

全国中文核心期刊  
中国科技核心期刊  
美国《工程索引》(Ei) 收录期刊

ISSN 0559-9350  
CN 11-1882/TV  
CODEN SLHPBI

# 水利学报

SHUILI XUEBAO  
JOURNAL OF HYDRAULIC ENGINEERING

Vol.49 No.5 2018



2018  
第 49 卷 **5**

# JOURNAL OF HYDRAULIC ENGINEERING

Vol. 49 No. 5, 2018

(Monthly)

## CONTENTS

- Models of the return period calculation for seasonal flood .....  
..... SONG Songbai CHENG Liang WANG Zongzhi (523)
- Investigation of density current plunging II: Experiments and theoretical analysis .....  
..... FAN Jiahua QI Wei DAI Qing (535)
- Experimental analysis of the formation process of lacustrine shallow-water delta .....  
..... BAI Yuchuan HU Xiao XU Haijue ZOU Dasheng BAI Yang (549)
- Viscoelasticity characteristics of mortars in static and dynamic rheological test .....  
..... HE Zhen JIANG Rui LI Yang (561)
- Quantitative study on hydrology relationship between the Yangtze River and Poyang Lake and its  
changes ..... HU Zhenpeng FU Jing (570)
- Experimental research on crack calculation of hydraulic RC beams with high-strength rebars .....  
..... ZHU Eryu LI Dongdong QI Ming ZHU Li (580)
- Research on anti-freezing pattern of shallow buried pipe by replacement filling of pipe trench in sea-  
sonal frozen area ..... BAI Jing XIE Chongbao WU Zhiqin (588)
- Study on the flow patterns and rectification measures of box culvert of urban storm water pumping  
station with oblique pipe culvert .....  
ZHANG Rui XU Hui CHEN Yuling FENG Jiangang ZHOU Chuntian WANG Xiaosheng (598)
- Quantitative evaluation of riparian ecological restoration in Liao River based on remote sensing .....  
..... YANG Gao LI Ying FU Bolin WU Jisheng XING Zefeng (608)
- Wetland evolution and restoration from historical perspective: A case study of Yongnian Lake .....  
..... FU Hao XU Chaowei WANG Lingyue YANG Xiaoliu (619)
- Multi-objective optimal operation of key reservoirs in Ganjiang River oriented to power generation,  
water supply and ecology ..... CHEN Yueyun MEI Yadong CAI Hao XU Xinfa (628)
- Research on water depth inversion in reservoir area based on multi band remote sensing data .....  
..... ZHANG Lei MOU Xianyou JI Honglan ZHANG Baosen (639)

# 水 利 学 报

SHUILI XUEBAO

第 49 卷 2018 年 第 5 期(月刊)

## 目 次

- 分期设计洪水重现期计算模型研究 ..... 宋松柏 程 亮 王宗志 (523)
- 异重流潜入现象探讨 II: 浑水水槽实验与分析 ..... 范家骅 祁 伟 戴 清 (535)
- 入湖浅水三角洲形成过程实验模拟分析 ..... 白玉川 胡 晓 徐海珏 邹大胜 白 洋 (549)
- 砂浆静-动态流变的黏弹塑性特征 ..... 何 真 蒋 睿 李 杨 (561)
- 长江与鄱阳湖水文关系及其演变的定量分析 ..... 胡振鹏 傅 静 (570)
- 水工混凝土构件配置高强钢筋后裂缝计算研究 ..... 朱尔玉 李冬冬 齐 明 朱 力 (580)
- 季节性冻土区管道浅埋换填防冻模式研究 ..... 白 静 谢崇宝 吴志琴 (588)
- 斜向管涵进流城市雨水泵站箱涵流态分析及整流措施研究 .....  
..... 张 睿 徐 辉 陈毓陵 冯建刚 周春天 王晓升 (598)
- 基于遥感的河岸带生态修复效应定量评估—以辽河干流为例 .....  
..... 杨 高 李 颖 付波霖 吴计生 幸泽峰 (608)
- 历史视角下的湿地演变与恢复保护——以永年洼为例 .....  
..... 傅 豪 徐超伟 王凌越 杨小柳 (619)
- 面向发电、供水、生态要求的赣江流域水库群优化调度研究 .....  
..... 陈悦云 梅亚东 蔡 昊 许新发 (628)
- 基于多波段遥感数据的库区水深反演研究 ..... 张 磊 牟献友 冀鸿兰 张宝森 (639)

## EDITORIAL BOARD

### HONORARY PRESIDENTS

SUO Lisheng HU Siyi LIU Ning

### CONSULTANTS

LU Youmei ZHU Erming GAO Anze ZHANG Zezhen CHEN Bingxin GAO Jizhang

### PRESIDENT

KUANG Shangfu

### VICE PRESIDENTS

WU Hongwei TANG Xinhua JIA Jinsheng YANG Xiaodong

### MEMBERS

CAI Ximing CAI Yuebo Chandra Madramootoo (Canada) CHEN Jin CHEN Houqun CHEN Qiuwen  
CHEN Minjian CHEN Shengshui CHEN Zuyu CHENG Guoyin CHENG Xiaotao DENG Jiaquan  
Desmond Walling(UK) DU Leigong FANG Hongwei FENG Ping FENG Shaoyuan FNEG Shurong GAN Hong  
GAO Zhanyi GU Hong GUO Jun GUO Qizhong(U.S.A) GUO Shenglian HAN Qiwei HE Jianbing HU Chunhong  
HUAI Wenxin HUANG Jiesheng HUANG Qiang HU Zuoliang Hyo-Seop Woo (Korea) JIA Jinsheng James  
Yang (Sweden) JIANG Naiqian JIE Yuxin JIN Juliang KANG Shaozhong KONG Xianjing KUANG Shangfu  
LI Jiren LI Jia LI Jiusheng LI Wanhong LI Yun LI Yuanyuan LI Zantang LIAN Jijian Xu Liang(U.S.A)  
LIU Handong LIU Xiaoyan LIU Yulong LIU Zhiping LU Jinyou LU Wenxi MA Hongqi MA Jianhua  
NI Jinren NIU Xinqiang Norihisa Matsumoto(Japan) PENG Caide QIN Boqiang Roger Falconer(UK) SHEN Zhenzhong  
SHU Longcang TIAN Bin WANG Fujun WANG Guangqian WANG Hao WANG Lizhong WANG Renkun  
WANG Wensheng WANG Xiaohong WANG Yicheng WANG Xiaogang WEI Qiwei WU Hongwei WU Pute  
WU Zhongru XIA Jun XU Zeping XU Zongxue XU Weilin YANG Dawen YANG Kailin YANG Xiaodong  
YAO Shuanxi YAO Wenyi YU Qiyang ZHANG Chaoran ZHANG Chunsheng ZHANG Guoxin ZHANG Limin  
ZHANG Jian ZHANG Jianmin ZHANG Jianyun ZHANG Yongbo ZHANG Zongliang ZHENG Peiming  
ZHONG Denghua ZHONG Pingan ZHONG Zhiyu ZHOU Xiaoguang ZHU Bofang ZHU Xingming ZUO Qiting

### CHIEF EDITOR

CHENG Xiaotao

### DEPUTY CHIEF EDITORS

GAN Hong XU Zeping

## 《水利学报》第九届编辑委员会组成名单

名誉主任：索丽生 胡四一 刘 宁

顾 问：陆佑楣 朱尔明 高安泽 张泽祯 陈炳新 高季章

主 任：匡尚富

副 主 任：吴宏伟 汤鑫华 贾金生 杨晓东

主 编：程晓陶

副 主 编：甘 泓 徐泽平

编 委：（以汉语拼音为序）

蔡喜明(美国) 蔡跃波 Chandra Madramootoo(加拿大) 陈 进  
陈厚群 陈求稳 陈敏建 陈生水 陈祖煜 程国银 程晓陶 邓家泉  
Desmond Walling(英国) 杜雷功 方红卫 冯 平 冯绍元 冯树荣  
甘 泓 高占义 顾 洪 郭 军 郭祺忠(美国) 郭生练 韩其为  
何建兵 胡春宏 槐文信 黄介生 黄 强 户作亮 禹孝燮(韩国)  
贾金生 姜乃迁 介玉新 金菊良 康绍忠 孔宪京 匡尚富 李纪人  
李 嘉 李久生 李万红 李 云 李原园 李赞堂 练继建  
梁 旭(美国) 刘汉东 刘晓燕 刘玉龙 刘之平 卢金友 卢文喜  
马洪琪 马建华 倪晋仁 钮新强 松本德久(日本) 彭才德 秦伯强  
Roger Falconer(英国) 沈振中 束龙仓 田 斌 王福军 王光谦  
王 浩 王立忠 王仁坤 王文圣 王小红 王义成 汪小刚 危起伟  
吴宏伟 吴普特 吴中如 夏 军 徐泽平 徐宗学 许唯临 杨大文  
杨开林 杨晓东 杨效亮(瑞典) 姚栓喜 姚文艺 于琪洋 张超然  
张春生 张国新 张利民 张 健 张建民 张建云 张永波 张宗亮  
郑沛溟 钟登华 钟平安 仲志余 周晓光 朱伯芳 朱星明 左其亭

## Models of the return period calculation for seasonal flood

SONG Songbai<sup>1</sup>, CHENG Liang<sup>2</sup>, WANG Zongzhi<sup>2</sup>

(1. *College of Water Resources and Architecture Engineering, Northwest A & F University, Yangling 712100, China;*

2. *Hydrology and Water Resources Department, Nanjing Hydraulic Research Institute, Nanjing 210029, China*)

**Abstract:** Annual maximum flood and seasonal maximum flood sequences are two different type samples. Their return periods and design values are very important to operate flood control safely, improve benefit and utilize flood resources of reservoirs. According to the definition of the return period, using mathematical statistics, return period formulas of independent and identically distributed variable and multivariable hydrologic events were derived. Then, the return period calculation models of annual maximum flood and maximum flood of seasonal flood were presented. Employed the Monte Carlo test, the return periods are consistent with the empirical return periods. These results indicate that the return period models derived in this paper are correct. Finally, taking the 7 days maximum flood volume of Nansi Lake during 1963–2008 as an example, the formulas of parameters estimation of seasonal maximum flood and probability distribution of annual maximum flood were given, illustrating the calculation problem of the design seasonal maximum flood. The models and calculation methods in this paper are expected to provide theoretical support for the design seasonal flood calculation in China.

**Keywords:** seasonal flood; return period; total probability; mixed distribution; maximum value distribution

## Investigation of density current plunging II : Experiments and theoretical analysis

FAN Jiahua, QI Wei, DAI Qing

(China Institute of Water Resources & Hydropower Research, Beijing 100048, China)

**Abstract:** This is the second part of the paper which presents the flume test and theoretical analysis results: (1) In the upstream and downstream reaches of the plunge point, the velocity and sediment concentration profiles in the longitudinal direction, and the density current interface curves downstream of the plunge point were measured in the flume tests. Also a data analysis of the criterion  $F_p$  at the plunge point was made. (2) Theoretical analysis of the plunging flow in a reservoir backwater region, and in a navigation guiding channel were investigated, by applying the energy and momentum equations. There are four equations of  $F_p$  at the plunge point as related with  $h_d/h_p$ , which are derived and verified by flume test data. (3) The four equations of  $F_p=f(h_d/h_p)$  were also compared with the theoretical analysis results of  $F_p$ , derived by different researchers.

**Keywords:** density current; density current plunging; flume experiment; theoretical analysis

## Experimental analysis of the formation process of lacustrine shallow-water delta

BAI Yuchuan<sup>1</sup>, HU Xiao<sup>1</sup>, XU Haijue<sup>1</sup>, ZOU Dasheng<sup>2</sup>, BAI Yang<sup>3</sup>

(1. *State Key Laboratory of Hydraulic Engineering Simulation and Safety, Tianjin University, Tianjin 300072, China;*

2. *Jiangxi Provincial Water Conservancy Planning and Designing Institute, Nanchang 330029, China;*

3. *School of Port Coastal and offshore engineering, Hohai University, Nanjing 210098, China*)

**Abstract:** Based on the natural model method, a set of experiments were conducted to study the formation and development process of shallow water delta. The evolution process of the channel was analyzed according to the change of channel patterns and flow field. By changing the upstream sediment concentration and the downstream water level, the influence of different boundary factors on the channel lateral movement and the channel patterns was studied. The results show that: (1) the channel changes among straight, distributed and no channel patterns, and downstream deposition leads to the raise of topography, anti-water pressure and upstream deposition phenomenon, which promote the channel to move laterally with a certain period; (2) the flow pattern and velocity of the surface flow of the delta vary with the channel patterns and the evolution stages, and (3) more upstream sediment concentration and lower downstream water level result in shorter evolution cycles of the channel and larger movement angle, which leads the movement point moves to the upstream. Moreover, the shapes of the channel change from bird-foot to radial shape. In this evolution process, the upstream sediment concentration plays the dominant role comparing to the water level, which cannot affect the river channel patterns fundamentally.

**Keywords:** lacustrine shallow-water delta; natural model method; channel patterns; flow field; periodic evolution

## Viscoelasticity characteristics of mortars in static and dynamic rheological test

HE Zhen, JIANG Rui, LI Yang

(*State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan 430072, China*)

**Abstract:** Based on the theory of static and dynamic rheology, the viscoelasticity of high performance mortar is studied using a coaxial cylinder rheometer. With a low water-to-binder ratio, the slump flow of mortars is about the same by adjusting the dosage of superplasticizer. The static rheological test results of fresh mortars indicate that the addition of fly ash microsphere (FAM) or limestone powder (LP) can reduce the yield stress, plastic viscosity and thixotropy, as well as their growth rate over time. The dynamic rheological test results reflect the higher intensities of partial physical crosslinking network and the reduction of energy consumption in changing of flocculent structure flowability in mortars when FAM or LP has been added. It has been proved that the static apparent viscosity and dynamic complex viscosity, the area of static hysteresis loop and the area surrounded by dynamic loss modulus – speed curves both show a strong consistency along with hydration time. Measuring static and dynamic rheological behavior simultaneously can comprehensively describe the viscoelasticity of mortars.

**Keywords:** static rheology; dynamic rheology; high performance mortars; limestone powder; fly ash microsphere; viscoelasticity

## Quantitative study on hydrology relationship between the Yangtze River and Poyang Lake and its changes

HU Zhenpeng<sup>1</sup>, FU Jing<sup>2</sup>

(1. *Nanchang University, Nanchang 330029, China;*

2. *Jiangxi Water Resources Institute, Nanchang 330013, China*)

**Abstract:** The storage in the Poyang Lake is affected by runoff from the watershed itself and the Yangtze River flow. The hydrological relationship between the Yangtze River and Poyang Lake is obtained by statistical analysis of hydrological monitoring data from Hankou and Xingzi stations, representing Yangtze and Poyang respectively. (1) When the flow of Hankou is less than  $15,000\text{m}^3/\text{s}$ , the impact of the Yangtze River on the outflow of the Poyang Lake is not obvious, and the outflow from the lake is mainly free to go out with larger range of stage in the lake. (2) When the flow of Hankou exceeds  $18,000\text{m}^3/\text{s}$ , the retarding role of the Yangtze is becoming significant to the outflow from Poyang, storing 31.9% ~ 81.4% of inflow in the lake. (3) When the water level at Xingzi is between 10.5 – 16.5 m and the flow of Hankou is more than  $20,000\text{ m}^3/\text{s}$ , the floodwater may flow from the Yangtze into the Poyang Lake. However, such phenomena may not occur when the water level at Xingzi is lower than 8m. Some changes have taken place in the relations between Poyang and Yangtze since 2000, which are mainly shown in weakening the retarding effect of the Yangtze River on the outflow of Poyang Lake, bringing forward and prolonging the dry season of the lake and magnifying the daily fluctuation amplitude of water level in the lake. Quantitative study of these relationships is of great importance to utilize water resources and to protect water environment and aquatic ecology in the Poyang Lake.

**Keywords:** hydrology relationship; variety; quantitative; statistical analysis; Yangtze River; Poyang Lake

## Experimental research on crack calculation of hydraulic RC beams with high-strength rebars

ZHU Eryu<sup>1</sup>, LI Dongdong<sup>1</sup>, QI Ming<sup>2</sup>, ZHU Li<sup>3</sup>

(1. School of Civil Engineering, Beijing Jiaotong University, Beijing 100044, China;

2. China Railway Engineering Consulting Group Co. Ltd, Beijing 100055, China;

3. Subway Operation Technology R & D Center of Beijing Subway, Beijing 102208, China)

**Abstract:** In order to study the crack calculation of hydraulic RC beam with high-strength rebars and guide the revise about calculation formulas of crack given by Design Code for Hydraulic Concrete Structures (DCHCS), 32 RC beams were tested under flexural loading to analyze the development and property of crack. With almost 167 beams' crack data collected from the author's tests and other researchers' tests, the calculation for crack width was discussed by analyzing the development of calculation method about crack width given by DCHCS. The results show that the development of the crack width is similar to the RC beams with low-strength rebars. But the test values about maximum crack width are greater than the calculated values. Based on the experimental data, the calculation formulas for average crack spacing and maximum crack width are given, which can work well with the results of all tests. The calculation formulas about crack width not only can be used for the RC beams with high-strength rebars, but also can be applied to the specification revision for DCHCS.

**Keywords:** the hydraulic RC beam; high-strength rebar; the revise of DCHCS; average crack spacing; maximum crack width

## Research on anti-freezing pattern of shallow buried pipe by replacement filling of pipe trench in seasonal frozen area

BAI Jing<sup>1</sup>, XIE Chongbao<sup>1</sup>, WU Zhiqin<sup>2</sup>

(1. *China Irrigation and Drainage Development Center, Beijing 100054, China;*

2. *Heilongjiang Provincial Hydraulic Research Institute, Harbin 150080, China*)

**Abstract:** Pipeline is an important part of water-saving engineering in well irrigation area. The laying mode of pipelines will directly affect investment and construction progress of water-saving engineering, and have significant influence on its efficiency and service life directly. A series of shallow buried pipeline experiments was conducted in a low temperature laboratory in the paper, temperature in pipelines and pipe deformations were obtained dynamically in a cycle of freezing and thawing condition. The influences of different pipeline buried depth, heat preservation measures, replacement filling on pipe working condition were analyzed through comparative study. As for temperatures in pipe, deep replacement mode and heat preservation facilities had little effect on the temperatures within pipelines, while buried depth and backfilling measures temperature had significant influence on the internal temperatures of pipelines. The internal temperatures were increased when pipelines are buried deeper. The heat preservation function of EPS lightweight soil was better than that of perlite powder mixed soil. In terms of pipeline deformation, the performance of deep replacement via slag was superior to that of similar measurement by sand. Pipe deformation decreased obviously after increasing pipeline buried depth. Compared with working condition of complex processing, replacement measures of pipe trench by slag could be achieved similar anti-freezing effect. In view of machinery needs and the operability of anti-freezing measures, the paper recommended 80 cm pipe buried depth and slag replacement in pipes where the frozen depth is less than 2.3m.

**Keywords:** seasonal frozen area; PE pipe; shallow buried mode; replacement filling

# Study on the flow patterns and rectification measures of box culvert of urban storm water pumping station with oblique pipe culvert

ZHANG Rui, XU Hui, CHEN Yuling, FENG Jiangang, ZHOU Chuntian, WANG Xiaosheng

(*College of Water Conservancy and Hydropower Engineering, Hohai University, Nanjing 210098, China*)

**Abstract:** In order to study the influence of the oblique inflow on the hydraulic characteristics of the urban storm water pumping station and explore the effective rectification measures to improve the adverse flow pattern, the flow patterns and rectification measures of box culvert of urban storm water pumping station with oblique pipe culvert were studied based on computational fluid dynamics method. Three different rectification measures were designed and set in the gate shaft to improve the adverse flow pattern and water distribution uniformity, and the best scheme was verified by the physical model test. The research results showed that the flow maldistribution and some adverse flow patterns in each of box culvert channel, e. g. transverse flow, backflow, vortex flow, were caused by the inflow from oblique pipe culvert. The adverse flow patterns would deteriorate the inflow condition in the pumping station forebay and affect the security performance of the pumping station. The rectification measures, including splitting-flow pier, composite beam and back-to-back guide pier, could significantly and efficiently improve the flow patterns and flow distribution uniformity. Not only the box culvert flux distribution unbalance factor drop to between positive and negative 0.03, but the total flow distribution uniformity was increased to 0.905. The research achievement of this paper could offer some valuable references to the similar type of urban storm water pumping station.

**Keywords:** urban storm water pumping station; box culvert; flow pattern; flow distribution; rectification measures; numerical simulation

## Quantitative evaluation of riparian ecological restoration in Liao River based on remote sensing

YANG Gao<sup>1, 2</sup>, LI Ying<sup>1</sup>, FU Bolin<sup>3</sup>, WU Jisheng<sup>4</sup>, XING Zefeng<sup>1, 2</sup>

(1. Northeast Institute of Geography and Agroecology, Chinese Academy of Science, Changchun 130102, China;

2. University of Chinese Academy of Science, Beijing 100049, China;

3. College of Geomatics and Geoinformation, Guilin University of Technology, Guilin 541006, China;

4. Song-Liao Basin Aquatic Environmental Science Research Institute, Changchun 130021, China)

**Abstract:** Physical Structural Integrality (*PSI*) is a fundamental feature of riparian ecosystem. Riparian ecological restoration effect is able to be evaluated by quantitatively analyzing *PSI*'s variation. This study is addressed to evaluate riparian ecological restoration of Liao River conservation area using *PSI* value in 2010 and 2016. *PSI* value is calculated through evaluation indicators, e.g., vegetation percent cover, water level width and human disturbance derived from remote sensing (RS) data and validated by field measurements. The variation and clusters of *PSI* values were calculated by Hot and Cold Spots Analysis (Getis-Ord General *G*<sub>i</sub> Statistics) to discriminate stable and weak area of riparian zones. The results indicated that there was no significant difference between evaluation results based RS and field measurements. The average value of *PSI* increased from 63.47 to 72.07 after the riparian ecological restoration, and the length of riparian zone under the sub-healthy condition decreased 189.5 km which accounted for over 97.1% of 2010. The riparian zone achieved significant restoration effect accounted for over 27.5% of the entire riparian zone of Liao River, then the structural stability was obviously improved. The riparian *PSI* value in 2016 existed five statistically significant hot and cold spots, on which local spatial autocorrelation was strong. The cold spots with low-low clusters of *PSI* values were in the vulnerable riparian zone, which was consistent to the riparian zone with poor ecological restoration effect. The research results can provide reference for plain rivers in northern China to evaluate riparian ecological restoration effect and indicate restoration position in the future, which are of particularly important application value for the ecological restoration projects lacking field measurements.

**Keywords:** riparian ecological restoration; physical structural integrality; RS and GIS; Hot Spot Analysis; spatial cluster distribution

## Wetland evolution and restoration from historical perspective: A case study of Yongnian Lake

FU Hao, XU Chaowei, WANG Lingyue, YANG Xiaoliu

(*Peking University, Beijing 100871, China*)

**Abstract:** Wetlands protection and restoration is a hot study in recent years. Studying the evolution of a wetland and its surroundings with a historical perspective is a great help to understand the wetland and make it more effective to protect the wetland. Yongnian Lake in Hebei Province is a typical wetland, which has been involved in heavily human activities for more than five hundred years but still keep natural features. It is used as a case in this study to examine its evolution in historical perspective and prove the effectiveness of this method. We find that: I. Guangfu City has a longer history than Yongnian Lake, and Yongnian Lake has always been strongly affected by high-intensity human activities; II. Water surface of Yongnian Lake decreased greatly after 1949, and it is mainly because of the hydraulic engineering and reclamations; Yongnian Lake still has the potential to become a better wetland; III. Flood control is the main function of Yongnian Lake, while ecological functions is less important; the restoration of Yongnian Lake should be based on the opportunity to build the wetland park, and ensure its water supply both on quantity and quality.

**Keywords:** wetland restoration; high-intensity human activities; Yongnian Lake; historical evolution

## Multi-objective optimal operation of key reservoirs in Ganjiang River oriented to power generation, water supply and ecology

CHEN Yueyun<sup>1</sup>, MEI Yadong<sup>1</sup>, CAI Hao<sup>1</sup>, XU Xinfu<sup>2</sup>

(1. Wuhan University, State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan 430072, China;

2. Jiangxi Provincial Institute of Water Sciences, Nanchang 330029, China)

**Abstract:** Taking key reservoirs in the Ganjiang River basin as the research object, seven main water use regions were generalized in the basin to develop a multi-objective optimal operation model oriented to the demands of power generation, water supply and ecology. The operation model was designed to maximize power generation of the reservoir group, minimize total water deficit of the water region while minimizing flow alteration of Waizhou Station, taking account of different objectives of reservoirs, the water demand of main regions and the requirements of the ecological instream flow. The multi-objective particle swarm optimization method was adopted in solving this model to obtain the non-dominated solution set of the three objectives under different inflow frequencies, and the competition relationships among them were investigated. Then the corresponding water level process and water shortage situation of typical schemes were analyzed. The results indicate that the degrees of competition relationships among the three objectives are different. The competition between power generation and ecology, and that between water supply and ecology are fiercer, and the one between water generation and water supply is weaker.

**Keywords:** power generation; water supply; ecology; non-dominated solution set; multi-objective particle swarm optimization

## Research on water depth inversion in reservoir area based on multi band remote sensing data

ZHANG Lei<sup>1</sup>, MOU Xianyou<sup>1</sup>, JI Honglan<sup>1</sup>, ZHANG Baosen<sup>2</sup>

(1. College of Water Conservancy and Civil Engineering, Inner Mongolia Agricultural University, Hohhot 010018, China;

2. Yellow River Institute of Hydraulic Research, Yellow River Conservancy Commission, Zhengzhou 450003, China)

**Abstract:** Remote sensing inversion is a new method for measuring water depth, which has a positive effect on dam operation and sedimentation study in the reservoir area. In light of the defect in statistical correlation analysis that the water depth of a remote sensing pixel represented by a single bathymetric value, this paper presents a method which takes multi point data in one pixel standing for the depth of the pixel. Taking the Haibowan reservoir in Inner Mongolia as the pilot area, the inversion factor for water depth was selected to represent the correlation between water depth and the combination of each band, and fifteen groups of dual band and five groups of multi-band inversion models were set up with different number of inversion factors in three forms of linear, quadratic and exponential equations. The better five were chosen from them, and their accuracy was tested by the sample of detection points which were not involved in the modeling, and these models were compared by the test. The results show that the optimal water depth inversion model of Haibowan reservoir is a multichannel inversion model with 12 inversion factors, and the mean absolute error of which is 0.68 m, taking 13.59 % of the average water depth. Combined the characteristics of remote sensing in short cycle and lower cost, the model can be used in a certain extent, but the inversion error of water depth might be larger in the water areas with sediment concentration and near the land.

**Keywords:** remote sensing; multi-band inversion model; water depth inversion