Zhao are turned into climate scenarios.

The influence of climate factors on water cycle process is complicated and multilevel. In this article, only the impacts of temperature and precipitation on water resources are studied. Temperature and precipitation are inter – acted, but in this paper, it is assumed that temperature and precipitation do not inter – act each other, and their spatial distributions are invariable. The first climate scenarios are applied.

4.1 The Yellow River headwater area

The environmental problems of glacier degradation, frozen earth degeneration, and lake drying up interact and are aggravating each other under the impact of climate change. At present time, the environmental depravation of the headwater area of the Yellow River (denotes the upstream of the Tangnaihai hydrological station) has weakened the carrying – capacity of water resources. The headwater area is the main water source of the Yellow River. The problems of water resources decrease and shortage will bring an important influence on the socio – economy in the Yellow River basin for a long time. Therefore, this paper focuses on the simulation analysis on runoff response to the climate in headwater area of the Yellow River Basin.

4.1.1 Simulated Scenarios

According to the tendency of climate change in recent year in headwater area of the Yellow River basin, 8 Scenarios are selected, that is, the air temperature increase 1 ℃ and 2 ℃, and decrease 1 ℃ and 2 ℃; precipitation increase 10% and 20%, decrease 10% and 20%.

4.1.2 Scenarios analysis

4.1.2.1 Impact of air temperature on water resources

The proportions of runoff change in 45 – year series were simulated based on the assumed scenarios. The result is shown in Fig. 2.

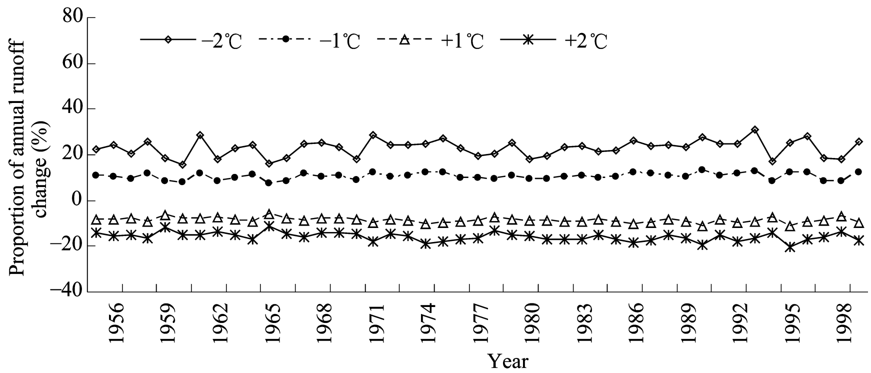


Fig. 2 Response of annual runoff to the air temperature change in 45 – year series

The response of annual runoff in 45 – year series to temperature change is same. Runoff decreases with increase of temperature, while increase with decline of temperature. It can be clearly seen that in a same scenario the proportion of runoff change is at a same level without obvious relation with precipitation amount.

On the basis of the annual runoff analysis, the response of average monthly runoffs to temperature change was studied (Fig. 3).

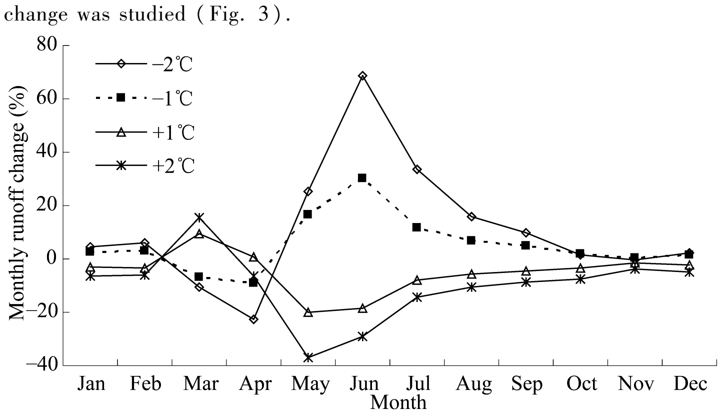


Fig. 3 Average of monthly runoff under temperature change (1956 ~ 2000)

The response of monthly runoffs averaged in the 45 – year series to temperature change is quite different from that of the annual runoff in the basin. The curves in Fig. 3 intersect in spring season every year. Because the headwater area locates at altiplano where there is perennial snow, when the temperature turns to be above 0 ℃ in March or April every year, the snow melts into water which causes spring flood. Thaw, the main part of the runoff at this season, is sensitive to temperature change, so monthly runoff increase when temperature increases. The maximal proportion of change is 63.67% under temperature increase 2 ℃ in March, 1989. From November or December to January or February of the next year, when the temperature is so low that the snow could not melt even under the temperature increase, the runoff response to the temperature is insensitive. From May to October every year when the air temperature is above 0 ℃, temperature change affects the evaporation greatly, so monthly runoffs decrease with temperature increase as the main part of runoff is surface flow.

The above results are consistent with the study results of the climate change impact on hydrological regimes in the Rhine basin by Middelkoop et al. (2001), although they adopted a different approach from this study. Middelkoop et al. (2001) used the results of UKHI and XCCC GCM – experiments and found higher winter discharge as a result of intensified snow – melt and increased winter precipitation, and lower summer discharge due to the reduced winter snow storage and an increase of evapotranspiration.

4.1.2.2 Influence of precipitation on water resources

The response of annual runoff to the precipitation (seen in Fig. 4) is larger than that to the temperature change. The runoff increases when the precipitation increases and in a same scenario the proportion of runoff change is at a same level.

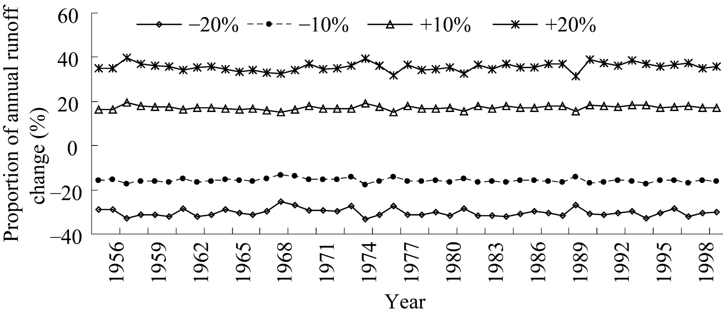


Fig. 4 Response of annual runoff to the precipitation change in 45 – year series

The response of average monthly runoffs to precipitation change was also studied (Fig. 5).

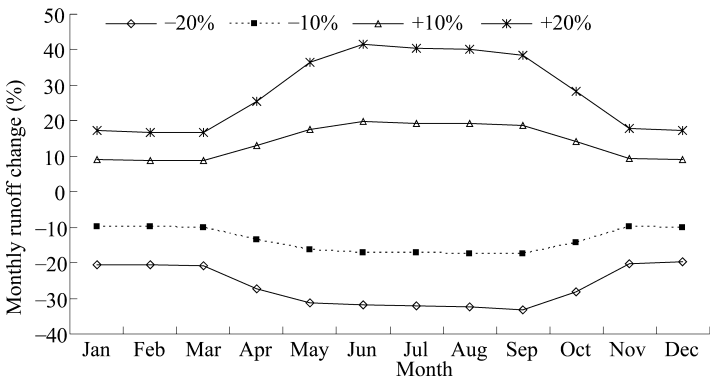


Fig. 5 Average of monthly runoff under precipitation change (1956 ~ 2000)

We could see the different proportions of runoff change in different months. The response to precipitation change could be divided into three phases, the dry season phase, the wet season part, and the transitionary season phase. At the first phase, from November to the next March, because of the tiny rainfall, the proportion of runoff change maintains at a same lower level which is close to the precipitation change proportion. During the wet season, from June to September, the change proportion is at a higher level which is about 1.5 to 2.0 times of the lower proportion in dry season. During three transitionary months, April, May, and October, the change proportion is between the other two phases.

4.2 Yiluo river basin in the middle reaches of the Yellow River Basin

The Yiluo river basin locates in the warm belt and climate is controlled by the season. This basin is one of multi – rainstorm area in the middle reaches of the Yellow River basin. The flood have the characteristic of concentration, big in amount, broad in area, long in during time, thus this area is selected in this paper to be analyzed.

4.2.1 Simulation scenarios

According to the some previous researches results (IPCC, 2001; Wang, 2000; Gao, 2002), the air temperature has an increasing tendency, from 0.3 ℃ to 5.8 ℃. While changes of the precipitation differ, some forecast increase but other decrease and the increase range is larger than that of decrease. Therefore, five scenarios are assumed in this paper to study the influence of air temperature and precipitation on water resources with air temperature increasing by 5 ℃ and extreme temperature 5.8 ℃, and precipitation decreasing 5%, increasing 5% and 10%. The basic scenario is the situation with underlying surfaces in 2000 and meteorological series from 1956 to 2000.

4.2.2 Scenarios analysis

4.2.2.1 Impact of air temperature on water resources

The normal annual air temperature was 12.6 ℃ in Yiluo river basin. It is assumed that the daily temperature in 1956 ~ 2000 increased 0.6 ℃ (about 5%) and kept the other input data and parameters invariable in scene 1. The daily temperature increased by 5.8 ℃ in scene 2.

Change of air temperature, consequentially resulting in change of water cycle, impacts the radiation, latent heat, sensible heat, and heat exchange, moreover, impacts evaporation and transpiration process, which company with energy exchange process. And the evapotranspiration change causes change of hydrological process such as runoff and infiltration, and then further change the water cycle process and water resources.

As shown in Table 6, 0.6 ℃ increase of air temperature caused that: the total water resources decreased 0.7 × $10^8 m^3$, 24%; surface water resources decreased 0.7 × $10^8 m^3$, 2.4%; groundwater resources decreased 0.3 × $10^8 m^3$, 2.1% with indistinctive change of groundwater nn – overlapped with surface water.

When the air temperature increase of 5.8 ℃, the total water resources and its compositions were attenuated more seriously, and the evapotranspiration process was quickened. As a result, the total water resources decreased 19.0%; the surface water resources decreased 19.2%; groundwater resources decreased 16.1% with indistinctive change of groundwater non – overlapped with surface water. Compared to the scenario 1, the influence on water resources is more obvious in scenario 2, but the ratio of water resources change rate to the temperature change rate is smaller.

As to the subentries of water resources, the response of surface water to the temperature change is more sensitivity than that of groundwater.

Table 6 Influence of temperature change to total water resources

Unit: $10^8 m^3$

Scenarios	Annual average temperature (℃)	Surface water resources	Groundwater resources		Total water resources
			Total	Non – overlapped with surface water	
Basic	12.6	29.1	16.4	0.29	29.4
Scene 1	13.2	28.4	16.1	0.30	28.7
Scene 2	18.4	23.5	13.7	0.30	23.8

The change of air temperature also impacts the temporal distributions of evaporation and runoff inside one year. Along with the temperature increase, the evaporation presents an increasing tendency, but the runoff presents an opposite tendency. The most impact on evaporation and runoff appeared in July, August, and September.

4.2.2.2 Influence of precipitation on water resources

Three Scenarios are designed to analyze the influence of precipitation on water resources. Maintaining the model input data and parameters unchanged, 5% of daily precipitation from 1956 to 2000 in was the increased third scenario; 10%, increased in the fourth scenario; and 5%, reduced in the fifth scenario.

Precipitation is the only source of water resources, which plays a crucial role on the basin water cycle. The results show that the change tendency in water resource and precipitation are the same.

5% increase in precipitation resulted that surface water increased 11.3% with runoff coefficient increasing from 0. 22 to 0. 23; groundwater resources increased 7. 9% with 6. 1% increase of groundwater not overlapped with surface water, and the total water increased 11. 2%. With increase of precipitation, the total water resources and its composition increased, and the increase will be significant.

5% decrease in precipitation resulted that surface water decreased 10. 7% with runoff coefficient decreasing from 0. 22 to 0. 20; groundwater resources decreased 7. 9% with 6. 2% decrease of groundwater not overlapped with surface water, and the total water resources decreased 10.9%.

From the above analysis, it can be concluded that the trend of changes in total water resources and its composition brought by precipitation changes are consistent; surface water are more sensitive than groundwater resources to change of precipitation; With continuous increase of precipitation, all the water resources increased significantly. Changing in the same magnitude, the impact of increasing and decreasing precipitation on surface water and total water resources is different, as shown in Table 7.

Table 7 Impact of precipitation on total water resources Unit: $10^8 m^3$

Scenarios	Annual average precipitation	Surface water resources	Groundwater resources		Total water resources
			Total	Non – overlapped with surface	
Basic	133.7	29.1	16.4	0.29	29.4
Scene 3	140.4	32.4	17.7	0.31	32.7
Scene 4	147.1	35.8	19.0	0.33	36.2
Scene 5	127.1	25.9	15.1	0.28	26.2

Changes in precipitation also impacted the temporal distribution of runoff and evaporation, in which the greatest impact is on runoff, flood peak runoff and evaporation focused on the July, August and September.

5 Conclusions

The change tendency of climate during the past fifty years in the Yellow River basin is analyzed in this paper. The WEP – L model is applied to simulate the natural hydrological cycle from 1956 to 2000 in the Yellow River basin. The data in the period of 1956 to 1980 and 1956 to 2000 is used as the model calibration and validation, and the result is reasonable. On the basis of the some previous research results, climate scenarios is assumed in this paper to analyze the response of water resources to the main climate factors such as precipitation and air temperature in the headwater area of the Yellow River basin and the Yiluo river basin in middle reaches of the Yellow River basin as studied area. The main results are as following:

(1) The general tendency of air temperature in the Yellow River basin, although still with some differences in the process, was increase, which was consistent with the tendency of global warming to some extents. The air temperature changed largest in the headwater area. Precipitation showed a fluctuated decline tendency.

(2) The annual average air temperature from 1980 to 2000 increased 0. 5 degree but precipitation decreased 28mm in the Yellow River basin, compared with those from 1956 to 1979. Decrease of precipitation resulted in decrease of water resources, but increase of air temperature resulted in increase of evaporation, and corresponding reduction of surface water and recharge of groundwater. Under the action of these two main factors, the change of water resources was that, surface water resources decreased 3.03 billion m^3, groundwater resources decreased 2. 5 billion m^3 with 380 million m^3 decrease of groundwater non – overlapped with surface water reduce, and the total water resources decreased 3.42 billion m^3. Analyzed from sub – basins, the changes of water resources differed due to difference of change in precipitation and temperature.

(3) The tendency of total water resources and its composition was the same as change of precipitation. Surface water was more sensitive than groundwater resources to change of precipitation. Changing in the same magnitude, the impact of increasing and decreasing precipitation on surface water and total water resources were different. The change of air temperature also impacted the temporal distributions of evaporation and runoff in a year.

(4) Increase of air temperature resulted in the decrease o f the total water resources and its compositions, including surface water resources and groundwater, while the groundwater non – overlapped with surface water changed little. Increase of air temperature caused increase of surface temperature, which will cause increase of evapotranspiration. With the gradually increase of air temperature, the reduction of total water resource and its compositions were strengthened and the evaporation from land was quickened. The change of air temperature also impacted the temporal distributions of evaporation and runoff in a year.

(5) In the headwater area of the Yellow River basin, the average of monthly runoff under temperature change was different from the annual runoff. In every spring season, monthly runoff increased when temperature increased. From November or December to January or February of the next year, the monthly runoff response to the temperature was insensitive. From May to October every year, monthly runoff decreased obviously with temperature increase because of the evapotranspiration increase.

(6) In the headwater area of the Yellow River, the monthly runoff response to precipitation change could be divided into three phases, the dry season phase, the wet season phase, and the transitionary season phase. At the first phase, from November to the next March, the proportion of runoff change maintains at a same lower level which was close to the precipitation change proportion. During the wet season, from June to September, the change proportion was at a higher level which is about 1. 5 to 2. 0 times of the lower proportion in dry season. During three transitionary months, April, May, and October, the change proportion was between the other two phases.

References

IPCC . Technique guideline of impact assessment of climate change and suitable countermeasure [R]. WMO, UNEP, 1994.

Jia Y. , Wang H. , Zhou Z. , Qiu Y. , Luo X. , Wang J. , Yan D. & Qin D. Development of the WEP – L distributed hydrological model and dynamic assessment of water resources in the Yellow River basin. J. Hydrol. 2006,331, 606 – 629.

Metoffice. PRECIS2 Update[M]. London :Metoffice ,2002.

Jiang Tao, Chen Yongqin, Chen Junhe, et al. study on impact of future climate change on hydrology cycle and water resources in China[J]. Journal of Zhongshan university (natural science), 2000,39(supplement),151 – 157.

Jia Y. , Wang Hao, Wang Jianhua, et al. Development and validation of distributed hydrological model in the Yellow River basin[J]. Journal of natural sources. 2005, 20(2): 300 – 308.

Jia Y. , Ni G. , Kawahara Y. and Suetsugi T. Development of WEP model and its application to an urban watershed[J]. Hydrological Processes, 2001, 15(11): 2175 – 2194.

Kite G. W. , U. Haberlandt. Atmospheric model data for macroscale hydrology[J]. Journal of hydrology, 1999, 217:303 – 313.

Maidment, D R. Handbook of Hydrology. 1 McGRAW – HILL, New York,1992.

Zhou Z. , Zhu H. , Jia Y. Precipitation interpolation temporally and spatially in large scale basin. Proc. of annual academic congress 2004, China Society of Natural Resources[C]. 2004. 499 – 606.

Evapotranspiration Monitoring and Validation in the Weihe River Basin and Upper Yellow River Basin

Marjolein De Weirdt[1], ***Andries Rosema***[1], ***Zhao Weimin***[2], ***Steven Foppes***[1], ***Wang Chunqin***[2] and ***Dai Dong***[2]

1. EARS, Kanaalweg 1, 2628 EB Delft, the Netherlands
2. Hydrology Bureau, YRCC, Zhengzhou, 450004, China

Abstract: The actual evapotranspiration (ET_a) of land surfaces is most crucial information for water balance assessment and runoff modelling. In the Sino-Dutch cooperation project "Establishment of a Satellite Based Water Monitoring and Flow Forecasting System in the Yellow River Basin" actual evapotranspiration in the basin is monitored with the EWBMS methodology. Geostationary FY-2C satellite information from the VIS and TIR spectrum is used to derive daily actual evapotranspiration data fields and treating the ETa calculation by the energy – balance approach. It is concluded that the quality of rainfall run-off modelling and water resources assessment is highly improved by spatially continuous and near real time evapotranspiration data. The focus in the project is on the source area of the Yellow River and the lower Wei River basin, the largest tributary of the Yellow River.

Key words: evapotranspiration, remote sensing, energy balance, water balance

1 Introduction

The Energy and Water Balance Monitoring System (EWBMS) provides daily and ten daily averaged data fields of actual evapotranspiration for the entire Yellow River basin. The ability to measure and monitor evapotranspiration on a spatially and timely continuous basis is crucial when assessing water resources and can significantly improve the results for river runoff modelling and hydrological applications. Together with the EWBMS rainfall data fields (Foppes, 2007) the actual evapotranspiration data are used to feed the water resources forecasting system for the source area of the Yellow River and the high water forecasting system in the lower Wei River (Maskey, 2005, 2007; Venneker, 2007).

2 Energy Balance and EWBMS

The energy used for evaporation of water from the land surface (LE) can be derived with the energy balance at the surface of the earth. The energy balance equation is written as:

$$I_n = G + H + LE + E \quad (1)$$

where, I_n is the net radiation, G is soil heat flux, H is sensible heat flux, LE is latent heat flux and E is photosynthetic light use (all in W/m^2). When vegetation is present, part of the solar radiation is used for photosynthetic electron transport E. This component amounts over vegetated surfaces on the average about 5% of the absorbed global radiation (Rosema et al., 2004). For timescales of one day or longer, G can be ignored and assumed zero so the energy balance equation reduces to:

$$I_n \approx H + LE + E \quad (2)$$

2.1 Radiation

In order to derive the latent heat flux LE from the energy balance equation, the components sensible heat flux H and net radiation I_n need to be known. Net radiation is calculated as the net result of short wave solar radiation and long wave radiative fluxes. This energy component can be written as:

$$I_n = (1 - A) I_g + L_n \quad (3)$$

where, I_g is the daily global solar radiation, A is the surface albedo and L_n the net long wave radiative flux. The incoming global solar radiation I_g at noon is obtained by:

$$I_{gn} = St\cos i_s \quad (4)$$

with S the solar constant (1,355 W/m^2), t the transmission coefficient (Kondryatyev, 1969) and i_s the solar zenith angle. The daily global radiation I_g is obtained by integration of the daily solar cycle and is a function of day number and latitude. For a cloudy pixel, the transmission coefficient through the cloud t_c is derived from the cloud albedo according to a relationship derived from the Kubelka-Munk theory.

The surface albedo is derived from the FY-2C visible band imagery. A satellite calibration and an atmospheric correction procedure converts satellite counts from the visible spectrum to planetary albedo and finally to surface albedo. For the atmospheric correction a modified version of the global radiation transmission model of Kondratyev (1969) is used.

The net long wave radiation component L_n is calculated from the surface and atmospheric temperatures and emissivities:

$$L_n = \varepsilon_0 \varepsilon_a \sigma T_a^4 - \varepsilon_0 \sigma T_0^4 \quad (5)$$

Land surface emissivities ε_a on the average vary between 0.85 (desert) and 0.95 (vegetation) and an average value of 0.9 is assumed. Atmospheric emissivity ε_0 is derived with the Brunt equation, based on relative air humidity values. Below clouds, it is assumed that upward and downward fluxes cancel ($L_n \approx 0$).

2.2 Temperature

Surface temperature T_0 is derived with the thermal infrared satellite images. From TIR satellite pixel counts, planetary temperatures are obtained after satellite thermal infrared calibration. Conversion to surface temperatures is done with an atmospheric correction method that uses information from the air temperature at the top of the boundary layer. In this procedure, the surface temperature at noon and at midnight is derived from the relationship between planetary temperature and surface temperature, described as:

$$(T_0 - T_a) = k/\cos(i_m) \,.\, (T'_0 - T_a) \quad (6)$$

in which, k is the atmospheric correction coefficient, i_m is the satellite zenith angle and T_a is the air temperature at the top of the boundary layer (Rosema et al., 2004).

The air temperature T_a is derived by plotting the noon planetary temperatures T'_{on} versus midnight planetary temperatures T'_{om}. They show a linear relation which is determined by the regression $T'_{on} = aT'_{om} + $ b. In case of perfect heat exchange with the atmosphere there is no temperature difference between surface and atmosphere which results in $T'_{on} = T'_{om} = T_a$. Combining both relations, air temperature is found from $T_a = b/(1 - a)$. The procedure is applied to a shifting window of 200 km by 200 km in which T_a is assigned to the centre pixel.

With the EWBMS surface temperature T_o and air temperature T_a the daily average air temperature at 1.5 m above the surface ($T_{1.5\,m}$) can be determined. EWBMS calculates $T_{1.5\,m}$ with a linear interpolation between surface and air temperature, which was derived with observed 1.5 m temperatures from 5 WMO-GTS stations in China. EWBMS $T_{1.5\,m}$(K) is calculated as:

$$T_{1.5\,m} = 1.066,2\,[0.45\,(T_{on} + T_{om})/2 + 0.55T_a] - 12.9 \quad (7)$$

in which, T_{on} and T_{om} are the surface temperature at noon and at midnight respectively (both in K).

2.3 Sensible heat flux

Heat exchange from the surface to the atmosphere is formulated as:

$$H = (\alpha_c + \alpha_r)(T_0 - T_a) = Cv_a(T_0 - T_a) + 4\varepsilon_0\sigma T^3(T_0 - T_a) \quad (8)$$

in which, α_c is the convective sensible heat transfer coefficient and α_r is the radiative sensible heat transfer coefficient. C is the drag coefficient, v_a the average wind speed (m/s) and σ is the Stefan Boltzman constant. The difference between surface temperature and temperature at the boundary layer determines the magnitude of the sensible heat flux H. The drag coefficient C depends on aerodynamic roughness of the area and is determined as:

$$C = (0.37\ 10^{-3}\ h + 0.92)\exp(-h/H) \quad (9)$$

in which, h is the elevation of the surface and H is the scaling height. The first term in Eq. (9) quantifies effect of elevation on aerodynamic roughness of the area and the second term expresses the influence of decreasing air density with elevation. Roughness is assumed to increase slightly with altitude when the terrain becomes more irregular and the surface more complex at higher elevations. The size of the roughness elements is comparable to scale of the FY-2C satellite imagery (3 to 5 km) on which roughness elements at pixel size are determined by hills, plateaus and mountains. The effect of air density is quantified by the scaling height H which was determined from the relationship between air pressure and elevation:

$$H = -h / (\lg P - \lg P_o) \quad (10)$$

in which, P is the atmospheric pressure and P_o is the sea level atmospheric pressure. With Eq. (10) and pressure measurements at four locations in the Yellow River basin at various altitudes resulting scaling height was determined at 83.39 m.

From the sensible heat flux at noon, the daily averaged value is obtained assuming a constant energy partitioning or Bowen ratio during the day. The default output of the Energy Balance model is the convective daily sensible heat flux. Together with the photosynthetic light use this product is subtracted from net radiation and the resulting output product is actual evapotranspiration.

3 Results and validation

Fig. 1 shows the total sum of EWBMS ETa in the Yellow River basin for the year 2006. Evapotranspiration diminishes from south to north and from east to west. Highest annual evapotranspiration sums of 500 mm to 600 mm are found in the west and southwest of the basin in Shandong, Henan and Shaanxi Provinces. The northeast provinces Inner Mongolia, Gansu and Qinghai are much drier and annual evapotranspiration in 2006 is around 100 mm to 200 mm.

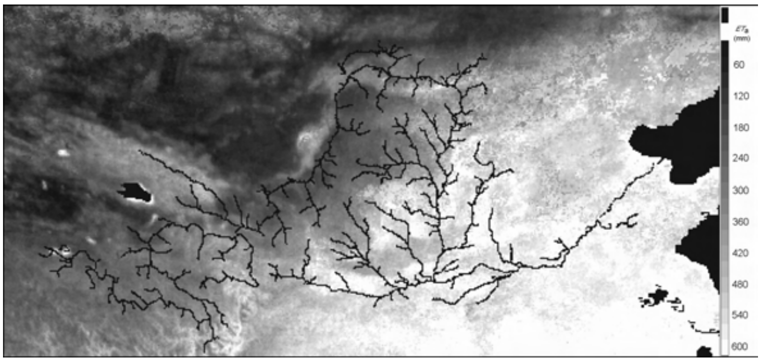


Fig. 1 Total actual evapotranspiration (mm) in the Yellow River Basin for the year 2006

3.1 Validation of 1.5 m daily average air temperature

A comparison between EWBMS derived 1.5 m daily average air temperature $T_{1.5\ m}$ and WMO-

GTS reported $T_{1.5m}$ was made for 15 locations in the Yellow River basin. In the source area of the Yellow River, validation was on a daily basis with a data set of 6,579 temperature observations from 9 stations for the entire year 2000 and 2001. In this period GMS satellite imagery was used for validation purposes. The results are presented in Table 1. The GTS and EWBMS temperatures correspond very well with a mean coefficient of determination r^2 ranging from 0.68 to 0.9 with an average value of 0.81 and an overall r^2 of 0.72. Observed differences in $T_{1.5m}$ range from 0.08 ℃ to 3.36 ℃ with an average difference of 0.94 ℃. The observed differences were smaller in summer, spring and autumn than in winter for both years.

Table 1 Validation of EWBMS 1.5 m air temperature with GTS data in the Yellow River source area

WMO (n°)	Station name	Longitude (decimal °)	Latitude (decimal °)	Altitude (m)	R^2		Observed $T_{1.5\,m}$ difference (℃)	
					2000	2001	2000	2001
52943	Xinghai	99.98	35.58	3,323	0.860	0.830	1.945	1.780
56043	Maqin	100.25	34.47	3,719	0.820	0.820	1.667	1.180
52974	Tongren	102.02	35.52	2,491	0.790	0.850	−2.456	−3.080
56033	Maduo	98.22	34.92	4,272	0.900	0.870	3.139	2.810
56046	Dari	99.65	33.75	3,968	0.810	0.810	0.920	0.910
52957	Tongde	100.65	35.27	3,289	0.850	0.850	2.508	−0.080
56151	Banma	100.75	32.93	3,750	0.720	0.680	−0.648	−0.900
56065	Henan	101.60	34.73	3,500	0.790	0.820	3.359	2.540
56067	Jiuzhi	101.48	33.43	3,629	0.770	0.740	0.985	0.340

In the lower regions of the Yellow River basin and in or near the Wei River basin, $T_{1.5m}$ was validated with a data set of 2,060 observations from 6 stations for the entire year 2006. Table 2 shows RMSE and r^2 for each of the stations. Average mean coefficient of determination r^2 is 0.73. EWBMS underestimates the observed $T_{1.5\,m}$ temperatures at 5 locations with higher reporting GTS temperatures than EWBMS temperatures. The average observed difference is −1.39 ℃. Observed differences are comparable for all four seasons, with no notable change in observed differences for the winter period. Fig. 2 shows the correlation on daily basis of Yulin and Yanchi station in 2006.

Table 2 Validation of EWBMS 1.5 m air temperature with GTS data in the lower YR

WMO (n°)	Station name	Longitude (decimal °)	Latitude (decimal °)	Altitude (m)	R^2	Observed $T_{1.5\,m}$ difference (℃)
53723	Yanchi	37.78	107.40	1,349	0.75	−1.13
53646	Yulin	38.23	109.70	1,058	0.80	−2.18
53903	—	36.00	105.70	1,921.4	0.71	−0.90
53810	—	37.00	105.90	1,345.2	0.75	−2.48
56093	—	34.40	104.00	2,315.8	0.66	−2.81
52996	—	35.38	105.00	2,450	0.73	1.17

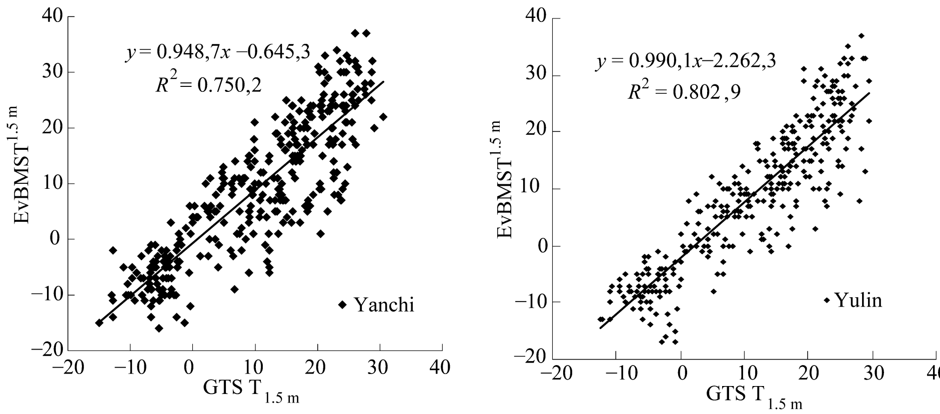


Fig. 2 EWBMS 1.5 m air temperatures versus ground measurements at the GTS stations Yanchi and Yulin in 2006

Fig. 3 shows the yearly course of 1.5 m air temperature at Yulin for 2006. The overall trend of both $T_{1.5\ m}$ data sources match well. In general the EWBMS temperatures are a little lower during most of the year but this trend is not seen in October and November.

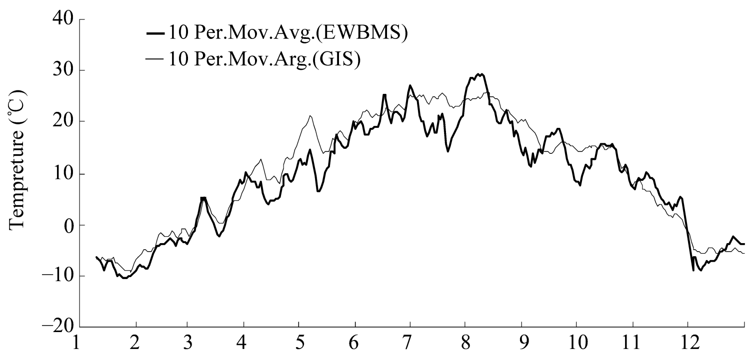


Fig. 3 Comparison of 10 day moving average of $T_{1.5\ m}$ of EBMS and WMO-GTS at Yulin in 2006

3.2 Validation of net radiation

Four net radiometer instruments were part of the weather stations that were installed at each LAS location. The net radiometer instrument has an up facing sensor that measures the solar and far infra red energy received from the hemisphere (180°) and a downward facing sensor that measures the energy received from the soil surface. The two values are converted to one output signal that represents the net radiation and sent to a datalogger where they are averaged and stored every 10 minutes. To compare with daily EWBMS net radiation products, daily values are averaged from the 10 minutes interval measurements.

Fig. 4 shows the time series of 10 daily averaged net radiation for EWBMS products and ground observations at Jingchuan site in 2006. The correspondence between both series is very good during most of the year. Only during the winter months January, November and December EWBMS net radiation is higher than the radiation measured at the ground. On a daily basis, RMSE is 28 W/m^2, average observed difference is 10 W/m^2 and coefficient of determination r^2 0.80 for this location.

On a ten daily basis the average observed difference reduces to 6 W/m^2 and RMSE to 14 W/m^2.

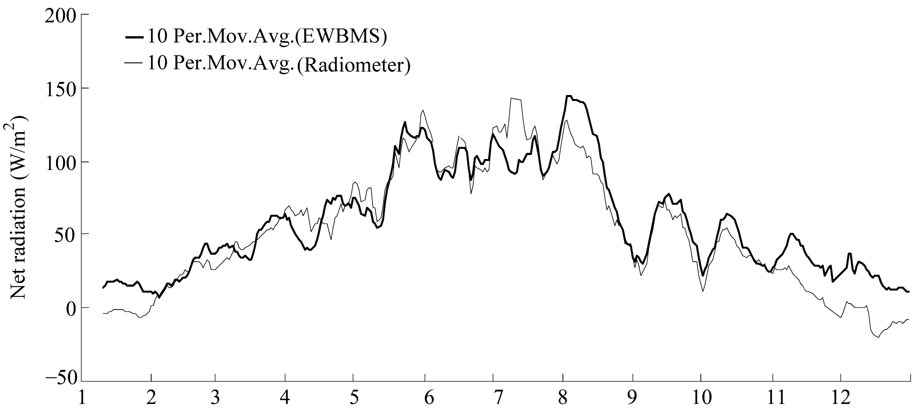


Fig. 4 10 daily averaged net radiation at Jingchuan measured with the net radiometer and determined by EWBMS in 2006

At Tangke and Xinghai, EWBMS net radiation products are lower than observed at the ground. On a daily basis, observed difference at Tangke is −11 W/m^2 for measurements from April to August 2006, at Xinghai average difference is −19 W/m^2 from May to October, 2006. Respective RMSE values are 41 W/m^2 and 32 W/m^2 and mean coefficients of determination r^2 0.4 and 0.61 (see Fig. 5). At Maqin only data were available for August, September 2005 and April, May 2007. For this period average observed difference on a daily basis is −16 W/m^2 and RMSE is 26 W/m^2.

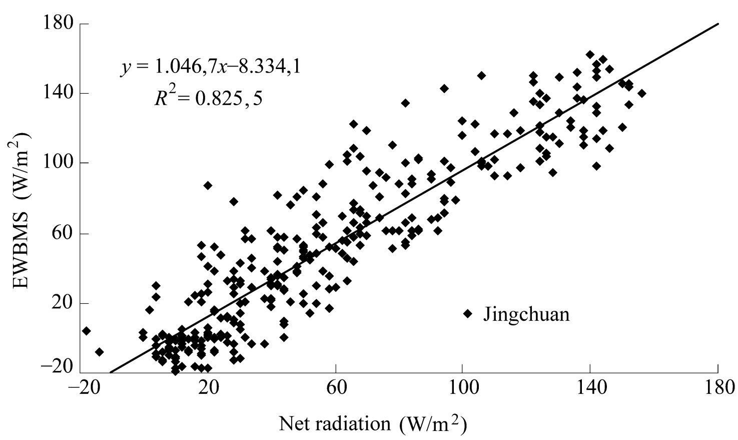


Fig. 5 Correlation of EWBMS net radiation and net radiometer measurements at Jingchuan in 2006

3.3 Validation at field scale

Four Large Aperture Scintillometer (LAS) devices were installed to measure and validate the sensible heat flux independently. The scintillometer is an optical device used to monitor the fluctuations in the refractive index $C_n^{\,2}$ of the turbulent atmosphere over a relatively large area (Meijninger, 2003). $C_n^{\,2}$ is derived from the relative intensity fluctuations of a received signal.

With additional data from a meteorological weather station installed with each LAS system, heat fluxes from the surface layer into the atmosphere can be calculated. The advantage of the LAS is that it measures the sensible heat flux along a path up to a few kilometres length. The scale of the measurement is thus similar to that of the satellite pixel. Three locations on the Qinghai plateau where meteorological data are scarce were chosen where the meteorological instruments and the LAS information provide with a unique source of data. A fourth LAS system was installed in the Wei River basin in Jingchuan. Specifications of the location, path length and effective height above the surface of the LAS instruments are given in Table 3.

Table 3 Location and configuration of the LAS systems for validation of sensible heat flux

Location	Latitude (decimal °)	Longitude (decimal °)	Elevation (m)	Height of transmitter above surface (m)	Height of receiver above surface (m)	Effective height LAS (m)	Path length (m)
Jingchuan	35.33	107.35	1,039	2.8	10.9	23.7	1,343
Maqin	34.46	100.23	3,730	6.7	5.2	5.8	1,110
Xinghai	35.58	99.98	3,310	13.7	6.6	16.3	1,871
Tangke	33.38	102.45	3,434	7.7	7.3	7.52	586

Sensible heat flux at Tangke was measured in April and May 2006. Mean observed difference on a daily basis for this location is -0.81 W/m^2 and RMSE is 17 W/m^2. Correlation on a daily basis is low (0.32) but increases on a ten daily basis (0.77). The errors are random and observed differences on a daily basis are balanced equally with EWBMS observations in 43% of the cases lower than LAS measurements and in 57% of the cases larger than LAS measurements. On a ten daily basis the RMSE decreases to 6 W/m^2 and the integration over the entire period yields a sensible heat flux error that is only 2% different from the LAS measurements. Even when correlation on a daily basis is quite low, the sensible heat flux results are still good and reasonable considering estimations of the water balance and evapotranspiration monitoring on a ten daily basis can be sufficient for good runoff and high water forecasting (see Fig. 6).

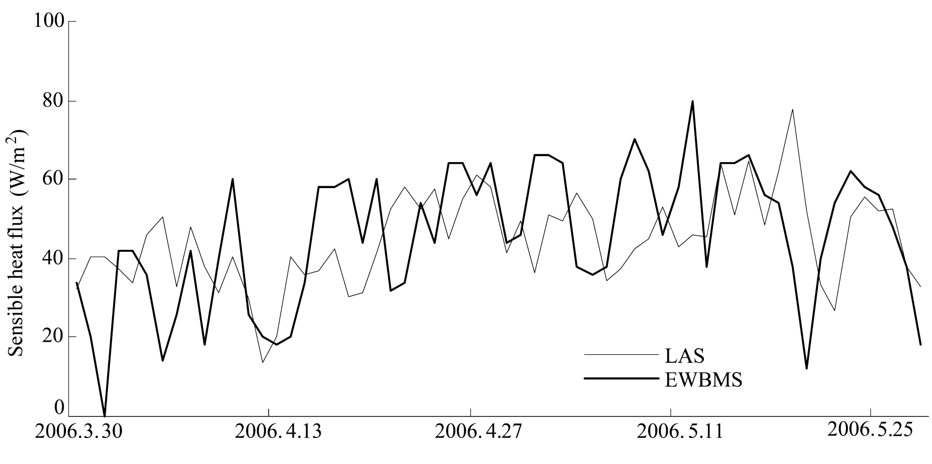


Fig. 6 Daily sensible heat flux from LAS and determined with EWBMS at Tangke location for 30/03 until 28/05/2006

3.4 Validation at catchment scale

The strength of the remote sensing technique is to describe the spatial variation of the latent heat fluxes at the regional scale. It is therefore interesting to validate the total volume of water evaporated from a large area like the Wei River basin or the source is of the Yellow River.

Considering there is no other loss of water than evapotranspiration, the effective precipitation and hence the runoff in the basin on a yearly basin should be more or less equal to discharge. The results from EWBMS based evapotranspiration maps are compared with the difference between EWBMS rainfall and measured discharge at Tangnaihai, the outlet of the source Yellow River (Table 4). This is a reasonable and true validation of water balances and most important for the water resources and high water forecasting systems.

Table 4 Annual water balance of the Upper Yellow River source area up to Tagnaihai for 1999 until 2001

Year	EWBMS rainfall (mm)	Observed discharge (mm)	Estimated ET_a as water balance residual (mm)	EWBMS ET_a (mm)	ET_a difference (%)
1999	502	190	312	328	5
2000	441	121	320	333	4
2001	478	108	370	349	−6
Total	1421	419	1002	1010	0.8

Difference between EWBMS actual evapotranspiration results and river runoff based estimation of annual actual evapotranspiration on a 3 yearly basis is only 1%, with a deviation of 5% on a yearly basis. Space and time integration improve the accuracy due to reduction in the error component. These accuracies are very good and can not be improved much further on the short term considering there are also random errors in the discharge and precipitation component of the water balance.

4 Conclusions

In this study data fields of temperature, net radiation and sensible heat generated by EWBMS with FY−2C satellite imagery were compared with point measurements at the earth surface. Reasonable good correlations and small errors were found for temperature and net radiation output. Errors are reduced by averaging the output results over a period of 10 days. Sensible heat flux validation shows an error of 2% when integrating over a period of 2 months. More important for runoff forecasting is the result in terms of water balance. Compared to the difference between precipitation and measured discharge a three yearly balance shows an error of only 1% for the period from 1999 until 2001.

References

Foppes, S. Precipitation and Water Balance Monitoring the Weihe and Upper Yellow river, 2007.

Kondryatyev, K. Y., Radiation in the Atmosphere, Academic Press, New York, London, 1969.

Maskey, S., Venneker, R., Zhao, W. A Large−Scale Distributed Hydrological Modeling System for the Upper Yellow River Basin using Satellite−Derived Precipitation Data., Proceedings of 2nd IYRF, 2005.

Maskey, S. Flow and Forecasting in the Weihe Sub-Basin, 2007.

Meijninger, W. M. L. Surface Fluxes over Natural Landscapes Using Scintillometry. Wageningen University, 2003.

Rosema, A., Verhees, L. Sun, S., Fu, R., Li, F., Zhao, Z., Wu, R., Hu, L., You, R., Zhang, Y.Y., Wang, N., Yang, X., Jiang, D., Liu, H.H., Ma, Z., De Bruin, H., Bink, B., and Wu, X. , China Energy and Water Balance Monitoring System. Scientific Final Report Oret Miliev project 98/53, commissioned by the State Forestry Administration, 2004.

Venneker, R. Overview of the Large Scale Hydrological Model,2007.

Norwegian Experience in Sustainable Water Management, Environment Protection, Flood and Erosion Control and Climate Development Research

Linmei Nie[1], ***Arne Tollan***[2], ***Oddvar G. Lindholm***[1],
Lillian ϕygarden[3], ***Jim Bogen***[2] and ***Eirik J. Fϕrland***[4]

1. Department of Mathematical Science and Technology, Norwegian University of Life Science Drøbakveien 31, P. O. Box 5003, 1432 Ås, Norway
2. Norwegian Water Resources and Energy Directorate (NVE), Middelthuns gate 29, P. O. Box. 5091 Majorstuen, 0301 Oslo, Norway
3. Norwegian Institute for Agricultural and Environmental Research, Fr. A. Dahlsvei 20, 1432 Ås, Norway
4. The Norwegian Meteorological Institute, P. O Box 43 Blindern, 0313 Oslo

Abstract: This paper aims to provide an overview of experience for sustainable water management in Norway. It covers professional areas of integrated water management including urban stormwater management, hydropower development and environment protection, hydrological data collection and flood control, soil erosion and control measures from agricultural areas, ecosystem conservation in river catchments and sediment transportation, and the long – term development of climate change.

Water management should be systematic and predictable, and based on the principle of legality. Selected central acts regulating water management aspects, important regulations including regulations on drinking water, sewage purification, licence fees, safety and supervision of watercourse installations were reviewed. The recognition of the economic value of water is visible in many parts of Norwegian water legislation. Several aspects of urban stormwater management, as a whole of integrated water management, were highlighted in part 1 of the paper. Hydropower development related regulations concerning on environment protection were described in part 2. Floods caused by typical climate in Norway, structural and non – structural measures to mitigate floods were summarised in part 3. Erosion from agricultural areas, control measure, monitoring system were summarised in part 4. Research regarding erosion process in river catchments, glacial erosion, and erosion in clay areas, mountain and arctic rivers, and sediment transportation in rivers were presented in part 5. Climate development in Norway during 1900 ~ 2100 was given in the last part of the paper, where regional climate downscale models, empirical and dynamical downscaling, were introduced. Results of climate variation – temperature and precipitation in Norway in the latest 100 ~ 150 years and scenarios of climate development during the 21st century were presented.

Key words: sustainable water management, urban stormwater, floods, erosion, climate change

1 Sustainable water management

This part summarised the Norwegian experience in water resources management and urban stormwater management.

1.1 Definitions

The words sustainable, integrated and management invite comments and definitions. By water management is here meant the legally based activities of public bodies aiming to allocate, control and protect water resources. Water management in Norway is carried out on three levels: national, regional and local. Operational management is often performed by private or semi – public entities having gained a licence from a public authority.

Sustainable is here meant to imply covering the legitimate demands of today without compromising the needs of future generations. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Integrated is a term with often diffuse meaning. In the context of managing water, it could include (Tollan, 2002):

(1) Recognising and respecting the natural circulation of water;
(2) Understanding the impacts of land use on water circulation;
(3) Using the catchment or aquifer as the management unit;
(4) Remembering that matter is continuously moving between soil, air and water;
(5) Remembering that water finally enters the oceans;
(6) knowing that water quantity and quality are closely connected;
(7) Kespecting the aesthetic value of water bodies in the landscape;
(8) Protecting rivers, lakes and wetlands as habitats for plants and animals;
(9) Considering all legitimate water uses on an equal basis;
(10) Ensuring close links between central and local management.

Water management should be systematic and predictable, and based on the principle of legality, i. e. decisions regarding private persons should have authority in law. Norwegian legislation consists in general of enabling acts and regulations. Selected central acts regulating water management aspects are: ① Water Resources Act (2001); ② Act relating to regulation of watercourses (1917); ③ Pollution Act (1981); ④ Planning and Building Act (1985); ⑤ Act relating to Nature Conservation (1970).

Important regulations, mandated in these Acts, include regulations on Drinking water, Sewage purification, Licence fees, Safety and supervision of watercourse installations (RMPE, 2006).

1.2 Some guiding principles in norwegian water legislation and management

Recent international thinking on integrated water management has focussed on certain guidelines, which are gradually being implemented in national water legislation in many countries. Examples are the outcome of the 1992 Dublin conference on Water and Environment, summarized in the so – called Dublin principles. In the case of Norway, in addition to the principles of integrated water management outlined above, the following may be highlighted.

1.2.1 Decentralisation and public participation

These are longstanding aspects of democracy in public management, expressed for instance in the Planning and Building Act, requesting the planning authorities on all administrative levels to actively inform the public about ongoing project planning. Further: "Individuals and groups affected shall have the opportunity to participate actively in the planning process". This is achieved among other things through extensive use of public hearings, for instance in the case of hydropower schemes. The same intention is expressed in the Dublin principle that decisions should be taken at the lowest appropriate level.

1.2.2 Sustainable water management

This concept, which originated in the 1987 report "Our common future" of the World Commission on Environment and Development, is reflected in various terms in Norwegian water – related legislation. The Water Resources Act e. g. aims to ensure socially proper use and management of river systems and groundwater. The purpose of the Pollution Act is to "prevent pollution and waste from reducing Nature's capacity for production and renewal". Concrete management tools are many: Environmental Impact Assessments (EIA); various kinds of planning documents (flood zone maps, maps of vegetation cover / geology / hydrology / etc., Master Plan for hydropower development). In connection with airborne pollution the concept of critical limits for Nature's tolerance has been used, in particular in dealing with international agreements to reduce long – range impacts. Also the so – called precautionary principle has been accepted, meaning that scientific uncertainty should not be an excuse for not taking action, when there is a risk of very serious or irreversible environmental damage.

1.2.3 Water as an economic good

The recognition of the economic value of water is visible in many parts of Norwegian water legislation. The national Master Plan for hydropower development uses e. g. economic criteria in categorising development projects. The Pollution Act adheres to the Polluter Pays Principle, and the cost of national water supply and sanitation services are close to 100% covered from fees. There are many examples of governmental support for water – related infrastructure and major actions to mitigate pollution threats.

1.3 Administrative organisation

Norway, like many other countries, has a rather diversified freshwater management structure. At the national level, there is no Ministry of Water Affairs. However, the following water – related ministries are important:

(1) Environment (natural resources, nature protection, protection against pollution);

(2) Petroleum and energy (physical interventions, in particular hydropower development);

(3) Health and care services (health aspects of water supply, water as a food article);

(4) Fisheries (aquaculture);

(5) Local government and regional development (support for local water supply);

(6) Agriculture (fish diseases, irrigation and drainage in agriculture) At the next, subordinate level, three water – related directorates are mentioned here:

(7) Norwegian water resources and energy directorate, NVE (hydrology, licensing, safety in rivers, flood protection);

(8) State pollution control authority, SFT (licensing according to the Pollution Act, emission control, water (and air) quality monitoring);

(9) Directorate for Nature Management, DN (outdoor life, inland fisheries).

Additional directorates and other governmental institutions deal with i. e. drinking water quality, aquaculture, transport on watercourses, erosion, flood damage, and emergency preparedness. Water – related R & D is carried out by universities and research institutes.

County and municipal administrations are very important links between the central government and citizens. Municipalities are responsible for local water supply and sanitation services, and licensing of individual emissions and discharges. Counties have licensing authority in certain cases, and are bodies of appeal regarding municipal decisions.

1.4 Urban stormwater management

Over the last decades Europe has witnessed a growing number of floods in urban areas. Climate change and rapid urbanisation will exacerbate this trend. Flooding incidents in urbanised catchment areas has lead to great public concern and anxiety and the economic impacts are often severe. Besides structural measures aiming at a reduction of the probability of flooding, new integrated approaches need to be developed and implemented to adapt the urban environment to climate change by further reducing its vulnerability.

Laws, regulations and guideline on storm runoff were introduced. Several aspects of urban stormwater management solutions including Sustainable Urban Drainage (SUD) measures, open flood ways on the ground and measures against erosion are also addressed. Norwegian laws, regulations and new mandated Norwegian guidelines for sewer designing or rehabilitation against flooding were presented, and standards of EC and Nordic countries were compared.

1.4.1 Laws, regulations and guideline on storm runoff

The Water Courses Act – § 7

To reduce the inflow to the drainage pipe network, the relevant authority (normally the municipality) may demand infiltration of storm runoff to the ground from a new development.

The Water Courses Act – § 47

The municipality has full responsibility if flooding damages are caused by inadequate maintenance and operation of open and above ground drainage systems.

The Pollution Control Act – § 24 a

In 2001 a new version of the Pollution Control Act was published. In its paragraph § 24a it states that: "The owner of an underground sewerage or drainage system is responsible for the damages this system causes if the hydraulic capacity of the system is not sufficient to avoid flooding." It also says that even if the network owner has dimensioned the system in accordance to the generally accepted engineering practise he will be responsible ("objective responsibility"). The network owner also has full responsibility if the damages are caused by inadequate maintenance and operation.

The technical regulation pursuant to the Plan and Building Act

Drainage and storm runoff shall not cause inconveniences or damages even at the return period for the dimensioning rain.

The municipality may decide that the storm runoff shall be drained separately or be infiltrated into the ground.

A revised version of the regulation will probably include the following:

(1) The municipality may restrict the discharge of storm runoff to the municipal network.

(2) Open flood ways on the ground must be included in the area plan and be dimensioned and planned so damages on buildings will not occur at the dimensioning return period of rains.

The Norwegian (NORVAR) guideline (Replacing NS – EN 752)

The Norwegian association for water and sewerage works (NORVAR) issued national guidelines for dimensioning rain return periods in December 2005 (Lindholm et al., 2005).

These return periods are shown in Table 1. The guideline also urges the municipalities to heed the following recommendations:

Table 1 Minimum return periods (years) for dimensioning rains in Norway in residential and commercial areas (Lindholm et al., 2005)

Design rain	Main type of area	Dimensioning occurrence of flooding
5	Low damage potential rural areas	10
10	Residential	20
20	City centre/Industry commercial	30
30	Areas with very high damage potential	50

(1) Open nature based BMP – solutions should be preferred to conventional ones if possible.

(2) Urban drainage guidelines should be incorporated into all levels of the normal area planning of the municipalities.

(3) The municipality should plan for storm runoff that cannot be handled by the pipe system to be conveyed in open floodways without causing damages. The dimensioning return period for the

analyses of safe open floodways should be 100 years.

(4) Polluted storm runoff should be treated before discharging it to receiving waters.

In Table 2, the Nordic guidelines and the CEN – standard for return periods in central city areas are compared.

Table 2 Dimensioning return period (years) for city areas in the nordic countries

	Separate sewer system		Combined sewer system	
	Only full pipe capacity	Surcharge to critical level	Only full pipe capacity	Surcharge to critical level
Denmark	1	5	2	10
Finland	2	3		
Iceland	5	10	5	10
Norway	20	30	20	30
Sweden	2	10	5	10
EN – 752	5	30	5	30

The following conclusions on return periods may be drawn:

(1) Iceland, Norway and the CEN – standard do not differentiate between separate and combined sewer systems.

(2) Denmark, Finland and Sweden use a return period of 2 years or less for full pipes in separate systems, while Iceland and the CEN – standard use 5 years. Norway use 20 years, which is way above the other countries.

(3) For full pipes in combined sewer systems, Iceland, Sweden and Finland use 5 years, but Denmark use only 2 years and Norway use a return period as high as 20 years.

(4) For surcharge to critical levels in a separate system, we can see three classes. Denmark and Finland use 5 years or less. Iceland and Sweden use 10 years and Norway and the CEN – standard are way above with 30 years.

(5) For surcharge to critical levels in a combined system, Norway and the CEN – standard use 30 years and the other countries use 10 years.

1.4.2 A need for a new engineering practise on handling of storm water

The main goals for handling of storm runoff should be:

(1) To prevent damages on health, properties, and environment.

(2) To use the storm runoff as a resource in the urban areas.

(3) To strengthen the biodiversity in the city.

Examples of SUD – measures (Sustainable Urban Drainage) that could be enforced by the Plan and Building Act are:

(1) Saving and strengthening of the vegetation like trees, grass areas, etc.

(2) A width of the roads that gives as little as possible of sealed surfaces.

(3) Permeable road and parking surfaces.

(4) Use of infiltration solutions.

(5) Infiltration trenches and ponds.

(6) A maximum allowable discharge to the pipe network.

(7) Use of swales instead of conventional trenches and gutters.

(8) Use of absorbing soils on top of more impermeable soils.

(9) Use of "green" roofs.

(10) Cisterns for collection of runoff from the roofs.

2 Hydropower development and environment protection

It is legally required to have a governmental concession before developing hydropower resources. The application should comprise a technical – economic plan as well as environmental and social impact assessments. Concession is granted only when the benefits are judged to be greater than the disadvantages. Applications are subjected to an extensive assessment involving relevant environmental authorities (State Pollution Control Authority, Directorate for Nature Management, Regional governors, as well as public hearings. Concessions are granted by the Ministry of Petroleum and Energy on recommendation by the NVE (see above). Major cases may be decided by the national parliament. The period from ca. 1950 ~ 1980 was characterised by strong growth in hydropower development, until Norway today produces close to 120 TWh annually, which means that Norway is the World's sixth greatest hydropower producer. This chapter is mainly based on RMPE (2006) and Perdersen (2007). Case studies are introduced in this part to address the adverse impacts of hydropower development on rivers.

2.1 National plan for protection of rivers

Many hydropower projects have been controversial, and led to strong protests in the 1960 ~ 1970s for reasons of nature protection. At that time, 1973, the first National Plan for Protection of Rivers was adopted. Revised and extended protection plans were adopted in 1986, 1993 and 2005, and close to 400 rivers with a hydropower potential of 44 TWh are now protected from development. The purpose of the plans is to maintain the environmental diversity from the mountains to the sea, by protecting whole catchments. The current plans only protect against hydropower, but a restraining policy should also be exerted towards other kinds of development activities that might have even greater environmental impacts.

There is still an opening for development of mini and micro hydropower (< 1 MW) in protected watercourses, but only if the development does not counteract the protection criteria. In practice, the policy is restrictive and permissions are only granted in special cases.

2.2 Master plan for hydropower development

During this same period the need for comprehensive and long – term planning of future hydropower development became obvious, and the national Master Plan for hydropower development was put in place 1986. The Master Plan categorizes actual hydropower projects according to economic and technical viability, as well as potential conflict level regarding environmental and cultural values. Based on an overall assessment, the projects are divided into three categories:

Category I: hydropower projects those are ready for immediate licensing and consequently "go projects",

Category II: hydropower projects that need approval by parliament, and

Category III: "no go" projects due to disproportionately high development costs and/or high degree of conflict with other user interests, including environmental interests.

The plan has later been supplemented and categories II and III have been merged.

Only projects with the highest economical and least conflict potential can be forwarded. Projects with an installed capacity less than 10 MW or an annual production below 50 GWh are, however, exempted from appraisal through the Master Plan system. Licensing conditions will often include requirements for mitigating environmental problems. Such measures may be a specified minimum rate of flow, weirs for maintaining the local water level, restocking of valuable fish etc. There is today a political resistance against large hydropower projects. Increases in electricity demand are expected to be covered by upgrading and extension of existing power plants, energy saving measures, and a combination of new small hydro and other renewables.

2.3 Small hydropower

In Norway, the interest for small hydropower (< 10 MW) is growing rapidly. At present the annual production from small hydropower is 5 ~ 6 TWh, of a theoretical potential of 25 TWh. The economy of small hydropower projects is obviously important. Projects with investment costs up to approx. 0.38 EUR per kWh are regarded as economically feasible (2007), but this may of course change over time.

More than 200 applications are currently in some stage of the licensing process. The licensing follows the regulations in the Water Resources Act, but is simplified compared to larger projects. A general description of possible environmental impacts and conflicts is required, and a detailed report on biodiversity, with focus on red listed species, is compulsory.

In order to ensure better management of cumulative impacts arising from several separate projects within a limited area or basin, the Government has called for development of master plans at the regional (county) level. Such plans will provide guidance for developers, presumably resulting in better applications and discouragement of poorly planned projects. The county administrations will coordinate the planning process and final plans will be approved by the county councils.

The first step in the process will be to demarcate "planning areas" in each county based on maps for the development potential for small hydropower. The second step will map interests that are sensitive to small hydropower, such as landscape, biodiversity, recreation and tourism, cultural heritage, fishery, unaffected "wilderness" areas and Sami interests (reindeer husbandry). These sector interests will be classified according to their intrinsic "value", in order to define possible areas of conflict. The final step includes development of management policies and regulations based on the systematised information for each of the planning areas. Approved plans will direct the licensing process at the national level.

National guidelines for assessment of small - hydropower applications are derived from the national policies and goals, such as landscape and environment, biodiversity, recreation, cultural heritage, Inland fishery and interests of the Sami people, an indigenous population group mainly associated with northern Norway.

2.4 The impact of diurnal hydropower peaking on erosion and sedimentation processes

In Norway, hydropower has been developed for more than 100 years, and a number of hydroelectric power projects have adversely affected rivers courses and caused physical and biological changes. Short time variations in water level and water discharge caused by the operation of power stations is referred to as hydropower peaking. As the use of electric energy may be subject to diurnal variations, short term changes in power production are desirable. Nuclear or fossil fuel power plants are not able to operate in this way. The environmental effects of hydropower peaking was thus investigated in a Norwegian research project. Both physical and biological investigations were included. The various factors affecting erosion caused by peaked regulation in different types of hydropower reservoirs are discussed and a preliminary classification of reservoirs in terms of erosion caused by diurnal peaked regulation is presented by Bogen and B? nsnes (2000). Groundwater and gully erosion may cause problems in all reservoirs surrounded by glacifluvial, glacilacustrine or recent fluvial deposits. The intensity of this erosion is influenced by the hydraulic conductivity of the sedimentary deposit and the drawdown rate of the reservoir. The area exposed to erosion depends on the drawdown level. Winnowing of fine fractions also takes place during seasonal regulation, thus little sediment is available in the most frequently used regulation shore zone. In reservoirs with a sustainable sediment supply from the catchment area, sediment will be available for wave erosion and resuspension. The bathymetry of the reservoir and the extent of shallow areas are important in this context. Wave motion is of minor importance to erosion and resuspension in deep reservoirs. Peaked regulation creates favourable conditions for groundwater erosion. The rapid drawdown of the water level results in uncompensated porewater pressure in the sedimentary deposits along the exposed shoreline. At some locations this excess porewater pressure caused sheet slides and groundwater spring sapping erosion.

3 Flood situation and flood control measures in Norway

This part sums up the structural and non – structural flood control measures for large river floods and flood consequences and resolutions in urban areas.

3.1 Typical climate and floods in Norway

Norway situates at the northernmost in the world. It extends from its most southerly point at 58° latitude to beyond 71° in the north and a length of more than 1,700 km. Because of its northerly location, the country is covered by snow for about four months in the south, and six to seven months in the far north and in mountain areas. However, due to the warm flow of the Gulf Stream in the North Atlantic, the country's climate is mild, and the mean temperature in winter in the coastal areas is around zero degree, thus precipitation comes as snow and rainfall alternatively. Annual average precipitation varies from 2,000 mm in the south to less than 1,000 mm in the north. In mountain areas, it often exceeds 3,000 mm in small inlands along the coast. Brekke, in Sogn and Fjordane country, had a record of 5,596 mm annual precipitation in 1990.

In addition to precipitation, snow – melt in the early spring is a significant contribution to ground and surface water. Consequently, floods are typically caused by rainfall in summer and autumn or by a combination of rainfall and snowmelt in early spring. In addition, there are winter floods also cause by snowmelt and rainfall according to the historical flood records. As a result, in Norway, there are floods through four seasons in a year: spring floods, summer floods, autumn floods and winter floods. Among them, the autumn floods and the spring floods are the two major flood scenarios (Roald, 2003; Brox, 1995; NOU, 1996; Herschy, 2003).

3.2 Flood control and mitigation measures

3.2.1 Structural flood control works

Structural flood control works have played an important role in flood mitigation. 2,185 dams and reservoirs have been built in Norway since 1,753. An overview is given in Table 3 below. There are five major types of dam among them: concrete dam (872), earth dam (149), brick dam (407), rock filling dam (387) and wooden dam (50) according to the analysis by Kartulf, a GIS – based program (Nie, 2004).

Table 3 Overview of dams and reservoirs in Norway

Height (m)	No. of dams	Reservoir volume (million m^3)	No. of reservoir
≤100	4	>1,000	15
30 ~ 100	111	100 ~ 1,000	137
<30	2,068	<100	2,033
Sum	2,185	Sum	2,185

3.2.2 Flood forecasting and warning systems

3.2.2.1 Observation and database

The Norwegian Meteorological Institute is responsible for the observation and forecasting of precipitation (rainfall and snow), temperature and other meteorological variables. The Norwegian

Water Resources and Energy Directorate (NVE) operate hydrological observation in the whole country. 4676 hydrological gauge stations are registered in NVE's database, Hydra II. Moreover, there are stations operated by power companies, local municipalities or interesting personnel, which are not included in NVE's database. NVE has developed a system for processing large amount of hydro – meteorological time series, with tools for quality control, data correction, data presentation and analysis, Hydra II (Taksdal, 1999).

3.2.2.2 Flood forecasting and warning

NVE operates a flood forecasting system for public flood warning at national level. The system is based on:

(1) Precipitation and temperature measurements from around 100 synoptic weather stations provided by the Norwegian Meteorological Institute.

(2) On – line monitoring of discharge and stage in 80 catchments (including automatic telemeter and telephone answering systems), see Fig. 1 (left).

(3) Real time operation of hydrological models (conceptual rainfall – runoff models) to forecast discharge for 60 catchments based on quantitative precipitation and temperature forecasts (example from one catchment, Fig. 1, right). These models are updated on a daily basis and discharge forecasting is made for the coming six days.

(4) On – line transmission from several snow pillows, information from snow surveys and satellite pictures. A gridded snow model is used to calculate snow – maps for Norway.

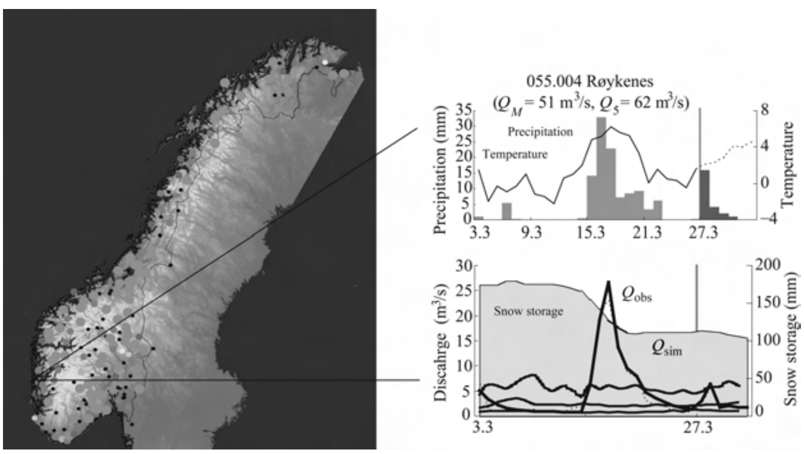


Fig. 1 Map of discharge observation stations (left) and observed and forecasted discharge (right)

Flood warnings are issued based on the predicted discharge in comparing with the annual mean flood. A flood warning will be issued if the predicted discharge at one or more stations exceeds a return period of five years; a warning about large flood is issued when simulated discharge at one or more stations exceeds a return period of 50 years. As long as the extreme situation continues, the flood warning office at NVE will keep updating the forecasting messages and published at Norwegian text TV and NVE's website: www.nve.no.

3.2.3 Flood inundation map project

After a major flood in south eastern Norway in 1995, a governmental commission gave several recommendations in order to reduce flood damage in the future.

The flood inundation map project was started by NVE in 1998. NVE is manager of the project and professionals at NVE also do most analyses. Other organisations such as the Norwegian mapping authority and private consultants participate with basis data. The municipalities are active partners in the mapping process and contribute with local information on water levels in previous flood events as well as measurements during floods within the project period.

The flood inundation map project includes the areas in Norway with the largest damage potential. The plan is to map 188 river stretches, covering 1, 750 km river length in 168 municipalities. Total cost is estimated to 8 million USD and the project period lasts 10 years from 1998 to 2007.

The project produces the following results:

(1) The maps are produced digitally, to make the users able to make their own presentations in combination with other information, using their own tools.

(2) High accuracy mapping was chosen, in order to make the users able to use the results in land use planning without further analyses.

(3) Land surface is represented by a DEM (Digital Elevation Model) based on detailed elevation data and the riverbed is represented by surveyed cross sections. Expected accuracy of the DEM is ± 30 cm.

(4) Through flood frequency analyses and hydraulic simulations water levels for 10, 20, 50, 100, 200 and 500 years floods are calculated. Expected accuracy of the computed water levels is ± 30 cm.

- Inundated areas are determined using GIS (Geographical Information System).
- Historic events related to other known hazards in the river system, such as ice jams, ice run, erosion, debris flows etc, are identified based on information from local informers and archives, without trying to relate the events to statistical probability.
- The final results from each river reach are delivered to the users both as a report with paper maps and as digital data. The presentation is standardized at scale 1∶15,000 with cross sections, levees etc marked. Water levels for all computed floods are presented both in a table and in a graph (longitudinal profile).

The digital flood map can be used together with the guideline of land use and safety in flood exposed areas (Toverød et al., 1999) for flood control.

3.2.4 Urban Flooding

Like the international situation, the urban water sector in Norway is facing a considerable evolution because of climate change, existing infrastructure is ageing and deteriorating and urbanization. Several Norwegian cities have been affected by serious floods making impact to several properties. Insurance companies' report of a steady and strong increase of flood related damage throughout the last 15 years, see Fig. 2. An inventory to Norwegian municipalities revealed that nearly all of them had been affected by flood events, and 56% considered this as a priority problem. However, only a minority of cities made analysis of potential hazards and very few had preparedness plans.

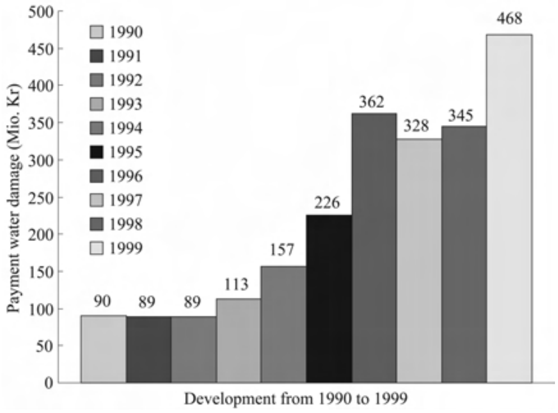


Fig. 2 Increase of flood – related damage cost to properties compensated by insurance companies (Stensrod, 2001)

New engineering guideline for sewer design and rehabilitation had been mandated in 2005, which was described in part 1 of this paper, and where in addition to the traditional structural measures, non – structural measures to managing storm runoff are recommended by the authorities.

In NVE's hydrological observation networks, 9 gauge stations are operating today to collect data, temperature, precipitation, water level and discharge, and snow and snow melting with short time resolutions (Nie, 2005). Advanced models have been developed to simulate flooding and sewer overflow from the networks (Matheussen, 2004; Nie, 2004; Rosvolt, 2000).

A total of approximately 50 retention and clarification arrangements for run – offs from highways and major roads have been constructed in Norway. The run – off installations in Norway normally comprise of wet retention ponds, constructed wetlands and infiltration facilities (Åstebøl og Hvitved – Jacobsen 2005, 2006).

4 Soil erosion from agricultural areas and control measures

This part summarized soil erosion from agricultural areas, monitoring and control measures. and the impact of hydropower development and erosion protection works on sediment transport in Norwegian rivers.

4.1 Soil erosion from agricultural areas

Diffuse runoff from agricultural areas in Norway has been especially focused from the beginning of the 1980 – ties. In areas with marine sediments and cereal production, south eastern and middle of Norway, soil erosion is a main source for sediment transport and phosphorus losses from agricultural areas to water. In many inland lakes such runoff is a main source for nutrient losses giving eutrophication and poor water quality. It also led to episodes with toxic algae blooming where water could not be used for bathing during summer or drinking water supply. These problems increased during late seventies and beginning of eighties due to changes in agricultural and environmental policies.

It was political decisions, promoted by subsidies that led to change in productions systems. Cereal production was concentrated to eastern and middle of Norway while milk and meat production were concentrated to western and northern part and inland districts. In areas with cereal production this led to increased arable land with tilling of agricultural areas during autumn time. When the soil was autumn tilled it was left open for erosion during autumn rainfall and snowmelt during winter period. Especially when snowmelt occurred on partly frozen ground, soil losses were high. Many of these areas with autumn tilled soil had earlier been grassland or pasture with minimum of soil losses. It was the change in production system, both crops and tillage system with increased autumn tilled soil that led to increased soil losses.

The change in land use, production system from grassland to cereals also led to artificial land levelling. Former ravine landscapes used for pasture, was not suited for heavier and larger machinery for cereal cropping. To be able to utilize agricultural areas better for cereal production and larger machinery land, levelling was necessary. Farmers were given subsidies for levelling of the land. In some municipalities more than 40 % of agricultural land was levelled. However, land levelling in areas with marine sediments led to very serious soil erosion in the agricultural landscape. Soil erosion increased 2 ~ 3 times in these regions due to land levelling. This was due to two factors:

(1) Increased erosion risk on levelled soil due to soil physical properties of the levelled soil. Underground soil being exposed by levelling has weak soil structure, low content of organic matter, high density, low infiltration capacity, few cracks and macropores. Because of this weak soil structure it is vulnerable to surface runoff and erosion. General erodibility is estimated to increase 3 ~ 13 times after leveling depending on leveling operations.

(2) Land levelling procedures. Erosion was not focused by the start of the levelling and bulldozers often mixed topsoil by subsoil. Surface runoff was not under control and led to erosion

both on the field and especially in the stream bank between field and stream. Stream bank erosion and erosion around hydrotechnical equipment led to severe gullying and sediment transport in streams with amounts equal to transport in rivers from glaciers. All this led to restrictions and land levelling is no longer permitted without special permission. Topsoil must be put back after levelling and surface runoff must be controlled. Outlet from drainage pipes and pipes from levelling must be protected. Streambanks must have special slope gradients and must be grass covered.

Because there were so much visible erosion in levelled fields it was decided that improvement of control with surface runoff and hydrotechnical equipment was necessary. Levelled fields were controlled and plans for improvement were made. It was also given subsidies for repairing these erosion damages to agricultural fields. Due to these unwanted effects, erosion research started about 1980, both for documentation but especially for testing effects of measures to reduce soil losses.

4.2 Control measures

In 1988/1989 there was an algae disaster in the North Sea which led to International agreements upon reducing pollution loads. In the North Sea Declaration the European countries bordering the North Sea agreed to reduce contributions of phosphorus and nitrogen by 50 %. This led to increased focus on runoff from agricultural areas and the authorities decided to set focus on control measures. Soil erosion is a major source for phosphorus losses from agricultural areas. The Strategy of Norway was to reduce erosion by implementation of a soil mapping programme in the exposed watersheds and to establish Agro – Environmental Sceme stimulating ploughing in spring time on the most erosive soil types. Erosion risk maps classify soil erosion risk into four classes – low, medium, high and very high erosion risk. The erosion risk maps are being used by the extension service and advisors when planning measures to reduce erosion on farm level.

From 1991 the authorities decided to give farmers subsidies for no autumn tillage irrespectively of erosion risk. After 1993, these subsidies were targeted on areas with high erosion risk. Farmers are allowed to choose crops and tillage, but special subsidies are given to promote environmentally friendly management. The following measures to reduce erosion are open for economic support to the farmer:

- Conservation tillage;
- Catch crops;
- Construction of sedimentation ponds;
- Buffer strips;
- Grassed waterways
- Repair of hydro – technical equipment for controlling surface runoff.

From 2003 each Norwegian farmer has been obliged to have an Environmental Plan for their farm and measures, and to reduce erosion is a part of it. In exposed watersheds special regulations have been made to reduce soil losses.

At present about 50 % of the areas is tilled only in spring and current support is given at annual rates of 50 ~ 175 Euro /ha. Farmers have given a quick response to subsidies for no autumn tillage in the first years after introduction of the payment (Fig. 3). Subsidies for catch crops were introduced in 2000 and led immediate to an increase of area.

Farmers receive up to 70 % of cost for establishment of buffer zones and sedimentation ponds.

Buffer zones 5 ~ 15 m have in experiments shown to reduce particle transport with between 55% ~95 %. Sedimentation ponds with a size of less than 0,1 % of catchment area have shown to be effective in reducing sediment transport by 50 % ~60 %. Because of these positive results and subsidies these measures have become more popular to implement. Spring tillage, harrowing or ploughing have in research reduced soil losses to a factor of 14 % ~30 % compared to autumn ploughing. For all these measures there has been a good cooperation between research, agricultural and environmental authorities, advisory service and farmers organizations. Farmers' behaviour and soil erosion in Norway is strongly influenced by agricultural and environmental policy.

From 2005 agricultural authorities introduced Regional Environmental Support Programme in agriculture for each county. They focus both on cultural landscape and on pollution from agriculture. Each county can design and make priorities for subsidies for reducing of pollution e. g for reduced erosion. Farmers' organizations are involved when the profile of programme is decided. The Agricultural State Authority compares and approves the programme from the counties.

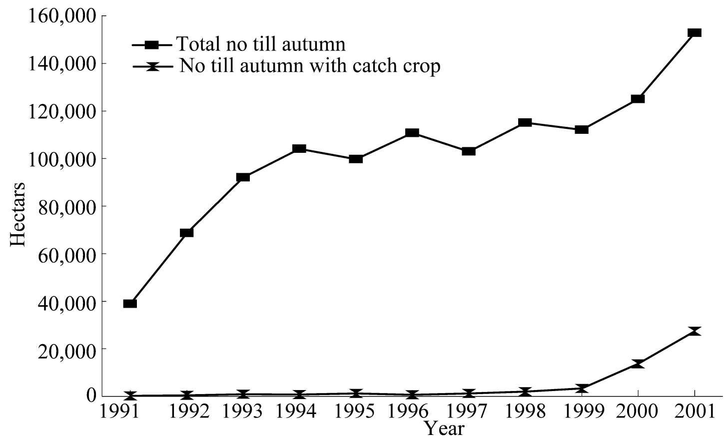


Fig. 3 Total area receiving subsidies for reduced tillage (no tillage in Autumn) and total area with no tillage and catch crops (Lundekvam et al., 2003)

4.3 Monitoring

Since 1991 the National Agricultural Environmental Monitoring Programme (JOVA) has monitored water quality in streams in catchments dominated by agricultural activities. The programme is financed by the Norwegian Agricultural Authority and Jordforsk (Centre for Soil and Environmental Research) is in charge of the programme. 10 agricultural catchments varying in size from 1 ~ 20 km^2 is included. Runoff is continuously measured, water samples taken and analysed for suspended solids, phosphorus and nitrogen. Pesticides are monitored in a special part of the programme. One of the major objectives of the programme is to document the effect of different agricultural production systems and site – specific characteristics on erosion and nutrient losses (e. g Bechmann et al. 1999, Vandsemb et al., 2002). Results are utilized to advice local and central policymakers about agricultural production systems and their environmental effects. Farmers in these catchments give detailed information about their farming activities related to crops, tillage, fertilisers, pesticides etc. This information is collected yearly for the individual farms in the catchments and any changes in practices are thereby recorded. Such information is vital when studying trends in water quality. Political decisions e. g subsidies may have an influence on choice of cropping systems and tillage operations and therefore also on water quality. In addition annual variations in weather conditions have a significant influence on losses from fields. The information gathered from the individual farms is essential to relate changes to farming activities or to weather conditions. During the monitoring period new subsidies are introduced in the monitored catchments like: reduced tillage, catch crops, buffer zones and sedimentation ponds.

4.4 New challenges

Implementation of the EU Water Frame Directive will influence further work with measures to reduce erosion and diffuse pollution from agricultural areas. The Water Frame Directive focuses on the watershed scale and good ecological status of water. It requires identification of the different contributing sources from all sectors. If good ecological status is not achieved, then measures must be implemented.

5 The impact of hydropower development and erosion protection works on sediment transport in Norwegian rivers

According to the Water Resources Act and the Act relating to regulation of watercourses described in the parts 1 and 2 of the paper, mandatory measurement should be carried out to document the impact of human interference with rivers. In this way, data that may be used as a basis for the operation of a hydropower plant takes into account all the different interests in a river basin. Such investigations are also used to improve conditions and take factors of environmental importance into account in future projects. A number of reference stations in various sedimentalogical environments are thus operated by the Norwegian Water Resources and Energy Directorate (NVE). Some of these stations are also operated to measure biological parameters. Several ways in which processes of erosion may affect sediment concentration and load are discussed below in selected case studies.

5.1 The sediment monitoring programme in reference river basins

The sampling strategy at the sediment monitoring stations operated by the Norwegian Water Resources and Energy Directorate (NVE) differs from the ones included in the JOVA programme. Whereas the JOVA stations are collecting composite weekly samples, the NVE stations sample in time mode only to cover the transport during individual flood events. Sampling strategy and laboratory methods followed procedures established by NVE as described by Bogen (1992).

Measurements have shown that the sediment yields of Norwegian river basins range widely in character and may display extreme temporal variations. Six types of sediment source areas have been recognized: marine clay areas, forested upland, catchments in the Arctic and mountain areas, glacier outlets, glacier – fed rivers and cultivated land (Bogen, 1996). These source type – areas were defined as areas with essentially the same kind of soils, processes of erosion and sediment production. Sediment delivery from subglacial erosion is the most significant sediment source in Norwegian mountain Headwater Rivers. The glaciers thus strongly influence the water quality and the seasonal runoff variations of the downstream river reaches. The large supply of bed load in coarse fractions also controls the morphology and stability of downstream river reaches. A comparison of sediment yield of different sediment source areas in Norway is given in Fig. 4.

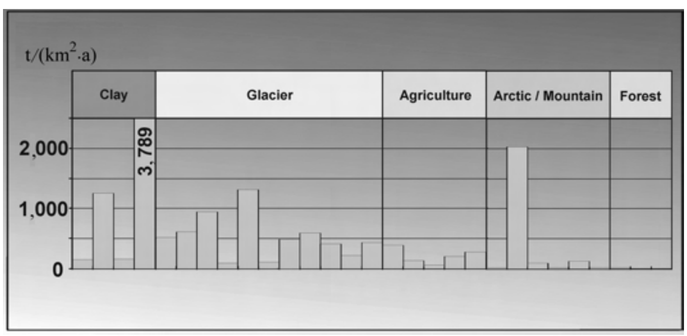


Fig. 4 River sediment yield in different source type – areas

5.2 The impact of erosion protection work on sediment transport in the river Gråelva

In another clay area in central Norway, on the river Gråelva, sediment transport monitoring was carried out in conjunction with the construction of erosion protection works. Parts of this river channel were even more unstable than the degrading parts along the river Leira. The bed of the main river was raised and covered by an armouring layer of cobbles and boulders. To prevent further degradation in the tributaries, their erosion bases were also artificially raised. The work was initiated in July 1992 but progress varied much from year to year. By 2001 a total of 10 km had been secured along the main channel and tributaries.

In 1992 and 1993, when conditions were still close to their natural state, maximum sediment concentrations were in the range of 15,000 ~ 25,000 mg/L and the calculated annual suspended sediment transport was 163,000 and 99,000 t/a, respectively, corresponding to sediment yields of 8,150 and 4,950 t/(km^2 · a). In 2000 and 2001, maximum concentrations did not exceed 6,000 mg/L and the annual sediment transport had decreased enormously, to 11,800 and 18,500 t/a, respectively, giving sediment yields of only 590 and 925 t/(km^2 · a), Fig. 5. A year – to – year variability controlled by climatic variables was, however, still present (Bogen and Bønsnes, 2004).

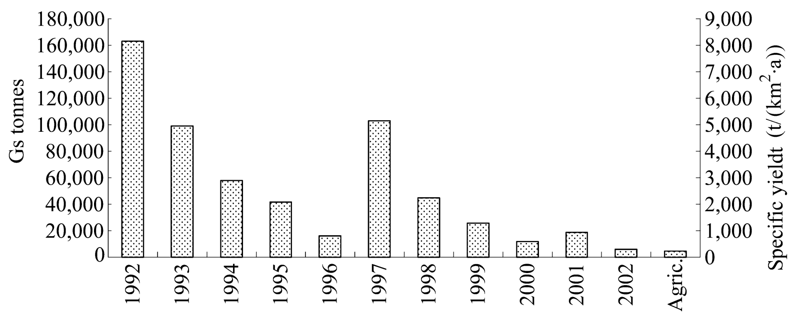


Fig. 5 Annual suspended sediment yield in the river Gråelva decreased during the years 1992 ~ 2002. Agric = yield from agricultural areas.

6 Climate development in Norway during 1900 ~ 2100

The climate in Norway is characterised by large temporal and spatial variability. The large natural variability at northern latitudes also influences the Norwegian climate for daily, seasonal, annual, decadal, etc. time – scales. The physio – geographical conditions in Norway cause steep climatic gradients even over short distances, e. g. from lowland areas to mountain regions and from coast to inland areas. Substantial local and regional gradients exist for annual precipitation as well as for extreme rainfall events. There have been substantial climate variations in Norway during the 20 th century, and the latest IPCC (2007) report indicates a stronger future warming during the 21 st century at high northern latitudes than in most other parts of the globe.

6.1 Climate variations in Norway during the latest 100 ~ 150 years

The annual mean temperature in Norway has during the latest 130 years (Fig. 6) increased by between 0.5 and 1.5 deg C in different parts of the country (Hanssen – Bauer, 2005). The increase in annual mean temperature is statistically significant at the 1% level everywhere except in the interior parts of the Finnmark County. The winter temperature has increased significantly (at least at the 5% level) in 3 of the 6 Norwegian temperature regions. Spring temperatures have increased significantly everywhere. Summer temperatures have increased significantly in northern regions, and autumn temperatures have increased significantly everywhere except in mid – Norway and the inland of the Finnmark county.

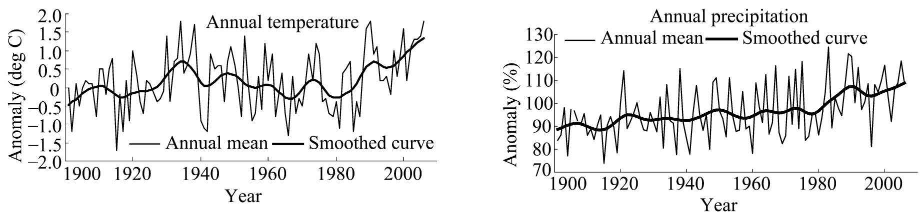


Fig. 6 Annual temperature and precipitation for the Norwegian mainland, 1900 ~ 2006

* Anomalies are deviations from the 1961 ~ 1990 averages ("normals"). The smoothed curve indicates decadal variability, while the thin line represents values for single years.

Annual precipitation in Norway has during the latest 130 years (Fig. 6) increased statistically significantly (5% level) in 9 of the 13 "precipitation regions" in Norway (Hanssen – Bauer, 2005). No region shows a negative trend. The largest increase (15% ~20%) is found in North – Western regions. Autumn precipitation has increased significantly in North – Western, and to some degree in inland regions. Summer precipitation has increased significantly in most of the northern regions.

For studies of influence of changes in precipitation on water management and environmental and ecological conditions, extreme rainfall events are of particular interest. Trend analyses of the maximum 1 – day precipitation indicate an increase since 1900 for two thirds of the stations (Alfnes & Førland, 2006). The change is moderate for most of the stations and the trend is significant at 5% level at only 4 of the 33 long – term series studied. The largest increase in the maximum precipitation is found in the South – Western part of Norway. However, stations with no trend or negative trend, although insignificant, are also present in this area.

6.2 Modelling regional climate change

Coupled atmospheric – ocean global circulation models (AOGCMs) are the most sophisticated tools for modeling global warming. The resolution in the AOGCMs is presently sufficient for modeling large – scale features, but in general too coarse to enable these models to reproduce the climate on regional or local scale. In order to produce scenarios with spatial resolution useful for local impact studies it is thus a need for downscaling the AOGCM results. Regional modeling (dynamical downscaling), statistical methods (empirical downscaling) or combinations of these techniques may be applied for this purpose. In Norway both dynamical and empirical techniques have been applied to downscale results from AOGCMs (Bjørge et al., 2000; Hanssen – Bauer et al., 2003, 2005).

6.3 Projections of climate development during the 21st Century

To reduce uncertainties in the scenarios for Norway, dynamically downscaled results from different global climate models are combined (see (http://regclim.met.no). The models used are the British UK Met Office Hadley – Centre HadCM3 model (HAD), the German Max – Planck – Institute's ECHAM4/OPYC3 model (MPI), and the Norwegian Bergen Climate model (BCM). Simulations are performed for different IPCC SRES (IPCC 2007) emission scenarios (e.g. IS92a, A2, B2 and A1b). The main results for future climate development in Norway are presently based on empirical downscaling and on a combination of dynamical downscaled simulations for HAD and MPI with emission scenario B2.

The annual temperature in Norway is projected to increase by 2.5 to 3.5 deg C in different parts of Norway from 1961 ~ 1990 to 2071 ~ 2100 (Table 4). The largest temperature increase is projected in interior regions and in northernmost Norway. The downscaled scenarios indicate that the winter temperature will be 2.5 ~ 4.0 deg C higher than the present level, with the largest increase in interior parts of the Finnmark County. Summer is the season with the smallest projected temperature increase, 2.0 ~ 2.5 in most parts of the country. Number of days during the winter season with minimum temperatures above zero deg C will increase by 10 ~ 25 days in coastal and lowland areas in Norway (http://regclim.met.no).

Table 4 Average change in temperature (deg C) from the period 1961 ~ 1990 to 2071 ~ 2100

Region	Annual	Spring	Summer	Autumn	Winter
Total (Norwegian mainland)	2.8	2.9	2.4	3.3	2.8
Finnmark & Northern Troms	3.2	3.3	2.2	3.5	3.6
Nordland & South – Troms	2.7	2.9	2.0	3.1	2.7
Western Norway (incl. Trøndelag)	2.6	2.7	2.3	3.2	2.4
Southeastern Norway	2.9	2.8	2.6	3.5	2.8

* Results are based on dynamically downscaled scenarios from two global climate models (MPI and HAD, B2 emission scenario).

The projected changes in precipitation from 1961 ~ 1990 to 2071 ~ 2100 (Table 5) indicate that the annual precipitation will increase by 10% ~ 15% in different regions in Norway. The increase is largest (~ 20%) along the South – Western coast and far north. The largest seasonal changes are found for the autumn; where the increase in Western, Central and Northern – Norway is larger than 20%. In South – Eastern Norway the precipitation during autumn and winter is projected to increase by 15% ~ 20%, while the summer precipitation in parts of this region may be reduced by up to 15%.

Table 5 Average change in precipitation (%) from the period 1961 ~ 1990 to 2071 ~ 2100

Region	Annual	Spring	Summer	Autumn	Winter
Total (Norwegian mainland)	13	13	3	20	13
Finnmark & Northern Troms	14	11	12	23	7
Nordland & South – Troms	12	10	13	18	6
Western Norway (incl. Trøndelag)	13	14	2	20	14
Southeastern Norway	12	15	– 5	19	18

* Results are based on dynamically downscaled scenarios from two global climate models (MPI and HAD, B2 emission scenario).

The combined downscaled results are also used to study changes in extreme precipitation (http://regclim.met.no). The results indicate that for all of Norway daily rainfalls that are considered extreme today will be more common in the future according to these scenarios.

6.4 Uncertainties in projections of future climate

Substantial uncertainties are involved in the production of global scenarios and in downscaling of scenarios to regional and local scales. The most important sources of uncertainty are: (a) Variations in the climate system lead to unpredictable natural variability. (b) Uncertainty in the projections of future changes in natural (solar radiation, volcano eruptions) and anthropogenic (release of gases and particles) climate forcings. (c). Uncertainty concerning future changes in land – use and (d) Imperfect climate models (forcings and processes, physical and numerical treatment of processes, poor resolution, and weaknesses in downscaling techniques.

7 Conclusions

This review paper collects Norwegian experience in several fields of sustainable water management, hydropower development and environment protection, ecological reservation from different areas and in rivers and the climate development trends in the last 100 ~ 150 years. The experience may provide reference for sustainable water management in the Yellow River and in other river basins in China or other countries. Acknowledgement

The five co - authors have contributed to this review paper from their individual professional fields. The paper is under the implementation of project - Bilateral Cooperation for Sustainable Water Management towards Environmental and Ecological Effects between the joint Norwegian Institutions in Norway and the Yellow River Conservancy Commission in China, supported by the Norwegian Research Council.

References

Alfnes, E. and Førland, E. J. (2006). Trends in extreme precipitation and return values in Norway. met. no report 2/2006 Climate.

Bechmann, M., Eggestad, H. O., Våje, P. I., Stålnacke, P & Vagstad, N. (1999). The Agricultural Environmental Programme in Norway. Erosion and nutrient runoff. Results including 1998/1999. Jordforsk report no. 103/99. ISBN 82 - 7467 - 3549. 31 pp.

Bjørge D, J E Haugen, T E Nordeng. (2000). Future Climate in Norway. DNMI Research Report 103, Norwegian Meteorological Institute, Oslo.

Bogen, J. (1992). Monitoring grain size of suspended sediments in rivers. s 183 - 190 in: J. Bogen, D. E. Walling and T. Day: Erosion and sediment transport programmes in river basins, IAHS publ no 210, 538s.

Bogen, J. (1996). Erosion and sediment yield in Norwegian rivers, p 73 - 84 in: D. E. Walling and B. W. Webb (eds) Erosion and sediment yield: Global and regional perspectives, IAHS - publ no 236.

Bogen, J. & Bønsnes, T. E. (2000). Virkninger av effektregulering påerosjon og sedimentasjon i vannkraftmagasiner. Rep: 16 i Effektregulering - Miljøvirkninger og konfliktreduserende tiltak. Statkraft, Høvik, 66s.

Bogen, J. & Bønsnes, T. E. (2001). The impact of a hydroelectric power plant on the sediment load in downstream water bodies, Svartisen, Norway. Science of the Total Environment, special issue 266, pp. 273 - 280.

Bogen, J. & Bønsnes, T. E. (2004). The impact of erosion protection work on sediment transport in the river Gråelva, Norway, p 155 - 164 in: Sediment transfer through the fluvial system, eds: V. Golosov, V. Beyaev and D. E. Walling.

Braskerud, B. (2001). The influence on vegetation on sedimentation and resuspension of soil particles in small constructed wetlands. Journal of Environmental Quality 30 (4): 1447 - 1457.

Brox, Gunnar. (1995). Flooding in east Norway (in Norwegian), NVE Report No. 1995: 34.

Børresen, T. & Riley, H. (2003). The need and potential for conservation tillage in Norway. Proceedings International Soil Tillage Research Organization`s 16 Conference. Brisbane, Australia.

DANVA. (2005). Funktionspraksis for afl? bssystemer under regn. Baggrundsrapport for skrift nr. 27. København. 2005.

European Committee for Standardisation. (1997). EN - 752 - Drain and sewer systems outside buildings Part 4: Hydraulic design and environmental consideration.

Hanssen - Bauer I, E J Førland. (2000). Temperature and precipitation variations in Norway 1900 ~ 1994 and their links to atmospheric circulation. Int J Climatol 20, No 14: 1693 -

1708.

Hanssen – Bauer I, O E Tveito, E J Førland. (2000). Temperature scenarios for Norway. Empirical downscaling from ECHAM4/OPYC3. DNMI Klima Report 24/00, Norwegian Meteorological Institute, Oslo.

Hanssen – Bauer I, O E Tveito, E J Førland. (2001). Precipitation scenarios for Norway. Empirical downscaling from ECHAM4/OPYC3. DNMI Klima Report 10/01, Norwegian Meteorological Institute, Oslo.

Hanssen – Bauer, I., E. J. Førland, J. E. Haugen & O. E. Tveito. (2003). Temperature and precipitation scenarios for Norway: Comparison of results from empirical and dynamical downscaling. Met. no report 06/03 Klima.

Hanssen – Bauer, I., C. Achberger, R. E. Benestad, D. Chen and E. J. Førland. (2005). Statistical downscaling of climate scenarios oevr Scandinavia. Clim. Res. 29, 245 – 254.

Hanssen – Bauer, I.. (2005). Regional temperature and precipitation series for Norway: Analyses of time – series updated to 2004. met. no report 15/2005 Climate.

Herschy, Rag. (2003), World Catalogue of Maximum Observed Floods, the International Association of Hydrological Science (IAHS), publication 284, ISBN: 1 – 901502 – 47 – 3 and ISSN: 0144 – 7815.

IPCC. (2007). Climate Change 2007: The physical science basis. Working group I contribution to the Intergovernmental Panel on climate change fourth assessment report.

Lindholm, O og Nordeide, T. (2000). Relevance of some criteria for sustainability in a project for disconnecting of storm runoff. Environmental Impact Assessment Review vol. 20 p. 413 – 423.

Lindholm, O., Endresen, S., Thorolfsson, S., Sgrov, S. and Jakobsen, G. (2005). Veiledning i overvannshåndtering. NORVAR – rapport 144. Hamar, Norway.

Lindholm, O. and Bjerkholt, J. (2007). Dimensioning of sewerage and drainage systems in the nordic countries". The COST C22 "Urban Flood Management" Book "Advances in Urban Flood Management" Taylor & Francis. ISBN 9780 4154 36 625.

Lindholm, O., Greatorex, J. and Paruch, A. M. (2007). Comparison of methods of sustainability indices for alternative sewerage systems – Theoretical and practical considerations. Ecological indicators, vol. 7, Issue 1, January 2007, Page 71 – 78.

Lundekvam, H., Romstad, E. & øygarden, L. (2003). Agricultural policies in Norway and effects on soil erosion. Environmental Science & Policy. 6: 57 – 67.

Matheussen, B. V. (2004). Effects of anthropogenic activities on snow distribution and melt in an urban environment (Ph. D. Thesis). Norwegian University of Science and Technology. ISBN 82 – 471 – 6346 – 0 ISSN: 1503 – 8181.

Myllyvirta, I. (2005). Function requirements for sewer systems in Finland. Ninth Nordic Sewerage Conference". Stockholm 7 – 9th November 2005.

Nie, L. M. (2004). Flooding Analysis of Urban Drainage Systems (Ph. D. Thesis). Norwegian University of Science and Technology. ISBN 82 – 471 – 6240 – 7, ISSN: 1503 – 8181.

Nie, L. M. (2004). Flood situations and flood control in Norway. The Proceedings of the 9th International Symposium on River Sedimentation, Vol. II, pp. 515. 523, 18 – 21 Oct. 2004, China.

Nie, L. M. (2005). The State of Urban Hydrological Data in the National Monitoring System in Norway. Abstract proceeding of UNESCO IHP VI Workshop of Integrated Urban Stromwater Management in Cold Climate, Trondheim, Norway, Nov. 3 – 4, 2005. ISBN 82 – 471 – 6035 – 8.

Norwegian Official Commission (NOU) (1996). Flood Protection Measures (in Norwegian), NOU 1996:16, Ministry of Industry and Energy, ISSN: 0333 – 2306; ISBN: 82 – 583 – 0404 – 6.

Pedersen, T. S.. (2007). Contribution to: Common implementation strategy for the water framework directive. WFD and Hydro – morphological pressures. Policy paper (in prep.)

Roald, Lars Andreas. (2003). Public lecture notes.

Rosholt, L. P. (2000). Pollution based real time control of urban drainage systems (Ph. D. thesis). Norwegian University of Science and Technology, ISBN: 82 – 7984 – 062 – 1, ISSN: 0802 – 3271.

Royal Ministry of Petroleum and Energy of Norway (RMPE). (2006a). Acts relating to the energy and water resources sector in Norway (original in Norwegian), 80 p.

Royal Ministry of Petroleum and Energy of Norway (RMPE). (2006b). Regulations relating to the water resources sector in Norway (original in Norwegian), 173 p.

Royal Ministry of Petroleum and Energy of Norway. (2006c). Facts 2006: Energy and water resources in Norway, 129 p.

Saltveit, S. J. (ed.). (2006). Ecology of rivers – impacts of river flow changes. A compilation of current knowledge (in Norwegian). NVE, 152 p.

Stensrod, O. (2001). Development of water – related damage. Presentation by Gjensidige NOR.

Skarphedinsson, Sigurdur. (2005). Personal communication. Reykjavik Iceland.

Syversen, N. (2002). Cold – climate vegetative buffer zones as filters for surface agricultural runoff. Ph. D thesis. Agric. Univ. Norway, 2002:12.

Svensk Vatten. (2004). Dimensionering av allm? nna avloppsledningar P 90". Stockholm.

Taksdal, S. (1999). Hydrological data in Norway – an overview of Sept. 1999, Vol. 1 – 3, NVE publications: 1999:9.

Tollan, A. (2002): Water resources (in Norwegian). Lectures at University, 227 p.

Toverød, B. S., Høydal, ø. and Berg, Hallvard. (1999). Guideline of Land use and safety in flood exposed areas (1/1999), ISBN 82 – 410 – 0378 – 1.

øygarden,, L., Lundekvam, H., Arnoldussen, A. & Børresen, T. (2006). Soil erosion in Norway. In: Boardman, J. & Poesen, J. 2006: Soil Erosion in Europe. John Wiley & Sons. 855 pp: pp 1 – 17.

Astebøl, S. O. and Coward, J. E. (2005). Monitoring the performance of a wet pond for treatment of highway runoff in Oslo. The Norwegian Public Roads Administration, UTB report 2005: 02.

Astebøl, S. O. and Hvitved – Jacobsen, T. (2006), Protection of water resources in planning and construction of roads. The Norwegian Directorate of Public Roads, handbook 2006:261.

Discussion on the Construction of Economic Structure System Adapting to Water Resources Carrying Capacity

Jiang Bingzhou, ***Cheng Xianguo*** and ***Jing Ming***

Yellow River Institute of Hydraulic Research, Zhengzhou, 450003, China

Abstract: As for the increasingly severe water resources crisis, water saving society construction is the crucial solution for social economic sustainable development. The construction of economic structure system compatible to water resources carrying capacity is the sticking point for water saving society, which can be realized through the approaches such as industrial structure adjustment, urbanization, adjustment of agricultural structure, cropping pattern, and introduce of virtual water theory, etc. Then water resources will be lead to the vocations with high benefit and the benefit of water resources will be enhanced a lot.
Key words: economic structure, water resources, carrying capacity, water saving society

Water saving society (WSS) building is a right way to support sustainable development in China and alleviate stress of water resource. The aim of WSS is to improve water use efficiency through adjusting economic structure, developing water saving irrigation and prior developing the vocation with high water use efficiency.

1 Industrial structure adjustment adapting water resource carrying capacity

Characteristic industry with higher preponderant comparative advantage and market potential should be cultivated and speeded up vigorously. Simultaneously lengthens the industrial chain, transforms the resources superiority and the comparison superiority as the economical superiority, to adjust optimizes industrial structures, and realize tradition agricultural economy to modern industry economy reforming. Through readjustment of the economic structure impetus water used structure adjustment. Agricultural water consumption structure should be reduced greatly; the second industrial water consumption proportion obtains the effective enhancement. The support water resources transform to the high benefit profession, enhance use benefit of the water resources. At present, the thermoelectricity generation, the spinning and weaving, the papermaking, the steel and iron, the petroleum and so on 5 high water used excessively concentrate in the north lack the water area, causes this area water resources supply and demand contradictory day by day prominent, the water environment worsens the condition aggravating, brings the ground water level to drop, the surface subsidence and the water pollution question is serious. Therefore, when formulates the region social economy development plan must consider fully water resources condition and enhance items of basic construction. It should the ecological influence that project construction did to resources consumption. In the area of water resource insufficient the agriculture and service industry project should be limited. Through adjusting industrial structure, water should be used into the high benefit domain. An area carrying on the industrial choice and the adjustment according to the resources carrying ability, the development has the comparison superiority industry, not only cannot reduce the economic society to develop, but can realize in the higher level sustainable development. In Ningxia area, it has the tourist resources superiority which the energy and the mineral resource superiority, the agricultural and subsidiary products superiority, are characteristic and so on. Developing vigorously takes the superiority agricultural product as raw material agricultural product processing industry, the promotion industrial development level. Accelerates to develop the characteristic resources ,Ningxia should hold matrimony – vine, the dairy product, the Islamic cow mutton and potato four big strategic leading industry series processing ability in the domestic and foreign markets, as well as has the resources superiority and the industrial foundation, the characteristic competitive advantage obvious, has the very big development potential to brew grape, the vegetables, the corn, the high quality rice and wheat, the feed and the fresh water fish and so on six big regional characteristic product processing, simultaneously had to speed up has the relative superiority, the product already has certain well – known, development potential great place characteristic products and so on modern Chinese native medicine and healthy product, chemistry bulk drugs and papermaking, wool in the market development. Forms the industrial chain, the industrial belt and the industrial group is a body agricultural and subsidiary products intensive processing system, the making brand, extends unceasingly the agricultural products processing industry chain, the promotion superiority agricultural product added value and competitive ability. Consummates the traveling service system, Ningxia will make the feature tourism destination. Through the industrial structure adjustment, has provided the advantageous support for the Ningxia water resources sustainable use. The Gansu Province, Zhangye has displayed hydro energy and the mineral resource superiority. It will complete the electricity, the coal, and the tungsten three big articles as emphasis. Middle and upper reaches Hei River, 8 power plant installing equipment aggregate capacity may achieve above 1,000,000 kW, has been completed at first step at present; in Pingshan and Caohuatan coal mine, the coal reserves respectively amounts to 120,000,000 ton and 300,000,000 tons, at present drilling. The reserves 436,000 ton Sunan extra large type tungsten ore has completed. After the electricity coal tungsten three big resources developmental item completes, the year may realize the sale to receive 9,450,000,000 Yuan, fundamentally will improve Zhangye industry benefit greatly. And develops the private ownership system economy through the expanded attract/bid for/invite investments, speeds up the small project construction. It will form Zhangye characteristic industry leading economical pattern. The future of Zhangye will be the water consumption small industry department replacing the water consumption big industry department. The region will limit development of the high water consumption project, and reduce water consumption.

2 Urbanization building adapting to water carrying ability

The urbanization is the only way of society's development that must be taken in water scarcity regions; the urbanization construction must consider the water resources bearing capacity. The scale moderate and small townships town will be the prioritize one. To develop the urban development space, break wall bonds existing city and countryside, establish the city and the region integration metropolis circle level, cultivate and develop the regional key city positively. Construct the small city according to local qualification.

Mentions the rural population industrial shift and the spatial shift to a strategic altitude, on the one hand advances the rural population urbanization advancement positively, and speeds up the system innovation and the policy adjustment more importantly. Implements the new independent ecology immigration pattern, through the extension agriculture industry chain, strengthens the rural education, carries on large – scale professional skill training to the youth farmer; The peasant laborer g service system and the labor market should be established to urge more farmers change the traditional living manner. According to Gansu blue design of building developed medium city, Zhangye improves its city function gradually. The city zone was enlarged and city capacity ability improved with small town building started. Water resource press of the city was alleviated to maintain society and ecological development.

The urbanization needs to embark from the water resources, considering fully the water resources bearing capacity, to establish the macroeconomic regulation and control mechanism as "decides the urban development reasonable scale by the water, decides the cities industry development by the water". To achieve truly supplies to need and the development by the water.

3 Agricultural structure adjustment adapting to water carrying capacity

Agricultural production is the important work of countryside in many years in China. The agricultural structure was not changed with the core of planting. Until the 90's last stages, the grain supply – demand relation has had the historical transformation; the agricultural resources reasonable disposition is raised to the program.

The crop production issued as high water consumption with lower output. Constructs in WSS must consider fully national and various regions water resources condition. In arid region, planting area of some high water consumption plant such as price and winter wheat should be limited. The enhancement crop assortment improvement, the adjustment crop production structure, develops the water – preservation agriculture vigorously, gradually establishes the agricultural economy structure system and water resources bearing capacity adapts. The change of "dual structure" to "ternary structure" should be implemented according to local development. In the modernized agriculture, speeds up the development animal husbandry and the aquatic products industry, reduces the crop production to account for the proportion, the optimization plants raises industry the structure. Focuses in the agricultural sustainable development, implements positively takes back from agriculture also the forest, also the grass, also the lake system, restores with the protection ecological environment. During increase agricultural economy total quantity, reduces the agricultural production the water consumption, is the water resources to the high benefit, the high efficiency profession pasts provides the foundation; While the agricultural economy structure to saving water highly effective direction adjustment, using the water rights, the water market theory makes the instruction, the guidance agriculture internal water rights to high professions and so on benefit, high efficiency forestry and herd fishery pasts.

Zhangye city has reformed agriculture structure with a great degree. in 2000 ~ 2003, it compressed paddy rice sown area 6,700 hm^2, the strip – cultivated fields 27,000 hm^2, area of forest grass taken back from agriculture is 47,300 hm^2. In 2000, the rate of grain and economic plant was 58:42, and in 2003 the rate of grain, economic and grass was 26.5:61.5:12. The construct with proper priority grass livestock product processing, the seed processing, the fruits and vegetables product processes and the light industry processing of raw material four big main item enterprise group, leads the whole city planter structure adjustment. in 2004, the agriculture, forestry, animal husbandry, and fishery output value of Ningxia is 1.26×10^{10} Yuan. the crop production, the forestry and the herd fishery proportion is 58.3:5.1:36.6. according to Ningxia's actual situation, estimated to 2020, Ningxia agriculture, forestry, animal husbandry, and fishery output value is 2.66×10^{10} Yuan, the crop production, the forestry and the herd fishery proportion is 35:10:55, in which crop production output value accounts for the total output value 58.3% to reduce 35% from the present situation, the water demand occupies the total proportion of crop production, the forestry and the herd fishery will reduce from 86.8% to 79.7% at the present situation level, through the agricultural economy structure adjustment, the total water demand of agriculture, forestry, animal husbandry, and fishery will reduce from present situation level 7.72×10^9 m^3 to 6.24×10^9 m^3. Ningxia agricultural structure adjustment will adapt to local water resource situation and also take a great role in Ningxia sustainable development.

4 Agricultural structural adjustment adapting to water carrying capacity

As the population but limited arable land, China's main grain crop in the long structure. Foods direct is impact on the economic development and social stability in overall national. With the process of agricultural modernization and the development of the commodity economy, the shortage of agricultural products in China has passed a basic balance between grain supply and demand. Cultivation of food crops, cash crops and forage crops ternary structure gradually. However, agricultural production is the main food crops, cash crops and livestock development in a relatively disadvantaged. Agricultural simplex variety, and bad quality, and do not have a competitive advantage, particularly land – intensive products, there is no effective competition, have competitive advantages in high – tech agricultural products are mainly labor – intensive agricultural products. Therefore, the conditions must be played around the natural, economic and social advantages, such as structural readjustment of the crop.

Structural readjustment of the crop, we should give full consideration to the bearing capacity of water resources to ensure the basic food production, 400 kg per capita consumption of food products to around the premise of strict water restrictions on the cultivation of rice and other crops ratio. Positive develop economic crops and economic fruit. Vigorously promote the production of fodder crops, and create conditions for the development of stockbreeding. Economic development around is the key characteristics, forming different brands of agricultural products.

Water shortage in the Ningxia region in 2004 reached 1,737.6 million mu of crops sown area, the sown area of grain which reached 1,187.5 million mu, accounting for 68.3% of total acreage. The sown area of grain is too large; the trend has further exacerbated the shortage of water resource. Therefore, based on the bearing capacity of regional water resources, the future of water – intensive products, Ningxia should gradually reduce the area under cultivation. According to a slight surplus of self – sufficiency in food security strategy; rationally determine grain production capacity, high quality grain production project. Compression high water, low efficiency, marketable varieties, stable, high quality wheat, rice, corn, and small budgets acreage, formed to bring high – quality grain production. Expand the production of high – quality forage, feed, forage and crop rotation implemented. Agriculture and livestock bigger and stronger, extend the industrial chain. Development of medlar, wine grapes, melons, vegetables, fruit, such as high efficiency, increase the effect of economic crops, and eventually food crops coordinated development of the crops and forage crops basic pattern. According to Ningxia region, it will be the status quo, and in 2010 the per capita food safety standards to 422 kg. 2020 rose to 472 kg. Ningxia region in 2010 and 2020 based on total grain demand of 270 million tons and 340 million tons respectively, agricultural crop mix as the fundamental basis for determining the reasonable irrigation acreage sown area of grain and grain size.

5 Virtual water of the theory on the impact of economic structure system

Virtual water is the first time Tony Allan Who is a British scholar has raised in the early 1990s. Virtual water refers to the production of products and services required quantity of water. The introduction of the concept of food security analysis and research provide a new way of thinking. Virtual Water Strategy is water – poor countries or regions through trade or from water – rich countries to buy water – intensive agricultural areas (especially food) to obtain water and food security. Traditionally, people are accustomed to the water and food security problems in the region to find a solution within the scope of the problem. Virtual Water from the strategic point of view, systems thinking and the method used to find a wide range of issues related factors from the valley to find solutions to issues outside the scope of internal problems to deal with strategies to promote effective water resource commodity exports, water production and import of food products are not enough, the shortage of water resources in the form of a final settlement through trade and food security. From a global perspective, China does not have advantages in grain production, water resources and food consumption market. Not a threat to national economic security in the conditions, many imported food products such as water, the water savings can be used for industrial development, animal husbandry, and the ecological environment, the efficient use of water resources.

6 Conclusions

China is a country with agriculture as the dominant industry, and establish water – bearing capacity to adapt to the economic structure, strategic restructuring of the socio – economic needs in a longer period of unremitting efforts. In economic restructuring are the establishment of the macro – control and management of water – bearing capacity, the ability to adapt to the economic structure the crucial. The government must be in the process of strategic readjustment of the economic structure, it is necessary to strengthen the government's macro – control capabilities for structural adjustment. determine the direction of restructuring and adjustment of the scientific steps to perfect the system, structure and mechanisms, such as land management, standardized agricultural production; Second, it is necessary to raise the guidance of the market economy, management and control; Third, it is necessary to strengthen the government 's economic transformation and service capabilities, including information services, and technology services, water carrying capacity to adapt to guide the socio – economic reorientation.

References

Wang Shucheng. Water Right Management with Water Saving Society[J]. China Water Resources, 2001,4:6 – 8.

Sun Xuetao. Status and Function on Water Right System Development in China[EB/OL]. http://www.hwcc.com.cn, 2005.

Li Xi, Tian Baozhong. Some Thinking and Practices of Water – saving Society Establishment[M]. China Water Resources and Hydropower Publishing House,2003(10).

Li Xinwen, Chen Qiangqiang. The Summary on Development Tendency of Foreign and Domestic Virtual Water[J]. Research On Development, 2005(2).

Song Jianjun. Solutions of the Problems of Water Resources in China's Northwestern Areas[EB/OL]. http://www.cpst.net.cn, 2005 – 05 – 25.

Cheng Guodong. The Innovation Field of Water Resources and Water Safety[J]. Bulletin of the Chinese Academy of Sciences, 2003(4).

Ecosystem Benefits from Safety Operations in River Meuse

P. J. Meesen and ***E. M. Sies***

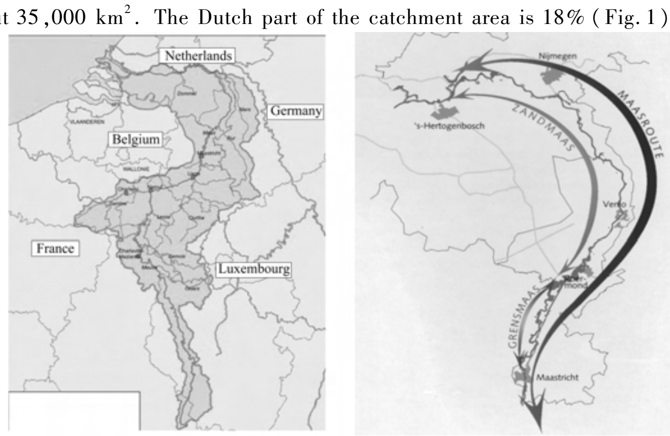
Public Works and Water Management, Civil Engineering Division, PO Box 20.000, 3502 LA Utrecht, The Netherlands

Abstract: The floods of 1993 and 1995 along the river Meuse made clear that the Netherlands was not sufficiently armed against the risk of flooding. A large – scale water management project in the river Meuse was born. The Ministry of transport, public works and water management in co – operation with the Province of Limburg and the Ministry of Agriculture, Nature and Food Quality has as goal to make the Meuse a safe, navigable river for future generations but also a haven for plants and animals. Within a combination of several flood protection measures opportunities for the creation of new conservation areas and the improvement of existing plant and wildlife habitats has been availed. It is possible to achieve both safety and ecological benefits within a large – scale project.

Key words: ecosystem benefits, safety operations, river meuse

1 Introduction

The Meuse river is approximately 950 km in length from its origin in France to its access to the sea. It originates in the Langres Plateau in France at an altitude of about 500 m above mean sea level. The Meuse river finds its route through Belgium where it is joined by the Sambre river. Within Belgium the Meuse winds eastward skirting the Ardennes and enters the most southern part of the Netherlands near the city of Maastricht. In the Netherlands the river flows in northern direction down to the city of Nijmegen where it turns westward. In the Netherlands it merges with the Rhine into an extensive delta, eventually flowing into the North Sea near Rotterdam. The total stretch of the river Meuse within the Netherlands is about 300 km in length. The total catchment area of the Meuse is about 35,000 km^2. The Dutch part of the catchment area is 18% (Fig. 1).



Catchment Area River Meuse River Meuse within the Netherlands

Fig. 1

The Meuse is fed mainly by rainwater all year round. Flow is generally highest in winter. Especially in the Ardennes section of the Meuse rainwater drains quickly from the surrounding countryside into the river. This means that in case of heavy rainfall in the Ardennes, the Meuse in the Dutch part (Province of Limburg) will be running high within twenty – four hours. Furthermore the Meuse is an important waterway in Western Europe. In Belgium the Albert Canal links the Meuse with the port of Antwerp and in the Netherlands the Meuse is linked with Rotterdam and other Dutch ports by the intricate system of Dutch waterways. The Meuse is one of the chief thoroughfares of Europe.

To ensure all – year – around navigability despite the low summer flow, water levels in large stretches of the Dutch Meuse are also permanently controlled by weirs. The main exception is the Grensmaas (Dutch name, literally Border Meuse), the river stretch that forms the border between Belgium and the Netherlands from Maastricht to Maasbracht. In this part, the river is uncanalized, fast flowing and meandering over shallow gravel banks. As the river is virtually not navigable, barge traffic is shipped via the parallel Juliana Canal. The canalised stretch of the Meuse between Maasbracht and Lith, is easily navigable. The Meuse is not embanked until it turns westward at Mook. The embanked part of the river is characterized by a wide river valley having settlements in the winterbed of the river.

The observed discharge of the Meuse, at the Dutch border, varies between 0 m^3/s and 3,100 m^3/s (Huisman, 2004). The average discharge for the river Meuse is 320 m^3/s and the design discharge is 3,800 m^3/s (1:1,250 years, present).

The river Meuse serves many different purposes. Besides a conduit for rainwater and an important transport route for inland shipping its banks accommodate agriculture, plants and wildlife and recreational activity. The water that flows through the Meuse is used as drinking water, for industrial processes and as cooling water. Furthermore the river's summer bed is an important source of sand and gravel.

The high water levels of 1993 and 1995 have caused considerable social and economic damages. The impact of both floods was enormous (Fig. 2).

Fig. 2 Flooding of the Meuse in 1993 and 1995

Knowing that flooding problems due to climate changes may increase the Dutch government decided that measures should be taken to avoid this kind of flooding problems in the near future. A project organization of the Dutch Ministry of Transport, Public Works and Water Management, called RWS Maaswerken was formed to bring down the flood risks to 1:250 per year with a discharge of 3,275 m^3/s for the unembanked sections of the river (current safety level varies between 1:20 to 1:50 per year for a discharge of 2,700 m^3/s). For the embanked section of the river the safety level remains 1:1,250 per year for a discharge of 3,800 m^3/s.

Realizing that a large – scale operation along the river was needed the Dutch Ministry of Transport, Public Works and Water management, in cooperation with the Province of Limburg and the Ministry of Agriculture, Nature and Food Quality created a new policy by adding two extra tasks making the Meuse a safe, navigable river for future generations and a haven for plants and animals. RWS Maaswerken's task fits within the domestic and international policy of giving rivers more space, both for water discharge and for ecological recovery. The aim of this policy is to ensure that future generations can continue to live and work along the river and spend their leisure time enjoying it as well.

2 RWS maaswerken and a new strategy to avoid flooding

In the past problems with flooding were solved by heightening the embankments along the river.

Although this approach proofed to be rather sufficient a new approach is needed to meet other and new interests within the surrounding of the river. More intelligent river basin management is needed using wetlands and alternative methods to decrease the water levels in case of high discharges. The project organization RWS Maaswerken made a programme wherein flood protection, nature conservation, inland navigation and gravel extraction go hand – in – hand. In 2002 the Dutch government, following the procedure of stakeholder participation, accepted this programme. Within a period of about 15 years, major investments are required to reinforce dikes, deepen riverbeds, create flood channels, and excavate and remove enormous quantities of soil. Furthermore locks will be improved and bridges will be raised to fulfil new criteria for inland shipping; stretches of banks will be exposed to the forces of erosion; and natural banks and habitats for flora and fauna will be allowed to develop.

To manage this programme using the slogan: "Tomorrows Meuse" the RWS Maaswerken project office is divided into three specialist units, each one focusing on a different part of the project:

The Sand Meuse (Zandmaas) is the stretch of the river between Roermond and ' s Hertogenbosch. The project focus is on flood protection and the limited development of conservation land (570 hectares in all). A combination of measurements will protect the area from being flooded again:

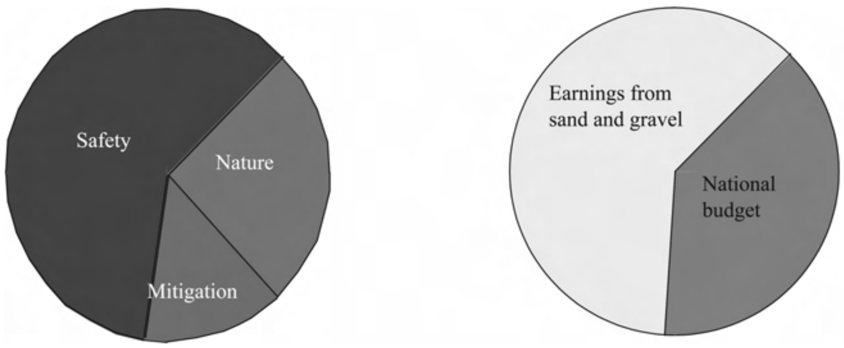
- Dikes at the cities along the river will be raised and reinforced.
- The summerbed of the river will be broadened and deepened.
- Large flood channels will be constructed in the winterbed of the river. In case of high water these flood channels start flowing and discharging water, lowering the level of high water in that specific area.
- A retention area of about 500 hectares will be created west of the city of Roermond. This retention area will only be used in case of emergency. In case of extreme water level the basin will be filled with water lowering the water level in the river.
- At several places along the Sand Meuse riprap will be removed from the banks allowing the process of erosion and sand deposition to take place and creating new habitats for flora and fauna by that.

The Border Meuse (Grensmaas) is the unnavigable stretch of the river between Maastricht and Roermond. Three targets have been set here: flood protection, gravel extraction and nature conservation, with 1,000 hectares being set aside as conservation land. The banks along the Border Meuse will be allowed to erode. Widening the river will produce about 52 million t of gravel satisfying the nations major demand for gravel (as a basis for building material) in the next few decades.

The Meuse Route (Maasroute) is the name given to a package of measures that will improve navigability along the Meuse. These measures will encompass three canals, the Juliana Canal, the Lateraal Canal and the Maas – Waal Canal. The Meuse will be navigable for double – barge pushtow units, i. e. measuring 190 m in length, 11.4 m in width and with a draught of 3.5 m. Some parts of the river can handle barges with containers stacked up to four high (see Table 1, Fig. 3).

Table 1 Figures river meuse works

Item	Figures
Costs flood protection and nature development	1.4 billion
Costs improvement shipping route	391 million
Timeschedule	Start: 1995 Completion first phase: 2015 (flood protection) Completion second phase: 2022
Involved parties	3 ministries 6 water boards 42 Dutch local authorities 1 Belgian Province



Costs per item　　　　Budget to finance the project

Fig. 3

3　RWS maaswerken

3.1　Dredging operations sand meuse

To reduce the risk of flooding a combination of measurements is needed. Due to local circumstances the alternatives for measurements differs from place to place. Based on the new water management strategy (see chapter 2) and starting point to give more space to the river the designers started the plan for a new Meuse riverbed. Where the available area near the river is limited and extra grounds cannot be obtained, for example due to existing infrastructure, other solutions were designed. In such cases deepening the river seems rather effective. In case when even deepening the river is not possible, for example due to the soil conditions and risk of extreme transport of sediments, heightening the dikes has been chosen as ultimate option.

The effect of the combination of measurements on high water levels has been calculated with the advanced 2d computer model WAQUA. As the existing situation differs also the effect of the measurements differs locally (Fig. 4).

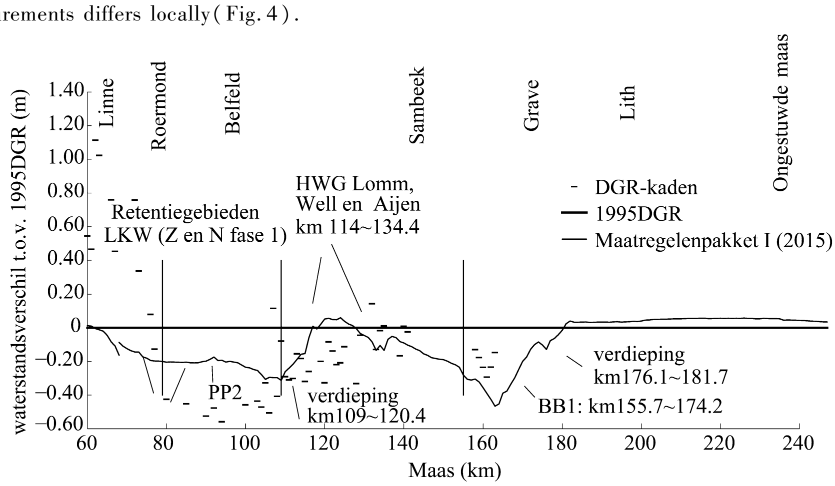


Fig. 4　Effects on water level calculated with 2d computermodel WAQUA

Dredging and deepening the riverbed is one of the measurements. For example to reduce the risk of flooding till 1∶250 per year near the city of Hertogenbosch it is needed to deepen the riverbed between the weirs of Grave and Lith, over a stretch of 5 km with 3 m which means excavation of 1.45 mln m^3 of gravel. Together with the dredging operations in other parts of the river's summerbed this excavation will produce more than 5 mln m^3 of gravel. All measurements will reduce high water levels with 0 to 40 cm, depending on the particular location.

3.2 Other possibilities for giving more space to the Sandmeuse river

Dredging and deepening the riverbed is just one of the measurements for reducing the risk of flooding by giving more space to the river. Other measurements are flood channels and lowering of adjacent land. Flood channels can be created as smaller side channels or larger high – water channels. Side channels will prevent ground water flowing to the river directly. High – water channels function the same but in addition they are able to discharge large amounts of water in case of high waters (Fig. 5).

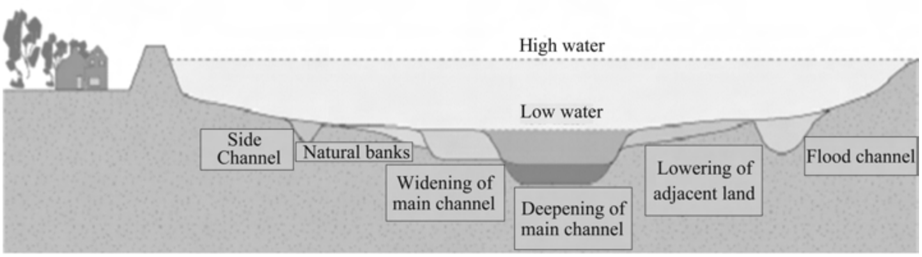


Fig. 5 Possibilities for giving more space to the flow of the river

3.3 Sand meuse operations – Nature conservation

3.3.1 Allowing erosion of banks / natural banks

On three locations along the Sandmeuse the rip – rap covering the banks will be removed with a total length of about 1,5 km. At Bergen, Aijen and De Waerd the Meuse is allowed to erode the banks up to 50 to a maximum of 100 m inland. The flow of water, combined with the waves mainly resulting from ships passing by, will cause natural erosion and create new habitats for flora and fauna (Fig. 6).

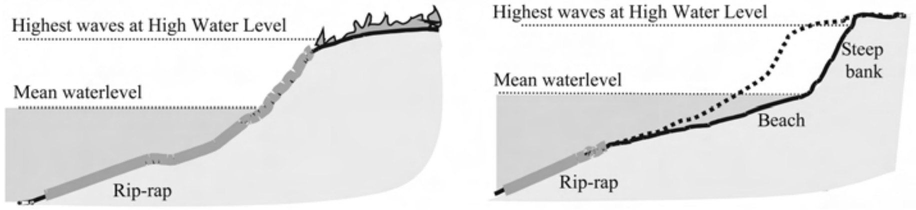


Fig. 6

Eventually, sandy beaches will form along these stretches, such as used to be seen along the Meuse before 1970. Small patches of woodland will also develop, offering a home to nesting birds and plants.

Depending on the local circumstances (waves, current, development of woodland, soilconditions) the end result will be either a shallow sand beach or a steep bank.

The resulting bank provides many opportunities for ecological development (Fig. 7).

- A shallow, sandy summer bed provides habitat for riverine fish such as Barbel, Chub and

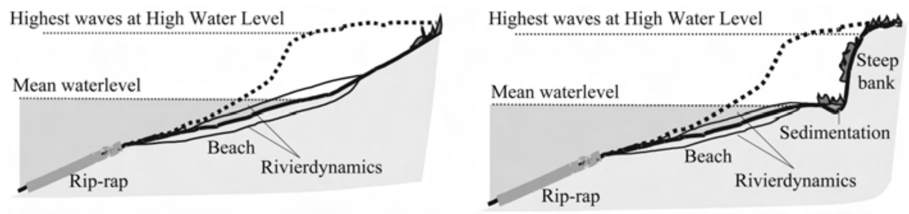


Fig. 7

Gudgeon, and macrofauna such as Caspian mud shrimp, Mayfly larvae and the water beetle Haliplus fluviatilis.

- Islands of sand may be used by macrofauna such as ground and rove beetles, and by foraging or nesting birds (Common tern, Pied avocet). In addition, mammals such as bats, Eurasian beaver and Eurasian otter may use sand islands as part of their home range. Pioneer vegetation will consist of Brown galingale, Black mustard, Devil's beggartick, Oak – leaved and Red goosefoot, Golden dock, Common lambsquarters and Great yellow cress.
- A steep river bank will have little or no vegetation, consisting of pioneer and early successional species (goosefoot, dock and beggartick species). Potential fauna includes mining bees, Eurasian beaver and Eurasian water shrew. Steep banks provide excellent opportunities for species that dig nest tunnels, such as Sand martins and king fishers.
- Shallow temporary waters (> 20 days/year) alongside the river, having clay or sandy soils, may be suitable habitat for fish like Rudd and Pike provided that these waters are sufficiently large. Moreover, ducks and geese may benefit from temporary waters. Aquatic plants such as Sago pondweed, helyophytes (Yellow iris, cattails), and macrofauna (Whirlpool ramshorn snails, the midge Clinotanypus nervosus) will find suitable habitat too.

The banks will be inspected regularly. The rate of erosion will be monitored to ensure the safety of property and infrastructure. To determine the ecological development of the banks the appearance of the above mentioned species is monitored.

3.3.2 Flood channel lomm

A good example where ecosystem benefits from the safety operation is the high – water flood channel at the village of Lomm. This flood channel has three functions:

First of all it's a source of useful gravel. In the next ten years approximately 5,5 million m^3 of gravel and sand will be excaved at Lomm. The floodplanes will be lowered and the flood channel has to be created. By realizing more depth than needed it produces materials which can be used in industry.

Secondly it's a deposit of soil and sediments, which comes available due to dredging operations from other projects along the river and which are useless for re – use. The excavation will be filled up with a. o. 1,5 million m^3 of dredged material.

And thirdly it will find its definite destination as a high – water flood channel within a natural and ecological very attractive landscape. When the river rises, water will be diverted into the flood channel so that it can be discharged more rapidly downstream. The water level deceases locally with approximately 10 cm.

The flood channel at Lomm makes good breeding grounds for fish, while the banks offer ideal conditions for new woodland and marsh vegetation. The new conservation land that is to be developed along the flood channel at Lomm will be linked directly to Barbara's Weerd, another conservation area. The result will be a long ribbon of living nature.

Integrating these three functions needs good coordination. The time schemes of excavation the floodchannel has to be linked the producing of sediments and soil within the other projects (Fig. 8).

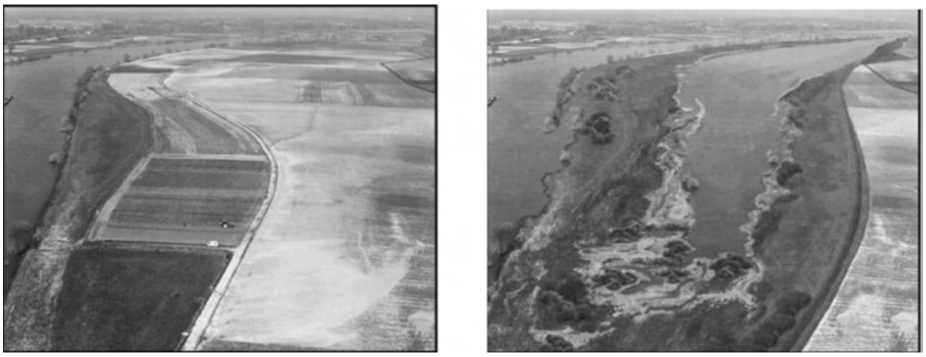


Fig. 8

3.4 Border Meuse operations – nature conservation

Within the project Border Meuse three goals come together: reduction on the risk of flooding, production of gravel and approximately 1,250 hectares new rough nature. To realize these goals in the period 2007 ~ 2022 the area of the river will be transformed, creating a "living river" meandering and with a variety in river banks, flora and fauna.

Over a length of 40 km nearby the city of Maastricht several projects will be realized, widening the riverbed, lowering the floodplains and realizing flood channels. All this plans are based on an environmental impact assessment study, which has been finalized in January 2006.

A consortium based on dredging contractors, a gravel mining company, land owners and a nature association will realize the project at twelve different locations. The consortium will realize all the aspects of the project, from permits till the execution of the works. In total approximately 53 million t of gravel will be excavated. Most of this material will be used for industrial purposes. For 16 million t out of these 53 million t there is no market and this material will be restored several deposits within the area.

All of the flood protection methods have one thing in common. It takes a lot of dredging, digging and transport of soil materials like gravel, clay and sand. The extraction of gravel, clay and sand offers an exciting opportunity to combine flood protection with the creation of new conservation areas and the improvement of existing plant and wildlife habitats. Furthermore earnings from sand and gravel make it possible to reduce the project costs to nil(Fig. 9).

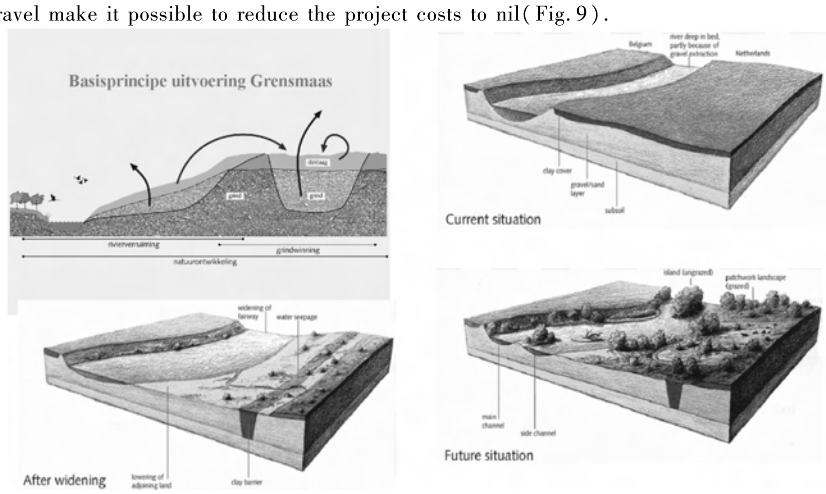


Fig. 9 Principles used within the projects Border Meuse

Gravel will be extracted at twelve sites along the south part of the river. The loamy top layer will be removed first and gravel extracted from the surface. Enlarging the river in this way will help create an attractive natural landscape. The river will reclaim the shallow gravel pits, creating new habitats for flora and fauna.

At the Isle of Bosscherveld a 3 m thick clay top layer will be removed bringing the gravel back to the surface as it used to be in the past. The flow of the river will realize some banks, small islands and channels in the riverbed. Within the area some walking and biking track will be constructed.

At Borgharen the river will get its original flow by widening the riverbed and lowering the floodplain. The area will be a nature area. In addition some structures for canoeing will be constructed.

North of Itteren, an area with lots of flooding problems in the past, the river gets more space by widening the riverbed and lowering the floodplains. In this area the river will be able to realize its own area with sandbanks and gravel banks, channels and small islands. Also this area will get the nature function. In addition a bridge to be used by wildlife will constructed to connect this nature area with other nature areas.

At the small town "Aan de Maas" another nature area will be realized in combination with additional space for the river lowering the risk of flooding. In this area the riverbed will be widened and flood plains will be lowered.

The project at the location of Meers contents all principles as mentioned above. This project is considered as a trial project. By widening the riverbed over a stretch of 2 km the river willregain its original shape. The area will be reshaped in a nature area.

Due to a lack of space nearby the town Maasband a flood channel has been chosen as a solutions to reduce the risk of flooding.

At the town of Urmond a dispocal facility for sediments out of mining projects will be removed. In addition the riverbed will be widened and a connection will be made between this new nature area with an existing nature area.

At the western part of the town Nattenhoven the floodplains will be lowered. Using the released clayey materials in a small earth body the area will be prevented from dehydration.

At Grevenbicht a new flood channel will create an island. Due to the fact that the island contains contaminated sediments this island itself will remain intact. Due to the new flood channel the existing retaining structure will be replaced within a distance of approximately 120 m.

The town of Koeweide is located nearby a river bend. The riverbed at this bend will be widened creating a huge natural riverbed. In addition some structures for canoeing will be constructed making it possible to visit this area(Fig. 10).

Fig. 10 Present and future situaton at Meers

At Visserweert the riverbed will be widened and a flood channel will be realized. A special bridge construction will connect the town, which will be cut off by the flood channel to higher grounds(Fig. 11).

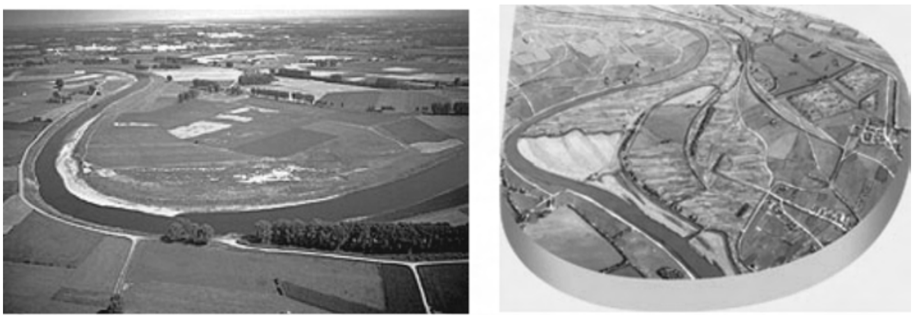


Fig. 11　Present and future situation at Koeweide

The execution of the works will be done using land born equipment like backhoe excavator, bulldozers, shovels, graders and dumpers and water born equipment like cutter suction dredgers, pontoons and equipment for classification of sand and gravel.

References

Tomorrow's Meuse. Published by RWS Maaswerken.

WWF Background Briefng Paper; Managing floods in Europe: The answers already exist; 26 September 2002. WWF Danube – Carpathian Programme; WWF Living Waters Programme – Europe.

MER Dekgrondbergingen Grensmaas; Consortium Grensmaas B. V. 195264. RM. 215. R001.

The European Water Framework Directive and Sustainable Water Management

José Albiac

Deparment of Agricultural Economics, CITA – Government of Aragon, Spain

Abstract: The scarcity and degradation of water resources is an important environmental problem in Europe. The use of water by the different economic sectors creates scarcity in some regions, and a widespread water quality degradation from point and nonpoint pollution. Water scarcity is serious in Southern countries, with a strong demand during summer for irrigation and tourism. Despite regulations and large investments in water treatment plants, water quality degradation remains high in many river basins. The improvement in water management requires better information and knowledge on surface and ground water and on their associated ecosystems. These tasks need time and resources, and the lack of data and knowledge on the underlying biophysical processes in the use of water resources, precludes and adequate and sustainable management. This knowledge is essential for designing reasonable control measures, such as the ones required by the Water Framework Directive.
Key words: European Water Framework Directive, water scarcity, water quality degradation

1 Introduction

The problem of water stress and water quality is one of the main environmental issues in Europe, together with climate change, air quality, biodiversity and soil quality. With respect to water quantity, withdrawal of water resources in Europe is above 20 percent of renewable freshwater resources. The major pressures on water quantities occur during summer in Southern countries, because of irrigation demand and tourism activities. In the coming decades, the likely increase of withdrawals and climatic change will result in more intensive pressures on water quantities in these Southern countries.

With respect to water quality, the problems are driven by pollution of water resources. The pollutants are nutrients and organic matter, and dangerous substances such as heavy metals and chemical compounds. The nitrate emissions from agriculture have decreased somewhat in the last decade in most rivers, but there still remaining problems of eutrophication and pollution of drinkable water. There are less rivers strongly polluted as a consequence of reduction in organic matter loads, the use of detergents free of phosphates, and the operation of new treatment facilities in urban centers. However, around 20 percent of European surface waters still have severe pollution problems.

The European Framework Directive, approved in 2000, is an important initiative of the European Union, intended to protect all continental, subsurface and coastal waters. It has a great potential to solve water scarcity and water quality problems in Europe by 2021 when the first management cycle deadline ends, and by 2027 which is the final deadline for meeting the objectives.

However, there are two aspects in water resources management that are difficult to solve and may hinder the attainment of the objectives. One is the sustainable management of aquifers and the other is nonpoint pollution control, and the cause of the difficulties is that they are common pool resources characterized by serious problems when trying to implement policy measures that work.

The design of reasonable measures for the management of aquifers and nonpoint pollution requires information and knowledge on biophysical processes linked to aquifers dynamics and pollution transport and fate. Generating this information and knowledge is demanding in resources and takes time. The design of measures by the water authorities must also take into account the strategic behavior of stakeholders in the design of measures. Aquifer management and nonpoint pollution control involve cooperation among stakeholders (Albiac et al, 2007), and this is a daunting task for water authorities because of the difficulties in managing common pool resources.

2 Water demand by sectors and water scarcity problems

Water abstractions in Europe for all uses reach at present 307,200 hm^3, of which 115,100 hm^3 are used in agriculture, another 104,000 hm^3 in cooling and electricity production, 53,300 hm^3 for urban demand and 34,900 hm^3 for industrial demand (Table 1). Water for cooling and electricity production

Table 1 Water use in selected European countries (2001)

Country	Total water extractions (hm^3)	Urban use (hm^3)	Industrial use (hm^3)	Irrigation (hm^3)
France	40,400	5,500	5,600	600
Germany	5,800	1,100	300	900
Greece	37,700	3,800	1,400	24,600
Hungary	33,500	5,800	3,600	4,800
Italy	8,900	900	100	7,700
Poland	5,600	700	200	500
Portugal	56,200	10,100	9,600	25,900
Spain	11,600	2,200	600	1,000
United Kingdom	9,900	800	400	8,800
Bulgaria	15,900	6,300	1,600	1,900
Romania	7,300	2,500	900	1,000
Turkey	39,800	4,300	3,500	31,000
Total Europe	307,200	53,300	34,900	115,100

Source: EEA (2005b), INE (2004, 2005), IFEN (2005).

returns to water courses with small changes in quality. However most water is used for agricultural, urban and industrial purposes, which degrade the quality of water returns. These consumptive uses generate water stress in many European regions, and problems of point and nonpoint pollution of water courses. There has been a reduction of total water abstractions in the last decade, although tendencies differ widely among sectors. The likely outlook for next decades are increases in water use by agriculture and industry, strong reductions for cooling and electricity production, and stability in urban water use (EEA 2005a).

Agriculture accounts for more than a third of total water extractions, and the volume of irrigation water will grow to cover the expansion of irrigated acreage in the South of Europe, Hungary, and EU candidate countries such as Turkey. Economic development may increase the use of water by the industrial sector, in particular in Eastern countries and EU candidates. The use of water for cooling and electricity production will be cut by half, as a result of more efficient refrigeration systems in power generating facilities. The new tower cooling systems reduce the amount of water by two orders of magnitude per megawatt – hour, compared to current refrigeration systems with single circulation. Urban demand represents 20 percent of abstractions, and its evolution will be stable since it depends on countervailing factors such as household size and income, water prices, and technological change that improves water efficiency.

In Central and Northern European countries such as Germany, France and UK, the main water abstractions are for power generation, which will fall strongly in coming decades, while industrial use may increase. In contrast, the main water use in Southern countries is irrigation, with join abstractions by Spain, Italy and Turkey above 80,000 hm^3 (Table 1). Irrigation water demand would increase as a consequence of the expansion in irrigated acreage, and also because of the impact of climatic change on water crop requirements in the coming decades. Urban and industrial water demand will increase en Eastern countries and Turkey, following the rises in household incomes and industrial activities up to Western countries' levels.

In summary, Northern and Central European countries do not face problems of severe water stress, and their main extractions are used for power generation which return to watersheds. These extractions are going to decrease substantially and the outlook for next decades is less water stress in these regions. This is the case for the Rhin, Elbe, Loire, Vistula, Oder, Rhone and Garonne. The more serious problems of water scarcity take place in the arid and semi – arid regions of Southern Europe, such as the southern half of the Iberian and Italian peninsulas, and the Anatolian peninsula. The use of irrigation water is very large in these regions, and scarcity problems will worsen because of the expansion of irrigated acreage and the increase of water demand for tourism activities in coastal zones. In the coming decades, the effects of climate change would have also a negative impact on available water resources in Mediterranean countries.

3 Water quality problems

Surface, subsurface and coastal waters have different uses, including domestic, industrial, agricultural irrigation, recreation, and support of aquatic ecosystems. Human activities are linked to water and land resources and generate wealth, but these activities degrade also water quality through point and nonpoint pollution. To cope with this water degradation, different quality standards have been implemented depending on the final use given to water. There are two alternatives to reach the appropriate quality standard: one is to reduce the pollution loads at water courses, and the other is water treatment of the waters being used. The more demanding standards are those for drinkable water.

The volume of wastewater increased considerably during the last century, due to industrial development and the growing consumption of households. The effects of discharge of residual waters depend on the sewage network and treatment facilities, the industrial production processes, and the type of products consumed by households. In recent decades, there has been a surge in the urban population linked to sewage networks and treatment facilities, although there are considerable differences among European regions. Almost all the population in Northern European countries is connected to water treatment facilities, but only half the population is connected in the new member countries of the European Union.

The Urban Wastewater Treatment Directive, passed in 1991 and modified in 1998, required building depuration plants with secondary treatment in urban centers with population larger than 15,000 inhabitants by 2000, and with population larger than 2,000 inhabitants by 2005. The Central and Northern European countries have already depuration plants with secondary and tertiary treatment. Tertiary treatment is more advanced than secondary treatment, and reduces the emission loads of the nutrients phosphorus (up to 60%) and nitrogen (up to 90%). Tertiary emission loads of phosphorus and nitrogen are 0.1 kg per person and year, respectively. Countries in the South of Europe, together with France, Belgium and UK, only have depuration plants with secondary treatment, and the emission loads of phosphorus and nitrogen are 0.4 and 3 kg per person and year, respectively (EEA 2005a).

The Urban Wastewater Treatment Directive has achieved a significant reduction of polluting emissions on surface waters, curbing the environmental damages on aquatic ecosystems. However, the level of emissions from treatment plants remains high and may cause eutrophication problems in vulnerable areas.

The number of dangerous substances that may affect water quality is high, with very different sources. The manufacturing industry is responsible for most of the emissions of heavy metals (lead, mercury, cadmium), while other substances such as nutrients and pesticides come basically from agriculture. A few number of substances have been regulated in the last decades resulting in a fall of their emissions, but the emissions abatement is not general. Table 2 shows pollutant concentrations in selected European rivers. There are important pollution loads by nutrients (nitrates and phosphorus) in rivers Thames, Guadalquivir and Seine, and a high concentration of heavy metals in rivers Seine, Tajo, Guadalquivir and Porsuk.

Table 2 Water quality in selected European rivers (average 1999 ~ 2001)

Country	Watershed	BOD (mg O_2/L)	Nitrates (mg N/L)	Phosphorus (mg P/L)	Lead (μg/L)	Cadmium (μg/L)	Chromium (μg/L)	Copper (μg/L)
Norway	Skienselva	0.2*	0.2	0.02	0.1	0.01	0.15	0.58
Sweden	Dalalven	0.1*	0.1	0.02	0.5	0.02	0.37	1.46
Denmark	Gudena	2.6	1.3	0.10				
UK	Thames	2.0	7.4	1.36	3.3	0.10	1.27	6.63
Netherlands	Maas	2.6	5.2	0.21	3.4	0.21	2.34	4.47
Belgium	Meuse	2.2*	2.5*	0.70*	3.2*		1.00*	2.05*
Germany	Rhein	2.9*	2.6	0.14	3.8	0.20	2.99	8.59
	Elbe	8.8*	3.3	0.19	2.5	0.23	1.76	5.42
	Weser	2.2	4.0	0.17	4.5	0.20	2.03	4.40
France	Loire	3.7	3.3	0.26		0.37*		
	Seine	3.1	5.6	0.63	22.1*	2.18*	24.67*	15.03*
Spain	Guadalquivir	4.2	6.1	0.95*	10.2*	2.27*		5.73*
	Ebro	5.0	2.5	0.20	7.7*	0.23*	0.64	1.61
	Guadiana	2.6	2.0	0.69*				
Portugal	Tejo	2.3	1.0	0.24	24.3*	5.00*	22.33	1.67
Italy	Po	2.2	2.1	0.23				
Greece	Strimonas	1.3*	1.4	0.08		0.64		
Turkey	Porsuk	1.2	1.2	0.07	4.3	5.00	6.33	5.00

Source: OECD (2005). The symbol * indicates that the average is for years 1993 ~ 1995. The Oxygen Biochemical Demand (BOD) measures pollution by organic matter, and water is considered drinkable for BOD between 0.75 and 1.50 O_2 mg/L.

There has been a reduction of phosphates in detergents used by households in last years, with a fall in the phosphorus load in treatment facilities from 1.5 to 1 kg per person and year. Meanwhile, the nitrogen load has remained constant at 5 kg per person and year. The phosphorus loads received by water courses originates from urban and industrial point sources and agricultural and livestock nonpoint sources, while most of the nitrogen loads come from nonpoint agricultural and livestock sources.

Although information on the status of aquatic ecosystems in Europe is quite scarce, it seems that the water quality in some rivers is improving. The improvement results from the abatement of emissions of organic matter and phosphorus linked to new treatment facilities in urban centers, and the abatement of heavy metals and chemical substances undertaken by industries. However, the nitrogen and phosphorus loads coming from agricultural nonpoint pollution are not controlled, and the relative importance of this pollution is increasing. Thus, between 50 and 90 percent of the nitrogen loads in surface waters comes from agriculture. Pollution problems from agricultural sources are characterized by the uncertainty of the source location, and by the impossibility (or very high cost) of measuring the emission loads of each farmer. This question has important implications for the design of pollution abatement measures, since point pollution control measures are useless, and more sophisticated measures are required.

The intensive use of fertilizers is a severe problem in Central and Northern European countries. Fertilizer consumption in these countries is above 150 kg/ha, while consumption in Southern countries is below 150 kg/ha. Fertilizer consumption corresponds to the sum of nitrogen (N), phosphorus (P_2O_5) and potasium (K_2O). Fertilizer consumption is above 200 kg/ha in Germany, Belgium, France, Netherlands, Ireland and UK. For example, the nitrogen surplus in soils is 215 kg/ha in Netherlands and 100 kg/ha in Belgium and Germany, compared to 40 kg/ha in Spain (EEA 2003), and this surplus is the origin of the nitrate pollution of water media. Therefore, the problems of water quality from agricultural nonpoint pollution are more serious in Central and Northern European countries, while the main problem in Southern countries is water scarcity.

Concern on water scarcity and water quality has resulted in the development of an extensive body of rules and regulations in the European Union: the Water Framework Directive (2000) and the directives of Drinking Water (1998), Integrated Pollution Prevention and Control (1996), Urban Wastewater Treatment (1991), Nitrates (1991), Dangerous Substances (1976, integrated in WFD in 2006), and Bathing Water Quality (2006).

This legislation has attained important results in curbing point pollution from urban and industrial sources, due to the construction of treatment facilities in urban and industrial centers, and the fall in the emissions of dangerous substances from industrial processes. The consequence has been an improvement of the quality of surface and coastal waters, and less pressure on aquatic ecosystems. However, the problems of agricultural nonpoint pollution remain, in particular those of nutrients and pesticides (European Commission 2002), and also the problems of water scarcity in Mediterranean countries.

4 The water framework directive

The European Union approved an important legislation to protect water resources, the Water Framework Directive, which was subsequently enacted in European Union member countries. The Directive creates a common framework of action in water policy, whit the objective of protecting continental surface waters, transitional waters, coastal waters and subsurface waters. This protection intends to avoid any further degradation of water quality and to improve the aquatic ecosystems conditions, promote the sustainable use of water preserving in the long run the available water resources, protect and improve water media through the abatement of emissions and discharges, reduce gradually the pollution of subsurface waters, and finally contribute to curtail the effects of floods and draughts. Water management is organized at the level of river basin district. The Directive aims at securing a sufficient supply of surface and subsurface water in good condition, attaining a balanced and equitable supply, and contributing to a significant water pollution abatement.

European countries have defined the river basin districts and basin authorities by 2003, and have completed the characterization of pressures, impacts and economic analysis of basins by 2004. The results have been used to evaluate the impact of human activities and to identify the areas requiring special protection, guiding the elaboration of the basin management plans and the programs of measures by 2009. Water pricing policies will be introduced in 2010, and the programs of measures will be operational in 2012, in order to reach the environmental objectives in 2015.

The Directive introduces the principle that water prices should be close to full recovery costs, to improve the efficiency in the use of water. The full recovery cost must include the abstraction, distribution and treatment costs, and also the environmental costs and the resource value. The Directive establishes a combination of emission limits and water quality standards, with deadlines to achieve appropriate quality for all waters ("good ecological status"). Water management should be based on basin districts and stakeholder participation, and water prices paid by users should approach full recovery costs.

The principle of cost recovery is one of the key elements in the economic analysis advocated by the Directive. The increase in water prices up to recovery costs is a very interesting measure in the industrial and urban sectors, since the industrial and urban water demand respond to water prices, and a higher efficiency in water use is obtained. To the contrary, water demand in irrigation does not respond to water pricing, and this fact questions full recovery costs in irrigated agriculture as a valid alternative for water quantity assignment.

Setting some minimum price levels for irrigation water will make farmers understand that water is not a free good. However, using water pricing as a mechanism to allocate water in irrigation is questionable, and Cornish and Perry (2003) and Bosworth el al. (2002) show compelling results from the literature and from empirical studies that demonstrate the impossibility of using water prices to assign water in irrigation, both in developed and developing countries. As alternative to water pricing, these authors indicate that introducing water markets is much more reasonable, although difficult to implement. Therefore, the emphasis of the Directive on water prices is useless to reduce irrigation demand in Mediterranean countries, and Spain is a clear example of this as discussed in the next section.

In order to reach the objectives of the Water Framework Directive, the measure of choice for water scarcity caused by urban and industrial demand is water pricing. Collective irrigation systems based on dams and canal networks should be controlled through command and control measures, while irrigation districts based on individual pumping from aquifers need sophisticated incentives schemes, that entice the cooperation of farmers in water conservation.

Additional measures against scarcity are reutilization of water from treatment plants and seawater desalination, although their use is quite limited at present. Another aspect is improving the conveying and distribution networks, since their condition affects largely total water extractions required to cover the demand of water sectors. Water losses in channeling networks are substantial in many European countries. Upgrading the conveying facilities would imply large savings but also large investments.

5 Applying the water framework directive: the case of Spain

Water resources extraction and utilization by sector in Spain are presented in Table 3. Extractions are close to 40,000 hm^3, of which 6,200 hm^3 are used for cooling in electricity production, and 32,000 hm^3 cover the demand from irrigation, water supplying companies and other industrial and service sectors. Losses in primary and secondary distribution networks are large and reach 5,500 hm^3. Household demand is 2,600 hm^3 with an average price of 1 /m^3, and industrial and service demand is 3,200 hm^3 with an average price of 0.25 /m^3. Net irrigation demand is 20,700 hm^3 and prices are related to the type of agriculture. In inland irrigation areas with collective systems of dams and canals, and field crops of low profitability, prices are below 0.06 /m^3. In the

Table 3 Water resources extraction and utilization by sector in 2002 Unit: hm^3

	Total	Agriculture	Water companies	Other sectors	Cooling
Extractions	38,200	25,200	5,400	1,400	6,200
Surface	32,500	20,900	4,200	1,200	6,200
Ground water	5,700	4,300	1,200	200	
Network losses	5,500	4,500	1,000		
Utilization					
Agriculture	20,700	20,700			
Households	2,600		2,600		
Other sectors	3,200		1,800	1,400	
Cooling	6,200				6,200

Source: INE (2006) and Martínez & Hernández (2003). Figures do not include hydropower extractions, estimated by MIMAM (2000) at an average of 16,000 hm^3.

irrigation areas of eastern and southeastern Spain with individual pumping from aquifers and high profit crops, the rank of prices is between 0.09 and 0.21 /m^3.

The growing pressure of these economic activities has created problems of water scarcity and quality degradation, mostly linked to groundwater. The more severe problems are located in southeastern Spain, with pressures coming from agriculture, urban sprawling and tourism on the Mediterranean coast. In inland Spain, surface water resources are under the effective control of basin authorities that manage resources wisely.

The European Water Framework Directive approved in 2000 was enacted in the Spanish legislation in 2003, just after approval of the Spanish National Hydrological Plan (2001) and National Irrigation Plan (2002). The National Hydrological Plan involved large investments (19 billion euro) aimed at increasing water supply for agricultural, urban and industrial users. Its main project was the Ebro interbasin transfer from northeastern to southeastern Spain, to alleviate the severe degradation of water resources in the area. The National Irrigation Plan involves investments (5 billion euro) to modernize the largely outdated irrigation facilities, in order to save resources, enhance competitiveness and reduce pollution.

The National Hydrological Plan was subsequently modified in 2005, substituting the large Ebro water transfer that was its main project, by the AGUA project based on expanding water supply through seawater desalination. Both versions of the National Hydrological Plan, with the Ebro transfer or with the AGUA project, maintain the traditional approach of expanding water supply.

The National Irrigation Plan has a good potential of saving water and curbing pollution through investments in advanced irrigation technologies. These investments do not guarantee the solution to all problems, but it is obvious that technical innovations in irrigation systems facilitate the private and public control of water quantity and quality. Realizing the potential of the National Irrigation Plan will require strong coordination between water authorities and irrigation water user associations.

One reason for coordination is the issue of water returns after investing in networks and plot irrigation systems. Water losses in distribution canals and plot irrigation systems return to watersheds, and when water losses are reduced through investments in upgrading networks and irrigation systems, the problem may appear that farmers use the saved water in more water demanding crops or in expanding irrigation land. The consequence could be an increase in evapotranspiration and the reduction of water flows in watersheds. The solution is reducing water concessions to countervail the eventual evapotranspiration increases.

Water resources degradation in southeastern Spain is driven by the pressure of intensive agriculture based on individual abstractions from aquifers, together with pressures from urban development and tourism over the Mediterranean coast. Aquifer overdraft reaches 700 hm^3, in the Júcar (160), Segura (220), Sur (70), and upper Guadiana (220) basins. The massive overdraft is the consequence of decades of ground water mismanagement, despite the fact that ground water was declared public domain in 1985. Registration of both concessions and private rights of ground water is far from completed, and the number of illegal wells could be above one million. In contrast, water scarcity and degradation is rather moderate in inland Spain because irrigation is based on collective systems: basin authorities control concessions, river flows and dam reserves, while irrigation user associations manage irrigation districts. The experience and competence of this institutional setting ensures ecological flows, and the management of droughts and floods.

The basin authorities in southeastern Spain do not control the number of wells or the volume of individual extractions from aquifers linked to very profitable crops, and hence they can not impose recovery costs. Furthermore, the required price level to curb demand in these areas is above 3 /m^3, which is politically unfeasible (Albiac et al. ,2006). To the contrary, basin authorities may impose any water price in the areas of inland Spain based in low profitable crops, because they have absolute control in collective irrigation systems. But the question is then the following: why they should play around allocating water through water pricing when they can make direct and wise water allocations.

Another hurdle for applying water pricing in irrigation comes from the results of the studies by Martínez and Albiac (2004 and 2006), showing that water pricing is the less cost – efficient measure to abate nitrate pollution from agriculture.

There are some examples of unconvincing water policies being applied in Spain. One is the Plan of the Upper Guadiana, currently under discussion. The Plan of the Upper Guadiana aims at curbing overdraft in the Western La – Mancha Aquifer and recovering the Tablas de Daimiel natural park, one of the main wetlands in the country. Previous efforts to sanction illegal abstractions were turned down by the central Spanish administration, which implies sending the wrong signal not only to those exploiting illegal wells but also to those with legal wells but pumping in excess and depleting the aquifers. Instead of curtailing abstractions, the plan anticipates investments of 4 billion euro to eliminate 220 hm^3 of overdraft. What is surprising in this enormous investment is that no economic valuation study has been undertaken on the environmental damages caused by the loss of this wetland, that could justify the large investments. Furthermore, the large investments in the Upper Guadiana will not work without careful designed incentives to gain farmers' cooperation. If the plan approach is generalized to the 500 hm^3 of aquifer overdraft in the Júcar, Segura and Sur basins, then the investments needed would amount to 10 billion euro.

A second example of a questionable water policy is the current AGUA project. The AGUA project includes investments of 1.2 billion euro to build desalination plants and expand supply by 600 hm^3, of which 300 hm^3 are for irrigation purposes in the coastal fringe. Although there is a potential irrigation demand in the area from greenhouses and other high – profit crops, the pumping costs are much lower than desalination costs, and farmers will not buy desalinated water. Public investments in desalination are only justified if basin authorities are able to strictly enforce a ban on aquifer overdraft, forcing farmers to buy desalinated water. But the solution found by the water authorities is subsidizing desalinated water up to the level farmers are willing to pay (pumping costs).

An aspect of water management in Spain that should be stressed here is the institutional, technical and organizational competence of basin authorities dating back one hundred years. Basin authorities in Spain (Confederaciones Hidrográficas) have a richness of information which is lacking in most European countries, and they are very competent in managing surface water. There is also a high level of competence in the water business sector (construction, distribution, depuration and desalination) and in the dynamic irrigation agriculture of southeastern Spain.

The problem for achieving a sustainable water management in Spain is not a lack of technical capacity, physical capital or human resources, but the absence of political will in the design and implementation of reasonable measures. Solving the degradation and mismanagement of water resources in southeastern Spain is the key issue for moving towards a sustainable management of water resources in Spain. Any supply side policy of expanding water availability, such as the former Ebro interbasin transfer or the current AGUA project, is questionable as far as groundwater mismanagement continues. Demand side policies such as forbidding aquifer overdraft or taxing water abstractions are technically and politically unfeasible, because basin authorities can only deal at present with surface water. Although there are informal water transactions in southeastern basins, the introduction of formal water markets requires enormous and persistent efforts. The Water Law was modified in 1999 to promote formal water markets, but it has not spurred any significant transaction in almost ten years. In any case, the introduction of formal water markets would require the control of ground water. The experience of water markets in Australia and California demonstrates that economic instruments alone fail to protect water resources, and therefore command and control instruments have an important role to play.

The tasks ahead for basin authorities in Spain are quite challenging, since aquifers are common pool resources with impure public good characteristics (rival but non – excludable) and with environmental externalities. Their sustainable management requires that public authorities setup incentives that give rise to cooperation among agents managing the resource, in order to achieve the collective action needed for water conservation.

6 Summary and conclusions

One of the important environmental questions in Europe is the scarcity and degradation of water resources. In Europe, the annual extraction of freshwater attains 20 percent of renewable resources, and the main pressures derive from the urban, industrial and irrigation consumptive uses. These uses create water scarcity in some regions, and a widespread water quality degradation from point and nonpoint pollution. Water scarcity is a serious problem in Southern European countries, with a strong demand during summer for irrigation and tourism. Water quality degradation is driven by human activities which generate pollution from nutrients, organic matter, heavey metals and other chemical byproducts.

There are no serious problems of water scarcity in Northern and Central European countries, and their main extractions for energy production are going to diminish. In the semiarid regions of Mediterranean countries, such as the southern half of the Iberian, Italian and Anatolian peninsulas, there is a massive use of water for irrigation. In these regions the scarcity outlook will dim because of expanded irrigated acreage and tourism in coastal areas, and because climate change will reduce available resources.

The industrial development and the growing consumption by households during the last century explain the strong degradation of water resources. The efforts to curb pollution in Western Europe were started in the seventies through several European directives. This legislation addressed the effects of point pollution emissions from urban and industrial discharges, which depend on sewage collection and treatment facilities.

Despite these efforts undertaken by public administrations in the last decades, pollution by nutrients and heavy metals remains high in many watersheds of the more important river basins in Europe. The extensive European regulation has facilitated large investments in water treatment plants and technological innovations in industries and households, which have limited or reduced the emissions of some pollutants, but the abatement of emissions is not general. The efforts on urban and industrial point source emissions should continue, and effective control on nonpoint pollution is needed such as abatement of nutrients and pesticides from agriculture.

The future of water resources in Europe would depend on the management measures taken to solve the different problems in each European region. Water scarcity in Southern Europe could worsen considerably by further uncontrolled extractions and the effects of climate change. Solving the scarcity problem may require reallocating some water from off – stream use by agricultural, urban and industrial users to environmental uses both in aquifers and streams, and also in the coastal wetlands. There are serious problems of water quality degradation in almost all European countries, although their characteristics depend on the local pressures of human activities and the measures being taken in each region.

The case of Spain shows that the implementation of the Water Framework Directive is not an easy task. Both the Spanish Ministry of Environment and the European Commission Environment Directorate advocate water pricing in irrigation and using the Common Agricultural Policy to penalize farmers. Research projects funded by the European Commission and some other studies recommend also these flawed policy options❶.

But the problems of scarcity and quality degradation can not be solved with these two policies. Water pricing is a very good instrument for industrial and domestic demand, but it is useless for irrigation. Water pricing is not a workable option because ① there is no control on the huge number of illegal wells and the quantities pumped from aquifers; ② water shadow prices are above 3 euros/

❶ An example is the article by Downward and Taylor (2007) on Almería, which states that sustainable management can be achieved by water pricing and augmenting water supply through desalination. Irrigation water use in Almería is around 260 hm^3, and domestic and industrial use is around 90 hm^3. Water pricing could affect industrial and domestic demand, but not irrigation aquifer pumping. Since the growing urbanization pressure on the coast will take over any water pricing savings in industry and urban demand, scarcity from irrigation aquifer overdraft will continue. Desalination can not work either, because farmers will not buy desalination water unless a strict enforcement of overdraft is in place, a daunting task for the administration. The implication is that the measures advocated by Downward and Taylor can not deliver the collective action required for water conservation. Examples from EU research projects are: WFD meets CAP (www. ecologic. de/modules. php? name = News&file = article&sid = 1369), Aquamoney (www. aquamoney. org), AquaStress (www. aquastress. net), WADI (www. uco. es/investiga/grupos/wadi), POPA – CTDA (www. popa – ctda. net) and POLAGWAT (http:// susproc. jrc. es/docs/waterdocs/FinalRep150802. pdf).

m^3, a price politically unfeasible since desalination costs are 0.50 euros/m^3 and urban water prices are around 1 euro/m^3; and ③ the administration lacks the information on aquifer dynamics precluding the enforcement of sustainable extractions.

The Common Agricultural Policy is also useless to influence water extractions in southeastern Spain, because CAP subsidies are targeted towards continental products such as field crops, while production in the area consist in Mediterranean crops such as fruits and vegetables which have negligible CAP subsidies. The design and implementation of reasonable measures required by the Water Framework Directive is a difficult task not only in Spain or the Mediterranean member countries, but also in the whole European Union. The improvement in the management of water resources involves better information and knowledge on surface and subsurface resources and on their associated ecosystems. These tasks need time and resources because of the complex biophysical, spatial and intertemporal dimensions involved. At present data on water quantity are not very good in the European Union, and data on water quality are even more limited. The quantity figures of the European Environment Agency do not match national figures (for example Spain and France), and water quantity information from countries such as Italy is not available.

Knowledge on the underlying biophysical processes is critical for water management, specially for managing aquifers and controlling nonpoint pollution, and this requires the availability of basic facts on aquifer and pollution characteristics and dynamics at local watershed scale. Regarding pollution, information is needed on the emission loads, the pollutants transport and fate processes, and the ambient pollution in water courses. Also, the lack of economic valuation of damage costs to aquatic ecosystem from aquifer overdraft and nonpoint pollution, precludes the assessment of the benefits of policy measures.

Even when all the biophysical knowledge is available, managing the quantity and quality of surface and ground water is quite challenging because of the public good characteristics of water and the associated environmental externalities. The design of measures must take into account the strategic behavior of water stakeholders, setting up incentives for cooperation in order to achieve water conservation through their collective action. Both aspects, biophysical knowledge and collective action, are unlikely to be in place by 2020 not only in Europe but worldwide.

References

Albiac, J., Martínez, Y. and Tapia, J. (2006) Water quantity and quality issues in Mediterranean agriculture, in: OECD (Ed.) Water and Agriculture: Sustainability, Markets and Policies (Paris: OECD).

Albiac, J., Dinar, A. and Sánchez – Soriano, J. (2007) Game theory: A useful approach for policy evaluation in natural resources and the environment, in: A. Dinar, J. Albiac & J. Sanchez – Soriano (Eds.). Game Theory and Policy Making in Natural Resources and the Environment. Routledge Explorations in Environmental Economics. (Abingdon: Routledge).

Bosworth, B., Cornish, G., Perry, C. and Van Steenbergen, F. (2002). Water Charging in Irrigated Agriculture. Lessons from the Literature, Report OD 145 (Wallingford: HR Wallingford).

Cornish, G. & Perry, C. (2003). Water Charging in Irrigated Agriculture. Lessons from the Field, Report OD 150 (Wallingford: HR Wallingford).

Downward, S., & Taylor, R. (2007). An assessment of Spain's Programa AGUA and its implications for sustainable water management in the province of Almería. southeast Spain, Journal of Environmental Management 82, 277 – 289.

European Commission (2002). Implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Synthesis from year 2000 Member States reports, Report COM (2002) 407, Directorate – General for Environment (Luxembourg: Office for Official Publications of the European Communities).

European Environment Agency (2003). Europe's water: An indicator – based assessment, Topic Report No 1 (Copenhagen: EEA).

European Environment Agency (2005a). European Environmental Outlook, EEA Report No. 4 (Copenhagen: EEA).

European Environment Agency (2005b) Sectoral Use of Water in Regions of Europe, EEA data service (Copenhagen: EEA).

Institut Francais de L'Environnement (2005). Données essentielles de l'environnement (Orleans: IFE).

Instituto Nacional de Estadística (2004). Estadísticas del Agua 2002 (Madrid: INE).

Instituto Nacional de Estadística (2005). Cuentas satélite del agua en España (Madrid: INE).

Martínez, Y. & Albiac, J. (2004). Agricultural pollution control under Spanish and European environmental policies, Water Resources Research 40 (10), doi:10.1029/2004WR003102.

Martínez, Y. & Albiac, J. (2006). Nitrate pollution control under soil heterogeneity, Land Use Policy 23(4), 521 – 532.

Martínez, L., & Hernández, N. (2003). The role of groundwater in Spain's water policy. Water International 28(3), 313 – 320.

Ministerio de Medio Ambiente (2000). Libro Blanco del Agua en España, Dirección General de Obras Hidráulicas y Calidad de las Aguas, Secretaría de Estado de Aguas y Costas (Madrid: MIMAM).

Organisation for Economic Co – operation and Development (2005). OECD Environmental Data. Compendium 2004 (Paris: OECD).

Yellow River Harnessing and Sustainable Water Resources Development

Shu – Qing Yang

Div. of Civil & Environmental Engrg. , Korea Maritime University, Busan, Korea

Abstract: This paper deals with the strategies for the Yellow River harnessing based on the systematical analysis. It is found that the high concentration of sediment is responsible for the phenomenon of "hanging river", and the river basin suffers the sharp temporal and spatial variation in water resources, which results in flood threat and dry – up river bed alternatively, consequently the river has had a major impact on China's economical development and ecological system. To ease the water shortage and secure a balanced water and sediment, this paper proposes the methods including: ① to construct ocean reservoirs to retain the flood water in the river mouth; ② to install of soft pipes along the river course to enhance the water velocity for flushing the sediment and for stabilizing the main channel. The preliminary study shows that these two methods could greatly mitigate the flood disasters and quench the thirsty in the basin, its effect could be more apparent when the basin water management scheme incorporates the South – to – North Water Diversion Project.

Key words: Yellow River harnessing, sustainable, water resources development, introduction and background

1 Introduction

The Yellow River is the second longest river in China. Tracing to a source high up Yagradagze Mountain, it loops north, bends south and flows east for 5,464 km until it empties into the sea, draining a basin of 745,000 km^2, which nourishes 107 million people. The loess plateau in Yellow River middle basin is one of the world's badly eroded regions, it contributes over 90% of 1.6 billion tons sediment carried by 58 billion tons of water annually, every year about 400 million tons of sediment deposits on the lower reach, which results in rising of the riverbed with a speed of 0.1 m/year. Yellow River is the cradle of Chinese civilization; it is the mother river for Chinese due to its high sediment load, which generates the vast fluvial plains for Chinese. However, it is also a sorrowful river due to breaches in flood seasons. Currently, the river bed is 4 ~ 7 m higher than the ground outside the river (known as suspended river), as China has become more populous, the floods of the Yellow River have become increasingly dangerous as tremendous loss could be incurred if the flood broke the river levees. Before 1950, the residence in the river basin, especially the lower reach suffered various dike – breaching, on average the river had made twice of breach within three years and changed its course once in a century. After 1950, the levees have been strengthened and heightened, and the floods have been discharged into the sea without a breach. Therefore, a question arisen is how to discharge the floods safely in future as the riverbed is continuously raised, and the height of the earth levees gradually approaches its limit. The way to do so in the history was to change the river course naturally, then new levee was build along the new course. It is obvious that the strategy is no longer able to be applied further for nowadays population in the plain is very dense; the cost for changing the river course is very high. On the other hand, the modern technology is much more advanced relative to the ancient period, which enables us to mitigate the river's flood disaster using different strategies. In the past 50 years, the people in the lower reach of the basin didn't suffer the flooding disaster, but they suffered the drought disaster. Since 1972, the lower reach has ran dry – up bed 21 times because many intakes in upstream have drawn the river water for their own use. In 1997, the flow was cut off for 226 days in 704 km of lower reach, it results in serious economical and ecological problems in the lower plain and delta.

Therefore, the urgent challenge is how to quench the thirsty and how to mitigate the possible flood disasters. The purpose of this paper is to develop a two – in – one scheme to ease the drought and flooding disasters and the feasibility of the scheme will be discussed.

2 Review of current strategies for water supply and sediment control

The following strategies have been used by Yellow River Conservancy Commission (YRCC), an agency of the Ministry of Water Resources in charge of the Yellow River basin for sediment and flood control, which includes:

(1) Broadening river and reinforcing dykes;

(2) Impounding water and intercepting sediment;

(3) Intercepting flood and sediment at upper reach, draining it at lower reach and retaining it on two riversides.

Among the annual runoff (about 58 billion m^3), 38 billion m^3 is legally allocated for agricultural, industrial and domestic consumptions and 20 billion m^3 is used to flush the sediment from Xiaolangdi reservoir to Bohai sea (see Fig. 1). To retain the precious water in the lower reach, He and Hu (2000) suggested developing the inland reservoirs in the plain by diverting the sediment – laden flow to the reservoirs. Rigid concrete plates are suggested to form an enclosed waterway, thus sediment in the waterway could form a levee of the plain reservoir and the water could be released to the reservoir after the sediment was removed. A successful model was established in Dongyong city near the river mouth. Zhang H. et al (2000) suggested that as all problems in the river are related to the deficient water, an effective way is to flush the sediment by diverting water from neighboring watersheds during flood seasons to Yellow River, therefore the flood disasters in neighboring watersheds could be mitigated and the water stress in the basin be alleviated.

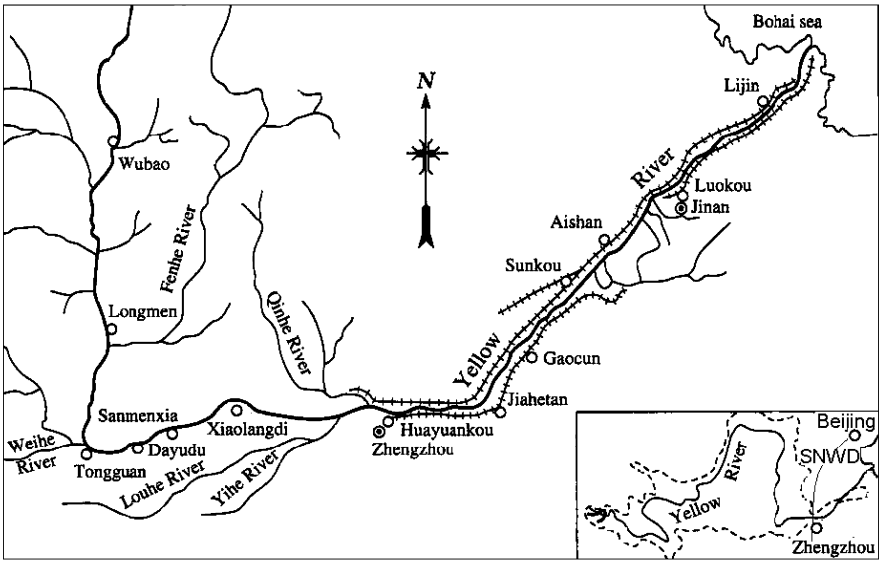


Fig. 1 Location of gauging station along the Middle and Lower Yellow River

Xie (1980, 1999) ascribed the continuous growth of river bed to the hydrodynamic conditions at the estuary where the weak lognshore and offshore current is incapable of transporting the high sediment load, consequently, the deposition and enhancement of sediment at the river mouth causes the continuous growth of riverbed in whole lower course. Lin, et al (2000) also highlighted the importance of harnessing the river mouth; they suggested pumping the seawater to Lijin for flushing the estuary, therefore the mixture of seawater and sediment may generate the density currents in the coastal waters, and the density currents could drive the sediment far away from the river mouth. Other experts also realized the importance of the river mouth in order to harness the lower reach of the river. For example, Emperor Kangxi (1654 ~ 1722) clearly instructed to his offices in 1697 that "the river mouth is crucial for floodwater goes to the sea without disasters in the basin; to achieve this, the prerequisite is to dredge the river mouth regularly or to increase artificially the current speed of the estuary". Apparently, it was impossible to apply effective apparatus to dredge the river mouth 300 years ago even the emperor had found that the high sand bar at the river mouth is responsible for the low draining capacity of river course, which subsequently results in flood disasters in the basin.

3 Proposed scheme to balance the sediment and water stress

The lower reach of Yellow River is a typical meandering river with characteristics of wide floodplain and unstable main channel with gentle longitudinal slope, heavy sediment loads. Every year 20 billion m^3 of water in Xiaolangdi Reservoir is compulsorily used for the purpose of flushing 1.2 billion tons of the sediment into the sea, in other words at the river mouth, there is plentiful freshwater to be developed. On the other hand, in the lower reach engineering measures should be taken to increase the efficiency of flushing sediment, thus the water used for flushing sediment could be reduced or more sediment could be carried to the sea. To do so, the width of water route should be narrowed, so that the flow velocity and sediment concentration could be enhanced; and also the flow route should be as straight as possible, thus most of the potential energy could be converted to transport the sediment. This strategy was first suggested by Pan Jixun (1521 ~ 1595) who was in charge of Yellow River's regulation and flood defense from 1565 to 1592. He suggested to "build dikes to hold water and let water carry away the sand", i. e., the sediment – laden flow will be confined within a narrow channel and the sediment will be kept in suspension, thus the river bed could be flushed. Since the prerequisite for this strategy is the sturdy levees that are able to resist the severe scour and erosion when the high velocity appears in the channel, the floodwater often breached the levees and flood disaster still occurs frequently after Pan's strategy was applied in the river's regulation. One of the evidences is the continuous growth of river bed as shown in Fig. 2, in which the vertical scale of water level increment from 1950 to 1999 is different from that of level in 1950. The parallel river bed profiles clearly indicate the trend of river bed development. From Fig. 2, one is able to conclude that the continuous rising of water level at the river mouth causes the steady rising of it in the whole lower course, in other words, the river mouth somehow functions as a tailgate of a flume in the hydraulic laboratory, the higher the tailgate is, the higher the water level in the flume. This is why Pan's strategy cannot solve the problem of "suspended river" eventually because he did not lower the level of riverbed at the river mouth, and it has subsequently enhanced the water level in the whole river course, thus the level of river bed at the river mouth is the datum level for erosion control and it could be termed as "erosion basis". Unless the erosion basis is artificially lowered, the continuous rising of water level or bed along the river course cannot be avoided this conclusion can be drawn from Table 1.

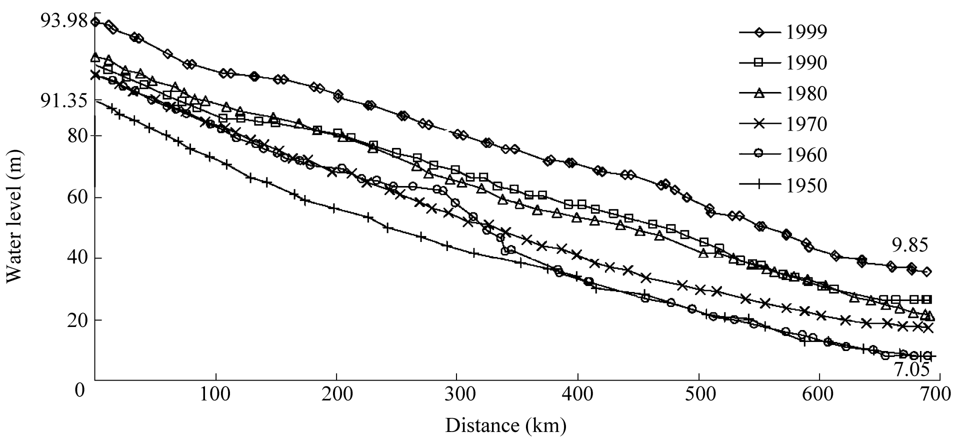


Fig. 2 Measured water level along the river course at $Q = 3,000\ m^3/s$

Table 1 Water level in lower reach hydrological stations at $Q = 3,000\ m^3/s$

Year	Huayuankou	Jiahetan	Gaocun	Sunkou	Aishan	Luokou	Lijin	Outlet
1950	91.35	72.53	59.62	44.89	38.20	27.50	11.49	
1955	91.76	72.54	60.56	45.55	38.70	27.50	10.82	
1960	92.25	73.56	60.77	46.66	38.35	27.41	11.41	7.05
1965	91.53	72.25	59.88	45.47	37.73	26.85	11.85	8.00
1970	92.19	73.66	60.95	45.96	39.05	28.15	12.35	8.11
1975	92.76	74.36	61.81	47.25	40.15	29.75	13.40	8.62
1980	92.80	74.34	62.15	47.14	40.10	29.70	13.20	8.45
1985	92.50	73.90	62.15	47.25	40.15	29.68	12.48	8.26
1990	92.68	73.99	62.12	47.51	40.60	30.12	13.15	8.93
1995	93.20	74.60	63.00	48.37	41.26	30.76	14.10	9.85
1999	93.98	75.38	63.54	48.65	41.80	31.40	14.24	9.85
Distance (km)	0.00	96.68	169.61	287.80	351.67	453.51	621.31	693.39
Bed level incre. (m)	2.63	2.85	3.92	3.76	3.60	3.90	2.75	2.80
Yearly incre. (m)	0.05	0.06	0.08	0.08	0.07	0.08	0.06	0.07

In order to solve the problem of "suspended river", one has to first lower the erosion basis at the river mouth before Pan's strategy is applied. Otherwise, the dikes have to keep pace with the raising bed until its limitation, and the flood defense system has to face the cycle from breaching dikes to new dikes along a new river course. Therefore, in the view of river regulation, lowering the bed at the river mouth is the most important in the master plan of river regulation and water resources development. Another basic problem in Yellow River Basin is how to alleviate the water stress. Currently, the river supplies in additional 4.1 billion m^3/year of water to cities like Tianjin and Qingdao which lie outside the river basin. Annual water shortage of the basin by 2000 is placed in the range 8.516 billion m^3, even so, about 1/3 of Yellow River's annual flow is discharged to the sea for flushing sediment and it is wasted completely after the freshwater meets with sea water. Hence, in the view of water resources development, we need to try our best to salvage the water of flushing sediment. Thus, we may conclude that the emphasis of water resources development in

Yellow River basin should be place on the river mouth too. Therefore, based on the aforementioned analysis, the attention or strategic emphasis for water resources development and flood control could be jointly paid on the river mouth, possible solutions for water resources development, sediment control and flood disaster mitigation could be found in the river mouth. This paper provides one of the solutions: ① to construct the coastal reservoirs to collect the freshwater that runs to the sea, thus the water demand in the cities near the coastline could be met; ② to install soft pipelines in the river to control the flow orientation inside the widely meandering flood plain and to narrow the main channel; ③ to divert water from the middle route of South – to – North Water Diversion Canal (SNWD) for flushing the sediment, thus 20 billion m^3 of water in upstream reservoirs could be consumed by the basin and the water stress in the basin could be alleviated. On the other hand, the water from SNWD canal would be collected in the coastal reservoirs and it would be diverted to SNWD's original destination, i. e., Beijing and Tianjin. The feasibility of the aforementioned scheme is discussed in the following sections.

3.1 Coastal reservoirs and water resources development

As mentioned Table 2 shows the yearly runoff into Bohai Sea, it is obvious that the flow is discharged into the sea and it is wasted. If this runoff can be developed, it will greatly alleviate the water stress in lower reach of Yellow River and the neighboring regions, i. e., Huai and Hai plains. By constructing properly barriers to separate seawater and freshwater, the river water can be stored in the ocean easily. The solid barriers can be constructed using many ways, such as closed earth dikes or concrete seawalls. The technology of traditional reclamation can be directly applied to construct the coastal reservoir, and recently developed "sand bags" are also recommended to build the barrage of coastal reservoir, one of the barriers built in Yangzi estuary for sediment control in the navigation channel is shown in Fig. 3. Obvious, the waters on both side of the barrage could be different, one seawater, the other river water.

Table 2 River flows and sediment transport measured in Lijin Station from 1986 to 2000

Year	freshwater $\times 10^9$ m^3		Sediment $\times 10^9$ t	
	May – Sept	Yearly	May – Sept	Yearly
1986	8.71	15.7	0.153	0.169
1987	5.10	10.8	0.077	0.096
1988	15.2	19.4	0.802	0.812
1989	14.4	24.2	0.527	0.599
1990	13.0	26.4	0.351	0.469
1991	3.9	12.2	0.080	0.249
1992	9.5	13.4	0.448	0.482
1993	12.1	18.5	0.380	0.471
1994	11.8	21.7		
1995	11.6	13.7		
1996	13.5	16.7		
1997	1.9	4.2		
1998	8.43	10.11		
1999	4.11	6.6		
2000	1.9	4.0		
Mean	9.01	14.5		

To build the coastal reservoir, one has to concern the meteorological and hydrological conditions in Bohai Sea, which is shown in Table 3. It is worthwhile to notice that the wave and tidal heights are much less than other places in the world, which indicates that the Yellow River mouth is an ideal place to build the coastal reservoir for the very gentle coastal waters. Therefore, one may conclude that in terms of economic and technological views, the construction of coastal reservoirs in the Yellow River is feasible.

Fig. 3 Sandbag barrage in Yangzi Estuary

Table 3 Meteorological and hydrological conditions in Yellow River mouth

	Beach slope	Tidal variation (m)	Wave height (m)	D_{50} (mm)	Wind (m/s)	Current (m/s)
Mean	1:3,000	2.22	0.6	0.003	4.6	0.22 ~ 0.41
Maximum	1:2,000	3.44	3.78	0.036	23	1

However, another important issue that must be considered is the life span of the coastal reservoirs as the river is famous for its high concentration of sediment transport. The mean sediment concentration (S) of the river flow is 24.7 kg/m^3, and if we assume that every year 10 billion m^3 of river water go to the coastal reservoir (V_w), then the sand volume (V_s) introduced by the river flow is:

$$V_s = SV_w/\rho_s \tag{1}$$

where ρ_s is the density of sand ($\approx 2,650 kg/m^3$). From Eq. (1), one obtains every year the volume of sediment introduced by river water is 93.2 million m^3, if the reservoir covers area (A) of 500 km^2, then the yearly sea bed increment (Δh) is

$$\Delta h = V_s/A = 18.6 \text{ (cm)} \tag{2}$$

if the mean water depth in the reservoir is assumed to be 8m, then the life span of the reservoir would be 43 years. In fact, the life span would be extended if two parallel levees and a pumping station are built inside the coastal reservoir as shown in Fig. 4. The pumping station could be used to drive the freshwater to the water - demand regions in drought periods, cleaner water could be released to the reservoir after sediment was removed in the space between the two parallel levees. The tidal gates would be opened to flush the sediment in the narrow channel during low tide and the pumping station could also increase the velocity to wash the sediment. The river flow would be released to the sea directly without mixing with the clean water in the reservoir. Therefore, the life span of the coastal reservoir would be extended and the good quality of freshwater would be remained if proper management strategies for the tidal gate's operation were introduced. The shortage of water resources in Yellow River delta can be alleviated if the ocean reservoir was constructed as shown in Fig. 4. The good quality freshwater will be retained in the reservoir, the polluted water will be used to flush the sediment to the sea with the aid of additional energy from the pumping station.

As aforementioned, the river mouth or the erosion basis plays an important role in the phenomenon of "suspended river", the prerequisite to tame the river is to control the rising of riverbed at the mouth, this goal could be achieved when the pumping station is built, because as long as the pumping station operates regularly, the scour hole could be formed and the erosion basis could be lowered or at least stabilized, consequently the stabilized river mouth would control the rising of whole riverbed, or the "suspended river" would not be deteriorated.

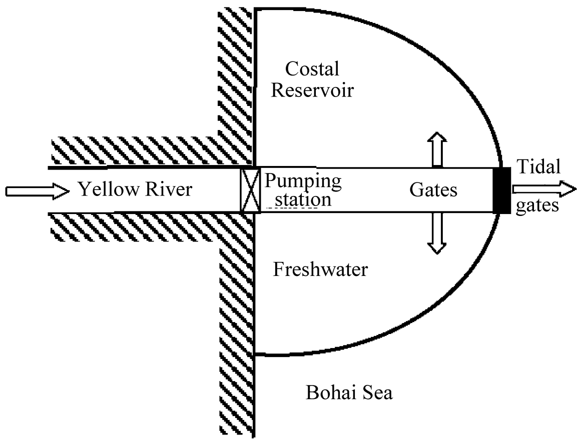


Fig. 4 Proposed coastal reservoir in the river mouth

However, as shown in Table 2, the runoff to the sea was less than 10 km^3 in some drought years, such as 1997, 1999 and 2000; then the question is how to secure the water supply in the delta in these years. Besides, how to increase the water quota in the upper reaches is also a challenge for the water resource development in the basin. Noticing Chinese government's schemes of South – to – North Water Diversion (SNWD) that the water from Yangzhi River goes via an artificial canal and a tunnel under the Yellow River near Huayuankou (see Fig. 1) to Beijing, one may find that the water stress in the basin could be effectively alleviated if the water from Yangzhi River was diverted to the Yellow River first and functioned as the water to flush the sediment from Huayuankou to the river mouth, then the Water from Yangzhi River could be retained in the coastal reservoir and finally the river water could be pumped to the original destination of SNWD, i. e., Beijing. The original canal length of SNWD from Yellow River to Beijing is 764 km, which is reduced to 450 km if the suggested scheme is adopted. On the other hand, if the water of SNWD was used to flush the sediment in the lower course of Yellow River, it means that the water quota for middle and upper reach could be added up to 20 billion m^3 because the water for flushing the sediment would no longer come from the Xiaolandi reservoir in the Yellow river, but from the Yangzhi River. Therefore, the proposed scheme could greatly ease the water stress in the basin.

3.2 River hamessing and sediment control

As mentioned before, the main concern for flood disaster mitigation is to find a proper way to control the sedimentation in Yellow River. Unless the sediment is well controlled, the levee breach will certainly occur sooner or later after the height of earth levees reach its limitation, as the river bed and dikes grow 10 cm/year on average. This growth trend becomes worse in recent years as the scarce rain in 1980s and 1990s resulted in the sediment deposition in the main channel. To protect their home and farmland, 1.78 million people who reside in the floodplain have to build the secondary suspended river, that is the bed of main channel is higher than the floodplain, the latter is 4 ~ 13 m above the surrounding ground level (see Fig. 5). In 2002, the floodplain was flooded when the flow rate was only 3000 m^3/s due to the breach of dikes of secondary suspended river. In order to avoid the catastrophic flood disaster and ensure the safety of people in the floodplains and plains, one has to lower the main channel bed effectively and to develop proper way to stabilize the meandering main channel.

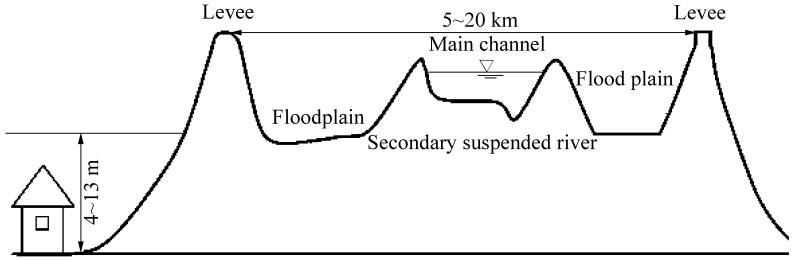


Fig. 5 Typical cross section of suspended river and secondary suspended river

As mentioned, there are two factors that jointly result in the phenomenon of "suspended river", one is caused by the continuous growth of riverbed at the mouth; the other is caused by the weak sediment – carrying capacity. After the former is solved by using the pumping station at the mouth to control the rising of erosion basis, the latter becomes an important issue. In order to increase the sediment – carrying capacity, the strategy of "build dikes to hold water and let water carry away the sand" was proposed about 400 years ago. However, in practice the river engineers always try to narrow the main channel using the earth dikes; it is effective in a certain extent to increase the flow velocity and subsequently the sediment – carrying capacity, but these solid dikes frequently failed under the impact of flood waves, consequently the main channel has to be widened enough and the flow velocity is reduced significantly, this is why the route of meandering main channel has never been stabilized in the history. In order to enhance the sediment – carrying capacity in the meandering main channel and then to lower the secondary suspended river, this paper suggests narrowing the main channel with soft piping system as shown in Fig. 6, instead of the artificial levees. In Fig. 6, the pipe is closed at both ends, and the water can be pumped in to the pipe from the holes at the top of the pipe, and also the excessive water inside the pipe could be released these holes, the pipe could be fixed using the anchorage system (Yang, 2004).

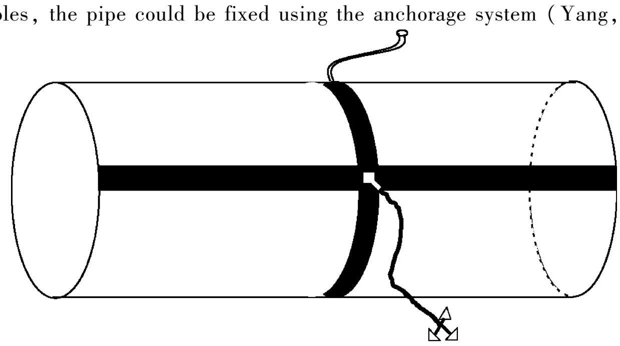


Fig. 6 Inflatable soft pipe system

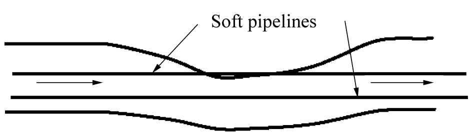
Currently, many large reservoirs have been built in the middle and upper Yellow River, the discharge released from the reservoirs generally is less than 2,600 m^3/s and the water depth in the lower river is less than 2 m, the slow current results in the sediment deposition in the lower river and finally the secondary suspended river has been formed. Noticing that the water depth in the river is less than the diameter of commercialized soft pipe, one may conclude that the pipelines similar to the widely used inflatable rubber dam could be used for the river regulation. Different from the rubber dam that bears the water pressure difference on both sides, the water levels on both sides of soft pipelines are almost same when the pipelines are jointly installed in the main channel as shown in Fig. 7. The drag force acting on the straight pipelines could be expressed in the following

$$F = C_d \rho \frac{U^2}{2} A_1 \tag{3}$$

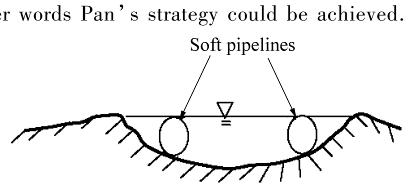
in which C_d = drag coefficient of the pipe; ρ = density of sediment – laden flow; U = flow velocity; and A_1 = frontal area of the pipe projected onto a plane perpendicular to the path of flow. Obviously, in a straight channel the pipelines are parallel to the flow direction and A_1 is very small, thus the drag force in the flow direction on the pipelines is negligible. On the other hand, the water between the two pipelines flows downstream with velocity V, but beyond is the dead water zone the flowing water zone, which results in that the trend of two pipelines moves close to each other similar phenomenon can be observed when two ships are operating in close proximity, they will be attracted to each other, thus the width of flowing zone would be reduced, and in turn the velocity and sediment – carrying capacity could be increased. The pressure difference in the direction perpendicular to the flow path could be estimated by Bernoulli equation, i. e. ,

$$\Delta p = \frac{\rho}{2} U^2 \tag{4}$$

where: Δp is the pressure difference. As the main channel is not always straight, the forces in the channel bend should be greater than that in the straight channel, in thus case the pipeline lines with anchorage system could help to straighten the meandering channel gradually. This could be understood by imaging that in a bend the flow turns its direction and the flowing force will act on the flexible pipeline arched on the riverbed, thus the width of bend would be reduced, thus the concave side is protected and the erosion on the convex side occurs. Thus, with the constraint of pipelines, the flow direction has to be changed, the meandering flow route would be weakened as the flow strength in the transverse direction has been reduced, as a result, and the longitudinal flow strength would be enhanced, the sediment always accompanies with the flow, therefore erosion in the longitudinal direction would occur. After a long period, it could be observed that the meandering channel becomes a straight channel. When a long straight channel is formed, instead of meandering channel, the energy slope, in turn is increased, consequently the velocity and sediment – carrying capacity is also increased. In the meantime, due to the protection of pipelines the erosion on both banks of the main channel would be not very serious relative to the riverbed, thus one may conclude that with the introduction of flexible pipeline in the Yellow River, the banks could be protected and erosion could occur mainly in the riverbed, or in other words Pan's strategy could be achieved.



(a) Plane view



(b) Cross section in the main channel

Fig. 7 Narrowing and straightening the main channel using the soft pipe lines

It is worthwhile to discuss the deformation of the pipeline size in the river as the water depth varies along the river course (see Fig. 8). Obviously when a pipeline is full of water, it would be inflated at these locations where the pipe encounters the deep water; similarly the pipe will be deflated at the places where it is located on the shallow water, the pipe deplete its water at the positions above the river water surface, all these automatic deformation with the variation of riverbed elevation could be achieved because the holes at its top could release the excessive water, thus inside the pipe the water can move from high level to low level along a pipe. Hence this specially designed system will automatically adjust its size the longitudinal bed profile, and it could efficiently block or reduce the transverse flow, and force the meandering channel to be a straight channel, and also enhance the sediment – carrying capacity as well as protect the banks.

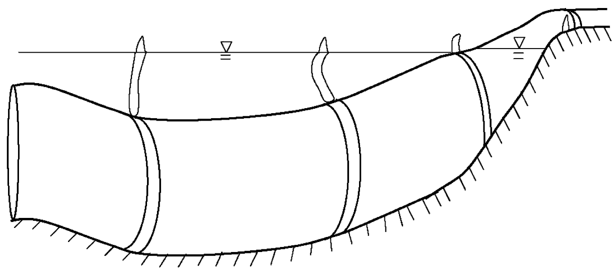


Fig. 8 Deformation of soft pipeline along the river course

4 Conclusions

Yellow River is one of the most complicated and difficult rivers to be harnessed in the world where the flood and drought happen frequently and bring huge disasters to the residents along the river. Based on the systematical analysis of the Yellow River harnessing and developing, the strategy for the Yellow River management was proposed in the paper that includes the river basin management from river controlling and training works, water resources management, flood protection, sediment control. To harness the river and get rid of disasters, this paper proposed the following strategies after analyzing the current status in the Yellow River, they are: ① The disasters are basically caused by the high sediment load carried by unbalanced water, thus in the suspended river and even the secondary suspended river are formed, which results in great flood threat to the residents in the basin. In order to lower the riverbed, one has to diminish the effect of continuous growth at the river mouth, thus the pumping station at the mouth would be effective for the purpose to stabilize the erosion basis. ② To quench the thirsty in the basin and other cities like Beijing and Tianjin, this paper suggests that ocean reservoirs be constructed to nourish the deltaic area, and pumping station mentioned could supply the freshwater water to the destination where the water is needed in drought seasons. Thus the partial floodwater would be developed into useful water resources. ③ This study found that the river basin would benefit from the modified scheme of South – to – North Water Diversion which diverts the water from Yangtze River to the river as the flushing water, then the middle and upper basin would add about 20 billion m^3 of water for their own use, and the water demand in the lower basin would be also met. Besides, as the flushing water would be collected in the ocean reservoirs at the river mouth, and the freshwater could be re – used by the original water users of SNWD. This optimal scheme would greatly alleviate the basin's water stress if it was implemented. ④ To enhance the efficiency of flushing sediment and also to protect the banks of main channels, this study suggests that a specially designed pipeline system be used to narrow the width of flow zone and increasing the velocity and sediment – carrying capacity.

References

He F. R. and Hu, C. H. (2000). Study on methods to mitigate flood and drought disaster in Yellow River. Sediment Research.

Mu Y. W. and Mu, Y. Y., (2001). Using methods of three river channels, flood diversion anddredging to keep Yellow River from deposition. Yellow River Forum, www.yellowriver.gov.cn.

Xie, J. H. (1999). Preliminary Study on current status of Lower reach of Yellow River and

theregulation methods. Sediment Research, No. 1.
Xie J. H. (1980). study on the longitudinal bed profile of lower reach of Yellow River and it's evolution. People's Yellow River No. 1.
Yang, S - Q. (2002a). How to alleviate global water stress: case study about China water diversion scheme. Proc. 13th IAHR - APD congress, Singapore, 614 - 618.
Yang S - Q. (2002b). Strategy of water resources development in small islands. Proc. 13thIAHR - APD congress, Singapore, 642 - 645.
Yang, S. Q. (2001). Preliminary study on strategies of Yellow River regulation and water supply in the lower reach. Yellow River Forum, www. yellowriver. gov. cn.
Yang Shuqing. (2004). Water partition wall of soft pipes, Patent No.: 03257886. 5 (Chinese Patent).
Zhang H. W. and Zhang, J. H. and Yao, W. Y. (2000). Strategies of Yellow River Regulation. Sediment Research.

Promoting Integrated Yellow River Water Resources Management with Water Management Lessons from the Netherlands

Hu Yurong[1], ***Wang Jinzhou***[2] and ***Li Yuehui***[3]

1. Department of Water Resources Management and Regulation, YRCC
2. Information center, YRCC
3. Department of International Cooperation, Science and Technology, YRCC

Abstract: This paper extensively analysizes the integrated water resources management in the Netherlands. According to the current existing issues in the Yellow River water resources management and the future facing challenges, some approaches and measures are put forward to promote the integrated water resources management in the Yellow River, referring to the experiences of the Netherlands in terms of water management structure, water legislation system and water planning.

Key words: integrated water resources management, experience, the Netherlands, Yellow River

As the main water source of north – western and northern China, and with only 2% of water resources of China, the Yellow River provides water to the 15% of farmland and 12% of population in China, and also takes responsibility for the long distance water transfer to the regions outside the Yellow River basin. With the rapid social and economic development of the basin and the other regions concerned, water stress is increasing in the Yellow River, and ecological degradation is also on the rise. The healthy life of the Yellow River suffered serious threat. The practice of river management and governance at home and abroad proved that the implementation of an integrated water resources management provides a major support for maintaining the healthy life of the Yellow River, realizing the harmonious coexistence between man and water and promoting the optimum water resources distribution and sustainable socio – economic development.

1 The integrated water resources management in the Netherlands

The Netherlands is a densely populated and highly developed country with small territory. It is located in the north – western Europe, and consists largely of the deltas and floodplain of the Rhine, Meuse and Scheldt rivers. The territory of the Netherlands encompasses a land area of 34,000 km^2, among which is the reclamation land area of 20,000 km^2. The country's topography is extremely flat and low; approximately one third of the territory has a land surface below mean sea level, 65 percent of the territory is threatened by floods. The total annual runoff is 10 billion m^3; the amount of water per capita is 687 m^3. Due to the special topography, the complex water management system was established in the Netherlands. The well – known dam, delta works and dense networks of ditches and canals were constructed to provide a safe protection line for the Netherlands. In addition, the complete water management system and water law as well as scientific and democratic decision guaranteed integrated water resources utilization and management in the Netherlands. In the last decades, water conservancy and flood control oriented water management concept has developed into the multi – level concept of paying an equal attention to water conservancy, environment protection and ecology in the Netherlands

1.1 Water management organization in the Netherlands

Water management organization in the Netherlands is divided into three classes. The central government is at the top level. The second is the provincial level, including Provinces, the Water Board and Drinking Water Supply Company. The last is the municipal level, mainly including

Municipalities and lower level Water Boards. Among these organizations, the Water Board is a special, democratic, non – governmental, public and financially independent institution.

At the central government level, the Ministry of Transport, Public Works and Water Management is the most important water management institution of the Netherlands. Its responsibilities are to constitute and adopt overall strategic water legislation and water policy of the Netherlands, as well as to plan and manage national water body and water resources, which also takes into account the other important sectors such as land use planning and environmental management. It is mainly responsible for managing national surface water, including large rivers, major canals, estuaries, territorial sea, flood control and some protection dams and dikes against the tide. The Ministry supervises the Provinces, the Water Boards and Municipalities.

At the provincial level, the main water management institution is provinces. Its responsibilities are to formulate and adopt provincial strategic water management plan and policy, which takes into account the overall water management policy of the Ministry. It is mainly responsible for managing groundwater and surface water quality of the province. The Water Boards are authorized to manage surface water quality by the provincial government in most provinces. The Province supervises the Water Boards and Municipalities. Drinking Water Supply Company is responsible for supplying drinking water. Although these companies belong to private institutions, the public institutions hold a share.

At the municipal level, the municipalities are mainly responsible for managing the sewerage system, and transporting the collected wastewater to the wastewater treatment plants of the water boards.

The Water Boards of the Netherlands exist parallel with the three governing levels in a special management and organization way. They are responsible for managing flood control and surface water quantity and quality within the regional scope. As a professional management institution, water boards directly represent interests of the public, proprietor and landowner. The Water Boards operate according to the principle of "pay, say and interests". Only those persons with an interest in local water management ("stakeholders") pay for the activities of and are representative in the Water Boards. The greater one get interest in the Water Board activities, the more one pay, the more one say. The financial income of water boards mainly come from the water service fee and pollution tax paid by the inhabitants and enterprises. .

1.2 The water legislative system in the Netherlands

After a long time efforts, a set of the perfect water legislation system was established in the Netherlands. The coordination and unification exist between various water legislations. Different water management institutions have specific and clear responsibilities of water management activities in accordance with water legislation. This provides strong assurance for integrated water resources management. These water legislation mainly includes *Water Act*, *River Act*, *Delta Act*, *Pollution of Surface Water Act*, *Groundwater Act*, *Soil Protection Act*, *Water Management Act*, *Water Broad Act and Flood Protection Act*, giving rise to a fairly complete legislative system that regulates various water – related activities.

The water policy focused on the different aspects of water resources management during the different phases. In 1968 the first water policy was formulated with emphasis placed on flood prevention; in 1984 water quality was emphasised in the second national water policy; in 1989 integrated water resources management was focused in the third national water policy; in 1997 the fourth national water policy focused on water environment and sustainable development.

1.3 Water resources planning system in the Netherlands

The Netherlands stressed that water resources management should be carried out in planning system way. The planning system can specifically analyse the existing issues in flood control and water supply and demand, and put forward the corresponding solutions. Water Management Act, which was enacted in 1989, stipulated specific responsibility of various governing levels on establishing and implementing water resources planning. Meanwhile, Water Management Act provided for management plans at central, provincial and water board levels. The central government established national strategic water management plan. The provinces established regional strategic water management plan. The Water Boards established operational regional water management plan. The regional strategic water management plan by the province and the operational water management plan by the Water Boards, make national strategic water management plan work very well within the regions. In addition, all plans, both strategic and operational, are required to be revised every 4 year.

The water management plans focus on the ecological and environmental protection, which make rivers and lakes recover their natural conditions as much as possible. During the establishment of water management plan, it is emphasized that the concept of harmonious coexistence between man and water should be followed.

1.4 The mechanisms of financing the costs of the public water management in the Netherlands

1 percent of national income, which equals to 240 dollars per capita, was used for water works construction and water resources management every year. Due to the establishment of the perfect investment and costs recovery system, the famous large – size water works were built, and the high standard infrastructures on water supply and drainage, wastewater treatment system were also established. Financing the costs of public water resources management is based on the principle of "pay, say and interests" in the Netherlands. Public authorities have to apply the following order of priorities to finance costs. Firstly, the interested parties or authors of harmful activities get the first priority to finance the cost; Secondly, common provisions get second priority, levies or taxes finance these provisions. Finally, the general budget defines the third and lowest financing priority.

2 The main issues in the Yellow River water resources management

2.1 Unclear division of water management responsibility between the basin level and the local level

Due to unclear division of water management responsibility between the basin level and the local level, and lack of effective coordination, unification, constraints between all involved water sectors, it is difficult for Yellow River Conservancy Commission to act as river basin management organization. Some water activities such as the layout of industry and agriculture, pollution control, resource exploitation, aquaculture and ecological protections, which are closely related to healthy river, were managed by other sectors in accordance with law. Each sector explores and manages water resources in one – sided and monopoly way in terms of its single goal and local interests, without the effective information exchanging and consulting mechanism. Therefore, there are some difficulties to effectively solve the urgent issues of the resources, environment and ecology of the Yellow River Basin.

2.2 The incomplete combined management system of water pollution prevention and water protection

The combined management system of water pollution prevention and water protection is still required to be improved. Due to lack of legal authority, river basin management organization cannot play the full role in supervising and guiding water resources protection and water pollution prevention. At present, the Yellow River water pollution is severely worsening. This is mainly related to more attention being paid to the economic development by the local level while less attention is paid to ecological and environmental protection. Although the prevention and control of water pollution should be also carried out regarding the river basin as a unit, with overall planning and complete treatment and protection, at present, the river basin management organization is not responsible for developing planning of water pollution prevention and control, and also not for supervising planning implementation.

2.3 The incomplete river basin legislative system

The river basin legislative system is still not complete, lacking the combination and unification between various water legislations. On the one hand, although the Water Law stipulated water management responsibilities of river management organization and local government, these provisions are very brief and principal. Some water regulations and water policies need to be formulated by the river management organization and local government according to the characteristics of rivers and regions. At present, in practice, some river management regulations which matched to Water Law is still not complete. On the other hand, in the process of implementing some water protection regulations, there is overlapping responsibilities between water conservancy sector and environment protection sector, lacking effectively coordinated and consultancy mechanisms between these two various sectors. Therefore, some legislation concerned with water protection still needs to be further revised and completed.

3 The future situations faced by the Yellow River water resources management

At present, the exploitation rate of the Yellow River runoff is already close to 70%, far exceeding 40% that is regarded as reasonable limits by the international community. With the gradual implementation of the western development strategy, West – to – East electricity transfer, the central rise in economy, and the food security. The major changes will occur in the macro – structure and allocation of the Yellow River water resources. The stress of water supply and anti – dry up is increasing. The water demand from industry, agriculture and ecology can not be met. The risk of zero flow occurrences will still exist in the mainstream of the Yellow River during the periods of water use peak. As a river basin management organization, on the one hand, it has responsibility for ensuring drinking water security, food supply and economic development with the rational water utilization, aiming at supporting the sustainable economic and social development of the river basin and other regions concerned. On the other hand, the river basin management organization also has to ensure the minimum ecological water requirement for river ecosystem process as much as possible, and to guarantee no drying up, aiming to sustain the healthy life of the Yellow River. The Yellow River water resources management is facing serious challenges and pressures.

4 The countermeasures of facilitating integrated Yellow River water resources management

The so – called integrated water resources management refers to that the effective water management will be carried out in an integrated and systematic way based on placing water resources into the society – economy – environment complex system. Its objectives are to realize the equitable attention paid to water exploitation, utilization and protection, the unified management of water quantity and water quality, the uniform regulation of surface water and groundwater, and the integrated utilization of raw water, recycled water and seawater. It provides assurance to promote the social and economic development with sustainable utilization of water resources, and without causing any damage to major ecology system or endangering water demand of the future generations. The final goal is to realize the harmonious profits among the economy, society and ecology with the exploration and utilization of water resources. In fact, the integrated Yellow River water resources management means the readjustment process of the interests of all beneficiaries involved. It focuses on maximizing the comprehensive benefits from economy, society and ecology through improving the management and exploitation ways of water, land and related resources, on the requisition of without harming the river' benefits. The related management system, mechanism, technology and measures are required to guarantee the implementation of the integrated Yellow River water resources management.

4.1 Establishing the effective and orderly water resources management system

The water management system that is based on the combination of management by catchments and administrative regions has to be established. For basin level, the authority, effective and coordinate water management operation mode should be explored and established, including macro – regulation by government, democratic consultancy, water market mechanisms and extensive participation of stakeholders in water management. For the administrative regions, the integrated water resources management has to be implemented between the urban and the rural areas, it includes the integrated management of water supply, water saving, water drainage, treated water utilization and wastewater treatment.

As the main responsibility of the government, the government should play the dominant role in water resources management. But the role of water market also has to be stressed in water allocation, it can help to realize the optimum water distribution and improve water use efficiency and profits. In addition, a set of complete management system should be established to restrict and manage water activities, and to solve the interest conflict between all concerned sectors in a coordinated way. The mechanism of all concerned stakeholders participating in decision making process of some important water issues needs to be enacted. The participating platform should also be provided. The great efforts are made to improve the ways of the public participation in river management, for example, establishing water information publishing system. The process on decision – making, implementation and supervision of water management affairs should be separated. Finally, we hope that water management mode will be established with overall planning, common decision – making, different responsibility, shared information, economic motivation and social supervision.

4.2 Developing comprehensive river water resources planning in a scientific manner

The comprehensive river water resource planning is an important measure to facilitate integrated water resources management. The planning should be developed under supervision and guidance of the scientific concept of healthy river. The river should be considered as one important component of socio – economic and environmental system so as to coordinate the inter – relationships between water exploitation, soil erosion control, ecological protection and water quality protection. The inter link between the physical factors of the river itself as well as climate change, human activities and environmental effects also should be taken into comprehensive consideration. The plan should clarify the long term and short term goals of keeping the healthy life of the Yellow River, put forward the required countermeasures to reach the corresponding goals, build and perfect various systems, and reach the maximum integrated benefits.

On one hand, the carrying capacity of water resources and water environment can be improved by strengthening structural and non – structural measures. On the other hand, some advices and suggestions are made on the layout of economic development to facilitate the adjustment of production structures and some changes in economic growth ways. In addition, based on the comprehensive river planning, the various functional planning are coordinated in an overall way. And the regional planning is supervised and constrained by the river basin planning.

4.3 Establishing the complete water legislative system of the Yellow River

The legislative system can restrict human behaviour. In order to keep the healthy life of the Yellow River, and to support social and economic sustainable growth within the basin and some regions concerned, the water legislative system should be built and completed. The management way should be innovated. The water management procedure should be standardized. The process of formulating "the Law of the Yellow River" and "the Regulation on the Management of the Yellow River Headwater Region" should be further promoted. The present legislative system on river management should be revised to clarify the rights and responsibilities of all beneficiaries concerned and river basin organization. The rules that should be followed by human activities also have to be identified. The complete water legislative system can provide strong assurance for the integrated Yellow River water resources management.

4.4 Strengthening the construction of water management informatization

The information, science and technology play a great promotional role in integrated water management. The information monitoring and processing systems have to be built to collect real – time data on meteorology, hydrology, sediment, water quality, ecology, and topography and water works for the whole basin. The simulation model on water recycling process should also be built with fairly good feedback function. We hope that informatization process will facilitate and promote modernization of water management.

References

Cheng Yan, Fu Chun, Water Management Systems and the integrated water management in the Netherlands[J]. China Water Resources. 2004, No. 03. P. 70 ~ 71.

Jang Wenlai. Study on water security strategy of China in the 21st century[EB/OL]. http://www.stcsm.gov.cn/learning/lesson/zonghe/20021203/lesson – 5. asp.

Pieter Huisman, How the Netherlands Finance Public Water Management[J]. European Water Management Online, Official Publication of the European Water Association, 2002.

Wang Yahong, Preliminary analysis of the difference of water management between China and the Netherlands[J]. Zhejiang Water Conservancy and Hydropower Institute Publications, 2002, No. 3.

Laws of Runoff Variation and Inflow Situation in the Upper Yellow River

Gu Minglin[1], ***Qiu Shuhui***[2] and ***Mao Liqiang***[2]

1. Upper Reach Branch, Hydrology Bureau of YRCC, Lanzhou, 730030, China
2. Hydrology Bureau, YRCC, Zhengzhou, 450004, China

Abstract: Based on the analysis for causes and laws of runoff variation and results of flow predicting model on the upper Yellow River, this paper put forward that the precipitation in the upper Yellow River will increase probably over decedes in future, accordingly, it will turn into relative ample – flow phase the next decade.
Key words: runoff, laws, expectation, the upper Yellow River

1 Introduction

Tangnaihai hydrological station on the upper Yellow River is an inflow station of Longyangxia Reservoir, the area upper the station is the main runoff yielding area of the upper Yellow River, the inflow runoff is 35% of total volume of the whole Yellow River, and above 95% and 75% of inflow into Longyangxia and Liujiaxia reservoir respectively. The yearly inflow of Longyangxia Reservoir (Tangnaihai station) is 20.2 billion m^3, while 72% of that in the flood season (from June to October). So the volume variation of inflow holds the balance to the water resources utilization in the upper reach and even in the whole Yellow River Basin.

The area upper Tangnaihai is Qinghai – Tibet Plateau with great number of mountains, rivers, lakes and marshlands, the total area of lake moors amount to 2,000 km^2, it belongs to high – cold humid region with great climatic difference and well – growing vegetation. There are three sources of runoff inner the basin, natural precipitation, snow – ice melting and groundwater recharge. The volume of runoff and peek discharge mainly depends on precipitation and its time – space location.

This area is little influenced by human activities, the runoff at Tangnaihai station has no manual intervention and with observed data for over 40 years since station setup in 1956. For the integrity of runoff data analysis on the upper Yellow River, the runoff data at Tangnaihai station has been extended using observed runoff data at Shangquan station based on technical specification and then made reasonableness test, the results show that there is no obvious difference on relevant parameters (mean, coefficient of variation and coefficient of skewness) between extended series (1920 ~ 2004) and measured series of monthly and yearly runoff at Tangnaihai station. Using runoff series data during 1920 ~ 2004 to analyze the laws of runoff variation at Tangnaihai station, it shows an alternative process with high or low flow. For the climate variation and continuous rising of air temperature, it predicted that the precipitation will increase probably during the future several decades in the upper Yellow River. Tangnaihai station has experienced low – flow period since 1990s, while it will turn into relative high – flow period the next ten years.

2 Analysis on runoff in the upper Yellow River

2.1 Runoff and precipitation

Precipitation is one of the most important sources of runoff in the upper Yellow River, its volume and distribution determines the volume of runoff and peak discharge. The Upper Yellow River locates Qinghai – Tibet Plateau, with short rainy season mainly concentrating summer and autumn, while mainly snow during winter and spring. The precipitation during September has a major contribution to the runoff during this month and even the eight months later, the period from

September to the next May is the key period for water use in the upper reach and also the ice – control period in the Ningxia – Inner Mongolia reach, therefore the precipitation in September and the inflow during long period after runoff forecast can be used.

2.2 Runoff and ground sensible heat of Qinghai – Tibet Plateau

Precipitation is the direct source of river runoff, but for the well – done runoff forecast, it has to seek the other influencing factors. The research by Sun Guowu, etc. shows that the plateau heat source variation in summer is one of major causes led to runoff changes in the plateau area and even the upper Yellow River. While Tang Maocang, etc. pointed out that there has some correlativity between previous geothermal variation and latter runoff changes, at the same time, the plateau ground sensible heat flux in winter has a good coincidence relation with the river runoff in summer, that is to say that when the plateau ground sensible heat flux in winter (February) increases, the runoff in the upper reach in July will be higher correspondingly. The plateau thermal abnormity in winter can also be characterized as a previous index of summer runoff abnormity in the upper Yellow River.

2.3 Background of atmospheric circulation generated by runoff

Atmospheric circulation is the most direct meteorological factor affected river runoff. With the analysis on circulation characters in the corresponding period during high – flow years and low – flow years in the upper Yellow River, Ma Jingxian, etc. pointed out that there has obvious difference on circulation characters in the corresponding period between high – flow years and low – flow years. At the 500 hPa height field, it is characterized in East Asian continent during high flow year with strong subtropical high pressure, obvious plateau trough, positive east and negative west in departure filed, higher east and lower west in height field, while during low flow year with weak continental subtropical high, obvious plateau ridge, negative east and positive west in departure field, lower east and higher west in height field. While it is characterized at 100 hPa height field with extremely strong South Asia High during high flow year and quite weak South Asia High during low flow year.

For the sake of runoff forecast, it needs to analyze the influence of previous circulation on the latter runoff. It shows from the analysis by Mr. Huo Shiqing, etc. that the rainfall and runoff during flood season (from June to October) in the upper Yellow River has the closest relation with circulation in January, the next is February and December. Runoff volume in flood season at Tangnaihai station and 100 hPa height field has negative correlation in polar area at high latitudes and positive correlation at middle latitudes, at the same time, there is a positive correlation field in the northeastern coastal area along the Atlantic and Pacific Ocean for each, and so does the similar distribution at 500 hPa.

3 Analysis on the laws of runoff variation in the upper Yellow River

3.1 Division of high flow year and low flow year

According to general runoff analysis and forecasting criteria for evaluation, the runoff within ± 20% of the average belongs to normal range, while that more than 20% and less than 30% of the average runoff belongs to the range on the higher side, that more than 30% of the average belongs to high flow range, that more than −30% and less than −20% of the average belongs to the range on the lower side, and that less than −30% of the average belongs to low flow range.

Within the ranges above mentioned, to calculate corresponding fluctuation coefficient (k_p = current yearly runoff / mean runoff), and then the intervals with high flow, normal flow and low flow of historical fluctuation coefficient can be analyzed.

Table 1 k_p of Tangnaihai Station in the Upper Yellow River

High flow year		Normal flow year	Low flow year	
High flow	Flow on higher side		Flow on lower side	Low flow
>1.46	1.46 ~ 1.05	1.04 ~ 0.93	0.92 ~ 0.79	<0.79

Table 2 Runoff cycling period with high flow and low flow at Tangnaihai Station

Cycling period with high and low flow			High flow period			Low flow period		
Start - stop years	Years	k_p	Start - stop years	Years	k_p	Start - stop years	Years	k_p
1920 ~ 1938	17	0.94	1920 ~ 1921	2	1.04	1922 ~ 1933	11	0.71
1939 ~ 1951	13	0.99	1933 ~ 1938	5	1.06	1939 ~ 1943	2	0.9
1952 ~ 1968	17	1.04	1943 ~ 1951	8	1.09	1952 ~ 1960	9	0.9
1969 ~ 1989	21	1.06	1961 ~ 1968	8	1.18	1969 ~ 1974	6	0.87
			1975 ~ 1986	12	1.24	1990 ~ 2004	14	0.87

It can see from above tables that the alternative cycle of runoff at Tangnaihai station can be divided into 4 full cycling periods with high and low flow and one separate low flow period since 1920, each cycling period has different length of time, but their k_p values close to the mean value. At present, it is in the fifth low - flow period started from 1990.

3.2 Annual and interannual variation of runoff

3.2.1 Annual variation of runoff

Annual allocation of runoff mainly depends on direct recharge from river flow, the annual runoff allocation at Tangnaihai station is characterized with groundwater recharge in winter with least volume in January and February, ice - snow melting recharge gradually increasing after March, great rainfall recharge from June to October, so it takes place annual flood peak in July, August and September at Tangnaihai station, the largest proportion on runoff allocation occurred in July and September.

Table 3 Annual allocation of runoff at Tangnaihai Station

Month	1	2	3	4	5	6	7	8	9	10	11	12	Full year
Mean monthly discharge	168	165	218	359	580	897	1,290	1,060	1,200	957	470	223	632
Percentage of yearly runoff(%)	2.21	2.17	2.87	4.73	7.64	11.82	17.0	13.97	15.82	12.61	6.19	2.94	100

3.2.2 Interannual variation of runoff

The area above Tangnaihai station has little influences by human activities, compared with the other regions, its interannual variation coefficient of runoff is relative small, the C_v value is less than 0.3. The runoff variation at Tangnaihai station since 1920 was characterized as low flow period in 1920s, normal flow period from 1930s to 1950s, the runoff on the higher side in 1960s, normal flow period in 1970s, the runoff on higher side in 1980s and runoff on the lower side since 1990s. Based on statistics and five - level probability distribution categorized by high and low flow years above mentioned, it shows that probability occurred in low flow years was the largest with noticeable negative skew distribution, the next occurrence with utmost probability was high flow year, therefore the runoff forecast on the upper Yellow River should be emphasized with skewness forecast.

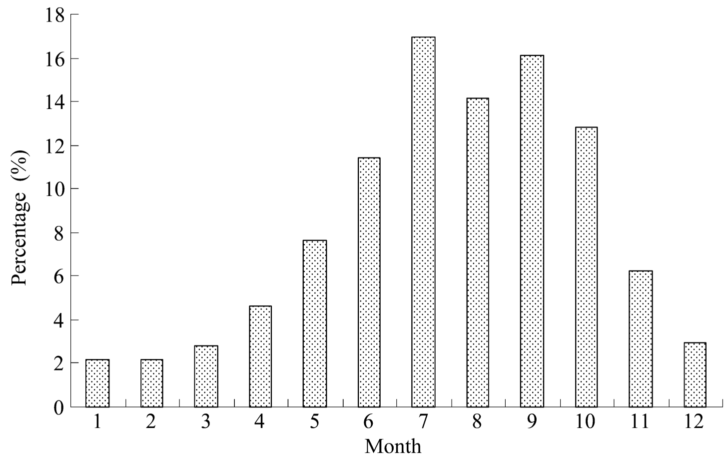


Fig. 1 Percentage of monthly runoff in the yearly runoff at Tangnaihai Station

Table 4 Variation of High and low flow in different decades at Tangnaihai station

Decades	Annual mean discharge	Average k_p	Departure(%)	High or low flow
1920 ~ 1929	504	0.82	-22.4	Lower flow
1930 ~ 1939	580	0.94	-6.37	Normal flow
1940 ~ 1949	636	1.03	3.08	Normal flow
1950 ~ 1959	577	0.94	-6.48	Normal flow
1960 ~ 1969	686	1.12	11.1	Higher flow
1970 ~ 1979	646	1.05	4.72	Normal flow
1980 ~ 1989	763	1.24	23.7	Higher flow
1990 ~ 2004	557	0.87	-14.7	Lower flow

3.3 Continuity of runoff

For the runoff recharge during winter half year in the upper Yellow River mainly depends on groundwater, so the continuity of runoff in winter is quite good, but that in summer is relatively weak. The interannual continuity between low flow years is better than that in high flow years.

Using yearly runoff series to plot differential curve of yearly runoff fluctuation at Tangnaihai station (see Fig. 2), it can show obviously the changing laws of high or low flow years after contrast analysis. The descending curve during 1920 ~ 1933 indicates the runoff was in low flow period, while the rising curve during 1934 ~ 1950 shows the runoff was on the higher side, there was an alternative process with low flow and period on higher side during 1951 ~ 1959, 1961 ~ 1967, 1967 ~ 1973, 1974 ~ 1988 and 1989 ~ 2002. The irregular long continuous variation of runoff with continuous high or low flow process is a matter of a law of nature from hydrological factors changes.

3.4 Periodicity of runoff

Both hydrological factors and long - term variation of atmospheric circulation and meteorological factors which influence the hydrological factors present fluctuation phenomenon (cyclic variation) in different degree. Spectrum Analysis based Fourier analysis is the commonly used method for the research on the laws of these fluctuation phenomenon. Using the data series of yearly mean discharge at Tangnaihai station to conduct power spectral analysis, harmonic analysis and analysis of variance, then to make significance test and can get significance cycles with 2 years, 3 years, 6 ~ 7 years, 10 years, 12 years, 17 years, 20 years, 23 years, etc.

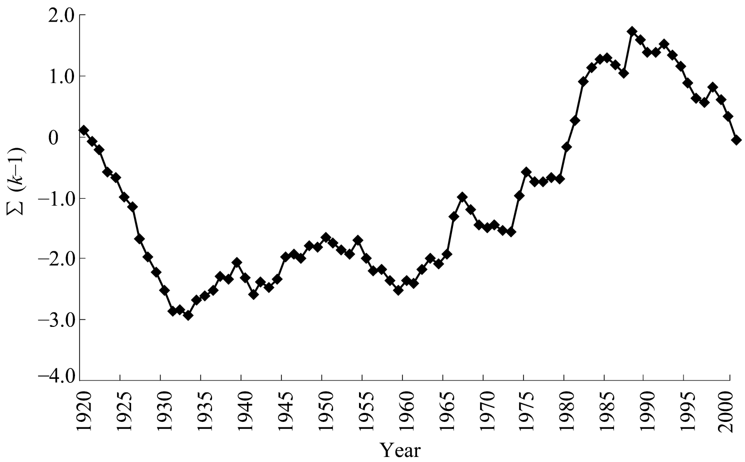


Fig. 2 Differential curve of yearly runoff fluctuation at Tangnaihai Station

The existence of such cycles of runoff variation in the upper Yellow River is of some physical significance. Firstly, the cycle of runoff variation with 3 years and 6 ~ 7 years is identical with 3 ~ years cycle of ridge location of subtropical high (Xu Guochang and Dong Anxiang, 1982) and about 7 years cycle of amplitude transition of polar migration, both them are important systems influencing precipitation in western China. The variation will bring about changes of earth centrifugal force system, thereby causing the variation of atmospheric circulation, air quality and moisture transport, and then to affect the changes of hydro – meteorological factors. Zhang Xiangong analyzed and researched on monthly area index of subtropical high and sea – temperature data of equatorial eastern Pacific Ocean during 1951 ~ 1984, the result shows that strength variation of subtropical high has the main cycles with 3 years, 2 years, etc., and also concludes that the vibration of subtropical high for 3 – 4 years was mainly subject to sea temperature. Subtropical high is one of main systems that affected precipitation of the whole Yellow River basin, so about 3 – years cycle of runoff variation in the upper Yellow River probably reflects air – sea interaction. The existence of about 2 – years cycle has been proved in the research conducted by many hydro – meteorologists (Huo Shiqing and Wen Liye, 1996). 16 – 17 years cycle correspond with 17 – years of natural cycle of stratosphere existing objectively, and the existence of 22 – years cycle is probably related with motion laws of celestial bodies and medium and long – wave cycle of sunspot variation (Chen Xingfang, 1995). The research also shows that the activity of sunspot has long – cycle variation with about 200 years and medium and short variation with 22 years and 11 years or so (Kang Xingcheng, 1992), it is related closely with variation of meteorological factors and large – scale drought and water – logging in China, as well as the influence to runoff variation in the upper Yellow River. When activities of sunspot increase, it will be in period that E – type circulation develops and W – type circulation weakens, the strengthening of E – type circulation is favorable to air exchange between south and north area, meanwhile, with weakening of W – type circulation, the thermal low at Qinghai – Tibet plateau strengthens, precipitation increases in the northeastern area of Qinghai – Tibet plateau and thus the runoff in the upper Yellow River increases accordingly. Conversely, when E – type circulation weakens and W – type circulation develops, the runoff in the upper Yellow River will reduce correspondingly.

4 Expectation on inflow situation in the Upper Yellow River

Many scientists in the world used 35 global weather patterns under standard situation with discharging of 6 representative greenhouse gases, and then predicted global climate variation during the following 50 ~ 100 years in future (IPCC, 2001). Although each pattern has different predicted result and also including really uncertainty, all the results show that increase of greenhouse gases is the largest factor to cause climate change in the 21st Century. Based on weather patterns abroad, Chinese scientists developed and set up our own weather pattern, supposing CO_2 concentration increases continuously and aerosol concentration changes, then predicted that the future climate change in China is the same as the trend of global climate changes, the mean temperature will be rising continuously and probably going up 1.7 ℃ during the period of 2020 ~ 2030 and then 2.2 ℃ in 2050. Rising extent of air temperature increases gradually from south to north, there will be obvious rising of air temperature in northwest and northeast China, by the year 2030, it will probably go up 1.9 ~ 2.3 ℃ in the northwest region, 1.6 ~ 2.0 ℃ in the southwest region and 2.2 ~ 2.6 ℃ in Qinghai – Tibet.

Since 1990, the upper Yellow River took place the phenomenon of runoff on lower side for continuous 13 years, except for higher flow in 1999. Owing to sunspot activities and influence of atmospheric circulation, the process of runoff variation in the upper Yellow River consists of a series of cycling periods with high or low flow in different duration. After occurrence of low – flow period over ten years since the late 1980s, it will turn into significant high – flow period in the upper Yellow River. In the case of CO_2 doubled in future, using regional weather pattern to calculate that the air temperature will go up 2.7 ℃ and precipitation increase 25% averagely in northwest region during the years of 2040 ~ 2050 or so, if considering natural factors and human activities, the air temperature will go up 1.9 ~ 2.6 ℃ and precipitation increase 4% ~ 34% by the year 2050, the glacial meltwater will increase above 50% calculated by experiences. It is expected in the west part of northwestern China that the precipitation and runoff will be on lower side after high period for years, and for the east part including the upper Yellow River basin, the precipitation maybe increase in the near future and probably turn into high – flow period. If put joint action of greenhouse and sulfide aerosol into consideration, the mean air temperature will be rising continuously in the northwestern region including the upper Yellow River basin and the range of increase is larger than the other regions in China. From the point of season in the early stage of 21st century, the situation in the northwestern region is the same as that in the world with largest increasing range of temperature in winter and precipitation increases mostly in summer. According to the law of alternative cycle with high and low flow in the upper Yellow River, the results about future climate that scientists predicted show that the air temperature will go up and precipitation will increase in the upper Yellow River, the variation of yearly runoff will take on a rising trend at Tangnaihai station in the upper Yellow River in the next ten years.

References

Lan Yongchao, Kang Ersi, Jin Huijun, et al. Analysis on Runoff Characteristics and Changing Trend in the Upper Yellow River[J]. Geoscience Advance, 1998,13(13):112 – 120.

Institute of Geography, Chinese Academy of Sciences, Atlas of Qinghai – Tibet Plateau[M]. Beijing Science Press, 1990, 77 – 79.

Gao Zhixue, Song Zhaosheng. Survey of Hydrography in the Upper Yellow River Basin [J]. Hydrology, 1984, (3):55 – 58.

Feng Song, Tang Maocang, Wang Dongmei. New Evidence on Qinghai – Tibet Plateau being Starter of Climate Change in China[J]. Science Circular, 1998, 43(6):633 – 636.

Shi Yafeng, Shen Yongping, Li Dongliang, et al. Discussion on the Present Climate Change from Warm – dry to Warm – wet in Northwest China [M]. Beijing Meteorological Press, 2003.

Tang Haixing, Chen Yongqin, Chen Xi, Research to the Effect of Global Warming on Water Resources in Dongjiang River Basin Using Random Method [J]. Hydroscience Advance, 2000, 11(2):159 – 163.

Arnell. N. W. Climate Change and Global Water Resources[J]. Global Environmental Change, 1999, 9:531 – 549.

Comprehensive Evaluation of Floodwater Resources Utilization in the Flood Detention Areas of the Huaihe River

Tang Ming[1,2] and ***Shao Dongguo***[1]

1. State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan, 430072, China
2. Office of Anhui Flood Control and Drought Relief Headquarters, Hefei, 230022, China

Abstract: Study on the benefits and risks of the floodwater resources utilization is very necessary for guiding the plan for the flood detention area function transformation project and ensuring the exertion of flood control function. On the basis of consulting a great deal of literatures about the flood detention areas of the Huai River, this paper analyzes the necessity and approaches of the resources utilization over floodwater in this district, and studies the benefits and risks of the floodwater resources utilization by making use of the flood detention areas themselves. Finally, a comprehensive evaluation is discussed concerning the floodwater resources utilization in the flood detention area.
Key words: floodwater, resources, benefit, risk, the flood detention area, the Huai River

1 Preface

The population density of the Huai River Basin is 615 /km^2, which is the biggest among the seven river basins in China, therefore the contradiction between human and water is extremely prominent. Long time ago, farmers cultivated and dwelled on the low – lying areas and the river course during dry seasons, where flood had receded, and built small earth dikes for protection, then current flood detention areas have gradually formed, which destroyed original water environment, as well as intensified water disasters. Nowadays, with water resources being more and more scarce and the voice of floodwater resources utilization being higher and higher, hydraulic engineers naturally turn their eyes on these flood detention areas, and many people assume that these areas can store water and perennially maintain a certain water level as to increase the storage capacity, resulting in alleviation of the local drought situation.

Since the flood detention areas are dotted along the Huai River with large affected area and dense population, the policy – makers shall, before transforming the functions of these flood detention areas, cautiously take into consideration of how to properly resettle the inhabitants there, how to evaluate the social impacts resulted from large – scale resettlement, how to appraise the change of flood control function of these areas, how to estimate the change of the ecological environment after storing water and how to evaluate the socioeconomic benefits from the water resources utilization. It can be seen from above that the evaluation of the resources utilization over floodwater of the flood detention areas along the Huai River not only relates to the economy, but also to society, ecology, etc. Therefore, it's extremely essential to study the benefits and risks created by the resources utilization over floodwater of the flood detention areas, which can provide guideline to the planning of the flood detention area function transformation project, and ensure its flood control function.

2 General situation of the flood detention areas along the Huai River

The Huai River Basin has such characteristics as fluky climate, special landform and complex river system. After the flood occurring in 1954, the Central Government ascertained the policy of harnessing the Huai River, which was "storing some water while discharging flood", and demanded people to pay equal attention to storing and discharging floodwater in the middle reaches of the Huai

River. On the one hand, the floodwater from mainstream and its tributaries was stored in lakes and low – lying land, on the other hand, the extra was discharged through the harnessed river course. At that time, some low – lying lands often inundated were reconstructed into flood detention areas with certain standard. And with the emban kments moved back or reinforced, the river course widened and the industries developed, some partial adjustments and other changes to the flood detention areas have been made. So far, there are 27 flood detention areas distributed along the Huai River, with a total area of 3, 858 km^2, total population of 1, 727, 000 and total cultivated area of 3,495,000 mu (1 mu = 666.7 m^2), which includes 10 flood storage areas such as Mengwa and Chengxihu, and 17 flood passage areas such as QiuJiahu and Jiangtanghu.

The flood detention area is an important component of flood control engineering system and a base for people to live and produce as well. Due to the impacts from floodwater detention, the safety construction greatly lags behind, the flood disasters directly threaten local people's life and property, which restricts the local socioeconomic development. There are four main problems. Firstly, there is a large population who live dispersedly, hence it's of great difficulty to evacuate them before using these areas. In addition, due to the fixed assets unceasingly increasing with the economic development, the property damage is tremendous once these detention areas are used. Thus, it's hard to make the decision whether to use these flood detention areas or not, which may result in these areas not to be used timely. Secondly, the standard of the safety infrastructures constructed is too low to prevent from flood disaster effectively. Thirdly, the laws and regulations on how to manage these detention areas are so needed that the management is very difficult in these areas. Fourthly, it's difficult for the flood passage areas to dynamite a portion of dike in flood season, which leads to unsatisfactory effect of discharging floodwater. Simultaneously, the duration of high water level is long, therefore it's difficult for flood water to recede, which increases the disaster losses and even seriously affects the production restoration.

3 The necessity and approaches of floodwater resources utilization

According to the estimation by the Anhui Investigation & Design Institute of Water Resources and Hydropower, the local multi – annual average amount of water resources in the northwest of the Huai River Basin (the west of Guo River Basin) is 6.7×10^9 m^3, and its average amount of water resources is 460 m^3 per person; the local multi – annual average amount of water resources on the south of the Huai River is 8.4×10^9 m^3, and its average amount of water resources is 1,038 m^3 per person. According to the international water shortage index, the south of the Huai River Basin is regarded as water shortage district, and the northwest of the Huai River Basin is serious water shortage district due to its scarce water resources.

The northern area mainly depends on fully using local water resources and extraneous water from the Guo and Ying rivers. As to the areas along the Huai River, besides fully using local water resources, the most effective way is to utilize the floodwater resources along the mainstream of the river to solve its water shortage problems. Aside from tapping the existing potentials of the upstream reservoirs and multitudinous large – scale water gates, floodwater resources utilization should take advantage of these detention areas as to play a sufficient role.

The approach of the floodwater resources utilization in the flood detention areas along the Huai River is to choose some flood detention areas to store water all the year round, namely retiring farmland to lakes, which can effectively lessen the contradiction of water scarcity in dry years, and then alleviate water scarce problems in the middle and lower reaches of the Huai River, especially in its northwest.

There are differences in its natural geographical environment, functions and operation conditions, peripheral socioeconomic status and development prospect for each flood detention area, so their function adjustment should be treated differently, such as separately studying their possible beneficial water levels, structural or non – structural engineering measures, investment required, benefits from water supply and so on. In addition, the influences made from the function adjustment of each area on flood control effect, ecological environment, social security, economical development and so on, should be properly evaluated as to make a comprehensive evaluation on its feasibility and rationality.

4 The benefits and risks of floodwater resources utilization

4.1 The benefits and risks of reallocating and utilizing floodwater resources

Storing water in the flood detention areas is to realize the resources utilization over floodwater, which transforms from purely preventing from flooding to giving room to floodwater and leaving precious freshwater resources for the water shortage areas. Besides the direct benefits from water supply, it can also bring socioeconomic benefits, for instance, impulsing the development of the tourism, fish breeding and other relevant industries, which can increase job opportunities and promote the local socioeconomic development.

The risks of floodwater resources utilization mainly come from the uncertainty of water abstraction and water consumption. The volume of water flowing by gravity into the flood detention areas is subject to the water level of its main stream, hence its uncertainty affects the water supply cost. In addition, the water consumption's quantity and structure are decided by local socioeconomic level, therefore its uncertainty also affects the water supply benefits.

4.2 The benefits and risks of land function adjustment

Storing water by the flood detention areas will promote the local agricultural development and have a positive influence on lessening flood disasters and adjusting the local planting structure in rural areas.

But the land is the most important living means for local farmers and the contradiction between large population and less land is very prominent in those areas, so it's very difficult to allocate land to those land – lost farmers. As to those affected persons whose main production outlet is agriculture, the living pressure is huge once they lose their land. Furthermore, local farmer's partial income comes from the public land protecting the riverbank, however, such losses, partly contributing to their incomes, will not be compensated by the local government, which would further aggravate their poverty.

4.3 The benefit and risk of resettlement

Resettlement is an important component of the engineering construction, and also a complex systematic project. Proper resettlement is a premise in China's resettlement policies, meanwhile some measures are taken, which conjoin compensation and subsidy in earlier stage and production support in latter stage, to create a basic living condition for those land – lost farmers. Therefore, some correlative training, job opportunity provision and social welfare guarantee during resettlement implementation will help those affected people get rid of poverty as soon as possible. Furthermore, if people and their properties can be permanently moved out of the flood detention areas before water storage in these areas, the government will not need a lot of efforts on temporary movement, post – disaster reconstruction and preventing displaced people moving back any more.

In the meantime, we should also realize that the displaced people's quality and skill are generally low, and their viability and competition ability are relatively weak, thus the unemployment will gradually come forth. Moreover, after the large influx of displaced people, the pressure on resources and social services will increase in the host areas, which intensifies employment competitions, social conflicts and health risks.

4.4 The benefits and risks of flood control regulation

The regulation problem of flood detention areas is the focus and difficulty in the flood control of the Huai River. Whether using the flood detention area or not is a difficult selection. However, after the flood detention areas store water perennially, once facing the decision – making of flood – diversion, our decision – makers needn't take into account the large number of properties, and need not organize an emergency evacuation. So the using of the flood detention areas is more efficient and timely, which can get more time for implementing other flood control regulation scheme, thereby increase the regulation flexibility.

However, once the flood detention areas have stored water perennially, their effective storage capacity will be reduced, as a result, the timing and effect of flood diversion would be directly affected, which may increase the possibility of using other flood detention areas and indirectly raise the flood control pressure of the emban kments on the lower reaches.

4.5 The benefits and risks of ecological environment

When the flood detention areas store water perennially, the acreage of the lake along the Huai River will be enlarged. The massive water body has a larger regulatory function to the environment and brings great ecological benefits. They can play an important role in climate regulating, water source conserving, flood controlling, pollutant degradation, biodiversity protecting and providing production and living resources to the local residents.

The main ecosystem risk is that these lakes are gradually silted up by river sediments after the flood detention areas store water perennially.

5 Comprehensive evaluation of floodwater resources utilization in flood detention areas

From above, we can know that there are also many risks besides the tremendous benefits from the floodwater resources utilization in the flood detention areas along the Huai River. Therefore, scientifically quantifying these benefits and risks will lay a foundation for the efficient floodwater resources utilization in the flood detention areas. So it's necessary to establish a set of scientific evaluation system about the floodwater resources utilization containing all the multidimensional evaluation indexes such as the rationality of society, economy, ecology and resources. It can provide comprehensive evaluation outcomes and scientific basis for the floodwater resources utilization through ascertaining scientific evaluation criteria and selecting some reasonable evaluation indexes.

5.1 The basic principles of the evaluation system of the floodwater resources utilization

The comprehensive evaluation of the floodwater resources utilization is a complex system project, whichever index you have selected only reflects a certain aspect of the benefits. In order to evaluate the benefits rationally, it's essential to set up a series of comprehensive evaluation indexes, which can reflect various levels of the benefits and risks coming from the floodwater resources utilization in the flood detention areas. Such principles as integrity, independence, development, pertinence, maneuverability and hierarchy should be followed.

The principle of integrity requires that this system should reflect entire influences on the local development after the function adjustment of these flood detention areas, such as the benefits from flood control, society and environment, and the risks from them.

The principle of independence requires that these indexes shouldn't overlap each other in case of increasing the evaluation difficulties.

The principle of development requires that these indexes should be dynamic, which can comprehensively reflect the trend of benefit development after the reconstruction of flood detention areas.

The principle of pertinence requires that these indexes should reflect the influence of the integrated reconstruction of flood detention areas in the whole basin, as well as quantify the influence from each flood detention area, which can specifically judge the feasibility of each flood detention area's reconstruction.

The principle of maneuverability requires that the complexity of index system should be moderate, which can be conducive to popularize too. If the index system is too simple, it cannot reflect the connotation of the evaluated object, so as to affect the precision of evaluation. If the index system is too complex, it may go against the development of evaluation.

The layered principle requires that index system should possess a hierarchical structure, namely, a regularity combination of all indexes. These indexes should have some appurtenant inherent relations instead of an out – of – order combination of many indexes. Their system can be divided into three levels generally, namely, the collectivity index, the classified index and the subentry index. Thereby, we can evaluate the floodwater resources utilization either on the view of the integer or the branch, which can entirely hold the trend of development in the Huai River Basin.

5.2 The framework of evaluation system of floodwater resources utilization

According to the above principles, we put forward a framework of the evaluation system of the floodwater resources utilization in the flood detention area after considering the situation in this stage (Fig. 1), which includes economic benefits, social benefits, environmental benefits, the losses and risks of resources utilization, resettlement, flood control and ecological environment.

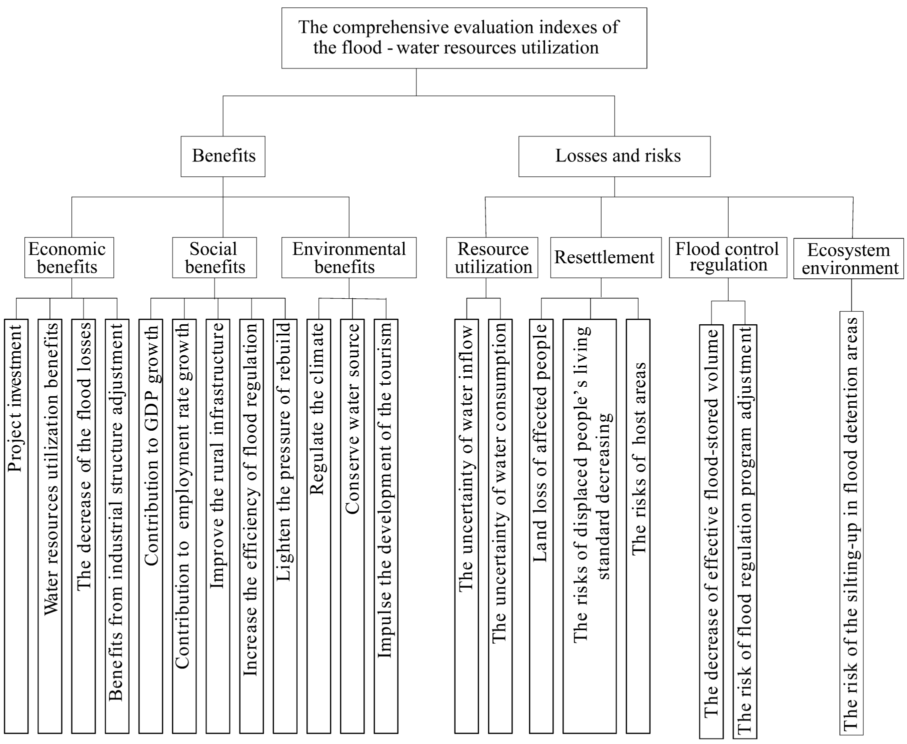


Fig. 1 The evaluation system diagram of floodwater resources utilization

5.3 The comprehensive evaluation methods of floodwater resources utilization

Common comprehensive evaluation methods include the Matrix Analysis, Evaluation Method by Experts, Combined Indexes Evaluation, Delphi Technique, Synthetic Index Evaluation, Fuzzy Comprehensive Evaluation, Analytical Hierarchy Process, Data Envelopment Analysis, Artificial

Neural Network, Gray Decision – making and so on.

No matter which comprehensive evaluation method you select, how to decide the weight of index is the most important work in the evaluation. The weight of index reflects its degree of importance in their system in the form of number, namely incarnates a multiple – objective attribute. However, it's difficult to pinpoint the degree of importance of all indexes in practice. Therefore, according to the difference in the method of determining the weight of index, comprehensive evaluation methods have been divided into two categories – the subjective evaluation and objective evaluation. Subjective judgment is adopted to determine the weight of the index in the subjective evaluation method. But how to determine the weight of index in the objective evaluation is based on the inherent characteristics, correlation and variation between those evaluation indexes. Each method has its own merits or shortcomings.

Therefore, when evaluating the prospects of floodwater resources utilization in flood detention area, we should choose an appropriate comprehensive evaluation method to combine the subjective factors and objective factors, so that we can take into account the relativity among indexes while taking full account of the opinions of experts. If we do that, we can make the evaluation to incarnate the inherent characteristics of each index, and make its result more objective and reasonable.

6 Conclusions

In summary, we can know that the floodwater resources utilization is essential according to the conditions of water resources in the Huai River Basin. Meanwhile, those multitudinous flood detention areas provide a predominant condition for floodwater resources utilization. However, there are many risks in the process of utilization. Therefore, it's necessary to evaluate floodwater resources utilization based on the principles of seeking truth from facts and of respecting science. We should adhere to the principles of assuming moderate risks while ensuring engineering safety and the efficiency of flood control, to establish a scientific comprehensive evaluation system, and we should choose a reasonable method to comprehensively evaluate the benefits, risks and losses followed the floodwaters resources utilization.

References

Shao Dongguo, et al. The riskmanagement theory and the technical studies on the floodwater resources utilization, National Science and Technology Research Project in the Tenth Five – Year Plan.

Wang Hao, Yin Junxian. Review on the Risk Management of Floodwater Resources Utilization[J]. Water Resources Development Research, 2004 (5).

Cheng Dianlong, Shang Quanmin, et al. Treat the Floodwater Resources Utilization with Scientific Spirit and Positive Attitude[J]. China Water Resources, 2004(15):25 – 27.

Exploitation and Utilization of Water Resources and Sustainable Development in the Irrigation Area of the Lower Yellow River

Zhan Zisheng, ***Chen Weiwei*** and ***Cao Huiti***

Yellow River Institute of Hydraulic Research, YRCC, Zhengzhou, 450003, China

Abstract: The water problem in the irrigation area of the lower Yellow River becomes more and more serious with the strained supply – demand relations on water resources. At present, water resources issue causes a series of profound problems, such as irrigation areas decreasing with years. Based on analyses of the current water resources situation and a series of problem about water resources utilization in the irrigation districts of the lower Yellow River, the countermeasures for sustainable development are put forward in the following aspects, improving infrastructure construction of the irrigation districts, integrating water resources management for the irrigation districts, strengthening water saving advertisements, developing water saving agriculture, establishing and impooving water commodity market and so on.

Key words: sustainable development, exploitation and utilization, water resources, irrigation area of the Yellow River

1 The general situation of the irrigation area

The irrigation districts of the lower Yellow River refer to the area irrigated by the water of the mainstream from Taohuayu to the estuary. The irrigation districts were constructed in early 1950s. In the past few decades, with the development of social economy and the continuous increase of water demand of the regions along the Yellow River, the irrigation area have been unceasingly expanded.

According to statistics, by the end of 2003, 98 irrigation districts of more than 6,700 hm^2 10,000 mu) had been completed in Henan and Shandong Provinces, by withdrawing water from the Yellow River, with a design irrigation area of 3.579,33 million hm^2, an effective irrigation area of 2.147,33 million hm^2, and a factual irrigation area of 1.974,67 million hm^2. The benefited areas involve 18 cities, 87 counties (districts) in both provinces, including the total land area of 92,000 km^2 and the total population of 52.71 million.

The irrigation districts of the lower Yellow River are the important production base for grain, cotton and oil in China, which play the vital role in guaranteeing high and stable production of grain, cotton and oil in Henan and Shandong provinces for many years. The lower Yellow River water has guaranteed agricultural use in profiting scope, at the same time Provided industrial and domestic use in some cities and the important industrial districts along the Yellow River.

In addition, the irrigation districts of the lower Yellow River also play the important role on improving ecological environment, protecting water resources, purifying air, restraining soil erosion and reducing sandstorm threat and so on.

2 The current situation of water resources exploitation and utilization

At present, 230 projects diverting water from the Yellow River are constructed in the lower Yellow River, in which, the culverts are 117, the lifting stations and pumping stations are 110, and the siphon culverts are 3. The total permission water – taking volume is 10.1 billion m^3 including 3.05 billion m^3 for Henan Province and 7.05 billion m^3 for Shandong Province respectively.

From 2001 to 2003, the annual water volume diverted from the lower Yellow River is 7.581

billion m^3, most of which is used for agriculture, the few used for industry, human and livestock's life, etc. Statistics have indicated that the water used for agriculture accounts for 93.6% of the total water diverted from the lower Yellow River, the water used for industry accounts for 4.9%, the water used in the human and livestock's life accounts for 1.0% and the other use accounts for 0.5%.

Besides diverting water from the lower Yellow River, the irrigation darea also extract the ground water and the local surface water. According to the Water Statistic Annuals of Henan and Shandong Provinces, the annual water – using volume of the irrigation darea is 11 billion m^3. In which, the Yellow River water is 6.64 billion m^3, the local surface water is 0.76 billion m^3, and the ground water is 3.6 billion m^3. The proportion of the Yellow River water, the local surface water and the ground water of the total water – using volume is 60%, 7% and 33% respectively. Moreover, proportion of the three kinds of water in Henan Province is 50%, 6% and 44%, and in Shandong Province is 65%, 7% and 28%.

By this token, the Yellow River water is still the main water source of irrigation diarea of the lower Yellow River. The water problem becomes more and more serious with the strained supply – demand relations on water resources. At present, water resources issue causes a series of profound problems, such as irrigation areas decreasing with years. Before South – to – North Water Transfer Project is put into operation, there is no possibility to increase the water resources in the Yellow River. Under the existing water resources condition, the irrigation area only can exploit its own potential to maintain the sustainable development.

3 The existing problems of water resources exploitation and utilization in irrigation areas

3.1 The incomplete, serious aging and disrepair engineering works and low degree of water resources utilization

The irrigation of the lower Yellow River were mostly built in three periods of the end 1950s, the begiming of 1960s and the 1970s. However, at that time for the influences of external conditions limited, universal insufficient investments, the lower construction standard and incomplete support construction, until now some irrigation still could not commendably display its benefit. According to the investigation on the large – scale irrigation districts by withdrawing water from the Yellow River in the Henan and Shandong Provinces, the length of the mainstream and branches with leakage, vulnerable spots and frequent flushing accounts for about 60% of the total canal, the effective proportion of canal structure is only 35%.

These conditions of the irrigation facilities reduce water utilization factor which is approximately 0.4 on average, unsuitable for the scarce water resources in irrigation districts of the lower Yellow River, and also affecting the further development of agricultural production to a great extent.

3.2 Disunited water resources management in irrigation area

The irrigation diarea only manage irrigation water diverted from the Yellow River, but the local ground water resources management is the responsibility of the local water administrative department, resulting in disunited water resources management. So, due to massively making use of the Yellow River water, the groundwater is shallow in the gravity flowing areas, and the development and utilization degree of groundwater is very low. But in the well irrigation area, owing to the short of water sources, over development results in the ground water overdraft, even in some areas forming the funnel area, which causes great influence on the water resources utilization efficiency of irrigation area.

3.3 Incomplete metering of water used in irrigation area

The matching engineering works, metering facility and system of the irrigation area are incomplete, thus metering of water used can not be able to carry out for the household. Without metering facility, saving and planning use of water become "water without a source, a tree without roots". The water supply without metering causes serious waste of water used by industry and agriculture and water saving without enthusiasm. The administrative departments at the irrigation areas have not assessed the water usage quota and water saving indicator, and the policy to encourage farmers to save water and improve irrigation method has not come forth. All of these also restrict water usage management of the irrigation areas.

3.4 Water price is lower than water supply cost

The water price for the irrigation districts of the lower Yellow River has not incorporated with a prompt adjustment mechanism according to the market supply and demand and cost changes, and the level of water price is much lower than the water supply cost. Although the water charge standard of the canal head in the lower Yellow River was raised by the state in December 2000, at present the standard of agriculture water charge to household in Henan Province is only 0.048 yuan/m^3, however, the agriculture water supply cost is 0.12 ~ 0.20 yuan/m^3, which only accounting for 24% ~ 40% of the cost. In the irrigation districts of Shandong Province the average cost of water supply for agriculture is 0.129 yuan/m^3, and the price of average water supply is 0.050,1 yuan/m^3, which only accounting for 39% of the cost. This disparity between agricultural water charge standard and agricultural water supply cost causes the irrigation district administrative departments to fall into a vicious circle of "no income if no water supply and less income if less water".

3.5 Lower collecting rate of water charge

On the one hand, because the people's water commodity consciousness is weak, and the irrigation area lacks the perfect charge system and the potent restriction measures, the collecting rate of water charge is low. Taking the irrigation districts in Henan Province as an example, in 1999, the receivable water charge was 3,640 thousand yuan, the actual water charge was 1,520 thousand yuan, and the ratio of collecting water charge was 41.8%. In 2000, the receivable water charge was 2,960 thousand yuan, the actual water charge was 1,340 thousand yuan, and the ratio of collecting water charge was 45.3%. On the other hand, the water to be supplied has always been taken as social welfare service for a long time and has not been integrated into the commodity price category. Therefore, the water charge collected has been diverted to any other purpose at will or enormously reduced. As a result, the irrigation area administration is in the loss condition for ages, not obtaining complete even essential compensation, maintaining the simple reproduction with difficulty, and causing the projects aging and disrepair as well as the water supply guaranteed ability dropping.

4 Countermeasures for sustainable water resources utilization

4.1 Increasing investments and perfecting irrigation area infrastructure

We first should carry out the systemic subsequent rebuilding and water saving reconstruction in the irrigation areas. Investment would defer to "Hydraulic Industrial Policy" that specifies the financing by way of national aid, and the fund or labor by local government, collective and people. Therefore, we should encourage developing the private project and the shareholding system project, simultaneously hearten the enterprise, the institution, other social group or individuals investing in constructing and developing the profitability water resources facilities in the irrigation areas. Secondly, we should establish the reasonable property right structure and the scientific and consummate operation and management system of the water conservation fixed asset, forming the pattern of diversity, various channels, different levels investments and the water conservation managed by the people or the society. At last, we should change the poor condition of the infrastructures of the irrigation areas fundamentally, and lay down the solid foundation for sustainable water resources utilization of the irrigation areas.

4.2 Integrated water resources management for irrigation areas

The integrated management for water resources in the irrigation areas shoud be carried out, the existing decentralized management of water resources reformed, and a large – scale modernized water resources management entity whit clearly identified property rights, independent management and operation, authority, highly effective and concordant established, conforming to the requirement of sustainable water resources utilization. At the same time, we should carry out the integrated planning, management and allocation, and establish water resources assignment plan from various levels in different year. Each kind of water sources in the irrigation areas, such as surface water and ground water, the local water and foreign water, the shallow ground water and the middle – deep ground water should be jointly utilized. Furthermore, thoy shoud be restricted by the economic lever to obtain reasonable and optimized water supply and use.

4.3 Realizing sustainable water resources utilization must place water saving on the first position

Since the agriculture is a large water consumer, the basic way to solve the water shortage problem lies in developing highly effective water saving technology of the comprehensive agriculture, and raising gradually the agriculture water efficiency in large areas and per cubic meter of water use efficiency. The phenomenon of eating "the cauldron water" left behind in the past should be thoroughly changed. Meanwhile, we should irrigate crops instead of watering fields, formulate the reasonable irrigation system, popularize the conventional water saving irrigation technology and new technology and method. At last, we should transform effectively the water saving benefit into the economic benefit, establish water saving mechanism and promote sustainable water resources utilization.

4.4 Propaganda is a key of realizing sustainable water resources utilization

At present, the supply and demand contradiction of water resources in the Yellow River is becoming fierce day by day. But some people and leaders in the irrigation areas are still not fully aware of the threat water scarcity to the locality and themselves. Therefore, they also do not understand the importance and urgency of water saving irrigation, still behave according to the traditional idea and method, and not yet know the social significance of water saving from the overall situation. As a result, strengthening propaganda is both inevitable and necessary. We should grasp the following several points firmly in the propaganda: ① Water saving is a basic national policy, and developing water saving irrigation is the only way that must be taken. ② The water is commodity and resources. It is not inexhaustible, and its use is not free of charge. It is valuable because it condenses the materialized labor, and moves indispensably according to the economic law. ③ We should propagandize water controlling according to law, implement water conservancy laws and regulations, adjust water relations according to law, have the explicit system of rewards and penalties for the phenomenon of water saving and wasting resources, and manage it by administrative and legal method.

4.5 Cultivating and perfecting a water market for the irrigation areas

The perfect water market will be propitious to sustainable water resources utilization and water conservation development. Establishing the perfect water market is as follows. Firstly, rational water price should be obearned. We should assess water price according to the water supply cost and the water function in increasing industrial and agricultural production, suppress the phenomenon of wasting water with economic measurements, and accelerate water saving work development. Secondly, we should establish the reasonable water charge collecting policy, implement the progressive price to the regions and units who use the water beyond their quotas, simultaneously deduct their water index allocated for the next year, and reward the water saving units, and give subsidy to them according to the amount of water saved. Thirdly, we should establish the transfer and compensation policy of water saving benefit. Along with the economical development and quickening up of town construction, the industrial and domestic use of water in cities and towns is increased to a great margin, occupying the agricultural water use unavoidably. The industrial production value per cubic meter of water is much higher than that of the agriculture. This economical and social benefit shifting is an inevitable trend of the agriculture shifting to the industrialization, but the benefit shifting should not be free, but should be properly compensated. The fourth is consummating charge system by measurement. Fifthly, the water administration should enhance service level and management capacity, and guarantee water supply quality.

5 Conclusions

Realizing sustainable development of the irrigation areas of the lower Yellow River is a systematic engineering. Optimizing configuration plan of water resources must be well done according to the water resources, projects, physical geography and planting layout, etc. Water saving irrigation and ecological agriculture construction should be paid attention to, and do well in making overall plans and factors into consideration, the reasonable planning, the integrated management and arrangement. Industrial and agricultural production structure adjustment must be strengthened, and water resources should be effectively managed according to law. In agricultural water saving, we must pay great attention to not only engineering water saving but also agronomy and biological technology water saving. At the same time, the system construction must be consummated from various aspects.

References

Wang Hongyan. Water Resources Utilization Status and Countermeasure Analysis of Henan Province, China Water Resources, July 2002.

Wang Ziying, Li Huian, et al.. Water Saving Method and Measurement Analysis of the Irrigation. Districts of the Lower Yellow River. Irrigation and Drainage, Vol. 19, 2001.

Shen Dajun, Liang Ruiju, Wang Hao, et al.. Theory and Practice of Water Price. Beijing: Science Press, 1999.

A Study on Precipitation Spatial Variability

Zhu Ruirui[1,2], ***Liu Changming***[1], ***Su Yujie***[3] and ***Dai Xiangqiang***[1,2]

1. Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of sciences, Beijing, 100101, China
2. Graduate School of Chinese Academy of Sciences, Beijing, 100039, China
3. Zhejiang Institute of Hydraulics and Estuary, Hangzhou, 310020, China

Abstract: Precipitation is resulted from a series of complex process. Spatial distribution of precipitation is affected by many factors, including geographical and meteorologic ingredients. In order to understand the mechanism and control it, many experts have conducted lots of researches. Many helpful insights have been achieved, but it is still very poor. Based on precipitation data measured by meteorological stations, a meaningful attempt that uses the certain climate pattern to explore basin spatial distribution of precipitation was implied in this research. Based on this consumption, the study on Wudinghe River basin in China shows that spatial distribution of precipitation is fairly non – uniform and mainly influenced by terrain and meteorologic factors.

Key words: spatial variability, precipitation, spatial distribution, standard deviation coefficient, non – uniform index, Wudinghe River basin

1 Introduction

Hydrologic simulation error is resulted from two major of model and aspects : model structure, arithmetic and input data. The former refers to certainty or uncertainty of model and calculation methods of the hydrological model. The latter relates to observation instruments, distribution of observation station. Network's density and spatial distribution, and time interval of the collected data are also highly related to the latter error. In fact, precipitation varies obviously over different time and place even at the same climate region or basin. Therefore, there is visibly spatial variability of precipitation over a basin, especially in drought areas. Not only is precipitation data one of important inputs of hydrological model but also its spatial distribution is a key factor affecting runoff simulation precision. Even more, ecosystem models of landscape region and global scale, such as MT – CLIM (Running et al. 1987), FOREST – BGC (Band, 1991), etc. have been developed in the latest twenty years, and spatial precipitation data also used as a key input of its environmental feature parameters. All the implication and advancement of spatial distribution of precipitation indicate the necessary of research into it.

Regional meteorology and geography are two important factors affecting spatial distribution of precipitation. Regional meteorology relates to atmosphere circumfluence and air pressure zone. The latter involves stably macroscopically geographic environment and unsteadily microcosmic terrain feature. Macroscopically geographic environment comprises geographic position (longitude and latitude) and macroscopical terrain factors (macrorelief, especially big mountain trend, total elevation, sea – land distribution and distance from sea). Microcosmic terrain factor here in refers to local elevation, slope and microrelief feature. Human activities also impact temporal and spatial precipitation distribution to some extent. Because meteorologic and geographic factors are regulated in spatial distribution, spatial distribution of precipitation is influenced by those effects.

Spatial modeling of a precipitation variable is of interest because many other environmental variables depend on precipitation. Accurate precipitation data only exist for point locations, the meteorological and precipitation stations, as a result of which values at any other point in the terrain must be inferred from neighboring stations or from relationships with other variables. Study methods generally include statistic model, spatial interpolation and synthesis techniques. However, in view of study theory and computing results, synthesis technique is a better arithmetic studying precipitation variable (Lang Tiangang, et al., 2002).

Many studies (Kurtzman and Kadmon, 1999; Oliver and Webster, 1990; Philip and Watson, 1982; Mitas and Mitasova, 1988) model the spatial distribution of a climate variable using interpolation methods. These techniques can obtain satisfactory results from limited data, based mainly on the geographic situation of the sampling points, on the topological relationships between these points, and on the value of the variable to be measured. Precipitation generally increases with elevation (Spreen, 1947; Smith, 1979), and so many authors have incorporated elevation into geostatistical approaches (Martinez – Cob, 1996; Prudhomme and Duncan, 1999; Goovaerts, 2000). Others have developed relationships between precipitation and various topographic variables such as altitude, latitude, continentality, slope, orientation or exposure, using regression (Basist et al., 1994; Goodale et al., 1998; Ninyerola et al., 2000; Wotling et al., 2000; Weisse and Bois, 2001). Nevertheless, accuracy of the results obtained by these methods in mountainous regions is still very limited (Basist et al., 1994; Daly et al., 1994). The inverse square distance technique developed by Nalder and Mein (1998) is taking into account of weather features grads change with altitude, latitude and elevation besides distance weights, but it is only adapted to bigger basin. Sevruk and Nevenic (1998) considered wind and terrain factors effects on precipitation distribution in a small prealpline basin. Wotling et al. (2000) used principle component analysis method to detect geography feature important influence on precipitation distribution and developed precipitation distribution pattern through digital elevation model (DEM). Collinge and Jamieson (1968) discovered wind direction on land surface and terrain were main effects on annual rainfall spatial distribution when they studied Tyne basin in U. K. Yang Liwen and Shi Qingfeng (1997) worked how wind impacted mountainous rainfall and pointed out that amount of mountainous rainfall was more than that of plain and that of windward slope is also beyond leeward slope with the wind. Fu Baopu (1992) studied geography and elevation effects on precipitation and indicated that wind direction had great influence on precipitation when joint angle σ between it and slope was close to zero and windward terrain slope α was 45 degree and that terrain would lead precipitation to increase greatly with the decrease of σ.

On the basis of precipitation data measured at stations, it is a meaningful attempt applying a certain weather pattern to explore spatial distribution of precipitation of a special basin. In this research, the Wudinghe River basin is selected to study precipitation spatial variability in China.

2 Methods and data

2.1 Study area

The Wudinghe River is the biggest branch located between Hekou Town and Longmen in the middle reaches of the Yellow River. The area of the Wudinghe River basin is 30,261 km^2. The river length is 491.2 km, and the river gradient is 1.97‰. The total area of soil erosion reaches 23,137 km^2, 76.5% of whole basin area. According to geography and soil erosion feature, the basin is divided into three parts: sand, headwaters and loess rolling ravine region. The location of the Wudinghe River basin and the ninety rainfall stations used to capture rainfall spatial variability is shown in Fig. 1. Its digital elevation map is as Fig. 2.

Sand region locates at the north and northwest of the Wudinghe River basin. Its total area is 16,446 km^2, accounting 54.3 % of the whole study area. 8,654.65 km^2 of the sand region area is on Yi Zhaomeng zone of the Mongolia Municipality and the other lies in Yulin zone of Shanxi Province. It is dry and the density of the water net system is some low. The terrain is very flat with elevation ranged from 1,000 m to 1,400 m. There is a large area of desert and a great difference in temperature between day and night in this region.

Headwaters region situates in southwest of the Wudinghe River basin. It covers 3,454 km^2, about 11.4 % of the whole basin area. The regions lies in Yulin zone of Shanxi Province, with elevation changed from 1,100 m to 1,600 m.

Fig. 1 Locations of the rainfall stations

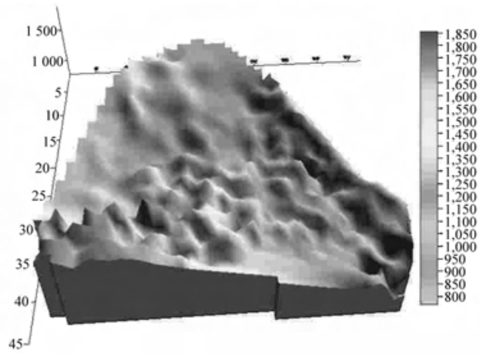


Fig. 2 Map of DEM of Wudinghe River Basin

Loess rolling ravine region stands in southeastward of the Wudinghe River basin. Its area is 10,361 km^2, 34.3% of the whole basin. 9,650 km^2 of the loess rolling ravin region is in Yulin zone and 711 km^2 is in Yanan zone of Shanxi Province. Land surface slope over 25 degree is about 60% of whole basin. And its elevation is varied from 612 m to 1,400 m.

2.2 Statistic indices

There are more than ninety rainfall stations located in the Wudinghe River basin, half of which have been built since 1975. Thiessen polygon method is widely used in precipitation preparation as an input to distributed hydrological model. This study uses it to describe spatial distribution of precipitation and discusses why it is not uniform on the basis of data measured by selected seventy – nine stations from 1980 to 2000.

Standard deviation coefficient C_v and non – uniform indices η, α are used to denote non – uniform degree of precipitation of the basin. Standard deviation coefficient C_v is the ratio of mean square error to mean value of precipitation eigenvalue, which indicates dispersion degree among different average value series. The closer the C_v is to one, the more dispersive the data series is, and vice versa. η is equal to ratio of mean and maximum value of precipitation eigenvalue, which shows reduction relationship between point and surface precipitation. Unlike C_v, the nearer the η is to one, the more uniform it is. α equals to the minimum point precipitation divided by maximum one. It denotes multiple relationships between two extreme values of point precipitation and non – uniform level of precipitation distribution over one basin. Precipitation α is distributed equably when α is equal to one. The greater the α is, the less uniform spatial distribution of precipitation is. They are computed as follows:

$$C_v = \frac{1}{\bar{X}} \sqrt{\frac{\sum (X_i - \bar{X})^2}{n - 1}} \tag{1}$$

$$\eta = \bar{X} / X_{max} \tag{2}$$

$$\alpha = X_{\max} / X_{\min} \tag{3}$$

where: $\bar{X}$ is the basin mean precipitation, mm; $X_{\max}$ is the maximum point precipitation of a basin, mm; $X_{\min}$ is the minimum point precipitation of a basin, mm; n is the number of rainfall station; C_v is the standard deviation coefficient of basin mean precipitation; η and α are two coefficients of basin precipitation non – uniform.

3 Results and discussions

3.1 Spatial distribution of precipitation

It is clear that the spatial variability of precipitation is significant in the Wudinghe River Basin (Table 1). The C_v increases not only with the decrease of η but also with the rise of α. Correlation coefficient between C_v and η is 0.87, but it reaches 0.92 between C_v and α. Rank the spatial variability of precipitation from high to low, sand region ranks first, then loess rolling ravine region and finally headwaters region. α is 1.538 in sand region. Nevertheless, it is only 1.173 in headwaters region. Furthermore, the C_v in headwaters region is the smallest in three regions. Among the three regions, precipitation volume of sand region is the least, especially the northwestward, which is of drought zone. Whereas, there is one rainstorm center in loess rolling ravine and headwaters region separately. Even in loess rolling ravine region, rainstorm with a great intensity and gale usually happens and its duration is very short in summer. In general, precipitation volume of the Wudinghe River basin takes on an obviously descending trend from the southeast to the northwest. There is the least precipitation in its northwest, which is about 250 mm every year. However, its southeast is with higher precipitation, which is about 430 mm every year.

Table 1 Non – uniform statistic indices of spatial distribution of precipitation

Region	C_v	η	α
Sand region	0.118	0.795	1.538
Headwaters region	0.059	0.919	1.173
Loess rolling ravine region	0.103	0.836	1.476
Wudinghe River basin	0.124	0.801	1.731

3.2 Analysis of factors affecting spatial distribution of precipitation

The precipitation data measured by rainfall stations maybe is influenced by the elevation, slope and hydrosphere source where rainfall station is located, so they usually show great difference. Airflow ascending speed is determined by slope wind speed, normal degree between wind direction and windward slope, hillside slope. Consequently, precipitation is also affected. When wind with a great speed and angle between wind direction and windward slope is much bigger, convergence – lifting function of airflow will become great. Then, windward slope is usually turned into rain area and leeward slope goes into rain shadow. When mountain trend is parallel to prevailing airflow or angle between them is very small, precipitation show little difference over two sides of mountain. Slope size can either strengthen or weaken weather elements affecting precipitation and either increase or decrease its loss, as well.

Elevation is degressive from west to east in the Wudinghe River basin with a continental monsoon climate. Precipitation is affected by air mass. Consequently, it is less between winter and spring but more in summer. Precipitation of the basin is weakly correlative with its elevation.

Correlation coefficient between them is 0.35 in headwaters region and 0.2 in sand region and 0.41 in loess rolling ravine region. Precipitation increases with elevation in headwaters region. Nevertheless, it is reverse fully in other two regions (Fig. 3). As Table 2 shows, precipitation is different with same elevation due to its slope or terrain aspect. Namely, precipitation is more in windward slope than in leeward. Because of wind direction, precipitation in northwest, west, north and east slope is less than that in southwest, south, southeast slope. The whole basin is regulated by vapor from Pacific Ocean and Indian Ocean. When southeast monsoon prevails, precipitation in southeast slope is larger than others because warm – damp vapor mass from sea will mainly influence on southeast of the basin and so does southwest direction. With similar slope, precipitation grows up with elevation increasing. Therefore, two rainstorm centers are formed in the whole basin, which are lies in the southwest and southwest.

Table 2 Statistics of terrain feature and annual mean precipitation

Location	Longitude (°)	Latitude (°)	Elevation (m)	Precipitation (mm)	Orientation	Distributed region
Bailangcheng	109.329	37.404	1,157	352.634	East	Headwaters region
Qingyangcha	109.212	37.371	1,289	402.886	Southwest	Headwaters region
Yangkelangwan	109.129	37.254	1,314	368.143	Northeast	Headwaters region
Maotuankulun	108.512	37.604	1,350	350.572	North	Headwaters region
Linwanqituo	108.979	37.287	1,379	345.715	South	Headwaters region
Liujiamao	109.012	37.487	1,407	343.396	East	Headwaters region
Xincheng	108.646	37.271	1,467	381.592	South	Headwaters region
Yanggaoshan	108.546	37.421	1,524	386.963	South	Headwaters region
Tianchiwan	108.879	37.337	1,528	397.381	East	Headwaters region
Hujianshan	108.179	37.237	1,575	372.301	Southeast	Headwaters region

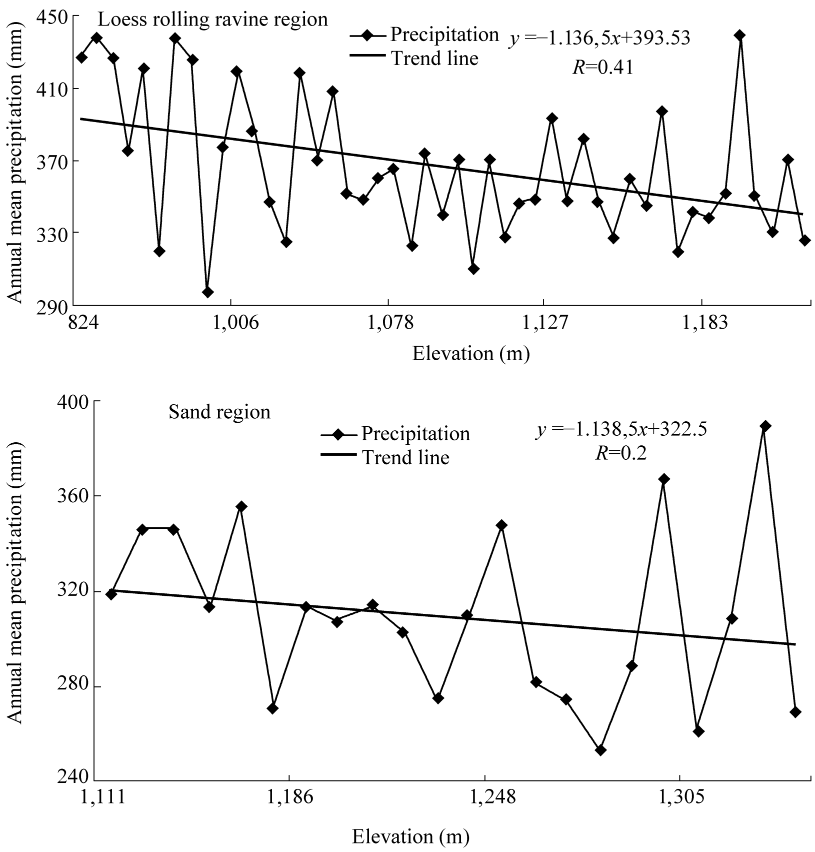
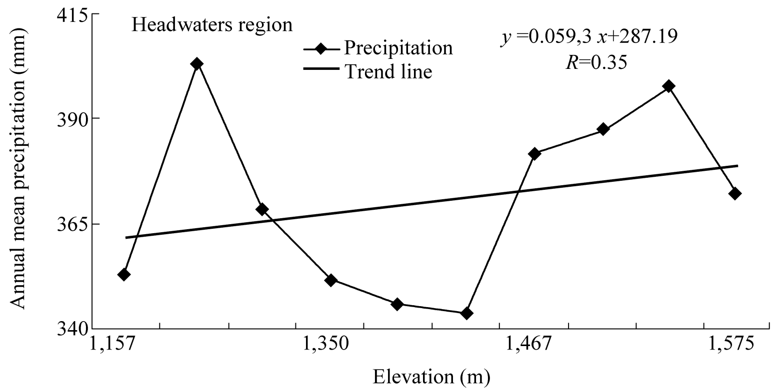


Fig. 3 Correlation between elevation and precipitation at the rainfall stations



Continued to Fig. 3

Taking another for example, the basin spatial variability of precipitation is less significant in the north than in the south of the old Great Wall. It is because that there is a large area of desert and flat terrain in its north but topographic relief is great in its south and it is nearer to sea and prone to be controlled by subtropical anticyclone from the Pacific Ocean and under pressure from the Indian Ocean. Southeast and southwest monsoon prevail over the whole basin, moist sea air mass brings a great deal of vapor and lead precipitation to increase. As a conclusion, spatial distribution of precipitation of the Wudinghe River basin is influenced by meteorologic and terrain factors.

4 Conclusions

Rainfall stations terrain, distance from sea and the basins meteorology impact spatial distribution of precipitation. There is a complex topography in the Wudinghe River basin. In order to study the impact of meterology and terrain on spatial variability of precipitation, the whole basin is divided into three sub – basins. The results show that spatial distribution of precipitation of the Wudinghe River basin is determined by meteorologic and terrain factors. In the same region, precipitation with same elevation is different, due to its slope or terrain aspect. Namely, it is more in windward slope than in leeward. With similar slope, precipitation increases with elevation. In general, spatial distribution of precipitation is very non – uniform in the Wudinghe River basin. Precipitation is more in the southeast than that in the northwest. Maximum point precipitation is 1.73 multiples as much as minimum one. The standard deviation coefficient C_v is 0.124.

In some degree, rainfall stations represent spatial distribution of precipitation, but precipitation data measured by them are not enough to study because their situation and density have some effects on it. So it is necessary to further study description method for basin spatial distribution of precipitation. For example, it will be developed to this way in the future that area rainfall information from radar and remote sense is combined with point rainfall data measured by ground stations in order to capture basin rainfall spatial distribution.

Acknowledgement

This research was supported by China Natural Science Fund Project (No. 40601015).

References

Band, C.. 1991. Forest Ecosystem Processes at the Watershed Scale: Basis for Distributed Simulation. Ecological Modeling, 56:171 – 196.

Basist, A., Bell, G. D., Meentenmeyer, V.. 1994. Statistical Relationships between Topography and Precipitation Patterns[J]. Clim. 7(9):1305 – 1315.

Daly, C., Neilson, R. P., Phillips, D. L.. 1994. A statistical topographic model for mapping climatological precipitation over mountainous terrain[J] Appl. Meteorol,33,2.

Fu Baopu, 1992. Topographic and elevation effects on precipitation[J]. Journal of Geography, 47(4):302 – 314. 2000.

Goovotrtsp Geostatical approaches for incorporating elevation into the spatial interpolation of rainfall [J]. Hydrol. 228:113 – 129.

Goodale, C. L., Alber, J. D.. Ollinger, S. V., 1998. Mapping monthly precipitation, temperature and solar radiation for Ireland with polynomial regression and digital elevation model[J]. Clim. Res. 10,35 – 49.

Kurtzman, D., Kadmon, R.. 1999. Mapping of temperature variables in Israel: a comparison of different interpolation methods[J]. Clim. Res, 13,33 – 43.

Lang Tiangang, Wang Xizhi, Dai Ruolan. 2002. Research of modeling method of normal precipitation spatial variability[J]. Journal of. Northwest Botany, 20(5):856 – 862.

Martinez – Cob, A.. 1996. Multivariate geostatistical analysis of evapotranspiration and precipitation in mountainous terrain[J]. Hydrol, 174(1 ~ 2):19 – 35.

Mitas, L., Mitasova, H.. 1988. General variational approach to the interpolation problem[J]. Comput. Math. Applic. 16 (12):83 ~ 992. Great Britain.

Nalder, I. A., Mein, R. W.. 1998. Spatial interpolation of climate normals test of a new method in the Canadian boreal forest[J]. Agric Meterol. 92:211 – 225.

Ninyerola, M., Pons, X., Roure, J. M.. 2000. A methodological approach of climatological modeling of air temperature and precipitation through GIS techniques[J]. Int. J. Climatol. 20(14):1823 – 1841.

Oliver, M. A., Webster, R., 1990. Kriging: a method of interpolation for geographical information systems[J]. Int. J. Geogr. Inform. Syst. 4(3):313 – 332.

Philip, G. M., Watson, D. F.. 1982. A precise method for determining contoured surfaces. J. Aust. Petrol. Explor. Assoc. 22:202 – 212.

Prodhomme, C., Duncan, W. R.. 1999. Mapping extreme rainfall in a mountainous region using geostatistical techniques: a case study in Scotland. Int. J. Climatol. 19(12):1337 – 1356.

Running, S. W., et al.. 1987. Extrapolation of synoptic meteorological data in mountainous terrain and its use in simulating forest evapotranspiration rate and photo synthese[J]. Canadian Journal of Forest Research, 17:472 – 483.

Sevruk, B.. Nevenic, M.. 1998. The geography and topography effects on the areal Pattern of Precipitation in a small prealpline basin[J]. Wat. Sci. Tech. 37:163 – 170.

Smith, R. B.. 1979. The influence of mountains on the atmosphere[J]. Adv. Geophys. 21: 87 – 230. Academic Press.

Spreen, W. C.. 1947. A determination of the effect of topography upon precipitation. Trans. Am. Geophys. Union[J]. 28:285 – 290.

Weisse, A. K., Bois, P.. 2001. Topographic effects on statistical characteristics of heavy rainfall and map ping in the French Alps[J]. Appl. Meteorol. 40(4):720 – 740.

Wotling, G., Bouvier, Ch., Danloux, J., Fritsch, J. – M.. 2000. Regionalization of extreme precipitation distribution using the principal components of the topographical environment [J]. Hydrol. 233: 86 – 101.

Yang Liwen, Shi Qingfeng. 1997. Wind effects on mountainous precipitation[J]. Hydrology. 6: 44 – 48.

Study on Groundwater Over – withdrawal Reduction in the North China Plain

***Tang Kewang*[1], *Chen Guifang*[2], *Li Yuanyuan*[3], *Hou Jie*[3], *Yao Jianwen*[2], *Tang Yun*[1] and *Nicolò Moschini*[4]**

1. Department of Water Resources, IWHR, Beijing, 100044
2. Planning and Design Management Burean of the South to North Water Transfer Project,Beijing, 100038
3. Department of Water Strategy, GIWP, Beijing, 100038;
4. SGI Studio Galli Ingegneria SpA – Padova Italy

Abstract: Groundwater over – pumping is widespread in the South – North Water Diversion Project's Beneficiary Region and continues for more than twenty years. The great water diversion project will increase water availability of the North China and provide historical opportunities for the solution of severe groundwater over – pumping. Based on the groundwater over – withdrawal reduction planning conducted by the Ministry of Water Resources, groundwater over – pumping status, induced ecological issues, possibility of over – pumping reduction are discussed. Major difficulties for the solution of groundwater over – pumping are analyzed and measures are briefed.

Key words: South – North water diversion, beneficiary region, groundwater over – withdrawal

1 Introduction

The South to North Water Diversion Project (SNWP) is a great strategic water allocation project in China. The objective of the SNWP is to increase water availability to the water scarce North China where urban and agricultural development rely on groundwater over – pumping for over twenty years. After the project implementation, groundwater over – pumping can be pressed and the aquifers can be used for the regulation of water resources.

The SNWP covers 230,000 km^2, including Beijing City, Tianjin City, Hebei, Henan, Shandong and Jiangsu provinces. The average precipitation is 640 mm and the south Henan province shows the highest precipitation being 800 ~ 900 mm and lowest area locates in the Hebei province being only 450 ~ 500 mm. Most (60% to 80%) of the precipitation concentrates in rainy seasons.

The total water resources of the SNWP covering area is 43 billion m^3, its average amount is 288 m^3/capita, which is much lower than the national average value (2,200 m^3). The average amount of Hebei Province is only 144 m^3. Since 1970s, the local water supply exceeded groundwater availability and over – pumping continued for more than 30 years. Land subsidence, seawater intrusion and groundwater quality deterioration occurs widely.

2 Over – pumping Extent

2.1 Shallow Groundwater

In 2003, over – pumped area of shallow groundwater is 57,700 km^2, accounting for 24.75% of the SNWP covering area. Almost all the plain areas of Beijing City and Hebei Province have over – pumping problems. For Hebei Province, saline water is distributed in the eastern plain and west part is largely under over – pumping.

Based on the ratio between actual pumping and availability of shallow groundwater, over – pumping is classified into two scales: moderate and serious. The moderate over – pumped area accounts 57% and the rest is serious over – pumped area.

2.2 Deep confined groundwater

In 2003, over – pumped area of deep confined groundwater reaches 73,700 km^2, being larger than the shallow groundwater and accounts for 31.6% of the SNWP covering area. All the deep groundwater of Tianjin City is under over – pumping. And over half of the total over – pumped extent is located in the Hebei Province.

Moderate over – pumped area of deep groundwater extends 17,200 km^2 and serious overpumped area 56,500 km^2.

3 Groundwater use in the over – pumped region

3.1 Shallow groundwater use

In the shallow groundwater over – pumped area, total groundwater use in 2003 was 13.75 billion m^3, while sustainable pumping amount is 8.14 billion m^3, groundwater over – pumped by 5.61 billion m^3. The over – pumping is mainly distributed in Hebei Province, accounting about two thirds as shown in Table 1. The total shallow well number reaches 790,000.

Table 1 Shallow groundwater uitilization of 2003

Provinces and cities	Use ($10^8 m^3$)	Sustainable ($10^8 m^3$)	Over – pumping ($10^8 m^3$)	Percentage (%)
Beijing	23.00	17.20	5.80	10.34
Tianjin	—	—	—	—
Hebei	74.00	37.00	37.00	65.95
Henan	21.30	12.00	9.30	16.58
Shandong	19.20	15.20	4.00	7.13
Jiangsu	—	—	—	—
Total	137.50	81.40	56.10	100.00

In the total groundwater pumping, urban domestic use was 1.14 billion m^3, and rural domestic use was 0.85 billion m^3, industrial use 1.91 bilion m^3, agriculture 9.85 billion m^3, the percentages are 8.29%, 6.18%, 13.89% and 71.64% respectively. The sector distribution of shallow groundwater use can be shown in Table 2.

Table 2 Sector distribution of shallow groundwater use

Provinces	Urban Dom.		Rural Dom.		Industry		Agriculture		Total ($10^8 m^3$)
	Use ($10^8 m^3$)	Ratio (%)	Use ($10^8 m^3$)	Ratio (%)	Use ($10_8 m^3$)	Ratio (%)	Use ($10^8 m^3$)	Ratio (%)	
Beijing	4.90	21.30	2.30	10.00	4.10	17.83	11.70	50.87	23.00
Tianjin	—	—	—	—	—	—	—	—	—
Hebei	3.90	5.27	3.60	4.86	8.50	11.49	58.00	78.38	74.00
Henan	2.00	9.39	1.40	6.57	3.70	17.37	14.20	66.67	21.30
Shandong	0.60	3.13	1.20	6.25	2.80	14.58	14.60	76.04	19.20
Jiangsu	—	—	—	—	—	—	—	—	—
Total	11.40	8.29	8.50	6.18	19.10	13.89	98.50	71.64	137.50

In general, agriculture is the biggest shallow groundwater user accounting for 71.64% of the total pumping. In Hebei province, agriculture accounts for 78.38% of the total pumping. The percentages of agriculture use in Shandong and Henan provinces are also much higher. Agriculture users can not afford the high water price of the SNWP. Therefore, it is crucial to find other ways for the agriculture groundwater users to reduce pumping.

3.2 Deep groundwater use

From water resources management, deep confined groundwater should be regarded as strategic storage which can be used during dry seasons or years. But the North China has a severe water shortage and deep groundwater has been over – pumped for more than thirty years causing many environmental problems. The six provinces and cities determined the sustainable deep groundwater pumping quantity in a conservative way.

Total deep groundwater pumping in 2003 was 4.27 billion m^3, in which urban domestic use accounts for 7.82%, rural domestic use 9.55%, industry 27.74% and agriculture 54.89%. Agriculture is still the biggest groundwater user. Two thirds of the deep confined groundwater is located in the Hebei Province. The total deep wells reach 130,000 in number.

3.3 Environmental issues reduced by over – pumping

In the SNWP beneficiary area, water shortage is serious and over – pumping of groundwater became inevitable for social and economic growth. However, long and increasingly more serious over – pumping has caused a series of problems constraining the sustainable development of the region.

(1) Land subsidence. Land subsidence primarily occurs in the over – pumped deep confined groundwater distribution areas like Tianjin, Cangzhou, Hengshui, etc. At present, there are 200 land fractures found in the over – pumped area and the greatest land subsidence reached 3 meters. According to related publications, by 1995, land area having over 200 mm subsidence reached 49,400 km^2. Land subsidence has posed a great deal of adverse impacts on flood control, infrastructure and land use.

(2) Wetland disappearance. Wetlands were densely distributed across the Haihe Watershed Plain in 1950s including the Baiyangdian Lake, Hengshui Lake, Qilihai Lake, etc. The wetlands were almost in a natural status covering about 10,000 km^2 in extent.

From 1960s and 1970s, the wetlands started to shrink and many lakes have disappeared up to now. In 1950s, the Baiyangdian Lake extended 3,801 km^2, by the end of last century, the area decreased to 538 km^2, shrinking by more than 80%. Disappearance of the wetlands is closely linked to the surface water utilization increase and groundwater level declining is also a major contributor to the wetlands change.

(3) Seawater intrusion. Due to groundwater level declining along the sea coasts, seawater intrusion occurred in many coastal cities like Dalian, Qinghuangdao, etc. The Liaoning, Hebei and Shandong provinces around the Bohai Bay are the major seawater intrusion affected areas. According to a survey, by 1993, there had been 112 counties or towns affected by seawater intrusion covering 1,434 km^2. The seawater intrusion has posed a great threat to drinking, farmlands and other water use.

4 Water availability analysis for groundwater pumping reduction

Groundwater over – pumping in the North China Plain is primarily due to water shortage. Therefore, it is crucial for groundwater over – pumping reduction to have extra water sources to replace the existing pumping. And the extra water should be used to replace groundwater rather than be used or consumed by new water users.

4.1 Potential water sources

In theory, many kinds of water can be used to replace groundwater pumping like local surface water, recycled water, rain water, sea water and transported water from other sheds. However, for the North China Plain, SNWP provides the most important water source for groundwater pumping reduction including direct and indirect replacement. The direct replacement water means water which will be supplied to the groundwater users by South – North Water Diversion Project, the indirect replacement water is the additional recycled water. In addition, salted water and treated seawater are the other replacement water which amount is very small.

Only the beneficiary areas of the east and middle projects (Phase I) of SNWP were taken into account for groundwater over – withdrawal.

4.2 Water quantity available

The SNWP (Phase I) will significantly increase water availability in urban and rural areas of the over – pumped plains and the urban water diverted by the SNWP may go into three ways: the first part can be used for direct replacement of the existing groundwater use in urban areas, the second part is used by urban users and original surface water use returned to rural areas which have the water rights and the last part is used to meet the growing demand and increased recycled water can become potential water for groundwater pumping reduction.

Based on water demand and supply scenarios of the six provinces, in the recent planning level year (2010), little water is available for groundwater over – pumping reduction before the SNWP implementation. In the medium year (2015) when water diverted by the SNWP can be available, there will be 4.81 billion m^3 of water for replacement of over – pumped groundwater and in the long run term (2020) water available for groundwater restoration can be increased to 5.86 billion m^3 as shown in Table 3.

Table 3 Water Availability of Six Provinces for Groundwater Over – pumping Replacement **Unit: 10^8 m^3**

Provinces	Near term(2010)	Medium term(2015)	Long term(2020)
Beijing	1.25	5.04	4.13
Tianjin	0	1.12	3.05
Hebei	6.40	27.21	33.40
Henan	0	8.78	9.96
Shandong	0.01	4.93	6.89
Jiangsu	0.72	1.00	1.21
Total	8.38	48.08	58.64

In urban areas, over 95% of the replacement depends on the SNWP and in rural areas, groundwater over – pumping replacement relies on various water sources including the SNWP, local surface water, recycled water and the like. It is evident that compared with 9.2 billion m^3 annual over – pumping, the Phase I SNWP can not provide adequate water for balance of over – pumped groundwater.

5 Groundwater pumping reduction quantity

Based on water availability analysis and demand/supply analysis, groundwater over – pumping reduction was planned for different level years as shown in Table 4.

Table 4 Groundwater pumping reduction planned for various periods

Provinces	Over pumping (10^8 m^3)	Reduced(10^8 m^3)			Percents(%)			Over-pumping Left (10^8 m^3)	Provincial distribution (%)
		2010	2015	2020	2010	2015	2020		
Beijing	5.80	1.20	6.50	5.00	20.69	100.00	86.21	0.80	2.55
Tianjin	1.75	0	1.12	3.05	0	64.04	100.00	0	0
Hebei	61.31	3.37	27.18	33.40	5.49	44.33	54.47	27.91	89.05
Henan	16.30	0	10.01	11.44	0	61.38	70.17	4.86	15.51
Shandong	6.43	0.01	4.93	6.89	0.16	76.65	100.00	0	0
Jiangsu	0.72	0.72	0.95	1.19	100.00	100.00	100.00	0	0
Total	92.31	5.30	50.69	60.97	5.74	54.91	66.04	31.34	100.00

It is evident from Table 4 that by 2020 over-pumping still exists in the North China Plain. Groundwater pumping will be reduced by 6.1 billion m^3 and there is still 34% of the over-pumping left. And 89% of the residue over-pumping is located in Hebei Province.

The over-pumping in urban areas can be reduced completely and the remaining over-pumping is mostly located in the rural areas.

After the implementation of the SNWP, the over-pumping of groundwater will be greatly reduced and groundwater will face historical opportunities for restoration. After the project getting into effect, current over-exploration will be cut by 66% in the long term (2020). In urban areas, groundwater sustainability will be greatly improved and restoration can be expected for Beijing, Tianjin and Jiangsu province with groundwater level recovering to a certain level.

Agriculture is the biggest groundwater user. 71.64% and 54.89% of the shallow and deep confined groundwater pumping is used for the agriculture. Under constraints of replacing water sources and water prices, it is much challenging for rural areas to press groundwater over-pumping. It is crucial for groundwater sustainable recovery to take agricultural water saving and water availability into account as a policy priority.

6 Some key issues

6.1 Measures for agriculture groundwater users and artificial recharge

The survey of groundwater use shows that agriculture is the biggest groundwater pumping sector and agriculture can not afford to pay the high water price of the SNWP. Even though returned surface water resources, recycled water and other water sources are planning for the rural areas, there is still a great deal of over-pumping expected in the long term.

In order to solve the tension of groundwater over-pumping in rural areas, some integrated measures need to be worked out. For instance, in rainy seasons or years, the SNWP can provide some free or cheap water for agriculture and ecosystems. Groundwater artificial recharge should be also studied for its feasibility and pilots need to be set up to show the effects of the efforts. And some efforts should be paid for agriculture water saving, especially water saving can be realized through the adjusting agricultural structure.

6.2 Integrated water management to maximize the benefit

According to the Master Planning of the SNWP, it is a strategic project aiming at the solution to the ecosystem degradation and groundwater over – pumping. But present policy mainly focuses on the cost recovery and little attention is given to the ecological service. And no adequate study is done to put forward a systematic temporal and spatial water regulation and allocation schemes to maximize the benefits of the project. It is indispensable to set up a systematic policy framework to maximize the benefits of the great project. For instance, similar to agricultural water use, systematic policies for water price, supplying cost and economy analysis of ecological water use should be set up.

Transboundary Water Resources Management in Africa

Luke ONYEKAKEYAH

Guardian Newspapers, Editorial Board, Isolo Lagos PMB 1217 Oshodi, Lagos Nigeria

Abstract: Concern that the per capita availability of freshwater in Africa has declined significantly in the last three decades led us to investigate what extent management action have been employed to ensure sustainable use of shared water resources. In an attempt to meet increasing national demand for water, some countries sharing common waters have in recent times been involved in conflict. Water resources – sharing among riparian states is tending to become a potential source of regional tension as evidenced in the Nile River and between Nigeria and Cameroon over the Bakassi Peninsula. This trend has the potential to explode into open armed conflict as available evidence indicates that most water systems in Africa are stressed.

The task was to obtain and examine empirical information and assess relevant case study and references from accessible documentation and expert contacts pertinent to the issue of shared water resources. The study focused on the Zambezi River as case study based on the following criteria:

(1) The Zambezi flows through the drought – prone Southern Africa sub – region, traversing 8 countries, where water is considered a critical resource that underlies all problems encountered in socio – economic development.

(2) The Zambezi is one of the most developed drainage basins in Africa, thus, much can be learned from the management actions applied.

(3) The river serves an estimated dependent population of more than 7 million people. This being one of the largest in Africa shows its critical importance.

(4) The Zambezi is top on the Southern African Development Community (SADC) agenda for water resources development in the sub – region.

2 countries, Zambia and Zimbabwe were visited out of the 8 countries sharing the watercourse where interviews were conducted. Questionnaires were sent to selected expert contacts in all the countries in order to obtain country specific data. Information was further sought from literature survey of published materials and documentation. Based on the information gathered and analysed, the major freshwater sources in Africa are under stress arising from several factors which include drought, soil erosion and sedimentation, rapid population growth, industrial pollution, commercial agriculture, mining activities and hydro – power development. Management actions have been initiated at community, national and international levels to address the problem. To ensure sustainability, we proposed some options and made recommendations to direct the course of management action.

Key words: transboundary, water resources, Africa, Zambezi River

1 Introduction

There are 54 transboundary drainage systems in Africa, which are shared by more than one country. Some of these are the Rivers Nile, Niger, Congo, Senegal, Orange, Limpopo and Zambezi. Some of these rivers traverse 8 countries thereby making them shared resources that require international cooperation to manage. These shared water resources, while serving the needs of the populations across international boundaries often constitute major source of conflict among the user nations. This underscores the need to study these international waters by assessing their uses, abuses, conflicts and to what extent international cooperation has been applied in their management. This paper is an attempt at making such an assessment on the management of transboundary water systems in Africa.

Africa has mean annual rainfall of about 670 mm. There are great regional disparities caused by climatic factors of wind system and pressure. The heaviest rainfall occurs along the equatorial belt, especially, in the Niger Delta and the Congo Basin. Along the West Coast of Sierra Leone, Liberia and Madagascar, the annual total exceeds 2,000 mm at 18°N, with a range of 1,000 mm along the Mediterranean coast of Morocco, Algeria and Tunisia.

South of the Equator, rainfall distribution is more complex. For example, there is a north south decrease between the Equator and the tropic of Capricorn, whereas, further south, there is an east – west decrease. The humid tropics generally receive more rainfall throughout the year, whereas, in the sub – tropic semi – arid regions, there is marked rainfall seasonality and frequent droughts. The variability of rainfall is more than 40 per cent in the deserts but less than 15 per cent over the tropics. Thus, the deserts are dry and water is deficient all the year round.

The climatic variability affects the runoff characteristics of Africa. There is abundant runoff in the tropical West and Central Africa sub – region. Comparatively, the overall runoff of the continent is lower than that of North and Central America, which have a land area of only 80 per cent that of Africa. The high evaporation rate of about 570 mm/year reduces the effectiveness of rainfall and leads to marked seasonality in the river regime.

According to Endersen and Myhrstad (1987), the total river runoff amount to 4.2×10^{12} m^3/year, and the total stable runoff is about 2.1×10^{12} m^3/year. The Congo Basin alone has more than 50 percent of the total river runoff. Africa withdraws about 3 percent of its annual river flow. However, the continent requires only 0.5 ~ 1 percent of the stable runoff, or a maximum of 1.06×10^{10} m^3/year to adequately supply its population. The main characteristic of the runoff is seasonality. This affects the utilization of the water resources and the methods employed in management.

2 Purpose and scope of the study

Worldwide, water has become a critical issue of concern. In Africa, the problem of water availability both in quantity and quality has become most critical. About a decade ago, the amount of water in the rivers and streams catered for the population. But the time is rapidly coming when there will be too little water for everyone to utilize (Onyekakeyah, 1996). Against the backdrop of the emerging scenario, this investigation was carried out with the following objectives in mind:

(1) To assess the resource value of international water systems in Africa with particular reference to the Zambezi River.

(2) To identify the factors affecting water resources development.

(3) To evaluate past, on – going and future action programmes designed to improve water resources utilization.

(4) To propose options and make recommendationsfor managing international water systems in Africa. This study, it is hoped would be useful to stakeholders involved in policy making in relation to the issues bordering on the use of international waters in reaching more rational decisions that would enhance the formulation of appropriate action programmes on water management.

Albeit, there are several international drainage systems in Africa, this study focused on the Zambezi River based on the following criteria:

(1) The Zambezi River is the fourth largest drainage system in Africa. It flows through the drought – prone southern Africa sub – region where water is considered as a critical resource that underlies all problems encountered in socio – economic development of the region.

(2) The Zambezi River is one of the most developed drainage basins in Africa, hence, much could be learnt from it in this regard.

(3) The Zambezi River serves an estimated dependent population of more than 7,250,000 people. This being one of the largest in Africa shows its importance.

(4) The Zambezi River is top on the Southern African Development community (SADC) agenda for water resources development in the sub – region.

The study addressed issues, which were posed in terms of the following questions:

①What constitutes the resource value of the Zambezi River? ② What factors affect the development of the water resources? ③ To what extent have action programmes initiated at international level enhanced the development of the river system? ④What could be done to enhance the optimal use of the waters?

These issues formed the task of this study, which explored the management issues affecting transboundary freshwater resources in Africa. Water resources – sharing among riparian states is tending to become a hot – spot for international tension and conflict as evidenced in the Nile River system and between Nigeria and Cameroon over the Bakassi Peninsula. Available evidence indicates that most water systems in Africa are stressed, meaning that the capacity of the waters to continue providing adequate water supply in quantity and quality is threatened. This trend has the potential to cause tension and could explode into open armed conflict unless urgent solutions are sought. It is therefore important to give such a critical issue much attention by way of in – depth study and or political understanding.

3 The Zambezi River system

The Zambezi River is a major drainage system in Southern Africa. It flows from the Central African Plateau in northwest Zambia through Zimbabwe and empties into the Mozambique Channel. Thus, it traverses 8 countries, namely: Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe, with a total length of about 2,560 km. 2 other large rivers namely: Kafue and Luangwa belong to the Zambezi drainage catchment area and flow from north to south. The alluvial plains of the Zambezi drainage system, with an altitude of about 300 m are among the lowest – lying parts of the region. Table 1 shows the major water systems of Southern Africa.

Table 1 Major drainage systems in Southern Africa

Water systems	Countries sharing	Est. dependent population
Zambezi	Angola, Botswana, Malawi, Mozambique Namibia, Tanzania, Zambia, Zimbabwe	7,250,000
Save	Mozambique, Zimbabwe	5,250,000
Limpopo	Botswana, Mozambique, Zimbabwe	5,485,257
Kafue	Zambia	2,000,000
Okavango	Botswana	235,257
Luapula	Zambia	2,000,000
Orange	Lesotho, South Africa	1,625,000
Kariba	Zambia, Zimbabwe	4,250,000
Tanganyika	Tanzania, Zimbabwe	6,250,000

Source: Onyekakeyah, 1996.

Most of Southern Africa lies in a drought – prone region, which experience drought conditions caused by prolonged absence of rainfall in both time and space. Thus, water is considered as a critical resource in the sub – region. Improved water management holds the key to development in several sectors of the region economy and could make positive impact on economic activity, quality of life and sustainability. The Zambezi River system could be particularly valuable for such development in the region.

4 Design and method of data collection

A two – week study visit was made to Zambia and Zimbabwe, two of the countries sharing the Zambezi River. The Zambezi River Authority has its headquarters in Lusaka, Zambia. The aim was to obtain detailed data on the management of the Zambezi River in particular and water resources of the region in general. The following institutions were visited:

- Department of Water Affairs (DWA), Lusaka, Zambia;
- Community Management and Monitoring Unit (CMMU – DWA), Lusaka;
- Human Settlements of Zambia (HUZA), Lusaka;
- Wildlife Society of Zambia, Lusaka;
- Department of Water Resources and Development, Harare, Zimbabwe; and
- Zimbabwe Environment Research Organization (ZERO), Harare.

These contacts yielded published information from water authorities, government departments as well as NGOs. Questionnaires were administered to identify expert contacts. Respondents were required to fill in pre – coded questions. This method yielded first hand information on the subject of investigation.

Information was further sought from public libraries in the two countries. The materials were reviewed and analysed to complement field data gathered from interview and consultations with civil servants, experts, academics and NGO officials. All the data collected were systematically analysed and they formed the basis of our conclusions in this paper.

5 Management Actions

5.1 Community responses

2 case studies, one from Zambia and the other from Zimbabwe were reviewed to illustrate community actions in water resources management. Being community self – help initiatives, they show how the local people assume responsibility outside official bureaucracies to provide water for themselves.

5.1.1 Kanyama water project (Zambia)

Kanyama community is a squatter settlement within Lusaka. Prior to initiating the water project in 1988, residents of the area obtained water from hand dug wells. Later on, they felt the need to have pipe – borne water supply. As a result, they approached the Lusaka City Council with a proposal to this effect but the Council had no funds to support the project. Consequently, the Human Settlements of Zambia (HUZA) an NGO, took up the challenge because Kanyama was an area that needed upgrading (Chitondo, 1991). WaterAid – UK provided the required funds through HUZA. The project was started in 1987 and was completed in 1989.

The project planning was done jointly by the community leaders of Kanyama, HUZA staff and personnel from the Lusaka Urban District Council. Implementation was carried out entirely by the community, with HUZA playing only a facilitating role. HUZA also provided the community with guidelines for guarding and maintaining the project. Other actors in the project were the Zambia Electricity Corporation, which installed the transformer and the Lusaka Water and Sewage Company, which took over the maintenance. The completion of the project provided a permanent solution to the problem of water supply in the area as the community now enjoys regular water supply.

5.1.2 Chivoteso water project (Zimbabwe)

The Chivoteso project dates back to 1984 when the community of Seke decided to embark on a water project as part of a large vegetable – growing project. The objective was to provide enough water for domestic consumption and for watering gardens and fruit trees that were intended to generate income (Mashongamhende, 1991). The project was initiated by the Association of Women Clubs (AWC). In 1987, the association received assistance from Africare and Environment Liaison Centre International (ELCI), which enabled the women to sink a well and installed a hand pump. The women accomplished the implementation, with technical assistance was from AWC staff. The project was successfully completed in 1987. The well has made it possible for project members to grow vegetables intensively all the year round and raise income and living standards.

5.2 National responses

5.2.1 Government effort to improve water sector performance (Zambia)

Recognising the need to achieve long – term improvements in the performance of the water sector and improve its attractiveness to foreign investments, the Zambian Government in 1993 set up an inter – ministerial committee ? Programme Coordination Unit (PCU). The PCU comprises all institutions involved in the provision of water and sanitation services (Chiwala, 1994). The PCU is a policy making body that targets the entire water sector. Its main objective is to advise the government on the re – organisation of the water supply and sanitation sector. Its tasks include:

- Recommending policy reforms for the water supply and sanitation sector;
- Defining the responsibilities of ministries andorganisations in the water supply and sanitationsector;
- Determining and recommending necessary reforms and re – organisation of the entire water sector;
- Proposing the creation of a framework for planning, development and maintenance of infrastructures in the water supply and sanitation sector;
- Encouraging and optimizing donor support; and
- Proposing reforms to strengthen various institutions with responsibilities in the water supply and sanitation sector.

The PCU, through its executive arm the Water Sector Development Group (WSDG), produced a policy document on water sector re – organisation, which was sent to the parliament for approval. Future proposals for the water sector are:

- Transforming the PCU into the National Water and Sanitation Council; and
- Creation of council – owned regional companies to assist in the delivery of water to peri – urban areas, in collaboration with the Ministry of Local Government and Housing.

The Zambian policy initiative represents a proactive step. It has the potential of improving water supply and sanitation services, as well as addresses other issues in the water sector. However, the approach adopted by the government to carry out such far – reaching reforms lacks public participation. The PCU failed to consider grassroots concerns to technical expertise in the development of such an important water plan.

5.2.2 Institutional arrangement for water management (Zimbabwe)

There are 2 authorities responsible for the provision of water in Zimbabwe. These are the Department of Water Development (DWD), and the District Development Fund (DDF), in the Ministry of Local Government, Rural and Urban Development. DWD is in charge of the construction of small and medium – scale dams and deep wells. Shallow wells are under the jurisdiction of the Ministry of Health and Child Welfare. Both DWD and DDF undertake the siting and sinking of boreholes in designated areas; however, maintenance is done by the DDF. According to Grizic (1980), the annual surface water flow available for use in Zimbabwe is 80 ~ 109 m^3. If this quantity were fully utilised, it would suffice for a population two to three times greater than that of 1990, even allowing for a doubling in per capita consumption.

Thus, the total hypothetical availability should not become a serious constraint for at least 30 years, by which time improved pumping technology, re – purification of urban water, and more economic irrigation methods would have become more widely used.

5.3 Regional responses

There are several identified water resource projects in the Southern Africa sub – region. These projects include: Zambezi River Authority (ZRA), Zambezi River Action Plan (ZACPLAN), Regional Hydrological assessment Project, HYCOS – SADC, Regional Hydroelectric Hydrological Programme (SADC Project), Water Resources Planning for SADC, SARP Region Water Sector Assessment, Southern Africa Friend Project and Rational for Water Sector Capacity Assistance. 2 of these projects focusing on the Zambezi are reviewed in the following sections.

5.3.1 Zambezi River Authority (ZRA)

The Zambezi River Authority (ZRA) is a bilateral cooperation between Zambia and Zimbabwe. The authority was originally established more than 40 years ago as an electricity institution. It mission is to effectively manage and develop in integrated and sustainable manner, the water resources of the common Zambezi River and the Kariba Dam Complex for power generation and other uses to the total satisfaction of all stakeholders.

In 1986, the Zambezi River Act was formally established. The authority was set up to generate power for the countries and probably for export to the neigbouring states. As a result, the activities of the body have centered on damming the Zambezi, more for electricity supply, water supply and irrigation. At present, the Zambezi has multiple dams, which include Kariba Dam (world's largest man – made reservoir), and Batoka George Dam, which is a contentious project. There is also the Victoria Falls, which is the world largest sheet of falling water. The falls drop some 90 m across a width of 1.7 km. Together with the adjoining national parks, Victoria Falls has been nominated jointly by Zambia and Zimbabwe as a World Heritage Site.

As a general rule, damming of major watercourses in Africa has taken place with minimal international and regional cooperation, and hence, with little attention given to either downstream or upstream impacts (Stiles, 1996). Effort however is being made to reverse this historic tendency and instead adopt a multinational planning system to improve efficiency and minimize the negative impacts of water use in riverbasins. Like similar inter – governmental institutions, the ZRA is faced with some pressing problems. Unilateral actions by some riparian states to maximize their use of the waters negate the principle of international cooperation. For example, Zimbabwe plan to divert the waters of the Zambezi for use in her arid western part is likely to face strong opposition from the countries of the sub – region. Moreover, there are reports that South Africa, which is not a member state of the Zambezi riparian states, is also planning to pipe water from the river, in her effort to explore alternative sources of water supply (Nyirongo, Pers. Comm). These and similar pressing issues need to be tackled by the ZRA.

The management of shared water resources within theframework of a river basin naturally involves political diplomacy. Experience shows that quite often, political interests invariably take precedence over economics. At present, the ZRA is a bilateral institution established by Zambia and Zimbabwe, with the exclusion of Angola, Malawi, Botswana, and Mozambique, which are also riparian states of the Zambezi Basin. One therefore wonders how policy decisions made by ZRA would be acceptable to the non – member states of the body. In order to make ZRA more regionally based, it is important that all the riparian states of the riverbasin should be admitted into the management institution. This would make the establishment more broad – based, and prevent unnecessary tension and conflicts over the utilization of the watercourse.

5.3.2 Zambezi River Action Plan (ZACPLAN)

In 1992, the treaty establishing the Southern African Development Community (SADC) came into force. Prior to this period, a major political challenge facing the countries was how to manage the international watercourse in an integrated manner, so as to prevent conflicting interests. Integrated management comprises all the tasks required to provide water of acceptable quantity and quality to satisfy the needs of user – sectors in an environmentally and economically sustainable manner. This approach is considered to ensure optimal utilisation of water resources for economic and social development. Against this background, various regional water resource action programmes have been mapped out under the framework of SADC. One of these action programmes is the ZACPLAN.

The overall goal of the ZACPLAN is to ensure that shared water resources of the Zambezi River are used in a manner that guarantees maximum long – term benefits to all the member states. This plan is most relevant in view of the fact that there is presently no broad – based institutional arrangement that involves all the riparian states of the Zambezi where mutually beneficial management issues could be discussed. The ZACPLAN, which was adopted by SADC in 1987, consists of 19 projects (ZACPROS). Category 1 projects were selected for immediate implementation as a matter of priority. 8 such projects were elaborated and presented for funding in 1989. The specific objectives and targets of ZACPROS are:

- To create an inventory of existing and potential development projects, evaluate the environmental impacts of major projects and initiate basin – wide information exchange;
- To develop regional legislation necessary for the management of the Zambezi, and minimum national legislation required by the riparian states for enforcement; to develop basin – wide unified monitoring system related to water quality and quantity;
- To develop an integrated water resource management plan for the Zambezi River Basin, create a relevant water quality and quantity database and review all sectors that benefit from or affect water resource development projects;
- To develop and adopt management simulation model, simulate the various development scenarios in the basin area and present integrated water resource management plan.

The SADC Environment and Land Management Sector (ELMS) was entrusted with the execution and coordination of the programme, assisted by a committee representing all member states. This later became the ELMS Water Resources Committee, responsible for advising ELMS on regional water resources issues. However, in 1996, SADC formally established the Water Sector and assigned its coordination to the Kingdom of Lesotho.

The Sector's vision is to attain the sustainable, integrated planning, development, utilisation and management of water resources that contribute to the attainment of SADC's overall objective of an integrated regional economy on the basis of balance, equity and mutual benefits for all the member states. As a result of this re – organisation, the programmes, projects, equipment and staff have been transferred to the newly established Sector.

The ZACPLAN constitutes a pragmatic action plan that has the capacity to revolutionise the management of the shared water resources in the region. Thus, to further strengthen the existing action programmes and pool regional resoures together, SADC has developed a Protocol on Shared Watercourse Systems. The Protocol provides a framework for the sharing of water resources in an equitable manner. Article 3 of the Protocol calls for the establishment and strengthening of Shared River Commissions as the institutions is directly responsible for the sustainable management of the integrated water resources in the region. The Protocol has so far been ratified by 11 member states, including Botswana, Lesotho, Mauritius, Malawi, South Africa and Swaziland. The signing and ratification of the Protocol are important milestones in the recognition of the need for a joint management and development of water resources in the SADC region to achieve economic integration.

It must be pointed out that in order for these efforts to succeed, the frameworks must safeguard against political interests. Furthermore, it is important that the authorities concerned should examine the possibility of integrating the ZACPROS into the already existing ZRA's action programmes. This is to avoid unnecessary duplication of efforts; pool limited resources together and evolve integrated river basin management. Considering the spate of re – organisation and coordinated action taking place among the countries, it is hoped that the mandate of SADC's Water Sector would be achieved.

6 Factors affecting water resources development

The following are the constraints affecting water resources development in the Southern Africa sub – region:

- Drought;
- Soil erosion and sedimentation;
- Rapid population growth;
- Industrial pollution;
- Commercial agriculture;

- Hydropower development;
- Mining activities.

7 Options and recommendations for the future

The following are the alternative strategies that would enhance management of the Zambezi River basin:

- Watershed protection;
- Conflict resolution;
- Demand management;
- Alternative sources of water supply;
- Pollution control;
- Human resource development;
- Hydrological data bank development;
- Institutional building;
- Legislation.

8 Conclusions

Based on the information gathered and analysed, it is certain that Africa is faced with critical watersupply problems. Apart from the physical and human constraints, none adoption of broad – based management strategy appears to be the major problem. The current and projected water demand is on the increase and there are calls for action from all stakeholders.

Recent developments in the water sector at local, national and regional levels however indicate a changing attitude by the authorities. Several actions are being proposed, others are ongoing and some have been completed. The Zambezi River Action programmes under SADC's Water Sector illustrate efforts at evolving new strategy at sub – regional level. The ultimate goal of the SADC Water Sector should be tomobilise resources for the projects and to develop comprehensive framework for integrated water resources development. Special emphasis should be placed on theparticipation of the local people and NGOs in the implementation of the proposed programmes. It is expected that with concerted effort and cooperation from all stakeholders, Africa would be able to harness her abundant water resources for improved livelihood and enhanced socio – economic development.

References

Chitondo, E. M. (1991). Human Settlements of Zambia and integrated water projects, Community Participation and Water Supply, AWN, Nairobi, 83 – 85.

Chiwala, B. (1994), Reorganization and institutional development in the water and sanitation sector, Paper presented at DWA/IRC Workshop, July, 1994.

Endersen, S. et al. (1987). Multinational water schemes, Proceedings Intl. Water Symposium on Drought and Famine, July, Olympic, London.

Grizic, P. M. (1980). Water the vital resource, Zimbabwe Science News, Vol. 14 (12), 297 – 298.

Mashongamhende, R. Y. (1994). The Association of Women Clubs and water supply in Zimbabwe, Community Participation and Water Supply, AWN, Nairobi, 92 – 95.

Onyekakeyah, L. O. (1996), Strain, water demand and supply directions in the most stressed water systems of Southern Africa except South Africa and Namibia, Water Management in Africa and the Middle East Challenges and Opportunities, IDRC, Ottawa, 203 – 224.

Stiles, G. (1996), Demand – side management, conservation and efficiency in the use of Africa water resources, Water management in Africa and the Middle East Challenges and Opportunities, IDRC, Ottawa, 3 – 38.

Planning in the Nile River Basin: A Regional Approach

Seifeldin H. Abdalla

Ministry of Irrigation and Water Resources, Sudan

Abstract: This paper examines a variety of approaches to the issue of planning in the Nile river basin with a special reference to the model of The Permanent Joint Technical Commission of the Nile Waters between Sudan and Egypt (PJTC) and experiences from eleven Sub – Saharan African (SSA) River Basin Organizations. The paper also highlights the complexity of regional planning taking into consideration the River Nile unique situation. Furthermore the study stresses the need for a regional planning approach, and suggests the appropriate tools to achieve it.

Key words: Nile, planning of river basin, regional approach

Regional river basin cooperation is now recognized as perhaps the major water resources issue for the 21st Century, and better river basin planning and management is one of the primary challenges now facing the riparian countries. During the coming decades, this will require constructive attention and action by leaders, politicians, and technical specialists alike if the issue of regional cooperation in water resources is to be resolved.

Efficient river basin planning and management must be comprehensive and is far more complex than building dams and control structures. It depends on the integration of the whole range of political, social, environmental and technical functions such as hydropower, irrigation, flood control, navigation, recreation, municipal and industrial water supply and water quality, and also depends on institutional functions such as management, financing, water pricing, cost recovery, water use and allocation, and social impacts.

Regional river basin planning is very different depending on the situation and the countries involved. Because of its importance for overall water resources management and strategy at the national, regional and international level, regional river basin planning is considered for this study.

This study will be devoted largely to suggesting various approaches and considerations for the regional planning process in the Nile basin with experiences from The Permanent Joint Technical Commission of the Nile Waters between Sudan and Egypt and eleven Sub – Saharan African River Basin Organizations[1] (SSA).

1 Introduction

At the end of colonial era, there was a growing thinking in African countries about the substantive, engineering, scientific, economic and institutional questions that are necessary and related to any planning of the rivers shared by one or more countries. There are numbers of models and principles that deal with legal – institutional aspects and analysis, and unfortunately very few about engineering, scientific, and economic aspects dealing with regional river planning and uses. In the last decades, experiences dictated the importance of formulating principles on the non – navigational uses of regional rivers or watercourses and suggested a recognized need for practical and regional cooperative frameworks of cooperation. The framework of cooperation should take into account the corresponding rights, needs, plans and uses of the other co – riparians, through the optimum use of water and adopting the appropriate legal and administrative principles that must

---

[1] Lake Chad Basin Commission, Ndjamena – LCBC; Niger Basin Authority, Niame – NBA; Organisation pour la Mise en Valeur du Fleuve Senegal, Dakar – OMVS; Oganisation pour la Mise en Valeur du Fleuve Gambie, Dakar – OMVG; Kagera Basin Organiztion, Kigali – KBO; Energie des Grands Lacs, Bujumbura – EGL and its parent organisation Commuaute' Economique des Pays des Grands Lacs – CEPGL; Environment and Land Management Unit, Maseru (responsible for Surface Water Affairs within SADC) – SADC/ELMU; Zambezi Action Plan co – ordinating unit at ZESCO; (the Zambia Electricity Supply Commission); Lusaka – SADC/ZACPLAN unit; Lesotho Highlands Development Authority, Maseru – LHDA; Zambezi River Authority, Lusaka – ZRA; Department of Water Affairs, Pretoria – DWA.

enlighten the behavior of countries sharing a regional river.

In the development of the legal – institutional framework of the Nile basin, particular basin experiences of the different international basins and the interaction between sovereignty – ownership concepts, have to be taken into consideration. In addition, the framework, should also consider development plans and the optimum use and development ideas of the developing riparian countries.

There is a clear interaction between the legal – institutional, engineering, economic and other aspects but the political aspects remain the backbone of analysis to attain a sustainable form of regional cooperation.

The severe drought stroke the Nile basin territory during the eighties due to climatic changes resulted in low precipitation coupled with the desertification and high population growth of the area, jeopardized the supply and integrity of fresh water at the basin countries and stressed the need for regional planning and cooperation. In recent years, there is a growing debate on water issues in the Nile Basin countries, not only because of the 80's drought nightmare that limited food production in the Nile Basin but also because of the ambitious development plans to boost food production and depend on irrigated agriculture rather than the fragile rain – fed agriculture. Indeed, this particular problem of more water needed for irrigation is likely to replicate itself almost every where that irrigation water is needed for poverty alleviation, food security, peace and development, and moves forward to dictate regional planning and cooperation.

The Nile basin has to be considered as a single integrated ecosystem where the interaction of water, air, land use and man has effects that are not only to be experienced within a given country (riparian) or the people living within that country, but also by the people and countries elsewhere in the basin. Hence from this regional perspective, any hazard on the ecosystem at one riparian country will have an effect on the well – being of the other riparian countries as a whole. Taking this into account, the Nile basin planning must consider the evolution of methods and principles to encourage the optimum exploitation of the basin systems by co – riparians, within some equitable framework. In addition, a pragmatic defensive concept that limits or prevents the negative impacts on downstream riparian countries must be matched with the positive exploitation of the upstream use of water resources.

2 Current issues and challenges in the Nile Basin Planning

From the earliest times, the Nile basin communities have understood the importance of water to sustain life, food, transportation and recreation. But the modern – day use of the increased population in the Nile valley coupled with the recurrent drought events have raised the water issue to the surface. Consequently, the term regional planning of water resources entered as a relatively new name to attain a certain regional destination or target through a specific national or regional goal. Under this philosophy, all shared water resources should be subjected to some discipline by the communities or states. The more scarcely the water (during drought times or elsewhere), the more urgent or vital the role of the riparians to plan, cooperate and manage that resource. With governments behaving individually according to their ambitious national water resources development plans, it was logical that states should begin to consider the optimum uses of water and avoid wastage, spoilage or general misuse. And to satisfy these, pragmatic plans to consider means, objectives, time – tables, and speculate on future needs, options and threats and from these speculations, plan programs of actions.

During recent years, the Nile Basin have undergone a rise in public awareness on the use and development of water resources as water is realized later as a limited resource and has to supply all riparian countries and withstand all the threats of its quality and time frame quantity and distribution. Consequently some concepts about principals of regional planning or regional water management have evolved. Regional planning of water resources have to be based on the geophysical facts as well as the social needs and the importance to think, rationalize, and plan, regionally.

With the increased awareness on the horizon, some legitimate questions of the regional uses to which water as a regional shared resource should be put, and how best to protect it from the negative impacts and results of those uses. The question of regional uses and impacts of a scarce resource, and proper system management against the adverse effects of such uses, required knowledge, deliberation, co – operation, regional thinking and planning.

The word "regional planning" should be considered as a dynamic rather than a static concept. Many factors enter the regional planning process; the time – scale, the recent and future economic environment, demographic considerations, political regimes and attitudes, institutional systems and the nature of the varied resource along the riparians in quantity, distribution and time scale.

The regional planning of water resources is now being a social necessity taking into consideration the scarcity of the resource and its vital importance as it is widely used for different purposes. It is of – course, intrinsically difficult because more than one planner is involved. The regional planning involves two or more political processes, two or more cultures and economic systems, which should be harmonized; two or more nations must share a common perspective, normally from two different vantages: upstream or downstream, more or less affluent, etc. All of these differences must be reconciled and integrated if there is to be regional planning in the basin. In addition, fragmented national, water master plans also have to be integrated into a basin – wide co – operative plan recognizing and harmonizing both the regional projects and national programs. Above all, there is also a need to accommodate into one regional plan a model of optimum use of a river basin, and take care of the sovereignty issues, and replace sovereignty with equity and equitable distribution.

The Helsinki Rules (ILA, 1966) and generally the International Law has helped to design frameworks of fairness and guides for cooperation for riparians. However, planning together and recognizing minimum principals to share a river system on grounds of equity, equitable utilization, no – harm and optimum use is not really clearly defined. In most cases regional agreements are facilitated by a middle organization agency or institution (i. e. World Bank in the case of Nile Basin Initiative) trying to help reaching a common ground between the two or more riparians on soft issues. Nevertheless, the process of coming up with a clear agreed upon formal obligation of a base line of regional river planning is still embryonic.

Indeed no model agreement (apart from the New York Principles (1958) and the Helsinki rules, adopted by the Internal Law Association, (ILA, 1966)) is now available to serve riparian countries to reach an agreed framework. That is due to the nature of regional rivers, their complexities and uniqueness, and depending upon prevailing conditions, needs and priorities. Since a benefit for one riparian might pose a threat or harm to the other riparian. That dictates people sharing one river have to sit together, agree upon methods of joint planning, and seals an obligation to the plan. That will be reflected in confidence building among riparians and pave the road for a possible basin – wide approach to planning and action. This will help avoid touching the interests of a co – riparian and avoid any disputes, develop rational solutions, and lay grounds of dispute settlement in case of a national development plan causes significant harm for a co – riparian upstream or downstream (Rogers, 1993). So there is no alternative to regional planning since it offers the best solution for the common use of shared river basin, and therefore, it is important to renew our commitment to cooperation to accelerate the transition to regional planning.

3 The PJTC Model

The are various types of river basin planning authorities around the world with mandates and institutional formats ranging from ones that have authority to plan and execute to the one's that are mainly designed for data gathering and verification. In this part, the operational experience of the Joint Technical Commission of the Nile Waters between Egypt and Sudan (PJTC) will be examined with regard to data gathering and mandates to planning and execution.

The River Nile, the second longest river in the world, passes through ten countries, Burundi, Rwanda, Tanzania, Kenya, Uganda, D. R. Congo, Ethiopia, Eritrea, Sudan and Egypt, is the direct source of livelihood for its inhabitants, and is the main source of irrigation and hydropower activities. The conservation, control and regulation of the Nile and its tributaries has, therefore, a major impact on the economic development of the entire riparian area, particularly in respect of irrigation, drainage, swamp reclamation, hydroelectric power generation, navigation and provision of community water supplies.

Egypt and Sudan have realized that countries sharing the same river basin must foster closer co – operation by conducting joint studies, exchanging relevant information and formulating plans for the use and adequate conservation, control and regulation of common river basins in order to ensure equitable and optimal utilization of the water, for the benefit of all riparian states. A complete network of hydrological stations has been installed to measure most of the tributaries during all seasons, and observe the morphological behavior of the river.

As the river Nile requires further projects for its full control and maximum yield, Egypt and Sudan have concluded several agreements, the last and foremost being the agreement for the complete utilization of the Nile Waters, signed at Cairo, 8th November 1959. The main points of the agreement may be summarized as follows:

(1) Each country's share of waters was agreed, taking into consideration, the required right of each country to the water used prior to the signing of the agreement, control of river waters flow into the Sea and the future development of each country.

(2) Because considerable quantities of the Nile waters were being lost in the swamps, the two states considered it essential to plan and construct conservation projects in the swamps regions and divide the net yield between them and contribute equally to the costs.

(3) In order to ensure technical co – operation, enhance research and necessary studies between the two states, as well as hydrological surveys in upper reaches, the two states agreed to form a Permanent Joint Technical Commission for Nile Waters (PJTC).

(4) To insure future cooperation between riparians, the two countries made a clear reservation regarding future water utilization by other riparians, as a recognition of equitable utilization of the Nile Waters

The function of the PJTC is to plan, supervise, and implement approved Nile Projects between the two states, and to plan a fair arrangement in case of a series of low flow years (PJTC Report, 1972). Thus, the functions of the PJTC are deliberative, investigatory, supervisory and advisory. Furthermore, the Commission is responsible for the advance planning of all projects for the increase in the Nile yield, but other national single or multi – purpose projects for the development of water resources are the sole responsibility of each state.

The data gathered or obtained by the Commission is mainly for aid of planning and cooperation between the two riparians. What distinguish the Commission, however, is that data are gathered jointly and individually and that joint staff is involved in the data – evaluation process (PJTC members and experts). There is no fundamental distinction between data found by teams jointly and data gathered only by the individual teams. However, there are some difficulties in dealing with data which may or may not be verifiable and therefore not effectively usable by the commission or the technical committees.

The commission has an advisory activity coming from the commission data gathering and evaluation duties. Such advice is limited to essentially technical matters – engineering or scientific or may shift to policy recommendations involving choices between alternative uses, priorities and other riparians issues. It is a mark of considerable importance for the Commission to move from the purely technical role to one that includes policy suggestions as well.

The Commission also includes powers to advise on (or manage) the regulation of levels and flows involving boundary and transboundary water between the two states (i. e. dams operations and flows) and this has an effect or related to social and economic activities. This regulatory authority seems very rare in other commissions available in the literature. At the international level, the Amazon basin authority as well as other Latin American institutions, suggest agencies that are more empowered by agreement to plan, manage and fund, and regulate the waters and related land uses for the whole or a part of a basin region (Medina, 1978). A legitimate question is whether this delegation of power would be acceptable to many states over time?

The PJTC Commission has machinery for dispute settlement, since its regulations allow for ministries responsible of water resources in the two countries to represent their Governments if dispute issues arise between the PJTC members. However, from experiences of the last four decades, the Commission has gained a dispute avoidance mechanism. The long existence of the Commission often permits to convert policy dispute or disagreement into a technical one – the classical way of avoiding open conflict, where there is a hard factual core to be understood. Its recommendations or decisions normally represent an operational consensus within the system of the institution. Thus, conflicts over planning of use, claims, or structures that affect one of them may be debated or perhaps agreed upon, when classical diplomacy, without such a commission, might have found the resolution much more difficult to achieve.

The successful planning process must contain an efficient dispute avoidance or conflict resolution mechanism. In the PJTC, the two sides always use planning as a dispute avoiding opportunity. Indeed, by providing the PJTC, already operating over four decades of time and engaged in varying degrees of short – term, mid – term or long term planning, enough confidence there is a reasonable chance that potential future conflicts arising out of competing claims to uses of the shared water between the two states, may be avoided or anticipated. The opportunity to plan as a result of data – gathering or dispute characterization has an advantage that it will make the members of the PJTC always aware of problems that may ignite or initiate conflicts. The two countries (Sudan and Egypt), by developing confidence in the Commission, will encourage it to alert Governments as to possible sources of conflict when purely national claims, activities and plans begin to appear. It should be remembered the stress that the Helsinki and other rules, place on the assertion of maximum rights over that portion of the river within a state's territory. This alerting roles, not only helps to avoid disputes but also, indirectly, encourages the planning process by converting national plans for water uses by a single riparian into regional concept that takes into account the rights and interests of other co – riparians (D. Le Marguand, 1977).

The PJTC between Sudan and Egypt has authority to construct important works (e.g. Jongolei Canal) depending on the common purpose of the 1959 Agreement under which the Commission operates. Nevertheless, the technical difficulties of combining planning, monitoring, dispute avoidance, funding, regulation, construction etc., into one agency are so formidable. There are very few models of international agencies (even in the Amazon system) suggest the willingness of the states to go this far in the creating of planning – execution agencies for the total joint management of a multi – national river basin or sections of it.

The conclusion we can draw from the PJTC experience, is that experiments with sub – basin planning, and sub – basin management, run from the simple data – monitoring by PJTC staff comprised of the two riparians (two – nationals) is a mechanism of multi – national authority to manage all of the water potential of the basin or sub – basin including related planning and operation questions that derive from such conditions. A high degree of political harmony, common cultural, economic and confidence are needed to move from rather simple and dual form of river basin cooperation to more elaborate schemes where planning and execution are delegated by the co – riparians to their joint instrument created for that purpose. Yet, in spite of the successful Nile Basin Initiative (NBI) programs and activities, the general reluctance of states in the Nile Basin, even states with similar cultural traditions, and lack of confidence to go the full distance of cooperation and joint planning should be encouraged by the Sudan – Egypt experience.

4 Planning experience from Sub – Saharan African (SSA) river basin organizations

In March 1987, a World Bank mission visited eleven organizations, comprising seven river basin organizations and three regional organizations associated with international river basin development in West, Central and South Africa. In addition, the mission held discussions with the Department of Water Affairs, Republic of South Africa, (Rangely et al, 1994). The organizations of Sub – Saharan Africa comprise one third of the area of all international river basins of the world, and shared by thirty – five out of the forty – one countries in Continental SSA.

There are several forms and objectives of the above mentioned organizations: ① Those focused on the development of water resources, ② Those covering water and a range of other activities such as agriculture, energy, transport, fisheries and forestry, and ③ Overarching organizations whose mandate includes water resources development and other activities throughout its member states.

The SSA organizations concentrate on construction show more progress than those that engaged primarily in planning. That does not exclude planning from the mandate of the SSA organizations. But experience have shown that planning is more difficult to accomplish than construction of works since the process of planning involves a wide range of political decisions at each step and hence is liable to debate and delays.

For the construction, once the initial decision is made then supervision and implementation of the project can take place accordingly.

Most of the visited SSA river basin organizations have a weak planning capability, since planning involves training and experience that is not readily available. This is particularly clear at the basin level but also exists at the project level. And successful planning in these organizations is mainly carried out by international consulting firms, which hopefully at the end could transfer technology to the staff of these organizations.

Planning in SSA organizations hardly exists and often is a prerequisite to any project program, and it has not reached an operational stage due to problems of institutional capacity. Regional cooperation made it clear that there is a dire need to build up planning capabilities in regional river basin organizations bearing in mind that there will be severe limitations for the years to come. There are also economic, social and environmental constraints associated with river basin planning, dictated the need for continuous high level personnel training and adequate transfer of planning technology, and might call for a long – term human resource development program.

River basin master plans should be prepared regionally considering the basin as one unit, and that could be achieved by integrating the national plans and harmonized them into one integrated basin plan. The final regional plan should be dictated by the technical and political considerations. It is this putting together process that creates the formula and atmosphere for regional cooperation.

There is a need now, not tomorrow, to devote more effort to regional planning. This applies particularly to the Nile (our study for this paper), and so far, only partial planning has been achieved. Thinking regionally is the first step in regional planning. The next step is preparing national plans taking into consideration the broad potential of the basin as a whole. The will pave the way for future basin – wide planning.

5 Tools for successful regional planning

To attain integrated regional water resources planning, the appropriate planning tools should be chosen such as:

Strengthen National Capacities in Planning: Capacities for multi – country project planning should be strengthened to contribute towards improved integrated water resources planning in the Nile Basin. Focus on project planning should be given to strengthen skills in the identification and preparation of projects, addressing issues such as project prioritization, feasibility analysis, cost benefit analysis, and stakeholder involvement.

Emphasize an Integrated River Basin (& Sub – basin) Approach: An integrated river basin approach is a pragmatic mechanism for solving conflicts and driving collaborative developments. Within each of the Nile Basin countries there are opportunities to develop collaborative mechanisms involving national agencies that play key roles in planning and management of water resources in the various sub – basins. Such mechanisms have the potential to integrate technical, economic, social, legal, and environmental aspects of river basin management (World Bank - TEA, 2001)

Develop a Decision Support System (DSS): The DSS and simulation models are important to support integrated basin and sub – basin planning approaches for the Nile Basin. It is needed to evaluate transboundary opportunities for planning and cooperation based on shared information and data. It will also build the technical foundation to enhance the sustainability and facilitate water resources regional planning and management. The DSS model should be comprehensive to support national, sub – basin and regional needs. (World Bank – WRPM, PD, 2001).

One of the important and integral components of the DSS is the Nile Basin Model (NBM). The NBM should be able to analyze different future water resources planning options and predict implications of various strategies. The first step in the NBM should concentrate on basin hydrology and river system behavior, on a regional basis, and with adequate accuracy and reliability according to available data (Sutcliffe and Parks, 1999). One fundamental condition for the NBM to succeed is its ability to describe the Nile Basin River system response to changes in hydrology, interventions, and allow assessments of impacts that may have transboundary implications, with the desired accuracy. This will support more detailed river basin planning options and environmental assessments. The NBM model should be dynamic to accommodate long – term expansion and simulate different processes, such as, socio – economic and environmental issues. Furthermore, and with recent advances in Geographic Information Systems (GIS) and Remote Sensing techniques, the output of the model should be temporal and spatial to represent changes in operational policies. Calibration and validation of the model is of vital importance to ensure matching of the model with observations.

The development of the DSS of the Nile Basin should be conducted in close co – operation with all the riparian states at the technical as well as the decision – making level. This will ensure that the model is acceptable, relevant, transparent, and sustainable.

Strengthen Data/Information Systems: Integrated planning and joint investment of the Nile Basin water resources at the basin and subsidiary (Sub – basin) level depend upon access to reliable data and information, as well as adequate modeling and decision support tools to analyze the information. In many basin countries, monitoring networks, databases, and facilities to process and analyze water resources – related information are not well developed or are not functioning effectively. The data that do exist are often scattered across several government departments and are difficult to assess. Differences in data collection, processing, and record – keeping procedures, both within countries and across the Basin, mean that data are often inconsistent and creates problems in providing adequate assessments. As cooperation and confidence grow across the Basin, accurate information will be critical for planning, at national, sub – regional and regional levels.

Raise Public Awareness: Increased public awareness is needed in regard to the importance of treating water as a precious resource and of the benefits derived from planning and management of natural resources (Shady and Grover, 1996). National and basin – wide communication programs are required to create a culture of awareness of the opportunities for beneficial planning and cooperation in the Nile Basin.

Involve All Stakeholders: Participation of stakeholders in development of national water resources policy and strategies and planning of water resources projects is essential to insure ownership, transparency, and responsiveness to peoples needs. The benefits of stakeholders' participation come when all sections of society are well informed and empowered to contribute to program planning and can help to put together societal, national, and regional interests (Sharma et al., 1996).

With application of the appropriate regional planning tools, still remains the most important question of the challenge to successfully make the critical transition from the planning stage, in which goals and priorities are established, to the implementation stage during which the objectives are incrementally reached on a regional, national and local basis (World Bank – TEA, 2001).

6 Conclusions and recommendations

The PJTC experience is a unique but encouraging example for a technically and politically credible mechanism showing a symbol and reality of parity and integration among co – riparians of un – equal strength. It is advisable that river basin commissions, whether given general powers to plan or not, should at least be granted dispute settlement procedures either of an investigative, recommendatory or arbitral type or all three.

Following the SSA example, it is possible that organizations designed for joint use of a shared river basin to be used as planning mechanisms, if they prove that they already capable of carrying effectively the common wishes and needs of the states involved.

The SSA experience has shown that few countries have adequate national water plans, strategies and policies. Developing a national water resources plan is an effective starting point for the regional long – term development plan, which is vital if NB countries are to meet their priority challenges for sustainable water resources management. Therefore, substantial technical assistance in planning of shared water resources is needed to Nile Basin countries, from data gathering to indicative basin planning and development.

The PJTC and SAA experiences, suggest that regional planning will be an unlikely choice of approaches to common water resources, unless the sense of reciprocal interest is powerful enough to encourage such planning. The experience also raised funding problems of planning facing river basin organizations, and hence it is recommended that commissions to follow a satisfactory theory of self – funding to avoid reluctance of governments to support such important institutions.

Regional planning is complex and has different forms, and hence no one planning philosophy that can be applied as required to advance planning and cooperation in the Nile Basin (NB), and considers the interests of all the riparians. The riparians have to develop their own model.

The interest of the Nile Basin countries may be best served by having a commission at their disposal which they can trust to help gather and share data and evaluate joint alternative projects and uses, and hence envisage and construct meaningful joint plans for the optimum development of the Nile river basin system.

NB countries need to adopt a systematic planning approach that incorporates socio – economic, ecological, and equity considerations, and requires users of water resources to think holistically and to make local, sector, national plans, strategies, and policies consistent with regional long – term sustainable planning goals, that meet all the development imperatives of the Nile basin.

Enhancement of human, technical, financial, organizational, and institutional capacity is the key strategy for attaining successful regional planning.

Create a large pool of different disciplines in all Nile Basin countries, (e. g. engineers, scientists, lawyers, economists, administrators, etc.) who have learnt the fine art of planning and have the capability of working together. They have had to develop a transboundry sense of thinking and responsibility where the benefit of the region is often to be preferred to the national benefit.

Awareness of water resources challenges, issues and opportunities is an essential starting point for improving water resources planning and management, and needs to be enhanced among the public, executive level, national political level, and at the sub – regional, regional and basin level. Building awareness should concentrate on the need for integrated and joint planning, management and development approach of transboundary resources. And a water culture needs to be promoted that emphasizes planning and conservation practices. Policy makers must understand the connections between catchments, control systems, hydraulic problems, and human land use practices.

A necessary condition for more efficient and lasting planning of water resources is to follow a systematic approach which requires a broad – based partnership that extends the level of stakeholders' participation – public and private sectors, farmers, local communities, NGOs and special interests – to participate in all aspects of decision – making and water resources planning. Such a comprehensive approach will allow each riparian country to assess its water plans in a multi – sector framework taking into account transboundary considerations.

Data and information system (physical, technical, socio – economic, etc…) relating to water resources in terms of quantity, quality, accessibility, dissemination, and use are generally inadequate to achieve successful planning throughout the Nile Basin. It is necessary to improve systems through better technology, trained human resources, strengthened capacity and capital.

The recurring long – term droughts of the 1970s and 1980s make drought proofing a particular concern in the Nile Basin countries, and hence regional plans, strategies and cooperation for information, prediction and management of drought need to be developed, and continuously refined to mitigate the social and economic consequences of droughts to benefit from a regional approach.

References

D. LeMarquand. 1976. Politics of International River Basin Co – Operation and Management. Natural Water Resources Journal, Vol. 16, P. P. 883 ~ 901.

D. LeMarquond. 1977. International Rivers: The Politics of Co – Operation. Vancouver, B. C., Wastewater Research Centre, University of British Colombia.

ILA. 1966. International Law Association, Report of the forty – eighth conference (New York, 1958) and Report of the fifty – second conference, (Helsinki, 1966).

Medina, R. 1978. The Future of the Amazon Basin. Inter Ciencia, Vol. 3, No. 4.

PJTC. 1972. Annual Report of the Permanent Joint Technical Commission of Nile Waters between Sudan and Egypt. First year: 1960 – 1961, Cairo.

Rangely, R., Thiam, B., Adersen, R., et al. 1994. World Bank Technical Paper No. 250, Africa Technical Department Series, International River Basin Organization in Sub – Saharan Africa.

Rogers, P. 1993. The Value of Co – operation in Resolving International River Basin Disputes. Natural Resources Forum, P. P. 117 ~ 131.

Shady, Aly M. and Grover, B. 1996. Strategic Consideration for the Comprehensive Water Resources Development of the Nile River Basin. Canadian Water Resources Journal. Vol. 21, No. 1.

Sharma, N., Damhaug, T., Gilgan – Hunt, E., et al. 1996. African Water Resource, Challenges and Opportunities for Sustainable Development. World Bank Technical Paper No. 331, Africa Technical Department Series.

Sutcliffe, J. V. and Parks, Y. P. 1999. The Hydrology of the Nile. Special Publication No. 5, International Association of Hydrological Sciences, Wallingford, UK.

World Bank. 2001. Water Resources Planning and Management (WRPM), Project Document (PD), Nile Basin Initiative (NBI), SVP.

World Bank. 2001. Transboundary Environmental Analysis (TEA) (GEF, UNDP, W. B), NBI, Shared Vision Program (SVP).

Addressing Transboundary Issues in the Kura – Aras River Basin

Gevorg Nazaryan

USAID,PA Government Services Inc. , Armenia

Abstract: The region is known by its tensed political situation, in particular, within the Nagorno – Karabagh, Abchasia and South – Ossetia conflicts. The political situation and absence of the diplomatic relations among several countries hampers in establishment of any cooperation in transboundary water management issues, which is resulting in deterioration of water quality, degradation of ecosystems in river basin, increase of flooding and bank erosion, etc. Thus, the countries of the Southern Caucasus have failed to develop a legal basis for the management of the water resources that they share. Indeed, how these rivers are managed has barely been discussed. Although Georgia and Azerbaijan have signed a number of agreements and memorandums, and have made provisions to share data, the lack of equipment and funds to undertake systematic monitoring of water availability and quality means that little data exchange has occurred.

However, water is a key resource for the Southern Caucasus countries, contributing significantly to the agricultural sector, the export economy and energy production. This means that various issues should be addressed and measures should be undertaken to develop a basis for transboundary cooperation.

The paper discusses major concerns of South Caucasus countries in transboundary water management development for Kura – Aras river basin.

Key words: transboundary management, ecosystem degradation, floods

1 Introduction

There are 261 international rivers, covering 45.3% of the land – surface of the earth (excluding Antarctica). An estimated 40% of the world's population lives in internationally shared river basins and are dependent for their water security on effective transboundary water management. A total of 145 nations include territory within international basins. 21 nations lie in their entirety within international basins; including these, a total of 33 countries have greater than 95% of their territory within these basins. These nations are not limited to smaller countries, such as Liechtenstein and Andorra, but include such sizable countries as Hungary, Bangladesh, Byelarus, and Zambia. Moreover, in larger countries the need for effective water management between provinces or states is of a similar order of magnitude as in international basins[1].

Effective and balanced institutional arrangements for management are a regional public good, with particular characteristics. Transboundary water management is a club – type of good: its provision depends on the riparian countries that cooperate. It is also a means – type of international public good, because it facilitates the provision of important public goods, such as national water security, regional conflict mitigation and the protection of important international eco – systems.

The Kura – Aras river basin is one of the internationally significant river systems, which is seriously degraded and continues to be threatened.

The basin covers the territory of Armenia, Azerbaijan, Georgia, Iran, and Turkey. The total area of the Kura – Aras basin is approximately 188,400 km^2, occupying the greater part of the South Caucasus. The basin spreads over the major part of eastern Georgia; over 60% of Azerbaijan, excluding the Great Caucasus watershed range in the northeast of the country and the Lenkoran region; the entire area of Armenia; the northwestern part of Iran and territories of northeast Turkey.

---

[1] See: Wolf, A. , J. Natharius, J. Danielson, B. Ward, and J. Pender. 1999. International River Basins of the World, International Journal of Water Resources Development 15(4) 387 – 427.

Table 1 shows the distribution amongst the five countries.

Table 1 Distribution of the riparian countries in the Kura – Aras River Basin

Country	Total country area (1,000 km^2)	Area in the basin (1,000 km^2)	Area of the country (%)	Area of the basin (%)
Armenia	29.8	29.8	100.0	15.8
Azerbaijan	86.6	55.1	63.6	29.2
Georgia	69.7	36.4	52.2	19.3
Turkey	771	28.9	3.7	15.3
Iran	1,648	38.2	2.3	20.3
Total	2,605.1	188.4	7.2	100.0

The Kura and the Aras contribute about 66% and 34% respectively to the total runoff. There are more than 10,000 rivers in the basin including many small shallow rivers.

The water regime is characterized by high spring flows from snow melt and low flows during the autumn and winter period. In the plains, the river meanders and the water of the Kura is characterized by high turbidity as the result of mobilization of erosion products along the bank, exacerbated by deforestation and flood irrigation.

2 Legal and institutional aspects

For Kura – Aras basin countries, ensuring the proper institutional setting is one of the key elements in successfully managing the basin's water resources. Institutions in most of the basin countries have a Soviet legacy. However, during the last several years some basin countries have made substantial progress in the improvement of the institutional framework of the water sector, supported by major changes in the legal framework.

Table 2 below summarizes the main functions of the water sector management authorities in the Republics of Armenia, Azerbaijan, Georgia and Iran. The table includes a description of the agencies responsible for water resources management and protection, tariff regulation, and management of water systems and infrastructure. The main functions of those agencies are also described together with the existing tools and enforcement mechanisms for implementation of those functions.

Table 2 Main functions of water sector management authorities in Kura – Aras Basin Countries

	Country	Water Resources Management and Protection	Tariff Regulation	Management of Water Systems
Responsible Agency	AM	Water Resources Management Agency	Public Services Regulatory Commission	State Committee on Water Systems under the Ministry of Territorial Administration Ministry of Energy
	AZ	Azerbaijan Amelioration and Water Economy Joint – Stock Company Ministry of Ecology and Natural Resources	Ministry of Economic Development	Azerbaijan Amelioration and Water Economy Joint – Stock Company Ministry of Fuel and Energy
	GE	Ministry of Environmental Protection and Natural Resources	Ministry of Economic Development Local Administrations	Ministry of Agriculture Ministry of Energy Ministry of Economic Development Local administrations
	IR	Ministry of Energy Regional Water Authorities	Ministry of Energy	Ministry of Energy

Continued to Table 2

	Country	Water Resources Management and Protection	Tariff Regulation	Management of Water Systems
Main Functions	AM	Water resources monitoring and distribution; Strategic water management and protection	Protection of consumer rights and tariff regulation for non – competitive water supply and wastewater treatment in drinking, household and irrigation sectors	Management of water systems under the state ownership; Assistance to development of water user associations and water user federations, organization of tenders on transfer of water systems' management; Management of water systems of energetic importance, that are under the state ownership
	AZ	Water resources distribution and management; Monitoring and protection	Protection of consumer rights and tariff regulation for non – competitive water supply and wastewater treatment in drinking, household and irrigation sectors	Management of irrigation water systems; Assistance to development of water users associations; Management of water systems of energetic importance
	IR	Coordination and management of water resources; Monitoring coastal areas, marsh beds, natural rivers, streams and public canals	Protection of consumer rights and tariff regulation for non – competitive water supply and wastewater treatment in drinking, household and irrigation sectors	Development and exploitation of urban water distribution system, collection and transfer as well as treatment of urban sewage within the legal city limits in each province
Main Functions	GE	Regulation of water use through providing permits; Monitoring of pollution and quality of water resources; Insuring compliance with legislation related to water pollution and water use.	Protection of consumer rights and tariff regulation for non – competitive water supply and water treatment in wastewater drinking, household and irrigation sectors	Water systems are in state ownership and are managed national or local governments; Except tertiary irrigation canals managed by Water User Associations and small hydro power stations managed by private companies
Enforcement tools/ me – chanisms	AM	Water use permits	Water system use permits	Management contract
	AZ	Water use permits	Water system use permits	Management contract
	IR	License	License	Regional Water Authorities
	GE	Water use permits including permits for water extraction and water discharges; Water quality standards	Water system use permits	Management contract

In the Kura – Aras basin countries virtually all of the water resources are considered to be part of the national wealth, with state agencies charged with their safe – keeping and utilization. National legislation in the basin countries stipulates the basic principles of management, utilization and protection of the water resources and water systems. In particular, they specify the principles of: satisfying the essential needs of present and future generations; preserving and increasing the volumes of the water reserves; encouraging effective utilization of water resources for the public benefit; establishing a coordinated and integrated management system of surface and ground water resources; reducing and preventing the pollution of water resources; and reimbursing the expenditure for the cleanup of polluted waters, amongst others.

After the collapse of former Soviet Union environmental legislation has undergone significant changes in Armenia, Azerbaijan, and Georgia. Currently in these countries the legal framework is relatively new, innovative and dynamic, and endeavors to be quite comprehensive. However, these laws are certain to be confronted with a number challenges as implementation moves forward. A major concern is the coherence and consistency among the many legal documents. This has led to some confusion with regard to the institutional arrangements. Table 3 shows the duplications, gaps and overlaps in the water resource oriented functions of the various government agencies in the Kura – Aras basin countries.

It can be seen from this table that water management in the Kura – Aras basin is fragmented and there are duplications in the various water resources management bodies at the national level within each country. Though this is not uncommon, it is a hurdle for successful transboundary river basin management.

Several donor – funded international projects❶ indicate duplication and gaps in water resources monitoring. For example in Armenia and Georgia, currently no organization is responsible for monitoring the quantity and quality of underground water resources. As for surface water quantity and quality, different agencies collect separate types of information, but there is very weak coordination among the agencies, and intra – country and inter – country data exchange mechanisms are virtually absent. Though compliance procedures for regulations and water use permits are in place, the institutions responsible do not have sufficient resources and capacities to enforce them appropriately.

Decentralized water resources management is a prerogative for the countries, but in reality it does not take place. Only Iran and Armenia have established basin management organizations which at this point, do not have enough capacity to undertake appropriate management of water resources at the basin level.

There are also gaps related to responsibilities for setting standards of water quality including: pollution discharges; development of procedures for compliance and enforcement of regulations and water use permit conditions; and the development and implementation of financially sustainable cost recovery incentive mechanisms.

A very important issue is that of funding. Inadequate funding is a significant impairment to progress in the irrigation and municipal sectors. There is also a lack of funding for water resource management and monitoring.

It should be noted that Armenia, Azerbaijan, and Georgia are currently working towards the harmonization of their institutional setting and legislation with the legislation of the European Union (EU), including the field of environmental protection, and in particular water resource management. Hence, the institutional structures of water resources management bodies are being organized to ensure the implementation of water protection policy in accordance with the requirements of the EU Water Framework Directive (N2000/60/EC, 2000). The introduction of basin management principles is a requirement of the Directive. Hence the directive is not only concerned with water quality but also with the equitable sharing of water at the basin level.

Table 3 Duplications, gaps and overlaps in the water resource oriented functions of the various government agencies in the Kura – Aras basin countries

Functions/Tasks	Armenia	Azerbaijan	Georgia	Iran
Formulation of laws and regulations	MNP, sectoral ministries	MENR, sectoral ministries	MEPNR, sectoral ministries	DOE, MOE, Sectoral Ministries

❶ USAID Project Water Management in the South Caucasus (2001 – 2004), EU TACIS Joint River Management – Kura River (2001 – 2004), USAID Program for Institutional and Regulatory Strengthening of Water Management in Armenia (2004 – 2007).

Continued to Table 3

Functions/Tasks	Armenia	Azerbaijan	Georgia	Iran
Water resources management and policies	MNP	MENR	MEPNR	MOE,
Monitoring of surface water quantity and quality	ASH, WRMA, EIMC	HMEM	MEPNR	NMO, MOE
Monitoring of groundwater quantity and quality	None	NGES	None	NMO, MOE
Water resources classification	WRMA	MENR		MOE
Water quality standards	None	None	MH, MEPNR	DOE, MOE
Standards for pollution discharges for classified water resources	None	MENR	MENPR	DOE
Monitoring of water use and pollution discharge	WRMA, BMO, SEI	None	MEPNR	DOE, MOE
Monitoring of drinking water sources and quality, and recreational water quality	SHAEI	MH	MLHSS	DOE
Monitoring of meteorological conditions	ASH	HMEM	MEPNR	NMO
Maintenance of water resources databases	ASH, EIMC, WRMA, RGF, SEI, SHAEI	LMIMCS, LNGES, CMPNE, MH	MEPNR, MLHSS	MOE
Development of National Water Program	WRMA, SCWS	None	MENPR, ongoing	DOE
Development of Basin Management Plans	WRMA	None	None	MOE
Issuance of water use permits	WRMA	AAWEMA	MEPNR	MOE
Development of rules and procedures for compliance assurance	MNP	DEEP	MEPNR	IRI Parliament
Implementation of compliance assurance procedures for regulations and permit conditions	SEI, WRMA, BMO	DEEP	MEPNR, MLHSS	MOE
Supervision of payment of water withdrawal and water discharge fees	None	None	TI	MOE
Application of penalties and fines	SEI	DEEP	MEPNR	DOE
Protection of drinking water sources	SHAEI	MH	MLHSS	DOE, MOE
Development of a policy and mechanisms for financing water management	MFE	MF	MED, MF	MOE

Continued to Table 3

Functions/Tasks	Armenia	Azerbaijan	Georgia	Iran
Formulation of agricultural policy and sector plan	MA	AAWEMA	MAS	MOAJ
Management of irrigation and drainage systems	SCWS	AAWEMA	MA	MOAJ
Water system use license and tariffs	PSRC	AAWEMA, MFE	MEPNR, CRS	MOAJ, MOE
Formulation of municipal water supply policy	Local Self - Gov., MTA	AAWEMA	MED	MOE
Management of municipal water systems	SCWS and municipalities (for different systems)	Azersu, LEB	LM	MOE
Operation of municipal water systems	YWSC, AWSC, communities, private companies	Azersu, LEB	LM	MOE
Regulation (issuance of water system use permit and approval of tariffs)	PSRC	MED	MED, CRC	MOAJ, MOE
Training and capacity building	None	None	None	DOE, MOE, MOAJ

Note: The following abbreviations have been used for the agencies:
AAWEMA—Agency for Amelioration and Water Economy of the Ministry of Agriculture; ASH—ArmStateHydromet; AWSC—Armenian Water Supply Company; Azersu—"Azersu" Joint - Stock Company; BMO—Basin Management Organization; CRC—Central Regulatory Commission; DOE—Department of Environment; EIMC—Environmental Impact Monitoring Center; HMEM—Department of Hydro - Meteorology and Environmental Monitoring; LEB—Local Executive Bodies; LM—Local Municipalities; LMIMCS—Laboratory of Management of Integrated Monitoring of Caspian Sea; LMPLSW—Laboratory of Monitoring of Pollution of Land Surface Waters; LNGES—Laboratory of National Geologic Exploration Service; LSG—Local Self - Government; MAF—Ministry of Agriculture and Food; MED—Ministry of Economic Development; MENR—Ministry of Ecology and Natural Resources; MEPNR—Ministry of Environment Protection and Natural Resources; MF—Ministry of Finances; MFE—Ministry of Fuel and Energy; MH—Ministry of Health; MLHSS—inistry of Labor, Health and Social Security; MNP—Ministry of Nature Protection; MOAJ—Ministry of Agricultural Jihad; MOE—Ministry of Energy; MTA—Ministry of Territorial Administration; NMO—National Meteorological Organization; PSRC—Public Services Regulatory Commission; RGF—Republican Geological Fund; SCWS—State Committee on Water Systems; SEI—State Environmental Inspectorate; SHAEI—State Hygiene and Anti - Epidemiological Inspection; TI—Tax Inspectorate; WRMA—Water Resources Management Agency; WUA—Water User Association; YWSC—Yerevan Water Supply Company.

3 Review of environmental transboundary issues

The main problems could be described as follows:

3.1 Assessment of water resources in the basin, formation of water supply and water demand

The water resources management institutions in the South Caucasus countries are currently in the stage of development and formation. However, from the point of view of water basin management it is necessary to assess all the water resources in the basin, i. e. to completely inventory water resources quality, quantity, form and distribution. This will provide an analysis of the existing water supply.

The water demand could be formed within the regulations of water resources management bodies by taking as principle "the supply dictating the demand". Until now the work on assessment of water resources, formation of water supply and water demand in the basin has not been implemented.

3.2 Drinking water supply

The sources of drinking water supply in the region are different. For example, in Armenia drinking water supply to majority of residential areas of Kura – Aras river basin is mainly implemented from underground springs, which have high water quality. Only in a part of Vanadzor town water is supplied from surface waters. At the same time in Azerbaijan the main sources of water supply are surface waters.

Centralized systems of potable water supply exist in almost all the cities of the basin. Some of these systems also supply nearby settlements and villages. At present there are significant difficulties in providing water supply to residential areas: water supply systems, communications and equipment are in a poor condition, the number of accidents and the level of leakage has grown; due to power shortage and high tariffs, pump stations are not operational, and norms of sanitary zones are not kept. Water loss (through wastage, leakages and failures), particularly from domestic and municipal water use, is an acute problem for the South Caucasus countries. Non – rational use of water is a widely spread practice throughout the basin. This is compounded by the low awareness of the population which currently has little regard for water efficiency and is often careless with its use.

3.3 Wastewater collection and treatment

Water pollution in the Kura basin comes from a number of land based sources including industrial and mining sites, agricultural lands, households in rural areas and municipalities. Wastewater treatment facilities are absent in many municipalities and enterprises, and are available only in some locations in the Aras basin in Iran. Most of the wastewater treatment facilities were built 20 ~ 30 years ago and are currently non – operational. The wastewater from residential areas is removed from the towns through collectors and directly discharged into open water basins without treatment. Because of the poor condition of pipelines and construction of the wastewater removal systems (collectors and networks) in the basin, the number of breakdowns has increased. Wastewater is discharged into rivers from different places, polluting the environment, and causing danger for epidemics. All the residents' appeals and complaints meet the same response – there is not even enough money in the budget for dumpsters.

Industrial development and the construction of industrial wastewater treatment facilities are not coordinated. The only exception is enterprises which have local wastewater treatment facilities. However, it should be noted that most of them are currently not operating. Of particular danger are wastewaters from the mining industry and tailing lagoons and dumps.

3.4 Floods and mudflows

Flooding and bank erosion in the Kura – Aras river basin has significant transboundary consequences. Anthropogenic interventions in the natural flow regime including river training and changes in land cover (intensive deforestation) combined with the degradation of natural floodplains as a consequence of urban development and agriculture, increases the risk of floods and mudflows in downstream countries. Deterioration in the flood protection infrastructure throughout the basin has worsened the situation. It is likely that climate change will further increase the risk.

Flooding and mudflow events in the Kura – Aras basin have adverse economic and social implications for the basin countries. Despite extensive investments in flood control schemes in the past, significant damage and occasional loss of human life still occurs. High floods have been reduced by the construction of a number of dams and reservoirs on the Kura and Aras rivers. However, Lack of flood protection reservoirs is listed as one of the main underlying causes of floods in the basin. There are insufficient financial resources for the construction and maintenance of flood control and defense schemes. This is compounded by the lack of a proper monitoring and flow forecasting system that would allow effective early warning.

The lack of integrated flood management is another issue that needs to be addressed in the basin and approaches restricted to flood control using only hard engineering solutions have to be revised, especially when the financial and environmental costs of such solutions are considered.

3.5 Degradation of ecosystem

Transboundary ecosystem degradation including increased trends of biodiversity loss, deforestation, and land degradation are observed throughout the basin. As mentioned above, the poor condition of water supply systems, the increase in the number of breakdowns, pollution of sanitary protection zones, improper chlorination levels, and water supply to population in hourly schedules have resulted in violation of drinking water quality sanitary standards. The lack of operating wastewater treatment plants, and the poor condition of collectors and wastewater networks, has caused wastewater to be discharged directly into rivers. This situation not only causes environmental pollution, violating the ecosystem sustainability, but also causes epidemics.

The decline of species has intensified over the last few decades, due to a large extent by habitat fragmentation and degradation. There has been a remarkable decline in several bird species, small mammals and several plant species.

Forest degradation in the Kura – Aras basin has intensified during the last two decades. Boundaries of the mountain forests remained more or less stable until the beginning of the 1990s, but since then, the situation has changed as a result of extensive logging, both illegal and authorized by government institutions.

Desertification and land degradation is a critical problem in the Kura – Aras basin. The main forms of degradation are salinization (especially in desert and semi – desert areas) and soil erosion (washing out of fertile soil). The most important reason for land degradation appears to be deforestation and overgrazing.

Increased demand on timber for commercial purposes is one of the major drivers of ecosystem degradation. This includes timber logging for use in the construction business nationally and for export, and has consequently resulted in a reduction in deciduous forest areas.

The energy crisis that has taken place during the last decade in the South Caucasus countries has also put great pressure on forests in the basin. The acute energy deficit in these countries, accompanied with poverty problems has resulted in excessive logging as the population has been forced to use wood for heating and cooking.

The causes are related to weak legislation and regulations, institutional complexities, poor law enforcement and low public awareness on the importance of biodiversity and ecosystem act together with financial constraints to create unfavorable conditions for protecting ecosystem integrity and biodiversity. The absence of integrated water resources management also contributes to this process.

3.6 Impacts from agriculture

The agriculture is the main water user in all South Caucasus countries. However, the application of fertilizers and pesticides has been significantly reduced in the basin over the last two decades. Furthermore, the usage of persistent chlorine – organic pesticides, such as DDT, hexachlorcyclohexane (HCH) and aldrine, etc has been prohibited in the region. However, recent studies indicate that there is strong evidence that the illegal application of banned chlorinated pesticides in the region is occurring.

The unregulated use of fertilizers results in diffuse pollution of both surface and ground water resources. Nutrient loading also comes from direct point source discharges of animal slurry from cattle and pig farms. These incidents have greatest impact in early spring during the snow melt, when waters wash out nitrates and phosphates from previous autumn applications.

3.7 Hydrological flow variation

Variation in hydrological flow has been caused by numerous human interventions including direct water abstraction from surface and groundwater bodies, increased evaporation due to impoundments, urbanization and deforestation. This has significant transboundary consequences and it has been calculated that 40 % of the natural runoff of the Kura and 27 % of the Aras runoff is lost to the Caspian Sea.

Severe water deficit has not occurred in the basin to date and consequently shortages of water have not presented any serious threats to the population. However, population growth and rapid economic development in the basin countries will impose increased pressure on surface and groundwater resources.

Climate change could also have a catastrophic impact in the medium and long term with potential scenarios indicating flow reductions of 50% because of increased average temperature and decreased precipitation.

Variation and reduction of flow has already affected fish species such as sturgeon in the Kura – Aras river basin and affected terrestrial ecosystems such as tugai forests. The construction of new reservoirs is likely to further alter flows.

4 Conclusions

After the collapse of former Soviet Union environmental legislation has undergone significant changes in Armenia, Azerbaijan, and Georgia. Although the legal frameworks are relatively new, innovative and dynamic, a major concern is the coherence and consistency among the many legal documents. This has led to some confusion with regard to the institutional arrangements.

Consequently, water management in the Kura – Aras basin is fragmented and there are duplications in the various water resources management bodies at the national level within each country.

This is compounded by regular and sudden structural changes in the Environmental Ministries in Armenia, Azerbaijan and Georgia after the collapse of former Soviet Union, which has destabilized these institutions.

Analysis of various donor – funded projects shows a lack of integrated environmental management. As a result, duplications of efforts frequently occur. In addition to this, there is a lack of institutional structures in the different economic sectors for planning, coordinating and supporting environmental activities.

In the Kura – Aras basin countries one of the technical tools to promote effective allocation of water resources and collection of corresponding fees are water use permitting systems. A number of regulations exist in Armenia, Azerbaijan, Iran and Georgia that define water use permitting procedures. Despite a comprehensive legal and regulatory framework, gaps still exist, which prevent the full and efficient implementation and enforcement of the water use permitting and associated payment system.

The Kura – Aras basin countries recognize the importance of transboundary cooperation and are trying to address priority transboundary issues with neighboring countries. However, the tensed political situation in the region hampers the development of joint measures on transboundary management of Kura – Aras river basin.

Review on Benefit Assessment of Soil and Water Conservation Measures in Gushanchuan River Basin

Wang Guoqing[1,2], ***Zhang Jianyun***[1], ***He Ruimin***[1], ***Jing Xin' ai***[3] and ***Yu Hui***[4]

1. State Key Laboratory of Hydrology – Water Resources and Hydraulic Engineering, Nanjing, 210098
2. Yellow River Conservancy Commission, Zhengzhou, 450003
3. Yellow River Institute of Hydraulic Research, Zhengzhou, 450003
4. Zhengzhou Meteorology bureau, Zhengzhou, 450000

Abstract: Benefit assessment of soil and water conservation measures in Gushanchuan River basin and corresponding assessment models were reviewed in the paper. Results show that different models led to different benefit assessment for Gushanchuan River basin. And the situation is partly due to shortcomings in statistic model itself and representatives of the employed data. Therefore, it is necessary to strengthen application research of physically – based hydrological models in the Loess Plateau instead of statistical models.

Key words: gushanchuan River basin, runoff and sediment yielding models, benefit assessment, soil and water conservation measures

The Loess Plateau is abundance in mineral and soil resources, and the favorable natural condition makes the area be an important base of agriculture and chemical industry. Influenced by drought climate conditions, the area is shortage in water resources. Meanwhile, soil and water losing is a serious environmental issue. To restore local ecological environment and improve development of social economy, large – scale soil and water conservation measures have been taken since 1970s. Benefit assessment of soil and water measures not only can provide scientific support for planning of ecological environment construction, but also be significant to rational development and utilization of water and soil resources.

To reveal causes of water and sediment variation in coarse silt abundance areas in the middle Yellow River, financed by national natural science fund, Yellow River soil and water conservation scientific research fund, Yellow River water and sediment variation research fund, and the 8th 5 – year national key project, benefit of soil and water conservation measures in Gushanchuan River basin have been studied, and previous achievements were reviewed in the paper.

1 Description of Gushanchuan River Basin

Gushanchuan River basin located in hilly and gully area with abundance and coarse sediment, where soil layer is thick and soil structure is more porous, so soil and water losing is very serious. Drainage area of the basin is about 1, 263 km^2 with main steam length of 79. 4 km. Outlet hydrometrical station of the catchment is Gaoshiya Station, and sketch map of the basin was shown in Fig. 1.

As the Gushanchuan River basin situates in Eastern – Asia monsoon climate zone, climatic condition is arid and low precipitation. Multi – year average watershed precipitation and potential evaporation is 430 mm and 1,287 mm respectively from 1960 to 1995. Precipitation in flood season from July to October is about 78.4% of the annual rainfall. Water resource in the basin is scarcity due to high potential evapotranspiration and low precipitation. Mean annual runoff depth is 76.2 mm, which is only about 18% of annual precipitation. Average annual sediment is about 23,640 thousand tons. Seasonal distribution of runoff and sediment is also very uneven, and mainly concentrate in flood period. The amount of runoff and sediment in flood period are about 74. 3% and 99. 1% of annual value respectively.

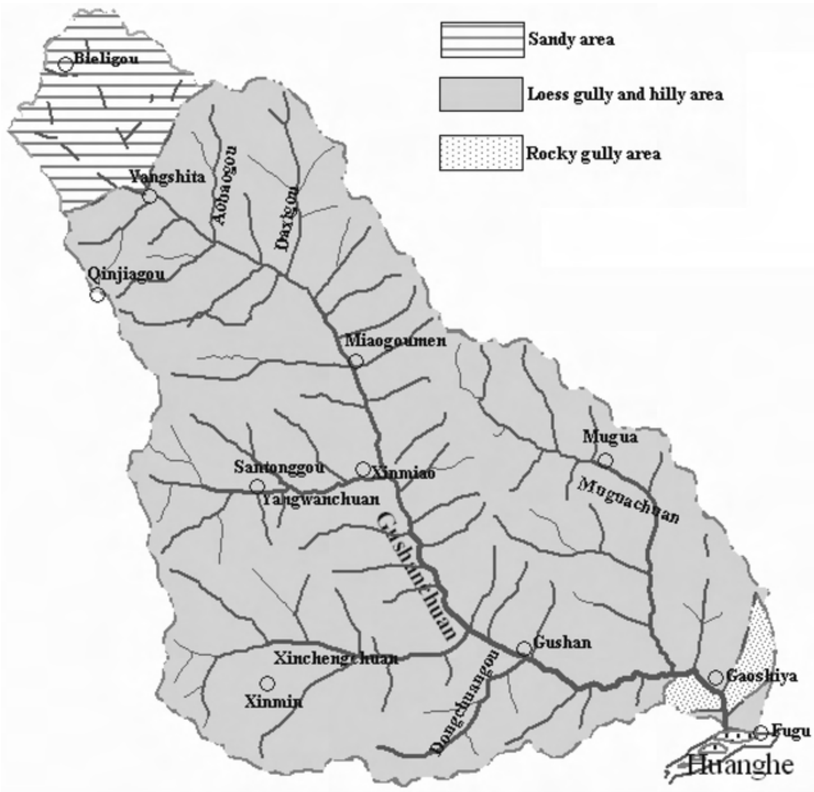


Fig. 1 Sketch map of the Gushanchuan River basin

2 Review on runoff and sediment yielding models used for benefit assessment

Benefit assessment methods for water and sediment reduction of soil conservation measures can be divided into 3 types: hydrologic simulation method, soil conservation method, and similarity comparison method. With rapid development of computer techniques, the hydrologic simulation method has attracted more attention and been widely applied. Therefore, many statistical hydrologic models were established to estimate water and sediment reduction benefit of soil conservation measures in the last decade. The first step of benefit assessment with hydrologic simulation method is to establish hydrologic model with natural hydrological data; and then, calculate natural runoff and sediment processes with the model and meteorological data in human – disturbed period, in which, soil conservation measures have been taken. Through comparing recorded and calculated runoff and sediment in the human – disturbed period, runoff and sediment reduction benefit could be estimated. Therefore, the key technique issue in soil conservation benefit analysis is to select or establish a qualified hydrologic model.

Because there were less human activities in the Gushanchuan River basin before 1970, data in the period was usually treated as "natural" and was used to establish benefit assessment models. The employed models in Gushanchuan River basin were briefly reviewed as follows.

(1) Based on the correlation analysis between annual runoff, sediment and annual precipitation, Yu Yiming, et al, have developed runoff and sediment yielding model in Gushanchuan River basin (Yu Yiming, et al., 1993). The calculation equations shown as follows:

$$R_a = 1,335 \cdot e^{0.004,5P_a} \quad (1)$$

$$Ws_a = 52.61 \cdot e^{0.008,462P_a} \quad (2)$$

where: R_a and Ws_a are annual runoff and sediment respectively; P_a is watershed annual precipitation.

(2) Financed by national natural science fund, Xiong Guishu, et al, has adopted the following equations to calculated natural runoff and sediment in Gushanchuan River basin (Tang Keli, et al., 1993).

$$W_W = \alpha_1 \cdot P_1 + \alpha_2 \cdot P_2 + \cdots + \alpha_m \cdot P_m \quad (3)$$

$$W_S = \beta_1 \cdot P_1 + \beta_2 \cdot P_2 + \cdots + \beta_m \cdot P_m \quad (4)$$

where: $\alpha_1, \alpha_2, \cdots, \alpha_m$ are graded coefficients of runoff yielding; $\beta_1, \beta_2, \cdots, \beta_m$ are graded coefficients of sediment yielding; $P_1, P_2, \cdots, P_m$ are graded daily precipitation; W_W and W_S are runoff and sediment respectively.

(3) Jiao Enze thought that precipitation in flood period and storm are main factors of runoff and sediment yielding, and assumed watershed area precipitation that is larger than 0.5mm/hr as effective rainfall to calculate corresponding rainfall density. Experimental formula for runoff and sediment calculation were obtained with observed data from 1954 to 1969 (Jiao Enze, 2002), and calculation equations were shown as follows:

$$W_a = 112 \cdot P_f^{0.63} \cdot I_e^{0.656} \quad (5)$$

$$W_{S_f} = 12.0 \cdot P_e^{0.7} \cdot I_e^{1.5} \quad (6)$$

where: W_a is annual runoff; W_{S_f} is sediment in flood period; P_f and P_e are rainfall in flood period and effective precipitation respectively; and I_e is rainfall density.

Calculated runoff and sediment in the natural period with the equations are quite closed to the recorded values.

(4) In order to make action of individual monthly effective rainfall and rainfall density more conspicuous, in the 8th 5 - year national key project, Xu Jianhua, et al. have put forward the following equations to calculate runoff and sediment for each month (Zhang Shengli, et al, 1997).

$$W_i = \alpha_1 \cdot P_{i1}^2 / T_{i1} + \alpha_2 \cdot P_{i2}^2 / T_{i2} + \cdots + b_i \quad (7)$$

$$W_{S_i} = \rho_m \cdot (1 - e^{-K(W_i - W_0)}) \cdot W_i \quad (8)$$

where: $\alpha_1, \alpha_1, \cdots, b_i$ and K are constants; P_{i_1} is effective precipitation in month i at No. 1 rainfall station; T_{i_1} is the number of rainy day corresponding to P_{i_1}; W_0 is base flow; W_i and W_{S_i} are runoff and sediment in month i respectively.

Correlation coefficients of the equations for each month are all above 0.95.

And meanwhile, annual runoff and sediment yielding statistic models have also been established for Gushanchuan River basin by considering annual feature of rainfall indexes, and equations were shown as follow.

$$W_a = 20.718 \cdot [0.397P_{30}^{1.49} + 0.315(P_f - P_{30})^{1.52} + 0.288P_a]^{0.822} \quad (9)$$

$$W_{S_a} = 0.069,2 \cdot [0.48P_1 + 0.24(P_{30} - P_1) + 0.23(P_f - P_{30}) + 0.04(P_a - P_f)]^{2.23} \quad (10)$$

where: P_1, P_{30} are maximum value of daily rainfall and 30 days rainfall; P_f is rainfall in flood period; and P_a is annual rainfall.

Correlation coefficients between annual runoff, sediment and feature rainfall are 0.955 and 0.926 respectively.

(5) In order to eliminate the effect of of short length data series on model construction, Li Xuemei, Xu Jianhua, et al, treated the influences of soil conservation measures on water and sediment as rainfall loss, and put forward a coefficient to describe the effect (Xu Jianhua, et al., 2000). Runoff and sediment calculation formula is as follows.

$$\xi = \frac{\sum W_{m_i} \cdot f_i + \sum V_{m_i}}{F_{l_s} \cdot \overline{P}} \quad (11)$$

$$W = -18.2 + 1.390,3(1 - \xi_1)P_1 I_1 + 0.005,1(1 - \xi_2)P_2 I_2 +$$

$$0.499(1-\xi_i)P_3I_3+0.582,4(1-\xi_4)P_4I_4 \quad (12)$$

$$W_S=-103.9+0.431,9(1-\xi_1)P_1I_1+0.060,3(1-\xi_2)P_2I_2+$$
$$0.324,7(1-\xi_i)P_3I_3+0.033,3(1-\xi_4)P_4I_4 \quad (13)$$

where: f_i is harness area of slop measures; W_{m_i} is maximum capacity of runoff holding of slop measures; V_{m_i} is rest capacity of channel measures; F_{l_s} is soil and water losing area; $\overline{P}$ is multi – year average precipitation at rainfall station; P_i is precipitation from May to October at rainfall station i; I_i is average daily precipitation at rainfall station i.

Correlation coefficients between runoff, sediment and all independence variables from 1956 to 1995 are 0.87 and 0.79 respectively.

(6) Ran Dachuan, et al. considered that runoff consists of base flow and surface flow, and surface flow was mainly produced from storms in flood period (Ran Dachuan, et al, 2000). Sediment and the two flow components were calculated by the following equations:

$$W_H=9.5\times10^{-4}P_{7D}^{2.894} \quad (14)$$

$$W_B=1.001(P_a+0.8P_{a-1}+0.5P_{a-2})^{1.191} \quad (15)$$

$$W_{H_S}=3.89\times10^{-4}P_{7D}^{2.875} \quad (16)$$

where: W_H and W_{H_S} are runoff and sediment produced from storms in flood period respectively; P_{7D} is sum of maximum rainfall in un – continuous 7 days; P_a, P_{a-1} and P_{a-2} are annual precipitations in current year, and in the two years before respectively.

Correlation coefficients between flood amount, base flow, flood sediment and corresponding variables are 0.97, 0.8 and 0.92.

(7) To strengthen physical base of runoff and sediment models, according to the mechanism of runoff yielding in Loess Plateau, Wang Guoqing, et al divided discharge into surface flow which is calculated by improved Green – Ampt infiltration capacity curve, and base flow which is calculated with liner reservoir theory. And Wang thought that dynamic forces of sediment yielding are from rainfall and surface flow. Based on the assumption, soil erosion equations were also established (Wang Guoqing, et al, 2001). Efficient coefficients of simulation to daily discharge and sediment flow from 1960 to 1969 are 83.3% and 87.1% respectively.

Above mentioned models have already applied in the Gushanchuan River basin. Except the last one can be treated as a simplified conceptual model, the rest 6 models are traditional statistic models. And validation results of these models show that all of them have good simulation results for natural runoff and sediment, calculated runoff and sediment are closed to recorded ones. Therefore, just from simulation result, these models are qualified to assess benefit of soil and water conservation measures.

3 Review on benefit of soil and water conservation measures in Gushanchuan river basin

Based on the simulation of natural runoff and sediment from 1954 to 1969 at Gaoshiya station, natural runoff and sediment processes in human – disturbed period were calculated with those models. And then, the impacts of soil and water conservation measures on runoff and sediment were estimated by comparing the calculated and recorded values of runoff and sediment in human disturbed period. And results are shown in Table 1.

The first 6 models were used to calculate annual runoff and sediment reduction of soil and water conservation measures, while the last one has only estimated average runoff and sediment reduction of that in typical storms. Results of the first 6 models show that although all models get same good runoff and sediment simulation results, runoff reduction benefits calculated with different models are relatively similar while calculated sediment reduction benefits are quite different. And Yu got opposite runoff reduction assessment benefit to the others for 1970s.

Table 1 Comparison of runoff and sediment reduction benefits by different models

Authors	Items	Runoff ($\times 10^4$ m^3)				Sediment ($\times 10^4$ tons)			
		Before 1969	1970s	1980s	1990 ~ 1995	Before 1969	1970s	1980s	1990 ~ 1995
Yu YM, et al.	Recorded	11,043	9,804	5,518		2,434	2,969	1,278	
	Calculated		9,270	7,947			2,429	1,953	
	Reduction		-526	2,429			-540	675	
	Benefit(%)		-5.8	30.6			-22.2	34.6	
Xiong GS, et al.	Recorded	5,376	6,644	3,544		2,480	2,969	1,250	
	Calculated		7,951	3,927			2,909	1,458	
	Recorded	1,307	383			-60	208		
	Benefit(%)		24.3	17.12			-2.4	8.4	
Jiao EX	Recorded	11,040	9,793	5,518		2,658	2,978	1,278	
	Calculated		11,844	9,411			4,018.2	2,210.8	
	Reduction		2,051	3,893			1,040	933	
	Benefit(%)		17.3	41.4			26.4	43.2	
Xu JH, et al.	Reduction		1,700	2,600			-68	341	
Li, et al.	Reduction		1,652	1,561	1,160		559	513	358
Ran DC, et al.	Recorded	10,880	9,794	5,515	6,260	2,645	2,964	1,269	1,418
	Calculated		11,450	7,175	7,951		2,867	1,465	1,748
	Reduction		1,656	1,660	1,691		-97	196	330
	Benefit(%)		16.9	30.1	27.0		-3.3	15.4	23.3
Wang GQ, et al.	Recorded		1,405	6,800	1,478		785	285	509
	Calculated		1,537	8,654	1,950		907	417	832
	Reduction		132	1,854	472		122	132	323
	Benefit(%)		8.6	21.4	24.2		13.5	31.7	38.8

There are 4 rainfall stations available in Gushanchuan River basin; only 2 stations of Gao shiya and Xin Minzhen have longer data series. The rest 2 stations of Xin Miao and Gushan were established in 1966. Therefore, only 4 years complete data series can be used to establish assessment models. And this will lead to calibrated parameters have not enough representatives. It is known that statistical models have quite high interpolation accuracy but poor performance in extrapolation. Therefore, if hydrologic data that was used to establish model have no enough representatives, it is hard to ensure accuracy of calculated runoff sediment in human - disturbed period. Even if data series from 1954 to 1965 used here, only 2 rainfall stations can be used, issues of data consistence were also existed. Weakness in statistical model itself and issues of short data representatives are main reasons of much difference in benefit assessment result of soil and water conservation measures by different methods.

4 Conclusions

To reveal laws of runoff and sediment yielding, except models mentioned in the paper, any other empirical, semi - empirical formulas and physically based hydrological models were also put forward in the recent years. Compared with statistical models, physically - based hydrological models have themselves merits, which can solve issues of data extrapolation with poor accuracy by analysis on regional distribution law of parameters. And the merit has attracted more attention from scientists and scholars. And now, representative models in our country are HUM model (Tang

Liqun, et al., 1995), THUM model (Xie Shunan, et al. 1995) and model developed by Cai Qiangguo (Cai, et al., 1998). In addition, great development in the field have also been gotten in abroad, for instance, typical USLE have been improved to RUSLE (USGS, 1997). ANSWERS model (Beasley, 1996), EUEOSEM model (Morgan, 1995) divided a basin into many cells to simulate soil erosion process, which is physically – based distributed hydrological models. LISEM model (Deroo, 1996) has combined GIS technique and was widely applied in Europe. The Loess Plateau is famous for complexity of soil and sediment losing, although these models have gotten good validation in many basins, these maybe still hard to be directly used in the Loess Plateau. Therefore, it is of essential to strengthen application research of these physically – based models in the middle Yellow River.

Coarse silt abundance area in the middle Yellow River is key area of national soil and water conservation, runoff and sediment reduction benefit assessment is one of an important work of ecological environment construction planning in the area, and assessment method is the basis to do the job. Although many works have been done for Gushanchuan River basin, application of physically – based distributed hydrological models still need to be strengthened in further. It is benefit to reduce uncertainty in benefit assessment, and enrich knowledge of hydrological simulation techniques.

References

Xu Jianhua, Niu Yuguo. Water and Soil Conservation Projects impact on runoff and sediment in Area with Abundance and Coarse Sediment of the Middle Yellow River, Yellow River Press. Zehngzhou, 2000, P232 – 241.

Zhang Shengli, Li Zuo, Zhao Wenlin. Variation causes and developing tendency of water and sediment in area with abundance and coarse sediment of the middle Yellow River. Yellow River Press, Zhengzhou, 2000, P146 – 159.

Ran Dachuan, Liu Linwang, Zhao Liyi, et al. Water and soil Conservation in the reach from Hekouzhen to Longmen of the Middle Yellow River and variation law of Water and sediment. Yellow River Press, 2000, P130 – 175.

Tang Keli, Xiong Guisu, Liang Jiyang et al. Soil erosion in the Yellow River basin and variation law of runoff and sediment. China science and technology press, Beijing, 1993, P220 – 225.

Wang Guoqing, Chen Jiangnan, et al. Runoff and sediment yielding models by storm and its application in typical tributaries of Loess Plateau. Journal of soil and water conservation, 2001, No 6: P40 – 42.

Yu Yiming, Zhao Weijing, et al. Benefit on water and sediment reduction of water and soil conservation and variation of water and sediment in area with abundance and coarse sediment of the middle Yellow River.

Effects of Environmental Change on Runoff in Yiluohe River Basin of the Middle Yellow River

Wang Guoqing[1,2], ***Zhang Jianyun***[1], ***He Ruimin***[1], ***Jing Xinai***[3] and ***Huang Ruiying***[4]

1. State Key Laboratory of Hydrology – Water Resources and Hydraulic Engineering, Nanjing, 210098
2. Yellow River Conservancy Commission, Zhengzhou, 450003
3. Yellow River Institute of Hydraulic Research, Zhengzhou, 450003
4. Yishusi Water Conservancy Bureau, Xuzhou, 221009

Abstract: Runoffs in many rivers in China have been decreasing over the last decades. How to identify the contributions of human activities and climate change to runoff variation is a hot topic, a difficulty problem as well. The performance of Australia water balance model is tested in Yiluohe River basin, and the model is employed to Analyze effect of climate change and human activities on runoff in the River basin. And results show that Australia water balance model performs well on monthly discharge simulation in Yiluohe River Basin. On average, 58% and 42% of total runoff reduction from 1970 ~ 1995 were caused by climate change and human activities. and climate change is main reason of runoff reduction in Yiluohe River basin.

Key words: Yiluohe River basin, hydrological simulation, climate change, human activities, runoff variation

1 Introduction

The Yellow River is shortage in water resources. In recent years, ecological environment in the middle Yellow River has been deteriorating partly due to climate warming and high – density human activities. And these eco – environmental problems are evident on runoff sharply decreasing in most tributaries, flow run dry in the downstream of the Yellow River, desertification and drought aggravation in the central reaches of the middle Yellow River, and so on. How to evaluate runoff regimes in the middle Yellow River under changing environment has become an essential problem. There have been several recent studies on the subject, however, empirical models were mostly established and employed to analyze causes of runoff variation in previous studies (Xu et al. ,2000; Ran et al, 2000; Zhang et al, 1998). And application of conseptual hydrological model on the subject study was quite rare. Due to the shortcoming of poor extrapolation of the emprical model, different models could result in different conclusions even for a same river basin (Wang et al. 2004). Contrary to empirical model, conceptual models not only have physical explanation, but also have strong ability for runoff series extrapolation. And so, conceptual hydrologic models are often believed to be useful in assessing the impacts of environmental changes on regional hydrology (Arnell, 1999). Development of hydrologic simulation technique has experienced long history of more than half century, and hundreds of hydrologic models have been developed in the world. Most hydrologic models currently in use have been developed for humid basins, and perform well in these basins. However, arid or semi – arid basins, such as Yellow River basin is very distinct in hydrologic behavior (Chen, 1996). Hydrologic regime is not only dominated by high density rainfall, but also affected by large – scale human activities (Wang, 2000). Therefore, hydrologic simulation of Yellow River Basin has been a challenge to hydrologists for a long time.

Taking Yiluohe River basin of the middle Yellow River as an example, Australian water balance model is calibrated and employed to evaluate impacts of climate change and human activities on runoff regime in the river basin.

2 The study basin

The Yiluohe River is the first – class tributary of the Yellow River, which originates from Luonan county, Shannxi province, runs through Xionger Mountain from South – west to North – east, and empties into Yellow River at 5 km below Heishiguan hydrometric station. The drainage area of the river basin is 18,563 km^2 with main stream length of 974 km. The Yiluohe River system consists of two main tributaries of Yihe River and Luohe River. Longmenzhen is the most downstream hydrometric station on Yihe River with drianage area of 5,318 km^2 and river length of 264.8 km. And Baimasi is the most downstream hydrometric station on Luohe River with drianage area of 11,891 km^2 and river length of 446.9 km. The middle and upper reaches of Yiluohe River is mountain area and densely covered with bush vegetation, the lower reaches is covered with thick loess layer, where vegetation is sparse and soil erosion is very serious.

Yiluohe River basin situates in Eastern – Asia monsoon climate zone, average annual precipitation is about 660 mm, and 60% of which concentrates in the flood season from June to September. Areal distribution of annual rainfall is uneven, which varies from 850 mm on the upper reaches to 550 mm on the lower reaches.

Since 1970s, Two large – scale reservoirs of Luhun and Guxian have been built, and a large quantity of water supply works have also been constructed to improve local irrigation condition. In order to prevent water and soil losing, large – scale soil and water conservation measures have been taken in the basin. Till to 1999, 1,445 hm^2 of terrace, 6,751 hm^2 of reforestation area have been constructed, and the formed check dam land was up to 672 hm^2. These human activities have impacted hydrological regimes in the basin greatly.

3 Australia Water Balance Model

The AWBM model (Australia Water Balance Model, AWBM model) is a catchment water balance model that can relate runoff to rainfall with monthly or daily data. The model has 6 parameters, and has already been applied in some semiarid or humid basins which are located in America, Australia, and other countries (Wang, et al., 2005). The structure of AWBM model is shown in Fig. 1. And calculation principle was introduced below.

AWBM model uses three surface stores to simulate partial areas of runoff yield. The capacities of the three surface stores are C_1, C_2, and C_3, and the corresponding area percentage of the surface stors are A_1, A_2, and A_3 respectively. The constrait condition is $A_1 + A_2 + A_3 = 1$. Usually, the default value of A_1 is 0.134, A_2 and A_3 are 0.433. Water balance of each surface store is calculated independently. At each time step, rainfall is added to each of the three surface moisture stores and evapotranspiration is subtracted from each store, water balance equation can be described as following:

$$Store(n,m) = Store(n-1,m) + Rain(n) - Evap(n) \tag{1}$$

where, $Store(n, m)$ and $Store(n-1, m)$ are surface stores numbered m in the interval n and $n-1$. $Rain(n)$ and $Evap(n)$ are rainfall and potential evaporation in the interval n; and n is the numbered calculation interval; m is the number of surface stores, and $n = 1 \sim 3$.

If the value of moisture in the store becomes negative, it is reset to zero. If the value of moisture in the store exceeds the capacity of the store, the store is reset to the capacity, and the moisture in excess of capacity partly flows into surface flow store, and the remainder becomes recharge of the baseflow store.

$$EXCES(n,m) = Store(n,m) - C(m) \geqslant 0 \tag{2}$$

$$S(n) = S(n-1) + \sum_{m=1}^{3} [(1 - BFI) \times EXCES(n,m)] \tag{3}$$

$$B_s(n) = B_s(n-1) + \sum_{m=1}^{3} [BFI \times EXCES(n,m)] \tag{4}$$

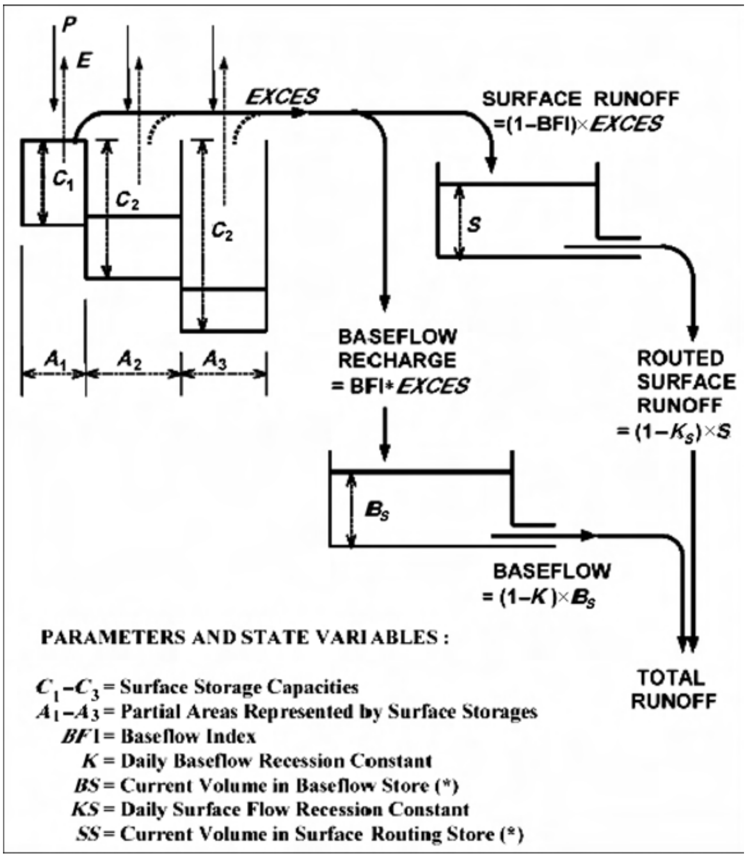


Fig. 1 Schematic diagram of AWBM model

where, $S(n)$ and $S(n-1)$ are surface runoff routing stores in the interval n and n − 1. $B_s(n)$ and $B_s(n-1)$ are the volumns of baseflow store in the interval n and $n-1$.

The surface runoff routing store and the baseflow store are depleted at recession constant rates of baseflow and surface runoff. And mathmatically are expressed as follow:

$$Q_S(n) = (1 - K_s) \times S(n) \tag{5}$$

$$Q_b(n) = (1 - K) \times B_s(n) \tag{6}$$

$$Q_C(n) = Q_S(n) + Q_b(n) \tag{7}$$

where, K and K_s are recession constants of baseflow and surface runoff respectively. $Q_S(n)$ and $Q_b(n)$ are calculated surface runoff and baseflow at time step n, and $Q_C(n)$ is the calculated discharge.

AWBM model totally has five state variables, which are three surface stores, surface runoff routing store and baseflow store. The six parameters of the model are capacities of three surface stores, baseflow index BFI, recession constants of surface runoff and baseflow, K_s and K.

4 Effects Of climate change and human activities on runoff in the Yiluohe River basin

4.1 Natural discharge simulation

Before1970, Yiluohe River Basin can be treated as a "natural basin" as there were less human activities in the period. Therefore, recorded hydrometeorologic data series from 1956 ~ 1969 were used to calibrate and verify AWBM model. The Nash and Sutcliffe efficency criterion (R^2) was employed to evaluate model performance using observed data and model estimates (Nash & Sutcliffe, 1970). Another goodness - of - fit index used is the relative error of volumetric fit (Re), those are mathematically expressed as:

$$R^2 = 1 - \sum_{i=1}^{n} (q_{r_i} - q_{c_i})^2 / \sum_{i=1}^{n} (q_{r_i} - \bar{q}_{r_i})^2 \tag{8}$$

$$R_e = \sum_{i=1}^{n} (q_{c_i} - q_{r_i}) / \sum_{i=1}^{n} q_{r_i} \tag{9}$$

where, q_{r_i} is the observed discharge, q_{c_i} is the simulated discharge, $\bar{q}_{r_i}$ is the mean of the observed discharge during the calibration period and n is the number of data examples.

In order to eliminate arbitary influence of initial values of state variables, the first year of data series is used as warming period, data from 1957 ~ 1965 is used as calibration period, and data from 1966 ~ 1969 is employed to verify model. Monthly recorded and simulated discharge from 1960 ~ 1969 at Heishiguan station are compared in Fig. 2. And the figure indicates that recorded and simulated discharge fit well. Statistical results shows that annual simulated runoff is close to the recorded, the relative error of volumetric fit is about 2.3%. Nash and Sutcliffe efficency critera in both calibration period and verification period are 81.4% and 76.8% respectively.

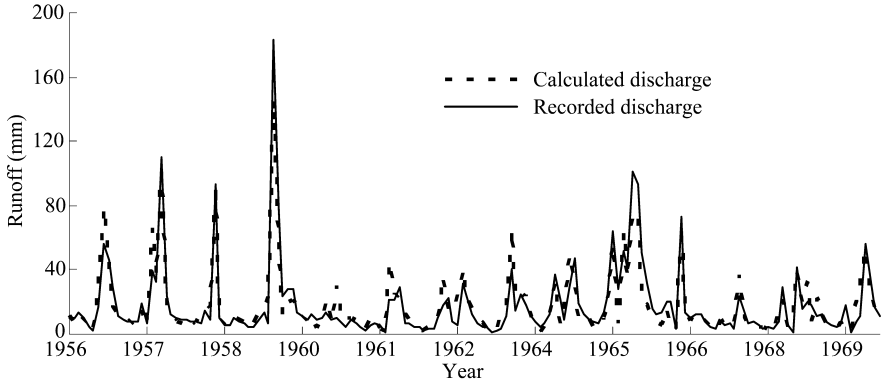


Fig. 2 Monthly recorded and simulated discharge at Heishiguan hydrometric station

4.2 Effects of climate change and human activities on runoff in Yiluohe River Basin

Hydrological variation is consequence of environmental change, which mainly refers to climate fluctuation (or climate change) and changes in underlying caused by human activities.

To keep no change in parameters, natural runoff in human disturbed period were extrapolated with AWBM model and recorded meteorological data in the period. According to the baseline, recorded runoff and simulated natural runoff in each decades, effects of climate change and human activities could be analyzed. And the detailed calculation method is described as follows:

$$\Delta W_T = W_{HR} - W_B \tag{10}$$

$$\Delta W_H = W_{HR} - W_{HN} \tag{11}$$

$$\Delta W_C = W_{HN} - W_B \tag{12}$$

$$\eta_H = \frac{\Delta W_H}{\Delta W_T} \times 100\% \tag{13}$$

$$\eta_C = \frac{\Delta W_C}{\Delta W_T} \times 100\% \tag{14}$$

where, ΔW_T is total change in runoff, ΔW_H and ΔW_C are runoff changes caused by human activities and climate change respectively, W_B are baseline runoff, and W_{HR} and W_{HN} are recorded and natural runoff in the disturbed period respectively. η_H and η_C are affected percentage of human activities and climate change on runoff respectively.

Taking recorded runoff in period from 1955 ~ 1969 as baseline, the difference between baseline and the recorded runoff in human disturbed period include two parts, one part is caused by human activities, and the other part results from climate change. The effects of climate change and human activities on runoff were analyzed and given in Table 1.

Table 1 Effect of climate change and human activities on runoff in Yiluohe River basin

Periods	Recorded runoff (mm)	Natural runoff (mm)	Total reduction (mm)	Climate – induced change		Human induced change	
				(mm)	(%)	(mm)	(%)
baseline	207.6	209.5					
1970 ~ 1979	108.6	151.9	99.0	55.7	56.3	43.3	43.7
1980 ~ 1989	154.5	180.2	53.1	27.4	51.6	25.7	48.4
1990 ~ 1995	72.0	120.4	135.6	87.2	64.3	48.4	35.7
1970 ~ 1995	117.8	155.5	89.8	52.1	58.0	37.7	42.0

Table 1 shows that: ① The recorded runoff in Yiluohe River basin has been markedly decreasing since 1970. And average annual runoff in 1990s is 72.0 mm, which account for about 35% of baseline. ② The natural runoff in each decades is much higher than the corresponding recorded runoff. ③ In 1980s, the absolute runoff reductions caused by climate change and human activities are 25.7 mm and 27.4 mm respectively, which are smaller than that in other ages. ④ For each ages, climate induced runoff reduction is more than 50% of total runoff reduction, and the highest is 64.3%, which occurred in 1990s. ⑤ On average from 1970 ~ 1995, impacts of human activities and climate change are 58.0% and 42.0% of total runoff reduction. And climate changeis main reason of runoff decreasing in Yiluohe River Basin over the past decades.

5 Conclusions

Runoffs in many rivers in China have been decreasing over the last decades. How to identify the contributions of human activities and climate change to runoff variation are a hot topic, as well as a difficulty problems. Australia water balance model was applied in Yiluohe River basin, and results indicate that the model has good performance on monthly discharge simulation of Yiluohe River basin, and climate change is main reason of runoff decreasing the in basin.

Yiluohe River is the largest tributary in lower part of the middle reaches, where is main sources of water resources and flood for the downstream. Changes in runoff and flood of the basin directly relates to utilization of local water resources and safety of flood control in downstream. Therefore, effect of environmental change on storm – induced flood in Yiluohe River basin should be enhenced, which could provide scientific surpport for flood control in downstream.

References

Boughton W. C. 1995. b: An Australian water balance model for semiarid watersheds [J], Jour. Soil and Water Cons., v. 50, no. 5 Sep – Oct, 454 ~ 457.

Boughton W. C., 1984 : A simple model for estimating the water yield of ungauged catchments [R], Inst. Engs. Australia, Civil Engg. Trans., v. CE26, no. 2, 83 ~ 88.

Chen J., Wang, Y. et al., 2005, Assessment method for soil and water conservation measures impact on water resources and sediment in the Loess Plateau. Yellow River press, Zhengzhou,

(in chinese).
Chen X. D.. 1996. Yellow River Hydrology., Yellow River Press, Zhengzhou. (in Chinese)
Nash J. E. and Sutcliffe J. 1970. River flow forecasting through conceptual models, Part 1, A discussion of principles, Journal of Hydrology, 10, 282 – 290.
Ran D., Liu, L. et al., 2000. Runoff and sediment variation & soil and water conservation in region from Hekouzhen to Longmen of the middle Yellow River, Yellow River press, Zhengzhou. p132 – 177, (in chinese).
Wang G., Jing, X. Et al., 2005. Comparison of hydrological models in Qingjianhe River basin. Journal of drainage and irrigation. 67(3): p32 – 37, (in chinese).
Wang G., Chen, J. et al., 2003. Overview of studies on runoff and sediment variation in Gushanchuan River basin on the Loess Plateau. Journal of North – western water resources and water engineering, 54(3): P13 ~ 16, (in chinese).
Xu J., Niu, Y. 2000. Impacts of soil and water conservation and water conservancy engineering on runoff and sediment in rich coarse silt area of the middle Yellow River, Yellow River press, Zhengzhou. p158 – 214, (in chinese).
Zhang S. Li, Z. et al., 1998. Causes and tendency of runoff and sediment variation in rich coarse silt area of the middle Yellow River, Yellow River press, Zhengzhou. p108 – 160, (in chinese).

Changes in Natural Runoff at Lanzhou in the Upper Yellow River in Recent 520 Years and its Forecast *

Wang Jinhua[1], ***Zhang Ronggang***[2], ***Kang Lingling***[1] and ***Wang Yunzhang***[1]

1. Yellow River Institute of Hydraulic Research, Zhengzhou, 450003
2. Hydrology Bureau of YRCC, Zhengzhou, 450004

Abstract: Based on the reconstruction data of Lanzhou station's natural runoff in the upper reaches of the Yellow River in recent 520 years, the cyclical and interim changes of the natural runoff have been analyzed. The analysis shows that Lanzhou station's natural runoff in recent 520 years has roughly gone through 8 wet and 7 dry periods, and it has significant and stable quasi – four years and 30 years cycles. Forecast analysis indicates that the average for the natural runoff in the next 30 years may be around 26.2 billion m3, slightly less than the average for many years; and its changes can generally be classified 4 periods: normal, higher, lower and higher.

Key words: change law, forecast analysis, natural runoff, the upper reaches of the Yellow River, Lanzhou

1 Historical changes of natural runoff in flood season at Lanzhou

The study indicates that the changes in long sequence of hydro – meteorological factors mostly have the more obvious characters with gradualness and cycle. The natural runoff of Lanzhou Station in flood season, and even that in the upper reaches of the Yellow River, and the historical drought and flood change in the Yellow River basin or their various regions also share such characters, just there is a certain difference of the main features of the elements with different regions and different time scales.

1.1 The graduation of natural runoff in flood season

We have to classify the rebuilding 520 – year – sequence according to the data of tree ring, drought and flood classes of the upstream region in order to make statistics of the regulations and characteristics of the changes of the Lanzhou station's natural runoff in flood season in history.

Therefore, the natural runoff in flood season in recent 520 years since 1485 is divided into such 5 grades as the higher, slightly higher, normal, slightly lower, lower, based on graduation criteria stated in the reference and draught and flooding regime of the upper reaches as follows:

Grade 1 (higher water year): $R_i > (\bar{R} + 1.17\sigma)$ (1)

Grade 2 (slightly higher water year): $(\bar{R} + 0.45\sigma) < R_i \leqslant (\bar{R} + 1.17\sigma)$ (2)

Grade 3 (normal water year): $(\bar{R} - 0.45\sigma) < R_i \leqslant (\bar{R} + 0.45\sigma)$ (3)

Grade 4 (slightly lower water year): $(\bar{R} - 1.17\sigma) < R_i \leqslant (\bar{R} - 0.45\sigma)$ (4)

Grade 5 (lower water year): $R_i \leqslant (\bar{R} - 1.17\sigma)$ (5)

In the formulas, $\bar{R}$ is the mean long term natural runoff of Lanzhou station in flood season (26.46billion m^3); R_i is annual natural runoff in flood season, σ is standard deviation.

Based on the above graduation criteria, we can easily rebuild 520 – year – sequence grades since the year of 1485, comparing the Lanzhou station's natural runoff in flood season with the criteria year after year. The results are listed in Table 1.

* Funded projects: The National Natural Science Fund Committee and YRCC of Ministry of Water Resources Yellow River Joint Research Fund (project approved NO.: 50279010).

Table 1 Grade results of Lanzhou station's natural runoff in flood season since 1485

Year	0	1	2	3	4	5	6	7	8	9
148						4	2	2	3	3
149	4	5	4	3	5	4	3	3	3	4
150	3	2	3	3	3	3	3	3	5	4
151	4	4	3	4	4	4	5	4	3	2
152	3	2	3	3	3	3	4	5	5	3
153	3	3	3	4	3	2	3	3	4	3
154	5	5	3	1	1	3	4	4	2	5
155	4	1	5	2	1	1	2	5	1	2
156	2	1	3	4	2	2	3	1	5	4
157	3	3	3	4	4	3	4	3	3	3
158	1	2	4	4	2	3	4	3	3	2
159	2	3	4	5	2	3	4	5	2	2
160	3	3	3	2	2	5	4	3	4	4
161	4	2	3	1	4	3	5	1	2	3
162	2	4	3	2	2	3	3	2	2	4
163	3	4	3	2	3	4	5	3	3	3
164	3	2	2	2	2	3	4	3	5	4
165	2	3	2	2	2	3	5	3	2	1
166	3	4	3	3	4	3	3	5	4	3
167	3	3	1	2	1	2	3	2	2	2
168	3	2	2	3	5	3	5	5	5	4
169	5	3	5	4	5	3	5	4	2	2
170	3	4	4	3	3	1	3	2	1	3
171	2	2	3	3	1	2	2	3	3	2
172	3	2	2	2	2	2	3	1	3	3
173	2	3	3	2	2	2	5	4	1	4
174	3	4	3	3	3	4	4	3	3	5
175	1	2	2	2	3	2	4	3	5	5
176	2	3	3	3	3	3	2	4	2	3
177	3	5	5	5	3	4	1	3	5	2
178	3	2	3	4	3	2	3	2	1	3
179	2	1	2	5	3	3	4	3	2	3
180	3	2	3	2	1	2	1	2	2	2
181	2	2	2	3	3	2	1	3	3	2
182	2	3	3	3	4	5	4	4	4	3
183	2	3	4	4	5	2	2	3	5	3

Continued to Table 1

Year	0	1	2	3	4	5	6	7	8	9
184	3	1	1	2	1	3	1	1	1	3
185	3	1	2	4	3	3	2	4	4	1
186	3	5	4	3	3	3	4	4	3	2
187	2	4	5	1	2	1	4	4	4	5
188	4	3	3	2	3	1	2	2	3	1
189	3	4	5	4	1	5	4	3	2	1
190	4	3	3	4	3	2	2	1	3	5
191	3	2	3	3	1	2	3	2	3	3
192	4	3	2	3	2	4	4	4	5	4
193	4	1	3	2	4	1	3	2	2	4
194	1	5	5	1	4	3	1	3	4	1
195	4	2	4	4	4	1	5	5	3	3
196	4	2	4	2	1	4	3	1	2	5
197	5	4	4	4	4	1	1	5	3	3
198	4	1	3	1	2	2	3	4	4	1
199	4	5	3	3	5	5	5	5	5	3
200	5	5	5	5	5					

Through the statistics about natural runoff higher and lower grades listed in Table 1, we can get the climate probability in Table 2, which shows the different gradual runoff occurred in Lanzhou for nearly 520 years.

Table 2 The critical value and characteristic statistical table for different gradation of Lanzhou station flood season natural runoff for nearly 520 years

Gradation	Form	Critical value	Years	Probability (%)	The average runoff (0.1 billion m^3)
1	Hight water year	$R_i > 318.59$	56	10.8	341.2
2	Slightly high water year	$285.38 < R_i \leqslant 318.59$	118	22.7	285.7
3	Normal water year	$243.86 < R_i \leqslant 285.38$	176	33.8	266.8
4	Slightly low water year	$210.65 < R_i \leqslant 243.86$	105	20.2	228.2
5	Low water year	$R_i < 210.65$	65	12.5	187.2

The data in Table 2 show that there are 56 years of higher water, 10.8% of the total number of years, its flood season natural runoff averages in 34.12 billion m^3, which is more 28.9% than that of the mean annual natural runoff in flood season. There are 65 years of lower water, slightly longer than those of the higher, 12.5% of the total years. It is approximately 55% of the mean natural runoff of the higher, moreover, a little smaller 29.3% than the mean for many years, the higher water years and the lower amount to 22.7% and 20.2% respectively. The highest number appeared in normal years, totaling of 176, with the occurrence probability of 33.8%.

1.2 Change of high, low water in flood season by stages

Fig. 1 gives the evolution curves of natural runoff and its 11 – year moving average in the upper Yellow River above Lanzhou. Combining correlative data, it is not difficult to see that the Lanzhou natural runoff in flood season changes more obviously by the stage in history, and went through the periods of 8 lower water and 7 higher water in roughly 520 years since 1485 (Table 3).

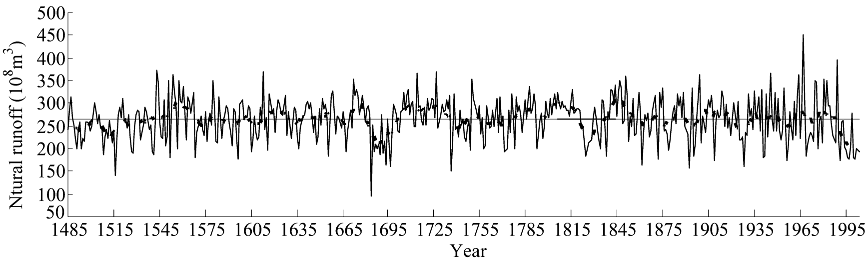


Fig. 1 Lanzhou natural runoff in flood season (fine line) and its 11 – year moving average curve (thick line)

Table 3 Lanzhou near a 520 – year renewal periods of higher and lower natural runoff features **Unit: 0.1 billion m^3**

Low water period								
from	to	years	average runoff	different gradation probability (%)				
				1	2	3	4	5
1485	1545	61	250.9	3.3	9.8	47.5	26.2	13.1
1546	1567	22	282.4	27.3	31.8	9.1	18.2	13.6
1568	1612	45	256.3	2.2	22.2	37.8	28.9	8.9
1613	1680	68	273.6	7.4	30.9	39.7	14.7	7.4
1681	1701	21	228.9	0	19.1	23.8	19.1	38.1
1702	1735	34	290.6	11.8	44.1	41.2	2.9	0
1736	1777	42	256.5	7.1	16.7	40.5	19.1	16.7
1778	1820	43	284.9	11.6	44.2	34.9	4.7	4.7
1821	1837	17	244.9	0	17.7	35.3	35.3	11.8
1838	1856	19	292.4	36.8	15.8	36.8	5.3	5.3
1857	1898	42	260.1	14.3	16.7	26.2	31.0	11.9
1899	1920	22	273.0	13.6	22.7	45.5	13.6	4.5
1921	1932	12	250.9	8.3	16.7	25	41.7	8.3
1933	1988	56	269.5	21.4	16.1	17.9	32.1	12.5
1989	2004	16	218.0	6.3	0	18.8	6.3	68.8
average		32	250.0	5.5	15.2	35.5	25.8	18
average		37.7	278.8	15.9	29.9	32.2	14.8	7.2

Table 3 shows that:

(1) Lanzhou natural runoff in flood season underwent 7 higher water periods in recent 520

years, and its average duration was 37.7 years, with the longest period of 68 years, and the shortest period of 19 years. The average natural runoff in flood season was 27.88 billion m^3 in the periods, 5.4% slightly more than the normal year average (26.46 billion m^3). The probability of the slightly higher water year (including higher water year) is 2 times more than that of the slightly lower (including lower year).

(2) Lanzhou natural runoff in flood season underwent 8 lower water periods in nearly 520 years, its average duration was 32 years, relatively shorter than the higher periods, the longest period is 61 years, and the shortest period is 12 years. The average natural runoff in flood season was 25.0 billion m^3 in the periods, 5.5% slightly less than the normal year average (26.46 billion m^3), and the probability of the lower water year (including slightly lower water year) is 2.12 times more than that of the higher (including slightly higher year). Especially the probability of the lower water year reaches as high as 18%, but the probability of the higher water year appeared only 5.5%, not reached 1/3 of the former.

The above results indicated that the period characteristic of Lanzhou natural runoff changes in flood season in the upper reaches of the Yellow River is very obvious. It also can be seen, at present, It is still in the lower water period beginning of 1989, and has been going on for 16 years until 2004, approximately 50% of the average duration of the lower period.

Therefore, the period of the lower at present has the possibility to be continuing in certain years before changing over to the higher.

1.3 The periodic changes of natural runoff

The periodic inter – annual change of hydrometeorology factors was confirmed as a major law by many studies and the actual data. The analysis of power spectrum and variance in the literature 5 is, at present, a better method in researching the main period of the factor time variation.

1.3.1 The analysis of power spectrum

The analysis of power spectrum is a kind of frequency – domain analysis method based on Fourier transform, the procedure is to decompose the total power of the time series to the different frequency components, get the main cycle according to diagnosing the variance contribution of the different frequency waves of the sequence, thus determine the primary frequency of the main cycle, namely the remarkable cycle concealed in the sequence.

Based on the method about obtaining the remarkable cycle in the literature 5, we analyzed the sequence of the Lanzhou natural runoff in flood season in the upper reaches of the Yellow River. Continual power spectrum can be get indirectly by self – correlation function as the power spectrum and self – correlation function are Fourier switch's important characters. The calculate steps are as the following:

First, calculate the self – correlations coefficient.

The self – correlations coefficient r(j) of sequence x_i, as the most lag time length is m, can be got by the following function:

$$r_{(j)} = \frac{1}{n-j}\sum_{i=1}^{n-j}\left(\frac{x_i - \bar{x}}{s}\right)\left(\frac{x_{i+j} - \bar{x}}{s}\right) \tag{6}$$

where, $j = 0, 1, 2, \cdots, m$ and $\bar{x}$ stands for the mean of the sequence, S is standard deviation of the sequence.

Second, calculate the coarse power spectrum estimated value

$$s_0 = \frac{1}{2m}\left[r_{(0)} + r_{(m)}\right] + \frac{1}{m}\sum_{j=1}^{m-1} r_{(j)} \tag{7}$$

$$s_k = \frac{1}{m}\left[r_{(0)} + 2\sum_{j=1}^{m-1}\cos\frac{k\pi j}{m} + r_{(m)}\cos k\pi\right] \tag{8}$$

$$s_m = \frac{1}{2m}\left[r_{(0)} + (-1)^m r_{(m)}\right] + \frac{1}{m}\sum_{j=1}^{m-1}(-1)^j r_{(j)} \tag{9}$$

Third, smooth the coarse power spectrum estimated value.

There is a certain error between the estimated value by the above method and the real spectrum, and then we should deal with the rough power spectrum estimated value with the smoothing method to obtain continuous spectrum value. Hanning smoothing factor used for the above smoothing, the factors are as follows:

$$s_0 = 0.5s_0 + 0.5s_1 \quad (10)$$

$$s_k = 0.25s_{k-1} + 0.5s_k + 0.25s_{k+1} \quad (11)$$

$$s_m = 0.5s_{m-1} + 0.5s_m \quad (12)$$

Forth, determine cycle.

The relation between the cycle (T) and the wave number (K) as follows:

$$T = 2m/k \quad (13)$$

Fifth, test of significance.

In order to determine the estimated value that is the most prominent in spectral band and to understand the statistical significance of the value, we need to calculate a standard process spectrum for a comparison. According to the sequence backward from the autocorrelation coefficient $r(1)$, we will adopt the red or white noise standard spectrum. The calculation shows in the sequence red noise standard spectrum shall be used for significant test.

After the calculation, it has obtained the power spectrum value (as shown in Fig. 2) of the Lanzhou natural runoff in flood season since 1485.

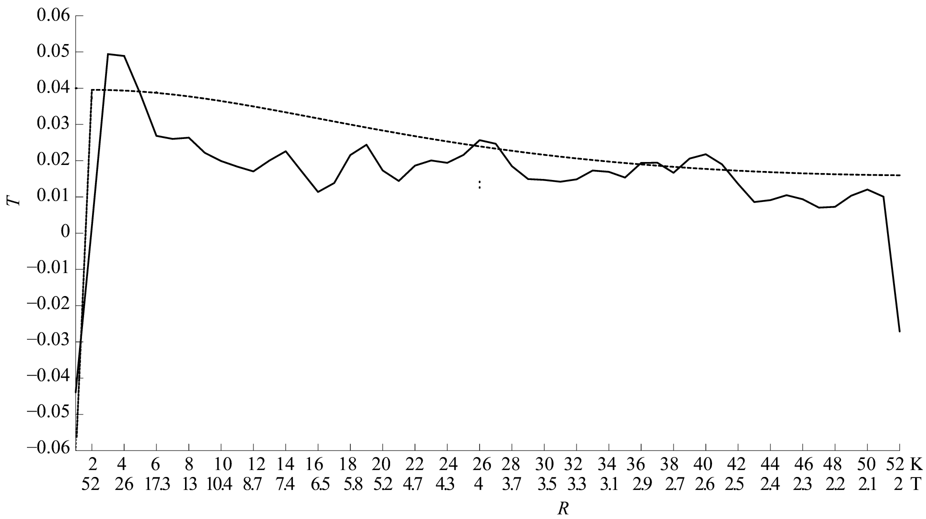


Fig. 2 The power spectrum (solid line) of the lakzhou flood season natural runoff sequence and the red noise standard spectrum $\alpha = 0.05$ (dotted line) figure

(The y − coordinate is the spectrum value, x − coordinate k is the wave number and T is a cycle) At the same time, Fig. 2 gives the power spectrum of Lanzhou's natural runoff sequence in flood season and the critical value of the red noise inter − scorers reliability $\alpha = 0.05$. The power spectral curve estimated peak point exceeding that of the standard spectrum illustrated that the corresponding cycle is notable. The cycle sequence is the first significant cycle. The second point, the third point … exceeding the standard spectrum summit in Fig. 2 are respectively for the second, third … notable cycle. Obviously, the estimated value of the power spectrum in 26 ~ 34.7 years cycle length is a more obvious peak value than that of the red noise standard spectrum ($\alpha = 0.05$), which shows that the period of the quasi 30 years is its first significant cycle and the other cyclical changes with a quasi − 4 (4, 3.9 years) and a benchmark 3 (2.9, 2.8, 2.6 years).

1.3.2 Variance analysis

The method of the variance analysis is also adopted herein for the period of Lanzhou's natural runoff sequence in flood season in nearly 520 years, and the results are showed in Table 4.

Table 4 The results of variance analysis with Lanzhou natural runoff in flood season

Serial number	Cycle (year)	F value	F ratio
1	4	4.401	2.096
2	23	2.166	1.547
3	26	2.061	1.472
4	33	1.794	1.380
5	8	2.267	1.334
6	85	1.481	1.234
7	116	1.476	1.23
8	60	1.446	1.205
9	16	1.773	1.182
10	232	1.4	1.167
11	94	1.4	1.166
12	80	1.399	1.166

It can be seen from Table 4 there are also more pronounced cyclical in the natural runoff changes in flood season for nearly 520 years. The significant cycles in which the confidence(α) is more than 0.05 (i.e. $F > 1.20$) are 4 years, 23 years, 26 years, 33 years, 8 years, 85 years and 7 years. it is not hard to see that the above significant cycles include the main cycles calculated by the method of the power spectrum and that two methods are consistent with the overall results, which clearly shows that the cycles are significant and stable.

2 Natural runoff in flood season change trend analysis

Consulted to a large number of domestic and foreign literatures, it is easy to see that there is not very mature approach to forecast the runoff tendency.

The Table 4 above indicates there is more notable cyclical nature in the evolution of the Lanzhou natural runoff in flood season in the past 520 years. So we can use the period superposition extension method to analyze the change tendency of the Lanzhou natural runoff in flood season on the upper reaches of the Yellow River.

After statistical analysis, we found that the fitting results of the superposition value superimposed by the six notable periods (4 years, 85 years, 94 years, 33 years, 23 years and 26 years) and the actual runoff were better, and in 507 years from 1485 to 1991 the correlation coefficient is 0.76, and the departure symbol of the natural runoff in the 77% 507 years coincided.

Meanwhile, we did the extension trial forecast using the reserved 13 years data since 1992 in order to test the effects of the extension prediction (Table 5).

Table 5 The effects statistic table of the period superposited extension trial forecast runoff volume Unit: 0.1 billion m^3

Year		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Rounoff	Forecast	293.2	277.4	196.1	240.7	206.2	225.5	256.6	279.3	242.7	209.9	234.8	226.9	238.8
	Fact	260.2	261.3	201.7	197.0	181.5	176.2	203.7	279.6	179.1	176.3	198.6	196.9	192.5
	Differenct/%	12.7	6.2	−2.8	22.2	13.6	28.0	26.0	−0.1	35.5	19.0	18.2	15.2	35.5
High and low gradation	Forecast	2	3	5	4	5	4	3	3	4	5	4	4	4
	Fact	3	3	5	5	5	5	5	3	5	5	5	5	5
	Judgment	half right	right	right	half right	right	half right	wrong	right	half right	right	half right	half right	half right

Table 5 shows the accuracy rate is not high for quantitative forecast demand, and if it is right that determining the relative error is less than 30% , there are 11 years, i. e. 84.5% of the relative accuracy rate. There are 9 years, in which, the relative error is less than 25% , and its relative accuracy rate is 69.2% . There are 5 years, in which, the relative error is less than 15% , and its relative accuracy rate is only 38.5% .

Regarding the extra long – range forecast, if we only hope that the trend of the forecast is correct, the effects of this trial forecast is better. Taking wet year (including slightly wet year), normal year and dry year (including slightly dry year) as the standard, there is only one effort made in 1998 in the trial forecast, thus, its accuracy rate is 92.3% .

Thus, the results which were drawn from the analysis of the change tendency of Lanzhou natural runoff in flood season in the next 30 years by using the method of period superposition extension still has some reference value.

Fig. 3 shows the future change tendency of Lanzhou natural runoff fitted and forecasted in flood season since 1990 Table 6 has listed Lanzhou natural runoff tendency in the future 30 years since 2005.

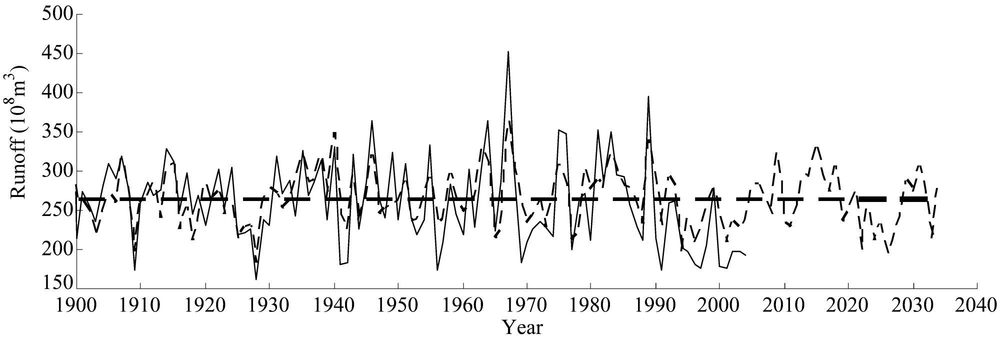


Fig. 3 Lanzhou natural runoff fitting since 1990 and its next 30 years extension curve

Table 6 The change tendency of Lanzhou natural runoff in flood season in the next 30 years

start	end	years	trend	average runoff (0.1 billion m^3)	high and low water gradation				
					1	2	3	4	5
2005	2012	8	Normal water periods	265.1	1	0	5	2	0
2013	2018	6	high water periods	300.3	1	4	1	0	0
2019	2028	10	low water periods	231.3	0	0	3	5	2
2029	2034	6	high water periods	272.4	0	2	3	1	0

It can be seen from Fig. 3 and Table 6, the change of Lanzhou natural runoff in the future still displays obvious stages. Combining the above analyses of the stage we can know that in fact it is still and will continue at the stage in low water period, generally we can believe:

(1) The average of Lanzhou natural runoff in flood season in the next 30 years may be about

26.2 billion m^3, close to the mean annual runoff, but slightly little. And its change tendency may be roughly divided into four stages: normal, abundant, low and abundant water year.

(2) In the 8 years until 2012, normal and dry years may appear mostly, but without exception of the possibility of individual wet years.

(3) In the 6 years from 2013 to 2018, the average runoff will amount to about 30 billion m^3, it will be the annual average of 10% ~20% more accounts. During the 6 years it will be mainly the slightly wet year with wet and normal years, and there may be the possibility of no appearance of dry and slightly dry years.

(4) 10 years from 2019 to 2028, the average natural flow will only be about 23 billion m^3, it will be slightly less 10% ~20% than the average. During the ten years it will be mainly the slightly dry year with normal and dry years, and there may be the possibility not to appear wet and slightly wet years.

(5) From 2029 to 2034 years, its average natural runoff will be about 27.2 billion m^3, slightly more than the average, During the 6 years, mainly normal and slightly wet years with slightly dry years, and there may not be the possibility to appear wet and dry years.

3 Summary

(1) In this paper, using the rebuilding Lanzhou 520 – year natural runoff data and statistical methods, we analyzed the historical evolution and the next 30 – year trend of the Lanzhou natural runoff in the upper reaches of the Yellow River in flood season, and the results obtained from the analysis can provide a basis for the basin planning, rational development and use of water resources and strategic regional flood and drought control.

(2) Due to limitation of the data, skills and specialized knowledge of the project team members, the results are preliminary, especially for the next 30 years natural runoff trend analysis, it is only some preliminary understanding, and the changes of abundant and low water in the basin are synthetically effected by many factors. Therefore, on the one hand, the Yellow River resources management and the dispatch must be strengthened according to this analysis and annual runoff tendency forecast; on the other hand, the departments concerned also should positively organize various specialized technical staffs to further strengthen the method research on the runoff change rule and its forecast in the upper reaches of the Yellow River.

References

Wang Yunzhang, Wu Xiangdiang. Discussion on Water and Sediment Series Extension. Stage and Periodic Change of Yellow River Middle Reaches, Scientific Research Collection of Yellow River Institute of Hydraulic Research of YRCC (the fourth volume), China Environmental Science Publishing House.

Wang Yunzhang. The Lengthening and its Change of the Runoff Series of the Yellow River Section from Lanzhou to Sanmenxia, Hydrologic Science and Technology Information, 1993(3).

Wang Yunzhang. The Upper and Middle Reaches of the Yellow River Inflow Series Lengthening and its Change. Shandong Weather, 1996(4).

Chinese Drought and Flood Grade Distribution Map for Recent 500 Years, chief edited by Central Weather Bureau Meteorology Academy of Science. Map Publishing House, January, 1981.

Wei Fengying, The Modern Climate Statistics Diagnosis and Forecast Technology, Beijing, Meteorological Publishing House, Oct. 1999.

Comparative Analysis on Evaporation Experiment in Huaibei Plain and the Lower Yellow River Area

Zhang Letian and ***Hao Zhenchun***

Water Environment Institute of Hohai University, Nanjing, 210098, China

Abstract: This paper conducted experiment and research on the two different evaporation data of Huaibei plain and the Lower Yellow River area, studied the different underlying surface condition and mode of evaporation, the water consumption and its trend of change were calculated and analyzed. The underlying surface condition of the Lower Yellow River area is very complex with water surface, meawhile distributing great deal bare bottomland and crops, while Huaibei plain is an alluvial plain deposited by various floods occurred both in the Yellow River and Huaihe River, there has difference on soil texture and recharging modes of groundwater and thus caused different influence of phreatic water on evaporation. This paper adopted theoretical arithmetic and physical model experiment research methods, using Pen – man – Monteith Formula recommended by FAO to calculate potential evaporation standing for water surface evaporation, as the great meteorological data volume needed for Pen – man Formula, this paper simplified and validated the rationality, meanwhile using Avey Yang Knoff empirical formula to calculate phreatic evaporation of the two areas and then to seek the changing laws and trends of soil evaporation with phreatic depth.

Key words: the Lower Yellow River, Huaibei plain, evaporation experiment, phreatic evaporation

1 Foreword

Nowadays, global water resources problems have been a key factor to affect and limit seriously human well – being survival and development, so it fairly needs to conduct reasonable and optimized allocation of water resources available for seeking good solutions on water shortage and supply – demand contradiction. With the speed economic development and increasing effects of human activities on climate, the climatic environment took place great changes than the past which results in the corresponding changes of human living environment, and hereby it needs to adjust the methods of water resources allocation. As one of the most important part of water circulation, evapotranspiration is deeply influenced by climate changes, therefore to explore and master the laws has increasing significance for water resources evaluation and optimized allocation in the context of global climatic changes.

However, under different condition of underlying surface, the effects of different climate on evaporation are different correspondingly, so it ' s highly necessary to conduct research on soil evaporation in different regions with various soil types. This paper analyzes the laws of phreatic evaporation based on the evaporation experiment in the Lower Yellow River area and Huaibei plain.

2 Equipments for evaporation experiments

In this experiment, we adopted the form of soil pillar evaporation and selected Huayuankou hydrological station on the Yellow River and Wudaogou hydrological station in Bengbu City of Anhui Province as experiment stations. Due to the obvious diversity of underlying surface and climate condition between the Lower Yellow River area and Huaibei plain, and the locations of the two areas can fairly represent their climate traits, the experimental results are comparable and illustrate a good prospect of application and extension.

2.1 Equipments of Huayuankou hydrological station in the Yellow River

The experimental soil pillar was built on the ground with the thick walls for heat insulation, the sun can blaze down without any screening objects and the height of trees around the pillar is below 20 cm, therefore, the effect of thermal environment from soil pillar may be ignored.

It needs to build 5 soil pillars in the experiment, making concrete soil boxes with inner size of 1 m × 1 m × 1.25 m. The phreatic depth of the pillars is 40 cm, 60 cm, 80 cm and 100 cm respectively with stable phreatic surface in the experiment. Considering the dissymmetrical settlement after the build of soil pillars, the steal concrete bases of 30 cm were poured, in view of heat insulation, we adopt the soil box with concrete of 30 cm thick and coat with whitewash to reduce absorption of solar radiation, meanwhile making rainproof bevel on the upper edge of soil pillars to prevent the rain over the range of soil surface into soil pillars, the inner wall and bottom was washed with bitumen paint of 2 mm thick as waterproof treatment. There was one water level observation pipe with graduation on soil column's ektexine, which was connected from bottom with soil columns to reflect the water level's changes of soil columns. There was one water - level observation pipe (transparent organic glass pipe) connected with the bottom setting on the outer wall of each pillar to reflect stage variation of phreatic water. It also set up central water compensation pipe (PVC pipe with diameter of 10 cm) in the pillars used for phreatic water recharge, and 5 soil - moisture observation pipes with descending depth (PVC pipe with diameter of 5 cm) to observe the soil moisture at different depth, meanwhile set up drainpipes on the bottom of soil pillars to discharge redundant water (soil pillar installation shown in Fig. 1).

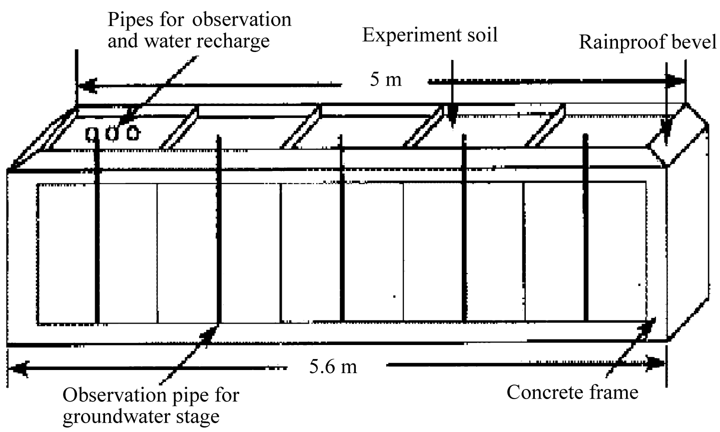


Fig. 1 Equipment installation of experimental soil pillar

Observation items in the experiment including soil moisture at different depth in the soil pillars, pheatic evaporation, air temperature, humidity, precipitation, water surface evaporation observed with E601 evaporation pan.

2.2 Equipment of Wudaogou hydrological station on the Huaihe River

Wudaogou station is located in the north 20 km from Bengbu City of Anhui Province (see Fig. 2), whose dynamic observation field for phreatic water consists of 62 lysimeters and underground observation room with inner diameter of 11 m and depth of 6.5 m. The lysimeter set up in the observation field is a kind of instrument to measure phreatic evaporation, precipitation infiltration and condensing capacity and carry out the whole evaporation experiment, it is mainly composed of the cylinder part with functional recharge and evaporation and water recharging device to control and observe water table artificially, the two parts connected by communicating pipe. There placed local undisturbed soil sample in the experimental cylinder based with gravel and sand bed as filtering layer, where the manual – control fixed water table is formed by the water recharging parts. When the water level reduces with the evaporation, the offset of the automatic water – recharging bottle appears on the water surface and begins to recharge water into controlling phreatic cylinder, the container will stop recharging water until the water table rises to the fixed position. The quantity of recharged water equals evaporation of groundwater, and then based this value to convert into phreatic evaporation intensity per unit area and per unit time.

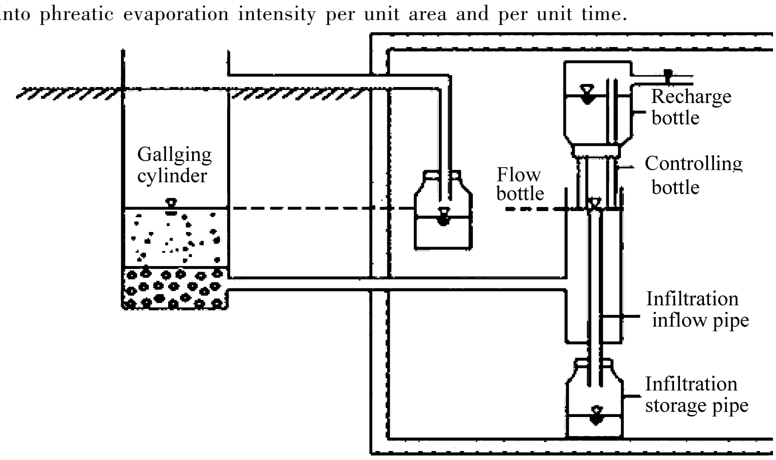


Fig. 2 Structure of lysimeter

In this research, we adopted the phreatic depth of soil pillars for experiment with 40 cm, 60 cm, 80 cm and 100 cm. In addition, Wudaogou hydrological station provides with self – contained hydro – meteorological observing devices and long series data for many years.

3 Comparison of climatic elements

The lower reaches of the Yellow River cross through Henan and Shandong Provinces, the area of both sides lie on Huang – Huai – Hai plain, belong to semi – humid and semi – arid climate characterized as less rainfall of about 500 mm annually, influenced by monsoon climate so that it is intensely hot in summer with alternative drought and waterlogging, while during winter it is severe cold and windy with clear wet and dry season, there has rare precipitation in dry season with long duration of low – flow period.

The Huaibei plain lies in the climate transition zone between north and south of China, belongs to warm temperate zone with semi – humid climate and prevailing monsoon, when winter monsoon blows from continent to ocean and the climate will be cold and dry, while summer monsoon blows from ocean to continent and the climate will be warm and humid. The average air temperature of the whole year is between 14 ~ 15 ℃ and descending from south to north but with small inter – annual variation. The mean annual precipitation is 869.6 mm in this area with small inter – annual changes that there have 3 ~ 4 times of difference between high and low precipitation year.

In the experiment, we choose climate elements of the same period to compare between Huayuankou and Wudaogou stations. The comparisons of temperature, humility, precipitation and water surface potential evaporation in September of 2005 are shown in Fig. 3 ~ Fig. 6, they show the climatic elements at Huayuankou and Wudaogou stations in this month respectively with precipitation of 98 mm and 115.9 mm, mean air temperature of 23.04 ℃ and 23.3 ℃, mean relative humidity of 73.2% and 86.8% , potential evaporation of 86.5 mm and 84.5 mm, we can see that there is small difference in temperature between the two areas, but the humidity of Wudaogou station on the Huaihe River is obviously larger than that of Huayankou station on the Yellow River, and the precipitation in summer and even in the whole year of Wudaogou station is relatively much more than that of Huayuankou station, thus the potential evaporation of Huayuankou station should be higher than that of Wudaogou station. It can be found out from observed data that, although the two areas are not far distant and with same trend of climatic changes showed from long serial data in recent years, Wudaogou hydrological station in Huaibei plain is obviously moister than that in Huayuankou station.

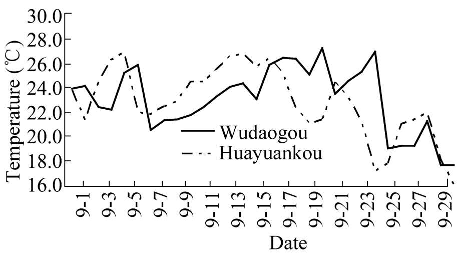


Fig. 3 Temperature

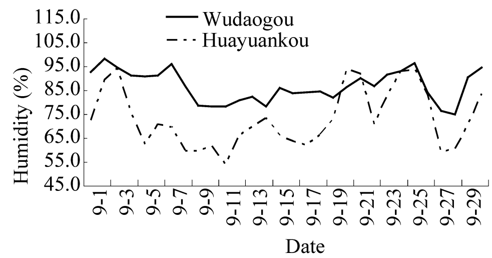


Fig. 4 Humidity

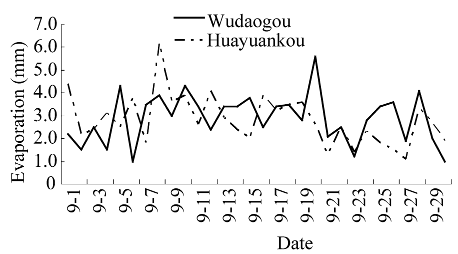


Fig. 5 Water surface potential evaporation

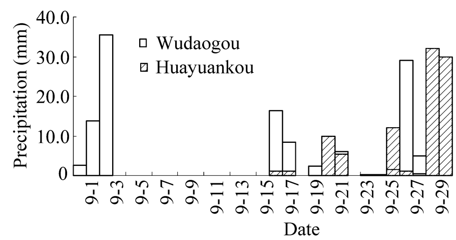


Fig. 6 Precipitation

4 Calculating method on potential evaporation and parameters comparison

In order to verify theoretically observed evaporation data, we conduct the calculation on daily potential evaporation based meteorological data series observed in the same term, compared with observed data and then to verify the representative of observed water surface evaporation data to potential evaporation. The Peng Man formula that recommended FAO is adopted in the theoretical calculation.

$$ET_0 = \frac{0.408(R_n - G) + \gamma \dfrac{900}{T_{\text{mean}} + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

where: ET_0 is the evaporation capacity of reference crop, mm/d; R_n is the net radiation, MJ/(m^2 · d) , G is the heat flux of soil, MJ/(m^2 · d) ; T_{mean} is daily mean air temperature at 2 m height above ground level, ℃ ; u_2 is the wind speed at 2 m height above ground level, m/s; e_s is mean saturation pressure, kPa; e_a is actual water pressure, kPa; Δ is the slope of air pressure curves, kPa/℃ ; γ is the meteorology constant, kPa/℃ .

Pen – man – Monteith Formula requires the data of the lowest, highest and average temperature, sunlight, wind speed, the lowest, highest and average humidity, however, it' s unpractical to obtain all the data in the actual calculation, so the lacking data can be reckoned or simplified in the circumstances of ensuring the main factors of temperature and humidity: ①the heat flux of soil G will be ignored for its little influence on annual daily calculation; ② outer space radiation can be calculated according to the latitude and longitude of the experiment place, the net radiation R_s can be reckoned by $R_s = K_{rs} \cdot \sqrt{T_{max} - T_{min}} \cdot R_a$, where K_{rs} is the coefficient, usually taking 0.17 for inland areas; ③ the wind speed is adopted local mean annual wind speed, taking 3.7 m/s for Huayuankou station, 2.5 m/s for Wudaogou station.

By establishing the direct relationship between temperature and humidity, the daily potential evaporation can be calculated from the observed data of the two areas. Fig. 7 and Fig. 8 illustrates the comparison of observed and calculated data on potential evaporation at Wudaogou and Huayuankou station in September of 2005, we can see that the changing trends of observed and calculated values in the two stations are almost identical with correlation coefficient of 0.783 and 0.763 respectively. The calculated daily mean potential evaporation data in the experimental period is fairly close to the observed data, which shows that the Peng Man Formula is suitable for the calculation of potential evaporation both in the two regions. In view of larger difference between calculated and observed data, after analyzing we think that the reason lies in the main factors of temperature and humidity adopted in the formula, in case of unusual weather such as strong wind and thunderstorm happens, the mathematic simulation method will lose intended precision.

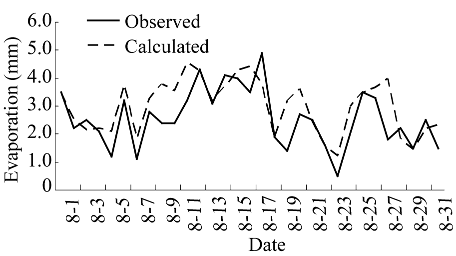


Fig. 7 Comparison of observed and calculated data on potential evaporation at Wudaogou station

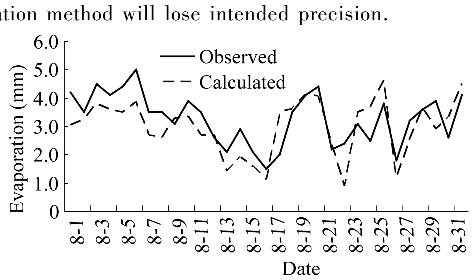


Fig. 8 Comparison of observed and calculed dataf on potential evaporation at Huayuankou station

5 Calculating method on phreatic evaporation and parameters comparison

Phreatic evaporation is mainly influenced by potential evaporation and phreatic depth, when the phreatic depth low, the under - layer phreatic water level can fully provide water for the soil, the intensity of phreatic evaporation will increase with the increasing of potential evaporation until reaches the upper limit of water conveyance capacity of soil, at the moment, if the potential evaporation continues increasing, the water conveyance capacity wouldn't satisfy water consumption for the upper - layer of soil whose soil moisture will lose correspondingly, whereas water conductivity will decrease which results in the decrease of intensity of phreatic evaporation. With the increase of phreatic depth, water lifting resistance gradually increased and the intensity of phreatic evaporation continuously decreased, when the surface phreatic depth reaches certain degree, dry soil layer formed on the soil surface, here the influence of potential evaporation on phreatic evaporation will become little in some extent.

The laws above mentioned have been embodied partially in the experiment conducted at Huayuankou and Wudaogou station, for instance, in the experiment on the underground phreatic depth of phreatic layer, the phreatic depth at locations of 40 cm and 60 cm is almost the same with the changing trend of surface evaporation, the change at 60 cm deep in the soil pillar is lightly less than that at 40 cm, but for the soil pillar with 80 cm and 100 cm depth, the dry layers are formed on their surfaces, it found according to observed data that the phreatic evaporation is relatively low.

Phreatic evaporation is calculated by Avey Yang Knoff Formula

$$E = ET_0 \left(1 - \frac{H}{H_0} \right)^n \tag{2}$$

where: E is daily mean phreatic evaporation in the time interval Δt, m/d; ET_0 is daily mean surface evaporation in the time interval Δt, m/d; H is the average depth of groundwater in the time interval Δt, m; H_0 is the depth of groundwater (limited depth) when phreatic evaporation stops Δt, m, taking 4 m for limited depth both in the two experimental stations; n is the index related to soil and climate usually taking value of 1 ~ 3 and then adjusted by SPSS software during calculation. In the condition of fairly close between calculated and observed data; n is 2.20 at Huayuankou station and 2.33 at Wudaogou station, correspondingly the calculated phreatic evaporation at the same phreatic depth in Huayuankou station is slightly larger than that in WuDaogou station, which accords with the observed phreatic evaporation.

It can be seen from the comparative figures of phreatic evaporation at different phreatic depth that the calculated values are fitting well to actual values, the correlation coefficients are all above 0.750 (see Fig. 9 ~ Fig. 10).

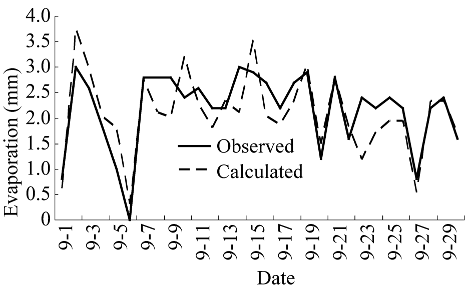


Fig. 9(a) Phreatic evaporation of 0.4 m depth in Wudaogou

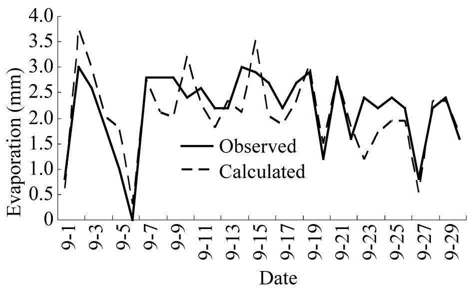


Fig. 9(b) Phreatic evaporation of 0.4 m depth in Huayuankou

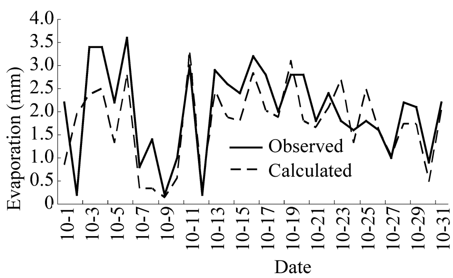


Fig. 10(a) Phreatic evaporation of 0.6 m depth in Wudaogou

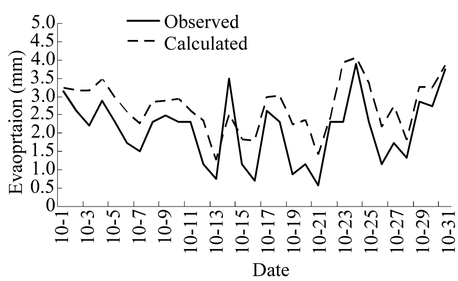


Fig. 10(b) Phreatic evaporation of 0.6 m depth in Huayuankou

6 Conclusions

The observed phreatic evaporation in the same period but with different weather condition was obtained from the experiment conducted at Wudaogou and Huayuankou hydrological stations, hereby analyzed the discrepancy between observed and theoretic evaporation by mechanism, adopted the empirical formula for calculation and compared with observed data, then validated the rules of surface evaporation and phreatic evaporation and obtained the better results. ① Owning to the humidity of the Lower Yellow River is obviously less than that of the Huaibei plain, and also considering the factors of temperature, rainfall and wind speed, so the potential evaporation of the Lower Yellow River area is obviously stronger than that of the Huaibei plain. ②With the increase of phreatic depth, water lifting resistance increased and the intensity of phreatic evaporation decreased, through comparison of the experimental data of the two areas, although potential evaporation of the Lower Yellow River is obviously stronger than that of the Huaibei plain, under the condition of larger preatic depth, the preatic evaporation of the two areas is both slight. ③Soil pillar experiment set the same phreatic depth in the two areas, the comparison of experimental data shows that the phreatic evaporation of the Lower Yellow River is slightly higher than that of Huaibei plain, but considering the actual preatic depth in the Lower Yellow River is obviously deeper than that of Huaibei plain and the setting value in experiment, we can conclude that the phreatic evaporation of the Lower Yellow River is slightly less than that of Huaibei plain in practice. In addition, the calculating parameters of phreatic evaporation under the two different climatic conditions were obtained in this experiment, which providing reference basis for phreatic evaporation calculation in the two areas.

References

Allen R G, Pereira L S, Raes D, Smith M. Crop Evapotranspiration – Guidelines for Computing Crop Water requirements[Z]. FAO Irrigation and Drainage, 1988.

Qi Rengui, Su Yuezhen. To Ascertain Parameters by V. A. Kovda Phreatic Evaporation Formula [J]. Irrigation and Drainage, 1998(2):47 – 50.

Liu Xinren. Soil Hydrology[M]. Nanjing: Hohai University Press, 1998.

Lei Zhidong, Yang Shixiu, Xie Senchuan. Soil Water Mechanics[M]. Beijing: Qinghua University Press, 1988.

Liu Yu, L. S. Pereira. Calculation Methods for Reference Evaporation with Limited Weather Data [J]. Journal of Hydraulic Engineering, 2001(2).

Preliminary Study about the Ecological Security Problem of the Soil Erosion Area in China

Dang Weiqin

Suide Experimental Station for Soil and Water Conservation, the Yellow River Conservancy Commission, Suide, Shaanxi, 718000, China

Abstract: The main ecological disaster in the soil erosion area in china is flood disaster, reduction in arable land, land degradation, water resource shortage and pollution, biodiversity decrease and so on. The main countermeasures are as follows: Firstly, developing the restoration capability of ecology and speeding up the comprehensive management of water and soil conservation. Secondly, controling soil erosion by law. Lastly, establish a scientific and reasonable soil erosion and ecological compensation legal system. In this paper we established a three – level and three security ecological security evaluation system that contains 15 indicators about soil erosion. We established the necessary ecological security early warning and protection system based on the evaluation system in soil erosion area.

Key words: soil erosion, ecological security, ecological construction, evaluation system, early warning and forecast

Ecological environment has gradually increased as ecological security issues in our country. It has become an important aspect of national security. It is the most basic function of government in every country to defense the national security and maintain the life of the national socio – economic normal and stability. National and military security is the primary concern. With socio – economic development, more and more factors affect national security. Now, people begin to concern the political security, economic security, and so on. Also the Safety focus is transforming. And the Ecological security is gradually appearing.

Ecological security is an important component of the social stability and national security. Ecological security of the country refers to a country's survival and development of the ecological environment at the state of no threats or little threats. Soil erosion areas are faced with many environmental problems. It has seriously threatened to the ecological security of the country. The outstanding performances are as follows: the increase flood disasters, reduction in the arable land, land degradation, aggravating land desertification, serious water shortage and pollution, drying up lakes and wetlands, the frequent sand dust storm, drying up rivers and biodiversity decrease. At the same time the biological environmental damage caused many disasters such as debris flow and landslides and so on. Obviously, they were closely related to serious soil erosion. These environmental problems caused by soil erosion have posed a serious threat to our country's socio – economic. As Mr Qu Geping said: "Soil erosion has become the most important environmental problem in our country".

1 The ecological disaster problem caused by soil erosion

1.1 The farmland ecological risk caused by soil erosion

The soil erosion led to the land degradation. The main performance is the reduction of soil fertility, damage soil structure, aggravation the desertification. Because of the Soil erosion, we lost arable land much too 270 million hectares. It also resulted in degraded grassland, desertification grassland and alkalization grassland about one million km^2 in all accounted for 50% of the total area of grassland. And after the 1990s, desertification land expanded 2,460 km^2 every year. At present, our country has 126 million ha arable land in which 16.67 million ha is sloping land and desertification land. So we should take some urgent measures to manage the soil erosion.

1.2 Soil erosion damages the water resource and aggravates flood disaster

Erosion results in the thin soil and declines water storage capacity of the soil. It is estimated that in the same rainfall conditions, the strength of a dramatic erosion of the soil and water erosion is the fourth and tenth respectively of the slight erosion soil. But the runoff is four times and 5.3 times of mild erosion soil. Due to huge loss of precipitation, soil moisture and total storage capacity of water is reduced. It made conflicts between soil moisture and water requirement of the crop sharp and crop dry. However the reduction of soil water infiltration and the increase in runoff will have a direct impact on the distribution of surface and underground water and disrupts the normal water balance.

1.3 The risk of soil erosion to the soil fertility and food safety

The amount of the water and nutrients absorbed by plants is proportional to the soil volume size occupied by its root, plants need the strong roots to absorb more nutrients in the soil. But the development of the root controlled by soil structure. Because the thin layer of soil will impact on which the root extends to the depth and breadth soil. So the soil with a worsening soil structure will have the problems, such as poor water and more surface runoff, flood, drought – prone. These problems will affect the availability of nutrients. The Loess Plateau is one of the most serious soil erosion areas in the world. The soil erosion sediment volume is about 3,700 $t/(km^2 \cdot a)$ in this region. Particularly in 7 ~ 9 month of the year, the heavy rain washed away a lot of surface soil. SO soil fertility has declined. The soil nitrogen, phosphorus and potassium were washed away about 4,000 tons every year because of the soil erosion which is closer to the country's total production of fertilizer in a year.

1.4 The harmful effects of soil erosion on the human environment

In the soil erosion area, human deforestation, over – grazing and cultivation on steep slopes and so on increased soil erosion, large areas of the bald mountain and ridge appeared in many areas, formed a bio – climatic zone that is not appropriate for the ecological landscape. In the Yangtze River the soil erosion area is much too 622,000 km^2 accounted for 34.6% of the watershed area.

1.5 Soil erosion accelerates water pollution and the sediment disasters

A direct result of soil erosion is that "Hill goes low, high Ancient River". Because the volume of losing soil from upstream is the same as the sedimentation volume soil of downstream. It is a basic rule that upstream erosion and downstream sedimentation in soil erosion. It is a common problem to fill up rivers and reservoirs, lakes, river channels and water pollution in the worldwide.

1.6 Erosion soil threaten to national economic development

In Tthe end of the 20 th Century, the numbers of cities reached 668, with the rapid urbanize, urban constructions change every day. There is no doubt that city building make the serious erosion problems appear which has become an important issue for urban modernization. The country of Three Gorges of the Yangtze River valley in Hubei Province moved three times because of landslide. Pishan and Minfeng country located in the southern part of Taklimakan Desert Mountain relocated two times because of wind hazards and the Cele country relocated three times. Shenzhen rapid urbanize caused extensive damage of vegetation landscape and natural stream change. At the same time serious soil erosion appeared. In 2002 year 184.9 km^2 area of the city's water and soil erosion which expanded 52 times compared to the original ones in which artificial soil area is 148.7 km^2 accounting for 80.4% of sum soil erosion.

2 The main measures to resolve the ecological disaster in soil erosion

2.1 Make full use of ecological restoration

Practice has proved that it is effective to carry out enclosure and protection of the soil erosion area and strengthen the management of the project. Relying on the forces of nature to make full use of the ecological self – restoration capability, it will not only accelerate the pace of soil erosion and improve the ecological environment, but also save money and work, it also has a good effective. Keeping with the natural law and conformity with China's national conditions is the most effective to prevent soil erosion and solve the slow pace of vegetation recovery of the major issues.

2.2 Accelerate the comprehensive management of water and soil conservation

Soil and water conservation management should be implemented in the area where is soil erosion, ecological environment fragility and backward production conditions. It should pay attention to the soil erosion quality and adhere to innovation as a driving force. Soil erosion and agricultural structure should adjust. We should emphasis on efficient soil and water conservation ecological agriculture. We take the three measures on engineering, biology, farming, and develop the peak, slope and channel. Making full use of interception, storage and irrigation and so on, at the same time, comprehensive manage the Hill, water, fields, forests, and strengthen control non – point source pollution, adapting to surrounding conditions, forestation or grass must be delimited, focus on the scale , concentration, pay close attention to water and soil conservation ecological construction to achieve social, ecological and economic benefits, effective protection of water resources and prevent the pollution of surface water and improve the local ecology and environment.

2.3 To prevent soil erosion by low

The reasons that caused serious soil erosion refer natural factors and human factors. Analysis from the worsening of the soil erosion situation since the 1950s, human factors are important. Therefore, in order to do a good job in soil and water conservation and protect the ecological environment, based on the intensify control, we must protect and prevention according to laws. The promulgation and implementation of "PRC Water and Soil Conservation Law", provide a powerful legal support for comprehensive prevention and control of soil erosion and effective protection and rational utilization of water and land resources. It indicates that our law to prevent water and soil conservation work has begun to enter a new stage. It is an important milestone of Soil and Water Conservation.

2.4 Establish a scientific and reasonable ecological compensation legal system for soil erosion

Ecological compensation is to restore, maintain and enhance ecological functions of the ecological system in which government directs the natural resources development and users that leads to damage of ecological function. The government will give the people economic and non – economic forms compensation who sacrifices for improving, maintaining and enhancing ecological services function. It is necessary to establish a scientific and reasonable soil erosion area for compensation legal system in the soil erosion area.

3 The key function of water and soil erosion and ecological construction to ecological security

Water and Soil Conservation and Ecological Construction are implements according to the characteristics of soil and water losses. After managing, vegetation coverage and vegetation diversity increased, the sediment reduced, Water resources got full exploitation, the area of basic farmland increased and Atmosphere Environment has been improved.

3.1 Vegetation coverage and vegetation diversity increased

Through water and soil conservation and ecological construction, vegetation coverage and vegetation diversity of soil and water losses areas has been obvious increased . Through ten years management of the eight big areas, vegetation coverage increased from 10.4% to 51.4%. There are 57,3000 km^2 flowing sanded land in the Wuding River Basin. We plant forest which were main constitute by bush wood to prevent sand flow. After that, the vegetation coverage of these areas increased from 1.8% to 38.8%.

3.2 The area of farmland has been increased

Most of the soil and water losses areas are lack of basic farmland. Through water and soil erosion and ecological construction, the living problems of people who live in this area have been solved. The income and the yield of grain has been increased notably too. For example, there are 200,000 hm^2 basic farmland have been constructed in eight big regions. 16.7% of these farmland are paddy field and other kind of field which were constructed this year. The area of this kind farmland in the eight big regions is 3.3 hm^2. As a result of technology to increase production, basic farmland can resist flood and aridity disaster more easily and the yield per unit of the farmland has been raised one to five times.

3.3 Raised the water resources using rate

Water and soil conservation intercepted a lager part of runoff which was lost before. A part of them were changed into soil water and ground water. That made the non – effective steam changed into plant's effective transpiration. It also cut down the transpiration's speed and improved the operation rate of rainwater and runoff . That improved the throughput and total biomass of the land. For example, because of the 1,000,000,000 m^3 water which was increased in eight areas, basic farmland can increase production 500,000,000 kg.

3.4 River sediment were reduced obviously

Through the water and soil conservation and ecological construction, the amount of the river sediment reduced obviously. That reduced the deposit in lower reaches of river, the reservoir and the lake. It also reduced the damage of soil and water losses to the ecological environmental to the downstream. After 15 years management to the upstream of Yongding River, the mean annual value of the sediment which enters the Guanting Reservoir reduced from 12,700,000 t to 3,790,000 t, reduced 70.2%.

3.5 Atmosphere environment has been improved

Vegetation can improve the atmosphere and the anvironment. It makes some area's microclimate turn to a positive direction. That can mitigate the dry of the plant, reduce the frequency of ecosystem disasters, such as hail, dry heat breeze and torrential rain. Mainwhile, many kinds of tree can resist and absorb some kinds of pollutant. For instant, arborvitae has strong antagonism to SO_2 and weeping willow has the same faction to Cl_2. Therefore, along with carrying on of the water and soil conservation, the atmosphere environment in district got an improvement gradually.

3.6 The soil's physical and chemical form has been improved

The work of the water and soil conservation cuts off the slope length and giving a new life to the micro landform. That made the time expend on the fusion of surface runoff be reduced. That also slow down the velocity of flow and erosion ability of the water was reduced too. At the same time, the number of residential units in the soil which have strong anti – erosion and stabilization increased. In the same situation of moisture water content, infiltrate rate raised. In the Yellow River Basin, non – point pollution has already been an important reason of the worsening of water quality. The nitrate nitrogen that contained in the water of Yan River has already over 10 mg/kg and phosphor soluble reached 8 ~ 10 mg/kg.

3.7 The land degeneration has been suppressed

Land sandy degeneration got obvious improvement through governs of water and soil conservation. The development of land sandy desertification and rocky desertification had been contained basically. Region's land sandy desertification had been governed and that also offered strong support to govern and develop the land sandy desertification and rocky desertification soil in our country. There are 573,000 km^2 quicksand area of the windblown sand region in the WuDing River Basin. Now 400,000 km^2 of them have been fixed or half fixed. Land sandy desertification has been contained efficiently.

3.8 Flood disaster has been lightened

The measure that sets up successive lines of defense through water and soil conservation, raised the general production ability of the watershed's agriculture and anti – disaster efficiently. In the rainstorm disaster of ZiYang town of Shan'xi Province on July 13th. 2000, the natural condition is similar that Longtan and Tiefu watersheds are placed in same rain – storm center. The disaster loss is smaller in Longtan for there has been carried on the general treatment of small watershed since 1992. Comparing with Longtan, in Tiefu watershed, the disaster loss is more heavy that its ruin area of farmland, reduction of food and the mount of tumbled down house has attained 6.2, 2.6 and 6.5 times of Longtan watershed. Meanwhile, the silt and disaster to lower reaches and have be reduced efficiently.

3.9 Ecological disaster, such as coast, debris flow , has been reduced

The ecological establishment of the water and soil conservation adopted the method which was formed by biological and engineering measure, we can extremely reduce the damage that caused by coast, debris flow and collapse through the administer of the ecological disaster. For example, through 5 years of management, 2,400,000 sediment has been totally blocked, more than 100,000,000 m^3 loose solid material has be stabilized. What's more, the amount of transmitting sand has be descended from 98,700 tons to 7,200 tons per year.

4 The evaluating indicator system of the ecosystem safety of the water and soil conservation area

The quantitative evaluation of water and soil conservation area's ecosystem safety is a necessary work to put the ecosystem safety into practice. Through this work, we can measure the feasibility of the change from a water and soil conservation area to an ecosystem safety area. On the basis of the result, we can make some change to the region and can make the practice of the ecosystem safety's continuing development go step further. The overall merit of the water and soil conservation area should contain territorial resources security, ecological security and environmental security。 So, according to the four basic principle of the indicator system, we designed an indicator system of ecosystem safety evaluation of the water and soil conservation area's, the indicator system contains 3 levels, 3 safety and 15 targets totally. Most of the targets can be measured and some of them can not be got from the interrelated departments. But, these targets are very important and can be measured after great effort was made. Among them, the national territory resources include the basic farmland, hillside cultivated and soil degradation (the sandy desertification, salinization, rocky desertification); biological security includes biodiversity indexes, the harm that biological invasiveness brings to ecosystem, forest and grass coverage, the kinds of tree and grass, and the amount of wildlife; and environmental security contains environmental pollution, the change of terrain and physiognomy (elevation, gradient and exposure), soil erosion, geologic hazard (including debris flow, coast and collapse), the decrease of water using rate, water resource pollution, damage by drought and water logging and so on.

Because the function of the biological security index of soil erosion area mainly is to provide dependable basis for ecological security decision, and the indexes of variety regions, areas and small watershed have the different traits. So the indexes mentioned above just be considered generally, the contents of specific index will be changed with the particular condition and trait of different small watersheds.

5 Establish the ecological security early – warning and protection system of soil erosion area

For insuring the ecological security, the soil erosion area must be carried on all – directionally and dynamic monitor. Build up the early – warning system of soil erosion area ecosystem, grasp the present condition and changing trend of the area in time to provide related decision basis for the policy – making of national department. We should formulate the weight standard of the ecological security of soil erosion area, and keep the ecosystem in a state which not only satisfy the present need, but also do not weaken the later generation's ability of satisfying their demand. The ideal statement of indexes in above assessment system, such as national territory resources, environment, biology, could be considered as the standard. Compared with the reality damage for giving different powers to various evaluation indexes factor, the standard could be synthesized "the general ecological security index of the soil erosion area". It could carry on a total evaluation to the ecosystem safe condition of the soil erosion area. Periodically issued the general ecological security indexes to make people to be more direct – viewing and vivid to understand the ecological condition of our country's soil erosion region, and enhance their attention to ecological environment. In addition to building up the macroscopic early – warning system of the ecological security, according to the different condition of their ecological environment, we have to establish and consummate special ecological security early – warning and the protection system to different regions.

Based on Social Benefits Monitoring Information of Yellow River Ecology Construction in Jiuyuangou Demonstration Region Knowing New Country Construction

Wang Hongxing[1,2], ***Ren Huaize***[2], ***Gao Yinfu***[2], ***Yan Ruixia***[3], ***Li Xiaolong***[2] and ***Wang Caiqin***[2]

1. Xi'an Huanghe construction Co. Ltd. Xi'an, 710043, China
2. Suide experimental station for soil and water conservation of YRCC · Suide, 718000, China
3. Experiment school in Suide, 718000, China

Abstract: This paper introduced the design and arrange of social benefits monitoring in demonstration region of Jiuyuangou watershed. According to summarize of the problem and experience, we can draw the following conclusion. The income of farmers is still at low level, different country production and income have different results, due to illness, poverty children's tuition fee, natural disaster, poor cultural quality, unreasonable production structure, sluggish rural market, shortage of agriculture invest. These are main factors that can't improve farmers living level. So the paper gives some suggestions about how to enhance the new country construction in soil erosion region.
Key words: new country construction, monitoring, social benefit, Jiuyuangou watershed demonstrate region

1 Introduction

The issue of soil erosion has been one of the major global environment problem and the maim barrier of developing economy. Our government pays more attention to prevent the problem, and work out the plan for water and soil protection and ecological construction in fifty years, and has regard for the social and environmental benefits monitoring.

2 The connotation of social benefits of soil and water conservation

Ecology construction of soil and water conservation is an important content in ecological environmental construction, as an essential condition, it decides its extensive sociability. The social benefit of soil and water conservation reflects the sociability. As for the management pattern which takes small watershed as one unit, the social benefit is the impacts for public benefit and individual benefit in river the basin. Its contribution or impact has the character of indirect, interval, potential, sluggish, holistic and long – term. Herein, it is difficult for us to express the relations between public and individual. Further more, the characters of unplusability and untransferability, it brings more difficulty to the social benefit evaluate. Because of these characters, they determine the social benefit among four main benefits of soil and water conservation lies in the qualitative states for a long time.

3 The design and arrangement of social benefits monitoring in Jiuyuangou demonstration region

Different evaluates choose different index system, the index system determine the corresponding monitoring means. To explicit ones, we can adopt scientific and reasonable monitoring method. Owing to social benefit monitoring involves complex social economy theory. These bring the huge troubles of designing and arranging in social benefit monitoring in demonstrate region of Jiuyan – gou.

3.1 The principle of design and arrangement

In the past, people only pay more attention to evaluate and ignore the monitoring. In fact, both are very close, the later base on the former, the reliability and validity of evaluation conclusion are determined by the reliable degree of evaluation information. If the monitoring is purposive and complete, the information is more abundant, the result of evaluate would be more representative, reasonable and systematic.

Monitoring should be combined with the economic benefits. Both trends are different, the former is more popular, the practical region in china are in the countryside and the main body, but the peasant household is the direct participate and can benefit—basic main body unit. So the social benefit monitoring of soil and water conservation base on the peasant household assist social economy in the survey.

3.2 The choice of typical farmers

The monitoring of water and soil conservation is made of peasant household monitoring and regional social benefit condition monitoring. The peasant household monitoring can be divide to typical peasant household monitoring and sample peasant household monitoring by the purpose, content and method of monitoring.

3.2.1 The monitoring of typical fcrmers

The purpose of typical peasant household is that choosing a typical peasant household and analyzing it, we can comprehend the situation about production operation thoroughly. The choosing and arrangement of peasant household base on the economic level of peasant household: excellent, better and bad. The criterion by the per capita income and grain and Enger coefficient three target. The standard of typical peasant household see Table 1.

Table 1 The selecting standard of typical farmers

Target	Typical peasant standard state		
	Bad(0grade)	Better(60 ~ 80grades)	Excellent(100 grades)
Per capita incone (yuan/ person · a)	<350	350 ~ 800	≥800
Per capita production (kg/ person · a)	<200	200 ~ 450	≥450
Enger coefficient	≥0.8	0.6 ~ 0.8	<0.5

In order to cooperate with that the typical peasant household get the rising benefits, we manage typical mass monitoring. In the typical land, river, dam, land, Terrance land slope land. In the forest arbor, bush, grass, economic plants. In the feeding animals sheep, pig, rabbit. We choose fifteen samples as the typical monitoring.

3.2.2 The monitoring of sample farmers

By the way of random seldom sampling, Gaoshegou was monitored, the purpose is to understand the situation of production to make sure the result is representative.

3.2.3 The monitoring of macroeconomics in the demonstration region

According to the real situation, we regard village as a unit, the content first land, population and labor, second the structure of using land, third the change of cultivated area, fourth industrial structure in rural area fifth social progress in country side.

3.3 The methods of monitoring

Two ways: typical peasant household monitoring and once only investigating.

3.3.1 Typical farmers' monitoring

The typical peasant who was selected should be monitored in long – term, continually and fixed place. They were trained and guided to finish it. The result should be summarized by the certain time.

3.3.2 Investigationonly one time

To combine the item investigate and social economy once a year. To adopt questionnaire survey house by house in advance.

4 The basic conclusions of monitoring

4.1 Income level and structure analysis

4.1.1 The state of income

In 2002, the income in the forty – five typical peasant households is 409.6yuan per person per year. The income lever of peasant is very low.

4.1.2 Income structure

The total income of the 45 investigated households is 248,520 yuan. Among of it, 176,700 yuan come from the first industry, occupy 71%; agricultural income is 138,400 yuan, occupy 55.7%; income of forest industry is 9,300, occupy 3.7%, income of stockbreeding if 29,000 yuan, occupy 11.7%. The second industrial income is only 5,520 yuan, occupy 2.2%. The income of the third industry is 66,300 yuan, occupy 27.0%. The labor income is the main component. The subsidy from turning farmland into forest and grass is 37,460 yuan, occupy 15% of agricultural income. The income in 2002 year see Table 2:

Table 2 The income structure of typical farmers in Jiuyuangou watershed

Unit: yuan

Item	The first industria			The second industria	The thire industria		
	Agriculture	Forestry	Stockbr-eeding		Transpor-tation industry	Servicing business	The rent service outputs an industry
Income(yuan)	138,400	9,300	29,000	5,520	14,800	17,700	33,800
Other strueture (%)	55.7	3.7	11.7	2.2	6.0	7.1	13.6
		71.1		2.2		26.7	

4.1.3 Analysis of the income status guo

Firstly, the income rising of peasant is slow. In the recent years, because of natural disaster impact the harvest of agriculture that is main income for farmers. Secondly, the gap of the income is very big; the survey of Li mingrong in Lijiazhai village in 2003 year see Table 3.

The income of ever – age person in planting and feeding is 2,200 yuan. Liu suili in Jiujiaping village who base on the grain only has 100 yuan income; the former is 21 times than latter. Thirdly, because of disaster, school fee, illness and engagement, The debt are more and more, seen from the chart four, the state of per capita income under five hundreds is 66.7%. The number of debt house is 21, it occupies 46.7%. Finally, the income of farmers mainly comes from the first industrial. The survey in 2002 is 338,800 yuan, 13.6% of income in rural area, but serious disaster household is 132,605 yuan, 57.3% of local year. see Table 4.

Table 3 The income change of farmers in Jiuyuangou watershed

Year	1978	2001	2002	2003
The income of average person (yuan)	62	370	409.6	389.4
The rate of increasing per year (%)		8.1	10.7	-4.9

Note: The number of survey in 1978, the statistic in 2001, typical household in 2002, 2003year.

Table 4 The statistical information of average in come

The type of household	Under 1,000 yuanaverage person		Under 500 yuanaverage person		Household of the debt	
	The number of household	Proportion of the househole of investigation%	The number of household	Proportion of the househole of investigation%	The number of household	Proportion of the househole of investigation%
2003	36	80	30	66.7	21	46.7

4.2 The limited factors of influencing farmers' income increase

4.2.1 The frequency of nature disaster

Due to the climate is drought and semiarid continental climate, the mean temperature yearly is 7.9 ~ 11.3℃, the rainfall is about 400 millimeter, most concentrating at in July, August and September. The climate character of the region is frequent drought. The basic condition of agriculture is very poor and the living circumstance is rather badly most peasants stand, the hungry compare the income of peasants only 65,070 yuan, in 2003. The income of peasant is reduced from 138,400 yuan to 73,330 yuan reduce 53 percent. Poor geographical condition, serious ecological environment and frequent natural disaster are the major limited factors.

4.2.2 Farmers with poor education

The culture structure of river valley monitoring is in Table 5. As we can see, half uncultivated is 6.73%. The people who have the degree under primary school occupy 37.02%. People of under middle school occupy 93.75%. These people negative to find job outside.

Table 5 The cultural structure of farmers in Jiuyuangou watershed

total population	No - educated		Under pupil		Under junion		Under senion		Beyond senion
	Person	%	Person	%	Person	%	Person	%	
208	14	6.73	77	37.02	195	93.75	208	100	0

4.2.3 Unreasonable industrial structure

In the household of survey, the income from the first industry occupy 71.1%, it is far higher than average level of local region, 49%; average level of Shaanxi Province, 32.9% and average level of the whole country, 25.4%. From the survey, the poor peasants, their income mainly come from crop planting, but the rich peasants have a small ratio of crop planting. The unreasonable industrial structure has become the main limited factor for the farmers.

4.2.4 The agricultural market slow development

Because market doesn't run well, the rate of forming goods is little, so the cash is very little. The most typical example is 80% of grain was changed in the survey of peasant household, the phenomenon of money shortage and little residual grain are very popular. This is also one of the poverty reasons.

4.2.5 The poor agricultural management

Poor management and income make the farm produce develop badly, the peasants add more labors but the income is still poor. The technology of peasant can't be improved so the unsteady income of farmer is seen usually.

4.2.6 Fund shortage basic facilities

Because of the shortage of money and invest in basic facility, lack of the ability of preventing natural disaster, the income of peasant is low. Most household who solve the problem of putting on and eating full, are still in the primary stage and have limited economic ability. They need the investment in the structure of industrial, item, experiments, expending scope, but most villages organize the contract and responsibility system of family. So the farmers can't get income from the collective business and they must pay money for the run of village committee. At the same time because the basic facilities of agriculture is rather poor so it is difficult for us to prevent nature disaster and develop our country.

5 The measures of constructing new country in soil loss area

Increasing the income of peasant is the start point of agriculture and economy. Not only relate to our country's development, stable and living level, but also to the whole national economy.

5.1 Improvement of industrial structure level

Be adapt to the needs of market and adjust the construction completely, by the principle of comparative advantage we focus three aspects to adjust the structure. Firstly, adjust the proportion of agriculture and not – agriculture stable the ability of producing farm production. Quicken the development of not – agriculture. Mark sure the two aspects are balanced, and the quality of country and abilities are implored. Secondly, adjust the proportion of agriculture, forestry, stockbreeding and fish, the forestry of river valley is shelter – forest, the pro portion of fish is too small. In this aspect the emphasis is stable plants, developing husbandry. Thirdly the inner proportion of planting is should be adjusted, adjust grain, economy to developing protein. Transform the traditional grain economy plant "two category structure" into grain, economy, feed, "three category structure". In the plants of grain green grain should be added. In the plants of economy tomato, vegetable should be added. In the plants of feeding, high protein should be developed harmoniously.

5.2 Improving the agricultural industrization level

Cultivate the leading industrial activity and developing agriculture, leader enterprise is the key item. Market system is the main point, Construction of the base land and peasant household are the basic item. Science and technology are assures. Sheep, tomatoes dates, bean and vegetable are the main industrials. Building market information, country service, special association agricultural quality monitoring and standard certificated to breakthrough the agriculture and industrial deeply, widely and exactly.

5.3 Strengthening agriculture infrastructure construction

Strengthen the basic facilities constructed in agriculture, protect agriculture ecology environmental. Firstly, enhance basic construction on farmland, quicken the fertile engineer transform and protect the farmland, popularize the technology of the drought plant activity and save the technology of saving water. Secondly, enhance the capital construction on farm production, the inner river valley construct, base on the village and radiate to the whole river. Third reinforce to protect agriculture resource and construct the base ecology environment and protect cultivated land. Grass and water resource supervise the pollution of agricultural environment and products, accelerate the engineer of planting the trees. Prohibit the illegal behaving of chopping the trees, try to turn the wasteland into the grass land and the forest.

5.4 Improving the quality of the labour's science and technology

Enhance agriculture trains and farm's culture lever, try to improve the farm's qualities and develop the economy increase the farm's income, talented staff is a key factor. Train the young farmers, make them become the expert in economic area and scientific area. Via spreading experience by them, improve the regional economy development. In order to improve the farmers' quality, develop agriculture using scientific technology, improve the scientific level in agriculture. Make science become the engine for basin economic development.

5.5 Increasing the agricultural investments

Increase the agricultural investment and improve the ability of agriculture development. Increasing the agriculture investment should use variety thinking to establish diversity of agriculture investment mechanism. The fist is to lead the farmer pay more attention to the agriculture. The second is to catch the opportunity of water and soil conservation demonstrate construction, use the dam of construction to popularize more item to change the backward country. The third is focusing the support of the financial department, make sure the increasing of agriculture. The fourth is improving the credit and adjust the direction of credit. For peasant stockbreeding and helping poor project, relax restrictions of assure and deposit.

Discussion on the Contradiction between Water Supply and Demand in the Yellow River and its Countermeasures

Zhang Ping[1], ***Hong Lin***[1] and ***Hao Caiping***[2]

1. School of Water Resources and Hydropower of Wuhan University, Wuhan, 430072, China
2. Shandong Yellow River Administration Bureau, YRCC, Jinan, 250011, China

Abstract: Yellow River, the maternal river of China, is of vital importance to the national economic development in China. With the development of social economy and the deterioration of ecological environment in the Yellow River basin, the contradiction between the supply of and demand for water resources of the basin is becoming more and more severe. This paper investigates the factors influencing the decline in water resources availability and the impact of this decline on the contradiction between water supply and demand in the Yellow River. The analysis is based on a historical study of the scarcity of rainfall and changes in climate, social economic development, water pollution and inter – sector water uses in the basin systematically. Finally, according to the analysis of the reasons for the water resources contradiction in the basin, the countermeasures to alleviate the contradiction are proposed in light of sustainable development.

Key words: Yellow River, water resources, contradiction between water supply and demand, countermeasures, sustainable development

1 Introduction

Yellow River is the most important water sources in the north and northwest of China. According to statistics, the area of the Yellow River basin is about 75×10^4 km^2, accounting for 8% of china's total land area. The annual river runoff is 58 billion m^3, which accounts for 2% of the national river runoff, bears the water supply to 12% of the national population and 15% of the national arable land. Yellow River supplys water to some important cities such as Tianjin, Qingdao, as well as more than 50 cities in Yellow River basin, which have exceeded the carrying capacity of the Yellow River water resources. Totally, 139×10^8 m^3 groundwater can be exploited, which accounts for 543 m^3 water resources per capita, only 1/15 of world's average, which is far less than international standard for a person of 1,000 m^3. Therefore, Yellow River basin is badly lack of water resources. In recent years, the water volume in the middle and lower of the Yellow River is becoming less and less, the water pollution is becoming more and more serious, and the water demand is increasing. Thus, the pressure of the shortage of the Yellow River water resources is becoming more and more severe, and the contradiction between water supply and demand is becoming more and more grievous. Sustainable use of water resources is an important strategy for economic and social development. Yellow River is the mother river of Chinese, the cradle of Chinese civilization, and will definitely affect the development of economic and the health of people who live along the Yellow River and in other regions. In this paper, the reasons for the obvious contradiction between supply and demand of Yellow River water resources and the existing solutions will be analyzed. It concludes with a number of recommendations.

2 Analysis of the reasons for the contradiction between water supply and demand in the Yellow River basin

2.1 Scarcity and uneven distribution of rainfall

Dominated by a continental monsoon climate, precipitation in the Yellow River basin is generally low and concentrated in a few months in a year. Annual rainfall gradually decreases from about 750 mm in the northern China to 440 mm in the loess plateau (such as Xi'an, Taiyuan, Yinchuan and Lanzhou in the central China) to less than 300 mm in the northwest of China (Fig. 1). Up to 70% of the annual precipitation is in the form of storm in the four months of a year, namely from June to September (Fig. 2).

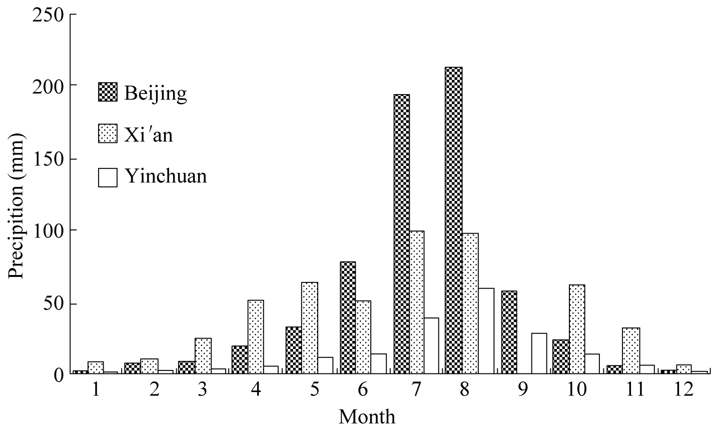


Fig. 1　Distribution of precipitation in Beijing, Xi'an and Yinchuan, China

Meanwhile, the annual evaporation in the basin is much more than the precipitation. In the lower reaches of the river, the annual evaporation ranges from 1,000 ~ 1,500 mm; in the middle reaches of the river, it ranges from 1,500 ~ 2,000 mm; while in the upper reaches of the river, it ranges from 2,000 ~ 2,500 mm. The annual runoff in the basin ranges from 50 ~ 150 mm, and the annual temperature ranges in 4 ~ 14 ℃. The annual frostless period is about 50 ~ 180 days, and the annual sunshine time is about 2,400 ~ 3,200 hrs.

Winter wheat and maize are the staple crops in the wetter part of the basin where annual rainfall is about 480 ~ 650 mm, and wheat is usually rotating with maize each year. Each year, wheat is usually planted in early October and harvested in early June, and the maize is sown shortly before or immediately after the wheat is harvested. The annual rainfall is not enough to support two crops, therefore supplementary irrigation is usually applied to the wheat during spring and early summer and occasionally also to the maize if summer rainfall is deficient.

The cropping pattern in much of the Loess Plateau is mainly a winter wheat monoculture with a 3 – month fallow during the rainy summer season, while in the drier and colder areas winter wheat is replaced by spring wheat rotated with field peas or millet every two years.

2.2　Changes in climate inducing cut down of the Yellow River inflow

In the last 50 years, the climate of the earth has become warmer and drier. Both annual average temperature and seasonal average temperature are on the rise. Especially after 1986, the temperature quickly climbed. In the 1990s, the precipitation dropped sharply, which induces water shortage more and more severe in the basin.

The rising temperatures are causing glaciers in the Yellow River source region to thaw on an expedited track. The Anemaqing Mountain in the Qinghai – Tibet Plateau is home to the majority of glaciers that feed water into the Yellow River. By 2000, the area of the glaciers in the mountain had shrunk by 17 percent in comparison to that in 1966, melting 10 times faster than the previous 300 years. The most seriously declining is the Yehelong glacier, which retreated by 77 percent between 1966 and 2000.

Permafrost is degrading considerably as a response to the temperature changes. Permafrost thickness and distribution have all undergone profound reduction. The active layers penetrate deeper, and the time for seasonal frozen duration is shortened. Permafrost, with its distinctive nature and wide distribution, is a vital factor in the vicious circle of ecological deterioration of the Yellow River source region. The permafrost decline is having a significant impact on the hydrology, ecological system and construction projects alike in the region.

Meanwhile, compounding the water shortage effect, the lakes in the Yellow River source region are shrinking through a combination of increased evaporation caused by higher temperature and a decline in rainfall. Meanwhile, wetland and marshland in the Yellow River source region have shrunken by 13.4%. Changing temperatures combined with the loss of moisture and change in soil nutrients arising from permafrost loss are affecting regional vegetation. Thus, the runoff into the Yellow River continued to drop, signaling that the source region cannot maintain as much water as before (Fig. 2).

Desertification is increasing at unprecedented speed. With the rising temperature, vegetation degradation and desertification became more severe. In the last 15 years, the soil pattern and its ecological distribution in this region have undergone drastic changes. A great proportion of the soil has deteriorated, and the desertification rate has arrived at 1.83% annually.

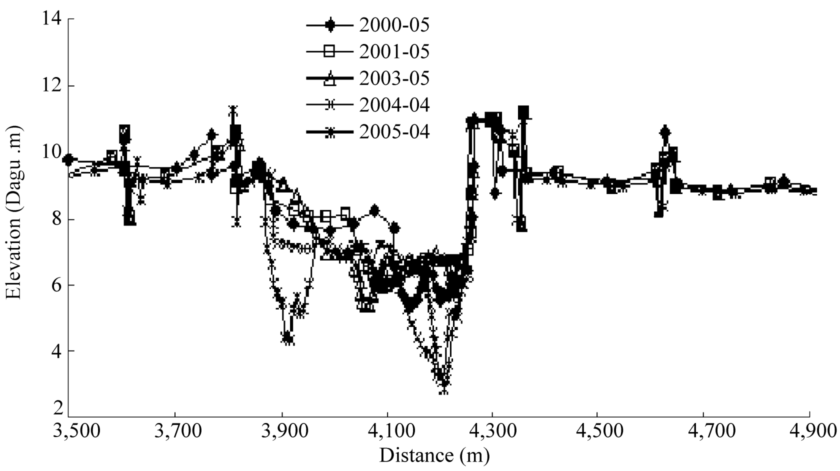


Fig. 2 Difference in mean monthly discharge between the period of 1987 ~ 1999 and the period of 1956 ~ 1986

2.3 The rapid increase in water demand due to social economic development

For nearly 20 years, with the increasing of population in the Yellow River valley, the development of the economic society and the implementation of the strategy of developing the western region, the demand for Yellow River water resources is increasing. According to the characteristics of the nature and society in the Yellow River valley, the water needs will continue to increase in the next 20 years, which will lead to the more serious shortage of water in industrial and agricultural production. Industrial and agricultural water consumption is not large, but the waste is also very serious. According to the statistics, industrial water consumption which is 10 ~ 20 times more than that of developed countries accounted for 8% of industrial and agricultural water consumption but little water is reused. The upper and middle reaches of the Yellow River basin is an energy – rich area, and the process of industrialization has accelerated. It is estimated that industry will maintain the growth rate of 1990 to 2000 in the next 20 years, so water consumption will inerease about another 1.5 billion m^3 in the total. Agriculture water consumption accounts for 92% of industrial and agricultural water consumption. Some irrigated areas still adopt the aging canal system, and water loss is serious. There are different levels of water wastage in life water consumption as well. The Yellow River irrigation area may be expanded and urban and rural water consumption will also increase. The zero growth of Yellow River water consumption is expected little considerable, and in

2020 Yellow River will be short of around 6 billion to 7 billion m^3 water.

All along, the Yellow River is facing a serious problem——"hanging river downstream". Preventing sand is a key to harnessing the Yellow River. The concept that sediment transport water consumption is first formulated at the Yellow River watershed planning program in the 1970s, and is unique to china. According to the study and calculation, if the situation of the lower reaches of the river is improved, there will need sediment transport water consumption of about 20 to 24 billion m^3 per year in average, 3.3 to 6 billion m^3 water is used to transport 1t sand. Water consumption for lakes, wetlands and ecological landscape in Yellow River valley accelerates the growth rate, and is expected to grow 1billion m^3 at least in the next 20 years. The ecological river water needs more than 3.5 billion m^3, according to the share calculations of the normal water supply into sea (21 billion m^3), compared with the measured water since 1986. However, some industrial water consumption comes from the water for transporting sand and ecological environment, so the ecological system deteriorates, and the situation of suspended river is worsening. To achieve harmony between people and water, maintain the health of the Yellow River and improve the ecological environment, the misused water needs to be returned to ecosystem.

Generally speaking, the pressure on the water resources of the Yellow River is growing, and is expected more serious by 2030 or by 2050.

2.4 Exacerbating water shortage due to water pollution

The Yellow River faces the threat of depletion of water, and the volume of sewage increases at the same time. The Yellow River pollution is worsening. Since 1990s, with the development of the economic society and the emerging of township enterprises, production and living water consumption increases fast, and wastewater emissions increase. However, water pollution control has seriously lagged behind, sewage treatment rate is relatively low, some of which do not meet the discharge standards and the use of fertilizers and pesticides is more and more in farming, so the amount of waste water discharged into the Yellow River each year will continue to increase. According to statistics, from 1999 to 2000, the volume of waste water increased from 3.26 to 4.22 billion t, about 29.4% increase, among it 31.8% increase is in industrial waste water, 23.7% increase in the life waste water[8]. The ecological environment is degrading, the water resources are decreasing, and waste water emissions are large, beyond self-purification ability, As a result, the water supply capacity of the Yellow River dropped.

There are also problems with the implementation of soil and water conservation measures. Soil erosion is a serious problem in the Yellow River valley, but soil and water conservation will store an amount of surface runoff. Storing runoff in the upper is bound to affect the middle and lower reaches of the Yellow River's water supply. However, it should be proof to look at relationship between soil and water conservation measures and the contradiction which is between supply and demand of water resources. Water pollution and some projects in the implementation of, such as soil and water conservation measures, has considerably reduced the supply of the Yellow River water resources.

2.5 Fragile management mechanism of the Yellow River water resources and irrational water distribution mode

On condition that the need of water resources is increasing and the supply is not sufficient, sound management mechanism and optimum water distribution control mode should be adopted to ease the contradiction between the supply and demand of water, but there are some problems currently.

In the market economy, the effective use of administrative measures to implement unified management and coordinate conflict of interest is getting worse. In the last 6 years when unified management is implemented, although the lower reaches of the Yellow River did not dry up, little sediment was brought into the sea, an average of 50×10^8 m^3 in 1999 to 2000, a large increase in 2003 to 2004, but not reach 10% of the allocation of the ecological environment water rights.

Although unified management mechanism is adopted, separate management in localities and departments still exists, and implementation of a system for water and water distribution control mode are not available. There is lack of management mechanism and a strong management tool. In addition, there has been more focus on Yellow River water allocation model economic and ecological benefits, but little focus on multi – angle studies and scalabilities of the distribution of water resources.

Shortcomings in the management of Yellow River valley makes outrageous use of the water resources and aggravates the contradictions between supply and demand of water resources. Large – scale use of the Yellow River water resources, the most prominent manifestation of which is that irrigated farmland in the area doubled to expand, began in the 1950s. Currently, 90% of the volume of the Yellow River water is for farmland irrigation, and irrigation rate is less than 40%. The demand for blind water expansion is beyond the Yellow River's carrying capacity.

3 Countermeasures

3.1 Inter – basin water transferring to solve the water crisis ultimately

By the end of 2000, some experts proposed the Three Gorges Reservoir project Huang Wei – economic program, which is significant to the allocation of Yangtze River and Yellow River water resources and measures to the problems of shortage of water in middle and lower reaches and ecological environment. Inter – basin water transfer from the Yangtze River to the Yellow River is a fundamental measure to harness the Yellow River. The Three Gorges Reservoir project increases the water resources of Yellow River, and meets the demand for water in the middle and lower reaches of Yellow River and supports the development of the western region by the replacement of water from middle and lower reaches to upper reaches of the river. Besides, it is necessary to build a harmonious relationship between water and sediment of the Yellow River by adjusting the relationship between reservoirs of Yellow River, improving the capacity of scouring sand and reducing sediment. So a long – term goal of the Yellow River will be reached gradually. In 2002 ~ 2006, the Yellow River Conservancy Commission tried 5 experiments on removing water and removing sand, totally using 21.16 billion m^3 water and bringing 2.854 billion tons of silt into the Bohai Sea. Removing water and removing sand is effective measures to harness the Yellow River sediment. Only by the inter – basin water transfer, can the Yellow River water be added, creating conditions for harnessing the Yellow River.

3.2 Enhancing sediment control through water and soil conservation

Except using water to carry sediment and regulate sand and water, an important strategy is soil and water conservation. But, water and soil conservation will result in cutting down a certain amount of runoff, which is of wide concern for the balance between soil and water conservation and water resources of the Yellow River. How to retain maximum sediment with the minimum loss of water? Effective soil and water conservation can retain sediment locally and decrease load of sediment into the river. If the soil and water conservation projects are improved, 90% of the sediment load of the river can effectively be reduced, about 22 billion m^3 of water can be saved annually.

3.3 The rational allocation of water resources in the Yellow River through whole society water – saving

In the contradiction between the supply and demand of water resources, it is important to optimize the allocation of water resources, improve water use in the economic, social and ecological benefits, and promote water conservation and rational use of water and protect water resources in the whole society.

Sime Yellow River water issues are more complicated, it is necessary to achieve optimal efficiency in the water basin – wide water distribution, and maintain a good ecological environment, and reduce the waste of water resources. The goal is to achieve optimum efficiency in the distribution of water resources, to narrow the regional gap, and ensure the interests of farmers. Along with the economic and social development, water conflicts have become more prominent. Reasonable use of sustainable development of the Yellow River water issue has become a core issue in the process. Countries around the world have adopted methods to the distribution of water resources including administrative allocation, water users or consultations allocation and distribution of water resources, these altogether three types. In view of the many problems that exist in the Yellow River water allocation, it is necessary to find a rational allocation model of water resources in the Yellow River.

4 Conclusions

Because of the restraints and the influence of natural elements in Yellow River valley, it is important to consider the relationship between basin and region , between short – term and long – term, between local and overall interests, handle the relationship among production, living and ecological water consumption, and carry out the implementation of the water resources in the Yellow River Basin by unified planning , allocation unified regulation and management, to resolve the contradiction between supply and demand of water resources in the Yellow River, so that sustainable development of Yellow River can be achieved.

References

Chen Xiyuan, Diao Lifang. Yellow River Water Resources and the Pre – protection measures[J]. Henan: Henan Polytechnic University Journal, 2006(10).

Chang Bingyan, Xue Songgui, Zhang Huiyan. Rational allocation and dispatch of water resources in the Yellow River basin [M]. Henan : The Yellow River Water Conservancy Press, 1998:9 – 18.

Deng Xiping, Shan Lun, Zhang Heping, Neil C. Turner. Improving agricultural water use efficiency in arid and semiarid areas of China[J]. Agricultural Water Management, 2006, 80: 23 – 40.

Ding Yongjian, Liu Shiyin, Xie Changwei, et al. Yellow River at Risk—Environmental Impact Assessment on the Yellow River Source Region by Climate Change[M]. Greenpeace, 2005.

Cui Qingrui. Knowledge of sustainable utilization of water resources of the Yellow River[J]. Shandong: Shandong Land and Resources, 2006:6 – 7.

Ding Ming. Increasing pressure on the Yellow River Water Resources Bearing Capacity [N]. Economic Information Daily, 2006(11).

Mu Xingmin, Wang Fei, Li Rui. Discriminately looking on the relationship between the water and soil conservation and water resources in the Yellow River[J]. China Water Daily, 2006(9).

Yao Zhijun, Liu Jian, Su Renqiong. The effects and comprehensive management countermeasures for the Yellow River Water Resources[J]. CAS: Resource Sciences, 2006(3).

Tang Weiqun. Sustainable development of the Yellow River water resources [A]. Hubei Province: China's Population Resources and Environment, 2005.2.

Guo Shuyan, Li Shizhong, Wei Yan. Three Gorges project: to increase the Yellow River water diversion, harnessing the Yellow River. Weihe strategic projects [N]. Chinese Economic Times, 2006(12).

Zhang Hongbo, Huang Qiang, Chang Jianxia. Discussion on Yellow River water allocation model and method[J]. Shaanxi: People's Yellow River, 2006(1).

Climate Development in Norway During 1900 ~ 2100

Eirik J. Føland

Norwegian Meteorological Institute, P. O. Box 43 Blindern, Oslo, Norway

Abstract: Annual mean temperature has increased by 0. 5 and 1. 5 degC in different parts of Norway since 1875. In southern Norway, the warmest decades of the last 130 years has occurred near the end of the series. In most parts of northern Norway, the warmest decade occurred around 1930. During the 21 st century, the annual temperature is projected to increase by 2. 5 to 3. 5 degC in different parts of Norway. The largest temperature increase is projected in interior regions in Northern Norway. The downscaled scenarios indicate a winter warming of 2. 5 ~ 4. 0 degC, with the largest increase in interior parts of Northern Norway.

Annual precipitation has increased in all regions in Norway during the last 110. The largest increase (15% ~20%) is found in north – western regions. The projections indicate that the annual precipitation will increase by 10% ~15% in different regions in Norway. The increase is largest (~ 20%) along the south – western coast and far north. The largest increase is found for the autumn season; while the summer rainfall in parts of south – eastern Norway may be reduced by up to 15% . For all of Norway daily rainfalls that are considered extreme today will be more common in the future according to the downscaled scenarios.

Key words: temperature, precipitation, climate change

1 Introduction

The climate in Norway is characterised by large temporal and spatial variability. The large natural variability at northern latitudes also influences the Norwegian climate for daily, seasonal, annual, decadal, etc. time – scales (cf. Fig. 1). The physio – geographical conditions in Norway cause steep climatic gradients even over short distances, e. g. from lowland areas to mountain regions and from the coast to the inland. Substantial local and regional gradients exist for annual precipitation as well as for extreme 1 – day rainfall. This is reflected in e. g. the design values for 1 – day rainfall with 5 – year return period, which range from ca. 30 mm in interior parts of southern and northern Norway, to more than 140 mm in parts of western and northern Norway. There have been substantial climate variations in Norway during the 20th century, and the latest IPCC (2007) report indicates an even stronger future warming during the 21st century at high northern latitudes than in most other parts of the globe.

2 Modelling regional climate change

Coupled atmospheric – ocean global circulation models (AOGCMs) are the most sophisticated tools for modeling global warming. The resolution in the AOGCMs is presently sufficient for modeling large – scale features, but in general too coarse to enable these models to reproduce the climate on regional or local scale. In order to produce scenarios with spatial resolution useful for local impact studies it is thus a need for downscaling the AOGCM results. Regional modeling (dynamical downscaling), statistical methods (empirical downscaling) or combinations of these techniques may be applied for this purpose (Hanssen – Bauer et al., 2003). In Norway both dynamical and empirical techniques have been applied to downscale results from AOGCMs.

2.1 Dynamical downscaling

Since AOGCMs have a typical spatial resolution of ~ 300 km, regional climate models (RCMs) have been developed during the last decades for dynamical downscaling of AOGCMs to regional and local scales. The hypothesis behind the use of RCMs is that they can provide meaningful small – scale features over a limited area at affordable computational cost compared to high – resolution GCM simulations. The RCM used in Norway "HIRHAM" (Bjørge et al., 2000) was run with 55 km grid distance nested within the global data available every 12 hours with a 300 km grid. The same physical parameterizations are used in the RCM as in the global model, except for tuning to account for the finer spatial resolution in the HIRHAM – model.

A successful implementation of a RCM depends on a number of conditions e. g. nesting strategy, domain size, difference in resolution between the AOGCM and RCM, the physical parameterisations, quality of the driving data and spin – up time. Generally the RCM cannot be expected to improve errors in the AOGCM results on a large scale, but should be able to develop small – scale features, at least due to more realistic surface forcing. As for its global counterpart, it is certainly necessary to realistically simulate present climate where analysed and observed data can be used for validation, as a first attempt to trust the output from climate change experiments.

The HIRHAM RCM simulations for Norway are usually carried out in two time – slices, one representing the present climate ("control run") and one representing future climate ("scenario run"). The lateral RCM boundary conditions for surface pressure, temperature, horizontal velocity components, specific humidity and liquid cloud water in 12 – hourly intervals and with sea surface temperature and sea – ice conditions are specified from the global model.

2.2 Empirical downscaling

Empirical downscaling of climate scenarios consists of revealing empirical links between large – scale patterns of climate elements (predictors) and local climate (predictands), and applying them on output from global or regional climate models. Successful downscaling depends on the following conditions: The climate model should reproduce the large – scale predictor fields realistically, the predictors should account for a major part of the variance in the predictands, the links between predictors and predictands should be stationary, and, when applied in a changing climate, predictors that "carry the climate change signal" should be included.

In most studies of empirical downscaling in Norway, monthly mean 2 m temperature (*T*) and precipitation (*R*) at selected localities are the predictands, while T and sea – level pressure (*SLP*) are used as predictors. Hanssen – Bauer and Fϕrland (2000) showed that *SLP* anomalies account for a large part of the observed variability of temperature and precipitation in Norway during the 20th century. The long – term trends especially for temperature were, however, not reproduced satisfactorily. Because of this, and in order to include the climate change signal, *T* was included as predictor. For temperature, *T* was used as the only predictor in the final models as the *SLP* field gave limited additional information. For precipitation both predictors were included initially, and *T* may be regarded as a proxy for precipitable water in the troposphere. In summer, the inclusion of *T* as predictor led to unrealistic results. This may be caused partly by poorer correlation between air temperature and humidity, and partly by weaker connection between air humidity and precipitation during summer. Consequently, in the final models, *T* was not applied as a predictor for precipitation during the summer months. Hanssen – Bauer et al. (2000, 2001) describe the empirical downscaling methods and results for Norway in detail for temperature and precipitation, respectively.

2.3 Comparison of results from empirical and dynamical downscaling

For Norway, Hanssen – Bauer et al. (2003) found that empirical downscaling tends to give higher warming rates than dynamical downscaling, especially during winter at sites that are exposed for temperature inversions. Though the differences are not statistically significant at the 5% level, it is discussed whether the geographical signature of the empirically downscaled warming rates, which implies a reduction in the average strength of ground inversions during winter, is reasonable. The dynamical downscaling model does not resolve ground inversions properly, and is thus not able neither to support nor contradict this feature. It is concluded that a reduction in frequency and/or average strength of winter inversions is consistent with the projected increase in wind speed and reduced winter snow cover in the lowlands. The results from the empirical downscaling are thus probably qualitatively right, although they may exaggerate this feature.

For precipitation, a statistically significant difference between dynamically and empirically downscaled scenarios was found in summer in southwest Norway. The results from the dynamical downscaling are probably the most reliable, as the empirical downscaling models for the summer months only can reproduce changes caused by changes in atmospheric circulation. There are also some differences between dynamically and empirically downscaled scenarios concerning the exact areas of maximum precipitation increase, but these are not statistically significant.

Empirical downscaling has been especially recommended in areas with complex topography as e.g. Scandinavia (Hanssen – Bauer et al., 2005). Further, the reasonably dense network of climate stations with records of 50 years or more provides a good base for the development of empirical downscaling models. Scandinavia thus has both the preconditions to develop empirical models and the need to apply them, adding values to the coarse climate scenarios provided by global climate models.

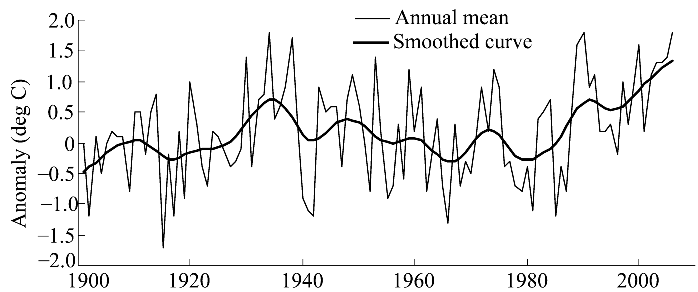
3 Climate variations in Norway during the latest 100 ~ 150 years

3.1 Temperature

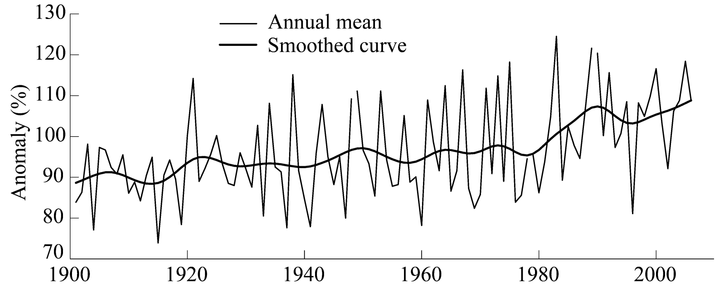
The annual mean temperature in Norway has during the latest 130 years increased by between 0.5 and 1.5 deg C (Hanssen – Bauer, 2005). The increase in annual mean temperature is statistically significant at the 1% level everywhere except in interior parts of Northern Norway. The winter temperature has increased significantly (at least at the 5% level) in 3 of the 6 Norwegian temperature regions. Spring temperatures have increased significantly everywhere. Summer temperatures have increased significantly in northern regions, and autumn temperatures have increased significantly everywhere except in mid – Norway and interior parts of Northern Norway. In spite of the linear trends: There have been substantial decadal and multi – decadal temperature variations during the last 130 years (cf. Fig. 1). A rather cold period around 1900 was followed by the so – called "early 20 th century warming", which culminated in the 1930s. A period of cooling followed before the warming which has dominated the country since the 1960s. In the regions in southern Norway, the warmest decade of the last 130 years occurred near the end of the series. In most parts! of northern Norway, the warmest decade occurred around the 1930s.

3.2 Precipitation

Annual precipitation in Norway (cf. Fig. 1) has during the last 110 years increased statistically significantly (5% level) in 9 of the 13 "precipitation regions" in Norway (Hanssen –



(a) Annual temperature



(b) Annual precipitation

Fig. 1 Annual temperature and precipitation for the Norwegian mainland, 1900 ~ 2006. Anomalies are deviations from the 1961 ~ 1990 averages ("normals"). The smoothed curve indicates decadal variability, while the thin line represents values for single years

Bauer, 2005). No region shows a negative trend. The largest increase (15% ~ 20%) is found in north – western regions. Autumn precipitation has increased significantly in north – western, and to some degree in inland regions. Summer precipitation has increased significantly in most of the northern regions.

For studies of influence of changes in precipitation on water management and environmental and ecological conditions, extreme rainfall events are of particular interest. Based on a large number of stations (>200) (Alfnes & Fϕrland, 2006) studied whether there were any changes in design values (return period of 5 years, M5(24 h)) for extreme 1 – day precipitation from the normal period 1961 ~ 1990 to the period 1975 ~ 2004. For more than half of the stations the changes were less than + 5%, but large gradients were found even between neighbouring stations. By analysing median values for groups of stations, it was found a general increase of up to 5% in large parts of Western Norway. In south – eastern Norway ("østlandet") there was a small increase in M5 – values in northern parts, whereas the changes were more randomly distributed in the rest of this region. For the rest of the country there were no distinct regional patterns.

For 33 stations with series back to 1900 the long – term variability was studied by analysing the 30 – years moving of M5 averages during the whole period (Alfnes & Førland, 2006). At some stations the M5 value for the most recent 30 – years period is close to maximum in the studied period and for other stations approximately at minimum. A local maximum in the periods ending around 1940 ~ 1960 and a tendency of increasing M5 values during the latest 10 ~ 15 years is seen for many of the stations. Trend analyses of the maximum 1 – day precipitation indicate an increase since 1900 for two thirds of the stations. The change is moderate for most of the stations and the trend is significant at 5 % level at only 4 of the 33 long – term series studied. The largest increase in the maximum precipitation is found in the south – western part of Norway. However, stations with no trend or negative trend, although insignificant, are also present in this area.

4 Projections of climate development during the 21st Century

4.1 Downscaling of climate scenarios for Norway

The empirical and dynamical downscaling results agree on central points concerning future development of temperature and precipitation in Norway. The projected temperature increase is at maximum in winter and at minimum in summer. The warming rate increases from south to north and from coast to inland. Both downscaling techniques give statistically significant precipitation increase of winter – precipitation in southern Norway and of autumn – precipitation in western and northern regions. Agreement between the downscaling models is no guarantee for the realism of the modelled climate change, but it adds credibility to the results, given that the large – scale scenario is realistic.

To reduce uncertainties in the scenarios for Norway, dynamically downscaled results from two global climate models giving quite different precipitation projection are combined (see (http://regclim. met. no). The models used are the British UK Met Office Hadley – Centre HadCM3 model (HAD) and the German Max – Planck – Institute's ECHAM4/OPYC3 (MPI) model. Simulations are performed for different IPCC SRES (IPCC 2007) emission scenarios (e. g. IS92a, A2, B2 and A1b). In this paper the dynamically temperature and precipitation scenarios are based on a combination of results from HIRHAM RCM simulations for HAD and MPI with emission scenario B2.

4.2 Temperature scenarios

The annual temperature in Norway is projected to increase by 2. 5 to 3. 5 deg C in different parts of Norway (Table 1). The largest temperature increase is projected in interior regions and in northernmost Norway. The downscaled scenarios indicate that the winter temperature will be 2. 5 ~ 4. 0 deg C higher than the present level, with the largest increase in interior parts of Northern Norway (cf. Fig. 2 and Table 1). Summer is the season with the smallest projected temperature increase, 2. 0 ~ 2. 5 in most parts of the country. Number of days during the winter season with minimum temperatures above zero degC will increase by 10 ~ 25 days in coastal and lowland areas in Norway (http://regclim. met. no).

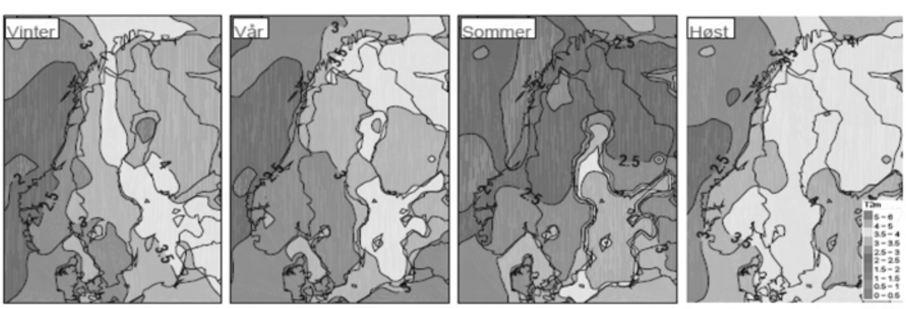


Fig. 2 Combined projections of changes (from 1961 ~ 1990 to 2071 ~ 2100) in seasonal temperature (deg C) from dynamically downscaled scenarios from two global climate models (MPI and HAD) based on B2 emission scenario

Table 1 Average change in temperature (deg C) from the period 1961 ~ 1990 to 2071 ~ 2100. Results are based on dynamically downscaled scenarios from two global climate models (MPI and HAD, B2 emission scenario)

Region	Annual	Spring	Summer	Autumn	Winter
Total (Norwegian mainland)	2.8	2.9	2.4	3.3	2.8
Northernmost counties	3.2	3.3	2.2	3.5	3.6
Southern parts of North Norway	2.7	2.9	2.0	3.1	2.7
Western Norway	2.6	2.7	2.3	3.2	2.4
Southeastern Norway	2.9	2.8	2.6	3.5	2.8

4.3 Precipitation scenarios

Fig. 3 and Table 2 display changes over 110 years from the period 1961 ~ 1990 to the period 2071 ~ 2100. The projections indicate that the annual precipitation will increase by 10% ~ 15% in different regions in Norway. The increase is largest (~ 20%) along the south – western coast and far north. The largest seasonal changes are found for the autumn; where the increase in Western, Central and Northern – Norway is larger than 20%. In South – eastern Norway the precipitation during autumn and winter is projected to increase by 15% ~ 20%, while the summer precipitation in parts of this region may be reduced by up to 15%.

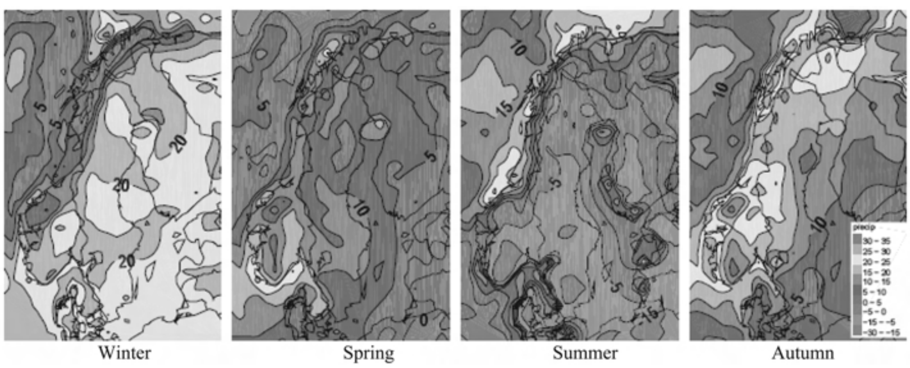


Fig. 3 Combined projections of changes (from 1961 ~ 1990 to 2071 ~ 2100) in seasonal precipitation (%) from dynamically downscaled scenarios from two global climate models (MPI and HAD) based on B2 emission scenario

Table 2 Average change in precipitation (%) from the period 1961 ~ 1990 to 2071 ~ 2100. Results are based on dynamically downscaled scenarios from two global climate models (MPI and HAD, B2 emission scenario)

Region	Annual	Spring	Summer	Autumn	Winter
Total (Norwegian mainland)	13	13	3	20	13
Northernmost counties	14	11	12	23	7
Southern parts of North Norway	12	10	13	18	6
Western Norway	13	14	2	20	14
Southeastern Norway	12	15	–5	19	18

The combined downscaled results are also used to study extreme precipitation (http://regclim.

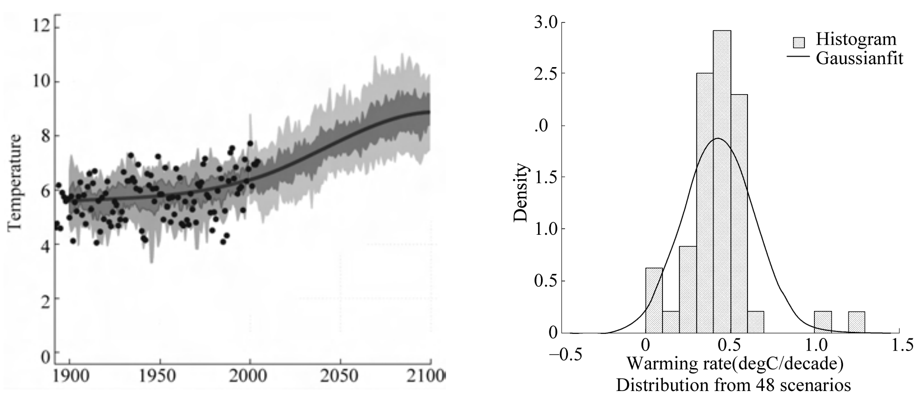
met. no). The results indicate that there will be an increase of 15 days per year with precipitation exceeding 20 mm/day in parts of Western – Norway. This is an increase in number of days with more than 20%. In the other parts of Norway the absolute change in number of days > 20 mm will be substantially lower. For all of Norway daily rainfalls that are considered extreme today will be more common in the future according to these scenarios. In some coastal areas in Northern Norway, daily rainfall values similar to today's annual maximum daily values may occur 2 ~ 3 times per year.

4.4 Uncertainties in projections of future climate

Substantial uncertainties are involved in the production of global scenarios and in downscaling of scenarios to regional and local scales. The most important sources of uncertainty are

- Variations in the climate system leads to unpredictable natural variability
- Uncertainty in the future changes in climate forcings:
    - Natural forcing: Solar radiation, volcanoes
    - Anthropogenic forcing: Release of gases and particles
- Changes in land – use
- Imperfect climate models:
    - Imperfect knowledge about forcing and processes
    - Imperfect physical and numerical treatment of processes
    - Poor resolution in the global models
    - Weaknesses in downscaling techniques

To study uncertainties in climate projections or Norway, both combinations of simulations (cf. Fig. 2, Fig. 3) as well as empirical downscaling techniques are used. Fig. 4 shows spread in projections of annual temperature in Oslo up to year 2100. Although there is a large spread in the different projections, all projections indicate increasing annual temperatures.



(a) Oslo annual temperature (b) Oslo temperature trends

Fig. 4 Uncertainties in projections of annual mean temperature in Oslo based on empirical downscaling from global climate models, AOGCMs

(a) Climate development based on 11 AOGCMs and emission scenario A1B.

(b) Spread in temperature projections (degC/decade) from 1961 ~ 1990 to 2071 ~ 2100 based on 48 combinations of AOGCMs and emission scenarios.

Acknowledgements

The paper is under the implementation of project – Bilateral Cooperation for Sustainable Water Management towards Environmental and Ecological Effects between the joint Norwegian Institutions in Norway and the Yellow River Conservancy Commission in China, supported by the Norwegian Research Council.

References

Alfnes, E. and Førland, E. J. (2006). Trends in extreme precipitation and return values in Norway. met. no report 2/2006 Climate.

Bjørge D, JE Haugen, TE Nordeng (2000). Future Climate in Norway. DNMI Research Report 103, Norwegian Meteorological Institute, Oslo.

Hanssen – Bauer, I., (2005). Regional temperature and precipitation series for Norway: Analyses of time – series updated to 2004. met. no report 15/2005 Climate.

Hanssen – Bauer I, EJ Førland (2000). Temperature and precipitation variations in Norway 1900 – 1994 and their links to atmospheric circulation. Int J Climatol 20, No 14: 1693 – 1708.

Hanssen – Bauer I, OE Tveito, EJ Førland (2000). Temperature scenarios for Norway. Empirical downscaling from ECHAM4/OPYC3. DNMI Klima Report 24/00, Norwegian Meteorological Institute, Oslo.

Hanssen – Bauer I, OE Tveito, EJ Førland (2001). Precipitation scenarios for Norway. Empirical downscaling from ECHAM4/OPYC3. DNMI Klima Report 10/01, Norwegian Meteorological Institute, Oslo.

Hanssen – Bauer, I., E. J. Fφrland, J. E. Haugen & O. E. Tveito (2003). Temperature and precipitation scenarios for Norway: Comparison of results from empirical and dynamical downscaling. Met. no report 06/03 Klima.

Hanssen – Bauer, I., C. Achberger, R. E. Benestad, D. Chen and E. J. Førland (2005). Statistical downscaling of climate scenarios oevr Scandinavia. Clim. REs. 29, 245 – 254.

IPCC (2007). Climate Change 2007: The physical science basis. Working group I contribution to the Intergovernmental Panel on climate change fourth assessment report.

A Basic Study on Water Income and Expenditure of Upstream Region in Loess Plateau

***Jinbai Huang*[1], *Osamu Hinokidani*[1], *Yuki Kajikawa*[1], *Yasuda Hiroshi*[2] and *Zhang Xingchang*[3]**

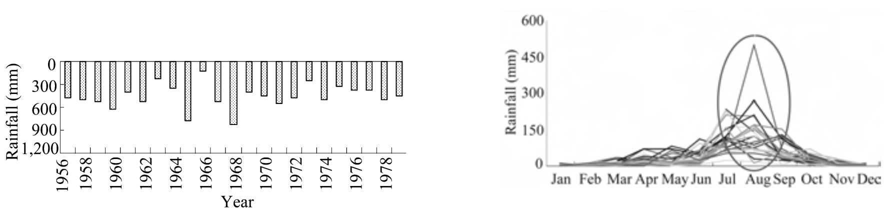
1. Faculty of Engineering of Tottori University, Tottori City, 680 – 8550, Japan.
2. Arid Land Research Center of Tottori University, Tottori City, 680 – 0001, Japan.
3. Institute of Soil and Water Conservation, CAS, YangLing City of Shaanxi, 712100, China.

Abstract: At present, desertification becomes a problem around Loess Plateau. Planting, as an effective measure to prevent land desertification will be performed in this region. On this purpose, it is essential to keep the water resource under control. In this paper, based on the result of local observation and field survey, we considered the water income and expenditure of study basin which locates at upstream in Loess Plateau. Thereby, for study basin, annual water income and expenditure was clarified basically and annual available quantity of water was also estimated. The result of this study is useful for correlative studies of water resource in the same region.

Key words: Loess Plateau, small basin, water income and expenditure, utilization of water

1 Background and purpose

Loess Plateau, as a wide – semiarid region, is very likely to turn into desert in the future, and we have to take preventive measures urgently. Planting is looked as an effective method to prevent land from desertification, so it is necessary to estimate the quantity of available water resource of Loess Plateau. However, the mean annual precipitation in this region is only 400 mm and occurrence of rainfall is non – uniform within a year, more than 60% occurs in rainy season as shown in Fig. 1. Hence, estimation of quantity of water becomes very difficult. In this study, on purpose clarifying basic characteristics of water income and expenditure of upstream region in Loess Plateau, we adopted a small basin as study location, considered annual water income and expenditure and estimated available quantity of water in 2006 year.

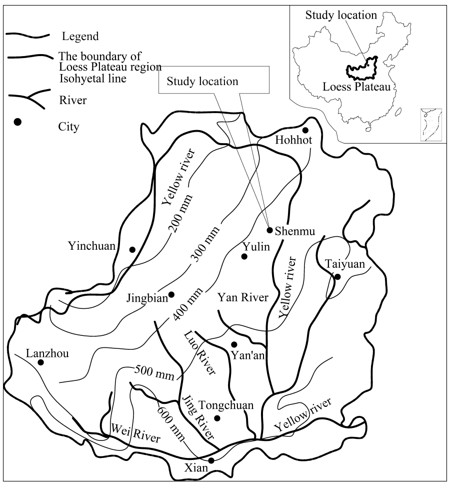


(a) Annual precipitation (b) Annual distribution of precipitation

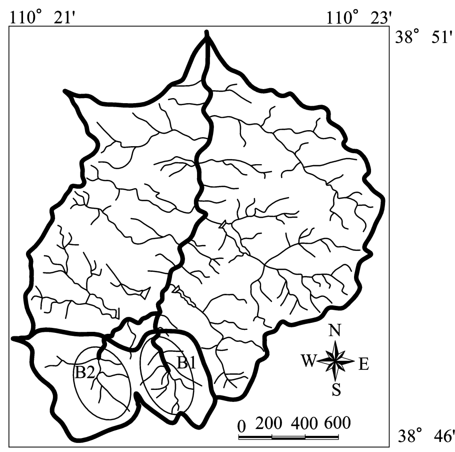
Fig. 1 Annual precipitation in study basin

2 Summary of study basin

The study basin was named Liudaogou who has typical topographical and hydrological characteristics of upstream region in Loess Plateau. This basin locates at north Loess Plateau, between longitude 110°21′ ~ 110°23′ and latitude 38°46′ ~ 38°51′ as shown in Fig. 2. In 2006 year, population in this basin was 533, and area of irrigation farmland was 20.6 hm^2.



(a)



(b)

Fig. 2 Location of study basin

The considered area of water income and expenditure is not the whole region of Liudaogou, they are two small basins which locate at upstream of Liudaogou basin, and separately named B1 basin and B2 basin as shown in Fig. 2. (b). A diagrammatical view of study location is as Fig. 3.

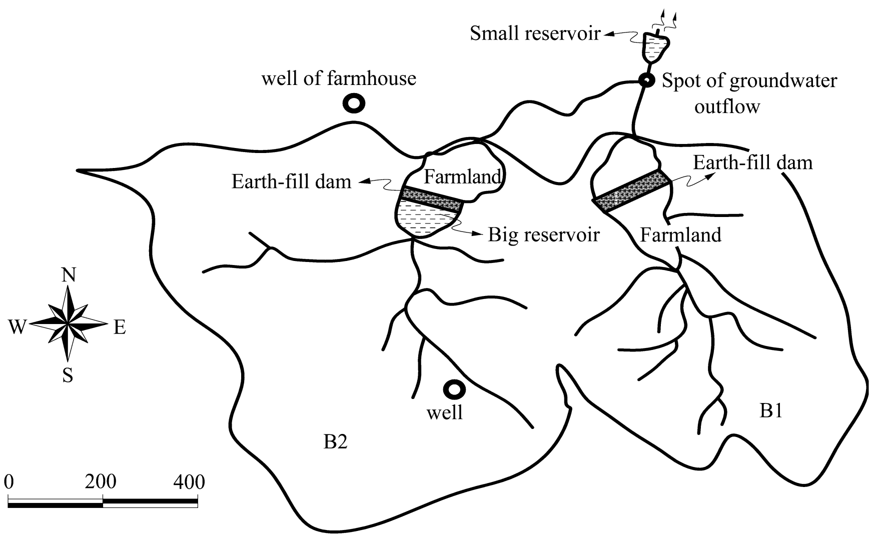
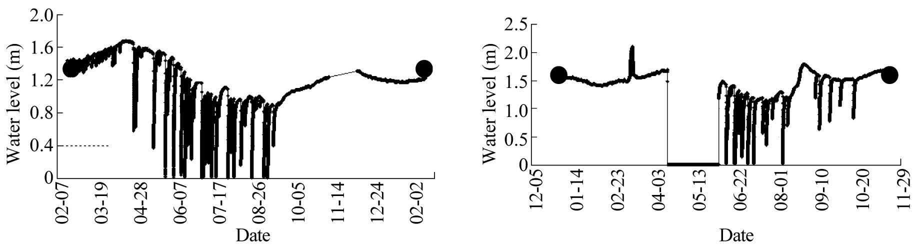


Fig. 3 Diagrammatical view of study basin

3 Basic water income and expenditure process

In study region, during winter season, in other word, from December to next March, because the topsoil is frozen, water income and expenditure of the soil which from surface of the earth to the depth of 100 cm keeps equilibrium. Especially, in winter, the surface flow can not occur, and the outflow of groundwater which occurs at the downstream of study basin is also frozen (Fig. 3).

From 2004 year, we observed the change of deep groundwater in a well of a farmhouse whose position is shown in Fig. 3. For observing method, we installed an automatic water level recorder, which was set by a certain interval of time, in this well. The observed result is shown in Fig. 4. By considering the observed result, we can understand that annual change of deep groundwater keeps equilibrium in study basin. Therefore, the main period of water income and expenditure of study basin is from April to the end of November every year and the basic process is just as shown in Fig. 5.



(a) Result of 2004 year (b) Result of 2005 year

Fig. 4 Change of deep groundwater in study basin

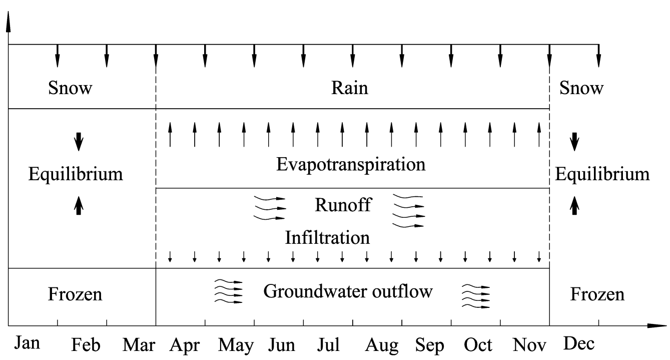


Fig. 5 Sketch map of the annual water income and expenditure

4 Quantity of water income

For a study basin, the annual quantity of water income is the total precipitation within a year. As the total area of B1 basin and B2 basin is 1.017 km^2, and mean annual precipitation is 400 mm, consequently, the annual quantity of water income of study basin is 4.07×10^5 m^3.

5 Estimation of each item of water expenditure

5.1 Quantity of surface outflow

Quantity of surface outflow was estimated by a runoff analysis model which was constructed by kinematic wave theory and by using the artificial stream network6). In 2006 year, the time of runoff calculation was from May 21 to November. By considering the calculated result, though quantity of surface flow of 2.76×10^4 m^3 occurred in B1 basin, the surface flow was stopped by a earth − fill dam which locates at downstream of this basin (Fig. 3) and was not able to flow out. In B2 basin, the total quantity of surface flow which occurred in consideration period was 3.29×10^4 m^3. A small part of 2.15×10^3 m^3 was stored in a big reservoir which locates at end of B2 basin, the result of 2.15×10^3 m^3 was estimated by analyzing the change of water level of this reservoir at the same time that surface flow occurred and was shown in Fig. 6. The most part of surface flow occurred in B2 basin was discharged by the artificial river channel at both sides of this reservoir during the rainy season. The main reason is to prevent an earth – fill dam, which built at the downstream edge of the reservoir, from being destroyed by flood in rainy season every year. Therefore, for study basin, the total quantity of surface outflow was 3.07×10^4 m^3 in 2006 year. The modeling of B2 basin was shown as Fig. 7, and the calculated result of surface flow by runoff calculation model was shown in Fig. 8.

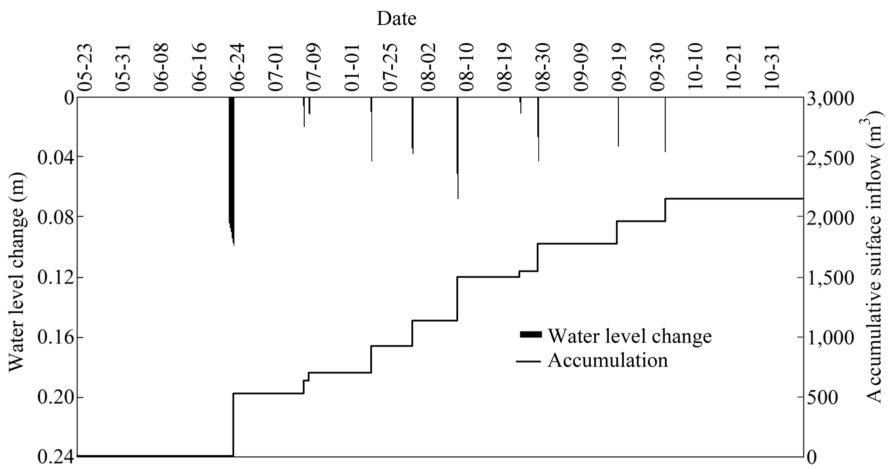


Fig. 6 Surface inflow of the reservoir in 2006 year

5.2 Quantity of groundwater outflow

In study basin, groundwater outflow includes two items. One is the groundwater outflow which occurs at downstream edge of study basin, another is life water of population who live in this region.

(1) There is a comparatively stable groundwater outflow at the downstream edge of study basin (Fig. 3). Since 2004 year, we observed the discharge of this groundwater outflow several times by a flow meter at a spot as shown in Fig. 3. By considering the observed result, the discharge of groundwater outflow from study basin was estimated to 1.01×10^{-3} m^3/s, thereby the annual (from April to the end of November) quantity of groundwater outflow was 2.09×10^4 m^3.

(2) Life water of inhabitants in study basin is from a well which locates at upstream of B2 basin also shown in Fig. 3. Based on the result of field survey of 2006 year, quantity of life water for one person was $0.35 \sim 0.40$ m^3/d, and for 533 persons, quantity of life water was about 200 m^3/d, and the annual quantity of life water was 7.30×10^4 m^3.

Sum up the result of (1) and (2), the total quantity of groundwater outflow was 9.39×10^4 m^3 in 2006 year.

5.3 Quantity of evapotranspiration

Generally, evapotranspiration points to the process that moisture enters the atmosphere. It includes precipitation closure, evaporation and transpiration. As above mentioned, the annual change of groundwater keeps equilibrium in study basin. Consequently, the quantity of

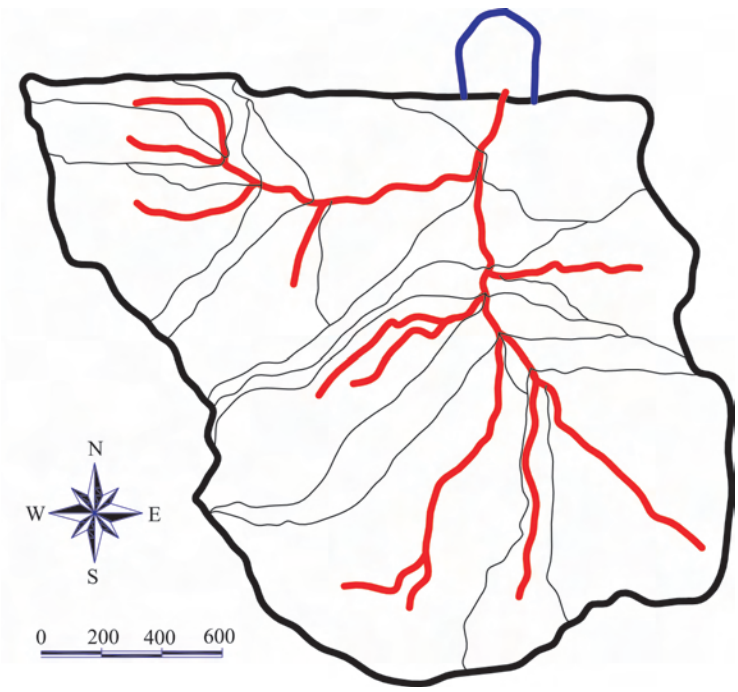


Fig. 7　Modeling of B2 basin

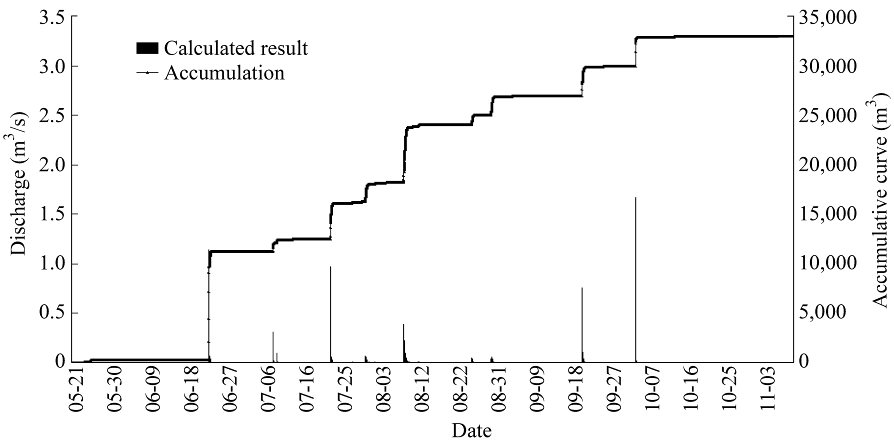


Fig. 8　Runoff calculation result of B2 basin

evapotranspiration can be estimated by subtracting quantity of surface flow and groundwater outflow from the total precipitation. Therefore, quantity of evapotranspiration was estimated to 2.82×10^5 m^3 which accounted for about 70% of the total precipitation in 2006 year.

5.4 Percentage of each item of water expenditure

Considered quantity of each item of water expenditure and the water income, percentage of each expenditure item was calculated as shown in Table 1.

Table 1 Relation between quantity of each expenditure item and income Unit: $\times 10^4$ m^3

Total quantity of water income	Evapotranspiration	Outflow		
		Surface flow	Groundwater outflow	
			Life water	Outflow
40.7	28.2	3.08	7.3	2.09
100%	69.3%	7.6%	23.1%	

6 Annual water consumption

Consumption of annual water in study basin includes two parts. One part is life water of inhabitants and another part is irrigation water. Irrigation water is taken from two reservoirs which position is separately shown in Fig. 3. As the scale of the two reservoir is considerable different, we named one is big reservoir which locates at end of B2 basin and another is small reservoir which locates at the downstream edge of study basin. According to result of field survey in 2006 year, the big reservoir and the small one separately undertook the total irrigation area (20.6 hm^2) of 70% and 30% every year. We estimated quantity of irrigation water which taken from the big reservoir by analyzing the observed data of water level change of this reservoir, and quantity was 1.38×10^4 m^3 from May 23 to November 10 in 2006 year. Based on this result, quantity of irrigation water from the small reservoir was estimated to 0.59×10^4 m^3 during the same period. The curve of water intake from the big reservoir is shown in Fig. 9.

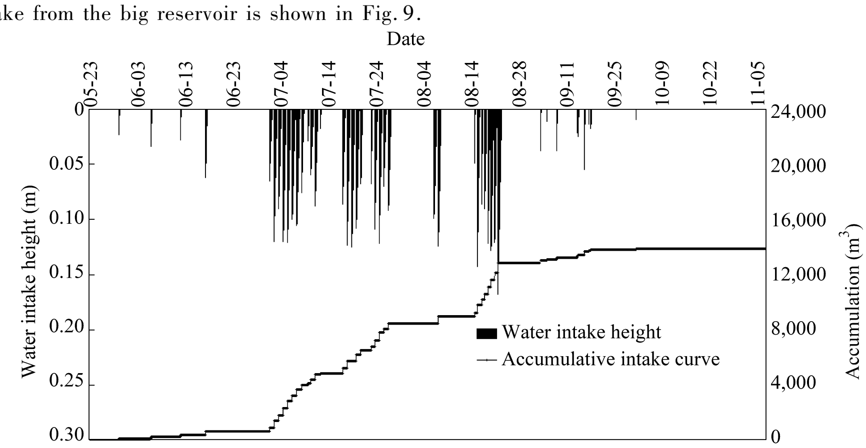


Fig. 9 Curve of water intake from big reservoir

Based on the estimated result, total quantity of irrigation water was 1.97×10^4 m^3. Therefore, quantity of the utilized water of study basin was estimated to 9.27×10^4 m^3 by adding quantity of irrigation water up to quantity of life water. The consumption of water only accounted for 22.8% of the total water income in 2006 year.

7 Relation between each item of expenditure

Naturally, there are some relations between each item of water expenditure and were considered as follows:

(1) Total quantity of outflow included quantity of surface outflow, quantity of groundwater outflow which occurs at the downstream of study basin, and life water. Therefore, total quantity of outflow was 12.47×10^4 m^3 and accounted for 30.7% of the total water income.

(2) Though irrigation water which taken from the big reservoir was used, however, this part of water was still in study basin and could be looked as recycled water. And another part of irrigation water from the small reservoir was irrigated into the farmland where is outside study basin. As this part of water was almost came from the groundwater outflow, so we thought it as a part of groundwater outflow and could not be recycled.

(3) Consumption of water included irrigation water and life water, as the relation between this part of water and other expenditure items is difficult to be considered clearly, we thought this part of water as a certain part of total water income.

8 Consideration result of water income and expenditure

Sum up the content as above mentioned, the considered result of water income and expenditure of study basin in 2006 year was shown in Fig. 10.

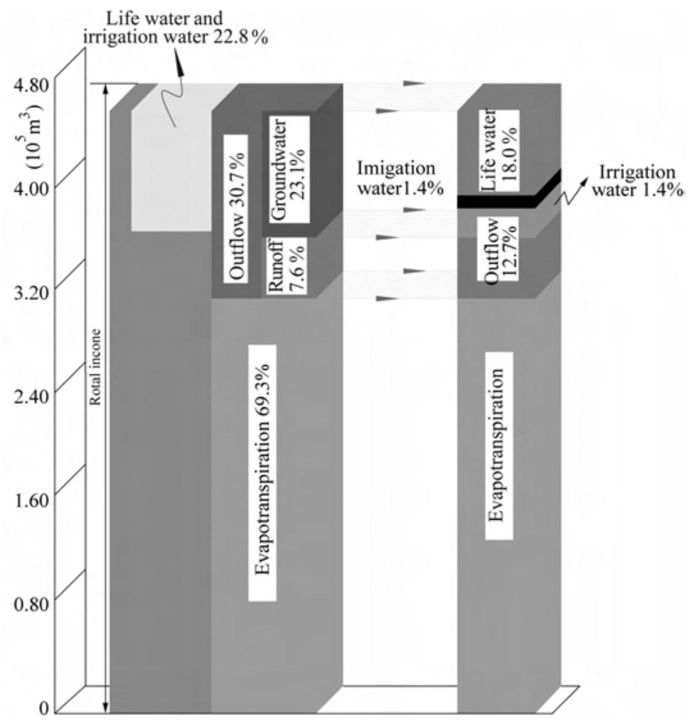


Fig. 10 Consideration result

According to the considered result, the annual consumption of water was only occupied 22.8% of the total quantity of water income. But quantity of evapotranspiration was approximate to 70% of the water income and was in predominant status among all items of water expenditure. Therefore, to the upstream region in Loess Plateau, as the annual available water resource is considerable deficiency, how to utilize the limited water resource effectively becomes an important research theme for this region.

References

Jiyong Zheng: Study on the Infiltration and Redistribution of Soil Water and the Spatial Variation of Soil Hydraulic Properties in Water – wind Erosion Crisscross. Institute of Soil Science. June 2004. S152.7, 631.43. pp.1 – 10.

Pute Wu and Youke Wang (et. al): Highly Effective Water Using Technique of Construction Vegetation with Forest and Grass in Loess Plateau. Northwest Agriculture and Forestry Technology University Publisher. China. 2002. pp.1 – 10.

Junliang Tian and Xianglin Peng (et. al): Soil geochemistry of Loess Plateau. Scientific Publishing Company, September 1994. pp.1 – 3.

Water and Soil Conversation Institute: Summary of? Shenmu Experimental Region. 2006. pp.1 – 5.

Jun Fan: Study on the Soil Water Dynamics and Modeling in Water – wind Erosion Crisscross Region on the Loess Plateau. Institute of Soil Science. Chinese Academy of Science. 2005. S152.7, UCD631.43. pp.30 – 45.

Osamu Hinokidani, Jinbai Huang and Hiroshi Yasuda: Study on the runoff characteristics of small basin in Loess Plateau. Memoirs of Eighth International Conference on Development of Drylands. 2006.

Prediction of Wadi Discharge in East – Central Sudan and its Impacts on Water Resources Management

***Tarig El Gamri*[1], *Amir B. Saeed*[2] and *Abdalla K. Abdalla*[3]**

1. Desertification Research Institute, the National Centre for Research, P. O. Box 6096 Peoples' Hall, Khartoum, Sudan
2. Faculty of Agriculture, University of Khartoum, P. O. Box 32 Shambat, Khatroum North, Sudan
3. Sudan Meteorological Authority, Khartoum, Sudan

Abstract: Seasonal streams (wadis) are of vital importance in dry and semidry countries including Sudan. Depending on rainfall variability, the annual discharge of such wadis was estimated to range from 3 to 7 km^3 per annum. In the present study two wadi – discharge prediction methodologies were used to predict the discharge of Khor (wadi) Abu Fargha. The first methodology depends on the ENSO (El Nino Southern Oscillation) event which was divided into six distinct stages. The discharge during each stage was compared to previously estimated rainfall in the dry zone of the Sudan during the concurrent stage. The methodology was found to illustrate about 83% of the discharge behaviour of Khor Abu Fargha. This high prediction skill is attributed to the fact that the wadi is located in an area that is influenced by the ENSO event and to the availability of the discharge data for consecutive 34 years. The use of global sea surface temperatures (SSTs) in rainfall seasonal forecast studies was initiated during the 1990s through the development of empirical – statistical models. Using such methodology the models predicting Abu Fargha discharges were found to excel those for some meteorological stations and the dry zone of the Sudan as well. This is attributed to the fact that wadi discharges represent the whole catchment area whereas rainfall data represent only the rain gauge readings. The models using May global SSTs achieved better predictability in Abu Fargha discharges the thing which was found to be consistent with the results obtained in previous studies by Kassala meteorological station which is located in the vicinity of the wadi. The paper illustrates the use of the wadi – prediction information in forecasting the available storage of the aquifers and concluded that combining the different information, realistic management of surface and ground water resources can be achieved. The study recommended the use of water conservation techniques, integrated dryland management approaches.

Key words: wadi, prediction, ENSO event, sea surface temperatures (SSTs), management

1 Introduction

Sudan is located in the northeastern part of Africa with an area of about 2. 5 km and an estimated population of 35 million people. Land degradation affects both the north and the south parts of the country (El Mustsfa, 2005). Aridity which dominates about two – thirds of country enhanced conflicts over the limited natural resources to the extent that social integrity and political stability were affected. It is worth mentioning that the dry and semidry region extends to about 96% of the total geographical area in North Africa (Saeed and El Gamri, 2000). Wadis are important water resources in the Sudan specially in areas remote from the Nile that are dominated by the Basement Complex or with high ground water salinity (Ahmed et al., 2004). Their use for water supply and agriculture has been practiced widely in the country. For instance the area flooded or irrigated from wadis is 300,000 fed which is equivalent to about 11% of the area irrigated from the Nile. For many locations e. g. northern Sudan integrated wadi management constitutes an optimal solution for addressing water scarcity (Salih, 1998). In the Sudan the total flow from non – Nile streams (wadis) varies from 3 to 7 km^3, following the erratic nature of rainfall, (MOIWR, 1999). Evaluation of the potential of such wadis and creation of sustainable development and management plans are of prime importance.

According to Ahmed et al. (2004) the major watersheds in the country are: Jebel Marra, Nuba Mountains, Red Sea Hills, Angasana Hills, Butana Hills and the Ethiopian Plateau (Gash and Baraka). Each watershed comprises many wadis and khors of various sizes and discharges that range from less than 1 million m^3 to about 100 million m^3. It is worth mentioning that most of these wadis originate inside the country and flow internally. However, part of them crosses the borders such as Azoom and Kaja that flow to Chad.

Due to the orographic effects of Jebel Marra the largest discharges are witnessed in Dar Fur where the gross wadi discharges were estimated at about 1 km^3 per annum. According to Seid Ahmed (2001) and Ayoub (1998) the Nuba Mountains and Jebel Marra were subjected to water erosion due to the combined effect of the removal of the vegetative cover and inclination (steep slopes).

2 Materials and methods

2.1 Khor Abu Fargha

This wadi originates from the highlands of Eastern Sudan within the Gedarif State at an altitude of 640 m above mean sea level (a. m. s. l.). Three tributaries of the wadi confluence in Gedarif town at an altitude of 590 m a. m. s. l. Ultimately the wadi joins River Rahad at an altitude of 430 m (a. m. s. l.), with a total difference in elevation of 210 m. According to NCR, (1982) Gedarif State like most parts of eastern Sudan is underlaid by the Basement Complex that occupies about 50% of the area of the country and hence the wadi constitutes a vital water resource for the area. The average annual discharge of the wadi is more than 4 million m^3 with a catchment area of about 5,000 km^2. Due to geological formations and soil type, the section upstream Gedarif is shallow and narrow. Hence, flood hazards are serious for Gedarif e. g. the famous flood on the 12th of August 1982 when more than the annual average discharge occurred during 4. 5 hours only. Previous studies proved that the wadi is responsible for the recharge of Abu Naga Aquifer near the town. However, recently it has been found that some branches of the wadi overly the Azaza aquifer. The aquifer was identified (12 km northwest of Gedarif) in the year 1990 after extensive geophysical surveys. It is worth mentioning that such alluvial aquifers cover about 2% of the area of the country often overly the Basement Complex (SRFAC/SUST, 2001).

The wadi discharge data were collected from the Wadi and Ground water Administration, Ministry of Irrigation and Water Resources. The data extend through the period from 1960 up to 1993 representing the whole gauging period of 34 years.

2.2 Influences of the different ENSO stages in wadi discharges

To Study the influence of the different stages of the ENSO event in Khor Abu Fargha discharges the discharge data were first classified into the six groups that coincide with the different stages of the ENSO event as suggested by El Gamri (2005). These namely are Starting La Nina (Sna), Starting El Nino (Sno), Dying La Nina (Dna), Dying El Nino (Dno), Well established La Nina (Wena) and Well established El Nino (Weno) The mean annual discharges as well as the mean for each ENSO stage were calculated and the discharge during each stage is represented as a percentage from the mean annual discharge. According to El Gamri et al. (2007) this classification is valid for the general rainy season of the Sudan and the similar conditions.

2.3 Correlation between global SSTs and Khor Abu Fargha Discharges (Development of empirical statistical wadi prediction models)

One of the recent developments during the 1990s and because of the mutual influences between the atmosphere and oceans the use of SSTs in rainfall prediction was started. According to Mutemi, (1999) the hypothesis can be stated as "if significant correlation exists between rainfall and SSTs it can be assumed that they will be related in the same way in the future". Hence empirical – statistical rainfall prediction models can be developed. According to El Gamri, (2005) such models were developed using the following software packages:

- Climlab2000
- Excel
- SYSTAT 8.0

The models for discharge prediction were developed in the same procedure used for rainfall prediction as illustrated by El Gamri, (2005).

2.4 Verification of forecast models

Contingency table and some of the associated scores were used for model verification. Contingency table lists the frequency (or relative frequency) of observations across two or more attributes (Atheru, 1999). The methodology was also used by Abdalla, (2002) and it proved to be satisfactory. To prepare the contingency tables, both forecasts and observations, for each particular model, were first arranged into a descending order. Then the set was divided into 3 groups the above – normal group comprises the top 12 years, and the normal group comprises the second 11 years and the last 11 years represent the below – normal group.

The following associated scores were used for model verification:

- Percent correct:

$$P.C. = (a + e + i)/T \times 100$$

where a, e and i are the numbers of correct forecasts in each category and T is the total number of forecasts.

- Post agreement (PA) and False alarm ratio (FAR):

Post agreement is the number of correct divided by the number of forecasts for each category. O

FAR is sensitive only to false predictions of the severe events, not to missed events.

$FAR = 1 -$ Post agreement of the severe event.

- Probability of detection (POD): hit rate

It is a measure of the ability to correctly forecast a certain category

$$POD = a/J,\ e/K,\ i/L$$

3 Results and Discussion

3.1 Influences of the ENSO event on wadi discharges

As shown in Fig. 1 during Sna Khor Abu Fargha showed markedly above – normal (about 13 times the normal) discharge which is consistent with El Gamri et al. (2007) on that the rainfall of the region is markedly above – normal during the same stage. The markedly above – normal discharge of Abu Fargha during Sno is in a disagreement with the normal rainfall of the region. The below – normal discharge recorded during Dna is also consistent with the markedly below – normal rainfall of the region. During dying El Nino Abu Fargha discharge and the rainfall are both within the markedly below – normal. The wadi showed above – normal discharge during Wena which is consistent with the markedly above – normal rainfall of the region. The markedly below – normal discharge recorded for the wadi during Weno is consistent with the below – normal rainfall of the region.

Hence, it can be concluded that this methodology is capable enough for predicting 5 out of 6 phases (about 83%) of the behaviour of Khor Abu Fargha i. e. with an excellent prediction skills. This can be attributed to the following:

- The availability of the discharge data of the wadi for 34 years.
- The wadi is located in an area that is influenced by the ENSO event.

However, during El Ninos of 1990s' Gedarif showed above - normal rainfall (Abdalla and Fota, 2001). This may illustrate the markedly above - normal discharge recorded for the wadi during Sno. It is worth mentioning that, Damazin tends to show markedly above - normal rainfall during El Nino of the same period. Critical studies are therefore highly recommended for recent rainfall behaviour in Eastern Sudan. However, this is consistent with Cobon et al. (2003) in that the skill in the forecasts occurred for La Nina rather than El Nino conditions.

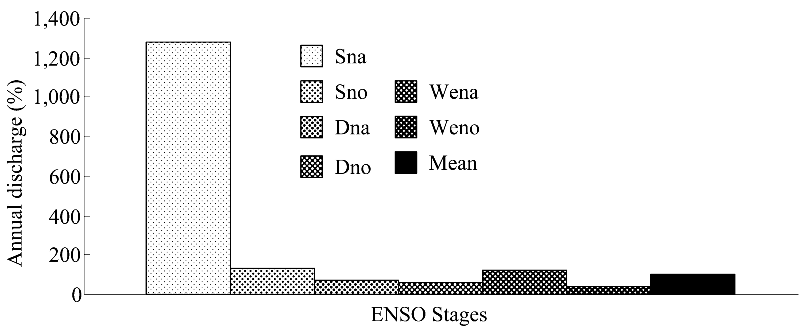


Fig. 1 Abu Fargha annual discharge during ENSO stages

3.2 Wadi prediction models

Appendix (1 A and B) shows the correlation maps between monthly (May/ June) global SSTs and annual discharge for Abu Fargha. On the other hand, Fig. 2 and Fig. 3 show the models predicting the discharge of Khor Abu Fargha using global SSTs of the two months of May and June respectively. Meanwhile, the Table 1 shows summary of the scores evaluating the two models.

The following are the developed empirical equations:

$$P_m = 0.454 \times AT4 - 0.773 \times IN3 - 0.471 \times IN5 + 0.828 \times PA3 - 0.283 \times PA5$$

$$P_j = -0.413 \times IN4 + 0.208 \times IN7 - 1.031 \times PA2 + 0.926 \times PA3 - 0.506 \times PA4 - 0.243 \times PA5$$

where, P_m is indicates the use of May global SSTs to predict the wadi discharge. P_j is indicates the use of June global SSTs to predict the wadi discharge. AT = Atlantic Ocean. IN = Indian Ocean. PA = Pacific Ocean. The numbers 2, 3, etc indicate location on the different oceans.

The models predicting Abu Fargha discharge show higher skills than those developed by El Gamri (2005) for predicting rainfall. For instance they achieve average PC and POD of 70% and 0.70 respectively which exceeds those of all stations and the Region as well. In addition to that the wadi discharge models achieved average PA and FAR of 0.96 and 0.06 respectively which are similar to those obtained for Kassala the station of the highest predictability. Excellence of the models predicted wadi discharges over those of rainfall may be attributed to the fact that wadi discharge data represent the whole catchment area of the wadi while rainfall data represent only the rain gauge readings at each particular station.

The model predicting wadi discharge using May SSTs achieved better predictability than that using June SSTs. However, the latter shows better skills in predicting PA and FAR with 100% predictability for both scores. In addition to that, this model also achieved POD of 0.92 which exceeded those obtained by El Gamri (2005) who studied rainfall prediction for some meteorological stations and the dry region of the Sudan. Hence, combining the skills of the two models, effective management plans can be developed for Khor Abu Fargha. The mutual use of prediction models is in agreement with Osman and Shamseldin (2002) who argued that combination of forecast models would normally improve the quality of the prediction.

The high prediction skills of global SSTs is also confirmed by Giannini et al. (2003) who used version 1 of an atmospheric general circulation model developed at NASA called (NSIPPI). When forced by global SSTs for the period 1930 ~ 2000 the model reproduced much of the variability in the observed Sahel JAS rainfall with a correlation of 0. 6. Hence, SSTs variability is instrumental in determining rainfall in the region, whereas coherent land – atmosphere interaction acts to amplify them the authors concluded.

The highest predictability achieved for Kassala meteorological stations over the other stations and the high skills performed in predicting Khor Abu Fargha discharges suggest that eastern Sudan, where both the wadi and the station are located, has got higher predictability than the other studied parts of the country. Another striking observation is that the models developed using May SSTs are better than those developed using June SSTs for both Kassla and Khor Abu Fargha. Such observation may suggest that global SSTs affects Sudan's rainfall with a lag – time for at least the eastern side. However, results obtained by Cobon et al. (2003) showed that the ENSO signal decreases with greater forecast lead – times in southern Africa, but with no significant difference for the lead – times 0 – 1 that correspond to June and May respectively in the present study.

Fig. 2 Abu Fargh actual vs. predicted discharge using May SSTs

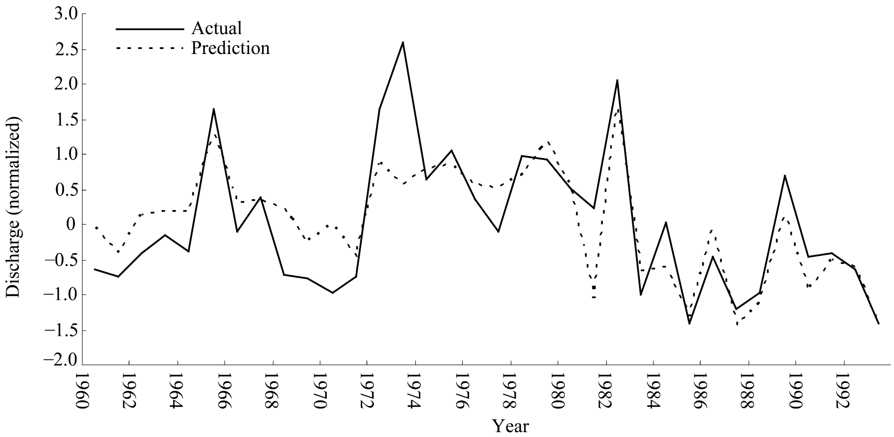


Fig. 3 Abu Fargha actual vs. predicted discharge using June SSTs

Table 1　Summary of the scores evaluating Khor Abu Fargha discharge prediction models

SSTs	Category	PA	FAR	PC	POD		
					AN	N	BN
May	AN – N	0.75	0.25	74%	0.75	0.73	0.73
	N – BN	1.0	0				
June	AN – N	1.0	0	65%	0.92	0.46	0.55
	N – BN	1.0	0				

Note: AN, Above – N ormal; N, Normal; BN, Below – Normal.

3.3　Water resources management in Gedarif area

As stated earlier Gedarif area like most parts of eastern Sudan is underlain by the Basement Complex that occupies about 50% of the area of the country and hence Khor Abu Fargha constitutes a vital water resource for the area.

Due to the combined effects of increase in population and activities and the presence of some refugee camps, Gedarif town can secure only about 40% of its water demand utilizing the current available resources. Azaza aquifer consists largely of consolidated fine sand and silt. According to Abdo (2004) its ground water potentialities and water quality are generally very good. Although the aquifer is covered by a thin layer of very low permeability there are indications of recharge from the wadi. This is reflected by the fact that the wells closer to the wadi show higher ranges of head variation. The thickness, storage coefficient and transmissivity of the aquifer were found to be 135 m, 0.002,5 and 50 m^3/day respectively.

As mentioned earlier some branches of khor Abu Fargha overly the alluvial Azaza aquifer. According to Abdo (2004) the recharge coefficient is estimated at about 5% of the discharge of these branches. Hence, the aquifer available storage can be forecasted utilizing the wadi forecast information using the following equation as suggested by Abdo (2004):

$$\text{Recharge Rate} = Rc \times Q$$

where, Rc is recharge coefficient; Q is wadi discharge, (m^3/month)

The usual practice is to estimate recharge using wadi water level but due to lack of such data discharges were used instead. However, according to Abdo (2004) relying upon wadi discharges is safer, in the sense that it certainly yields zero recharge when there is zero wadi flow. Alternatively, a non – zero recharge might be obtained if water levels and recharge are related inaccurately.

Artificial groundwater recharge is finding widespread use as a mean to increase groundwater reserves (Viessman et al., 1989). According to the authors the surface water spreading artificial recharge method is convenient for aquifers like Azaza provided that the top impervious clayey soil is removed.

This forecasted aquifer storage combined with the fact that the recommended permissible limit of drawdown equals to two – thirds of the saturated thickness of the aquifer (Abdo, 2004), the other characteristics of the aquifer and the demand of the different water users can be used to set more realistic planning and management rules for the aquifer instead of depending on long term averages.

One of the recent developments of Khor Abu Fargha is the construction of an earth dam in pursuit of solving the escalating water shortages of Gedarif. Such practice is common in various parts of the Sudan. According to Schwab et al. (1993) design of suitable water control and conservation structures requires that the following factors be taken into consideration:

- Equitable water resources allocation between the upstream and the downstream communities.
- For most purposes it is often more economical to have a periodic failure than to design for the greatest rainfall that has ever occurred.
- When human life is endangered, however, the design should handle runoff from storms even

greater than been recorded.

- Environmental considerations.

On the other hand, Orev (1986) illustrated the difficulties facing engineering works on very large (unpredictable) desert wadis with catchments of $\geqslant$ 1,000 km^2 and he attributed that to the following:

- Lack of adequate hydrological data,
- Large volume of water and sediment, and
- The high cost of structures needed to control such volumes.

Water volumes exceeding the design capacity may lead to washing out of earth dams e. g. Rawakeeb dam in western Omdurman area (El Gamri, 2004). This is confirmed by El Khidir, (1998) who attributed the frequent failure of such dams in the country for the disregard of sluice gates (to prevent silt deposition during the first few floods) and spillways (to regulate the amount of stored water to the design capacity).

Fadul et al. (2003) illustrated the use of Remote Sensing and GIS for planning water harvesting in North Darfur State. The authors used Landsat images to investigate the drainage systems (macro catchment areas), vegetative cover and surface conditions. Using GIS techniques information on soil, meteorology and others were added. Finally, the area under investigation was classified into catchment, runoff, storage and the target. The methodology proved to be technically feasible with a reasonable price. However, the authors recommended other parameters like the hydrology of the area, soil texture and depth as related to the adaptable crops to be included.

Ahmed et al. (2004) considered the discharge data (maximum, minimum and average) at a properly selected location as the most important data for wadi development through which the storage capacity and cost of the hydraulic structure can be determined. In addition to that and for successful development of the seasonal wadis the topography, soils, geology, climate of the area and close supervision of construction are to be considered

One of the traditional water harvesting techniques in the Sudan is to cultivate large discharge wadis like Khor Abu Fargha after recession (A/ Latif et al., 2003). On the other hand, simple obstructions like branches or small earth bunds or ridging and soil disturbance were made across low discharge wadis to improve the soil moisture condition. The latter practice can be adopted for the small branches of the wadi.

To improve productivity in rain fed areas e. g. northern Gedarif water harvesting and supplementary irrigation together with other improved crop production packages are to be adopted. According to Farah and Ali, (2000) these packages include optimum sowing date, optimum plant density and crop rotation. The authors argued that due to the erratic nature of rainfall it is difficult to apply the recommendation on sowing date. However, using water harvesting and supplementary irrigation will facilitate adoption of this recommendation. It is worth mentioning that a one day delay in sowing results in a loss of 1% ~ 2% of productivity. With regard to crop productivity water harvesting was reported by Farah and Ali, (2000) to achieve an increase by about 116% and when coupled with phosphorus and nitrogen fertilization the increase amounts to 166%. On the other hand, supplementary irrigation and addition of organic manure were found to increase productivity by about 130% in Khor Abu Habil in western Sudan. Improved productivity will assist in stopping the horizontal expansion in the rain fed sector freeing more lands for rangeland, forestry and environmental protection like control of gully erosion which affect vast areas in eastern Sudan (Seid Ahmed, 2001). On the other hand, water harvesting techniques were reported by A/ Latif (1995) to increase pasture and tree plantations 4 ~ 6 times. In addition to the above mentioned techniques, to prevent land degradation Adam, (2000) suggested the use of sustainable and integrated approaches in selecting hafeer size, use of machinery, moisture conservation and adopting agro forestry techniques.

4 Conclusions and recommendations

4.1 Conclusions

(1) The effect of the La Nina stage is direct and concurrent while El Nino works with a lag – time.

(2) The ENSO classification methodology was found to illustrate 83%, of the discharge behaviour of Khor Abu Fargha.

(3) Khor Abu Fargha discharge empirical statistical prediction models excelled those of rainfall prediction.

(4) Available groundwater storage and crop production can be projected utilizing forecast information.

4.2 Recommendations

(1) Rehabilitationand establishment of new wadi discharge gauging stations and meteorological stations are crucially needed.

(2) Studies on the hydrology of dry and semidry regions are to be initiated.

(3) The mutual use of prediction models is highly recommended to integrate the various skills of the models used.

(4) Improvement of the awareness in the potential uses of rainfall and wadi discharge forecast information is very much needed for appropriate management of conventional water resources.

(5) The use of the modern technologies of Remote Sensing and GIS are strongly recommended in water resources monitoring and management.

References

Abdalla, A. K. and Fota, M. A. 2001. Rainfall Atlas for the Republic of the Sudan. Sudan Meteorological Authority in collaboration with Drought Monitoring Centre Nairobi.

Abdo, G. 2004. Integrated management of wadi aquifers using mathematical modeling and optimization approach. Regional Training of Trainers in Integrated Water Resources Management. Unesco Chair in Water Resources, Unesco and UNDP. Khartoum, Sudan.

Adam, H. S. 2000. Conservation of dry lands. Proceedings of the Symposium on the Role of Agricultural Research in Combating Desertification in the Sudan, AOAD, Khartoum pp 46 – 54. In Arabic. Ministry of Science and Technology, Sudan.

Ahmed, M. K., Ahmed, S. A. and A/ Gadir, E. O. 2004. Seasonal wadis, institutions and water security. Proceedings of the Conference on Water Harvesting and the Future of Development in Sudan pp 517 – 529. Unesco Chair in Water Resources, Sudan.

A/ Latif, M. 1995. Adoptable water harvesting techniques in the Sudan. A paper presented in the Symposium on the Role of Scientific and Technological Research in the Sustainable Utilization of Dry and Semidry Areas. Agric. Research Corp., Wad Medani, Sudan.

Atheru, Z. K. K. 1999. Verification and evaluation of the forecasts: Fundamentals of forecast verification. Lecture Notes of the First Climate Prediction Capacity Building Training Workshop for the Greater Horn of Africa. Drought Monitoring Centre Nairobi (DMCN) in collaboration with WMO and UNDP.

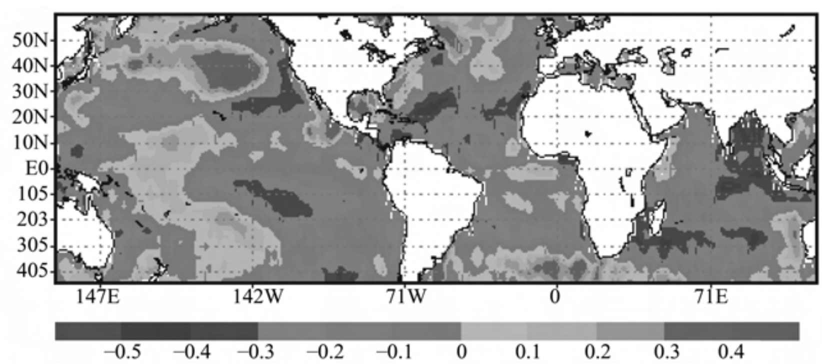
Ayoub, A. T. 1998. Extent, severity and causative factors of land degradation in the Sudan. Journal of Dry Environment 38(3) 397 – 409.

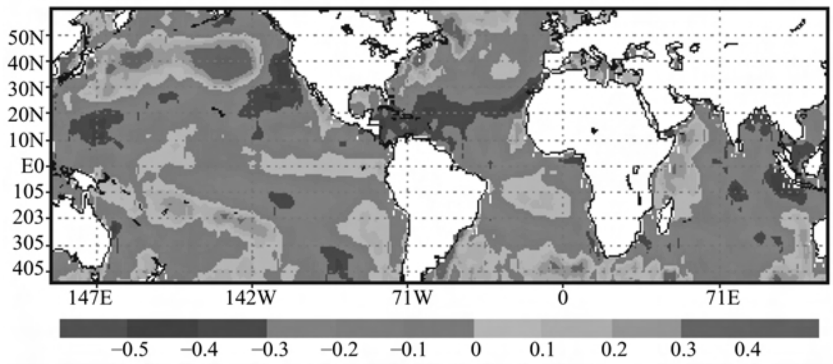
T. El Gamri. 2004. Prospects and Constraints of Desert Agriculture: Experience from West Omdurman. pp 57 – 73 Environmental Monitoring and Assessment Journal. Vol. 99 – 2004. Kluwer Academic Publishers, The Netherlands.

El Gamri, T. 2005. Rainfall Prediction and its Impacts on Water Resources Management in Central

Sudan. Ph. D. thesis. Faculty of Agriculture, University of Khartoum, Sudan.
El Gamri, T. Saeed, A. B. and Abdalla, K. A. 2007. On the Relation between Rainfall Prediction and the ENSO event. U. of K. J. of Agric. Sci. 15(1), 23 – 38, 2007.
El Khidir, A. M. 1998. A report on studying the possibility of making use of wadi's water in selected areas in Northern Dar Fur, Sudan. Intermediate Technology Development Group. Khartoum, Sudan.
El Mustafa M. A. 2005. National Action Programme for Combating Desertification Presented at the Workshop on the implementation of the UNCCD, Sudan National Assembly in collaboration with the Fedral Ministry of Agriculture and Forestry and the Dryland Coordination Group.
Fadul, H. M., Osman, A. O. and Hamid, A. 2004. Application of Remote Sensing and GIS for planning water harvesting in Wadi Kutum, North Dar Fur. Proceedings Water Harvesting and the Future of Development in Sudan Conference. Organized by Unesco Chair in Water Resources pp 15 – 24. Friendship Hall, Khartoum, Sudan.
Giannini, A., Saravanan, R. and Chang, P. 2003. Oceanic forcing of Sahel rainfall on interannual to interdecadal time scales. Science 302, pp 1027 – 1030.
Ministry of Irrigation and Water Resources (MOIWR), (1999). Sudan National Water Policy. MOIWR, FAO, UNDP.
Mutemi, F. M. 1999. Climlab2000 software. Lecture Notes of the First Climate Prediction Capacity Building Training Workshop for the Greater Horn of Africa. Drought Monitoring Centre Nairobi (DMCN) in collaboration with WMO and UNDP.
National Council for Research (NCR). 1982. Water Resources in the Sudan. Council for Scientific and Technological Research, National Council for Research. Khartoum, Sudan.
Orev, Y. 1986. A Practical Handbook on Desert Range Improvement Techniques. Interagency Group on Agricultural Biometeorology, FAO, UNEP, UNESCO, WMO. Geneva.
Osman, Y. Z. and Shamseldin, A. Y. 2002. Qualitative Rainfall prediction models for central and southern Sudan using El Nino Southern Oscillation and Indian sea surface temperature indices. Int. J. Climatology 22: 1861 – 1878. (www.interscience.wiley.com) visited June 2004.
Salih, A. M. A. 1998. UNESCOs IHP Programmes and wadi hydrology. UNESCO Cairo Office.
Seid Ahmed, H. A. 2001. Control of Gully Erosion in Upper Atbara River in El Showak, Sudan. Ph. D. Thesis, Sudan University of Science and Technology.
Schwab, G. O, Fangmeir, D. D, Elliot, W. J, et al. 1993. Soil and Water Conservation Engineering. 4th Edn. John Wiley &Sons, Inc.
Scientific Research and Foreign Affairs Centre/ Sudan University of Science and Technology (SRFAC/SUST). 2001. Integrated Water Resources Management. Technical Papers Series. TPS (2). SRFAC/SUST, Khartoum, Sudan.
Viessman, W., Lewis, G. L. and Knapp, J. W. 1989. Introduction to Hydrology. 3rd Edition. Harper Collins Publishers, New York, USA.

Appendix (1): Correlation maps between global SSTs and Abu Fargha discharges




50N
40N
30N
20N
10N
E0
105
203
305
405
147E
142W
71W
0
71E
−0.5
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
0.4

The Characteristics of Runoff Variation on Main Stream of the Yellow River

Li Hongliang and ***Liu Dongxu***

Hydrology Bureau, YRCC, Zhengzhou, 475004, China

Abstract: The length of annual runoff at Qingtongxia station and Shanxian station were extrapolated to 278 years and 236 years respectively with recorded stakes flow rising information in Qing dynasty. The variety of natural flow of Yellow River has obviously presented periodical change of rich and dry flow with uncertainty period through analysis on long term natural runoff. The variety of natural flow of Qingtongxia and Shanxian for many years is basically, but incompletely identical; the representative analysis of the series of natural flow shows that the upper stream and down stream should separate, the series length of natural flow for Qingtongxia is not little less than 83 years, the series length of natural flow of Shanxian is not little less than 70 years, the variety of average value just tend to stability basically. Here are three times that the withered water segment with continued eleven years appears in 236 years series for Shanxian; According to the data analysis in last few years, the withered water segment from 1990 to 2000 hasn't ended by 2002.

Key words: Yellow River, variety of natural flow, representative analysis, variety characteristic

The Yellow River is the second largest river in China, but water resources is quite deficient, with annual natural runoff (hereafter refers to as natural quantity) only accounting for 2.1% of total runoff in China. Moreover, but the spatial and temporal distribution of runoff in the Yellow River is quite uneven. Studies the multi – annual variation characteristic of Yellow River in the natural quantity has the vital significance to the water amount of resources science development, the optimized disposition, the reasonable use.

The study of natural quantity multi – annual variation of Yellow River often adopted the probability theory in 1950 s, in the 1960 s it starts to study its periodic change. In the periodic change research, has studies the periodic change about abundant, even and the dry, also has the research of periodic change in continuously waterless section, all yields certain result, for know the natural quantity the multi – annual variations of Yellow River, the benefit is significant.

This analysis is in the foundation which the past studied, using the size material of the defile in the upstream in the Qing Dynasty and the middle of Yellow River in waijintan to lengthen the hydrological data series as far as possible, discussed the abundant and dry change characteristic and the choice of the representation series in the natural quantity of runoff of Yellow River.

1 Data extrapolation

1.1 Data

The long – term continual river runoff material is the foundation of studying multi – annual variations of the amount of runoff. The most long and also quite complete observing data is the Shanxian hydrological station in the main Yellow River; from 1919 to 2000 the material is altogether 82 years. This controlling area of station count for 91.7% in the entire area, the yearly runoff occupies 86.7% in the entire basin runoff. In the Qianlong 30 years of Qing Dynasty (in 1765) the Shanxian's wanjintan is settled to measure the state of the water; This natural quantity multi – annual variation rule of the station basically may represent the natural quantity the multi – annual variations of Yellow River valley, simultaneously also has the condition to lengthen the material series.

The qingtongxia station in the upstream has the observing material from 1939 to 2000 altogether 62 years, the controlling area of the station occupies 71.2% in the upstream area, basically controlled the coming water volume from the upstream, the adding water between and toudaoguai is really micro. In the Kanghsi 48 years of Qing Dynasty (in 1709) the qingtongxia is settled to measure the state of the water. The multi – annual variation rule of runoff in the station may represent the Yellow River's upstream multi – annual variations, also has the condition to lengthen the material series.

1.2 Utilization of recorded hydrological information on stakes

The characteristic of Qingtongxia station and Shanxian station report the rising, does not report falling, according to analysis, the material to remember in recording rising to the flood has two forms: One for reporting partitions rising, like in 1803 defile will pile material record "in June 13, on 42th sudden rise seven feet three inches, also swells a two feet inch on 16th, in July 18, on 92th Huang Shuiyou rises five feet three inches, altogether swells including front ten feet four foot seven inches". Namely the first newspaper rises by the will pile zero gets up the newspaper, the latter newspaper rises beforehand newspaper to rise the size is a beginning, partitions the newspaper to rise gradually, accumulates each newspaper to rise the size, namely swells most greatly for the whole year the size. Another one rises for the tired accumulation of messages ktelegraph, if in 1813 the defile will pile material record "got up from May 29 to June 11 altogether swells one after another a seven feet inch; Continues with July third day date altogether swells eight feet three inches; Continues in September fourth day date to 11th altogether swells a nine feet inch". Namely each time the newspaper rises gets up by the will pile zero the newspaper, preceding time swells the size to contain in the latter newspaper rises in the size, each greatest size namely swells most greatly for the year the size. The accumulation swells the size to be bigger, the corresponding flood water volume is also bigger, the Yellow River flood season water volume approximately composes whole year water volume 60% ~70%, but the flood season water volume mainly comes from several flood water volume, this characteristic swelled the size for the will pile accumulation and the year amount of runoff establishment correlational dependence has provided the condition.

The Yellow River will pile material record swells the size is the builder's foot, with the modern metric system conversion relations is: one builder's foot is 0.32 m.

1.3 Data extrapolation at Qingtongxia Station

According to the hydrologic station research of Ningxia Autonomous Region the position of Shankou is in the north mouth of Qingtongxia, namely nearby the present hydrologic station of Qingtongxia. The will pile constructed in the Qing Dynasty Kanghsi 48 years (in 1709), at present collects to the related will pile high water material from 1723 to 1911 year altogether 128 years material, had swells the size to record specifically has 106 years, but also some 22 years have not specifically the size record, but had the qualitative record. The establishment relations between accumulation the size and the natural quantity of runoff in Qingtongxia see Fig. 1.

By the will pile material of shankou, counts flood season accumulation to swell the size every year, according to Fig. 1 to insert the natural quantity in the Qingtongxia from 1723 to 1911 altogether 106 years. Other 22 years lack swell specifically the size record year, then use "Chinese Near 500 Year Dry Water logging Distribution Atlas" (to hereafter refer to as "Atlas") the material, lack measured the year "Atlas" records the situation with is ambitious the pile to swell the size record year close achievement similar year, inserts 22 years material which makes up it to lack measured.

In 1741 (Qianlong six years), "Atlas" demonstrated for the dry year in the upstream. Minister plays calls "in June 13, on fourth a Yellow River sudden rise four feet inch …". According to the above swells the size looks up on Fig. 1 the year amount of runoff qualitatively is the lopsided year, demonstrates basically with "Atlas" consistent.

In 1803 (qing dynasty jiaqing eight years) , "Atlas" demonstrated Yellow River for the leaning waterlogged year in the upstream. The river minister plays since called "in Gan province the rain water excessively have been much, outside the Lanzhou city Yellow River swells a tall foot …,The Ningxia government office reports in July 23, 24 and so on the dates, Yellow River rises suddenly, submergence private land …". According to this year river minister reports the swells size, the looks up the year amount of runoff on Fig. 1 to determine as the abundant year, demonstrates basically with "Atlas" consistent.

Above example showed that, may use "Atlas" and unifies the related historical material make generalized analysis, firstly determined Yellow River yearly amount of runoff abundant, even, dry nature, refers to with has swells specifically the size year description similar year amount of runoff, inserts deficiently the swells size year material, is the series of amount of runoff lengthens from 1,723 to 2000 year altogether 278 year sat Qingtongxia station.

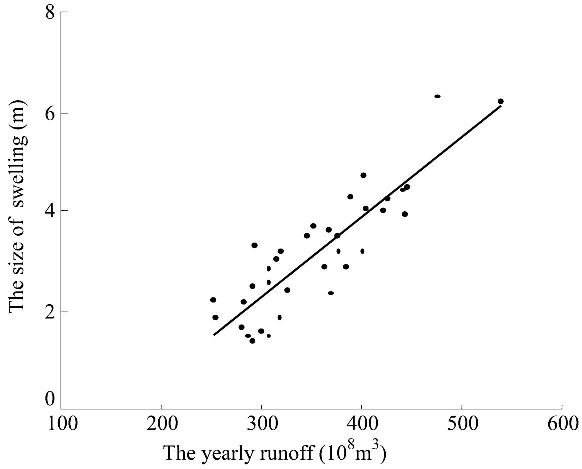


Fig. 1 The relation between accumulating flow rising and the natural runoff

1.4 Data extrapolation at Shanxian Station

Wan Jintan the will pile position nearby Shanxian, the Qing Dynasty Qianlong 30 years (in 1765) constructed the will pile, measured and reported the state of the water, until 1911 altogether 147 years material.

The yearly runoff measure of Shanxian station mainly comes from two regions, one is above Qingtongxia, and another is the sector between toudaoguai and Shanxian. The coming water above Qingtongxia, after stores and regulates the evolution along the regulation river course to Shanxian, is only the Shanxian flood base current. The size of water volume at Shanxian station in flood season, mainly is the flood season comes from the sector between toudaoguai and Shanxian. The flood between toudaoguai and Shanxian has two characteristics: one is in summer flood period rainstorm intensity is big, lasted short, creates the flood peak sudden rise and stands to drop sharply at Shanxian station. Second is in the fall flood season, the rainfall intensity is small, lasted long, which creates the flood peak slow rising, the peak is low and the quantity is big. The corresponding relations are between the coming water and the size of the swelling water by the summer flood and the fall see Fig. 2.

The water flood size statistics according to every year Beginning of Autumn date (for convenience, take August 10 as) before is the summer flood, Beginning of Autumn date later for fall high water.

By Wan Jintan will pile all previous years beginning of autumn date before and the beginning of autumn date will later accumulate swells the size, in Fig. 2 will insert and makes up the coming water between Shanxian and Toudaoguai, the two water volume will add together, namely for water volume between Shanxian and Toudaoguai; from this we can insert the runoff of Shanxian for 147 years. Wan Jintan lacks swells specifically the size material year, by the runoff of Shanxian records extend altogether for 236 years.

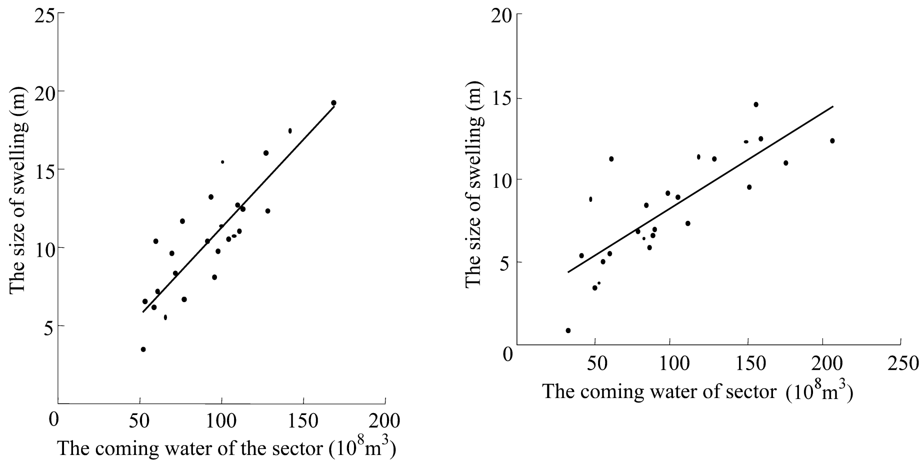


Fig. 2 The relation between accumulative flow rising and coming water at shanxian station

Using the above method to insert and make up the yearly runoff volume, although it is not extremely accurate, but qualitative is reliable, to studies the Yellow River natural quantity of the multi – annual variations are may the use.

2 The changing characteristic analysis for natural runoff of Yellow River

The curve of difference accumulate is the commonly used method to study the precipitation, the flood, the year amount of runoff change characteristic in some place. From left towards right, when the slope of curve is downward it expresses the dry season; Upward when expresses for abundant season; The level is expressed for approaching in the mean value normal water season. If the curve of difference accumulates to present to drop (or rise) continuously for the long time, expresses the long time continuously the waterless year (or continuously abundant water year). The big slope expressed the dry (or abundant) water degree is fiercer. The mathematical expression of the mold – comparing coefficient is as follows:

$$f(t) = \sum_{i=1}^{t} (k - 1) \tag{1}$$

Analysis of chart 4 may see, the multi – annual variations of runoff at Shanxian station station have the following characteristic:

Exists obviously abundant, dry circulates in turn the rule. The year number length in abundant, dry circulation section is not one, the longer for 89 years, the short is only 31 years. Takes its neighboring abundant, the waterless time whole year number suitable circulation section, the Shanxian station has two circulation sections, one from 1813 to 1901 year altogether 89 years, in which from 1813 to 1857 year for abundant water time 45 years, from 1858 to 1901 year for dry season 44 years; Another circulation section from 1902 to 1932 year altogether 31 years.

In the abundant or dry season, has the turning phenomenon similarly. Abundant season is abundant primarily, continuously abundant is more, and continuously waterless is small. Such as from 1813 to 1857 year the abundant water time has four sections continuously, it lasted for 5 years, it is generally from 3 to 4 years, the continuously waterless years is two sectors, it only lasted for 3 years.

The year average runoff volume in abundant time comparing to year average runoff in long series is more 7.2% ~9.2%, dry season annual mean runoff volume comparing to long series annual mean runoff volume lopsided 9.8% ~20.5%; the year circulation annual runoff volume is closely near the long series annual runoff volume for 89 years, like 1813 ~ 1901 the annual runoff volume of circulation section is 49.79 billion m^3 and close to the long series annual runoff volume 49.43 billion m^3; the difference of the circulation annual runoff volume and the long series annual runoff volume for 31 years is big, like 1902 ~ 1932 year circulation section annual runoff volume is 45.22 billion m^3, are less 8.5% than the long series annual runoff volume.

The average runoff volume in continuously abundant year is 56.5 billion ~ 62.8 billion m^3, comparing to the long series annual runoff volume is abundant to 70.7 billion ~ 13.37 billion m^3 (14.3% ~27.0%); The average runoff volume of continuous waterless year is 34.3 billion ~ 42.1 billion m^3, comparing to the long series annual runoff volume is lopsided 7.33 billion ~ 15.13 billion m^3 (14.8% ~30.6%).

The frequency in 236 years series of Shanxian station in the continual 11 year waterless sections to appear is 3 times (1860 ~ 1870 year, 1922 ~ 1932 year and 1990 ~ 2000 year), interval time for 52 ~ 58 year. The average runoff volume of continual 11 year waterless section is 32.25 billon ~ 42.13 billon m^3, the runoff volume lopsided 16.0% ~30.6% than normal years. According to the analysis of the near material, the waterless section from 1990 to 2000 is not over till now.

From a long - range point of the long series of major trend analysis, the multi - annual variations of the curve of runoff mold accumulates compared to the curve of coefficient difference to assume the sine wave change in the Shanxian. In 236 years it closes three sine wave change cycle, one cyclical average year runoff volume and the long series annual runoff volume is close. In the most harvest year the runoff was 84.2 billion m^3 (in 1850 inserts correction), it is more 70.3% than the long series normal value. The most harvest year the runoff in testing is 81.08 billion m^3, The most waterless in testing is 24.2 billion m^3.

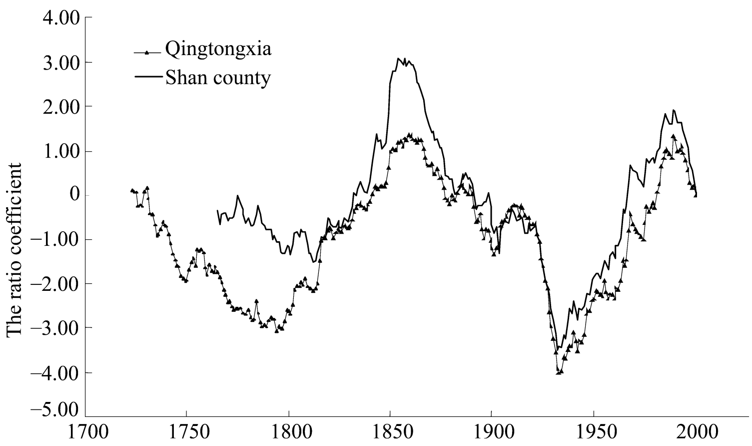


Fig. 3 The curve of mold – comparing modulus of annual runoff volume

Analysis chart 4 may see, the abundant, the dry cyclic change basically of qingtongxia in upstream of Yellow River corresponds with Shanxian, but incompletely corresponds. From the comparison with abundant and waterless in the two stations, the major part is corresponding, but also has not the corresponding place. Appears the waterless year section number in the 1765 ~2000 year for 236 years, the Shanxian station has 11 sections continuously, Qingtongxia has 12 sections, In which corresponds completely has 6 sections, the part corresponds has 3 sections, does not correspond mutually has 2 ~ 3 section; Appears the number of abundant water year section at Shanxian station have 9 sections continuously, Qingtongxia has 7 sections, in which corresponds completely has 4 sections, the part corresponds has 1 section, does not correspond mutually has 2 ~

4 section. Therefore in the upstream qingtongxia appears continuously abundant and the continuously waterless year, Shanxian stands for continuously abundant and the continuously waterless year possibility is very correspondingly big

In Qingtongxia station the long series annual runoff volume is 32.25 billion m^3, at Shanxian station the series annual runoff volume is 49.43 billion m^3, the natural quantity there has 65.2% to come from above Qingtongxia. in the natural quantity at Shanxian station.

3 The choice of material length of natural runoff of Yellow River

The computation of series average value of natural river runoff volume is relation to the length of series 、the series composition and the multi - annual variation rule relations closely. Fig. 4 and Fig. 5 for Qingtongxia and the Shanxian is the natural quantity accumulates the average process graph. The direct operation is 1723(1765) ~ 2000 year, the revoke settling of accounts is 2000 ~ 1723 (1765) year.

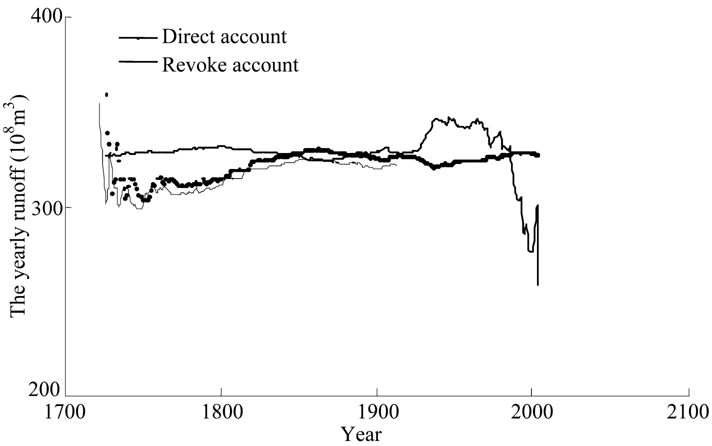


Fig. 4 The accumulating line of natural runoff volume at Qingtongxia

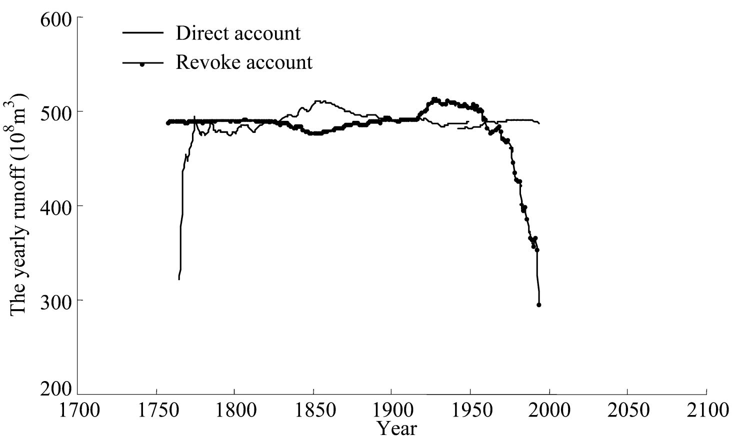


Fig. 5 The accumulating line of natural runoff volume at Shanxian Station

Analysis the change characteristic of Fig. 5 and Fig. 6 may see, from 1723 to 1806 year, its average value change only then tends to stably; The revoke settling of accounts from 2000 to 1918 year, its average value change only then tends to stably, the series length is 83 years. The Shanxian station direct operation from 1765 to 1834 year, its average value change only then is basic tends to stably; The revoke settling of accounts from 2000 to 1921 year, its average value change only then tends to stably, the series length is 70 years. In its series contains one time in a big way abundant, the dry circulation section, namely has continuously the abundant water year in the circulation section, also has continuously the waterless year, but also some part of even water year. The average value of Qingtongxia 83 years and with Shanxian which 70 years inquire into, inquire into the average value with the long series to compare, its error is ±2.0%. Therefore, the natural quantity series representative choice of Yellow River, upstream should separate the choice with the middle and lower reaches, qingtongxia station less than 83 years, Shanxian less than 70 years.

4 Conclusions

(1) The multi – annual variations of main current natural runoff volume of Yellow River have obviously abundant, the dry circulation, its cycle is not fixed.

(2) The basic correspondence runoff multi – annual variation is at Qingtongxia Station in upstream and at Shanxian station in middle stream, but incompletely corresponds; when application the special details should be concrete analysis.

(3) The analysis of yearly runoff series representation analysis, upstream and middle should be separate and choice analysis, the material of Qingtongxia station should not be less than 83 years, the material of Shanxian should not be less than 70 years, the change of its average value only then is basic tends to stably.

(4) the waterless sections appear the frequency is 3 times of continual 11 year in 236 years, according to the analysis of material, from 1990 to 2000 year is the waterless section, had not finished in recent years to 2002.

Discussion on the Sustainable Utilization of the Yellow River Water Resources

Sun Weijun*, *Zhang Zhiming and ***Feng Li***

Yellow River Binzhou Bureau

Abstract: The shortage problem of the Yellow River water resources has been becoming serious since 1990s. With the continual social – economic development along the river valley in the future, the Yellow River Water resources will scarcely meet the full demand of industry, life and ecological balance of the river course, though the Yellow River Integrated Water Regulation Conducted in 1999 has worked to prevent the zero – flow phenomenon on the lower main current continuously since 2000. In order to solve the shortage problem and maintain sustainable use of the Yellow River water resources, the authors propose: some researches need to be done on the entire – process management of water resources in accordance with Water Volume Centralized Dispatcher; price of water needs to be unified, with the aim of promoting more economical use of water in agriculture, industry and daily life; non – the Yellow River water should be encouraged as substitute resources; environmental protection of the Yellow River and other rivers should be reinforced to ensure the quality of water.

Key words: the Yellow River, water resources, sustainable, management

1 The shortage of the Yellow River water resources is becoming more and more serious

With the over quick development and utilization of the Yellow River water resources and the construction of reservoirs both on the main stream and its branches, the shortage problem of the Yellow River water resources has emerged since the early 1970s, but it has become manifest and arrested intensive attention since the 1990s as zero – flow began to appear continuously during the last decade. The Yellow River, which flows through main arid areas in North and Northwest China, covering Shanxi, Gansu, Ningxia, the Inner Mongolia, Shanxi, Henan, and Shandong provinces, can scarcely meet the full demand of agriculture, industry, daily life and ecological balance of the river course along the lower part of the river, especially for agricultural irrigation and the river course ecological balance. According to statistics, first zero – flow appeared in 1972, and it happened 22 years in 28 years since then, till the Water Volume Centralized Dispatcher started in 1999. Lijin County, in particular, had 226 days of zero – flow in 1997, about 62% time of the year. The Integrated Water Regulation Conducted in the Yellow River which was started in March, 1999 has worked well to prevent zero – flow during the past 8 years, however, the shortage problem of the Yellow River water resources still remains unresolved, and in certain periods every year some areas of the lower reaches of the river suffer from insufficient supply of water.

2 The reasons for shortage problem

The primary reason of the shortage problem lies in the insufficiency of the water resources of the river itself and the continual increase of demand from the basin areas. As the second largest river of China, the Yellow River provides only about 2% of the total runoff of the national supply, even smaller than that of Yangtze River's some branches. At the same time, however, the river is in the arid area of China where the all – ready relatively small annual rainfall is unfavorably concentrated in three months in June, July and August, which consequently leads to strongly big demand of water from the basin areas. Before the foundation of the People's Republic of China, and at the early stages of the Harnessing the Yellow River project, the insufficiency of water supply of the Yellow River was still to be revealed as the major task then was the elimination of flooding while water resources of the river were largely unexplored with no effective technology available for large scale utilization.

As the flooding of the river basically comes under control and the Yellow River's legend of "two brenches in three years" became history, large and middle scale reservoirs at upper and middle reaches and irrigation at the lower reaches grow out of nothing, from infancy to maturity. Till 2004, 882 small and above – sized reservoirs have been constructed, with the total storage capacity of 65.84 billion m^3, among which are 186 large and middle scale ones, with the total storage capacity of 63.34 billion m^3, far above the total volume of the main current of the river. Meanwhile, the irrigation area of the Yellow River has expanded to 753 million ha. Furthermore, the river also provides water for non – drainage areas including Hebei, Tianjing, and Qingdao etc, which subsequenely aggravates the present situation.

3 Solutions of the shortage problem to realize the sustainable utilization of Yellow River water resources

The nature of the issue lies in the gap between the limited resources of the river and the high demand from agriculture, industry, daily life and ecological balance of the river. For sustainable utilization of water resources, for best socio – economic efficiency, we need to improve the administration system and mechanism, take full advantage of non – the Yellow River water resources, which ultimately, demands the adoption of an entire – process management.

3.1 Establish an entire – process management system for maximum efficiency

At present, management of the water resources of the river relies heavily on the unified distribution at the canal head by administrative departments. The so – called "Unified Water Management at Canal – head" works well to guarantee flow of the main stream and healthy ecological balance in the river but it fails to monitor and evaluate actual situation of water utilization and efficiency. Therefore, an entire – process management model is in urgent need for irrigation areas as well. It may guarantee more reasonable distribution of water resources, social, environmental and economic benefit. Priority should be given to water uses with high social and environmental benefit, for some with low economic benefit, subsidies and governmental assistance may be in order.

At present, water resources of the Yellow River are managed by a split division: at canal – head, management is entitled to administrative departments of the YRCC, while at the irrigation areas, by irrigation bureaus of local governments. For different benefits and with different duties, the two find it hard to coordinate and cooperate, which makes the maximum efficiency impossible. If a unified model can be established, and the entire – process management can be realized, maximum benefit will be possible. The core of the model is the separation of administration and utilization and enterprises of water management should be introduced. In that case, the YRCC administrates the overall control of the water resources, the water management companies take charge of water distribution at the irrigation areas, local governments exercise coordination and supervision, hence, the sustainable utilization of the water resources of the river can be realized.

To further facilitate the entire – process management, the current water charge system needs to be modified. At present, in the lower reaches of the river, different prices are set for different water uses: agriculture, industry and daily life. The charge of agricultural water is lowest (for the best benefit of farmers) and the industrial water is 7.7 to 8.5 times of the former. The unfair system creates conflicts between different parties, the much – too – low agricultural water does not encourage economical use of water, and sectors at the canal head have difficulty in monitoring actual uses of water at the irrigation areas, all of which constitutes obstacles for effective management. Therefore, for their motivation and initiation, the right of setting different prices for different use should be granted to water – management enterprises, with the price at the canal head remaining the same.

3.2 Use price to promote more economical water use

In market economy, price is always the base way to solve the conflict between supply and demand. In recent years, many factories adopted measures for economical use of water after the price of industrial water was raised. Some power plants, for instance, with enhanced awareness, have begun to recycle water as best they can for cooling after the price increase. While before that, cooling was done almost entirely by water from the Yellow River, which was relatively cheap. It is obvious that price plays an important role in promoting more economical use of water and will definitely contribute remarkably in the future. At present, in agricultural irrigation which occupies over 90% of the whole utilization of the Yellow River water, serious waste and low efficiency exist as the result of the much – too – low price too. It is learned that irrigation by the Yellow River water costs far less than underground water while works much better that the latter. In addition to waste, equipment lack for water saving causes unnecessary loss and consumption as well. Provided that the price is can be raised, awareness of saving water will be enhanced at the irrigation areas and more water can be saved for places with more urgent need. To sum up, it is necessary to further reform the price system, increase prices of water and water resources to promote more economical use of water, achieve maximum benefit of the Yellow River water, and in the end, sustainable utilization of the Yellow River water.

It is a misconception that rising of water prices may add burden to farmers as it increases agricultural cost. In fact, water price of the canal head constitutes only a minor part of the total price which farmers pay, the major part being the management cost of the irrigation area and expenses caused by unnecessary loss and consumption of water. If reformation can be made on the water – saving technology and equipments, and more cost control can be exercised, water prices the users (farmers) pay will be actually reduced. So to counter argue the misconception mentioned above, the authors maintain that increases of water prices will not add much to the agricultural cost and farmers' burden, instead it will promote awareness of water – saving. On the other hand, government may help to promote water – saving by granting cash subsidies or by raising prices of crops. To minimize the influence of price increase, the government should issue compulsory laws and regulations to implement water – saving and add more input for reformation of water – saving technology and equipment. Management of irrigation areas should be assigned to enterprises (which exercise cost accounting, unlike government administration departments), and hence, reduce waste, enhance the awareness of water – saving and cost control, and ultimately minimize the influence of water price at canal head on cost of the irrigation areas. The government should set reasonable prices through cost accounting to prevent extra cost from irrigation areas being added to the water price actually pained by the users.

3.3 Make full use of other alternative water resources for the less dependence on the Yellow River

The shortage problem of the Yellow River water resources will become more and more acute with socio – economic development. Total dependence on the Yellow River water will inevitably deter the situation and even threaten major uses for industry, life and ecological balance. Therefore, it is imperative that we start research on non – Yellow River resources in the drainage areas and especially for areas with relatively lower demand for water quality, rain and flood resources should be fully explored. Reservoirs which can store rain in rainy seasons will undoubtedly help to relieve the pressure on the Yellow River. Surface underground water may satisfy some demand in certain circumstances. Only through exploration of alternative resources can the Yellow River water provide maximum social, ecological and economic benefits. Meanwhile, more radical measures need to be taken to improve water quality of polluted other rivers besides the Yellow River, thus making them substitutes to the Yellow River. To further facilitate use of alternative resources, government guidance is necessary, but the price leverage will play a greater role in creating an atmosphere of saving the Yellow River water by further raising the water price.

On the long run, the Yellow River will be basically the emergency water resources, meeting demands of daily life, ecological balance and for industry and agriculture in special circumstances. Only by taking full advantage of local water resources can maximum socio – economic benefits of the Yellow River water resources be guaranteed at critical moments.

3.4 Take more radical measures to protect and improve water quality

Another key for sustainable utilization of the Yellow River lies in the protection of the water resources. At the moment, the main stream and the branches of the river have been seriously polluted, water quality at most reaches far below the standard. According to a report from the YRCC, in 1980s, the river received 22 billion industrial sewage and life waste from both banks annually; in the 1990s, the number rose to 42 billion. In May, 2004, water quality in 72.5% reaches out of the 51 evaluated is below Ⅲ (2), among which 45.1% is even lower than Ⅳ; 35.5% out of 31 reaches evaluated of the main stream meet the standard of Ⅲ; 15% of the 20 reaches of the branches evaluated in May meet the standard of Ⅲ, and 15% meet the standards of Ⅳ and Ⅴ, while 70% below the standard of Ⅴ. If no radical measures were taken, the Yellow River water would not be usable in the future and the river would turn into a "dead river". To make it a "clean river", legal, economic and administrative measures should be employed comprehensively, by drawing intensive attention nationwide, as issues of zero – flow of the Yellow River and pollution of the Huaihe River have, more publicity in media and public surveillance, more severe punishment for illegal sewage disposal, and more thorough treatment of polluted water.

With the arrival of the 60th anniversary of "Harnessing the Yellow River", the Yellow River, a disaster river in history now is becoming the real mother river for the people, playing a more and more important role in social and economic development of the both banks. We should protect our mother river, keep her healthy and guarantee sustainable utilization of its water resources.

References

North China Water Conservation and Hydropower Institute: TIAN Jinghuan and so on The Influence on. Water Resources Amount from Water Surface Evaporation of Large and Middle Scale Reservoirs in Yellow River Valley , 2004.

Chinese Industry Newspaper Office: CHEN Jinliang: Near 40% of Yellow River Water Quality Exceeds the Allowed Standard Seriously, 2004 – 6 – 3.

A Preliminary Investigation of the Integrated Water Resources Management in Guiyang City

Zheng Yong

Guiyang Water Resources Bureau, Guiyang, 550005, China

Abstract: Based on the reviews of the current water resources management policy and practice in Guiyang, the Integrated Water Resources Management (IWRM) Project is proposed to implement in Guiyang. The Master Plan and detailed Sector Project for Guiyang IWRM has been investigated according to the concepts of IWRM. Also identified in this paper are the pertinent issues and constraints for implementation of IWRM in Guiyang.

Key words: integrated water resources management, Guiyang city, pratice

1 Water Resources basic condition of Guiyang City

Guiyang Municipality (GM) is situated in the middle of Guizhou Province, the capital and political, economic and cultural centre of the province. It has an area of 8,034 km^2 (4.56% of total area of the Province). By the end of 2004, the population of GM was 3.51 million (9% of the province) with GDP of 47.7 billion RMB (30% of the province). GM's Government has administrative jurisdiction over six districts, three counties and one suburban city.

GM is in a sub – tropical zone with mild winters and warm, humid summers, located on the watershed between the river basins of the Yangtze and Pearl Rivers. Annual rainfall averages is approximately 1,100 mm, and is highly seasonal with 74% occurring in the four months from May to August. It is estimated that 51% of rainfall runs off, amounting to an annual average water resources of 4.52 billion m^3. This is only about 1,288 m^3 per capita (for a population of 3.51 million in 2004), less than the internationally recognized water requirement of 1,760 m^3 per capita per annum and the national average in China of 2,180 m^3 per capita per annum.

Due to population growth and economic development, GM's water supply capacity will be expected to increase rapidly. An analysis shows that rapidly increasing urban population has seriously stretched the existing water supply capacity, resulting in reduced water pressure and water rationing, and shortage of irrigation water in dry periods. Based on growth of population from 3.6 million in 2005 to 3.9 million in 2010, GM forecasts its annual water demand that will be 1,460 million of cubic meters (MCM) in 2010 and 1,770 MCM in 2020. Without the Project, it is estimated that the annual water shortage will be 420 MCM in 2010 and 642 MCM in 2020.

The limited total water resources, unrational temporal and spatial distribution, severe seasonal water shortage as well as increasing contradiction between water supply and demand have urged the implementation of Integrated Water Resources Management (IWRM) in GM.

2 Introduction of IWRM

2.1 IWRM concepts

Since the early 1990s, the concept of Integrated Water Resources Management (IWRM) has received global attention. The concept of IWRM is widely recognized as the best effort to foster problem – oriented and solution – driven management of water and related resources.

Based on the Dublin Principles (proposed by the International Conference on Water and the Environment in Dublin, 1992), IWRM implies: ①an inter – sectoral approach; ②representation of all stakeholders; ③ all physical aspects of the water resources; and ④ sustainability and environmental considerations.

The Global Water Partnership describes IWRM as a process that promotes coordinated development and management of water, land and related resources, in order to maximize economic and social well – being in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000). It is the most promising way towards achieving sustainable use of water resources; it calls for a holistic management of watersheds.

2.2 IWRM plans

In contrast to prescriptive and rather rigid master plans, an IWRM – oriented planning process takes a flexible and dynamic approach to plan the development and management of water resources. Planning reflects the total activity in the system, typically defined as a river basin or sub – basin, including, for example, water resources development, agriculture, forestry, mining, urban water use and discharges, and other relevant land use. The planning process acquires a special role in strengthening good governance within a strategic water management framework of goals, policies and planned actions to achieve the goals, including river basin management plans, groundwater management plans, environmental assessment, social assessment, and economic assessment. It is very important to recognize the dynamic nature of the planning process because a significant value of the concept lies in its flexibility. The plans should be regularly monitored and amended in order to take account of recent development trends.

3 Guiyang city IWRM

Guiyang Integrated Water Resources Management (IWRM) Project, is a firm project for Asia Development Bank loan assistance in 2007. According to the principles of IWRM concept as well as the current water resources management policy and practice in Guiyang, The Master Plan and detailed Sector Project for Guiyang IWRM has been investigated.

3.1 Guiyang IWRM master plan

The objective of the Master Plan is to present an economically sound response to the water needs of Guiyang Municipality covering all forms of water use, both urban and rural. The Plan includes initiatives to develop new resources; improve irrigation facilities; manage demand and conserve water; enhance wastewater treatment and reuse of effluent; protect existing water resources; reform institutions; and introduce market – based measures to save water.

The Master Plan identifies there is good potential for further water resource development in order to overcome shortages in both rural and urban areas. The primary objective of the Master Plan is to ensure an increase in available water resources in line with GM's development needs.

3.2 Guiyang IWRM sector project

Based on the GM IWRM Master Plan, the project scope has been proposed to include a range of activities to support development of integrated water resource management, including measures for managing demand and improving water supply availability. Many of the activities including public participation, and strengthening of procedures and management arrangements, will be organized around the construction of 46 medium and small reservoirs, dams, agriculture irrigation systems, urban and rural water supply schemes, rainwater collection structures, and soil and water conservation sub – projects. They are summarized as follows:

(1) Establishment of one medium and two small reservoirs for urban water supply, including construction of dams, water conveyance tunnels, transmission pipelines, four water treatment plants (WTPs), and extension of the municipal water distribution networks.

(2) Construction of 43 small reservoirs for county township and rural water supply and irrigation, water conveyance systems, small township treatment facilities and irrigation systems.

(3) Rehabilitation and upgrading of irrigation schemes in 9 areas including installation or repair of intake structures, canals and aqueducts.

(4) Provision of 127,890 small water storage structures (surface impoundments, underground tanks, and mini reservoirs) in rural areas to catch spring water for human consumption, and rainwater runoff for irrigation and livestock.

(5) Conservation of soil and water in upper catchments of the water sources (800 km^2) with farm land restructuring, conversion of sloping farmland to terraces, areas planted with trees or grass, and fruit trees.

The Project will be implemented over a period of six years from 2007 to 2012. Estimated capital costs are RMB 2.59 billion (~ $334 million) for 128,248 project sites in 131 administrative areas, comprising the following segments:

(1) RMB 409 million for water supply subprojects in urban areas.

(2) RMB 998 million for water supply subprojects in villages and townships.

(3) RMB 834 million for irrigation, human and livestock water supply sub – projects.

(4) RMB 266 million for soil and water conservation sub – projects.

(5) RMB 80 million for project management.

In accordance with sector loan modality, six core sub – projects representing the five main types of infrastructure development activities were selected as suitable for ADB financing. The six core sub – projects and their proposed Implementing Agencies (IAs) are as follows:

(1) Zhushui Water Resources Industry Company for the Yudongxia Reservoir (18.6 MCM capacity), Urban Water Treatment and Supply (100,000 m^3/d) Subproject.

(2) Xiuwen County WRB for the Jinlong Reservoir (4.18 MCM capacity), County Water (8,822 m^3/d) and Irrigation Water Supply (6,468 mu farmland) Subproject.

(3) Xifeng County WRB for the Liaojiuzhai Reservoir (183,000 m^3 capacity), Rural Domestic (54 m^3/d for villagers and livestock) and Irrigation Water Supply (1,800 mu farmland) Subproject.

(4) Wudang District WRB for the Midsize Irrigation Rehabilitation (6,980 mu farmland) Subproject in Wudang District.

(5) Xifeng County WRB for the Small Scale Water Storage Structures (250 small tanks) Subproject.

(6) Huaxi District WRB for the Soil and Water Conservation Subproject within the 15 km^2 catchment of Huaxi Reservoir upstream of Naming River.

With the exception of the Yudongxia reservoir subproject, actual construction of these core sub – projects will commence in 2007, and they will be completed within the first two years of Project implementation. Most of the non – core sub – projects will be implemented after commencement of the core sub – projects; however, it is anticipated that construction for many of these will also commence during the first two to three years of Project implementation.

4 Discussion

4.1 Constrains to the IWRM in GM

Despite the promising potential of the IWRM in GM, there are some key constraints to the implementation of IWRM in GM, which can be summarized as follows:

(1) Institutional fragmentation – particularly not only horizontal fragmentation between institutions/agencies at the same level of government. Horizontal fragmentation of institutional responsibilities must be a top priority to get government agencies working more effectively together. Water resources planning and management are activities that span the roles and responsibilities of multiple agencies, and for most effective outcomes those agencies must jointly plan their activities and freely exchange information.

(2) An absence of participatory structures and consultative processes. The relative absence of participatory approaches to water resources management that involve the community to be served is

another important constraint in past practice. Community participation is particularly important in rural areas, where the introduction of WUAs and WUGs will be a key initiative, supplemented by community consultation during the planning and design of sub – projects. Community consultation should be integrated into all planning and project development processes and become an essential and reflexive component of those processes facilitating two – way communications. It needs to be part of the culture of government institutions that planning and project development cannot proceed without community consultation and participation. That will require not only changes in personal attitudes and management priorities, but incentives through introduction of criteria in staff evaluation procedures.

(3) Poor coordination between different agencies and inadequate information flows. Informal communications and negotiations between agencies have occurred in the past on an ad hoc basis, but improved partnership demands a more structured approach to joint planning and complementary management, with more formal mechanisms for working together on an ongoing basis. Formation of Poject Leading Groups (PLG) is a good initiative to provide a framework for a more structured approach, and we recommend that this be extended to the formation of PWGs to provide a second (lower) tier for joint planning at the operational level of management in addition to the senior executive level.

(4) A lack of comprehensive catchment – based systems analysis in the preparation of the Master Plan.

(5) A continued emphasis on supply – side solutions.

Past water resources management practice has been dominated by supply – side management, and there needs to be a strong shift towards demand management. This will be consistent with the current national campaign objective of a water savings society. There are many opportunities to save water and use water more wisely in the management of urban and town water supply systems as well as in irrigation systems. An action program of demand management measures should be prepared by water resource regulators and water providers for every distinct water supply system in GM. Adequate budget provisions should be allocated to ensure these programs become programs of action and not just of good intentions.

4.2 Strategies for IWRM – based institutional reforms

In response to above – mentioned constrains, a broad strategies for IWRM – based institutional reforms should be conducted as:

(1) Selective institutional reforms to remove specific anomalies and constraints to a more integrated approach.

(2) Clearer definition of the role and responsibility of the Water Resources Bureau as the agency with over – arching responsibility for overall water resources management.

(3) Establishing participatory structures, including Water User Associations (WUA) in rural areas, and involving other non – governmental stakeholders as appropriate.

(4) Improved coordination through joint working groups and standing committees to address specific problems such as: – rural water conservation and agricultural outreach to change cropping patterns, – industrial water saving, – promoting urban water saving, and – providing comprehensive solutions to water quality issues.

(5) Greater focus on water management based on catchments rather than on administrative jurisdictions.

In relation to the Guiyang IWRM Sector Project, potential capacity building needs were identified as relating to:

(1) The progressive implementation of IWRM principles throughout Guiyang city.

(2) Processing the approvals for non – core sub – projects.

(3) Application of participatory approaches including the establishment and development of local WUAs and Water User Groups (WUGs).

(4) Support to farmers for the application of revised cropping patterns to reduce the risk of crop

loss and increase crop yields.

(5) Implementation support to the municipal Project Management Office (PMO), local PMOs and relevant Implementing Agencies (IAs).

5 Conclusions

In general, implementation of IWRM is consistent with the national Water Law of 2002, and supports the intentions expressed in the Master Plan for integrated water resources development prepared by GM government in 2006. IWRM will develop solutions to current water related problems occurred in Guiyang, to achieve the intended aims and objectives of improving water use efficiency; Main measures include: raising public awareness of the value of water; reducing losses in water distribution systems, and finally fulfilling the national concept of a "water saving society".

Water Education in China—Development and Expectation

Zhang Haitao[1], ***Gan Hong***[1], ***Liu Ke***[1], ***Nicolò Moschini***[2] and ***Niu Cunwen***[1]

1. China Institute for Water Resources and Hydropower Research, Beijing, 100044, China
2. SGI Studio Galli Ingegneria SpA – Padova Italy

Abstract: The paper firstly illuminates the significance of water education action by analyzing the promotional effects of water education on water – saving society, water resources management and educational system in China. Then based on the development status of water education action and differences between China and other countries, the target and implementary framework of water education in China are proposed, and development strategy of water education action in future in China by means of several following aspects: using foreign experiences for reference, sponsoring Chinese characteristic water education, rational exerting the function of government and non – government organizations, strengthening research and practice guidance and advancing the central force of water education. Finally, the awareness of water saving and protection is waken up by advocating the value of "Know Water, Love Water, Save Water and Protect Water".

Key words: water education, water – saving society, water resources management, development strategy

As an indispensable element for human survival and health, water is essential for life. Saving and preserving water resources is crucial for alleviating poverty and hunger, and sustainable development of human society. The United Nations, on its General Assembly Fifty – seventh Session, proclaimed the year from 2005 to 2014 as "Ten – year Education for Sustainable Development (ESD)" in December 2002, and in December 2003, proclaimed the year from 2005 to 2015 as the International Decade for Action "Water for Life"! The primary goal of the "Water for Life" Decade is to promote efforts to fulfill international commitments made on water and water – related issues by 2015. Presently, water education has been taken as an important content of ESD and put in practice.

China, as one of the most populous countries in the world, is now faced with a serious situation of water resources. The average per capita per year water resources in China is only one forth of the world's averages. The serious water situation in China may however provide a good chance to promote water education within the general framework of ESD proposed by UN. To initiate detailed water education activities, it is also important to find a reasonable operating mechanism and draft specific strategy of water education. These activities will not only improve the awareness and ability of the public to save and protect water, but also promote water resources management and construction of water – saving society. To fulfill the tasks, detailed plans and roadmaps for water education, from a long – term perspective, need to be put forward.

1 Functions of water education

The sustainable utilization of water resources would considerably contribute to the construction of sustainable development. Water education, as works to promote such utilization behavior, would thus be related to sustainable development. Specifically, water education is attached with the following impacts: from the managerial perspective, it refers to the mode of water resources management that the public participates, and it is important basis and condition of building water – saving society, in addition, water education is a practical education, therefore, it is significant aspects of enhancing the civil diathesis continually to improve the whole education and nation diathesis.

In order to construct water – saving society, the following aspects need to be emphasized, including water resources demand management, water resources integrated management, infrastructure establishment, allocation of initial water right, the system construction for public participation, and multi – means such as administration, legislation, management, economic method, education, propaganda, and technology. The system of public participation is connected with water education, and it need a long term effort to realize public participation, so it is necessary to exert systemic water education as early as possible. Unless water education is exerted early, public participation will become " the shortest board " of building water – saving society; consequently affect its progress and effect.

Water education not only spreads water knowledge and water culture simply, but also an education method in school which mainly stresses practical activity and an action to create the society with water – saving atmosphere. It mainly exercises students " operational abilities and teachers" practical abilities, and improves public ability in acquiring correlative knowledge, this will be helpful to improve Chinese education and train civil diathesis.

2 Present situation of water education abroad and at home

In China, the basic situation of water education is that knowledge is scattered and not systemic, and the public pays more attention and less action. Scattered knowledge indicates that the introduction and knowledge of water is scattered, water knowledge is mostly mixed in the books referring to the knowledge of environment, resources and energy sources; systemic books about water education need to be compiled and popularized based on Chinese characteristic water resources and practical situation; More attention and less action indicates that the situation of water resources is severe, the public propagandize water education more and have more attention in water problems, however, the public seldom organize water educational activities, especially imperfect books, trainings, courses, lectures, labs and extracurricular activities on water education.

In developed countries, the ongoing education reform has made environment study a substantial part of the whole educational system. Furthermore, while stepping into the 21st century, countries such as the U. S, Japan, U. K and New Zealand has extended the concept of environment protection, evolving into the framework of sustainable development. The social dimension of environment education was also extended to adapt to the new demands derived from such evolution. Water education has become relatively systemic and mature in these countries, and the curriculums together with practical projects are more developed. Water education has begun to leave certain impacts on water resources management. Compared with these countries , the Chinese water education was in its initial phase, with emphasis on the introduction, imitation and application of foreign experiences and lessons.

This could correspond to the general situation of water education in most developing countries. Even some developing countries still have no consciousness to develop water education plans. In the Chinese scenario, as mentioned above, the main activities of water education for now still focuses on the introduction, imitation, and application of foreign lessons. However, China, as other developing countries, still need to set up the goals of their own, which are based on the national situation of water resources. Related plans also need to be developed, as roadmaps, to realize the clarified goals. It is expected that, in China, gradually, water education will be incorporated into educational curriculum, and the awareness of water saving would also be improved correspondingly; This may further call up concerted efforts and participation of stakeholders, building together a water – saving society.

3 Objectives and implementation framework of water education

In view of the current status of water education in China, it is necessary to carry out water education to achieve the following changes, including: ①Extend theoretical studies and slogans into real educational activities; ② Apply and transfer expertise and knowledge to training materials; ③Promote less acquirement to systemic study, and enhance the degree of participation.

To realize the changes, a series of goals need to be set up. A recent goal is to compile and popularize series of reading books on water education for students, teachers and the public; The systemic and integrated water education mechanism will also be founded during this period. The long – term goals are to introduce and impart sufficient water knowledge to the general public to arouse the mechanism of public participation to support building water – saving society and water resources management.

Water education programme must be implemented based on two objectives to realize four proposed changes through following approaches

Based on investigation of the situation and demands in China and abroad and learning the experiences in other developed countries, it is main road to compile and popularize the reading books by means of setting up the strong water education working nets, powerful activities (such as training, investigation, academic seminar and ect.) to form the widespread water education with Chinese characteristics, gradually improve public awareness of water saving . and protection, promote public participation of water management. The approaches are as follows (see Fig. 1).

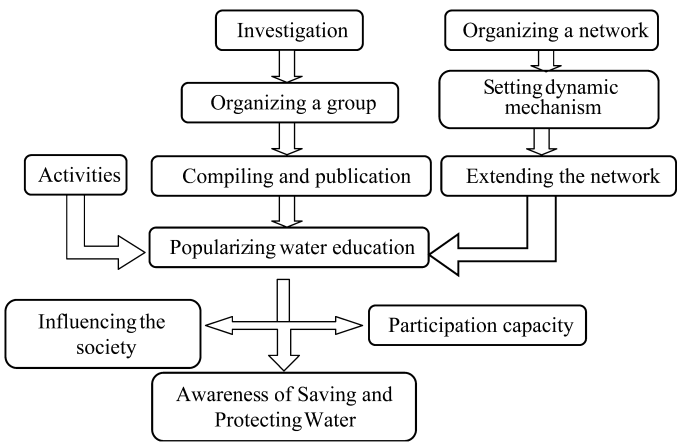


Fig. 1 Implementation framework of water education action

4 Development strategy in the future

Based on the situation, aims and implementation framework of water education, in line with the condition of water resources in China, future development have to focus on the following aspects.

4.1 Carry out sufficient investigation and research on the present situation of water education

On one hand, investigate, analyze and compare the situation of water education in China and other countries, including the main objectives, situation of the practitioners, governmental policies and measures, effects of non – government organizations, main contents, education forms and achievements, then choose an example. On the other hand, investigate and analyze the mode of participatory water management, including channel for transferring water knowledge, quantity assessment of water knowledge, and capacity building activities.

4.2 Advocate water education activities with Chinese characteristics to enclose water history, culture and water resources situation in China

In China, three points need to be considered to carry out water education. The first is the national water culture with a long history, the second is the difference on water resources between China and developed countries, the third is the different phase of development.

First of all, there is a water culture in China with centuries – old history. The culture specifically consists of works of the Chinese people on flood control, and the development of water resources in history. There are numerous well – known stories within the Chinese water culture such as the Dayu story recording ancient Chinese how to handle floods. Societal changes in the past are often closely related to water culture. Secondly, characteristics of water resources in China are different from the developed countries such as those in Europe. These could be various reasons, including the allocation of precipitation, characteristics of water resources and the mode of water consumption. Thirdly, compared with some developed countries, China is now in a different development phase with a large number of population but lower per capita water resources. The history and differences need to be enclosed in the training materials on water education, and learned by Chinese public.

4.3 Strengthen theoretical research on water education to guide educational activities

To form an effective operating mechanism, theoretical research is necessary to sustain the long – term development of water education. The main contents of theoretical research are as follow:

(1) The systemic water education knowledge adaptive to water resources character and education mechanism in China.

(2) Implementation organization and collaboration mechanism of water education.

(3) Implementation strategy, assessment system, supervision mechanism of water education.

4.4 Effective mechanism by means of the government's power and non – government's participation

To conduct full – scale water education, we must gain government's devotion, including policy and fund. And non – government' function is excellent at expertise knowledge and popularization. At the same time, close communication, sharing common resources and experiences, strong collaboration are all needed to promote sustainable water using and sustainable development.

4.5 Make Water education into an important impetus to promote sustainable water consumption, and sustainable development

Water education can help human beings to understand the difference between themselves and other creatures on the planet on the use of water. It also improves their awareness of their relationship with water, enhancing the value of water among people, and advocating their water protection activities. If water education as such could be further extended, the mode of sustainable water consumption could be further promoted, and water education will become an important impetus for building a sustainable future for all of us.

5 Epilogue

Students, teachers and public are all the objects of water education. Especially youths are the hosts for future, and they are also the strong power of building water – saving society, they are the most important object of carrying out water education plan. So in the long – term and macroscopical angel, the younger should be regarded.

At the same time, water education action is related to many factors and many branches will take part in this action, it includes many kinds of activities, such as dialogue between two ministries, collaboration between China and other countries, participation between experts and non – experts. So we must have common cognition, build up a favorable environment to popularize the education.

Popularizing water education is a course to gain the value of "Know water, Love water, Save water, Protect water", also a important tool to spread the concept of harmony between human and water, and a great power to hasten the sustainable development of human society. therefore it will be a precious wealth to persist in popularizing water education in China.

References

Shi Gendong. Education promoting sustainable Development [M]. Education and Science Press, Oct. 2004.

Cui Jinxing. The base and condition of building water – saving society [J]. Water Conservancy Development Research, May, 2004.

Liu Chaoji, Chen Hong and Li Qiang. Employee inspiritment based on water barrel principle [J]. Science Management. Jun, 2006.

Wang Xiaodong. The cognition of water – saving society [J]. Water Conservancy Development Research. Aug, 2003.

The Important Impacts of Natural Changes and Human Activities on Flood Frequency and Water – use Guarantee Rate

Wang Yujie[1] , ***Liu Sheqiang***[2] and ***Cui Tingguang***[1]

1. Management Bureau of Sanmenxia Multipurpose Project, YRCC. Sanmenxia, 472000, China
2. Sanmenxia Reservoir Branch office, Hydrology Bureau, YRCC. Sanmenxia, 472000, China

Abstract: By the calculation and analysis of the distribution changes of flow on some representative hydrological stations in the mainstream or branches of the Yellow River, it is found that the basic hydrological features (such as the maximum flood discharge, Annual runoff volume, flood season flow etc.) for the constructed, being constructing or constructed water project in any related area, are often interrelated in one region of the Yellow River basin or other basins. If the nature conditions change or human activities disturb, these parameters of features (such as mean value, *Cv* coefficient of deviation, skewness coefficient of skewness or *Cs*) will change relatively. It will result in the relative changes of flood frequency and water guaranteed in different sections of the river. Therefore, further analysis and research of quantitative changes is the basic prerequisite for the scientific decision – making, design, investment, effective management and utilization of water projects, and also plays an important and realistic role in flood and drought fighting.

Key words: flood frequency, the probability of water guarantee, distribution, changes, human activities, impact, the Yellow River

1 Preface

A lot of construction, management and operation of water project shows: due to the variety of natural conditions and human activities, the flood frequency and the probability of water guarantee changes at different sections in a regional related with rivers. Particularly, because of the impacts of human activities and long – term water diversion project, dam for storing water and soil conservation project in mainstream or branches, the changes of flood frequency and the probability of water guarantee is trend, fundamental and irreversible, during the design life or even longer period of these projects. Therefore, it is significant to further analyze and research the quantitative variation for the construction of these projects.

2 Characteristics and significances of changes in flood frequency and water guarantee rate

For flood control, flood frequency means that the features of river flood (The maximum flood discharge, Flood volume, etc.) are greater than the ratio P (%) (The frequency of a certain value to the total number of series), and reflects the average probability or probability of a flood. For the drought – fighting project, the probability of water guarantee refers to the probability P (%) of the time period, in which the water might be used by the relative sectors when the feature of water use is in smaller criteria, and actually reflects the average probability or probability of a drought. In theory, flood frequency and the probability of water guarantee are the abstract concepts of mathematical statistics. In fact, along with the change of time and conditions, and for the data of measure samples or the relative deduced approximations, various parameters for both flood frequency and the probability of water guaranteed may change systemically to some extent. These changes are closely linked with the change of natural conditions and human activities, including watershed rainfall, the change of ground surface conditions and those projects by human activities. In other words, flood frequency and the probability of water guaranteed is significantly changed and related with the objective conditions.

According to these features, it should be fully understood: before or during the early stages, the projects for flood and drought fighting, if the average frequency of flood and the probability of water guarantee is calculated from the long – term series of hydrological data without consideration of quantitative changes, these features and related parameters are often only of historical significance or are subjective for project planning. Actually, after the construction and operation of water projects, the flood frequency and the probability of water guarantee is meaningful to the values and benefits of water projects. That is to say, the unreasonable design value of flood frequency and the probability of water guarantee always deviate from the actual situation to some degree. This will influence economic and social benefits for the project of flood and drought fighting.

3 Basic foundation for the analysis of flood frequency and the probability of water guarantee rate

Based on long – term observation by scientists, it is found that dynamic rule is integrated with statistical rule in nature. This reflects that the inevitability (certainty) coexists and interacts with the chance (uncertainty). Flood frequency and the probability of water guarantee belong to this kind of issues.

100 years ago, A British scientist, Mr. Pearson discovered that the probability distribution curve for some random variables in biology, physics and economics random variables is not normal. After lots of research, he proposed 13 types of distribution curve. Many data proves that the random variable in hydrology is similar with Pearson type III curve.

Pearson III curve is an asymmetric single – peak curve with one finite point and one unlimited point. In which, there're three parameters. These parameters have a function with mean value, deviation coefficient Cv and skewness coefficient Cs (or skewness). Therefore, as long as Pearson III distribution of the mean value, Cv and Cs can be determined, it is possible to determine the probability distribution of random variable. In other words, the calculation, analysis and identification of the changes for the relevant parameters of runoff features (such as mean, Cv, Skewness or Cs), is basic to determine the changes of flood frequency and the probability of water distribution at representative hydrological stations of different sections of relevant regions.

4 Analysis of the changes of flood frequency and probability of water guarantee in the Yellow River Basin

4.1 Choice of time period

If analysis of the distribution changes of flood frequency and probability of water guarantee in the Yellow River Basin, we should consider the climate in the basin, conditions of ground surface, water abstraction, water diversion, storing projects, and soil conservation projects in the mainstream or branches of rivers. However, from the actual conditions during the past 60 years in the Yellow River Basin, if the changes of ground surface conditions are divided by time period, there is the complexity and uncertainty; If the operation of water abstraction, water diversion, storing projects, and soil conservation projects in the mainstream or branches of rivers is divided by time period, there's non – independent and non – representative; and it is difficult to divide the time period by multi – factors. Therefore, in this paper, only the factor of climate change in the basin is selected for the time period when calculating and analyzing the distribution changes of flood frequency and probability of water guarantee at different sections of the Yellow River Basin.

It is well known that the activities of sunspots on the sun's surface is cyclical (sunspot cycle), and the climate changes of the Earth is closely related with the cyclical changes of sunspots' activities. For example, during the flood season in 2003, due to groups of sunspot with larger areas on the sun's surface, there was the rare rainstorm in Western China in the Yellow River Basin during the past 20 years, and floods in the branches of the Weihe River and Yellow River. The cycle period of sunspot activity is basically 11 years. According to the international criterior, the year of 1755 is regarded as the start of the first cycle, and the year of 1999 belongs to the 23 cycle of sunspot activity. Therefore, the relative time period for flood frequency and probability of water guarantee is divided as follows: 1933 ~ 1943, 1944 ~ 1954, ..., 1988 ~ 1998 and 1999 ~ 2005. Based on these divisions of time period by the cycle of sunspot activity, it is thought that the relative analysis and calculation cannot affect the results of the long – term effects by the climate in the basin, conditions of ground surface, water abstraction, water diversion, storing projects, and soil conservation projects in the mainstream or branches of rivers.

4.2 The results of analysis and calculation

To obtain the good results of the distribution changes of flood frequency and probability of water guarantee in the Yellow River Basin, the main hydrological control stations are selected as follows: Lanzhou station, TouDaoguai Station, Tong guan Station, Huayuankou Station, Lijin Station in the mainstream, and Huaxan Station of the Weihe River, Hejin Station of the Fenhe River, Zhuangtou Station of the Northern Luohe River, Heishiguan Station in the Yellow River, Wuzhi Station of the Qinhe in the branches. More detailed hydrological measure data has been gradually collected since 1933. In terms of the criteria for the classification of time period above, for those features (the maximum flood discharge of the largest flood, annual runoff, runoff during flood season, and the maximum flow etc.), mean value, *Cv* coefficient of deviation and skewness coefficient *Cs* (or partial) were statistically calculated. All the results are shown in Table 1, Table 2 and Table 3.

Table 1 changes of mean value for major features on hydrological control station in mainstream and branches of the Yellow River Units: m^3/s, 10^8 m^3

Features	Years	Lanzhou	Tou daoguai	Tong guan	Huayuan kou	Lijin	Huaxian	Hejin	Zhuang tou	Heishi guan	Wuzhi
The maximum flood discharge	1933 ~ 1943	3,913		11,100			3,960	553	1,219		
	1944 ~ 1954	3,792	2,767	10,257	10,165	6,280	4,812	1,146	844	4,765	1,387
	1955 ~ 1965	3,616	2,771	7,072	8,928	6,531	4,239	993	845	3,098	1,112
	1966 ~ 1976	3,393	3,286	7,660	6,315	5,424	3,476	509	1,105	1,201	889
	1977 ~ 1987	3,525	3,140	6,956	7,526	4,757	3,098	339	756	1,484	677
	1988 ~ 1998	2,403	2,502	5,735	5,252	3,388	2,568	266	740	738	449
	1999 ~ 2005	2,006	2,151	3,117	2,834	2,169	2,146	99	326	747	344
	Long Series	3,416	2,891	7,480	7,305	5,092	3,530	577	915	1,855	817
Annual runoff volume	1933 ~ 1943	341.1		468.1			92.72	15.26	8.414		
	1944 ~ 1954	341.9	238.0	432.9	519.9	498.3	91.03	16.40	8.210	38.10	14.70
	1955 ~ 1965	330.9	249.5	424.6	494.3	489.5	94.85	17.80	7.560	43.09	17.05
	1966 ~ 1976	340.7	254.0	396.5	435.7	388.7	75.75	13.03	7.101	24.39	8.374
	1977 ~ 1987	330.5	241.1	365.6	400.5	291.0	69.32	7.455	6.370	26.36	4.485
	1988 ~ 1998	261.6	167.8	270.8	285.7	161.3	50.17	6.174	5.074	17.02	4.550
	1999 ~ 2005	251.0	132.5	204.5	215.0	114.8	46.22	3.022	4.611	18.15	5.952
	Long Series	323.2	227.2	374.1	413.8	343.9	77.93	12.49	7.064	28.20	8.965
Runoff volume during flood period	1933 ~ 1943	206.1		287.4			62.49	10.13	5.327		
	1944 ~ 1954	206.6	145.2	252.4	312.9	294.0	54.17	10.83	4.795	24.82	10.07
	1955 ~ 1965	218.4	155.1	260.2	291.4	296.0	55.28	10.52	4.494	25.71	10.84
	1966 ~ 1976	159.6	143.7	222.8	248.8	231.1	45.45	7.786	4.510	13.65	6.434
	1977 ~ 1987	176.5	133.3	209.3	236.3	191.4	45.71	4.678	3.968	16.72	3.496
	1988 ~ 1998	103.6	66.61	125.4	136.9	101.3	28.60	4.226	4.083	8.457	3.612
	1999 ~ 2005	102.3	47.62	90.57	86.07	64.17	30.83	1.722	3.140	10.58	4.336
	Long Series	177.2	124.8	211.6	235.7	210.7	47.80	7.888	4.506	16.57	6.320

Continued to Table 1

Features	Years	Lanzhou	Tou daoguai	Tong guan	Huayuan kou	Lijin	Huaxian	Hejin	Zhuang tou	Heishi guan	Wuzhi
Minimum discharge	1933 ~ 1943	338		268			44.0	2.60	3.82		
	1944 ~ 1954	322	175	345	405	280	40.1	6.40	4.00	10.8	0.63
	1955 ~ 1965	179	111	250	146	111	28.1	6.49	1.84	13.5	5.36
	1966 ~ 1976	261	84.6	188	93.0	38.0	7.54	2.03	2.21	5.39	0
	1977 ~ 1987	264	76.0	168	198	17.4	8.94	0	2.32	5.89	0
	1988 ~ 1998	277	71.4	123	116	0.887	3.19	0	0.91	6.62	0
	1999 ~ 2005	297	36.3	51.0	153	32.4	1.34	0	0	4.86	0.027
	Long Series	272	90.4	201	168	65	19.0	2.52	2.48	8.06	1.26

Table 2 Changes of coefficient for major features on hydrological control station in the Yellow River' mainstream and branches

Features	Year	Lanzhou	Tou daoguai	Tong guan	Huayuan kou	Lijin	Huaxian	Hejin	Zhuang tou	Heishi guan	Wuzhi
The maximum flood discharge	1933 ~ 1943	0.264		0.174			0.247	0.346	1.068		
	1944 ~ 1954	0.248	0.111	0.282	0.300	0.113	0.300	0.964	0.945	0.516	0.852
	1955 ~ 1965	0.261	0.306	0.434	0.540	0.287	0.244	0.549	0.749	0.797	0.511
	1966 ~ 1976	0.290	0.237	0.211	0.267	0.306	0.427	0.524	0.791	0.505	0.656
	1977 ~ 1987	0.279	0.298	0.472	0.414	0.290	0.422	0.632	1.039	0.738	1.638
	1988 ~ 1998	0.223	0.179	0.268	0.280	0.328	0.386	0.967	0.743	0.762	0.970
	1999 ~ 2005	0.172	0.124	0.265	0.334	0.434	0.642	0.516	0.606	1.137	0.795
	Long Series	0.303	0.283	0.403	0.479	0.372	0.399	0.974	0.951	1.050	1.006
Annual runoff volume	1933 ~ 1943	0.184		0.150			0.386	0.288	0.388		
	1944 ~ 1954	0.137	0.065	0.089	0.172	0.099	0.213	0.424	0.269	0.306	0.555
	1955 ~ 1965	0.201	0.274	0.267	0.333	0.430	0.361	0.440	0.556	0.512	0.576
	1966 ~ 1976	0.257	0.367	0.294	0.306	0.354	0.372	0.413	0.357	0.351	0.432
	1977 ~ 1987	0.175	0.256	0.251	0.275	0.391	0.485	0.498	0.400	0.575	0.790
	1988 ~ 1998	0.190	0.292	0.239	0.261	0.410	0.436	0.681	0.465	0.392	0.839
	1999 ~ 2005	0.095	0.121	0.161	0.185	0.643	0.495	0.569	0.466	0.649	0.918
	Long Series	0.214	0.333	0.301	0.356	0.543	0.430	0.579	0.447	0.609	0.889
Runoff volume during flood period	1933 ~ 1943	0.223		0.172			0.538	0.394	0.559		
	1944 ~ 1954	0.234	0.076	0.144	0.255	0.163	0.282	0.615	0.398	0.442	0.762
	1955 ~ 1965	0.249	0.325	0.334	0.386	0.463	0.425	0.598	0.634	0.611	0.660
	1966 ~ 1976	0.328	0.530	0.430	0.430	0.452	0.486	0.547	0.473	0.541	0.501
	1977 ~ 1987	0.279	0.400	0.368	0.372	0.461	0.567	0.708	0.390	0.708	0.904
	1988 ~ 1998	0.158	0.490	0.351	0.374	0.429	0.573	0.992	0.483	0.605	1.040
	1999 ~ 2005	0.139	0.258	0.358	0.343	0.703	0.698	0.689	0.558	0.950	0.983
	Long Series	0.344	0.506	0.427	0.466	0.572	0.534	0.720	0.516	0.763	0.919

Continued to Table 2

Features	Year	Lanzhou	Tou daoguai	Tong guan	Huayuan kou	Lijin	Huaxian	Hejin	Zhuang tou	Heishi guan	Wuzhi
Minimum discharge	1933 ~ 1943	0.044		0.292			0.221	0.768	0.332		
	1944 ~ 1954	0.113	0.139	0.197	0.253	0.610	0.504	0.584	0.554	0.177	1.732
	1955 ~ 1965	0.345	0.333	0.263	0.873	0.763	0.415	1.002	0.103	0.806	2.009
	1966 ~ 1976	0.179	0.435	0.355	0.975	1.568	1.674	1.598	0.122	0.566	
	1977 ~ 1987	0.125	0.441	0.446	0.586	2.018	1.578		0.194	1.088	
	1988 ~ 1998	0.140	0.491	0.531	0.551	3.162	1.156		1.283	0.857	
	1999 ~ 2005	0.087	0.284	0.675	0.463	1.262	1.378			0.548	2.177
	Long Series	0.239	0.488	0.491	0.827	1.710	1.035	1.761	0.650	0.929	4.442

Table 3 Changes of skewness for major features on hydrological control station in the Yellow River' mainstream and branches

Features	Year	Lanzhou	Tou daoguai	Tong guan	Huayuan kou	Lijin	Huaxian	Hejin	Zhuang tou	Heishi guan	Wuzhi
The maximum flood discharge	1933 ~ 1943	-0.019		-1.246			-0.304	0.644	1.570		
	1944 ~ 1954	1.013	0.199	-0.440	0.210	-0.213	2.084	2.052	1.416	0.533	0.519
	1955 ~ 1965	0.760	0.706	0.672	2.118	0.672	0.091	1.414	1.264	1.689	0.073
	1966 ~ 1976	0.680	1.872	-0.083	0.223	0.080	-0.330	0.270	1.791	1.603	0.746
	1977 ~ 1987	0.380	0.510	1.767	1.421	-0.515	-0.028	0.828	2.609	1.431	3.140
	1988 ~ 1998	0.189	0.554	0.379	0.305	0.410	0.055	1.575	1.599	1.081	1.113
	1999 ~ 2005	2.041	0.374	0.835	-0.860	-0.781	1.371	1.208	1.120	1.215	0.979
	Long Series	0.549	1.119	0.690	1.798	0.272	0.125	2.861	2.014	2.368	2.042
Annual runoff volume	1933 ~ 1943	-0.341		1.568			0.847	0.394	0.512		
	1944 ~ 1954	0.915	-1.278	-0.162	1.269	0.742	-0.312	1.316	0.366	1.193	1.149
	1955 ~ 1965	0.322	0.471	1.238	0.537	0.494	1.793	0.449	1.986	1.408	0.243
	1966 ~ 1976	0.635	0.699	0.632	0.701	0.834	-0.040	-0.065	-0.307	1.210	-0.384
	1977 ~ 1987	0.024	-0.324	-0.008	0.360	0.230	0.973	0.972	0.761	0.910	1.053
	1988 ~ 1998	1.459	1.338	0.153	0.040	-0.491	0.008	1.565	1.479	-0.161	1.039
	1999 ~ 2005	0.591	0.425	0.401	0.089	0.344	1.470	1.219	2.446	1.408	1.804
	Long Series	0.522	0.730	0.486	0.657	0.750	0.674	0.776	1.086	1.714	1.473
Runoff volume during flood period	1933 ~ 1943	-0.125		1.241			1.286	0.651	0.473		
	1944 ~ 1954	0.339	1.117	1.270	1.127	1.566	0.157	1.349	0.570	1.004	1.044
	1955 ~ 1965	0.627	0.257	0.641	0.748	0.680	1.280	0.164	1.664	1.138	0.214
	1966 ~ 1976	0.787	0.633	0.440	0.395	0.557	-0.205	0.162	0.262	1.613	-0.233
	1977 ~ 1987	-0.133	0.067	0.086	0.141	0.093	0.812	1.394	-0.094	1.069	1.677
	1988 ~ 1998	0.657	1.813	0.086	-0.021	-1.215	0.581	1.567	1.304	0.317	1.204
	1999 ~ 2005	1.490	0.511	1.249	0.242	0.251	1.470	1.667	2.445	1.843	2.013
	Long Series	0.371	0.665	0.439	0.608	0.790	0.905	1.002	1.016	1.501	1.282

Continued to Table 3

Features	Year	Lanzhou	Tou daoguai	Tong guan	Huayuan kou	Lijin	Huaxian	Hejin	Zhuang tou	Heishi guan	Wuzhi
Minimum discharge	1933 ~ 1943	0.027		1.109			-0.337	1.029	0.088		
	1944 ~ 1954	-0.757	-0.733	-0.293	1.785	0.494	1.435	1.535	0.000	-1.917	2.000
	1955 ~ 1965	-0.098	0.593	-0.864	1.215	0.270	0.231	1.650	-1.741	2.130	1.925
	1966 ~ 1976	1.038	1.487	-0.261	1.378	2.167	2.490	1.898	0.895	2.286	0
	1977 ~ 1987	-0.495	0.216	0.334	0.284	2.624	2.270	0	0.259	0.938	0
	1988 ~ 1998	-0.580	0.382	0.423	1.035	3.317	2.214	0	0.791	0.644	0
	1999 ~ 2005	0.687	-1.149	0.586	0.411	1.358	2.216	0	0	-0.212	2.581
	Long Series	-0.921	0.751	0.342	1.080	2.564	0.969	2.777	0.871	2.513	5.064

Based on the average values during different period at each station, the maximum flood discharge, annual runoff volume, runoff volume during flood period significantly decreased. For instance, at Tong guan station, compared the values during 1999 ~ 2005 with those during 1933 ~ 1954, the maximum flood discharge decreased by 70% from 10,000 to 3,117 m^3/s; runoff volume during flood period is by 66% from 265.5 billion m^3 to 90.57 billion m^3; the average of annual runoff volume is by 54% from the 446 billion m^3 to 204.5 billion m^3 (see Fig. 1, Fig. 2).

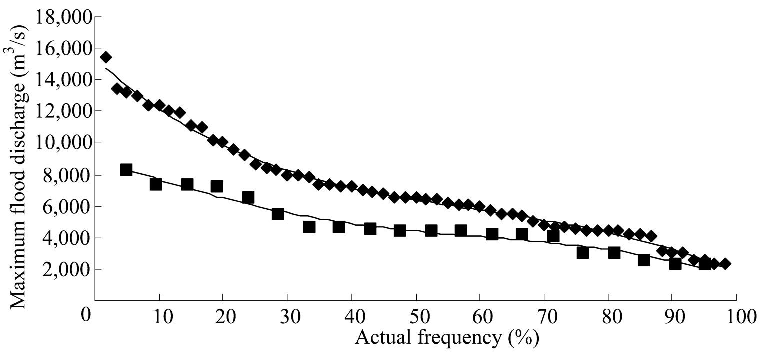


Fig. 1 Actual changes of Maximum flood discharge in the frequency curve in the Yellow River Tongguan Station

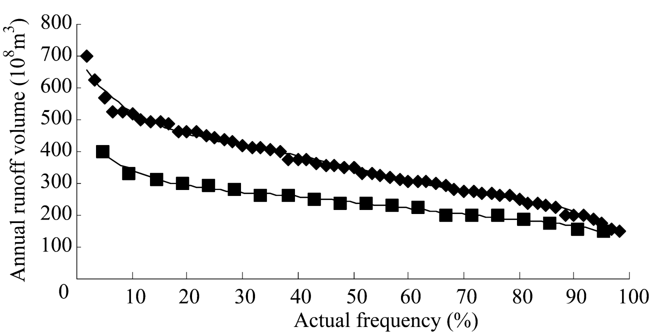


Fig. 2 Actual changes of Annual runoff volume in the frequency curve in the Yellow River Tongguan Station

Based on the change difference during different time period at each station, except for negative value of Minimum discharge in Lanzhou station, the coefficient of maximum flood discharge, annual runoff volume, runoff volume during flood period, and change difference of minimum discharge are all positive at all the rest stations. This shows that all these features keep good and stable decrease, and do not fluctuate with larger swing at each station, when the maximum flood discharge, annual runoff volume, runoff volume during flood period decrease. During the period of 1955 ~ 1998, the coefficient of change difference at both Tong guan station and Huayuankou station decreased slightly. It indicates that the annual runoff at these two stations reduced evidently, the relative change difference decreased further, and the features are more evenly.

Based on the skewness changes during different time period at each station, except for the negative value of Minimum discharge at Lanzhou Station flow, all the skewness values of maximum flood discharge, annual runoff volume, runoff volume during flood period, the minimum discharge are positive at all the other hydrological stations. This accord with the features of hydrological statistics. In which, the majority of the skewness of maximum flood discharge is larger than that of annual runoff volume and runoff during flood period at Tong station. The values of skewness at the station in the branches (Fenhe Hejin Station, North Luohe Station, Heishiguan Station in the Yellow River, Wuzhi Station in Qinhe River) are obviously larger than those at the station in the mainstream (Lanzhou Station, Toudaoguai Station, Tongguan Station, Huayuankou Station, and Lijin Station). And the value of skewness at the Huaxian Station in the Weihe River ranged from the values at the station in the mainstream of the Yellow River to that at the station in the branches.

Based on the analysis of calculation results above, it is thought that the constructions of water projects in Lanzhou Station, Toudaoguai Station, Tongguan Station, Huayuankou Station, Lijin Station in the mainstream of the Yellow River and Longyangxia Reservoir in the upper reach (large multi – year regulating reservoir), as well as the increase of water use in relative regions, are the basic reasons for the obvious decrease of maximum flood discharge, runoff volume during flood period, annual runoff volume, in each station. For the Huaxian station in the 1st largest tributary Weihe River, although there's no construction of larger reservoirs in the upper and middle reaches, water abstraction, water diversion, storing projects, and soil conservation projects in the upper and middle reaches of the Yellow River, cause the obvious decrease of maximum flood discharge, runoff during flood season and annual runoff in the lower reaches of the Weihe River. These distribution changes of features have resulted in the change of flood frequency and probability of water guarantee at different sections of relative regions in the lower reaches of the Yellow River, Particularly river reaches in the large water control project downstream, with the same frequency of the corresponding maximum flood discharge, floods small quantity, and the same small flow of water guaranteed rate increase, and also impact the planning and designing, management and operation of flood control projects to some extent.

5 The problems resulted from Variety of flood frequency and water guarantee rate

With the changes of global climate, the earth surface, water abstraction, water diversion, storing projects, and soil conservation projects in the mainstream or branches of rivers, flood frequency and probability of water guarantee are actually changing, change or will change. In the Yellow River and other rivers, or in the mainstream and branches, or in the upper reach, due to the long – term dam or other water projects, it is necessary for the distribution changes of flood frequency and probability at different sections of the river to influence for the water projects of flood and drought fighting. These impacts are concerned with the construction of projects evaluation and the process of decision – making, the scale and design of investment, construction period, the ratio of cost – benefit for normal operation of projects, and the ecological benefits etc. For example, some reservoirs built, although lower reach of water guaranteed rate has been raised. However, most of the year the reservoir water level to fall below normal water level, power generation amounted to less than the design value, These examples in water project construction, management and operation of the practice is not uncommon. For all these problems, we should give adequate attention.

Therefore, without quantitative analysis of the actual distribution changes of flood frequency and probability of water guarantee at different sections of the river, the values might be underestimated or overrated, and the wrong decisions might be made during the construction of the projects of flood and drought fighting. In addition, the relative scale of investment, design and capacity might be increased or decreased. At last, it is difficult to obtain the designed ecological, economic and social benefits.

6 Conclusions

In the Yellow River basin or others, basic hydrological features related to the construction of water projects (such as the maximum flood discharge, annual runoff volume, runoff volume during flood period. etc.) are often interrelated. When the natural conditions changed or disturbed by the human activities, the parameters for these features (such as average, Cv, Cs or Skewness) will consequently change. Only by grasping accurately the quantitative changes of flood frequency and probability of water guarantee in different sections of the river, so it is possible to make decisions, design, investment and utilize for the water projects scientifically and effectively. And perform the corresponding tasks of flood prevention and drought control by making full use of pesticides and drought Hennessy engineering works effectively.

Thinking about the Connotation of the River Water Ecosystem's Carrying Capacity Related to Sustainable Development

Hu Yawei, ***Cheng Xianguo***, ***Li Qiangkun*** and ***Sun Juan***

Yellow River Institution of Hydraulic Research, YRCC, Xinxiang, Henan, 453003, China

Abstract: The paper summarized the current cognition to water carrying capacity and its problems and considered that water carrying capacity and sustainable development have not been effectively combined. Emphases were taken on the analysis of the use and value of water ecosystem's carrying capacity after discussion about its concept, property and formation. And the conclusion was put forward that river water ecosystem is the main carrying body of water carrying capacity. Based on the theory of sustainable development, the connotation of river water ecosystem carrying capacity was discussed in detailed.

Key words: water ecosystem, water resources carrying capacity, connotation, sustainable development

Since 1980s more attentions and studies were paid on water carrying capacity in China, especially in the Yellow River Basin and the item of water carrying capacity gradually appeared in some resource's encyclopedia. In the recent researches about Yellow River water resources carrying capacity, its theory has been developed farther. But water resources carrying capacity has been still a concept whose extension and connotation are unclear. There are still some differences and insufficiencies on the connotation of water carrying capacity. Some new cognition was put forward to the connotation of water carrying capacity based on the ecological and economic analysis and sustainable development theory.

1 Water carrying capacity

1.1 The concept and its development

The word "Carrying capacity" originated from physics and means the limit load that the object has not any damages. Subsequently it was used in Ecology to measure the greatest number of individual species maintained by a particular region in a certain circumstance. In the study on the problems of resources shortage and environmental pollution, the concept of "carrying capacity" was developed and extended and was widely used to explain the limit of environment and ecosystem supporting development and particular activities. "Water carrying capacity" was put forward by the Chinese scholars in 1980s last century with the increasingly serious water problems. "Water capacity" With our water problems have become increasingly prominent scholars in the 20th century by the late 1980s raised the "water Source capacity of a country or region in the process of sustainable development an important part of natural resources capacity. Often is the scarcity of water resources and water – poor areas, the bottleneck restricting the development of human society, It's a national or regional scale integrated development and have an important impact. So far, the water is still no uniform definition of capacity. In 1997, Feng Jie, Liu Chuan, defined as: more water capacity in a certain region. certain material living standards, sustainable supply of water to the size and needs of present and future generations; In 2000, HE Xi: My definition of a watershed, an area at different stages of a country's socio – economic and technological conditions, in the rational development and utilization of water resources, under the premise water resources to maintain and support the local population, the total size of the economy and the environment; Yang – he Hui that the water resource capacity could be interpreted as a predictable technology, the economy, Dynamic changes in the level of social development and water resources based on the principle of sustainable development. To the maintenance of the ecological environment for the development of a virtuous circle, after reasonable optimum allocation socio – economic development of the region can provide the greatest support capabilities. Generally speaking, we can summarize that water carrying capacity is the ability that local water resources system in a particular region can support the scales of social economy and population in a certain standard of living under certain social development and the precondition of sustainable development.

1.2 Characteristics

In different ecological environment, water resources system has a "threshold" for supporting the social and economic development. The value of "threshold" depends on both ecological environment and social and economic systems. And its value is different under different time, different region, different ecosystem and different social economy. So water carrying capacity has the following characteristics:

(1) Temporal variability: Water carrying capacity changes with time and is constantly affected strongly by social and economic systems. This characteristic requires that people ' s economic activity should not only adapt to times changes, but also regulate water carrying capacity.

(2) Spatial variability: In different regions, the same quantity of water is the difference between the carrying capacity. We know that the environment is determined by a combination of natural factors and dissimilarities. Water resources are one of the important components. In response to the ecological environment and the process, the water is a relatively high sensitivity; the utilization of water resources can be a direct reflection of how much the stability of the ecological environment. So, when the ecological environment of weak, the water capacity is relatively small, on the contrary it is higher.

(3) Controllable characteristics: The size of the regional water capacity, on the one hand, subject to the ecological environment and the material structure; on the other hand, subject to human socio – economic activities.

1.3 Formation

The objective of evaluating water carrying capacity is to make clear relation ship between limited water resources and population, environment and economic development, find out the restricted factors and facilitates social sustainable development. However, the role of water resources for supporting regional development is not only the amount of available water, but also the affection to the whole society. A regional water carrying capacity, was composed of three parts. it is determined by the quantity of water capacity. Including water resources and water quality and water environmental harm defense capability. The mutual influence the relationship between both sides, but also independent of each other side; and the respective roles of the three elements vary, and each has a unique capacity and the current threshold. The purpose is to support the sustainable development of the same.

(1) Water carrying capacity is the ability of supplying water for regional population, environment, industry, agriculture and other purpose. It is to maintain production and social development of the "source of life". Measuring the capacity of water resources in the region and led the major components, the ability of its current and future capacity threshold. Determined by the balance of supply and demand, current capacity for water areas is currently under development in the water for the present population, economic and social development of supply capacity indicates that the development of the water resources of the region. The problems and support the development potential. The current capacity utilization rate of water resources available per capita water use per capita stood and said. Limit maximum water capacity or because of the abundance of water shortage areas have different levels of meaning: the shortage of water resources and poor regions is a reasonable distribution of population, environment and water production under the conditions water resources for water (including local and extraterritorial regulation may be quoted in

the water) zero growth in the total available water: For the area with plenty of water resources, it means the availability that all needs for water will be satisfied and there is zero increase of population and economy.

(2) Water carrying capacity for environment is the supporting ability for maintaining a healthy water area and human health in a certain water area and time. Implementation of the water and environmental quality objectives set for the ability to support human activities. General, have the largest capacity of the water environment, the smallest scale. Water capacity is the smallest in the self – purification ability of a body of water under the conditions minimum requirements to ensure water quality restrictions on human activity. Maximum capacity is the goal of maintaining a certain quality of the ecological environment under the conditions of the various measures to use pollution – free environment. Achieving a harmonious state of the water environment and human activities has the support capabilities. Water capacity exists between the maximum and minimum capacity of the environment is a very important capacity. It was meant in a certain environment or water quality objectives, to allow for a certain waters satisfied that the largest amount of certain pollutants. That is known as the environmental capacity. Namely, the capacity of the environment is the capacity of the environment to support human activities. It plays an important role in the aspects like development of water environment, prevention and control of water pollution, water management and conservation of water resources.

(3) Water is the region's defense capability against a defense of the water, thereby supporting economic and social development, based on the natural and social conditions, according to the establishment of disaster prevention, engineering and non – engineering measures combined defense system. We can to protect and support social development. Because of the uncertainty and economic defense input of water, people just require the standard with adapting to the development of the regional economy and the defense can minimize losses.

2 River water ecosystem carrying capacity

2.1 The development trend of river water carrying capacity

Study on water resources carrying capacity is still at an early stage in China. The water capacity is not yet mature theory, contents and methods of system. Recent research from the "water – ecology – economic" complex system of dual mode hydrological cycle and water balance and other macro – fields of water capacity, vegetation mechanism of micro water; hydrology and water resources from the scientific to the social and economic science, planning at different levels of science, the study of different disciplines, and multi – objective decision – making method System Dynamics, as a method of remote sensing and geographic information system technologies, Which belongs to a typical cross – disciplinary research area.

Ecological Economics to study water capacity at this stage are based on the theory of the ecological and economic analysis of water content. Ecological Economics from the perspective of the optimal allocation of water stood unified concept. Returning to ecological economics, values, outlook and demand balance principle as a guide, reunification of the optimal allocation of the overall water quality, sustainability, "Three – effective" harmonization and efficient use of the principle and the optimal allocation of water stood unified framework of the ideas and models. Compared with traditional economics as the basis for the optimal allocation of water resources, and achieve new progress in the conceptual and theoretical.

2.2 The main carrying body of river water resources

the current research capacity in water resources research, content and quantitative research method is still the main method of resource capacity to continue, Together with the development of the theory of ecological economics and sustainable development, these areas have shown a greater limitations. Main features: content analysis and has focused on water resources in quantitative terms. on the other hand, focused on individual objects in the production of human lives and economic use and the corresponding economic benefits overlook the water level in the ecosystem integrity of effectiveness and value. The combined capacity of sustainable development of water content still some problems, GDP expressed in various sectors of water resources for the economic scale is imperfect, or even incompatible with the connotation of development, sustainability and the relationship between the bearing capacity of water resources has not been clarified, and, The so – called principle of sustainable development is also not specific enough; water capacity in the application of the concept of a certain ambiguity. In short, the water capacity in the system based on the concept of research is still inadequate. his study have yet to broaden the perspective and methods: water carrying capacity by natural factors, also affected and constrained by many social factors, such as socio – economic status by the state policies (including water policy) and the level of social development and management mechanisms; integrated water resources of the region to consider the population, resources and environment and the ability to support economic development. So bearing river water should be defined as the main river water ecosystems.

2.3 River water ecosystem and its carrying capacity

River water ecosystem has four ecological service functions: life – support functions, for the production of the resource base, department of transportation waste degradation of the waste of life or production, providing comfort services. These eventually form a wide range of effectiveness or value for humanity. From the perspective of the ecosystem or ecological economics point of view, water resources and research capacity of all these aspects must be based on a full understanding of the stability and maintain river ecosystems, flexible, comprehensive and coordinated development of the system and human basis. Water ecosystem capacity refers to a certain period of time river ecosystems to maintain the natural, self – regulating ability, water resources and environment subsystem and the ability to supply to maintain the socio – economic activities of certain strength and the standard of living of the population volume. The water environment and water resources with a high degree of uniformity, carriers are region – specific water ecosystems. Human can through the construction and management of water resources for effective ecosystem management, to maintain river ecosystems and human health effects system running.

3 The Connotation of the River Water Ecosystem Sustainable Carrying Capacity

3.1 The ecological connotation

River ecosystem ecological carrying capacity has two meanings: the first one is that River water eco – system bearing on the overall effectiveness of the ecological limits development and use of river water should not exceed this limit as the prerequisite; Second, the water capacity have limitd meaning. So when water carrying capacity reached threshhold, it will certainly mean that the ecological limits can be fully utilized. Moreover, the ecological carrying capacity of water resources should be established to limit the overall ecosystem in the water, including at least three aspects : The water resources development and utilization of renewable water resources has reached; set water quality with the use of functional requirements, and the concentration of pollutants in the cumulative value should limit the following; aquatic ecosystems to meet the security needs of biodiversity and the ecological environment, and regional macro demand for water. Basically, the above three constitute the current environmental and ecological (use) of water content. River ecosystem carrying capacity of the existing water limit ecological limits of the fundamental reasons water is a basic component of the capacity, knowledge and analysis of the carrying capacity of water resources should regard this as a starting point. It should be noted that because of water ecosystems have a certain degree of flexibility. Therefore, the ecological carrying capacity of the river water is a dynamic ecological limit. Meanwhile, the river water eco – system with a maximum capacity also related to ecological construction and environmental protection goals.

3.2 The technical connotation

River ecosystem carrying capacity is not a purely objective concept, but related with the human role and has subjective side. River ecosystem capacity will be inexistent without specific scientific and technical background. It is not just a matter of bearing capacity of the river water ecosystems and the ecological limits on specific skills. Through water management and optimization improve the standard of science and technology. River water can increase the carrying capacity of ecosystems to the economy. By raising productivity at different stages of the overall technical level of the river water can increase the carrying capacity of ecosystem. Capacity so that the river water ecosystems have jumped at different times, also explained that the river water eco – system in time for the technical capacity dynamic. In short, the river water ecosystem capacity with a specific technical meaning, on the one hand, River water to raise the level of technology can increase the carrying capacity of ecosystems; the other hand, is the ultimate meaning of the concept of river water ecosystem capacity corresponding to a state of the best water management, of course, This can usually only occur in the ideal state.

3.3 The socio – economic connotation

Most attractive part is of capacity concept that it seems to be a given socio – economic existence is not dependent on the ultimate objective, River ecosystem capacity the same way. Often aquatic ecosystems and the ecological limits of the population can not be divorced from any specific regional needs and determine the effectiveness of specific values and, and the use of water resources and sewage disposal at the same level, through socio – economic optimization of the system (such as industrial restructuring), or the capacity of the socio – economic scale will be different. This makes the water capacity is also inevitable socio – economic connotations. Therefore, the river water is not only a natural ecosystem capacity of the largest, but there is a socio – economic aspect of the largest. That depends on the size of the largest components of the judging criteria, as well as the master. Population size can be seen as the product and per capita consumption of resources. Such is the scale of human behavior, the total external to the natural ecological system; it does not have much connection with the product. According to the principles of sustainable development, sustainable development of human society is the ultimate goal and that is to improve the quality of human life. Therefore, determined to be the largest development as a basic starting point, that is to say, River ecosystem capacity development should correspond to the worst state, and should be the best with the development of the state. Sustainability is a core concept of sustainable development. Sustainability is not required, nor does it mean that the inevitable increase in population size and economic scale. It asked whether the level of effectiveness of the combination of per capita in some time (even indefinite) is continuing. In summary, river water socio – economic with aspects of the ecological carrying capacity, the subjective side, socio – economic optimization of the system can increase the carrying capacity of the river water ecosystems.

3.4 The spatio – temporal connotation

River ecosystem capacity still has some time content: River water ecosystems on the regional scale water capacity is a certain ecological systems, the bearing capacity of " sustainable development of equitable geographical the requirement to meet the development needs of the region should not be affected, not to plunder the prerequisite for the development needs of other regions. Sustainability requirements must also be based on the geographical scale, the same river with different spatio – temporal scales water eco – system capacity is different. There are regional with river ecosystem loading factors such as the natural resources, the labor and technical resources; river ecosystem capacity in the time is a future concept; river ecosystem capacity is a long – term concept. Natural water ecosystems that it is a long – term interaction between the human reflection with a certain time scales. In quantitative terms, some variables should take the average on specific time slots.

References

Feng Shangyou. The introduction of water resources sustainable utilization [M]. Beijing Science Press,2000.

He Xiwu. Water resource the bears weight power, http://www. hwcc. com.

Hui Yanghe. Research on Evaluation Index System of Water Resources Bearing Capacity [J]. Bulletin of Soil and Water Conservation, 2001,21(2):30 – 34.

Huang Qiang. On system dynamic simulation model of water resources bearing capacity in duality mode[J]. Geographical Research,2001,20(2):191 – 198.

Long Tengrui,Jiang Wenchao,He Qiang. Water resources carrying capacity:new perspectives based on eco – economic analysis and sustainable development [J] . Journal of Hydraulic Engineering, 2004,1991:38 – 45.

Analysis on the Relationship between El Nino Event and Precipitation in Flood Season of the Yellow River Basin

Yang Tequn[1], ***Chen Dongling***[1], ***Rao Suqiu***[1] and ***Sun Wenjuan***[2]

1. Hydrology Bureau, YRCC, Zhengzhou, 450004
2. Hydrology and Water Resources Bureau of Sanmenxia Reservoir, Sanmenxia, 472000

Abstract: A new El Nino event has been formed in equatorial central and eastern pacific during the period of August 2006 to February 2007. It is always accompanied with extreme weather/climate in a large scale when El Nino event occurs, so it seems that there is a high probability of abnormal precipitation in the flood season of 2007 in the Yellow River basin with the occurence of the new El Nino event. Based on the analysis of precipitation characteristics in flood season of the Yellow River basin after the appearance of El Nino event since 1951, result shows that there is a high probability of more precipitation in the flood season in the next year of El Nino event in the middle reaches of the Yellow River basin. In the past, it happened typical floods in the summer of 1954, 1958 and 1977, and in the autumn of 2003 in the middle stream of the Yellow River basin.

Key words: El Nino event, flood season, Yellow River Basin, precipitation, flood

1 Introduction

El Nino is an abnormal phenomenon in tropical ocean and atmosphere, and it is always accompanied with global extreme weather/climate when El Nino event returns. Generally speaking, the primary precipitation condition will transfer to the south areas in China after El Nino event occurring, while there will be more precipitation in the Yangtze River basin and Huihe River basin with a high probability of less precipitation in the north of China, and less typhoons landing the country. In the same time, with a large scale of catchment, the precipitation in the Yellow River basin will present different characteristics in different regions when El Nino event returns. For an example, the last El Nino event occurred in the period of May 2002 to March 2003, as a result the total precipitation in the flood season (from June to September) of 2003 was distinctly more than the normal of the Yellow River basin, and it happened the most precipitation on record in the region of Jinghe River, Weihe River and Luohe River (shorted as Jing – Wei – Luo region), and the region between Sanmenxia reservoir to Huayuankou hydrological station (shorted as San – Hua region). Especially, in the period of late August to September of 2003 the precipitation was twice above as much as the normal in most regions of the Yellow River basin. A new El Nino event appeared in the equatorial central and eastern pacific in August 2006 and disappeared in February 2007, so it could conclude that the probability of abnormal precipitation will increase in the flood season of 2007 in the Yellow River Basin.

2 Relationship between El Nino and precipitation & flood in the Yellow River Basin

Based on the statistic and analysis of the characteristics of precipitation probability distribution in the flood season of the Yellow River basin in the next year of El Nino event, it shows that the probability of total precipitation being 20% more than the normal in the flood season is distinctly higher than the climate probability in the next year of El Nino event, especially in the region between Shanxi and Shaanxi (shorted as Shan – Shaan region), the number of years reaches to 46.7% that the precipitation is 20% more than the normal. And in the lower reach of the Yellow River, there are less years that the precipitation is normal, it just occupies 13.3% that the precipitation is among 10% more/less than the normal, contrarily, there is a high probability of abnormal precipitation. The anomaly probability distribution of total precipitation in the flood season in each region of the Yellow River basin in the next year of El Nino event since 1951 is show in Table 1.

Table 1 The anomaly probability distribution of total precipitation in the flood season in each region of the Yellow River Basin in the next year of El Nino event

Departure	Upper region of Lanzhou	Lan – Tuo region	Shan – Shaan region	Jing – Wei – Luo Region	San – Hua region	Lower Yellow River region
≥50%	0	6.7%	6.7%	6.7%	13.3%	6.7%
20% ~49%	13.3%	33.3%	40.0%	33.3%	13.3%	26.7%
10% ~19%	13.3%	6.7%	20.0%	0	20.0%	20.0%
+0 ~9%	33.3%	6.7%	6.7%	13.3%	13.3%	6.7%
–0 ~ –9%	13.3%	20.0%	6.7%	13.3%	6.7%	6.7%
–10% ~ –19%	26.7%	20.0%	13.3%	20.0%	26.7%	0
–20% ~ –49%	0	6.7%	6.7%	13.3%	6.7%	33.3%
≤ –50%	0	0	0	0	0	0

2.1 Relationship between El Nino and precipitation in the flood season in the upper reach of the Yellow River

The upper reach of the Yellow River is divided into two precipitation regions, upper region of Lanzhou and region between Lanzhou and Tuoketuo (shorted as Lan – Tuo region). The region upstream of Lanzhou locates in the northeastern of the Qinghai – Tibet plateau, where annual precipitation variation in the flood season is relatively little. In the next year of El Nino event, the number of years that the precipitation is below 10% more than the normal occupies 33.3%, and it is both 13.3% that the precipitation is among 10% to 20% more than the normal or above 20%, while also it occupies 13.3% that the precipitation is below 10% less than the normal, and 26.7% that the precipitation is among 10% to 20% less than the normal. In general, the number of years with positive departure of precipitation accounts for 60%, and the negative departure for 40%. Based on the statistics, it shows that in the next year of El Nino event, there is a high probability of normal or less precipitation in the flood season in the region upstream of Lanzhou, but without the year that the precipitation is distinctly less than the normal. In the other years, it occupies 48.8% that the precipitation is more than the normal, and 51.2% that the precipitation is less than the normal. Among them, it both occupies 17.1% that the precipitation is below 10% or among 10% to 20% more than the normal and 13.3% that the precipitation is above 20% more than the normal, while it is both 22% that the precipitation is below 10% or 10% to 20% less than the normal and 7.3% that the precipitation is above 20% less than the normal.

The precipitation features in Lan – Tuo region are very different from that of upstream of Lanzhou region. In Lan – Tuo region, the total precipitation in the flood season is relatively less, but its annual variation is very large. In the next year of El Nino event, the number of years that the precipitation is more than the normal in the flood season accounts for 53.3%, while it occupies 46.7% that the precipitation is less than the normal. Among them, it is 40% that the precipitation is above 20% more than the normal, and it is just 6.7% that the precipitation is above 20% less than the normal. It shows that in the next year of El Nino event, there are a lower probability of less precipitation in the flood season in Lan – Tuo region, and a higher probability of more precipitation. And in the other years, it is 36.6% that the precipitation is more than the normal, and 63.4% that the precipitation is less than the normal, especially it accounts for 36.6% that the precipitation is above 20% less than the normal.

2.2 Relationship between El Nino and precipitation in the flood season in the middle stream of the Yellow River

The Middle Yellow River consists of three regions, i. e. Shan – Shaan region, Jing – Wei – Luo region and San – Hua region. Shan – Shaan region is a primary sediment yield region of the Yellow River, and its precipitation features affect the flood forming in the middle stream of the Yellow River greatly. In the next year of El Nino event, the number of years that the total precipitation is more than the normal accounts for 73.3%, and it is just 26.7% that the precipitation is less than the normal. It occupies 46.7% that the precipitation is above 20% more than the normal in Shan – Shaan region, so there is a high probability of distinctly more precipitation. And in the other years, the number of years that the precipitation is more than the normal occupies 46.3%, and it occupies 53.7% that the precipitation is less than the normal. It is both 22% either the precipitation is above 20% more than the normal or above 20% less than the normal.

In Jing – Wei – Luo region, in the next year of El Nino event, the number of years that the precipitation is more than the normal occupies 53.3%, and it occupies 46.7% that the precipitation is less than the normal. During these years it is 40% that the precipitation is above 20% more than the normal, and 13.3% that the precipitation is above 20% less than the normal. In the other years, the number of years that the precipitation is more than the normal occupies 56.1%, and it occupies 43.9% that the precipitation is less than the normal, and it is 14.6% that the precipitation is above 20% more than the normal, and 12.2% that the precipitation is above 20% less than the normal.

In San – Hua region, the number of years that the precipitation is more than the normal accounts for 60% in the next year of El Nino event, and it occupies 40% that the precipitation is less than the normal, and it occupies 26.7% that the precipitation is above 20% more than the normal, and it is just 6.7% that the precipitation is above 20% less than the normal. In the other years, the number of years that the precipitation is more than the normal occupies 53.7%, and it occupies 46.3% that the precipitation is less than the normal. It occupies 25.3% that the precipitation is above 20% more than the normal, and 17.1% that the precipitation is above 20% less than the normal.

2.3 Relationship between El Nino and flood in the Middle Yellow River

Based on the statistics, there are six years appearing the flood with the peak more than 10,000 m^3/s at Huayuankou hydrological station since 1951. Among them, three years, i. e. 1953, 1958 and 1977, belong to the next year of El Nino event, and the other three years, 1953, 1957 and 1982 are all the El Nino event occurring year. So it could give the conclusion that the flood with the peak more than 10,000 m^3/s at Huayuankou station is related with El Nino event. In the same time, there are also six years that the flood peak is more than 5,000 m^3/s at Huaxian hydrological station of Weihe River, i. e. 1954, 1958, 1964, 1966, 1973 and 1981, and all the years belong to the next year of El Nino event except for 1981. Besides, it happened the most precipitation on record in the flood season of 2003 in both Jing – Wei – Luo region and San – Hua region, especially in the period of late August to September of 2003, the total precipitation is twice above as much as the normal, it experienced six flood events during the period at Huaxian station, and five of the flood peaks were more than 2,000 m^3/s.

2.4 Relationship between El Nino and precipitation in the flood season in the lower reach of the Yellow River

In the next year of El Nino event, the number of years that the total precipitation is more than the normal accounts for 60% in the lower reach of the Yellow River, and 40% that the precipitation is less than the normal. Among them, it both occupies 33.3% that the precipitation is above 20% more than the normal or above 20% less than the normal, and 20% that the precipitation is among 10% to 20% more than the normal, while it is both 6.7% that the precipitation is below 10% less than the normal or below 10% more than the normal. In the other years, the number of years that the total precipitation is more than the normal accounts for 53.7% , and it occupies 46.3% that the precipitation is less than the normal. Among them, it is 24.4% that the precipitation is above 20% more than the normal, and 19.5% that the precipitation is above 20% less than the normal. Based on the statistics, it shows that in the next year of El Nino event, there are few years that the precipitation is normal in the lower reach of the Yellow River, while there is a high probability of abnormal precipitation. For example, in the flood season of 1964 the total precipitation was 59% more than the normal in the lower reach of the Yellow River, and it was 46% less than the normal in the flood season of 1966.

3 Conclusions

Based on the statistic and analysis, the correlations between El Nino event and precipitation or flood in the Yellow River basin could be concluded as follows: In the next year of El Nino event, there is a higher probability of more precipitation compared with the other years, and without the year that the precipitation is above 50% less than the normal; in Lan – Tuo region and the middle stream of the Yellow River, there is a higher probability of total precipitation being above 20% more than the normal in the flood season in the next year of El Nino event compared with the climate probability, especially in Shan – Shaan region of the middle stream of the Yellow River, it accounts for 46.7% that the number of years when the precipitation is above 20% more than the normal in the next year of El Nino event; all the flood events with flood peak more than 10,000 m^3/s happened in El Nino occurring year or its next year at Huayuankou hydrological station; and there are few years that the precipitation is normal in the next year of El Nino event.

Although there are many factors that affect the long – term weather process, and the relationship among them is very complex with a lot of uncertain factors, it is certain that it is always accompanied with extreme weather/climate in a large scale when El Nino event returns. With the return of the new El Nino event, there is a high probability of abnormal precipitation in the Yellow River basin. So it is suggested to pay closely attention to it.

Analysis of Long – term Water Balance in the Middle Reaches of the Yellow River Basin

Yoshinobu SATO[1], ***Xieyao MA***[2], ***Masayuki MATSUOKA***[3], ***Jianqing XU***[2] and ***Yoshihiro FUKUSHIMA***[1]

1. Research Institute for Humanity and Nature (RIHN) 457 – 4 Kamigamo – motoyama, Kita – Ku, Kyoto 603 – 8047, Japan
2. Frontier Research Center for Global Change (FRCGC), 3173 – 25 Showa – machi, Kanazawa – ku, Yokohama 236 – 0001, Japan
3. Faculty of Agriculture, Department of Forest Science, Kochi University, 200 Monobe – Otsu, Nankoku, Kochi 783 – 8502, Japan

Abstract: To clarify the long – term water balance of the Yellow River basin, a new semi – distributed hydrological model was developed and applied to the middle reaches of the Yellow River basin. This analysis focused on the period during the past 40 years (1960 ~ 2000) using 128 meteorological stations data and high resolution remote sensing data. The model was based on soil – vegetation – atmosphere – transfer scheme and runoff formation model (SVAT – HYCYMODEL). To take the influence of vegetation change into consideration, an index of vegetation cover ratio (VCR) was introduced. By applying a VCR to the original hydrological model, the observed river discharge in the middle reaches of the Yellow River basin was captured by the model. According to the model simulation, it was found that the discharge from tributaries in the middle reaches of the Yellow River basin has been decreasing rapidly. Furthermore, the discharge ratio (discharge/precipitation) was also decreased significantly during the past 40 years. Consequently, we confirmed that the available water resources in the middle reaches of the Yellow River basin decreased considerably with not only precipitation decrease, but also increasing evapotranspiration ratio (evapotranspiration/precipitation) with the massive land – use change in the Loess Plateau.

Key words: water balance, middle reaches, land – use change, vegetation cover ratio (VCR), Loess Plateau

1 Introduction

In recent years, serious water – related problems such as droughts, flooding, or water pollutions have affected most large rivers in China (Xia and Chen, 2001; Liu and Xia, 2004). In particular, water shortages are becoming more and more serious in the northern China because of dry climate conditions and heavy water demands (Liu and Xia, 2004; Yang et al., 2004). The Yellow River is the second largest river in China and is the most important river for agriculture, water resources managements, and socio – economical development (Cai and Rosegrant, 2004; Liu and Xia, 2004). However, river discharges in the lower reaches of the basin have been decreasing continuously (Xia and Chen, 2001; Ren et al., 2002; Chen et al., 2003; Liu and Zheng, 2004; Yang et al., 2004; Xu, 2005). The riverbed of the lower reaches is higher than the surrounding area due to the sediment depositions. Almost all the surface water in the lower reaches is supplied from the upper and middle reaches. Therefore, it is necessary to predict the water balances in the upper and middle reaches, and the integrated water resources management is effective to mitigate the water shortage and to utilize the limited water resource adequately. To clarify long – term water balances within the Yellow River basin and to supply its quantitative information for the water resources management, a hydrological model can be used. However, it is difficult to apply existing hydrological models directly to the Yellow River basin because the basin includes various artificial factors induced by human activities (i. e., irrigation water intake, reservoir operations, and human – induced land – use changes). Thus, we developed a new hydrological model applicable to the Yellow River basin using long – term (1960 ~ 2000) meteorological dataset and high – resolution land surface classification map (Sato et al., 2007). In the previous study, we confirmed that our model can predict the amount of annual water intake for irrigation and the effect of the large reservoir operation on river runoff in the upper reaches (Sato et al., 2006). Therefore, in this study, we attempted to apply the model to the middle reaches and analyzed its long – term water balances to investigate the influences of land – use change induced by human activities.

2 Method

2.1 Study area

The Yellow River occupies the second – largest river basin in China. As shown in Fig. 1, the river originates on the Tibetan Plateau, winds through the semi – arid region around the Loess Plateau, and passes through the North China Plain before finally discharging into the Bohai Sea. The river has a total length of 5,463.6 km and a drainage area of 752,443 km^2 (excluding an isolated inflow area of about 42,000 km^2). In the present study, we focused on the middle reaches of the Yellow River basin located between Toudaoguai (40.16°N, 111.04°E) and Sanmenxia (34.49°N, 111.22°E) hydrological station. The catchment area is 306,780 km^2, which occupies about 40.8% of the Yellow River basin (752,443 km^2). Most of this region is located within the Loess Plateau.

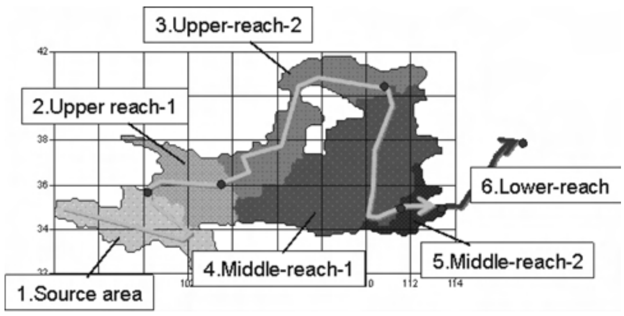


Fig. 1 Outline of the Yellow River Basin

2.2 Model structure

Fig. 2 shows the basic structure of our hydrological model. The model is based on SVAT – HYCY model developed by Ma and Fukushima (2002). The model consists of three sub models: ① heat – balance model, ② runoff formation model and ③ river routine network model. The input parameters of the model are routine meteorological data and remote sensing data. Both of them were interpolated into 0.1° × 0.1° grid scales. The remote sensing data includes elevation, land – use type, NDVI, and LAI dataset. The land – use type was classified into five categories (Type1: Bare land, Type2: Grassland & Crop field, Type3: Forest area, Type4: Irrigated area, and Type5: Water body) using a high – resolution land – use map over the Yellow River domain in 2000 developed by Matsuoka *et al.* (2005). Following three artificial factors were considered in this model: ① reservoir operation, ② irrigation and ③ land – use change (Sato et al., 2006). At first, to estimate the outflow from the reservoir, a simple reservoir operation model was applied. The model can simulate the influences of reservoir operation by using the following three parameters: ① inflow to the reservoir, ② water storage in the reservoir and ③ reservoir operation rules. Then, the discharge from the irrigation area during irrigation period (Q_{irr}) was estimated as follows: Q_{irr} =

Precipitation (P) - Potential evaporation (Ep). The water deficit of Q_{irr} was supplied from the nearest river channel. The discharge from non – irrigated period was calculated as same as bare land. The irrigation period (DOY: 90 - 300) was determined from seasonal change of LAI. The LAI in the vegetated areas were derived from NDVI created from monthly NOAA – AVHRR images in 2000 using the formulas of Biftu and Gan (2000). Finally, to clarify the influences of the long – term land – use change, the index of vegetation cover ratio (VCR) based on total vegetation area of 2000 was introduced. To estimate the actual evapotranspiration more precisely, we applied the following procedures. At first, we estimated the potential evaporation (Ep) following the definitions of Xu et al. (2005). Then, the evapotranspiration from each vegetated surface (Evt) without soil water deficit were estimated by the following formula of Kondo (1998).

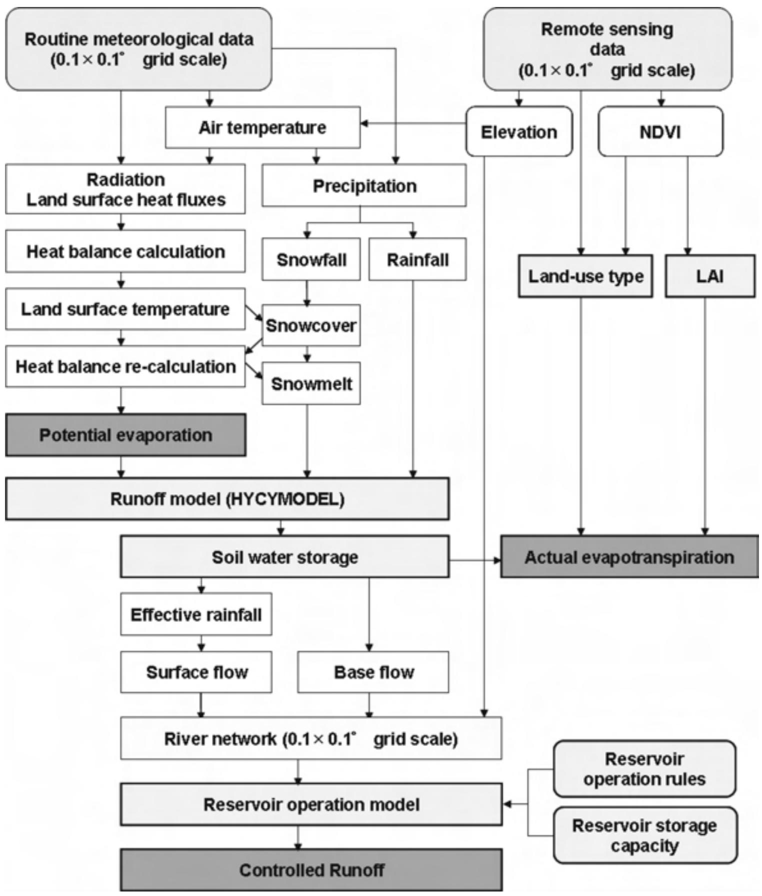


Fig. 2 Simplified flow chart of the model

$$Evt/Ep = 0.45 + 0.4\{1 - \exp(-1.5 \cdot LAI)\} \quad (1)$$

Finally, the actual evapotranspiration Ea was estimated by the following equations:

$$Ea = Evt \qquad (S_t \geqslant S_{max}) \quad (2)$$

$$Ea = (S_t/S_{max}) \cdot Evt \qquad (S_{min} < S_t < S_{max}) \quad (3)$$

$$Ea = 0 \qquad (S_t \leqslant S_{min}) \quad (4)$$

$$S_{max} = \{D_{50} + (D_{sig} \times 3)\} \times 0.5 \quad (5)$$

where S_t is the total soil water content derived from $S_u + S_b$ in the HYCYMODEL (Fukushima, 1988). D_{50} is the effective soil depth (600 mm) and Dsig is its standard deviation (100 mm). Smax (450 mm) and Smin (100 mm) are parameters to regulate Ea. These four parameters were determined empirically. Other parameters were set as same as the original SVAT – HYCY model (Ma et al., 2000; Sato et al., 2007). To simulate stream flow, the stream channels in a grid cell were lumped into a single channel which flows in the direction of the steepest slope among the surrounding eight grid points. To simplify flow estimates for a river network, the velocity of river flow was set as a constant (= 0.6 m/s) empirically.

3 Results and discussion

3.1 Performance of model simulation

Fig. 3 shows the performance of our model simulation. In the initial simulation (SIM – 1), we

Fig. 3 Performance of model simulation

applied a constant VCR (100%) to all the study periods. However, the estimated discharge underestimated the observed discharge during the period from 1960s to 1970s. In other words, our initial simulation overestimated the actual evapotranspiration. Thus, to reduce the evapotranspiration, we modified the value of VCR until 50% in the second simulation (SIM – 2). After that the observed discharges were reasonably captured by the model. In the present study, the following index was used to validate our model performance.

$$TWBE = (|\sum Q_{cal} - \sum Q_{obs}| / \sum Q_{obs}) \times 100\ \% \quad (6)$$

where, *TWBE* is the annual total water balance error (Fukushima, 1988), Q_{cal} and Q_{obs} are calculated and observed discharge respectively. By reducing the value of VCR, the *TWBE* of the 1960s and 1970s were decreased from 15.4% (SIM – 1) to 3.4% (SIM – 2) and from 20.8% (SIM – 1) to 7.0% (SIM – 2) respectively. The emergent error appeared in 1964 might be the influences of the artificial operation of the Sanmenxia reservoir. As a consequence, we found that it is necessary to consider the influences of land – use changes for estimating long – term water balance of the middle reaches of the Yellow River basin as well as irrigation and reservoir operation.

3.2 Change of long – term water balance in the middle reach of the Yellow River Basin

Fig. 4 shows the change of long – term water balance in the middle reach of the Yellow River basin. The input (INPUT) water into this basin is calculated as Q_{in} (inflow from the upper reach: observed discharge at Toudaoguai) + P (Precipitation). The Q_{out} is the outflow from the basin (observed discharge at Sanmenxia). So, the evapotranspiration loss (E) can be calculated as INPUT – Q_{out} assuming no significant change in soil water content during the period from 1960s to 1990s. The INPUT decreased 37 billion m^3. On the other hand, Qout decreased only 21 billion m^3 (less than 37 billion m^3). Thus, the evapotranspiration loss (E) should be decreased about 16 billion m^3, if there were no significant change of soil water content. The rapid decrease of Qout from 1960s to 1970s (–9 billion m^3) and from 1980s to 1990s (–13 billion m^3) can be explained by the decrease of INPUT (–18 billion m^3 and –21 billion m^3 respectively). The ratio of Q_{out}/INPUT was decreasing from 23.1% (1960s) to 15.2% (1990s). This implies the ratio of evapotranspiration/INPUT was increasing with the decrease of INPUT.

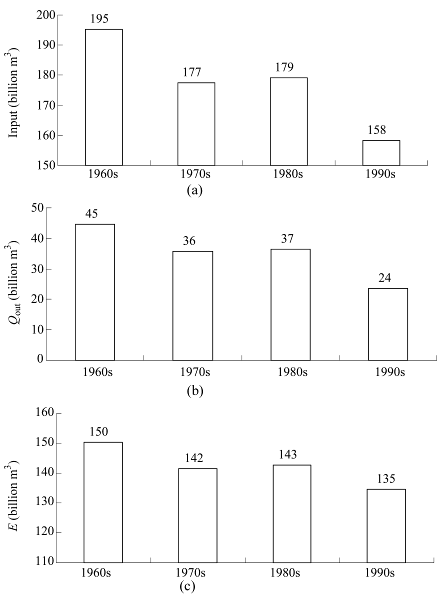


Fig. 4 Change of long – term water balance in the middle reach of the Yeelow River Basin

Fig. 5 indicates the long – term change of river discharge estimated by the model (SIM –2). By comparing this figure with Fig. 4(b), we can see that our model can reasonably capture the long – term change of observed river discharge in the middle reaches of the Yellow River basin.

Fig. 6 indicates the long – term change of evapotranspiration estimated by the model (SIM – 2). According to this figure, we can see that our model agreed well also with the observed evapotranspiration loss calculated by the water balance equation during the period from 1960s to 1980s (see Fig. 4(c)). However, the estimated evapotranspiration did not capture the observed evapotranspiration loss since 1980s. We assumed that this discrepancy was caused by the change of soil water content. The values of evapotranspiration in the Fig. 4 were calculated by the water balance equation assuming that soil water content is constant. On the other hand, the values of estimated evapotranspiration in the Fig. 6 were corresponding to the change of soil water content.

Fig. 7 shows the long – term change of soil water content estimated by our model. From this figure, we can see that the soil water content was decreasing continuously during the past 40 years. These results suggest that the discrepancy between Fig. 4(c) and Fig. 6 in 1990s can be explained by the regulation of the estimated evapotranspiration by the soil water deficit.

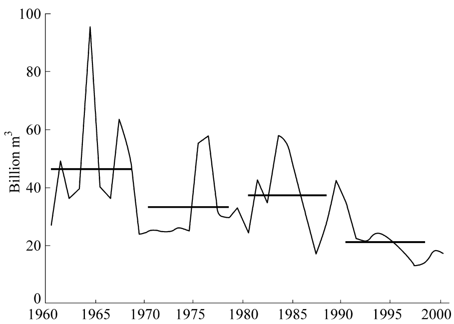


Fig. 5 Change of river discharge estimated by the model (SIM – 2)

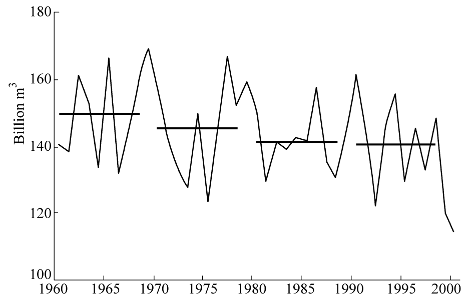


Fig. 6 Change of evapotranspiration estimated by the model (SIM – 2)

Fig. 8 shows the long – term change of the precipitation in the middle reaches of the Yellow River basin. By comparing this figure with Fig. 6, we can see that almost all the precipitation supplied into the middle reaches (142 billion m^3) were consumed by the evapotranspiration (141 billion m^3) in the 1990s. The evapotranspiration ratio (evapotranspiration/precipitation) was increased rapidly from 1960s (88.8%) to 1990s (99.3%). This result implies that the long – term massive land – use change conducted by the soil and water conservation in the Loess Plateau will increase the ratio of evapotranspiration during the past 40 years. Consequently, the discharge from the tributaries (Qtrb) in the middle reaches of the Yellow River basin estimated by the model had been decreasing significantly during the past 40 years (Fig. 9). The discharge ratio (Qtrb/P) was also decreased rapidly from 1960s (11.8%) to 1990s (3.5%). This implies that the river channels were drying up not only the main stream of the lower reaches, but also the tributaries in the middle reaches. Furthermore, it is also suggesting that the amount of available water resources in the middle reaches of the Yellow River basin was almost exhausted in recent years. Therefore, immediate attention and action including integrated water resources management should be encouraged in this area.

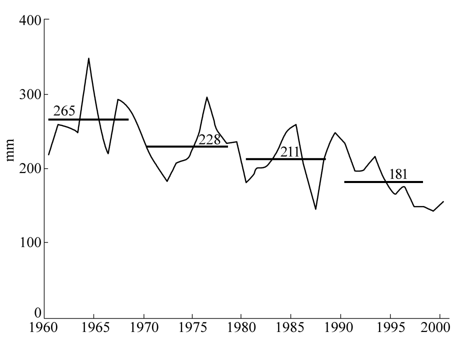


Fig. 7 Change of soil water content estimatd by the model (SIM – 2)

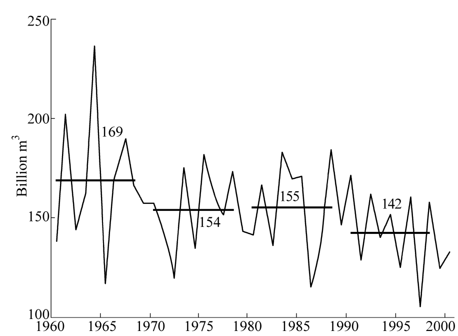


Fig. 8 Change of precipitation

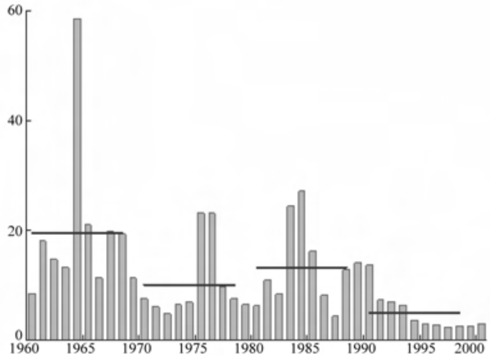


Fig. 9 Discharge from tributaries in the middle reaches of Yellow River Basin estimated by the mode

4 Conclusions

In the present study, we can see that in order to understand long – term water balance in the middle reaches of the Yellow River basin, it is necessary to consider the influences of the long – term land – use (vegetation) changes. The available water resources in the middle reaches were almost exhausted in recent years. The soil and water conservation conducted in the Loess Plateau will reduce not only soil erosion, but also river discharge with the climate conditions.

Acknowledgements

This study was supported by three research projects: ① the Yellow River Project of the Research Institute for Humanity and Nature (RIHN), ② a project to examine surface – water changes of the Yellow River domain (RR2002) funded by the Ministry of Education, Culture, Sports, Science and Technology of Japan (the Project Leader for both of these projects is Dr. Yoshihiro Fukushima of RIHN), and ③ the Chinese National Key Program: 973 project (G19990436) directed by Prof. Liu Changming of the Chinese Academy of Sciences (CAS).

References

Biftu G, Gan T. 2000. Assessment of evapotranspiration models applied to a watershed of Canadian prairies with mixed land – uses. Hydrological Processes, 14: 1305 – 1325.

Cai X, Rosegrant M. 2004. Optional water development strategies for the Yellow River basin: Balancing agricultural and ecological water demands. Water Resources Research, 40, W08S04, DOI: 10.1029/2003WR002488.

Chen J, He D, Cui S. 2003. The response of river water quality and quantity to the development of irrigated agriculture in the last 4 decades in the Yellow River Basin, China. Water Resources Research, 39, 1047, DOI: 10.1029/2001WR001234.

Fukushima Y. 1988. A model of river flow forecasting for a small forested mountain catchment. Hydrological Processes, 2: 167 – 185.

Kondo J. 1998. Dependence of evapotranspiration on the precipitation amount and leaf area index for various vegetated surfaces. Journal of the Japan Society of Hydrology and Water Resources, 11: 679 – 693 (in Japanese with English summary).

Liu C, Xia J. 2004. Water problems and hydrological research in the Yellow River and the Huai and Hai river basins of China. Hydrological Processes, 18: 2197 – 2210. DOI: 10.1002/hyp.5524.

Liu C, Zheng H. 2004. Changes in components of the hydrological cycle in the Yellow River basin during the second half of the 20th century. Hydrological Processes, 18: 2337 – 2345. DOI:

10. 1002/hyp. 5534.

Ma X, Fukushima Y, Hiyama T, Hashimoto T, Ohata T. 2000. A macro – scale hydrological analysis of the Lena River basin. Hydrological Processes, 14: 639 – 651.

Ma X, Fukushima Y. 2002. Numerical model of river flow formation from small to large scale river basins. In Mathematical Models of Large Watershed Hydrology, Sigh VP, Frevert DK (eds). Water Resources Publications: Highlands Ranch, CO; 433 – 470.

Matsuoka M, Hayasaka Y, Fukushima Y, Honda Y. 2005. Land cover classification over the Yellow River domain using satellite data. YRiS News Letter, 4: 15 – 26.

Ren L, Wang M, Li C, Zhang W. 2002. Impacts of human activity on river runoff in the northern area of China. Journal of Hydrology, 261: 204 – 217.

Sato Y, Fukushima Y, Ma X, Matsuoka M, Xu J, Zheng H. 2006. Analysis of long – term water balance of the Yellow River basin using the hydrological and water resources model – Impacts of the human activities –. YRiS Yellow River Studies News Letter, 6: 8 – 11.

Sato Y, Ma X, Xu J, Matsuoka M, Zheng H, Liu C, Fukushima Y. 2007. Analysis of long – term water balance in the source area of the Yellow River basin. Hydrological Processes (in Press).

Xia J, Chen Y. 2001. Water problems and opportunities in the hydrological sciences in China. Hydrological Sciences Journal, 46: 907 – 921.

Xu JX. 2005. Temporal variation of river flow renewability in the middle Yellow River and the influencing factors. Hydrological Processes, 19: 1871 – 1882. DOI: 10. 1002/hyp. 5652.

Xu J Q, Haginoya S, Saito K, Motoya K. 2005. Surface heat balance and pan evaporation trends in Eastern Asia in the period 1971 to 2000. Hydrological Processes, 19: 2161 – 2186. DOI: 10. 1002/hyp. 5668.

Yang D, Li C, Hu H, Lei Z, Yang S, Kusuda T, Koike T, Musiake K. 2004. Analysis of water resources variability in the Yellow River of China during the last half century using historical data. Water Resources Research, 40, W06502, DOI: 10. 1029/2003WR002763.

Integrated River Basin Management in Europe (Adricosm and Wamaribas Projects) and China (Wenyu River Project)

Augusto Pretner[1], ***Alessandro Bettin***[1], ***Luz Sainz***[1], ***Mao Bingyong***[1], ***Gan Hong***[2] and ***Jiang Yunzhong***[2]

1. SGI Studio Galli Ingegneria SpA – Padova Italy; DFS Engineering, Beijing
2. China Institute of Water Resources and Hydropower Research – IWHR, Beijing, 100044, China

Abstract: This paper illustrates the implementation of integrated river basin management in two European projects, WAMARIBAS in Italy and ADRICOSM in the Balkans, and one in China dealing with the restoration of the Wenyu River in Beijing. The common goal of the three projects is the abatement of pollutants in the receiving waters, badly deteriorated as result of anthropic actions. The projects employ state – of – the – art technologies for monitoring and modelling the hydraulics and water quality processes in the receiving waters and the sanitary infrastructure that discharges in the water bodies. The outcome is an evaluation of pollution sources and their impacts on the water bodies as well as the provision of an action plan with the optimal solutions to attain the required water quality standards. The experience gained by the writers in the implementation of the European projects has enabled the development of the "ECO – Plan Kit", a toolkit consisting of the best practice and ecological technologies for the integrated analysis of the wastewater cycle. The current project in the Wenyu River intends to develop a replicable methodology that can be applied to similar realities all over China and in other countries with analogous needs.

Key words: integrated, river, pollution, wastewater

1 Introduction

Human activities alter the natural balance of ecosystems and can eventually cause the extinction of species and the degradation of natural resources. The development of mega – cities, some of them in water poor areas, leads to severe water shortage and pollution. Not to mention the stress that intensive agriculture, farming, fishing and industrial development pose on water and land. The result is the decline in the quality and quantity of our water resources which manifests, amongst others, with a continuous decrease in the level of aquifers, the drying – up and pollution of rivers and lakes, the desiccation of wetlands and saline intrusion into inland water bodies. The need to pump water from deeper strata and the impaired quality of water and land are causing the abandonment of areas, which become prone to desertification, affecting the dependent ecosystems.

If we add climate change and the uneven distribution of water resources to the equation, the result is an urgent need for a sustainable policy that ensures the preservation of water resources for our future generations. The concern for water availability is aggravated by climate change and its devastating impacts in terms of extreme and more frequent droughts and floods. It appears clear how the violation of our environment for the economic benefit of today already has a high and global price, which is likely to increase in the future. Notwithstanding this dim picture, we have the possibility to reverse this situation through the application of "integrated water resource management", which is the worldwide recognised best practice for environmental management of water resources, and has become the basis of the legislation in the European Union concerning the protection of water resources, the Water Framework Directive (WFD). This Directive considers that the best model for an integrated water management is the river basin – the natural geographical and hydrological unit – instead of administrative or political boundaries. The Directive stipulates that a "river basin management plan" shall be established and updated every six years, including all the measures needed to ensure the good quality status of all waters in the basin, both surface and ground waters.

2 The approach and technologies used in the projects

2.1 Integrated river basin management

Integrated Water Resource Management (IWRM) at river basin scale is the approach that guides the implementation of the three projects presented in this paper.

IWRM techniques are nowadays widely promoted in Europe as result of the enforcement of the European Water Framework Directive (WFD, EC/2000/60) that requires all Member States to assess the quality status of all the waters within their "river basin units" and design and implement periodic river basin plans to ensure good water quality status of all waters.

The WFD sets the basis for a sustainable water resource management supported by appropriate technologies, integrated planning and co – operation between stakeholders. Its main principles are the consideration of surface and ground waters, a "combined approach for pollution control" based on both limit values at the emission and quality standards of the receiving bodies, a participatory approach and the use of economic instruments to achieve cost recovery for the water – good.

The writers have developed extensive experience in the implementation of projects focused on integrated water resource management – both at urban and river basin scales. In particular they have specialised in the use of numerical models and monitoring technologies for optimising the management of water and wastewater assets in respect of the environment.

In late 90's they worked in the implementation of "Integrated Wastewater", a project funded by the European Commission's Innovation Programme, which major objective was the integration of the mathematical models that simulate the hydrodynamics and water quality of the single components of the wastewater cycle, i. e. urban hydrology, sewers, wastewater treatment plants and receiving waters. The figure below illustrates the concept of integrated wastewater management as it shows the multiple aspects that must be considered from the time rainfall starts until wastewater – either treated or non – treated – reaches the receiving waters (see Fig. 1).

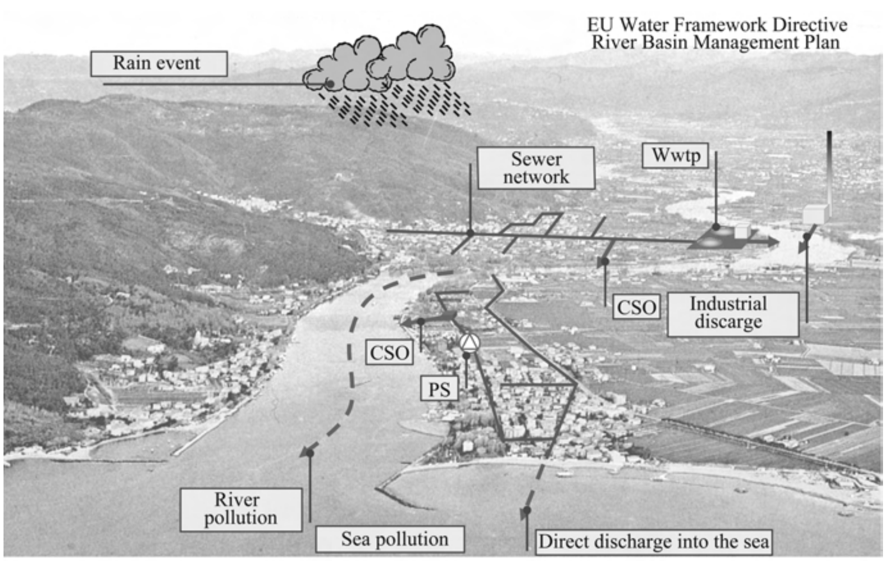


Fig. 1 Components of integrated wastewater management at a river basin scale

Building upon this knowledge, the writers have expanded their expertise with many other projects, some financed by the European Commission under the Environmental LIFE Environment Programme (the LIFE – Law and WAMARIBAS projects), and others financed by the Italian Ministry of Environment under international cooperation programs. Amongst these last, ADRICOSM is a landmark project, supported by the Italian Ministry of Environment, Land and Sea, and IOC – UNESCO, with the aim of enhancing modelling and monitoring technologies for rivers and coastal areas in the Adriatic region.

Over the last years one of their company's goals has been to adapt this methodology in countries outside Europe, taking into account the differences in wastewater infrastructure. In this effort their historic experience in the design and construction of major sewer networks and wastewater treatment plants in Italy has proved invaluable. Combining their expertise in wastewater master plans and design with the use of advanced technology for monitoring and modelling hydraulics and water quality, they have developed the "ECO – Plan Tool Kit", a Suite of methodologies and technologies for optimising the strategy to abate pollution in water bodies.

2.2 The "ECO – PLAN Kit©"

The ECOPLAN – Kit is the result of integrating the best practice and technologies that DFS – SGI has applied in numerous European projects aimed at combating pollution of receiving waters (Rivers, lakes, coastal areas) and adapting them to other international contexts. The ECO – Plan Kit is nowadays being implemented for the restoration of the Wenyu River in Beijing in a project that will last until April 2008.

The principle behind the ECOlogical monitoring, modelling and action PLAN Tool Kit – ECO – Plan Tool Kit – is to provide decision makers with the instruments for managing and analyzing the pollution related data in order to design the plan for the cost – effective restoration of water quality The tool kit gathers the following set of items:

- GIS Data Base of the river catchment;
- SCADA (Supervisory Control And Data Acquisition) system for metering water quantity related parameters;
- Water quality monitoring system based on site and laboratory analyses;
- Mathematical model of the river water quality and quantity validated with field data;
- Action Plan for water pollutants abatement.

The next part of this section provides a brief overview of some technologies involved in the ECO – Plan Kit, specifically the SCADA system, monitoring equipment and mathematical models.

2.2.1 The SCADA system

Supervisory Control And Data Acquisition (SCADA) is a process control system that enables the operator of a system to monitor and control processes that are distributed among various remote sites. In the specific case of Integrated River Basin Management projects, the SCADA system consists in the set – up of a network of monitoring equipment installed to collect data about the flows and water quality. The selection of the monitoring locations is carefully made to provide a picture about the hydrodynamic and water quality processes occurring in the integrated system, made of sewer network, wastewater treatment works, receiving waters. These locations could for instance include sewer overflows into the receiving waters, treatment plant's effluent discharge, critical cross – sections in the river, and so on. Monitors transmit data to the master station, where it is analysed in order to take decisions for optimizing the operation of the network to prevent pollution (e. g. closing gates to prevent overflows into the rivers, using the available storage in the sewer network to prevent discharges in the water bodies, etc.).

The four major components of a SCADA system are the Master Terminal Unit (MTU or Master), the Remote Terminal Unit (RTU or Slave), Communication Equipment and SCADA Software. The MTU, located at the operator's central control facility, enables two – way data communication and control of remote field devices. The RTU, located at the remote site, gathers data from field devices (pumps, valves, gates, alarms, etc.) in memory until the MTU initiates a send command. The SCADA software package allows the operator to view virtually all system alerts, warnings, and functions as well as change the set points, analyze, archive or present data trends.

Good SCADA systems today not only control processes but are also used for measuring, forecasting, billing, aoalyzing and planning. Today's SCADA system must meet a whole new level of control automation, interfacing with yesterday's obsolete equipment yet flexible enough to adapt to tomorrow's changes. A properly designed SCADA system saves time and money by eliminating the need for service personnel to visit each site for inspection, data collection/logging or adjustments. Additionally it may include real – time monitoring, system modifications, troubleshooting, increased equipment life, automatic report generating and operation of electro – mechanical plants.

2.2.2 The monitoring equipment

IRBM projects are based on the understanding of pollution sources and their impacts in the receiving waters. This involves the measurement of physical and water quality parameters in the components of the wastewater cycle, i. e. the sewers, treatment plant and receiving body. Some of the parameters that are commonly monitored include rainfall depth, water levels and velocities (i. e. flows), pH, suspended solids, temperature, dissolved oxygen, nitrogen, phosphorus, heavy metals (e. g. cadmium, chromium, copper, lead, mercury, and zinc) and chemical parameters.

Along with the telemetry network that makes part of the SCADA system, these projects usually conduct flow and water quality surveys at spot locations in order to further the knowledge about the integrated system and validate the mathematical models. The typical instrumentation used in an IRBM project comprises flow meters for sewers and rivers, multi – parameter water quality probes in the sewers, mobile rain gages for monitoring rainfall, water levels meters and portable quality automatic samplers for rivers.

2.2.3 The mathematical models

Mathematical models are "analysis tools" that consent water operators to assess the impacts of wastewater discharges into the receiving waters. Prior to the modelling activity, a major data collection is implemented, sometimes involving topographic and flow and water quality surveys. The collected data is used to build the mathematical models in order to simulate the flows and water quality within the sewers, treatment plants and the rivers. Typical modelling data includes physical characteristics of the system (topographical data, river cross sections, roughness coefficients, dimensions of the sewers and treatment plant components, etc.) as well as characteristics related to water quality (pollutant concentrations, dispersion coefficients, etc.).

The modelling activity varies depending on the needs of each project, and can range from a simplified river model with lumped pollution sources being represented, to integrated models of the sewer networks, treatment plants, rivers and coastal areas. What is common to all projects is that the model, no matter how simplistic or complex it is, must be a fair representation of the processes that really occur at wastewater facilities and the receiving waters. For this reason the modeller must be careful at selecting the data for model build and then must validate the models parameters. Once validated the models represent a powerful means to analyse the performance of the wastewater assets, identify "hot spots" causing major pollution, and verify the effectiveness of optional solutions.

The following Fig. 2 show some of the modelling results obtained with the ADRICOSM project in Tirana, the capital of Albania (1,000.000 inhabitants), where the pollution from urban and industrial catchment strongly affects the environmental quality of the river Ishem that flows through the city.

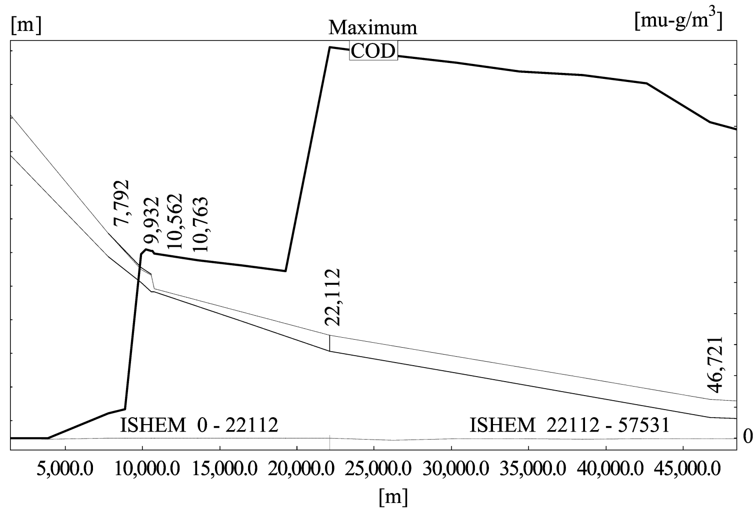


Fig. 2 COD profile along the Ishem River, where sudden increases correspond to the impacts of untreated wastewater discharges

3 The IRBM projects in Europe

This chapter describes two of the major projects conducted by SGI for integrated river basin management in Europe. The first one is WAMARIBAS, financed under the LIFE – Environment Program of the European Commission, from 2003 to 2005.

Secondly the ADRICOSM project has enhanced the capacity of the authorities dealing with water management in some Balkan countries with the ultimate aim of protecting the Adriatic waters. Using state – of – the – art mathematical models validated with field data, the project has identified the most appropriate measures to reduce pollution at the sources within the study basin, with a positive impact on the coastal areas. The following sub – chapters provide a more detailed overview of these two projects(Fig. 3, Fig. 4).

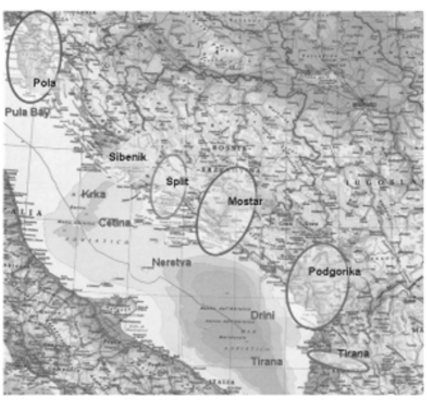


Fig. 3 Location of the study areas in the ADRICOSM project

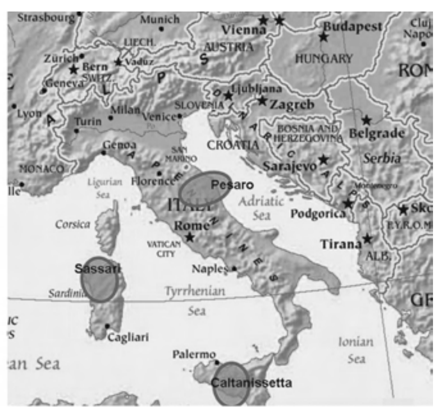


Fig. 4 Location of the study areas the in the WAMARIBAS project

3.1 The WAMARIBAS project

WAMARIBAS stands for WAter MAnagement at RIver BASin Level. This project pioneered the implementation of the WFD in Italy by applying many of its principles to three river basins in Italy, namely the Mannu, Foglia and Salso – Imera river basins in Sardinia, Marches and Sicily regions respectively. These basins face problems similar to those of many other catchments at national and international scale, i. e. point pollution from wastewater discharges, diffused pollution from agriculture, unsustainable exploitation and regulation of the rivers, droughts and floods, saline intrusion.

The WFD has set the context to manage all water resources within the river basins in an integrated fashion which entails the involvement of all stakeholders, consideration of interactions between ground and surface waters, a "combined approach" that evaluates both the quality standards at emissions and receiving bodies, and the provision of an economic value to water in order to ensure a more rational use. The WAMARIBAS project, inspired in these principles, was conducted through the participation of nine organisations responsible for water management at the three pilot catchments, including water companies, municipalities, provincial and regional bodies, environment agencies and engineering consultants and researchers. The partners gathered efforts to address pollution of receiving waters both at urban and river basin levels in order to identify the optimal solutions to enhance wastewater management at the pilot areas.

The project comprised topographic surveys of the wastewater infrastructure and rivers in order to characterise the sewers, wastewater treatment plants and rivers of the pilot catchments. Additionally flow and water quality campaigns were conducted to investigate the operation of infrastructure and the river system. These data were integrated in a set of information tools, namely a GIS database and mathematical models of the sewers, treatment works and rivers, that allowed the relevant authorities to evaluate the sources and impacts of pollution and simulate scenarios to enhance the quality of waters within the pilot river basins.

The mathematical modelling tools proved extremely useful in simulating the impact of pollution in the receiving waters caused by untreated wastewater discharges, particularly during rainfall events, and helped to optimise investments in sanitary infrastructure. For instance savings of over 5 Million Euro could be achieved due to a more careful dimensioning of the storm water tanks, that will prevent the discharge of eh first flush waters into the water bodies.

3.2 The ADRICOSM project

The Adricosm project was launched in 2001 within the Adriatic – Ionian Initiative, a specific action supported by the Italian Ministry of Environment to promote scientific collaboration among the seven riparian countries i. e. Albania, Bosnia – Herzegovina, Croatia, Greece, Italy, Slovenia and Serbia – Montenegro (see Fig. 5). ADRICOSM focuses on the protection of the Adriatic Sea, and has enhanced the near real time monitoring system and the near real time basin – shelf marine forecasting system to produce forecasts of marine currents, temperature, salinity and other physical parameters.

It has developed an IRBM strategy to mitigate land – based pollution on the rivers and coastal areas of the Adriatic through the mathematical modelling and monitoring of the components within the wastewater cycle, i. e. sanitary assets and receiving waters (rivers and coastal areas). ADRICOSM started with one pilot project in the Cetina river basin (Croatia) and the analysis of urban pollution from the city of Split. The benefits demonstrated by the study and the scientific interest it rose, led to its replication in other basins of Croatia (Bojana River including Pula Bay and Nerteva river, this last shared with Bosnia Herzegovina), one in Albania (Ishem river that crosses the capital Tirana) and one in Montenegro (Bokakotorka Bay). Furthermore ADRICOSM was assigned as a Type II Initiative at the World Summit on Sustainable Development (WSSD) in Johannesburg in September 2002 by the Italian Ministry for the Environment and Territory, providing a model for sustainable development of river basins and coastal areas.

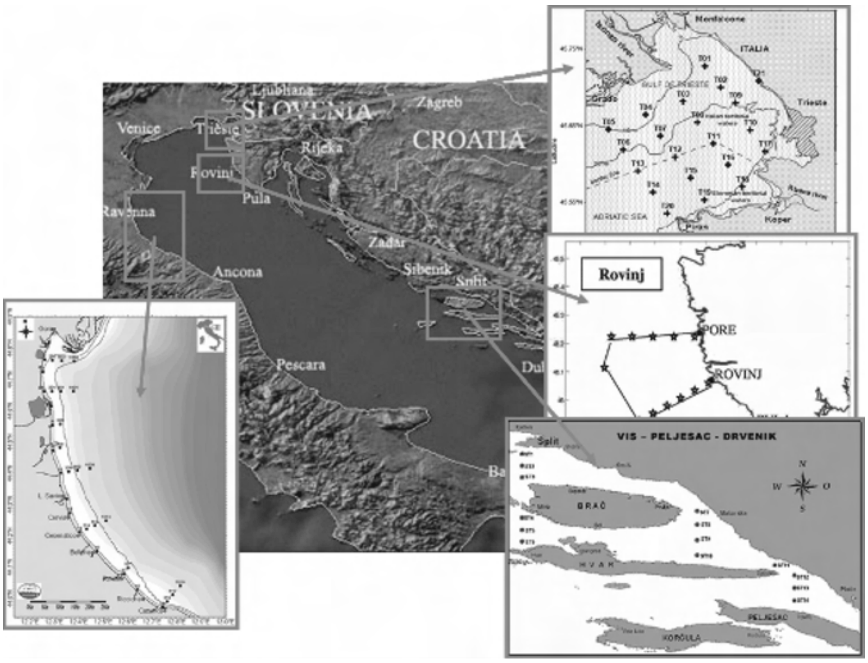


Fig. 5　ADRICOSM project study sites

Amongst the attainments of the project, the design of wastewater infrastructure was optimised to prevent spills of untreated sewage and combined sewer overflows. Fig. 6, Fig. 7 show the modelled COD concentration at Split coastline (Croatia) after 14 days of dry weather flow in the current situation. The colour scale provides an indication of the COD concentrations, being it highest (red) in the areas affected by wastewater discharges. Beside, the model results show how COD concentration can be dramatically reduced with the construction of the treatment plant and storage tanks.

Fig. 6　COD concentrations in the split coast

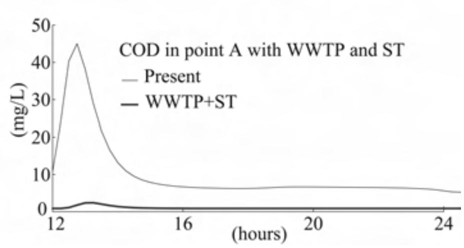


Fig. 7　Comparison of COD concentrations in the current situation and with appropriate treatment solutions

4　Application of IRBM in China: Wenyu River project

Wenyu River is one of the five main river systems in Beijing. It stretches for nearly 50 km, travelling through the Changping, Yanqing and Haidian Districts. There are about 800 million t wastewater discharges in the river, most of them not properly treated. Annual wastewater discharge is about 331 million tons, which is almost one third of the Beijing's total wastewater volume. An approximate quantitative analysis estimated that the pollutant load amounts of more than 5 million population equivalent.

The Qing River is the biggest tributary of the Wenyu River. The volume of wastewater discharged by Qing River is almost half of the total wastewater load in the Wenyu River. The main wastewater sources of Qing River are the North 3rd, 4th, 5th ring roads, northwest beauty spot area, Summer Palace and Winter Palace, Zhongguancun Science & Technology Park, China Science Academy, several public institutes and universities. Additional pollution sources in Wenyu River are more than 100 industrial enterprises in the Airport Industrial Park and sewage coming from Houshayu Town, Gaoliying Town, Zhaoquanying Town, Tianzhu Town.

Beijing Municipal Environmental Protection Bureau (BMEPB) has made the pollution control of the Wenyu River a priority and is committed to adopt the measures to ensure water quality meets "category IV standard" in the upper part of Wenyu River, upstream of the confluence of Qing River, and "category V standard" from this point to the river's end. In order to achieve this goal, BMEPB is collaborating with DFS – SGI in the implementation of the ECO – Plan Kit©, of the Suite of well proven technologies and activities to monitor, organise and analyse the information about pollution sources and impacts with the ultimate purpose of defining an effective mitigation and remediation action plan. SGI – DFS has set up the ECOPLAN – Kit© based on a solid experience gained in similar projects all across Europe, and through the application in the Wenyu rivers it will adapt the system to the Chinese context. This experinec will consent to further replicate the ECOPLAN Kit study to other basins facing similar pollution problems in China and other countries.

The components of "ECOPLAN – Kit©" include the GIS Data Base of the river catchment, SCADA (Supervisory Control And Data Acquisition) system, Water quality monitoring system, River water quality and quantity mathematical model validated with on site data and the Action Plan for pollution abatement.

The project, started in April 2007, is planned to last 12 months. It is structured in two implementation steps. The first phase of the project focuses on the assessment of the current water quality status of the Wenyu river, based on the characterisation of the pollutant sources and a comprehensive analysis of the hydrological, hydro – geological and hydraulic characteristics of the water system and the contributing basins. The outcomes of this phase will be simplified mathematical model of the river hydrodynamic and water quality and the design of a basic SCADA system for water quality and quantity monitoring. Based on the critical issues identified in the first project phase, the second stage will further the analysis of the pollution problems in order to formulate a River Basin Management Plan containing the priority actions to comply with Wenyu's water quality objectives taking into account the future socio – economic and environmental needs of the area. A SCADA system will be designed for the whole river basin to support future management strategies.

As in the European projects previously described, water management will be dealt with on a "river basin scale" and the macro – impacts of pollution loads will be assessed over the entire river system. This will provide an overall picture of the current situation and will consent to identify the worst affected areas or "hot spots", where more detailed analysis will be required.

The project will make extensive use of innovative technologies such as SCADA, monitoring and modelling systems, whose cost – effectiveness in managing water pollution has been long demonstrated. These tools will be adapted to the local context and will use the information held by various organisations. The great challenge of IRBM projects is in fact integrating all the knowledge about the entire "system" in order to provide a comprehensive understanding of the processes in the water body.

The ECOPLAN – Kit©: "ECOlogical monitoring modelling and action PLAnning tool Kit" tools developed for the Wenyu river will be supplied to BMEPB. It is in fact intended that the models will be accepted by the local government so that they become the River Quality Planning Tool. In this sense the project will carry out the dissemination of the project and its results in order to increase awareness about the water quality issues and state – of – the – art solutions based on IWRM concept and on the use of the ECOPLAN – Kit©.

Another important objective of the project is the capacity building of BMEPB, which will be trained in the use of the models and tools (SCADA, GIS, data base etc.) developed through the project. Workshops and training sessions will be held to pass knowledge about European best practice in river basin management and Water Quality Policies and Regulations.

5 Conclusions

Water is fundamental for life, but unsustainable exploitation has deteriorated its quality and quantity. For many years now the international water community is supporting the integrated water resource management at a river basin scale, which takes a comprehensive view for enhancing the status of all waters (surface and ground) and encourages the use of advanced technologies for the planning and management of water resources.

Upon the enactment of the European Water Framework Directive, the writers have participated in the implementation of numerous projects in Europe concerning the enhancement of water quality in receiving waters and the optimisation of asset management to protect the aquatic environment. Their projects have hinged on the use of state – of – the – art methodologies and technologies focused on improving the knowledge about the hydraulic and water quality processes taking place in urban wastewater infrastructure and the receiving waters. As result they have combined all these tools and methodologies into a tool – kit, the ECOPLAN – Kit©, "ECOlogical monitoring modelling and action PLAnning tool Kit", that consents the managers of sanitation utilities and water protection agencies to collect and analyse pollution data, with the ultimate aim of developing an action plan for upgrading the wastewater infrastructure and abate pollution.

The ECOPLAN – Kit© delivers a GIS Data Base of the river catchment, a SCADA system, a monitoring system to measure water quality, the mathematical model of river (water quality and hydrodynamic) and the Action Plan for pollution abatement.

The cost – effectiveness of SCADA, monitoring and modelling systems, for water pollution has been long demonstrated. Their development is an important step forward in optimising water resource management through an integrated approach. In the paper the achievements made in two European projects are described. Project methodology is explained in three major steps: the identification of "hot spots" (worst polluted areas), the analysis of causes (pollution sources) and the formulation of cost – effective solutions ("Action Plan against pollution"). The use of the ECOPLAN tools is fundamental for the efficient implementation of this methodology.

Additionally the paper discusses how the ECOPLAN – Kit© will be applied in a Chinese project for the quality restoration of the Wenyu River in Beijing. The authors are implementing this project for Beijing Municipal Environmental Protection Bureau (BMEPB) with the intention that the ECOPLAN – Kit© supports them in defining the immediate actions needed to comply with the set water quality standards and their future river quality plans. For this reason capacity building of BMEPB is an important project's component. The authors expect to demonstrate the validity of the ECOPLAN – Kit© in the Chinese context and enable its future application to similar situations in China and worldwide.

References

Water Framework Directive, 2000/60/EC.

Bettin, A., Pretner, A., Bertoni, A., etc.. The Irma concept applied to River Cetina and Split catchment, ACTA ADRIATICA 2006.

Bettin, A.. Innovation Partners, Venice Pilot in the fusina catchment: Integrated management of the sewer system, wastewater treatment plant and Venice lagoon. 3rd DHI Software conference, 7 – 9 June 1999 Helsingor, Danmark.

Olesen, K.W., K. Havano. 1998. Restoration of the Skjern River. Towards a sustainable river management solution. Second International RIBAMOD Workshop, 26 – 27 Feb. 1998, Wallingford, U.K.

Pretner, A. , Serrani, C. . Progetto LIFE "WAMARIBAS" Water Management at RIver BAsin Scale", Maggio 2006, Il Sole 24 Ore, Ambiente & Sicurezza.

United Nation Envrironment Programme, Mediterranean Action Plan, Priority Action Programme. 2000. River Cetina Watershed and the Adjacent Coastal Area, Environmental and Socio – economic Profile.

Water Research Center. 1987. A Guide to Short Term Flow Surveys of Sewer Systems. Nassco, Baltimore.

Water Research Center. 2001. Sewerage Rehabilitation Manual. Nassco, Baltimore.

Use of Artificial Wetlands in Urban Storm Water Quality Management

Farhad YAZDANDOOST[1] and ***Mohammad ZOUNEMAT KERMANI***[2]

1. Department of Civil Engineering, KNT University of Technology,
1346 Vali Asr Ave. Mirdamad Cross, 19697, Tehran, Iran,
Water Research Institute
2. Department of Civil Engineering, KNT University of Technology

Abstract: Surface water wetlands are a major and vital element of natural ecosystems. Amongst their various advantages and applications, artificial surface water wetlands play an important role in management of urban storm water quality. The treatment of the storm water as it flows through a wetland is the outcome of a complex interaction between the chemical, physical and biological processes that occur within the system.

Hydraulic efficiency is one of the most important factors that has a considerable effect on the design of artificial wetlands. As a criterion, the suitability of design of a wetland is judged by the specified range of this parameter. The hydraulic efficiency of a wetland can be regarded as its capability to treat the water flow through it.

The traditional way for evaluating the amount of hydraulic efficiency introduces the employment of a tracer to denote the quantity of the outlet concentration against the time. However, this is only possible in some natural wetlands. It is therefore necessary to use numerical methods for simulation and evaluation of various potential physical scenarios.

Here, the relationship between the hydraulic efficiency and the wetland shape in different situations (such as the position of artificial obstacles versus the water flow) has been initially investigated for simple conditions. A two dimensional depth averaged model based on the shallow water equations has been developed. An ADI solution technique has been utilized where Finite Differences method has been used in the computational procedures to descretise the main equations.
Key words: artificial wetlands, urban storm water, two dimensional modelling, hydraulic efficiency, hydraulic retention time

1 Introduction

Artificial wetlands have been constructed to treat a variety of liquid wastes, such as mine wastes, septic system effluent, storm water etc. This may involve restoring previously drained wetlands or constructing new wetlands in appropriate areas. Wetlands are divided into many types. The type under consideration in the present study is surface water wetlands.

Surface water wetlands have a significant role in the management of urban stormwater quality. The treatment of stormwater as it flows through a wetland is the result of a complex interaction between the physical, chemical and biological processes that occur within the system. Apart from the wetland's shape, there are many factors that affect the efficiency of wetlands. Among these factors, vegetation is reckoned to be the dominant feature, particularly in shallow water wetlands.

The concept of hydraulic retention time also plays an important role in the design of artificial wetland systems. The shape of the artificial wetland implies two – dimensional flow characteristics; however, presuming water flows through the wetland as a discrete plug, this may not be a true representation. Therefore, the total flow should be assumed as packets of water. Each packet of water will spend a different amount of time in the wetland, depending on the path taken as it flows through the system. Hence, there is not just a single hydraulic retention time. And in fact the hydraulic characteristics produce a hydraulic retention time distribution. The water's flow treatment in the wetlands, especially during a stormwater is unsteady; therefore a longer hydraulic retention time means more advanced treatment processes.

The aim of this study has been to investigate and quantify the relationship between the effect of assumed obstacles, and the hydraulic retention time distribution (and thereafter the hydraulic efficiency) for artificial surface water wetland systems. A two dimensional hydraulic model has been developed to investigate the way in which the hydraulic efficiency within a wetland system is influenced by the wetland shape.

2 The hydraulics of surface water wetlands

2.1 Hydraulic retention time

The physical, chemical and biological treatment processes that occur within an artificial wetland system rely on the flow of the water through the system to facilitate these treatment processes. Therefore, the hydraulic characteristics within the system have a significant influence on the efficiency of the wetland as a treatment device. Many wetland management problems can be attributed to poor hydrodynamic systems.

Under ideal condition, plug flow characteristics can be assumed within the wetland system. Essentially, this means that all of the water that enters the wetland stays in the system. The duration of this stay is referred to as the hydraulic retention time. The hydraulic retention time under ideal plug flow condition can be defined by Eq. (1).

$$T_n = \frac{VOL}{Q} \tag{1}$$

Where, T_n is Nominal hydraulic retention time; VOL is Wetland volume; Q is Flow rate through wetland.

However, in real wetland systems the water does not remain intact as a single plug as it flows through the system. All of the features described above play a role in the distribution of water as it flows through the wetland system and therefore affect the hydraulic retention time of any one packet of water within the system. In addition, the spatial variability of these features within a wetland system implies that the hydraulic retention time of water flowing through the system is described by a distribution, rather than a single value.

2.2 Hydraulic efficiency

The hydraulic efficiency of a wetland is the description of the water's flow treatment through it. Persson et al. (1999) defined the hydraulic efficiency λ of a wetland as the ratio of the time taken for a conservative tracer to reach a peak at the outlet, T_p, to the nominal retention time.

$$\lambda = \frac{T_p}{T_n} \tag{2}$$

Persson et al. (1999) has also shown that the hydraulic efficiency of the wetland is a good measure of the tracer response from a wetland. Furthermore, the hydraulic efficiency, λ provides an estimate of the number of continuously stirred tank rectors needed to model the treatment processes within the system. Besides this method, other technique have been presented for obtaining the hydraulic efficiency of an artificial wetland (Yazdandoost & Zounemat Kermani 2005). By the aid of this method, the hydraulic efficiency would be calculated as below:

$$\lambda = \frac{T_n}{T_{mw}} \tag{3}$$

where: λ is Hydraulic efficiency of the artificial wetland, T_n is Nominal retention time, T_{mw} is Mean whole retention time.

The mean whole retention time is the average of constituent times along the wetland's length. To obtaining each constituent time, the wetland was divided into several parts by using direct parallel lines along the wetland's length, so the wetland was separated into several regions. The area of each region must be equal, and it is evident that by using more regions the final results will be more accurate.

After running the two – dimensional model, the amounts of velocity in X and Y directions would be known (u and v), so it is possible to calculate the average amount of velocity in both X and Y directions on each line (depending upon the grid spacing). These parameters are shown as U_m and V_m, and can be obtained from following equations:

$$U_m = \frac{\sum_{i=1}^{n} u}{n} \tag{4}$$

and

$$V_m = \frac{\sum_{i=1}^{n} v}{n} \tag{5}$$

(n is the numbers of grid in each schematic line and m is the line's number)

W_m is known as the raster average velocity in each schematic line. And can be defined from Eq. (6).

$$W_m = \sqrt{(U_m^2 + V_m^2)} \tag{6}$$

Hence, according to the numbers of schematic lines (m), there is an equivalent constituent retention time, which could be calculated from the following equation:

$$T_m = \frac{L_m}{W_m} \tag{7}$$

Eventually, the amount of mean whole retention time may be calculated from the following equation:

$$T_{mw} = \frac{\sum_{m=1}^{I} T_m}{I} \tag{8}$$

I is known as the numbers of schematic lines in the wetland, therefore by using Eq. (3), the amount of hydraulic retention time can be estimated.

3 Two – dimensional model study

An accurate understanding of the relationship between the hydraulic efficiency λ and the wetland's shape requires detailed knowledge of the flow characteristics within a wetland system. To accomplish this aim, a tow – dimensional model was written by authors. The model solves the two – dimensional depth averaged shallow water flow equations using an iterative Alternating Direction Implicit (*ADI*) scheme to integrate the equations for mass and momentum conservation in the space – time domain. The equation matrices that result for each direction and each individual grid line are resolved by a double sweep (DS) algorithm. The equations are solved in Two – dimensional sweeps, alternating between X and Y directions. In the X – sweep the continuity and X – momentum equations are solved. In the Y – sweep the continuity and X – momentum equations are solved. At one time step the X – sweep solution are performed in the order of decreasing Y – direction, termed as the "down" sweep, and in the next time step in the order of increasing Y – direction the "up" sweep. After these processes there would be the "right" sweep and "left" sweep in the same way.

The model uses a rectangular coordinate system and was used to calculate steady flow conditions through each of the model wetland configurations. The finite differences method was used to discretise the equations.

4 Effect of different obstacles within wetlands on hydraulic efficiency

Using the model, the hydraulic efficiency of artificial wetland was investigated under specific conditions.

4.1 Assumed holes with specified depths in wetlands

The numerical model study was undertaken to investigate the effect of assumed holes with specified depths, on the distribution of flow through rectangular wetlands for a range of different amounts of depth.

Seven different wetland configurations were modelled, each of which had a surface area of 2,400 m^2, with the main depth throughout the system fixed at 100 cm. One of these wetlands was taken to be an ordinary wetland without any depth alteration. A summary of the wetland configurations modelled is shown in table1. A steady flow rate of 1,000 L/s was applied to each wetland, producing a nominal hydraulic retention time of $T_n = 40$ min. In all of the cases studied, the inflow was modelled as linear source and both the inflow and outflow were linearity collocated on the whole width of the wetland. In all of the cases studied, the numerical grid size was fixed at 1 m in both the *X* and *Y* directions(see Table 1)

Table 1 Wetland model configurations

Wetland Configuration	Length (m)	Width (m)	Distance of the hole from inflow (m)	Length of the hole (m)	Width of the hole (m)	Depth of the hole (m)
A1	86	28	—	—	—	—
B1	86	28	7	22	14	2
B2	86	28	7	22	14	3
B3	86	28	7	22	14	4
C1	86	28	14	22	14	2
C2	86	28	14	22	14	3
C3	86	28	14	22	14	4

The direction of the fluid through wetland is shown in Fig. 1.

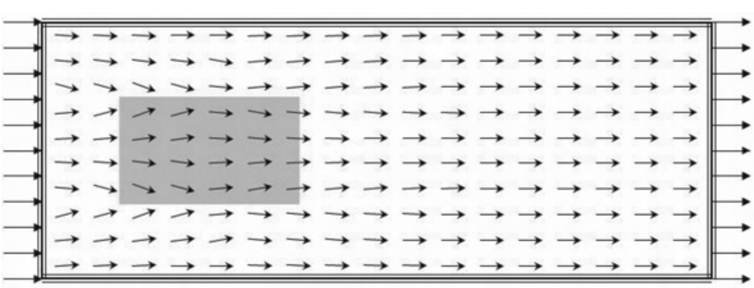


Fig. 1 Flow direction through the wetland (B and C series).

The model was run for all of the cases studied. Results are presented in Table 2.

Table 2 Results for Wetland Models

Wetland Configuration	Nominal Retention Time (min)	Mean Whole Retention Time (min)	Hydraulic Efficiency (%)
A1	40	40	100
B1	40	42.7	93.6
B2	40	43.7	91.5
B3	40	45.4	88.2
C1	40	41.7	95.8
C2	40	42.8	93.4
C3	40	45	88.9

The results signify that the hydraulic efficiency of a wetland is affected strongly by the depth of the hole and partly its location in the wetland.

The chart produced from this study can be used to predict the hydraulic efficiency in similar conditions(see Fig. 2).

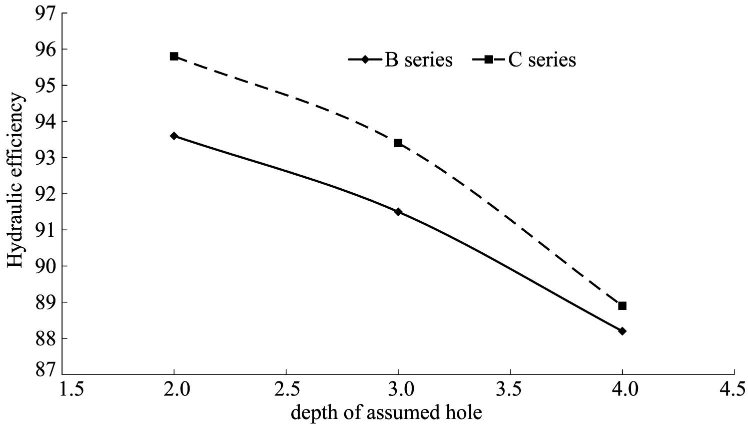


Fig. 2 Hydraulic Efficiency versus the depth of the assumed hole

4.2 Existence of an embankment opposite of inlet

For this case, five different types of wetlands (86 m by 28 m) were assumed. An embankment with 14 m length was situated within each of the wetlands. The situated distance of embankment in every wetland was dissimilar. In each case the inflow and outflow were assumed as sink and source in the middle of vertical edges (Fig. 3). In order to make a better comparison, wetland A2 was assumed as an ordinary wetland without embankment. Table 3 shows the characteristics and results of each type.

Table 3　The amount of hydraulic efficincy regarding to embankment situation

Wetland configuration	Distance of embankment from inlet	Nominal Retention Time (min)	Mean Whole Retention Time (min)	Hydraulic Efficiency (%)
A2	—	40	80	50
D1	14	40	61.6	65
D2	28	40	66.5	60
D3	42	40	69	58
D4	56	40	69	58
D5	70	40	70.2	57

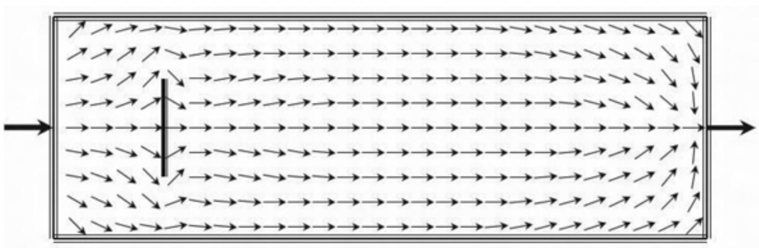


Fig. 3　Flow direction through the wetland (D series)

Enhanced hydraulic efficiency coefficients are presented in Table 4 for different compositions of embankments in different wetland types.

Table 4　Hydraulic efficiency coefficient vs. embankment distance ratio

Wetland configuration	A2	D1	D2	D3	D4	D5
The ratio of embankment distance from inlet to the length of wetland	—	0.16	0.32	0.48	0.65	0.81
Hydraulic efficiency enhanced coefficient	1	1,3	1,2	1,16	1,16	1,14

It is obvious from Table 4 that existence of an embankment can play an important role in increasing the hydraulic efficiency. Fig. 4 shows the rate of this improvement.

4.3　Assumed embankments in a zigzag layout

As it has been shown, existence of obstacles in wetlands can enhance and improve the hydraulic efficiency. This was further explored by emplacement of three embankments in an artificial wetland with equal lengths of 14 m (Fig. 5). The results show a 14% improvement in comparison with the case of no obstacles (Table 5).

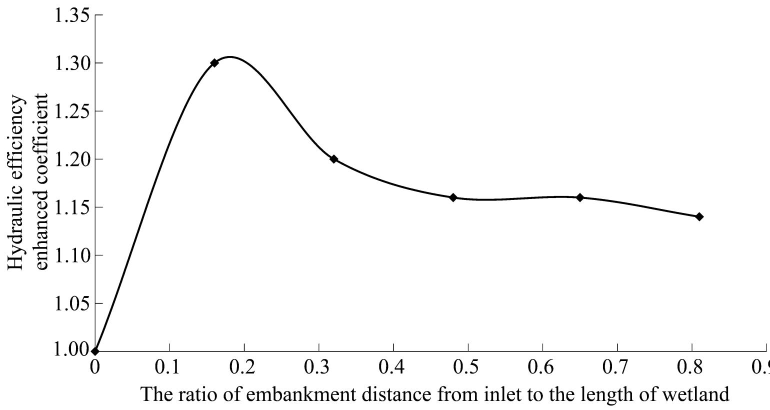


Fig. 4 The amount of Hydraulic efficiency enhanced coefficient

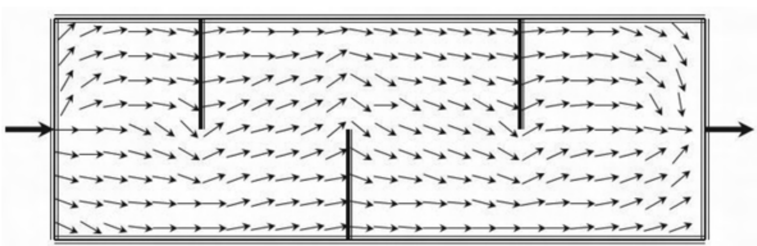


Fig. 5 Flow direction through the wetland (E type).

Table 5 Hydraulic efficiency in wetland with assumed embankments in a zigzag layout

Wetland configuration	Nominal Retention Time (min)	Mean Whole Retention Time (min)	Hydraulic Efficiency (%)
A2	40	80	50
E	40	63	63.5

5 Conclusions

Surface water wetlands are an important part of the urban stormwater management infrastructure. The accurate design of these systems requires a good understanding of the treatment processes occurring, along with a detailed understanding of their hydraulic characteristics. A numerical model study has been undertaken to quantify the relationship between the hydraulic efficiency and the effect of assumed obstacles within artificial wetlands. It has been shown that the hydraulic efficiency is affected by existence of obstacles. A wetland with a ragged bottom has a worse hydraulic efficiency than a plain bottom wetland. It has also been shown that the use of embankments as flow obstacles can improve the hydraulic efficiency and hence lead toe a more practical artificial wetland design.

References

G. A Jenkins., "The Hydraulic Efficiency of Artificial Wetlands", School of Environmental Engineering, Griffith University Press.

L. G Somes Nicholas, "Numerical Simulation of Wetland Hydrodynamics", Department of Civil Engineering, Monash University, Environment international, 1999, Vol. 25, No. 6/7, pp. 773 – 779.

P. Wachiniew, P. Czuprynski, P. Maloszewski & T. Ozimek., "Hydraulic Characteristics of a Constructed Wetlands", Faculty of physics and Nuclear Techniques, University of Mining and Metallurgy, Krakow, Poland, Geophysical Research Abstract, 2003, Vol. 5, 11959.

Yazdandoost & Zounemat Kermani, "Evaluating the Hydraulic Efficiency in Artificial Wetlands" XXXI IAHR congress, Seoul, 2005.

Strategy for Faster Development of Agriculture in Poverty Stricken Frequently Flood Affected Areas of South Asia *

KAMTA PRASAD

Institute for Resource Management and Economic Development, Delhi

Abstract: South Asia is one of the poverty concentration areas of the world. Within South Asia, poverty is concentrated in the frequently flood affected areas of Ganga – Brahmaputra – Meghna Basin comprising Bangladesh, Nepal and eastern part of India. Agriculture is the primary occupation of the flood affected people. But agricultural productivity low. The paper, therefore, explores possibilities of better utilization of agro – economic potential of flood plains for reducing peoples vulnerability and providing enhanced opportunities for food and livelihood securities to the flood affected people thereby reducing their poverty and improving their quality of life. Emphasis has been laid on a two – pronged strategy. First, changes are proposed in crop calendar, cropping pattern and activities allied to agriculture as a part of developing a flood escaping and flood tolerant cropping strategy to reduce the extent of crop damages caused by floods. Several options have been indicated. Second, a strategy to raise agricultural production in the flood free months through improved agricultural practices has been indicated. These comprise of development of irrigation as the critical element supported by improved technology and other infrastructural facilities and services. Various questions like what is the scope for such a strategy and how to bring it about have been examined.
Key words: flood management, agriculture production, reducing poverty, strategy, South Asia

1 Introductory

Notwithstanding the high growth rate exhibited in recent years by countries of South Asia in general and India in particular, poverty of a sizeable proportion of population continues to be a major problem in these countries. Further a majority of the poor in South Asia are disproportionately concentrated in areas affected severely by floods in the Ganga – Brahmaputra – Meghna Basin comprising Bangladesh, Nepal and eastern part of India. The frequent occurrence of sever floods along with the failure to adopt an appropriate development strategy for the severely flood affected areas has been the basic factor responsible for persistence of poverty in such areas.

Floods cause immense suffering to people, and livestock and damage crops, houses household goods and public properties resulting in physical and financial losses. In addition, there have been frequent cases of causalities due to drowning of both human beings and cattle as also outbreak of epidemics during flood. It is true that government and other agencies provide some relief including food, shelter and other helps, but these are neither adequate nor timely. Besides, there is also a long term adverse effect on the overall socio – economic development of flood prone areas resulting in chronic problems of poverty and food insecurity. This is because farmers in these areas tend to be apprehensive of making long term investment in farming, their main source of livelihood, since fertilizers and other inputs tend to get washed away if there is a flood. Investments in roads and railways also suffer damages caused due to floods. Consequently, such areas continue to remain economically backward. These areas also lag behind other areas in terms of social indicators like

* The Paper is based partly on the material collected from a WMO, Geneva, financed study on Community Approach to Flood Management in South Asia during 2003 ~ 2005, for which the author acknowledges thanks to WMO.

literacy rate, availability of safe and potable drinking water, status of health and sanitation etc. Drinking water procured mainly from tanks, ponds, open wells and shallow pumps, tends to get contaminated during the flood period. Communication linkages through rails/roads are not well developed. Financial institutions too have not made much inroads in such areas. As a result of these adverse factors, severely flood affected areas in India, Bangladesh and Nepal tend to be stricken with poverty.

Floods, no doubt also have some beneficial effects like deposition of fine silt (soluble substances such as agro/human/animal wastes etc.) having rich nutritional values that help in increasing farm fertility. The increase in soil moisture has a similar effect. Ground water too gets recharged. Tanks and ponds get filled up and the stored water becomes useful for fishery as well as for irrigation. But the gains are apparently lower than the losses as can be inferred from the widespread public demand for controlling floods. Hence, there is a need for intervention measures to reduce flood damages and increase productivity. Such an intervention should, of course, take note of the beneficial effects also.

2 Lessons from flood management

The world has acquired considerable experience of flood management by now. Most of the well known approaches to flood management, both structural as well as non – structural have been tried in some part of the world or the other. But the success achieved has been limited. The same has been the experience in South Asia. Floods in South Asia continue to occur even in the areas supposed to be protected from floods mainly due to breaches in and overtopping of embankments. Consequently, the average area affected by floods in South Asia has remained more or less the same despite increases in number of flood protection measures. As a result, the optimism of the earlier decades that the flood problem can be solved permanently has yielded ground to a more realistic assessment that providing complete immunity against severe floods is not viable. Hence, people in flood prone areas have to be impressed upon to live with floods. They should, of course, learn better techniques for survival so that their sufferings could be minimized. In other words, this would mean greater reliance on non – structural measures and increasing their efficiency.

3 Scope of the paper and the study area

Given the constraint of space, this paper analyses only one type of non – structural measures namely changes in cropping strategy and agricultural practices to reduce crop damages and increase crop yields. The paper explores possibilities of better utilization of agro – economic potential of flood plains for raising agricultural production, reducing poverty and improving quality of life of the people. The scope of the paper is restricted to areas in South Asia which are frequently affected by severe floods. These fall within Gangetic – Brahmaputra – Meghna plains having highest concentration of flood in South Asia. This region has a higher proportion of flood prone areas compared to its geographical area. In Bangladesh as well as in states of Bihar and Assam in India more than half of the geographical area is flood prone.

4 Rural and agricultural base of flood prone areas

A salient feature of the selected region is that it is predominantly rural and has agriculture as the primary activity. More than 80% of its population is rural. This percentage goes above 95 in certain districts. Moreover, the share of rural to total population in the region is also higher than the respective country average. Agriculture is the main source of livelihood. But agricultural productivity is very low. At the same time, population density is very high, the highest of South Asia and one of the highest in the world. For example, the population density in 2001 was 1,310 in flood prone Samastipur district of Bihar in India as against the national average of 324. Hence, per capita output becomes quite low resulting in widespread poverty. In view of the preponderance of agriculture, crop damages constitute the most important part of damages suffered by people from flood as given in the Table 1 for India. Crop area affected constitutes about 60 percent of area affected by floods, while crop losses are about 77% of total losses suffered by the people (Table 1).

Table 1 Estimate of crop damage due to flood in India during 1998 ~ 2002

Sector	Year					Annual average
	1998	1999	2000	2001	2002	
Total geographical area affected (m. hm^2)	9.1	4.0	5.2	3.0	2.9	4.8
Crop area affected (m. hm^2)	5.9	1.8	2.9	1.9	1.3	2.5
Crop area as % of total geographical area	64.8	45.0	55.8	63.3	44.8	58.3
Total loss suffered by People (Rs. Million) *	26,746	18,392	7,484	8,044	10,022	14,138
Value of Crop Loss (Rs. Million)	23,725	16,632	4,467	4,467	5,471	10,952
Crop loss as % of total loss	88.7	90.4	59.8	55.5	54.5	77.4

* Loss to Govt. properties like roads etc. are excluded.
Source: Central Water Commission.
Note: Figures are provisional.

5 Reduction in crop damages through changes in cropping and land use pattern

If crop damages in South Asia constitute a high proportion of the total damages suffered by its people due to floods, then any strategy that can reduce crop damages would be beneficial to people. Several possibilities in this respect are suggested below.

Damages to crops can be reduced if farmers adopt cropping patterns and crop varieties like sugarcane and jute which can tolerate normal depth and duration of flooding in the respective areas. Mixed cropping is another strategy in this connection. If two or three mutually tolerant crops but having different water requirements and harvesting times are grown on the same plot of land, then one may survive if there is flood and the other may survive if there is no flood. Such a strategy is already being followed by farmers in certain flood prone pockets of Bihar state in India. Farmers in such areas grow rice and moong or rice and til in combination in low lying flood prone areas in order to reap the benefit of dual harvesting from the same land.

Crop damages may be avoided, if farmers grow short duration crops that are harvested before the flood season such as quicker maturing varieties of Ahu and Aus paddy (in Bangladesh and Assam and West Bengal in India), maize, oilseeds, sweet potato, spices etc. Another possibility in case of an impending flood is the harvesting of pre – matured crops like maize which can be used as fodder. A third possibility is that farmers grow crops which can be transplanted immediately after the flood. For this purpose, farmers may preserve seeds for post – flood use in containers hanging from ceiling of the houses or keeping them with friends/relatives in flood free zones. These seeds may be used for preparation of seed nurseries on higher grounds. The seedlings grown there would be available for transplantation immediately after the flood water recedes. Suitable uplands for raising plant/nursery which are not likely to be affected by floods would also need to be identified for this purpose. Damages from flood can thus be minimized if a flood escaping and flood tolerant cropping pattern is adopted. It would be helpful in this context if an area specific monthly calendar of crop operations appropriate for the above purpose is developed. This calendar should be prepared and reviewed in consultation with agricultural experts.

The scope for damages may also be reduced by growing certain trees, medicinal plants and horticultural crops. One example is non – edible banana which can also be used for making rafts for transportation during floods. Water tolerant varieties of horticultural plants provide another example. Trees such as eucalyptus, acacia etc. have the additional advantage of providing bio – drainage in low lying areas, especially along railway tracks, roads, canals, rivers etc. Cultivation of fodder is also less susceptible to damage by flood.

Losses can be reduced through alternate land use practices. Very low lying areas which tend to be flooded or water logged, may be used for aquaculture and fish culture which are less susceptible to flood damages. Raising acquaculture crops like Makhana (euryale ferox) and Singhara as well as catching fish, tend to generate income during the flood when other income generating activities are disrupted. As far as fishing is concerned, there is often an apprehension that fishes may be carried away along with flood water causing significant loss of revenue to the growers. This may, however, be prevented by adopting either the technology of pen culture through net or raising boundary of the pond; the choice between the two would depend on cost implications. In order to promote aquaculture and fish culture, community should undertake desilting of village tanks at frequent intervals depending upon the extent of silting. It may be noted that making of nets required for fishing would also generate income for those engaged in this activity in villages. Net making, therefore, should be completed before the arrival of the flood season.

Poultry/duck rearing can be made lucrative in flood prone areas as these activities provide supplement to the family income when there are no other means of livelihood available during flood. Poultry and duck rearing have another advantage; these can move easily along with people during flood and, therefore, can continue to provide income.

6 Raising crop yields through irrigation

The experience in the past has shown that the yield from the earlier advocated flood tolerant as well as flood escaping varieties of crops is generally lower than that of other varieties. That is the reason why many of such varieties became less popular and even disappeared with the discovery of new and higher yielding varieties but more susceptible to flood damages. The strategy of flood escaping and flood tolerant cropping pattern would, therefore, be considered attractive by farmers only if it can be combined with a strategy for higher productivity during the flood free months.

The scope for this strategy would depend obviously on the duration of flood free months; the longer the duration, the more the scope. Flooding in South Asia is not a year long phenomenon but is restricted mostly to three months during June – July to September. This leaves the remaining 9 months or at least two thirds of the year free from flood for better management of water and land resources. The duration of the flood free period can be increased further through drainage improvement so that accumulated water may drain out more quickly.

Flood free months, however, happen to be dry months with inadequate soil moisture during the later part of the period. Cultivation during flood free months, therefore, is not very profitable because of inadequate soil moisture unless this deficiency is offset by irrigation which is not so in many parts of flood affected areas. A study team constituted by India's Planning Commission in 1985, drew pointed attention to inadequacy of irrigation in the flood prone areas of India's eastern states. Availability of irrigation would enable farmers not only to extend the cropping period as well as area but also to raise the per hectare productivity of crops because higher yielding varieties flourish more with assured supply of water. In this manner, farmers would be in a position to more than compensate for the potential loss of either not growing crops or growing lower yielding flood escaping or flood tolerant varieties of crops in the flood season, since productivity of irrigated cultivation in these areas is near about one and a half times more than that of unirrigated cultivation as may be seen from Table 2.

Table 2 Yield of major crops under irrigated and dry farming in flood prone states of India

Crop	Yield (kg/hm^2)		
	Unirrigated	Irrigated	Increase in irrigatedover unirrigated %
Assam			
Autumn Rice	1,172	2,008	1.71
Winter Rice	1,413	1,419	1.00
Jute	1,716	2,140	1.25
Wheat	1,246	1,520	1.22
Bihar			
Autumn Rice	1 068	1 569	1.47
Winter Rice	1,229	1,688	1.37
Wheat	1,621	1,997	1.23
West Bengal			
Autumn Rice (Aus)	1,622	2,319	1.43
Winter Rice (Aman)	1,730	2,200	1.27
Jute	1,815	2,272	1.25
Wheat	1,263	2,250	1.78

Source: Area and Production of Principal crops in India, Directorate of Economics & Statistics, Ministry of Agriculture, Govt. of India, New Delhi.

7 Problems of irrigation development in flood prone areas and suggestions for improvement

Modern irrigation development in the past used to be mainly in terms of canal or surface irrigation. Flood prone areas used to suffer in this respect since irrigation authorities considered it uneconomical to provide facilities for canal or surface irrigation in such areas. The reasons are well known. Floods not only damage canal structures resulting in frequent breaches but also cause higher rate of siltation in canals leading to reduced quantum of water for irrigation. These difficulties, however, do not apply in the case of ground water irrigation whose scope has been increasing during the past three decades in South Asia. Conditions in flood prone areas may be regarded as very favourable for groundwater irrigation because of adequate availability of sub – soil water at low depths. Hence irrigation in flood prone areas, which has been a problem so far, might turn out to be an opportunity.

Economic exploitation of ground water through tubewells requires electricity or diesel, the supply of both which is usually not assured in flood prone areas. Hence, better arrangements for adequate supply of electricity or diesel or any other form of energy as found appropriate for specific flood prone areas, must be made for promoting faster agricultural growth of such areas. Another difficulty has been due to a mismatch between available technology and socio – economic condition of bulk of farmers. Most farmers have tiny pieces of land holdings, average being less than a hectare per household. As a result, it is not economically viable for them to have tubewells of the standard sizes (usually 5 hp) available in the market. In order to overcome this problem, farmers should either form tubewell cooperatives whose management may not be easy or purchase water from others provided such water markets exist nearby. But such a facility is generally not available in the flood plains. It may be due to these reasons that even tubewell irrigation could not make much of a headway in major flood prone areas of South Asia during the past three decades during which it made much stride in flood free zones.

Fortunately, a cheap technology of extracting groundwater suitable for tiny holdings in flood plains where water is available at very low depths, has been developed in recent years, Known as treadle pump, this technology has spread rapidly in Bangladesh. Costing around Rs. 1,000 (or US \$ 2.0 to 2.5), it is within the financial capability of even the poorer farmers. It does not require recurring expenditure on diesel or kerosene. It can be operated conveniently by men, women and even grown up children. It can irrigate half an acre of vegetable or even paddy. As Tushar Shah points out, "the treadle pump is an outstanding example of how access to ground water irrigation can significantly improve the livelihoods of the ultra – poor". "For a marginal farmer with \$ 12 ~ 15 to spare, there could hardly be a better investment than a treadle pump, which has a benefit cost ratio of 5, an IRR of 100% and a payback period of a year". Hence irrigation through treadle pump or similar technology offers considerable scope for raising farm income in flood free months in flood prone areas of South Asia.

At the same time, other means of irrigation, wherever possible and economically viable, should also be developed. These may include river lift schemes or large tubewells. Because of the heavy cost involved, these would need to be financed by government. Later on, these may be handed over to farmers cooperatives or water users associations for better operation and maintenance on self supporting basis.

8 Technological upgradation

Irrigation yields better return if it is used along with improved seeds. In India, improved technological packages appropriate to the special requirements of flood prone areas have not been made available. Even in the case of rice, which is grown in a greater part of the country, and is very important for flood prone areas, improved varieties that have been developed are not suited to flood prone areas. Being short staple, these do not withstand more than a couple feet and of days of submergence in water. No significant attempt has been made to improve productivity of the traditional rice varieties which are tolerant to flood water.

Position is equally bad or even worse with regard to aquaculture crops such as Makhana (euryale ferox), and Singhara etc. which are specially suited to flood prone areas. A recent study of Makhana, which is a typical aquaculture crop grown only in the flood prone areas of Bihar, has thrown light on absence of any technological innovation. Being a crop which is grown mainly for sale and having a good market in the urban areas, it is an important source of cash income to the poor farmers. The techniques in vogue, however, are the same as those used for thousands of years. Its production is a highly labour intensive, time consuming and pain taking process. The entire process of cultivation, collection and processing etc. is carried out through manual labour without any mechanical support. Manual labour constitutes about 82% of cost of production. The Indian Council of Agricultural Research (ICAR), the apex organization in the field of crop research in India, had not taken any serious note of the problems of crop research in the flood prone areas. It is only recently that it has set up a centre for Makhana research at Shahanagar, Patna, Bihar. A more or less similar situation prevails with respect to Singhara and other typical crops of flood prone areas. A strong need, therefore, exists for improving the technological base of crop culture in flood prone areas of South Asia.

There is one more problem. Frequent exposure to flood risk has resulted in making people fatalist and sceptical of any new ideas and approaches. Sustained and vigiourous efforts, therefore, are needed to disseminate knowledge regarding improved technological packages to farmers in flood prone areas. This might be done through organizing awareness generation camps, workshops, training programmes, and visits of farmers to more progressive areas to get familiarized with the potential of changes in the cropping strategy to reduce crop damages from flood and to raise per hectare productivity during the flood free months.

9 Infrastructural facilities and support services

Irrigation and improved technology are known to give higher yields if these are combined with a package of supplementary inputs like fertilizers, pesticides and services like extension, marketing support, better transport etc. Flood prone areas usually lag behind other areas with regard to development of such facilities and support services. Frequent damages caused to them by flood make it costly to develop and maintain these structures and facilities. Authorities, therefore, did not consider it very attractive to invest on them in the past. Absence of irrigation and technological backwardness has been another reason for inadequate development of these facilities since the need was not very obvious. Thus there was a vicious circle of non – development.

In addition, whatever facilities that have been developed come to be seriously disrupted when a major flood comes. Flood causes serious damages to communication links e. g. railways, roads and bridges in terms of breaches and overtoppings at vulnerable points because of which the area tends to remain cut off from rest of the villages, towns and cities for a considerable number of days resulting in restricted movement of men and materials to these places during the crisis. As a result, normal life is paralysed. Perishable commodities from these areas like fruits and vegetables fail to fetch good market for want of connectivity with nearby towns/cities. Hence, development of transport network must receive a very high priority.

Improved productivity would also require sufficient storage facilities for seeds, fertilizers and farm output. In the absence of proper storage, grains stored in houses get wet and rot when high flood water enters houses. It creates environmental degradation by way of imanating foul smell in and aground the houses. This is one of the reasons behind outbreak of epidemics after flood. Hence, there is a need for storage/public godowns which should be located on high lands in flood prone areas. These godowns would also provide space for storing raw materials for handicrafts and cottage related activities, which can be made use of by the community members at the time of flood to supplement their family income.

10 Credit and insurance

Availability of credit at reasonable rates of interest plays a crucial role in development of agriculture as well as other economic activities. But the prevailing scenario with regard to availability of credit in flood prone areas has been quite unsatisfactory. The banking facilities, particularly number of bank branches as well as per capita availability of credit in flood prone eastern states of India, are owefully below the desired level compared to the rest of India. Hence, the reasons for poor performance of the banking sector in these areas may have to be identified with a view to improve efficiency.

The flood stricken eastern part of India has also been deprived of its due share in respect of getting refinance facility for irrigation tubewells under various loan schemes floated by the government from time to time. Table 3 below gives the data. It is, therefore, necessary that refinance schemes specific to flood prone areas may be formulated and tried for one or two crop seasons and, based on the experience gained, further improvement in the same may be brought about.

Table 3 Eastern India versus rest of the country

Region	No. of rural poor	No. of block	No. of darkblock	Refinance for tubewells (Rs. million)
North	27,154	645	189	13,939
Central	75,030	1,354	115	24,979
West	38,094	1,695	81	19,345
South	49,470	1,814	210	26,657
East & North – East	88,429	1,543	4	6,810
All India	278,177	7,063	599	91,730

Source: Tushar Shah: Wells and Welfare in the Ganga Basin in Kamta Prasad (ed) Water Resource and Sustainable Development, 2003, p. 397

Most households in these areas, therefore, resort to non – institutional sources of credit like village money lenders and traders. The rates of interest charged by village money lenders are unusually high. Institutional sources of credit must, therefore, be strengthened if farmers in flood prone areas are to prosper. Credit institutions should provide micro loans to small and medium farmers to install minor irrigation schemes like treadle pumps so that agriculture in the post flood period becomes more productive and profitable.

Insurance against flood is another area which needs to be looked into on priority. Flood affected people, though exposed to considerable risks, have not been offered insurance schemes suitable to their economic conditions. Adoption of improved farming as well as cattle rearing would be accelerated if a comprehensive flood insurance scheme is evolved and implemented in flood plains. Assistance of community leaders may be availed of to overcome problems of adoption, valuation of losses and settlement of claims.

11 Community participation

A new institutional framework may be needed for overcoming the several problems mentioned earlier since the prevailing system dominated by the government has not been effective enough to help the flood prone areas to the desired extent. This is mostly because of the usual delays, indifference, neglect and lack of accountability which characterize bureaucracy at different levels. A better approach could be through the involvement of the community in local level activities related to flood management including crop planning. Community participation is viewed as a process where the concerned communities function and contribute as a cohesive group to perform a pre determined activity. All adults living within flood prone villages or Panchayats would form part the 'community'. The basic premise behind this approach is that the involvement of the people would result in better formulation and implementation of projects related to their welfare. Official machinery may continue but should be concerned mainly with providing facilitating and catalytic support.

Transformation from the prevailing bureaucratic to the proposed community approach which focuses on self help, would require creation of new institutions and changes in the role of the existing ones including that of the government. This would also require identification of different types of tasks to be performed by the community and others. Such an approach would be more effective provided people are fully aware of the tasks involved and are trained for the purpose. Community participation in any activity would forthcome readily if community can foresee visible benefits from it. Hence, a vigorous programme of awareness generation and training would be needed.

Community approach is a new concept. But its feasibility was examined in detail while conducting a recent study on Community Approach to Flood Management in South Asia, sponsored by WMO, Geneva. A testing of the proposed framework for community participation in South Asia shows that the concept is feasible provided the community is organized, trained and empowered.

References

Census of India, 2001, Registrar General of Census, Government of India, New Delhi.

Tushar Shah, Wells and Welfare in the Ganga Basin: Public Policy and Private Initiative in Eastern Uttar Pradesh in Kamta Prasad (ed) Water Resources and Sustainable Development. Shipra Publications, Delhi, 2003, p. 394.

A Brief Note on Status of Makhana (Euryale Ferox), sent to the author in May 2004 by Prof. S. S. N. Sinha, Secretary, Shekhar Seva Sansthan, Laheriasarai, Darbhanga (Bihar) and Director of a Research Project on Makhana.

Report on Community Approach to Flood Management in South Asia submitted to WMO, Geneva by BUP, Dhaka, 2004.

A Discussion of Assumptions and Solution Approaches of Infiltration into a Cracked Soil

M. J. M. Römkens[1] and ***S. N. Prasad***[2]

1. USDA ARS National Sedimentation Laboratory, Oxford, MS USA
2. Dept. of Civil Engineering, The University of Mississippi, University, MS USA

Abstract: A model for predicting rain infiltration into a swelling/shrinking/cracking soil was proposed (Römkens, M. J. M., and S. N. Prasad. 2006. Agricultural Water Management. 86:196 – 205). Several simplifying assumptions were made. The model consists of a two – component process of Darcian matrix flow and Hortonian flow on the walls of the cracks. Model assumptions include: ① Water enters into the soil horizontally from the vertical cracked surfaces exclusively by diffusive flow, ②Vertical infiltration through the soil surface was negligible because of a severe surface sealing condition, ③Water flow along the vertical surfaces of the cracks is uniform over its circumference, and ④Wetting front advance interactions between adjacent vertical crack surfaces are assumed to be negligible. These assumptions will be examined and their effect on infiltration will be assessed. Also, alternative approaches involving different modular concepts for predicting infiltration and incipient ponding estimates will be examined.

Key words: cracked soil, infiltration, model, predict, examine

Rainfall infiltration in soils has been the subject of many studies during the last 60 years. While in the early years of this research the interest was motivated by hydrologic concerns of having adequate water for plant growth, in recent times this interest also included environmental concerns, i. e., reducing runoff from agricultural land. Prediction of rain infiltration for the most part has been point infiltration into a stable and uniform soil matrix using parametric, semi – analytical relationships or numerical approaches (Philip, 1974; Raats, 2001). Most situations concern non – ideal conditions, such as a changing soil matrix due to consolidation following tillage, the presence of swelling and shrinking material, or soil surface matrix changes due to the destructive impact of raindrops. Of those, rain infiltration into cracking soils is especially challenging, given the large influence differences in crack morphology have on rain infiltration. Recently, Römkens and Prasad (2006) described a model in which a rain infiltration prediction equation was developed for cracking soils, which includes the effect of rainfall intensity, a soil parameter (sorptivity), and the crack morphology, i. e., depth, width, and spacing. The objective of this report is to summarize the major findings, to discuss to a greater degree the underlying assumptions, and to offer suggestions for further improvements.

1 Experimental observations

The soil profile considered is a swelling, shrinking, cracking soil consisting of a high percentage of swelling clay of the montmorillonite type. This soil develops cracks during drying, which may be several cm wide and as much as 1 m deep. During a rainstorm event, rain may enter the soil profile either through the surface, falls directly into the cracks, or in case of a surface – sealed condition, collects on the surface and enters into the cracks as free water by gravity flow and is subsequently imbibed into the soil matrix. During the wetting phase the soil swells as evidenced by a surface elevation increase and by crack closure. Quantitative prediction of infiltration becomes extremely complex and depends on the degree of cracked condition (dryness), the dynamics of swelling (water imbibition characteristics), and the rainfall regime.

To ascertain the effect of crack morphology on infiltration, a series of laboratory studies were conducted on a prepared Sharkey clay soil, air dried, crushed to pass a 2 mm screen, packed into 65.0 cm × 85.0 cm × 15.0 cm box, and placed on a weighing platform which was subjected to a series of rainstorms of 30 mm/h, in some instances 20 mmh − 1, rainfall intensity and 3 h. duration. Following each storm event, the soil was allowed to dry for an extended period of time, which lead to the development of a cracking pattern of the type shown in Fig. 1. A total of six experiments were conducted, each consisting of 3 to 7 wetting and drying cycles. Observations indicated that, following each successive rainstorm, crack depth increased if soil was allowed to dry until evaporative losses on a daily basis were negligible. Fig. 2 shows the infiltration relationships

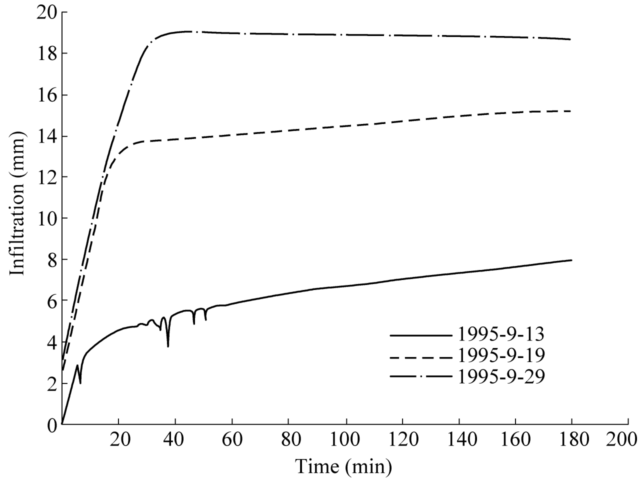


Fig. 1 Cumulative infiltration as a function of time for three successive rainstorms, each of 3 h duration and 30 mm/h rainfall intensity(Wells,1995)

Fig. 2 Physical image of a cracking pattern after several wetting and drying cycles for a Sharkey clay soil. The largest column size is about 12 cm

obtained for one of these experiments as a function of time for three successive rainstorms. The response was very similar for the other experiments. These results indicate that the curvilinear infiltration relationship for rain on a freshly prepared, air dry clay soil is similar to the rain infiltration response of any initially dry soil, except that the rapidly changing infiltration rate between 10 to 20 min into the storm reflects to some extent the effect of seal development that restricts water entry into the profile. During the early stages of the second and third rainstorms all rain enters the soil as indicated by the linear nature of the infiltration relationship and that equals the rainfall intensity. Then the rate of infiltration diminishes rapidly in a time span of a couple of minutes, to become linear again but at a much lower rate. In fact, the third storm suggests a negative rate, which is attributed to a net soil loss that more than compensates for the extremely low water addition rate by rainfall. Thus, the infiltration rate during this part of the third rainstorm is, for all practical purposes, negligible because of a surface sealed condition.

Besides infiltration and runoff measurements, the experiments also included surface profile measurements before and after each rainfall event using a non – contact infrared laser (Römkens et al., 1988). Furthermore, infiltration depth measurements were performed following selected rainstorm events using a needle penetrometer (Wells et al., 2006).

2 Model formulation

Based on the experimental observations, an infiltration model was formulated for infiltration into swelling/shrinking/cracking soils. This model assumes: ① Infiltration through the soil surface was negligible because of surface sealing; ② Excess rainwater on the soil surface will flow into the cracks along the vertical crack surfaces in a uniform manner over its circumference (Hortonian flow); ③ Horizontal infiltration takes place laterally from the vertical surfaces inward (Darcy matrix flow). Fig. 3 shows surface elevation data of the soil in a dry and wet state as well as the wetting front penetration into the soil profile before and after the first rainstorm (Fig. 3A) and after the third rainstorm (Fig. 3B). The cracking pattern has a polygonal geometry in which cracks surround soil columns in a prismatic arrangement. For reasons of calculation simplicity, we assume a quadrangular polygonal column structure of width l and height H. The data of Fig. 3 indicate the profound effect of cracks on the wetting front position , in which the wetting front penetration was

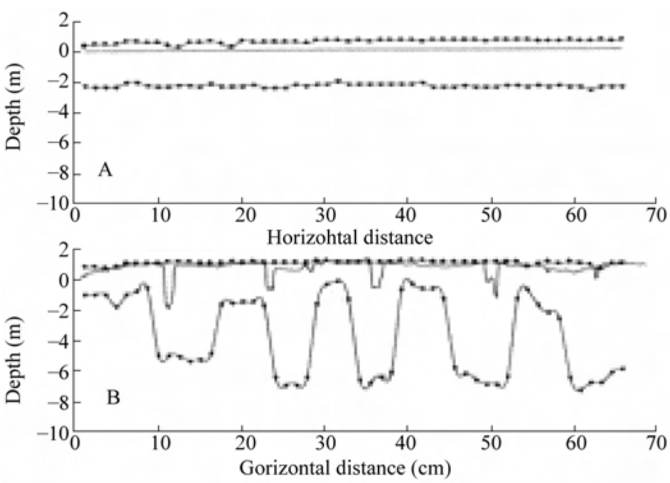


Fig. 3 Normalized surface elevation and penetration measurements following a series of simulated rainstorms on a Sharkey clay soil: (A) After the first rainstorm; (B) After the third rainstorm. The solid line represents the surface elevation prior to the rainstorm, the solid line with solid circle symbols represent the surface elevation immediately after the rainstorm prior to penetration, and the solid line with solid triangle symbols represents the final penetration depth (Wells, 2003)

deepest in the crack area that followed more or less the contours of the crack vertical surfaces. Also, the largest lateral penetration was consistently observed near the soil surface and the least lateral penetration was near the bottom of the crack. The shape of the wetting front following rainfall on a cracked soil suggests that the model assumption of uniform flow along the vertical surfaces of the cracks is, at least for this soil and experimental setup, a very reasonable one.

Wetting of the soil takes placed "layer wise" from the top of the column downward. Absorption into each layer is described by Richards' equation

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial x}\left(D(\theta)\frac{\partial\theta}{\partial x}\right) \tag{1}$$

subject to the conditions

$$\begin{cases} x = 0,\ t > 0,\ \theta = \theta_S,\ D\dfrac{\partial\theta}{\partial x} = finite, \\ x > 0,\ t = 0,\ \theta = 0 \end{cases} \tag{2}$$

where θ is the reduced water content, $\theta = (\theta' - \theta_R)/(\theta_S - \theta_R)$, θ_S is the saturated water content, θ_R is the residual water content, $D(\theta')$ is the soil water diffusivity function, t and x are the time and space coordinates, and θ' is the real water content. Eq. (1) governs water flow into a rigid medium with fixed coordinates. For a non – rigid medium the equation needs to be modified to reflect the changing matrix.

The amount of water entering the soil per unit column width of a quadrangular polygonal model is given by

$$q_o = \frac{il^2}{4l} = \frac{il}{4} \tag{3}$$

where i is the rainfall intensity and l is the crack spacing. The solution is expressed as a spectral series

$$\theta(x,t) = A_o\left(1 - \frac{x}{\delta_1}\right)^{\alpha} + A_1\left(1 - \frac{x}{\delta_1}\right)^{\alpha+1} + A_2\left(1 - \frac{x}{\delta_1}\right)^{\alpha+2} + \cdots \tag{4}$$

where A_i for $i = 0, 1, 2$, are time dependent constants and δ_1 is the wetting front depth (Römkens and Prasad, 1992), and α is a constant that describes the shape of the wetting front. For a concentration boundary condition of a semi – infinite long slice, the solution to a truncated uses the boundary condition

$$\frac{\partial\theta}{\partial x} = 0,\ \frac{\partial^2\theta}{\partial x^2} = 0,\ x = 0,\ t > 0 \tag{5}$$

The Ahuja – Swartzendruber diffusivity relationship (Ahuja and Swartzendruber, 1972):

$$D(\theta) = \frac{a\theta^n}{(\theta_S - \theta)^{n/5}} = \theta^n \cdot F(\theta) \tag{6}$$

is used in this study as it meets the requirements

$$\theta = 0,\ D(0) = 0 \tag{7a}$$

$$\theta = \theta_S,\ D(\theta_S) = \infty \tag{7b}$$

where n, α, and a are soil specific constants. For analytical consideration (Römkens and Prasad, 2006) it can be shown that

$$\alpha = \frac{1}{n} \tag{8}$$

The cumulative infiltration in a horizontal slice is given by

$$I = \int_o^{\delta} \theta(x)\,\mathrm{d}x \tag{9}$$

which, upon integration, yields

$$I = \frac{3\theta_S}{3+\alpha}\delta_1 = \lambda\sqrt{t} \tag{10}$$

with λ being the sorptivity.

2.1 Incipient ponding and cumulative infiltration

2.1.1 Incipient ponding

From the standpoint of runoff generation, two quantities are of interest: ① incipient ponding time, and ② cumulative infiltration. As was evident from the data presented in Fig. 2, these quantities depend to a large extent on the crack morphology, that is the crack width ($2w$), depth (H), and spacing (l). Fig. 4 shows a schematic representation of the area around a crack with wetting front penetrations at different times during a rainstorm. One scenario might be that at $t = t_m$ the crack is closing and the water film has advanced partway along the vertical column surface. Another scenario is that at $t = t_p$ the water film has reached the crack bottom ($h = H$). The crack is still present, though partial closing has taken place. In the hypothetical case, that the crack closes at $t = t_p$, t_p then becomes the field ponding time t'_p and runoff initiates. Using the mass balance equation

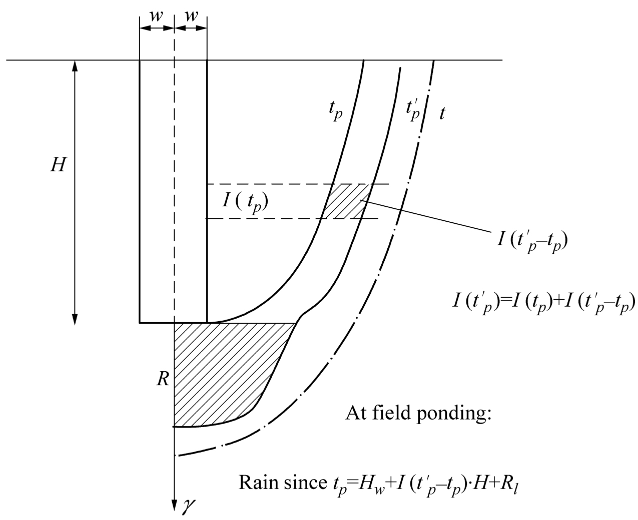


Fig. 4 A schematic representation of soil water content profiles in the crack area

$$q_o t = \int_o^h (I + c)\,dy \tag{11}$$

where c is the water film thickness on the surface, then it can be shown (R? mkens and Prasad, 2006) that

$$\sqrt{t'_p} = \frac{\pi \lambda H}{il} \tag{12}$$

For this special case, the field ponding time is in an exact manner related to the crack depth and spacing. In most storms, crack closure takes place either before the water film reaches the crack bottom (low rainfall intensity) or the cracks are only partially closed when the water reaches the crack bottom (high rainfall intensity) and the cracks start filling up. Then at t'_p the crack has filled with water, field ponding has started and runoff commences. For the latter case, the following approximate relationship can be deduced from Fig. 5.

$$q_o(t'_p - t_p) = Hw + \frac{1}{4}\pi\delta^2(t'_p - t_p) + \int_o^H I(t'_p - t_p)\,dy \tag{13}$$

where the first term on the RHS of Eq. (13) represents the water in the partially filled crack, the second term represents water in the region below the crack, and the third term represents the water that entered the column laterally in the interval between field ponding and the moment that the water film reached the bottom of the crack. Because of the dominant, diffusive nature of water flow into this clay soil, the flow in the sub – crack region is omni – directional, that is, the flow penetration is the same in all directions, and the shape of the wetted region can be described by a semi – circle with radius $\delta(t'_p - t_p)$. The wetting front advance for horizontal infiltration into a semi – infinite column with a saturated boundary condition is given by

$$\delta^2(t'_p - t_p) = A^2(t'_p - t_p) = A^2 T \qquad (14)$$

where A is a soil characteristic (Kirkham and Feng, 1949; Bruce and Klute, 1956) and T is the interval between field ponding and matrix ponding. Eq. (13) can now be approximated to read:

$$w = \frac{q_o T}{H} - \frac{1}{4}\pi A^2 \frac{T}{H} - I(t'_p - t_p) \qquad (15)$$

where $I(t'_p - t_p) = I(t'_p) - I(t_p)$. The crack width ($2w$) can be obtained from the difference in dry and wet soil bulk density. Given w, T can be estimated in terms of t'_p using an expression for t_p obtained from Prasad et al. (1999):

$$\frac{h}{q_o} = \frac{4\sqrt{t}}{\pi\lambda} + \frac{4c}{\pi\lambda^2}\left[\exp\left(\frac{\pi\lambda^2 t}{4c^2}\right)\cdot \operatorname{erfc}\left(\frac{\sqrt{\pi}\lambda\sqrt{c}}{2c}\right) - 1\right] \qquad (16)$$

2.1.2 Cumulative Infiltration

The total amount of infiltration at field ponding is given by the expression

$$q_o(t'_p - t_p) = Hw + \frac{1}{4}\pi\delta^2(t'_p - t_p) + \int_o^H I(t'_p - t_p)\,dy \qquad (17)$$

where the first term represents the cumulative infiltration in the soil matrix due to lateral imbibition up to time t_p. This is the time at which film flow along the vertical surface reaches the crack bottom. The second term represents the water volume infiltrating into the column for $t > t_p$ and the third term is the water absorbed in the sub – crack zone. For $t > t_p$, Eq. (17) can be rewritten as (Römkens and Prasad, 2006):

$$R = q_o t_p + \gamma\lambda H\sqrt{t - t_p}\beta + \frac{\pi}{4}\gamma\frac{A(t - t_p)}{\sqrt{t_p}}\beta \quad \textit{for } t \geqslant t'_p \qquad (18)$$

where γ represents ad adjustment factor that accounts for changes in the soil matrix and for simplifications and approximations in the model, β reflects or accounts for flow impairment into the cracks. The infiltration rate, when expressed per unit soil area for the quadrangular cracking model is

$$I_g = \frac{4R}{l} \qquad (19)$$

3 Assumptions

Various assumptions were made in developing this model. They are: ①Only diffusive matrix flow exist in the finely pulverized, compacted soil with aggregate sizes less than 2 mm and a high content (60%) of swelling clay. ②Infiltration into the clay soil surface was negligible because of sealing effects due to rainfall. ③Water flow along the vertical surfaces of the soil column is uniform over its circumference. ④ Infiltration takes place laterally from the vertical surfaces inward. ⑤Interactions of wetting front advances between adjacent vertical surfaces are assumed negligible. ⑥Bulk density changes within a horizontal layer upon wetting are assumed to be uniform. ⑦A quadrangular cracking pattern was assumed.

In reality, the polygonal crack structures are often seen but they may be irregular in size and shape and of different orders. Of these, the following assumptions are important ones: ①Uniformity of flow along the circumference that enters the crack, ②No interacting effects of water movement into the soil matrix from adjacent surfaces, ③Uniform density differences within each horizontal slice in the soil columns due to wetting.

3.1 Uniformity of flow on the column surfaces.

The film has a certain thickness c. While the experiments of this study indicated uniform flow along the vertical surface of the column it stands to reason that such a response is rainfall intensity dependent. Large rainfall intensity will cause excess rainwater to use preferential pathways into the cracks at selected points on the column circumference (Bouma et al., 1978). The cracks will fill with water and layerwise horizontal infiltration takes place from the bottom of the crack upward. In that case, the boundary condition is not a concentration dependent condition but a hydrodynamic one in that at any given position on the water covered vertical surface the water pressure increases as the crack fills up with water. The solution of the Richard equation will then be driven by the time dependent water pressure at the vertical surface rather than the controlled saturated water content used in this study. This will add considerable complexity to the problem. In one sense, the hydraulic pressure has a compression effect on the soil matrix of swelling clay, thereby decreasing the infiltration rate, and at the same time the build up of the hydraulic pressure during the crack filling process, tends to increase into the infiltration rate into the soil matrix.

In a rectangular shaped crack of width w, the rate of filling for a quadrangular crack pattern could be approximated by:

$$t = \frac{4}{il}[(H-h)w] - \int_h^H I(y)\,dy \tag{20}$$

Where $I(y)$ is the soil water content that infiltrated into a horizontal slice at $y = h$ under a hydrodynamic pressure boundary condition, and w is the real crack width at t. In this case, closure starts at the bottom of the crack, leading to a reduction in lateral infiltration into layers with closed cracks.

3.2 Two dimensional infiltration into the soil column

In this paper, the water entry into the soil column has been assumed to be one – dimensional. Actually, the layerwise infiltration process is a 2 – dimensional problem. Interactions of flow occurs from two adjacent vertical surfaces. These interactions may be very significant for small cross – sectional areas of the soil column or for the smaller number of corners in the polygon. One approach of addressing this problem is to describe the infiltration process as a 2 – dimensional flow problem using polar coordinates. In that case, the cracked soil surface can best be described by a collection of cylinders or truncated cones with height 4 H and 2 R as the cross – sectional diameter. Two requirements must be met: ① the horizontal surface area of the cylinder or cone with dry soil must equal the horizontal area of the real, dry polygonal soil column, and ② the crack volume and horizontal crack length per unit surface area of the cylindrical model shown equal or closely approximated those of the prismatic structure of the real soil. For a polygonal cracking pattern consisting of a prismatic structure of symmetrical polyhedrons with 4, 5, or 6 falls, a cylindrical model should be selected in which the horizontal cross section equals that of the polyhedron under dry conditions and a concentric cylinder with larger radius that of the same polyhedron under wet conditions (closed cracks). The radius of the cylinder, Re, for the 4, 5, or 6 fall polyhedrons is 0.79, 0.87, and 0.91 times the distance (R_4, R_5, or R_6) from the center of the polyhedron surface area to the apex or vertices, respectively. The effect of this model on the ratio of the circumference relative to the polyhedron is given in Table 1.

Table 1 Ratio of cylinder circumference to that of different polyhedrons being the same cross – sectional surface area

	Quadrangle	Pentagon	Hexagon
Cylinder Radius, Re:	0.79 R_4	0.87 R_5	0.91 R_6
Ration Circumference Cylinder/polyhedron	0.90	0.93	0.95

While the requirement of equal surface area for these polyhedrons with that of the cylinder is met, the circumference is smaller. This suggests that the infiltrate vertical surface areas of the polyhedron is larger than that of the cylinder. In swelling – clay soils, most infiltration takes place during the early stages of rainfall suggesting that the equal crack volume and horizontal crack length requirements are of paramount importance in selecting the radius of the cylinder model.

The Richards' equation in polar – coordinates is given by the following relationship.

$$\frac{\partial\theta}{\partial t}=\frac{\partial\theta}{\partial r}\quad D'(\theta)\frac{\partial\theta}{\partial r}+\frac{1}{r}D(\theta)\frac{\partial\theta}{\partial r}+\frac{1}{r^2}\frac{\partial}{\partial\varphi}D(\theta)\frac{\partial\theta}{\partial\varphi} \tag{21}$$

and the boundary conditions for this model with horizontal infiltration are:

$$\begin{cases}\theta=\theta_S,\ \dfrac{\partial\theta}{\partial r}=0 \quad \dfrac{\partial^2\theta}{\partial r^2}=0 \quad r=R \quad t>0 \quad D(\theta)\dfrac{\partial\theta}{\partial r}=finite \\ \dfrac{\partial\theta}{\partial r}=0 \quad r=0 \quad t>0\end{cases} \tag{22}$$

A common substitution is $\rho=\left(1-\frac{r}{R}\right)$ and an applicable spectral series for early stages of rain infiltration, when the wetting front tip has not reached the origin, may be given as

$$\theta=B+A_o(1-\rho)^{\beta}+A_1(1-\rho)^{\beta+1}A_2(1-\rho)^{\beta+2} \tag{23}$$

For a dry soil, the crack width associated with a cylinder is assumed to be w, so that the crack volume equals $\pi H(2Rw+w^2)$. The amount of rain water that enters the crack per unit length of the circumference is $q=\frac{R}{2}it$.

3.3 Density appearances

The initial bulk density of the prepared soil beds was very uniform. However, once wetting has taken place, but especially during the submerged drying phase, the matrix structure changes in an irreversible manner, impacting both the dry and wet bulk densities. The degree of these changes is difficult to ascertain. They consist of macroscopic visible changes, as indicated by cracks and microscopic changes reflected in the microstructure and interparticle relationship reflected by changes in the hydraulic characteristics of the soil, such as hydraulic conductivity and soil water retention relationship. In the model, the bulk density is assumed to be bimodal; one smaller valve for the wetted part of the soil profile, and one, larger value for the dry patch. Also, wetting front penetration into the soil columns is uneven in a cracked soil as clearly seen in Fig. 3.

4 Summary

An infiltration model was developed for swelling/shrinking/cracking soils. The model describes infiltration as a function of rainfall intensity, sorptivity, and the morphology of the crack network. Of the various assumptions made in the development of this model, three simplifications were reviewed and discussed uniformity of flow in a column surfaces, lateral flow interaction from adjacent surfaces, and bulk density differences between wet and dry soils.

References

Ahuj a, L. R. and D. Swartzendruber. 1972. An improved form of soil – water diffusivity function. Soil Sci. Soc. Am. Proc. 36:9 – 14.

Bouma, J. , L. W. Dekker, and J. H. J. Wösten. 1978. A case study on infiltration into dry clay soil. II Physical measurements. Geoderma 20: 41 – 51.

Bruce, R. R. and A. Klute. 1956. The measurement of soil moisture diffusivity. Soil Sci. Soc. Am. Proc. 20: 458 – 462.

Kirkham, D. , and C. L. Feng. 1949. Some tests of the diffusion theory and laws of capillary flow in soils. Soil Science 67: 29 – 40.

Raats, P. A. C. 2001. Developments in soil water physics since the mid 1960s. Geoderma 100: 355 – 387.

Philip, J. R. 1974. Fifty years progress in soil physics. Geogerma 12, 265 – 280.
Prasad, S. N. M. J. M. Römkens, R. R. Wells, and R. Neely. 1999. Predicting incipient ponding and infiltration into cracking soil. In: Proceedings of Nineteenth Annual Am. Geophys. Union Hydrology Days, Colorado State University, pp. 343 – 356.
Römkens, M. J. M., and S. N. Prasad. 1992. A spectral series approach to infiltration for crusted and non – crusted soils. In: Summer and Stewart (eds.) Chemical and Physical Processes: Advances in Soil Science. Lewis Publishers, pp. 151 – 170.
Römkens, M. J. M., and S. N. Prasad. 2006. Rain infiltration into swelling/shrinking/cracking soils. Agr. Water Management 86:196 – 205.
Römkens, M. J. M., J. Y Wang, and R. W. Darden. 1988. A laser micoreliefmeter. Trans. ASAE 31:408 – 413.
Wells, R. R., M. J. M. Römkens, J. – Y. Parlange, D. A. DiCarlo, T. S. Steenhuis, and S. N. Prasad. 2007. SSSAJ 7(3) (In press) A simple technique for measuring wetting front depths for selected soils.

Impact of Sedimentation on Environmental Flow and Compounding Natural Hazard in the Lower Catchment Area (Deltaic Environment) of Baitarani River Basin, Orissa

N. Rout, ***P. R Choudhury*** and ***P. K. Sahoo***

Baitarani River Basin Initiative, Orissa, India

Abstract: The catchment geomorphology, anthropogenic and land use modifications along a river basin influences sedimentation processes and leads to changes in the deltaic environments having differential implications to livelihood and ecosystem sustainability. Baitarani is a medium size river in the Eastern Coast of India having a drainage area of 14,218 km^2 with a length of 360 km. There have been 86 floods over last 100 years in this river causing much damage to lives and livelihood base in the basin. While, changes in land uses in its upper catchment are contributing higher pollutant load, reduced flow in the river is exacerbating the condition with little dilution. Increasing rate of sedimentation in the channel bed due to natural and anthropogenic changes is compounding these hazards. The drainage pattern of the basin is dendritic type and the catchment to delta ratio is 7 : 1 Its upper catchment is highly undulating terrain comprising of active and abandoned mine areas, wasteland, degraded forest and shifting cultivation patches. Dams constructed in the transition zone abstract the flow from upper forested basin for consumptive use and thus reduce the spill to the lower basin. The shallow aquifer condition, spread of water logging areas, and estuaries also reduce the flow in the lower catchment where it is almost flat. This paper highlights the associated factors that govern the sedimentation process in the basin and its impact on environmental flow at the confluence point of river mouth & frequency of flood at the lower deltaic plain and has delineated suggestive preventive and remedial measures.

Key words: sedimentation, environmental flow, flood, geohydrology, water – quality

1 Introduction

There is a need to understand the sedimentation and circulation process in a specific geohydrological unit with respect to erosion, transportation and deposition of sediments which occur due to natural process, anthropogenic activities as well as episodic events like cyclones, storm surges, floods etc. Monitoring of and understanding of sediment transport is required to understand their adverse affects like siltation of harbours, accumulation of sand bars to create navigation hazards, seasonal blockages of estuaries or degradatation of coastal environment.

Baitarani is medium size river in the Eastern Indian state of Orissa having a drainage area of 14,218 km^2. It is the third largest river of the state & is highly meandering in nature (see Fig. 1). It originates from Guptaganga hills at an elevation of 900 m aMSL (above mean sea level) at 21°31′00″ N latitude & 85°33′00″E longitudes and travels a distance of 360 km. before joining the Bay of Bengal. It joins with the second largest river of Orissa, the Brahmani, before merging into the sea together. The basin comprises of a major portion of Keonjhar, Bhadrak, Mayurbhanj and Jajpur districts and a small portion of Kendrapara, Sundargarh, Balasore and Anugul districts of Orissa state. An area of 736 km^2 lies in the state of Jharakhand. The basin lies between 850E longitude, 22°15′N latitude and 87°30′E longitude and 20°30′N latitude. The location map of Baitarani River Basin is as given below. It covers 42 blocks of 8 districts of Orissa fully or in part. The total population of the basin is more than 4 million.

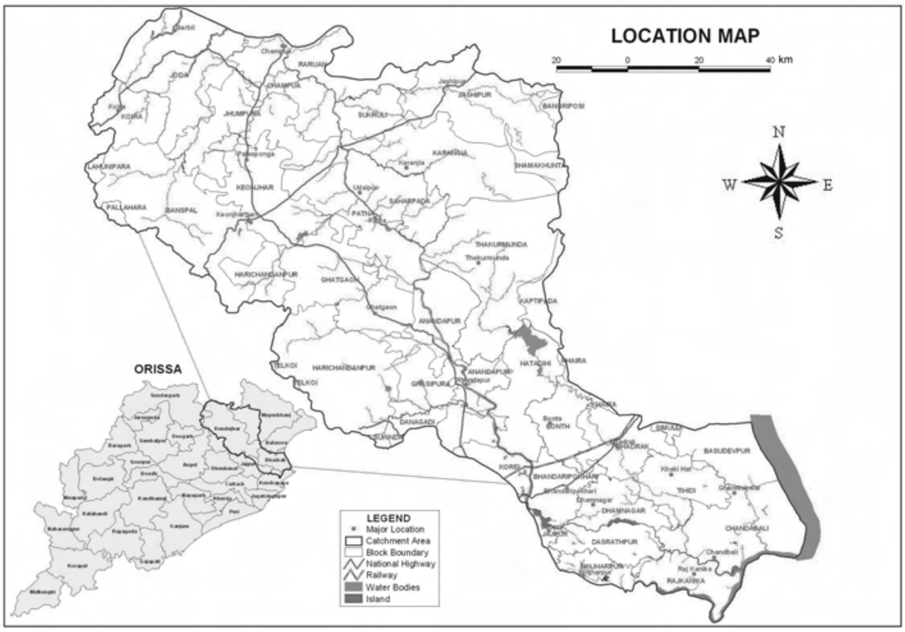


Fig. 1

2 River System

The river Baitarani has got 65 tributaries joining it from both sides. The average annual rainfall received by the basin is 1,600 mm[1]. Major soil types found inside the basin are red & yellow laterite and alluvial.

Due to difference in topography and geology, the pattern of drainage channels developed, somewhat differs in different parts of the basin. The Baitarani uplands show a trellised pattern of drainage, almost like newly formed peneplains. The streams originating from Similipal massif area in upper catchments and joining Baitarani from the left bank show a radial pattern of drainage due to specific physiography. In middle, Baitarani flows through deep incised valleys controlled by fault plains in most of its course. It is only on reaching plains, the river starts meandering. In coastal plains, lack of adequate drainage becomes a majorproblem causing water logging, formation of swamps and even lagoons. An integrated and well – planned water management system is pressing need for the development of the area.

2.1 Geology

The basin lithology may be grouped into two types of geological formations i. e. consolidated and un – consolidated formations. The consolidated formations include the hard crystalline formations belonging to Pre – Cambrian are found in the districts of Keonjhar, Mayurbhanj, Sundargarh, part of Anugul, the upper catchment districts and the rock types are mainly granite, gneisses, schistose, khondalite and Quartzite. The unconsolidated quaternary formations include Pleistocene, recent alluvium, older alluvium and laterites are found in the lower catchment districts of Baleswar, Bhadrak, Jajpur and Kendrapara. The coastal sediments reflect varied depositional

[1] INTEGRATED HYDROLOGICAL DATA BOOK (NON – CLASSIFIED RIVER BASINS)

environments fluctuating from fluviatile to estuarine and marine. The alluvium of quaternary formations comprises of a thick sequence of clay, silt, gravels, pebbles and calcareous concretions (see Fig. 2).

Fig. 2

2.2 Geomorphology

The entire Baitarani river basin may be broadly categorized into two geomorphic units as follows:

(1) Geomorphology of the Upper Catchment: Linearly disposed hill ranges, intervening valleys, pastures, uplands and peneplains occupying different heights and formed over different bedrocks characterize the upper catchment. They are divided under two sub – groups :

① Features above 500 MSL. There are numerous linear hill ranges and valleys conforming to the strike trend of many rock groups. The ridges are formed in competent rocks while the valleys are formed in the weaker rock formations.

Horse shoe syncline hill ranges and valleys② Features below 500 m above MSL. This is a very significant upland in north Orissa called Baitarani Upland. It is a low lying erosional surface in between Similipal plateau in the east and Keonjhar plateau in the west. The level difference between Baitarani upland and the neighboring highland is as much as 200 m to 450 m. This terrain shows an interlacing network of dolerite dykes, which stand out as low linear ridges running over lag distances. The general height of this upland varies between 300 ~ 400 m aMSL.

(2) Geomorphology of the Lower Catchment (Baitarani Delta): It is also called as Deltaic coastal plain. Baitarani at coastal regions covers some part of Jajpur and Anandapur, which mainly have alluvium soil. This coastal tract has been the receptacle of a vast pile of sediments ranging in age from pre – tertiary to recent. The alluvium of this region is of quaternary age, which comprises a thick sequence of clay, sand, silt, gravels, pebbles and calcareous concentrations (see Fig. 3).

The relief map is shown as follows:

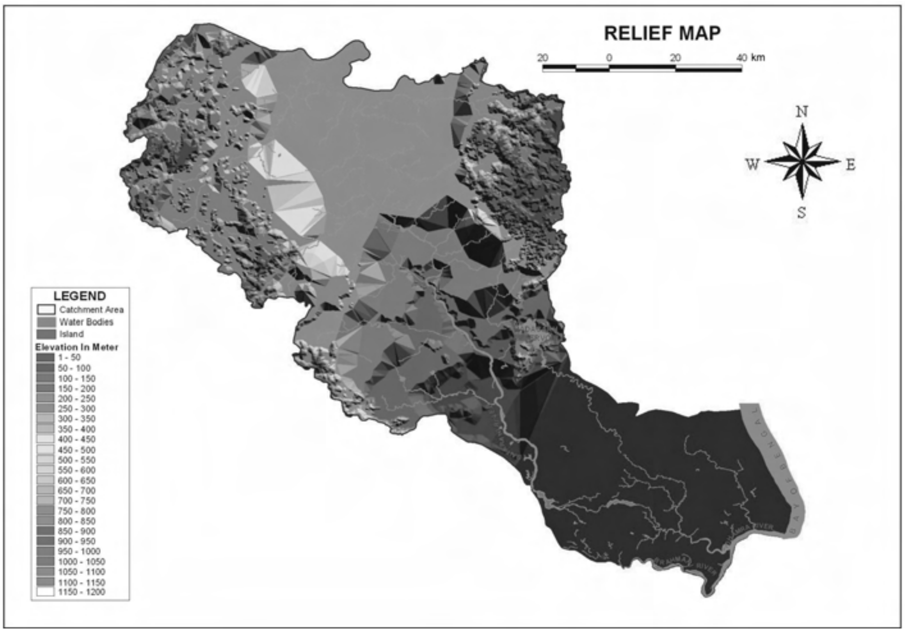


Fig. 3

3 Sedimentation process in Baitarani and its understanding

The geological characteristics of the basin seem to be responsible for the higher sedimentation process into the river basin causing of siltation of its riverbed.

The upper catchment i. e. the central plateau comprises of meta – sediment & controlled by severe fault & shear zones, which contributes more sediment into the basin. The principal rock groups of North Orissa are banded iron formation (BIF), meta – sediments, volcano sedimentary assemblages and several granite intrusive. Several faults & shear zones have been found in the rocks of Banded Iron Formation (BIF) of Joda – Noamundi area. Due to heavy mining activities and practices of shifting cultivation in the upper catchment a large quantity of sediment is added to the river during monsoon season. This lowers the carrying capacity of the river and thus even a medium rainfall can cause high flood in Baitarani.

Towards the middle catchment i. e. transition between upper and lower catchment, there exists a NE – SW trending fault running from Kamakhyanagar through Sukinda valley to Niligiri & further northeast along the eastern margin of Simlipal Plateau. It terminates all the Precambrian rocks on the west with the coastal plains & peneplains. The chromites bearing ultra basic bodies are located along this fault. All the major and medium dam structures are found in this area.

In the lower catchment, which is also called as Deltaic coastal plain of Baitarani, covers some part of Jajpur and Anandapur, which mainly have alluvium soil. This coastal tract has been the receptacle of a vast pile of sediments ranging in age from Pre – Tertiary to recent. The alluvium of this region is of Quaternary age, which comprises a thick sequence of clay, sand, silt, gravels, pebbles and calcareous concentrations. The Brahmani – Baitarani river systems joining at Dhamra river estuary in the north has formed a vast compound delta – complex in the Holocene that shows typical sub aerial and marine, tidal influenced transitional landforms comprising alluvial flood plain, natural levee, palaeochannel, abandoned channel, merging with the coastal plain in the lower reaches where aeolian and marine/tidal influenced land forms like sand dunes, beach, barrier –

island, spit, shoal, swale, beach ridge, tidal flat, tidal channels, creeks, and mangrove swamps are noticed in the deltaic coastal margin.

Depositional systems in Baitarani delta:

The monsoon – driven delta system (during southwest monsoon of mid. June to mid. October) of Orissa coast has been built under heavy monsoonal water discharge with episodic high floods carrying 99% of annual suspended sediment load and bed load transport of sands to the shore face and to the Bay of Bengal. While the fine suspended clay and silt type of sediments are deposited in the alluvial flood plain, tidal flat, tidal channel/creek and mangrove swamps building the subacrial alluvial flood plain facies and marginal delta front facies; a large part fluxes into the inner shelf to be deposited in the pro – delta environment, In the monsoon during high floods, a turbid suspended sediment plume may enter into the marine shelf and may extend to a distance of 15 km or even more. During the southwest monsoon period of August 2005, measurement of suspended matter at the delta head at the Baitarani river measured particulate concentrations of 385 mg/L. Suspended sediment in Dhamra estuary measured 650 mg/L. (Mohanty 2006) The suspended particulate load enters into the Bay of Bengal probably as a hypopycnal buoyant plume and/or friction – dominated plane jet depending upon the amount of fluvial discharge and hydrodynamic state of the inner shelf which is principally wave dominated during the monsoon and which may also be quite variable during times of high flood water discharge coinciding with severe cyclonic conditions. The sands carried as bed load are principally deposited in the shore region which acts as a depocentre for sands building up a complex of spits, bars, shoals and Barrier – islands, which may be breached during storms/ cyclones make the sands getting redistributed in the near shore region later. A strong northerly littoral drift of sands prevailing in the near shore regime together with the fluvial transport of sands again repair the barrier – island and spit – complex and these prograde in a northeasterly direction keeping harmony with the overall deltaic progradation in the coast. In the Baitarani – Brahmani river delta – complex the fluvial discharge ranged between 3,000 to 14,000 cumsec in the monsoon.

The analysis of sequential IRS – P4 OCM data (January – 2000) brought out extensive sediment plumes off the Dhamara River. These indicate sediment transport of around 100 ~ 200 km into the Bay of Bengal (Nayak, et al, 2005). A pattern matching method based on maximum cross – correlation and PAN data also show that coastal land forms of the delta are strongly influenced by the storm surge induced rapid changes apart from natural marine as well as terrestrial process. Anthropogenic activities accelerate these processes. This analysis (shore line data of 1928 ~ 1929, 1972 ~ 1973 and recent satellite data of IRS – ID LISS – III of 2001) suggests that although Mahanadi delta is prograding in general but there are critical areas affected by severe erosion and the region south of Dhmara is one such critical area. It has been observed that for a total area of 12,772 hm^2, 2,133 hm^2 area is the net erosion and 243 hm^2 area is net accretion.

4 Impact of Structural Measures in accelerating sedimentation

Construction of various irrigation structures across the river or its tributaries reduce the flow velocity as well as flow volume tremendously which enhances the sediment load in the reservoir. The embankments prohibit the spreading of sediment in a large area and thus aggravating the situation in a smaller area adjacent to the river bank.

4.1 Impact of sedimentation

4.1.1 Environmental flow and Water Quality

The Orissa coast is micro – mesotidal, and monsoonal wave – dominated to non – monsoonal mixed energy wave – tide dominated. The micro – tidal regime of the southern part of the Orissa coast changes towards the meso – tidal regime of the Baleshwar coastal area in the north where the coastline is inwardly crescent – shaped with a wide inter tidal sand flat development stretching to about 4 km offshore. Tidal currents on this mesotidal sector are strong, as larger tide ranges tend to generate stronger tidal currents, and large tide range implies a broad inter tidal zone. The river below the Salandi dam (a major tributary of Baitarani) the channel has deteriorated to a 30 ~ 40 m width and 3 ~ 4 m depth from the original bankful width and depth in the range 100 ~ 150 m and 6 ~ 10 m respectively. Salinity incursion progressively into the dry river, lowering of ground water table and its contamination from the irrigation effluent, incapability of the river to convey even moderate flood discharge and loss of fish yield due to non – availability of the critical attracting flow in July are some of the adverse environmental impacts of the dam. (Das, 2002).

Baitarani a mighty river during the monsoon, turns in the summer into more or less a stagnant pools of water held in deep gorges and depressions in the river bed. The river becomes totally incapable of washing down the pollutants, which are discharged into it from nearby towns and villages, mines and industries located in the basin. About 40% populations of 2,000 villages in 16 riparian blocks depend upon surface flow for drinking water and one fourth of them on river water directly (Census, 2001). As per the central Pollution Control Board of India the water quality of Baitarani falls under C category.

The Sukinda chromite mines lies in the N – W of Korei block of Jajpur district. The river Brahmani runs along the side of Korei, Jajpur, Binjharpur and Aul blocks of Jajpur district and Rajkanika of Kendrapara dist and meets Baitarani near Dhamra. These blocks are inside the Baitarani basin and mostly affected by Brahmani flow.

4.1.2 Flood – damage

Orissa coast on the Bay of Bengal, eastern India is prone to catastrophic and episodic natural hazard events of floods, and tropical storms/ cyclones having serious environmental impact and human concern in this thickly populated coastal tract (Mohanti, 1990, 1993). There has been 86 floods over the last 100 years in this basin. During floods the River Baitarani turns in to a large turbulent stream posing potential threat to the human lives and livestock in the basin. The maximum flood observed has been recorded as 4.36 lakh cusec in the year 1960 at Biridi G & D site. But during super cyclone on 29^{th} October 1999, the maximum flood discharge at Akhuapada was 4.98 lakh cusec.

Flood is a major problem in the middle and lower catchment of river Baitarani. Korei, Jajpur, Dasharathpur, Binjharpur, Bari block of Jajpur district; Bonth, Bhadrak, Basudevpur, Tihidi, chandabali, Dhamnagar, Bhandaripokhari blocks of Bhadrak district; and Aul, Rajakanika block of Kendrapara district and Anadapur, Ghasipura, Hatadihi blocks of Keonjhar district are generally subject to high flood during monsoon.

4.1.3 Change in river course

Almost every year in the rainy season the river is heavily charged with flood water and very often changes its course. During the flood of 1927 the river changed its course near Champua and inundated a considerable area surrounding it At a distance of about 40km from Karanjia (in Mayurbhanj district) there occurs a deep pool in the river Baitarani known as Bhimkund. Before reaching the pool at Bhimkund the Baitarani flows through a gorge in steps forming a series of picturesque rapids. At one place the river disappears underground and emerges at the pool. During flood of 1927 the top rock of tunnel was blown off and the present gorge appeared.

4.2 Present process and possible future Impact

4.2.1 Management – structural and non – structural

There is no large storage reservoir in the river to mitigate flood. At present, only flood protection embankments and saline embankment are the structural measures that can be taken up to protect the basin. The identified medium and major dam projects needs to be taken up and completed which can moderate flood to some extent in the basin. There are some escape being constructed by the line department at the upper part of the lower catchment to prevent flood in the down side of the catchment, but these escapes create severe flood hazard in the immediate areas As regards non – structural measures, flood forecasting and flood warning can prevent flood damages such as loss of human and cattle population to a great extent. As the river is highly meandering, construction of spurs can reduce stream bank erosion and thus the sediment load in the alluvial zone of the river. Proper land use practices and soil conservation measures can reduce the sediment addition from the upper catchment.

4.2.2 Increased resource exploitation

The basin is storehouse of different metallic and non – metallic mineral resources (1234 MT of Fe, Mn, Ni and Cr). There has been more mineral resource exploitation in the basin over last decade. The mine water discharge significant pollutants in the streams containing dissolved iron, manganese, trace heavy metals etc. and these are likely to be expanding with expanding mining activity. Metallurgical industries which dominate the industrial scene in the basin are significant water consumers and pollutant generator. Currently there are about 30 sponge iron industries inside the basin and it may go up in near future as number of companies are in the process of agreement. There has also been increased deforestation and an increase in sediment contributing land uses like mining, agriculture and urbanization. A perspective long – term basin land use planning seems to be the only solution, looking at the increasing bias towards such use – conversions in the name of economic development.

4.2.3 Climate change

The projected global mean sea level because of increase in atmospheric temperature is 0.09 to 88 mm over the same period, as a result of the thermal expansion of the oceans, and melting of glaciers and polar ice sheets. The physical effect of sea level rise are categorized into five types, i) inundation of low lying areas, ii) erosion of beaches and bluffs, iii) salt intrusion into aquifers and surface waters, iv) high water tables and increased flooding and v) storm damages. The average sea level rise for India has been reported as 2.5 mm per year since 1950's. The change in sea level appear to be higher on eastern coast compared to western coast. There is no plan in place to address this imminent threat. Even there are hardly any efforts towards tackling the problems of congestion at the confluence or to address the renovation of wetlands. A comprehensive and holistic planning of coastal zone management with respect to drainage management, wetland conservation and addressing of littoral drifts are required to be taken up to address these issues.

4.2.4 Integrated River Basin Management

Considering the present situations, predicaments and upcoming threats and the wide range of dimensions and factors involved, integrated and futuristic river basin management seems to the only effective approach. It is not only important for the present water resources managers and decision makers, to look the whole river system as an integrated unit blending the hydrological system with geomorphological features, land use and climate changes as well as coastal influences, but also to consider looking at a river as a living being in interaction with the human scape and landscape. Therefore, along with hydrology, other disciplines of natural resources management and the issues of governance and livelihood need adequate attention for an integrated basin management in the Baitarani context.

5 Some Suggested strategies

To reduce sedimentation/control coastal erosion the following recommendations are suggested to maximize protective measures:

(1) On coasts which experience severe storm surge, construction of sea wall/dyke protective structures offer maximum protection and should be considered subject to an appropriate engineering geological assessment.

(2) The height of rock packing/fencing structures/sea dykes must consider not only the expected height of the storm surge but also the possible coincidence with high Spring Tide

situations.

(3) Vertical/ inclined sandy shore faces should be maintained with strong rock slab thatching.

(4) Coastal plantations (such as casuarinas) should be nourished and carefully maintained as additional protection against coastal erosion.

(5) Against the background of International concern for appropriate maintenance of coastal areas, the guidelines of the Coastal Regulation Zones (CRZ) framed by the Government of India should be followed for the maintenance of the coastal area.

(6) Coastal catastrophic events should be regularly monitored and adequate research efforts should be launched for the mitigation of the impacts of natural hazards.

(7) As per the coastal zone regulatory Act, participatory flood zone mapping should be carried out & an implementable plan should be prepared.

(8) There should be dialogue between upstream & downstream stakeholders to address the issue with mutual cooperation & contribution.

(9) Community level disaster contingency plan to be prepared to encounter any such calamity.

(10) There should be an indepth study of all the resources at basin level and establishment of a basin level platform to negotiate such issues.

6 Conclusion

The geomorphological characteristics, induced landuse changes with motive of economic development and the natural and accelerated geo – hydrological changes in the deltaic and coastal environments of the Baitarini River Basin, seems to have not been given desired appreciation and attention by the decision makers and planners. Narrow focus on only irrigation enhancement and flood control through structural measures like dams and embankments respectively, has lead to bypassing of integrated understanding of whole river system as an unit linking catchment to confluence along horizontal plain through land uses to geomorphology in vertical cross – section. This approach is compounding the hazards of flood and deteriorating water quality and also poised to worsening future scenario in the wake of climatic and developmental changes occurring across basin landscapes. In order to address this situation, it is highly essential to understand, analyze and address the causes of sedimentation in the basin in an integrated spatial and temporal scale involving a multidisciplinary approach. It is also very important not to leave the dynamics of human scape in affecting changes in landscape and river scape and thus the integrated river basin approach should also lend attention to issues of livelihoods and governance in the basin.

Acknowledgement:

This study is a part of the Baitarani River Basin Initiative, which is a pioneering civil society initiative in India to enhance informed choices for enabling stakeholder voices. This initiative has been sponsored by Sir Dorabji Tata Trust, Mumbai. The authors also thank various stakeholders in government (esp Department of Water Resources, Govt of Orissa), academics and NGO who have directly or indirectly contributed to this action research initiative.

References

G. J. Chakrapani, Factors controlling variations in river sediment loads, Current Science, Vol. 88, No. 4, 25 th February, 2005, Department of Earth Sciences, Indian Institute of Technology, Roorkee 247 667, India.

G. Mathias Kondolf, Hungry Water: Effects of Dams and Gravel Mining on River Channels, Department of Landscape Architecture and Environmental Planning, University of California Berkeley, California 94720, USA.

Milliman, J. D. (Woods Hole Oceanographic Inst., MA (United States)); Syvitski, J. P. M. (Bedford Inst. of Oceanography, Dartmouth, NS (Canada)), Geomorphic/tectonic control of sediment discharge to the ocean: The importance of small mountainous rivers, 1992 Sep 01, Journal of Geology; Vol/ Issue: 100:5

M. A. Allison, S. A. Kuehl, T. C. Martin, and A. Hassan, Geology; February 1998; v. 26; no. 2; p. 175 – 178, Importance of flood – plain sedimentation for river sediment budgets and terrigenous input to the oceans; insights from the Brahmaputra – Jamuna River.

William B., David P., Department of Geosciences, Williams College, Williamstown, MA 01267, William. B. Ouimet@ williams. edu, Sediment budgets and stream Terraces: Reconstructing the effects of Historic land use on sediment Transport in the Birch Brook Catchment, Massachussetts.

Mohanti M., Storm havoc on Chandipur (North Orissa) coast, Eastern India, and the need for protection measures, Cogeoenvironment News Letter 13, July 1998.

Mohanti, M., 1993 – Coastal process and management of Mahanadi River deltaic complex, East Coast of India. Proceedings Coastal Zone' 93, American Society of Civil Engineers, New York, 15 pp.

Rajawat, A. S., Pradhan, Y., Thomaskutty, A. V., Gupta, M., Nayak, S., (Marine and Water Resources Group, Space Application Centre, ISRO, Ahmedabad – 380015, India., Coastal process along the Indian coast – Case studies basing on the synergetic use of IRS – P4 OCM and IRS – 1C1D DATA 2005.

Chakrapani, G. S., Factors controlling variations in river sediment loads, Current Science, Vol. 88, No. 4, 25th February 2005.

Mohanti, M., 1990 – Sea level rise: background, global concern and Implications for Orissa Coast. in Sea level Variation and its impact on coastal Environment (Ed. G. victor Rajamanickmam). Tamil University Publication No. 131, Thanjuvur, India, pp. 197 – 232.

Mohanti, M. – 2006, Delta Building on Orissa Coast Eastern India: Depositional and Stratigraphic Context, International Conference on DELTAS (Borneo venue): Depositional Systems and Stratigraphic Development In conjunction with two meetings: 3rd Annual Meeting of International Geoscience Programme (IGCP) – Project No. 475 Deltas in the Monsoon Asia – Pacific Region (DeltaMAP), and 2nd Annual Meeting of CCOP Project Integrated Geological Assessment for Deltas in Southeast and East Asia (DelSEA) January 13 – 18, 2006 Universiti Brunei Darussalam, Brunei.

Das, B. P., Environmental flow and River protection for Salandi, Orissa, India, www. riverfestival. com. au/ 2002/ files/symposium/BishuPrasadDas. doc.