2020

ANNUAL REPORT

IWHR

China Institute of
Water Resources and
Hydropower Research
中国水利水电科学研究院

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MESSAGE FROM THE PRESIDENT

Annual Report
2020

CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH

KUANG Shangfu, Ph.D.
President of IWHR

The COVID-19 pandemic has changed the whole world in many aspects and on many levels, and its influence is still going on in a way that might be unexpected by anyone. With the unremitting efforts of the whole world, many countries in the world have embarked on the way of recovery, and some of them have even achieved positive growth in GDP. Restoring the normal socio-economic life while keeping a close eye on the virus through strict and cautious prevention and control measures has become another “new normal” of people’s life. Thanks to the more precise diagnosis and tracing technology as well as more targeted quarantine policy, Chinese people are able to carry out normal production activities with limited interruptions, and IWHR also managed to achieve another fruitful year in this tough period.

Due to the serious pandemic situation, large scale face-to-face meetings could not be carried out as usual. However, international exchanges and communications have not been impeded thanks to the modern information and communication technologies. Video conferences, webinars and online lectures have now become the new preferred way of international communication in addition to the traditional emails and telephones. A total of 20 online meetings and events were organized by IWHR in cooperation with its international partners throughout the year, including the 17th IWHR-KICT Joint Seminar, the 29th Sino-Japan Technical Communication on Dam and River Environment Management, and the series of seminars and workshops on the occasion of the 85th anniversary of IAHR. Topics of the meetings cover global water security, climate change adaptation, flood management and drought relief, clean energy for carbon neutrality, and sustainable water infrastructures, etc., with accumulatively over 100,000 participants joined the events online and offline. During the year, we maintained an active engagement in the activities of WWC and AWC and advanced the preparation of the 4th World Irrigation Forum to be held in 2023 as the sponsor. We also deepened our collaboration and friendship with our overseas partners through the exchanges of warm greetings and the donation of medical supplies to those in need.

Despite the impact of the pandemic, IWHR maintained a continued growth in its R&D achievements and contract volume in 2020. Newly-signed contracts of the year totaled CNY 1.802 billion, up by 5.1% over the previous year. Throughout the year, IWHR accomplished 686 papers, 66 monographs, 421 patents, 28 standards and 46 ministerial/provincial awards.

IWHR’s research capacity has been more widely recognized by the international community. It ranked third in the 2020 Top Water Security Think Tanks, and was enlisted as the top 30 national scientific and technological innovation research institutes. Two of its research disciplines, engineering and environment/ecology, have entered into ESI Global Disciplines Ranking Top 1%, bringing IWHR into the crew of world-class research institutes.

IWHR continued to provide strong sci-tech support for the green development the country by drafting “China’s River Happiness Index Report”, conducting strategy research on soil and water conservation and watershed management and engaging in the preparation of “Fourteenth Five-Year Plan” on water science and technology for government departments and local authorities. It also actively contributed to China’s poverty reduction program by providing pairing assistance to impoverished areas in central and western China for their poverty alleviation effort in water sector with the provision of professionals and technologies.

Facing the unprecedented and overlapped global challenges, people has felt more than forever the importance of sustainable development to be pursuit through the joint effort of the whole humanity. With the progress of the social development, people are more eager to live in a world of harmony between human and water and to conquer the relevant problems with a nature-based solution. The theoretic exploration and technical research in these areas become increasingly necessary in order to achieve these common goals. IWHR would like to contribute its wisdom and talent to the whole world and to walk side by side with our global partners on this journey towards a beautiful shared future of mankind!

HISTORY

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CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH

1933
China First Hydraulic Laboratory

1935
Central Hydraulic Laboratory

1935
Tianjin Hydraulic Laboratory

1950
Nanjing Water Conservancy Division

1952
Experimental Group of Hydroelectric Power Construction General Bureau, Ministry of Fuel Industry

1956
Hydraulic Research Division, Chinese Academy of Sciences

1956
Beijing Institute of Water Resources, Ministry of Water Conservancy

1956
Hydropower Research Institute, Ministry of Electric Power Industry

1957
Institute of Water Conservancy and Hydroelectric Power Research

1958
Institute of Water Conservancy and Hydroelectric Power Research

1994
China Institute of Water Resources and Hydropower Research

2020
IWHR on the way

IWHR in Maps

China Institute of Water Resources and Hydropower Research (IWHR) is a national research institution under the Ministry of Water Resources of China, and is engaged in almost all the disciplines related to water resources and hydropower research.

With over 60 years of development, IWHR has grown into an indispensable think tank of the Chinese government for decision making and a backbone technical consultant in water related areas. It is at the same time the host of multiple international organisations or their Chinese branches, including WASER, WASWAC, IAHR, ICFM, ICOLD, ICID, GWP, IHA and ARRN.

With 13 research departments and four affiliated enterprises, IWHR is endowed with research capacity in: hydrology and water resources, water environment and ecology, flood control, drought relief and disaster reduction, soil and water conservation, river and lake management, water resources in rural and pastoral areas, hydraulics, geotechnical engineering, hydraulic structures and materials, earthquake engineering, hydro machinery and electric equipment, automation, engineering monitoring and examination, renewable power resources, water history and informatisation and remote sensing technology.

Department of Water Resources for Pastoral Areas (**Hohhot**, Inner Mongolia)

Tianjin Institute of Hydroelectric and Power Research (**Tianjin**)

The map of Beijing here is modified from Beijing Tourist Map (2016) by © Beijing Municipal Commission of Tourism Development

IWHR Headquarter (South)

IWHR Headquarter (North)

Daxing Experimental Base

Yanqing Experimental Base

Scan to find IWHR Headquarter (South) in **Google Maps**

Scan to find IWHR Headquarter (South) in **Baidu Maps**

CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH

中国水科院

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CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH

Vision and Strategy

The entrance of Beijing Wild Duck Lake Wetland

Vision

Vision

Striving to be the pioneer for creation and innovation of water related frontier science and technology

Mission

Supporting China's water resources and hydropower development to improve people's livelihood

Pioneering the world's development in water related science and technology

Spirit

Innovation | Practicality | Devotion | Dedication

Strategy

1 Goal

- To become one of the best in 2035 and to lead in 2050 the club of world-class research institutes of water resources and hydropower

2 Priorities

- Strategic, overarching, forward-looking and fundamental problems of water sciences
- Key technological problems incurred in huge hydro projects

3 Capacities

- Innovativeness in science and technology
- Competitiveness in market
- Competency in international arena

4 Bases

- Scientific and technological innovation
- Research, development and industrialization
- Training of top professionals
- International cooperation and academic exchange

5 Developments

- Human resources
- Relevant disciplines
- Research infrastructure and facilities
- Institutional settings
- Organizational culture

6 Excellences

- Research team
- Disciplines
- Facilities
- Management
- Technical achievements
- Socio-economic benefits

Annual Report 2020

CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH

The Hamaba tourist site in Inner Mongolia, China

Mission Achievement

IWHR Innovation

Key Technologies for Flash Flood Forecasting and Early Warning in China

Main Participants: DING Liuqian, SUN Dongya, LIU Changjun, HE Bingshun, LIU Ronghua, LI Changzhi, LI Qing, ZHAI Xiaoyan, TIAN Jiyang, MA Qiang, LIU Qi, ZHANG Xiaolei

Keywords: Flash flood disaster, forecasting and early warning, spatiotemporal variable source mixed runoff model, multi-stage progressive forecasting and early warning, meteorological warning of flash flood disaster

Scientific Issues and Technological Framework

Against the background of global warming and climate changes, with the increasing frequency of local extreme rainfall event and the growing socio-economic activities in mountainous regions, flash flood disasters prevention gradually become the short board in the overall flood control and disaster mitigation. As the death toll of flash flood accounts for about 70% of the total of flood related disasters, the monitoring, forecasting and early warning of this disaster have attracted growing attention from the international community. Since 2010, China has begun to implement the national flash flood disaster prevention and control project, carried out the national flash flood disaster investigation and evaluation, built a densely distributed rainfall monitoring network and established a flash flood monitoring and warning platform at national, provincial, municipal and county levels.

The key to early warning of flash floods is the analysis of rainstorm and flood in mountainous small watersheds lacking in data. However, the existing hydrological models are barely able to accurately reflect the nonlinear characteristics of hydrological processes in small watersheds under the condition of short duration rainstorm, and their calculation accuracy is quite low. With regard to this situation, China Institute of Water Resources and Hydropower Research (IWHR) has made active exploration and developed a distributed rainstorm flash flood simulation model applicable to different types of small watersheds, which has been applied to national flash flood warning platform and multiple regional ones, boosting the advance of hydrological models and the development of early warning technology for small watersheds in China.

Basic Data: National Small Watersheds and River Network

Based on the 1:50,000 DEM, DLG data and water conservancy project data provided by National Geomatics Center of China (NGCC), and combined with high-resolution image data, this project has for the first time divided the country into 535,858 small watershed units, with an average watershed area of 16km^2, involving 37,169 small rivers, 162,946 channels and 3.68 million rills over 0.5km^2.

An extended nationwide full-scale river network coding system has been formed based on the existing *Code for China River* (SL 249-2012). Taking small watersheds, water systems and nodes as the backbone, and based on the natural surface catchment relationship, this project has automatically established the topological relationship between the upper and lower reaches, which reflects the connectivity and orientation of river systems, and the national fine river network database for flash flood defense has therefore been constructed. On this basis, the basic attributes, three-dimensional terrain factors and underlying surface parameters of small watersheds have been analyzed and extracted based on the high-resolution DEM data, land use and soil texture data, providing important basic data for the analysis of rainstorm flash flood in small watershed.

Model Algorithm: Simulation of Spatiotemporal Variable Sources Mixed Runoff Model

Having proposed a model of spatiotemporal variable sources mixed runoff model based on the nonlinear one-dimensional infiltration theory of vadose zone soil, which realizes the simulation of mixed runoff under infiltration excess and saturation excess mechanisms at multiple layers horizontally and vertically, and a regional scheme of model parameters based on machine learning CART tree algorithm has been designed which could accurately match the model parameters with underlying surface factors which is applicable to humid, semi-humid and semi-arid areas.

Simulation Framework: CNFF Suite, China Flash flood Hydrological Simulation System

IWHR independently developed the professional software CNFF Suite for rainstorm flash flood in small and medium-sized watersheds of different types in hilly areas of China. The core of CNFF Suite is a new generation of nonlinear hydrological model framework for small watersheds with physical mechanism based on high-precision topographic and geomorphic big data. Adopting a layered architecture and modular design concept, this software integrates the spatiotemporal variable sources mixed runoff model, time-varying unit line model, variable parameter flood evolution model, flood storage and discharge calculation model of small and medium-sized reservoirs without data and spatiotemporal double discrete parallel computing algorithm, basically solving the problems of nonlinear runoff generation and confluence simulation and efficient calculation under the conditions of heavy rainfall with short duration in small watersheds. The model has been tested by nearly 12,000 floods in 361 basins, and the simulation accuracy has been improved by nearly 20%, with the calculation efficiency being increased by more than 100 times.

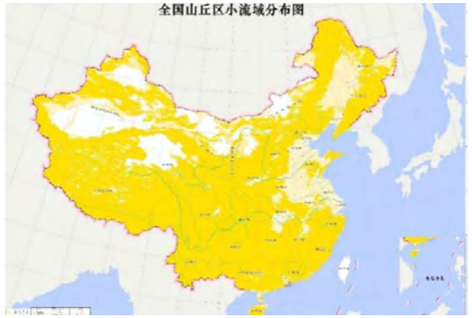
Application System

(1) Flash flood forecasting and warning platform

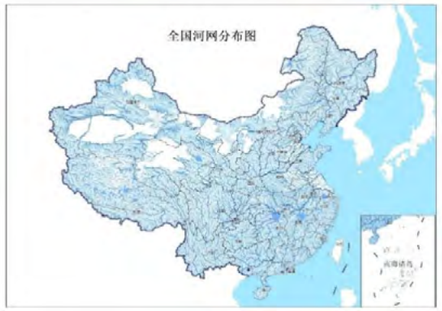
By integrating the framework of China's flash flood hydrological model and using the meteorological-hydrological coupling analysis technology, a multi-stage progressive forecasting and early warning system integrating meteorological early warning, near-term dynamic early warning and real-time rainstorm flood forecasting and early warning has been constructed, which supports short-term, near-term and real-time cascade early warning response. Based on the full-factor topological big data of flash flood disaster prevention, the early warning is directly located in the reach and dangerous areas, and the linked early warning between upstream and downstream in small and medium-sized basins is realized which improves the accuracy of early warning. The platform has been widely used in Fujian, Jilin, Henan provinces and many other places.

(2) Meteorological warning of flash flood disasters

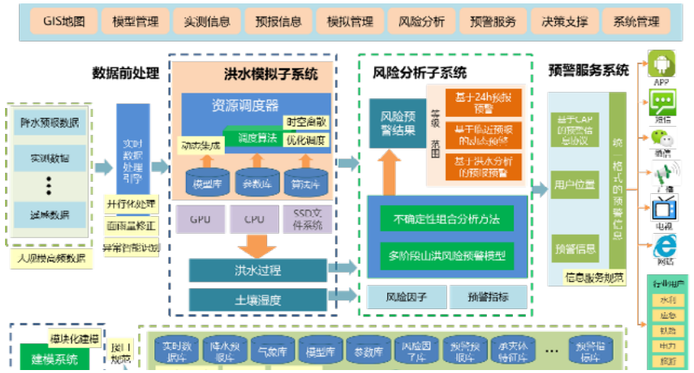
In order to enhance the public awareness of flash flood disaster prevention and minimize casualties, on 15 July 2015, the Ministry of Water Resources and China Meteorological Administration signed a memorandum on joint release of meteorological early warning of flash flood disasters to jointly carry out the relevant work. During the five flood seasons from 2015 to 2020, a total of 582 of early warning messages were released, of which 135 messages were broadcasted by CCTV, which effectively enhanced the public awareness of flash flood defense, played a significant role in disaster prevention and mitigation, and were recognized by the heads the Ministry of Water Resources on multiple occasions.



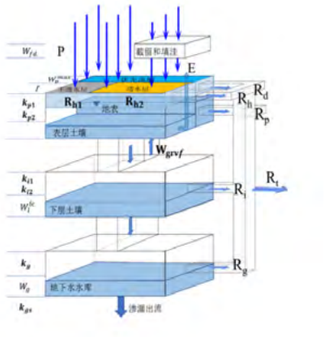
Division of 535,858 Small Watersheds in China



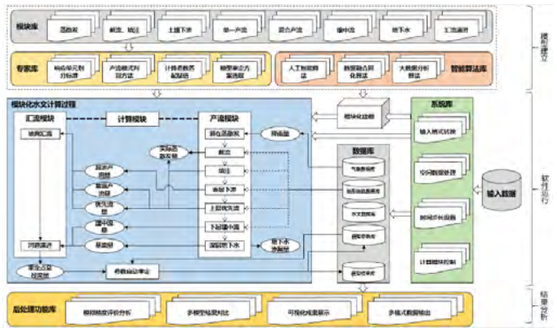
National Fine River Network



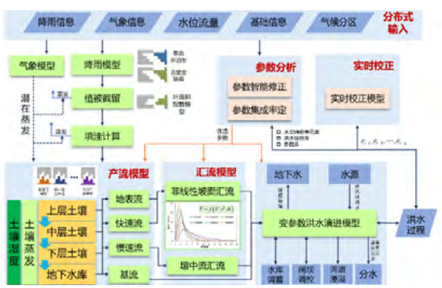
Flash Flood Forecasting and Warning Platform Framework



Vertical Structure of the Spatiotemporal Variable Sources Mixed Runoff Model

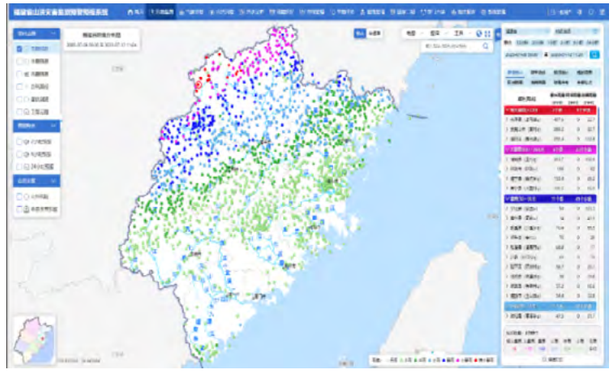


Object-oriented Modular Hydrological Modeling System Structure



CNFF Model Architecture

China Flash Flood Hydrological Simulation System



Provincial Flash Flood Monitoring, Forecasting and Warning Platform

Meteorological Warning of Flash Flood Disaster

Representative Researches

Limit Analysis Method System of High Slope Stability Based on Upper Bound and Lower Bound Theorems of Plastic Mechanics

Main Participants: WANG Xiaogang, WANG Yujie, LIN Xingchao, SUN Ping, LING Yongyu, ZHAO Yufei, DUAN Qingwei, LIU Lipeng, ZHANG Qiang, JIANG Long

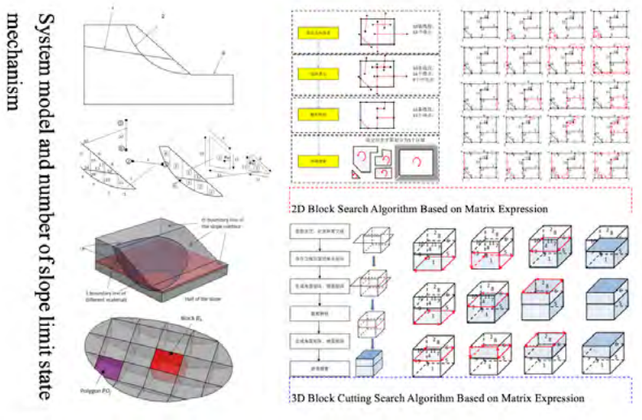
Background

The slope stability analysis method is one of the classical research problems in geotechnical mechanics. The traditional limit equilibrium method for slope stability analysis, that is statically indeterminate in force equilibrium, becomes statically determinate by introducing a number of assumptions. The introduction of these assumptions not only undermines the theoretical rigor of the method, but also challenges the applicability of such assumptions in practical engineering.

The key idea of the method system is without assumptions made and not to determine the factor of safety by solving force and torque equilibrium equations as traditional way. According to the upper and lower bound theorems of plastic mechanics, the traditional slope stability analysis, without any assumptions introduced, is converted to a mathematical optimization problem searching for the maximum and minimum safety factors. As the upper-bound and lower-bound factors of safety gradually approach the real solution, a complete and unified slope stability limit analysis method system is formed.

Achievements

- Having proposed a general method of generating a slope failure mechanism in limit state. Based on the limit analysis theory of plastic mechanics, the unified mathematical optimization model of the upper and lower bound solutions for two and three-dimensional slope stability analysis is established without introducing any assumptions. It not only provides a more rigorous theoretical basis for the slope stability analysis method, but also makes a breakthrough by extending two-dimensional analysis to three-dimensional one.

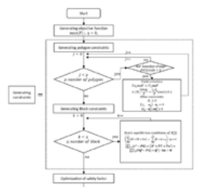


General Construction Method of Slope Failure Mechanism in Limit State

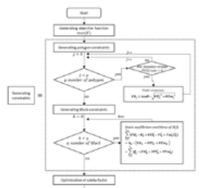
- Having put forward for the first time the reduced-dimension mathematical expression of medium and highly nonlinear constraint equations in the optimization model. To facilitate the convergence of the optimization model with large degree of freedom and improve the optimization efficiency and accuracy, an iterative solution method of logical judgment was proposed for complex optimization mode, making this method applicable to three-dimensional slope stability analysis.
- Having established for the first time a two-dimensional and three-dimensional slope stability limit analysis method system by integrating the upper and lower bound methods, which approaches the real solution for the factor of safety through the upper and lower bounds and can accurately determine the calculation error, marking a new breakthrough in the field of slope stability analysis. The relevant software system with independent intellectual property right has been developed and widely used in practical engineering.

Application

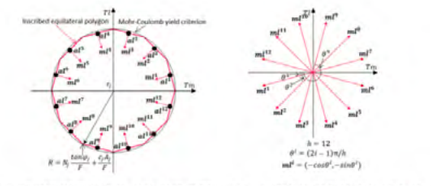
- The team has developed the software system for the slope stability limit analysis with independent intellectual property rights, which has been widely applied in more than 100 agencies and utilities in water resources, hydropower, transportation, railway, construction and other sectors, bearing favorable economic and social benefits. One monograph and 34 journal papers including 24 SCI/EI papers have been published; and five invention patents including one international invention patent and four software copyrights have been obtained.



Optimization Calculation Model for Lower Bound Solution for Safety Factor of Slope Stability

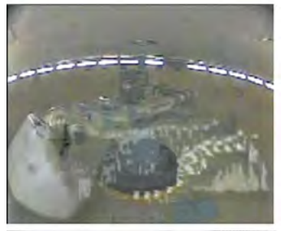


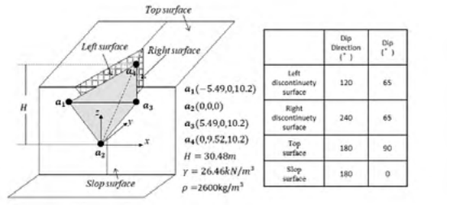
Optimization Calculation Model for Upper Bound Solution for Safety Factor of Slope Stability



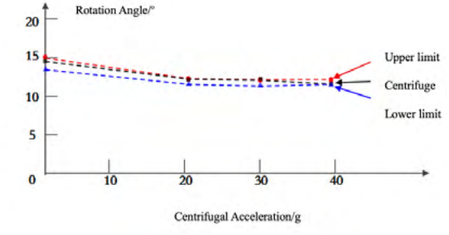
(a) Yield Criterion and Inscribed Polygon *(b) Interior Normal Vector of Inscribed Polygon*

Reduced-dimension Mathematical Expression of Yield Criterion





	Dip Direction (°)	Dip (°)
Left discontinuety surface	120	65
Right discontinuety surface	240	65
Top surface	180	90
Slop surface	180	0



Test Verification through Centrifugal Simulation Experiment of Wedge

Key Technologies for Water Cycle and Ecological Security in Semi-arid Regions

Main Participants: CHEN Minjian, ZHAO Yong, YAN Long, ZHANG Sheng, LI Tongsheng, DONG Kebao, WANG Yong, ZHOU Fei, DENG Wei, LIU Yanhong, JIN Xiaohui, MA Jing, LI Hongzhi, YANG Guiyu, HU Yajie

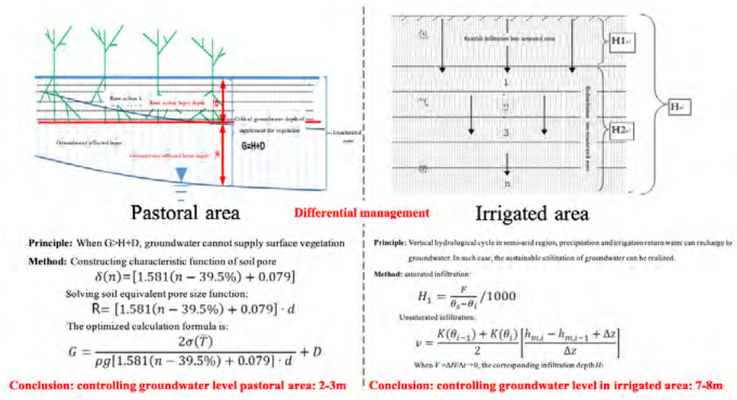
Background

This project aims to carry out theoretical and applied basic research on the major water resources and ecological problems caused by the development of water and land resources in the agro-pastoral ecotone of semi-arid regions. Under the condition of large-scale agriculture irrigation and groundwater extraction, grassland ecological space continues to shrink and groundwater level continues to decline in semi-grid regions, which poses a major threat to the survival and development of agricultural and pastoral areas.

In response to the above series of problems, with the support of the nonprofit research projects of the Ministry of Water Resources, this project has carried out a long-term rolling tracking study on semi-arid regions with annual rainfall of 200-400mm, water surface evaporation greater than 1,000mm and drought index between 3 and 7. It is a forward-looking and basic theoretical technology of hydrology, water resources and ecological security specifically targeted at semi-arid regions with remarkable creativeness.

Achievements

- Having discovered the influence mechanism of irrigation on groundwater formation in semi-arid regions, quantitatively revealed the disappearance of irrigation return flow and the change process of precipitation recharging groundwater caused by micro-drip irrigation, analyzed the influence of the combination of these two approaches for water table balanced groundwater exploitation and replenishment, and studied the impacts of micro-drip irrigation on the vertical hydrological cycle in semi-arid regions.
- Having formed an evaluation and analysis method for ecological pattern of agro-pastoral ecotone in semi-arid regions based on grassland natural attributes, established an evaluation method for regional ecological structure of agro-pastoral ecotone, and proposed the reasonable proportion of ecological landscape structure of grassland agro-pastoral ecotone in semi-arid region.

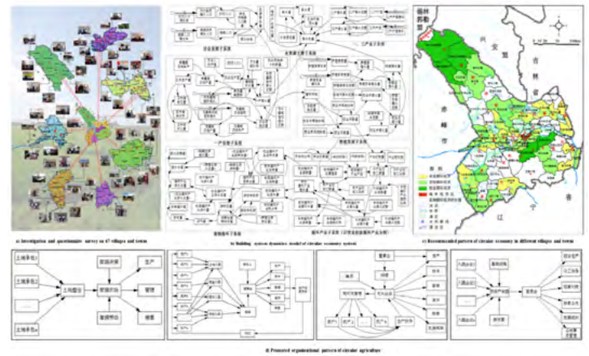


Controlling Groundwater Level Calculation Principles in Irrigated and Pastoral Areas

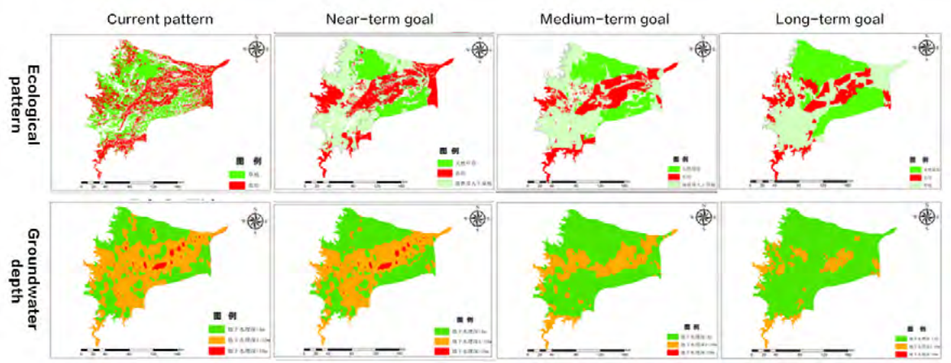
- Having put forward the differentiated management of groundwater control levels in the agro-pastoral ecotone in semi-arid region, proposed the so called “red line” based on the comprehensive study on the threshold groundwater table (including the threshold groundwater table of precipitation recharging groundwater and groundwater supplying vegetation) with physical mechanism and experimental evidence in semi-arid regions; established the model of groundwater dynamics and developed the principle and control criteria of groundwater well layout.
- Having proposed the development pattern of circular economy in semi-arid regions based on ecological security, created the ecological security analysis tool for the industrial chain of circular economy in the economic and social development parttern of semi-arid regions and established an innovative technical method with fundamentality and practicability.

Application

The research results have been applied and rolled out in Eastern Inner Mongolia in a timely manner bearing significant results, which have played a huge role in the ecological protection of grassland and rational utilization of groundwater. The project results have been rapidly promoted and applied in other areas in Inner Mongolia and Songliao River Basin. These achievements have technically supported the Ministry of Water Resources to strengthen the management of water resources in the West Liaohe River Basin of Inner Mongolia; and served as reference for the comprehensive treatment of groundwater overexploitation in typical areas of North China Plain. The achievements have also been extended to other provinces, such as Shaanxi Province, where differentiated regional management of groundwater is implemented.



Analysis of Circular Economy Development Pattern in Agro-pastoral Ecotone in Semi-arid Region



Suggestions for Ecological Pattern Adjustment in the West Liaohe Plain

National Standard for Seismic Design of Hydraulic Structures

Main Participants: CHEN Houqun, LI Deyu, HU Xiao, LIU Xiaosheng, WANG Haibo, ZHAO Jianming, ZHANG Yanhong, ZHANG Boyan, WANG Zhongning, TU Jin, LI Min, ZHANG Cuiran, OUYANG Jinhui, MA Huaifa

Background

After the Wenchuan earthquake, in order to meet the state's requirement that the dam does not break under the maximum credible earthquake and ensure national public safety, this standard is developed on the basis of lessons learned from Wenchuan earthquake and seismic research achievements of hydraulic structures.

Contents

- Using the ultimate limit state design method expressed by the partial factor to calculate the seismic structural factor γd for various hydraulic structures;
- Revising the parameters of standard design response spectrum on bedrock for ordinary engineering;
- Adding the requirement that the site's maximum credible earthquake should be determined according to the deterministic method or the probability method with an exceeding probability of 1% within 100 years of the reference period for the hydraulic structures with the engineering seismic protection category A, and that the special demonstration on its safety margin under maximum credible earthquake shall be carried out on disaster prevention of the uncontrolled release of reservoir;
- Specifying the dynamic analysis considerations of concrete gravity dam and arch dam with seismic protection category A;
- Stipulating that the dynamic analysis and safety evaluation using finite element method should be conducted for dam body and its foundation of embankment dam;
- Revising the characteristic values of dynamic strength and elastic modulus of dam concrete;
- Adding the seismic design rules for aqueducts, ship lifts and slopes.

Achievements

- Having developed the seismic prevention framework with two levels for important dam in which only repairable dam damage occurs under the design seismic action, and no uncontrolled release of reservoir water occurs under the maximum credible earthquake.

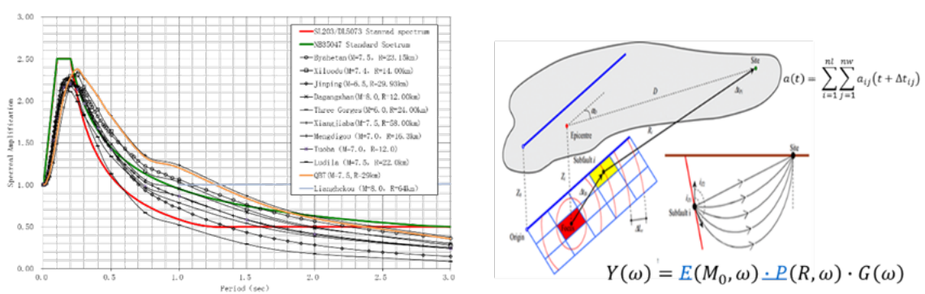


Fig. 1 Design Response Spectrum Determined by Scenario Earthquake Method and Maximum Credible Earthquake Determined by Stochastic Finite Faults Method

- Having proposed the method of determining the site-specific design response spectrum by scenario earthquake method for hydraulic structures with seismic protection category A and the method of determining the maximum credible earthquake by considering the surface source rupture process under the condition of large near-fault earthquake. (Fig. 1)
- Having put forward a constitutive model for dam concrete dynamic damage based on concrete test data and independently developed a parallel computing program for seismic damage and failure analysis of concrete dam -foundation system based on domain decomposition algorithm and high performance computing platform. (Fig. 2)
- Having revealed the failure mechanism and corresponding seismic safety limit state of the dam under the maximum credible earthquake and built the quantitative evaluation index system of no uncontrolled release of reservoir water under the maximum credible earthquake. (Fig. 3)

Application

These achievements have been applied to the seismic safety review of China's high dams over 150m, including the Three Gorges Hydropower Station, Xiluodu Hydropower Station, Wudongde Hydropower Station, Baihetan Hydropower Station, Xulong Hydropower Station, Benzilan Hydropower Station, Yebatan Hydropower Station, Lianghekou Hydropower Station, Shuangjiangkou Hydropower Station, Jinping I Hydropower Station, Dagangshan Hydropower Station, Mengdigou Hydropower Station, Ludila Hydropower Station, Longyangxia Hydropower Station, as well as the seismic design of high dams under construction in China.

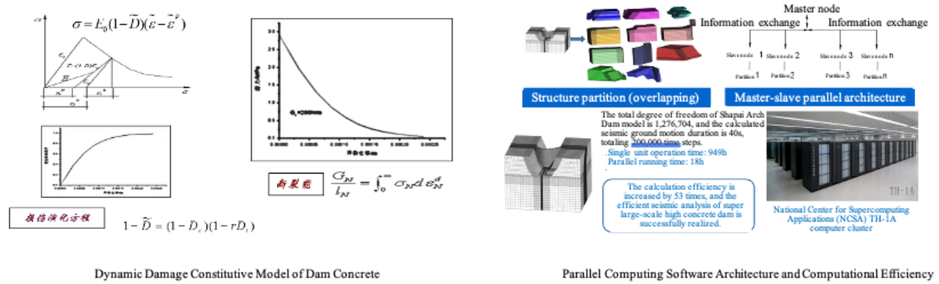


Fig. 2 Dynamic Damage Constitutive Model of Dam Concrete and High-performance Parallel Computing Software

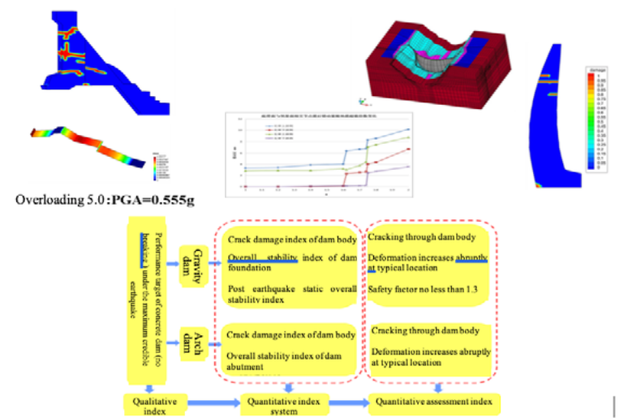


Fig. 3 Failure Mechanism of Dam under Strong Earthquake and Quantitative Index System of No Uncontrolled Release of Reservoir Water

Migration Mechanism of Key Zone in Water Cycle of Haihe River Basin and Attribution of Its Water Resources Attenuation

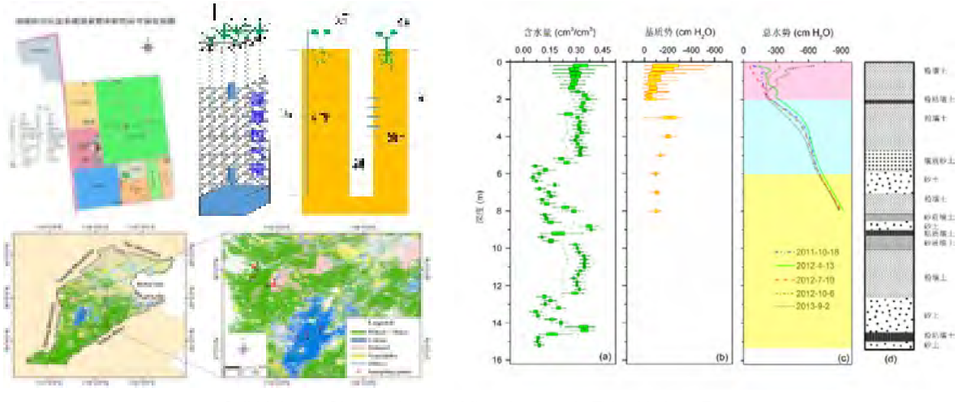
Main Participants: ZHAO Yong, ZHAI Jiaqi, WANG Qingming, REN Changjiang, GONG Jiaguo, HE Guohua, LIU Rong, MA Mengyang, HAN Jingyan, DIAO Weijie, YANG Miao, LI Enchong, GUI Yunpeng, WANG Yong, CHANG Huanyu

Background

In the past 60 years, the water resources in Haihe River Basin have declined sharply, which has caused serious water supply crisis and ecological and environmental problems. Where has the water gone? What is the reason for these changes? How will it evolve in the future? These problems are world-class scientific challenges and edge cutting research topics, bearing a profound impact on the water security and major project planning of the river basin. With the long-term support of the National Natural Science Foundation of China and major public welfare projects, the evolution mechanism of water cycle and the attributions of water resources attenuation in Haihe River Basin have been presented in a systematic approach, providing key support for water resources evaluation and the treatment of groundwater overexploitation in this river basin.

Achievements

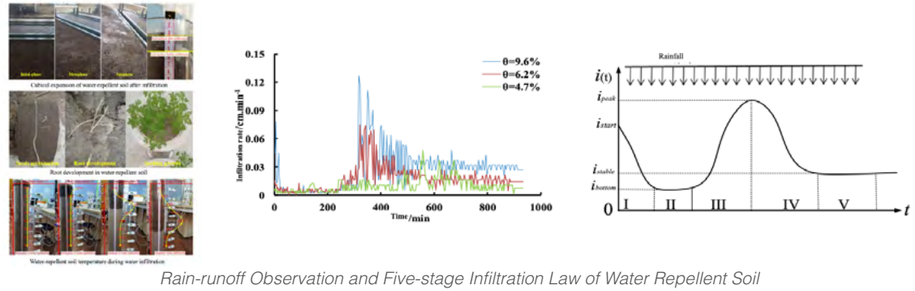
- Focusing on the key problem of soil moisture migration mechanism in thick vadose zone and based on in-situ observation and systematic simulation, this research has discovered the characteristics of zero water flux, proposed the three-layer variation laws of evaporation infiltration alternate change, unstable infiltration and relative stable infiltration in thick vadose zone, found the hysteresis and regulation effect of thick vadose zone, put forward the quantitative relationship between mean pore velocity and wetting front velocity, constructed the recharge coefficient of precipitation infiltration under different conditions in Haihe River Plain, identified the real reduction volume of groundwater abstraction with different irrigation efficiencies, and proposed the variation laws of groundwater attenuation in Haihe River Plain.
- Focusing on the new phenomenon that soil water repellency is enhanced in Haihe River Basin because of organic matter increase in the soil as a result of vegetation restoration, and based on extensive investigation, systematic experiment and artificial precipitation simulation, this research has revealed the soil water repellency characteristics and infiltration mechanism, discovered the five-stage precipitation infiltration characteristics of water repellent soil, obtained the reasons for the cumulative infiltration mutations and the change of single peak curve of infiltration rate and established a unified precipitation infiltration model for hydrophilic and water repellent soil to solve the problem of discontinuous inflection point of infiltration rate of hydrophobic soil and realize the mutual conversion with traditional infiltration models such as Horton.
- Focusing on the new problem that land subsidence significantly changes groundwater circulation parameters and water storage capacity, this research has put forward for the first time the nonlinear compressed water release numerical simulation method based on the time-series satellite interferometric radar (InSAR) evaluation, breaking through the barrier that GRACE satellite cannot separate the unrecoverable part of the deep groundwater reserves change, realizing the systematic evaluation of the influence of land subsidence on hydrogeological parameters, and reveal the law of irreversible inelastic water release coefficient and permanent loss of water storage capacity caused by large-scale land subsidence.
- Having analyzed item by item the formation and evolution mechanism of water resources such as precipitation, evaporation, vegetation restoration, water body, groundwater table and farmland tillage, simulated and evaluated the dominant factors and their respective quantitative contributions to water resources attenuation in Haihe River Basin in the past 60 years, independently developed the distributed water cycle simulation model adapted to the influence of strong human activities that realizes the systematic simulation of the dynamic transformation relationship of 12 representative human activities and 60 water cycle elements, predicts the amount of water resources in the basin under different changing conditions such as future climate, underlying surface, vegetation and groundwater table, and predicts the evolution trend of water resources in the future.



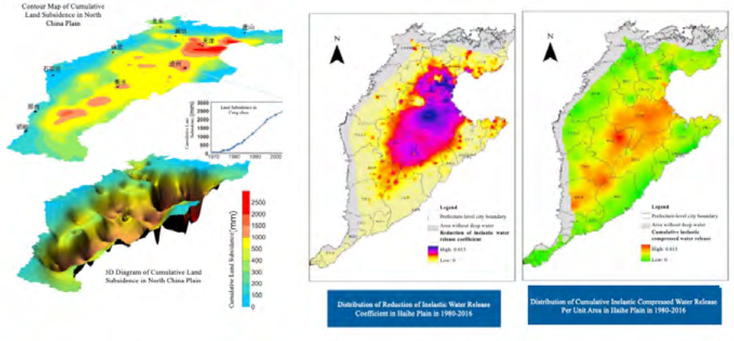
Soil Moisture Observation and Migration Law in Thick Vadose Zone

Application

After 12 years of research, 105 papers including 52 SCI and 14 EI papers and two monographs have been published; 35 patents and 16 software copyrights have been obtained; three pieces of important advices have been approved by the leaders of the Party and the State, systematically supporting the practice of water resources evaluation and the reverse of groundwater overexploitation in Haihe River Basin.



Rain-runoff Observation and Five-stage Infiltration Law of Water Repellent Soil



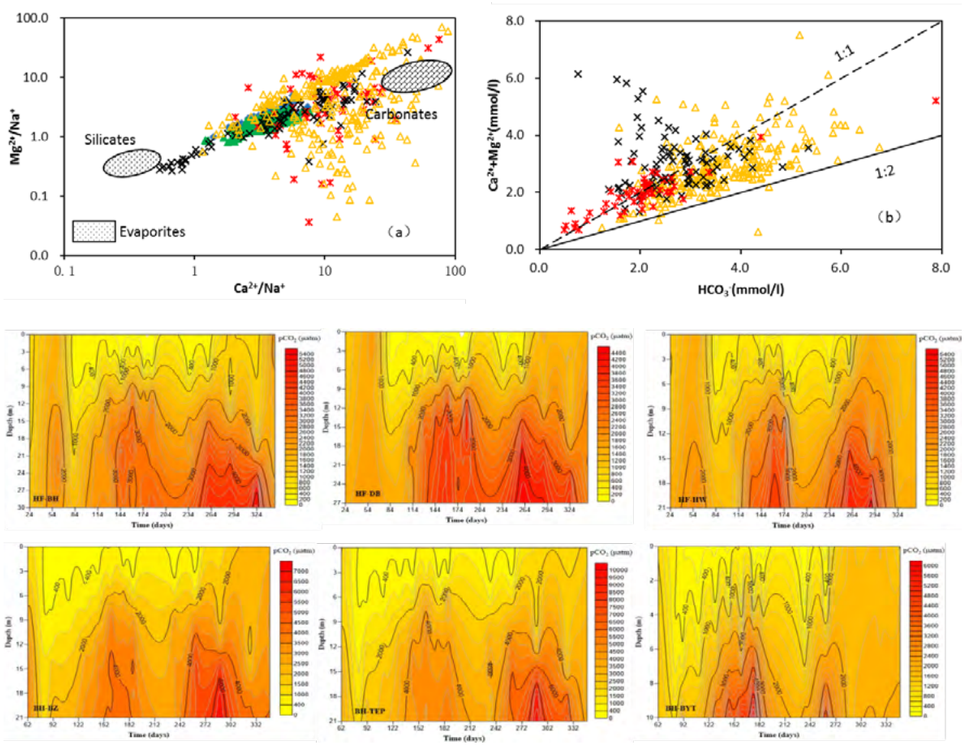
Water Release Coefficient and Reserves Change of Deep Groundwater in Haihe River Plain

Research on Carbon Cycle Mechanism and Water Environmental Impacts of the Three Georges Reservoir

Main Participants: WANG Yuchun, XIAO Shangbin, HU Mingming, LI Shanze, NIU Fengxia, LEI Dan, WAN Xiaohong, BAO Yufei, WEN Jie, CHEN Min

Background

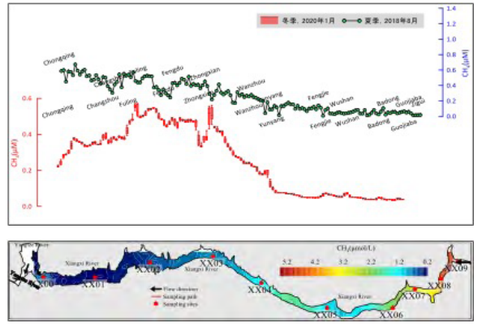
Reservoir interception has altered the natural runoff and material cycle process of rivers. The reservoir carbon flux and its biogeochemical cycle process are complex, which are the frontiers of the current inland hydrology and ecological environment research. The reservoir carbon flux is also a major issue related to the green energy attribute of hydropower and sustainable development. The weak theoretical research and the lack of awareness of relevant mechanisms seriously restrict the scientific evaluation of greenhouse gas emission reduction benefits of large hydropower projects. The reservoir carbon flux of the Three Gorges Project is directly related to the national strategy of China's energy security and sustainable development of hydropower, and it is an important work for the protection of the Yangtze River and the development of the Yangtze River Economic Belt.



Hydrochemical Analysis and pCO_2 Distribution Characteristics at Different Depths

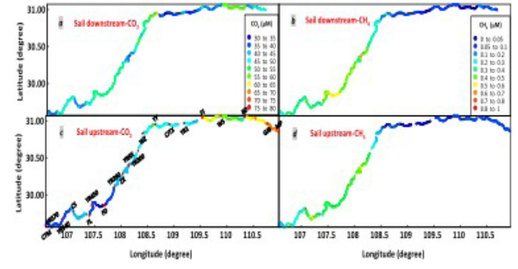
Achievements

- The project has carried out long-term observation of fixed station and key process research, and made important theoretical innovation in carbon flux and biogeochemical cycle mechanism of deep reservoirs.
- (1) Observation in fixed location of carbon flux and its environmental impact factors in important water areas in the Three Gorges Reservoir. Having developed the technology and equipment for the dynamic and continuous observation of air-water interface carbon flux with independent intellectual property, which has broken through the technical bottleneck of the current academic circles; carried out for the first time the continuous and high-resolution underway online observation of greenhouse gas in the main stream and tributaries of the Three Gorges Reservoir, systematically improving the observation efficiency and accuracy of greenhouse gas dissolved in different depths of the Reservoir, obtaining the long-term observation data and filling the carbon flux data gap of reservoirs in subtropical regions; and mastered the hydrochemical change characteristics and the thermodynamic equilibrium relationship of carbon transformation in the water environment, reaching a further understanding of the thermodynamic equilibrium relationship of water environment of the Three Gorges Reservoir in its process of swampiness.
- (2) Theoretical study on key processes of carbon biogeochemical cycle in the Three Gorges Reservoir. With the combined use of multidisciplinary modern technologies, including isotope tracing, molecular biology and environmental microbiology, this project has studied the mechanism of key interfaces and important processes of the Three Gorges Reservoir, understood the occurrence state and driving process of greenhouse gas in water body from the three-dimensional point-line-surface-body perspective of deep reservoir, and clarified the dynamics of carbon source flux and biogeochemical mechanism of key interfaces and processes in the Three Gorges Reservoir.
- (3) Carbon emissions accounting check and comprehensive impact assessment of the Three Gorges Reservoir. Having revised and corrected the preliminary estimation results of water-air carbon exchange flux of the Three Gorges Reservoir based on the quantitative analysis of key processes, put forward a new method to quantitatively calculate the carbon emission flux of the Reservoir in different operation modes, reaching an objective understanding of the emission level generated by the Reservoir, providing data and theoretical basis for the scientific evaluation of the green energy benefit of the Project.



Distribution of Dissolved Methane Concentration in the Three Gorges Reservoir

Distribution of Dissolved Methane and Carbon Dioxide Concentration in the Mainstream of the Three Gorges Reservoir



River Ice Monitoring and Forecasting Theory for Ice Flooding Prevention

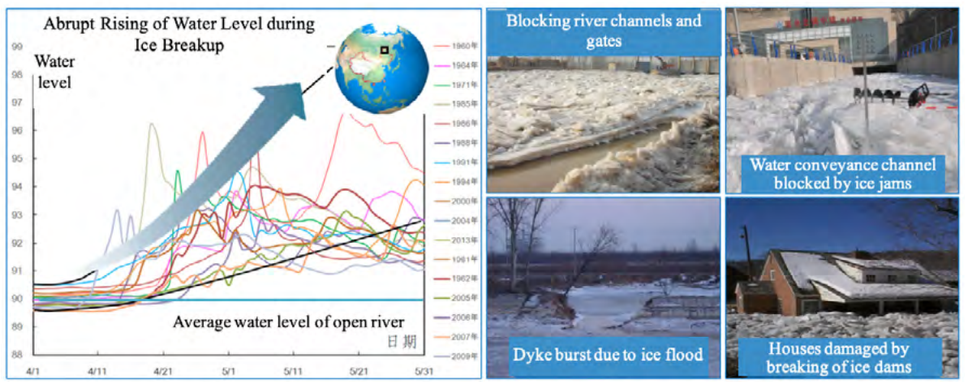
Main Participants: GUO Xinlei, WANG Tao, LIU Zhiping, FU Hui, YAN Denghua, YANG Kailin, TUO Youcai, WANG Jun, PAN Jiajia, LI Jiazhen, LIU Jifeng, PENG Xuming, MU Xiangpeng, GUO Yongxin, WANG Dangwei, WU Yunan, CUI Haitao, LU Jinzhi

Background

China is one of the most affected countries by ice jam disasters in the world, and it is urgent to solve ice problems and prevent ice disasters in Northern rivers and artificial ducts in cold regions for wintertime water safety management. To solve such problems, this project has proposed a series of theoretical methods, field equipment, and new technologies for avoiding ice flooding, preventing chain effects of ice jams, and promoting river ice studies. These research findings provided good examples for ice disaster prevention in cold region rivers and ducts with refined river ice models, developed recording devices, and improved the understanding of river ice processes.

Achievements

- Having invented complete sets of equipment for ice-flow regime integrating dual-frequency radar measurement and developed a new method for measuring the flow discharge and streamwise velocities with and without ice covers using the stream tube method, which solves the difficulties of large-scale synchronous continuous measurements with thick ice and deep water and emergency detection of ice jam and ice dam, with the efficiency improved by more than 90%;
- Having developed new methods such as flow-ice-sediment coupled algorithms, calculations of ice gouging on riverbanks, and anchor ice wave simulations by coupling the flow, ice and sediment theories, establishing the novel 2D flow-ice-sediment coupled mathematical model with more detailed physical processes increasing by 30%, which illustrates complex interactions between flow fluctuations, river ice movement, sediment transport, and channel evolutions in ice jam formation and release, and expands the basic research theory of river ice;
- Having identified the mechanism that the formation of ice jam and ice dam is mainly affected by “characteristics-thermo-dynamics”, and developed an ice dam forecasting model based on fuzzy neural network combined with the formation mechanism and internal changes of ice dams, which supports the long-term forecast of the freeze-up date and break-up date as well as the grade of ice flood disaster as early as 40 days in advance;



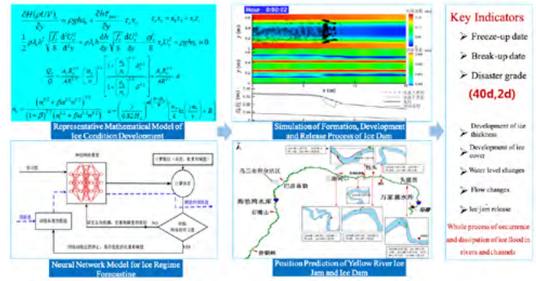
Typical Disaster Pictures of Ice Flood

- Having revealed the accumulation mechanism of ice jams such as inverted siphon of channel structures and gate ice jam, proposed the key hydraulic criteria such as ice jam thickness distribution, anti-ice jam critical water depth and critical number of Fr for floating ice transport; and established the theoretical method of preventing ice dam by blasting beneath ice, providing a direct basis for the solution of technical problems such as the time, location and layout method of blasting.

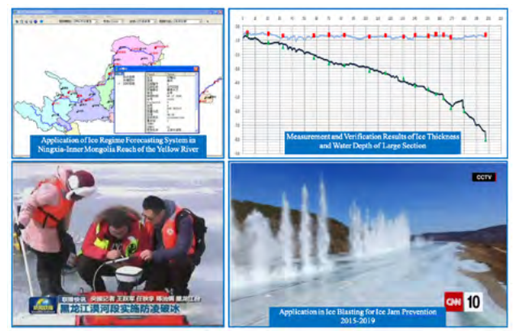
Application

The results have been successfully applied in domestic and international rivers, such as middle and upper reaches of the Yellow River, upper reaches of Heilongjiang River, the Niaraga River and the Peace River, as well as the Middle Route of the South-to-North Water Diversion Project and the relevant regulation and storage project, direct water supply project of Shanxi Yellow River Diversion Project and Hohhot Pumped Storage Power Station Reservoir, and significant economic and social benefits have been achieved.

Complete Equipment, Indicators and Applications of Integrated Ice-Water Regime Dual-frequency Radar Measurement



Ice Regime Forecasting and Flow-ice-sediment Coupled Simulation Technology



Application of the Complete Set of Technology

Crack Formation Mechanism and Key Anti-cracking Technology for High Concrete Dams

Main Participants: ZHANG Guoxin, ZHU Bofang, LIU Yi, LIU Youzhi, ZHANG Lei, LI Songhui, QIU Yongrong, ZHOU Qiujing, WANG Zhenhong, ZHU Zhenyang, ZHANG Yan, XIN Jianda, JIN Xinxin, Lei Zhengqi, LUO Xiangyu, LIU Ruiqiang, LIU Yu, MA Xiaofang, LI Jintao

Background

This technology belongs to the field of water conservancy and hydropower engineering, which is developed to solve the problems related to engineering safety and quality control. Crack prevention is an important task of concrete dam construction, and it is also one of the key points and challenges for construction control. Concrete cracking will affect the quality and durability of the project, and serious ones will even endanger the safety of the dam.

This project aims to solve the world-class problem of cracking prevention of high concrete dams. In view of the needs of temperature control for cracking prevention of high concrete dams and the shortcomings of existing researches, the research team has profoundly revealed the cracking mechanism of high concrete dams and improved the theory and method of temperature control for cracking prevention of high concrete dams by means of theoretical research, model testing, mechanism analysis, software development, field testing, system integration and application improvement in close combination with the construction and practice of high concrete dams; developed an efficient, large-scale finite element simulation software for temperature field and stress field which provide real-time simulation; as well as put forward the "9-3-1" overall solutions to prevent all kinds of cracks in high concrete dams, realizing the comprehensive intelligent control of the whole dam in whole process as well as the spatio-temporal temperature gradient and solving the chronic difficulty of "no dam without crack".

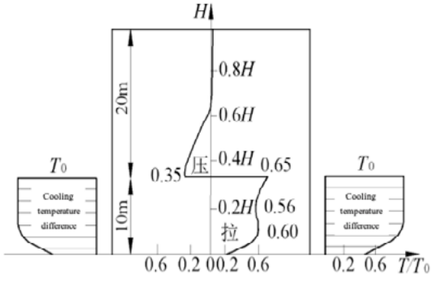
Achievements

- Having systematically revealed the law of temperature stress development and crack formation mechanism of high concrete dams and improved the theory of temperature control and crack prevention, which provides theoretical support for temperature control and cracking prevention of high concrete dams;
- Having proposed and integrated a variety of algorithms and mathematical models to describe the dam shape, material properties and changes in construction process, and developed a high-performance simulation analysis software for temperature stress of concrete dam, which realizes the simulation of temperature and stress field of the whole dam in the whole process from construction to operation, laying a solid foundation for dam performance simulation and safety evaluation;
- Having put forward the "9-3-1" overall solutions to prevent all kinds of cracks in high concrete dams, which include the nine-word principle (early protection, small temperature difference and slow cooling process), the three-stage cooling (early, middle and late stage) and one temperature control (intelligent control). The relevant temperature control strategies and methods were included in the specifications such as *Design Code for Temperature Control of Concrete Dam* (NB/T35092-2017) and *Technical Specification for Temperature Controlling of Hydraulic Concrete Construction* (DL/T 5787-2019), which provide important technical support for the high-quality and efficient construction of high concrete dams in China.
- Having presented a full-process intelligent temperature control methods and developed complete a set of equipment and software to realize the automatic acquisition, interconnection, real-time evaluation, real-time decision-making and intelligent control of the whole process from the outlet temperature, pouring temperature, placing temperature, highest temperature to the later temperature, providing important technical support for the effective guarantee of temperature control quality at the project site.

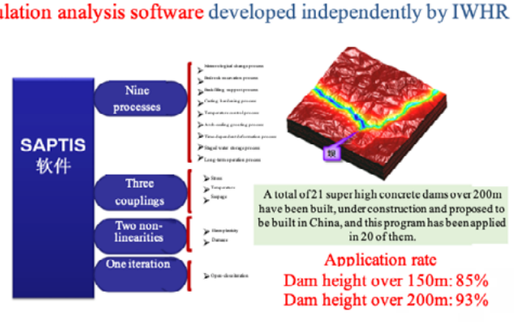
Application

The complete set of theory and method as well as technology and standard of temperature control for cracking prevention of high concrete dam proposed in this project have been widely used in 53 (over 100 meters) high dams and super high arch dams built or under construction in recent years, such as Laxiwa, Jinping I, Xiluodu, Wudongde, Baihetan, Ludila, Zangmu, Fengman reconstruction, Huangdeng, Datengxia, Yangfanggou and other dams, with the total value of research contracts reaching 350 million yuan, which has strongly supported the high-quality construction of these projects, bringing about economic benefit of more than 3 billion yuan.

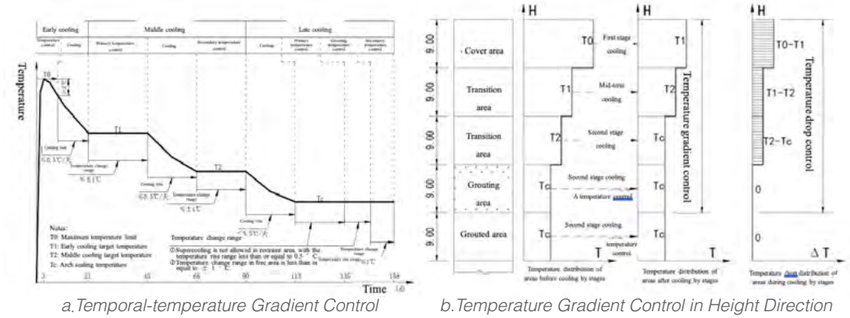
A total of 60 papers have been published, 15 invention patents, 11 utility model patents and 13 software copyrights have been obtained, three monographs and two specifications have been issued. The relevant norms, standards and methods will also better guide and guarantee the high-quality, safe and efficient construction of future projects, especially those in the western alpine region, bringing greater economic and social benefits. They are of great reference value for the future dam construction in countries along the Belt and Road and the development of dam construction technology in the world.



Superposition Principle of Double Constraint Surfaces for Cooling of Foundation Constraint Area

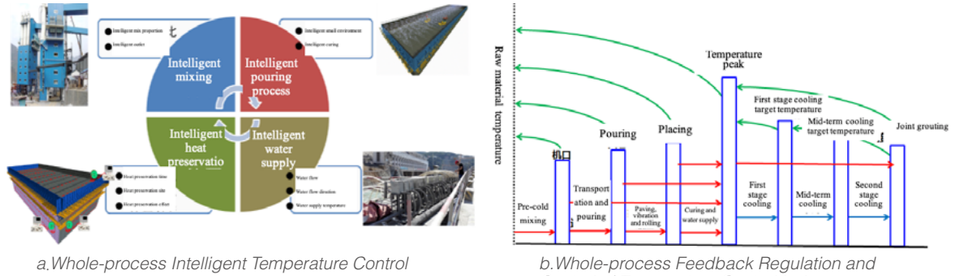


SAPTIS Simulation Analysis Software Functions



a.Temporal-temperature Gradient Control *b.Temperature Gradient Control in Height Direction*

Temperature Gradient Control Strategy in Time and Space Directions of Dam



a.Whole-process Intelligent Temperature Control *b.Whole-process Feedback Regulation and Control of Temperature Control Index*

Intelligent Temperature Control System

Standard Formulation and Engineering Application of Turbine Governing System for Hydroelectric Generating Units

Main Participants: ZHANG Jianming, LIU Tongan, WANG Cong, ZHANG Zhiyu, LI Na, ZHAO Wei, ZHENG Chu'ai, HOU Rui

Background

With the further development of China's hydropower resources, a large number of hydropower plants began to be constructed and gradually put into service, with increasing installed capacity of hydroelectric generating units and single unit capacity. The rapid development of renewable energy also leads to a more frequent participation of the hydroelectric generating units in peak shaving and frequency regulation, which puts forward new requirements for the functions, regulating performance indexes and performance tests of the hydraulic turbine governing system.

In order to strengthen the coordination of power grid and power source, improve power quality and further standardize the functions, performance indexes and test items of hydraulic turbine governing system, the project team has been leading the formulation, revision and translation of technical standards for hydraulic turbine governor and grid-related tests since 2010.

Achievements

- Having disclosed a method for measuring the flow inertia time constant Tw of the water diversion system of turbine that solves the problem that the industry has long been unable to measure the Tw; proposed a new test method for the servomotor response time constant Ty of hydraulic turbine governor which has a wide range of applications and is easy to operate; put forward a new speed dead band index of governor static characteristic, replacing the unreasonable previous index that had been used for decades.
- Having established a simulation model of the servo system of hydraulic turbine governor with higher accuracy, improved the simulation model of hydraulic turbine to raise the modeling and simulation accuracy of the turbine and governing system; proposed a test method for primary frequency regulation of hydroelectric generating sets, which is widely used in engineering tests.
- Being the first to propose the verification index and test method of isolated grid performance of hydroelectric generating units. This method reduces the risk of isolated grid test of hydroelectric generating units and improves the units' isolated grid operation capability.

Core Control Components of Hydraulic Turbine

Application

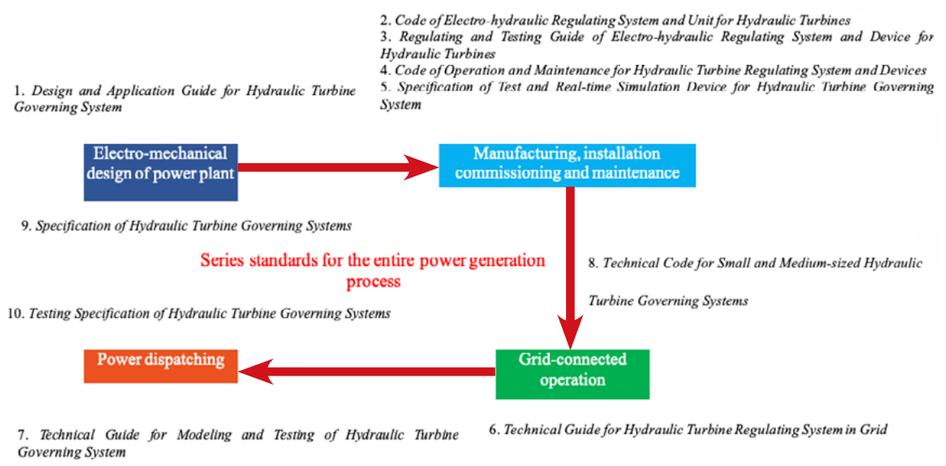
Ten series standards for hydraulic turbine governing system have been completed, including *Technical Guide for Hydraulic Turbine Regulating System in Grid* (DL/T 1245-2013), *Code of Operation and Maintenance for Hydraulic Turbine Regulating System and Devices* (DL/T 792-2013), *Design and Application Guide for Hydraulic Turbine Governing System* (DL/T 1548-2016), *Code of Electro- hydraulic Regulating System and Unit for Hydraulic Turbine* (DL/T563-2016), *Regulating and Testing Guide of Electro-hydraulic Regulating System and Device for Hydraulic Turbines* (DL/T 496-2016), *Technical Guide for Modeling and Testing of Hydraulic Turbine Governing System* (DL/T 1800-2018), *Specification of Test and Real-time Simulation Device for Hydraulic Turbine Governing System* (DL/T 1120-2018),*Technical Code for Small and Medium-sized Hydraulic Turbine Governing Systems* (SL 755-2017), *Specification of Hydraulic Turbine Governing Systems* (GB/T 9652.1-2019) and *Testing Specification of Hydraulic Turbine Governing Systems* (GB/T 9652.2-2019), and have been widely used in power dispatching institutions, hydropower plants, governor manufacturers and testing agency. The applications are mainly in the following forms:

1.The hydropower plant evaluates the performance indexes of the turbine governing system according to the standards.

2.The power dispatching institution conducts the grid-related management and evaluation of grid-connected hydropower stations according to the standards.

3.Equipment manufacturers produce qualified products according to the technical indexes required by the standards.

4.The testing agency carries out the performance tests, primary frequency regulating performance optimization and turbine governing system modeling tests according to the test methods specified in the standards.



Series Standards for Turbine Governing System of Hydroelectric Generating Units

Study on Dam Seismic Disaster Mechanism and Countermeasures

Main Participants: HU Xiao, ZHANG Yanhong, ZHONG Jufang, ZENG Di, YANG Chen, WANG Jing, CHANG Tinggai, GAO Jianyong, XU Lianghua, SU Kezhong, XING Guoliang, ZHU Hongdong, LV Wei, ZENG Xinxiang, ZHANG Lihong, LIU Guoqing

Background

In order to ensure the seismic safety of reservoir dams and prevent the occurrence of serious earthquake disasters, it is necessary to analyze the seismic disaster mechanism of dam structures, improve the existing seismic design concepts and methods, and put forward countermeasures to deal with earthquake disasters. This project mainly studies the dynamic characteristics of full-graded concrete and analyzes and evaluates the seismic safety of the dam in the case of Wudu gravity dam. It also studies the cracking damage mechanism and seismic measures of high dams under strong earthquake.

Wudu Reservoir is a large (1) water project in Fujiang River Basin. The dam is a concrete gravity dam with the maximum height of 120.34m. Longmenshan main central fault and Qianshan fault pass respectively near the tail and the first section of Wudu reservoir. The Wenchuan earthquake occurred on May 12, 2008 brought serious damage to Wudu gravity dam which was under construction then. By studying the damage and failure evolution process of Wudu concrete dam under strong earthquake, this project has revealed the damage and failure mechanism of concrete dam, improved the existing seismic design concepts and methods, put forward reliable aseismic measures and countermeasures to the earthquake disasters, and established the theory and method of major engineering dynamic disaster simulation, providing scientific support for the post-disaster reconstruction of Wudu gravity dam. The relevant research results also provide a basis for the preparation of strong motion monitoring specifications for hydraulic structures.

Achievements

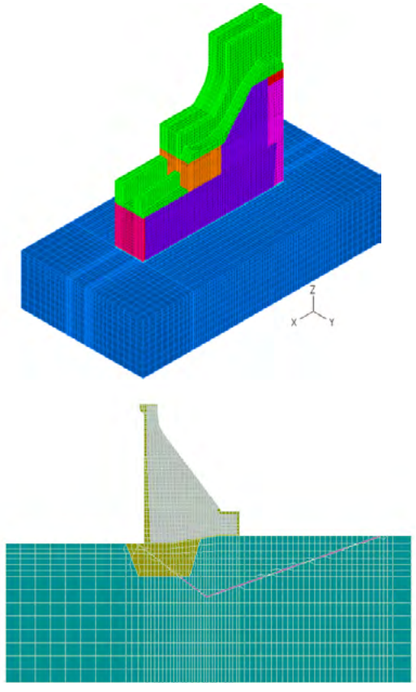
- Having defined the scope and technical terms of strong motion safety monitoring for hydraulic structures. During the Wenchuan earthquake, no complete strong motion monitoring records were obtained for hydraulic structures in strong earthquake areas, which was very unfavorable to improve the seismic design level of hydraulic structures and verify seismic measures. Regarding this situation, the main contents, operation and management regulations of strong motion monitoring of gravity dams, arch dams, earth-rock dams and other hydraulic structures are proposed, which provide relevant provisions and basis for the compilation of the first strong motion monitoring specification for hydraulic structures in China, and clarifies the scope and technical specifications of strong motion monitoring for hydraulic structures.

Reconstruction Site of Wudu Gravity Dam after Wenchuan Earthquake

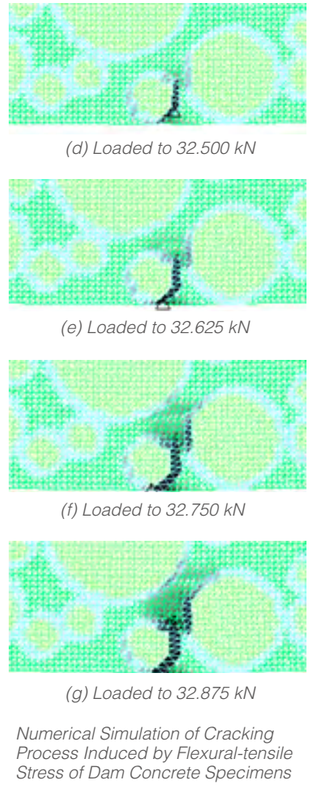
- Having established the nonlinear damage model of concrete gravity dam and revealed the damage and failure mechanism of concrete dam which overcomes the shortcoming of elastic-plastic model that cannot reflect the damage and failure mechanism of concrete materials. The seismic damage of dam concrete is caused by the formation and expansion of microcracks in concrete. Based on the seismic response characteristics of dam concrete and the basic concept of damage mechanics, a nonlinear damage model of concrete that can be used for seismic analysis of dams was proposed. The model is based on the assumption that the damage of concrete is isotropic, and the damage state is described by the tensile and compression damage variables. The model considers that there is still a part of residual deformation after the unloading of damaged concrete, the development of damage and residual deformation under uniaxial loading is represented by a set of empirical curves. The concrete damage criterion is given in the form of Drucker-Prager curve, and the undetermined parameters in the model can be determined by the test results of concrete materials. This model can be used to simulate the stiffness damage of dam concrete material under earthquake, the partial recovery of concrete stiffness under earthquake reciprocating action, and the existence of residual deformation of concrete after unloading.

Application

The first Technical Specification of Strong Motion Monitoring for Seismic Safety of Hydraulic Structures (SL486 - 2011) prepared according to the scientific research results of this project was promulgated and implemented in China on June 8, 2011. The research results of the project have been directly applied to the seismic design and post-earthquake recovery and reconstruction of Wudu RCC gravity dam, and widely used in the seismic design of other high concrete gravity dams.



Dynamic Characteristics of Overflow Section and Deep Anti-sliding Stability Analysis Model of Retaining Dam Section of Wudu Gravity Dam



(d) Loaded to 32.500 kN

(e) Loaded to 32.625 kN

(f) Loaded to 32.750 kN

(g) Loaded to 32.875 kN

Numerical Simulation of Cracking Process Induced by Flexural-tensile Stress of Dam Concrete Specimens

Research, Development and Application of New Numerical Simulation Technology for Multi-scale Water-sediment Movement

Main Participants: ZHANG Lei, WANG Dayu, HUANG Hai, WEN Zhou, LU Wen, ZHAI Zhengli, GUAN Jianzhao, FANG Chunming, MAO Jixin, LE Maohua, LIU Huifang, WANG Yousheng, GUO Ziyang, WANG Li

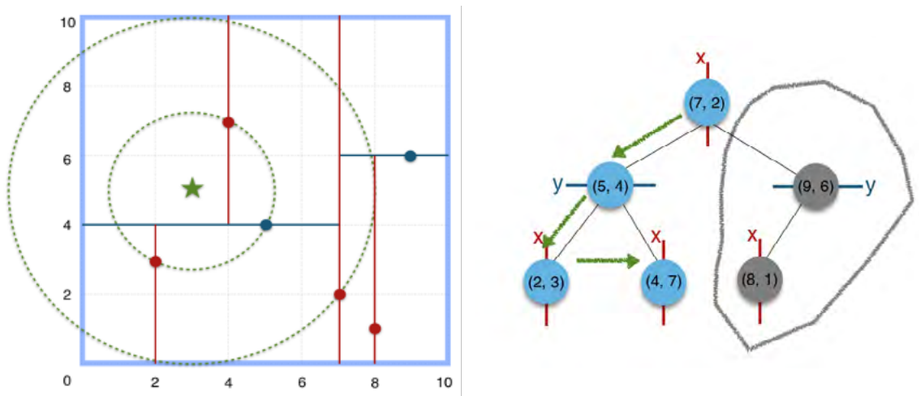
Background

The water-sediment mathematical model has become an important approach to solve the research and engineering problems in the field of sedimentation. Usability and efficiency are the determinate factors for the wide application of the water-sediment numerical simulation, while the cumbersome pre-and post-processing is usually the bottleneck restricting the application of the software, including the capture technology of missing terrain in river network space, automatic parameter calibration, automatic batch processing of results, deep learning and rapid prediction.

To counter these problems, this project carried out a systematic and in-depth study to overcome many technical problems that restrict the convenient and efficient application of software in the process of water-sediment numerical simulation. The research results have provided strong technical support for the study of the changes in the hydrological regime of the Yangtze River, the discovery of the evolution law of the density current of the Liujiaxia Reservoir of the Yellow River, and the planning of the Three-River Connection Project in Heilongjiang Province as well as other river regulation and safe and efficient reservoir operation projects, bearing signficant social and economic benefits.

Achievements

- Having developed the regional editing and automatic acquisition technology of terrain data and the automatic supplement and error evaluation method and technology of river network space missing terrain.
- Having developed the simulation technology of local baroclinic three-dimensional water-sediment density current movement.
- Having realized the automatic calibration of parameters, including the method of automatic calibration of roughness and initial gradation of bed sediment.

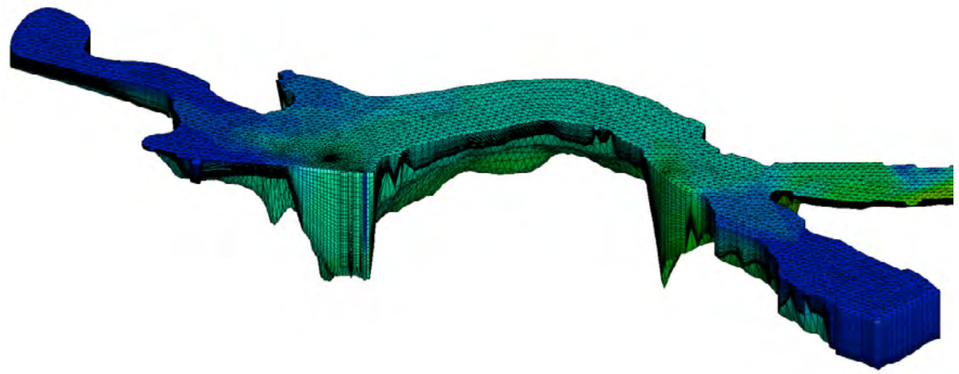


Schematic of the Nearest Neighbor Search Space of KD Tree

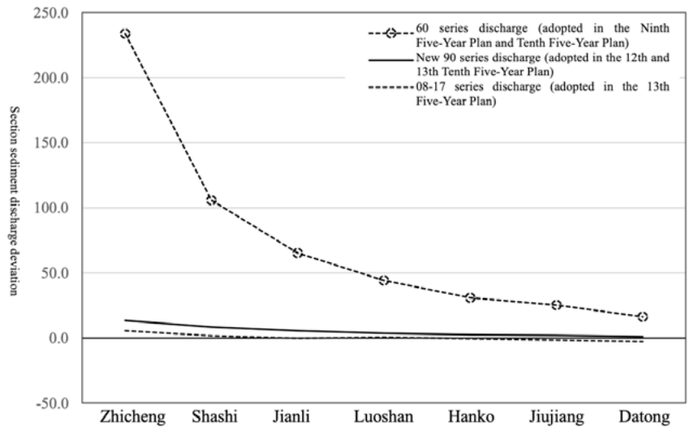
- Having achieved the rapid water-sediment prediction in large-scale river network section based on the deep neural network model.
- Having developed the standardized and automatic batch processing technology of results, greatly improving the efficiency of results compilation.
- Having applied the non-traditional water-sediment mechanism model, the deep neural network model to the rapid water-sediment prediction in large-scale river network section.
- The software and technology developed in this project has been widely used in the Yangtze River, Yellow River, Songhua River and other important basins, which greatly improves the work efficiency. The regional editing and automatic acquisition technology of terrain data and the automatic supplement and error evaluation method and technology of river network space missing terrain have been developed.

Application

The efficient and convenient water-sediment numerical simulation software and technology developed in this project has been widely used in the Yangtze River, Yellow River, Songhua River and other important river basins, which greatly improves the work efficiency bringing about significant economic and social benefits.



3D Topography of Taohekou in Liujiaxia Reservoir



Deviation of Sediment Discharge along the Path in Different Series

Research and Application of Agricultural Water Consumption Management---A Case Study of Turpan

Main Participants: ZHANG Baozhong, LEI Bo, DU Lijuan, PENG Zhigong

Background

Excessive emphasis on water supply control for agricultural water consumption management in arid areas might easily lead to more serious water shortage due to followed expansion of irrigation area after improving the water use efficiency. In 2018, 11 scientists from eight countries published an article titled “Irrigation Efficiency Paradox” on Science, which attracted worldwide attention. Focusing on this problem, ET (evapotranspiration) management concept has been developed and the transformation from “water withdrawal management” to “dual management of water withdrawal + water consumption” has been proposed in this project. By studying the threshold value of water-saving irrigation quota of Turpan region, the original concept and method of irrigation planning was upgraded to the stage of “double management of water withdrawal + water consumption”, and the agricultural water distribution scheme based on water consumption was put forward innovatively and promoted and applied throughout the Turpan region so as to achieve a leap in “water consumption control” from concept to wide-range application. The results can effectively promote the scientific management of water use in water scarcity areas due to the lack of resource and will be promoted and applied in the world as a successful case of the World Bank and Food and Agriculture Organization of the United Nations (FAO).

Achievements

- **Spatial-temporal optimization of crop water consumption threshold value.** This project proposed the method for determining the quota of economic water consumption and its optimized spatial-temporal distribution by studying the water demand law and water consumption characteristics of main crops such as grapes and vegetables, analyzed the multiple spatial-temporal variations of water productivity and economic water consumption quota and studying the conversion coefficient between water consumption and water withdrawal in different regions and different irrigation approaches, filled the blank of unclarified threshold value of suitable water demand and consumption for special local crops.
- **Water-saving planning technology with water consumption control.** Based on the characteristics of crop water consumption, this project studied the methods for determining the target volume of agricultural water consumption in different regions and different stages, put forward the measures and paths of agricultural water consumption optimization and established the technology and methods for water-saving planning based on the dual control of “water withdrawal + water consumption”, achieved a leap from concept to wide-range application in “water consumption management”.
- **Optimized allocation of agricultural water with water consumption control.** The project analyzed the historical evolution laws of climate change, water inflow and water consumption in Turpan Basin and studied the process of surface water inflow and farmland water consumption in years of different frequencies as well as proposed the agricultural water distribution scheme meeting the target of water consumption in multiple scenarios according to the water-saving planning.
- **Monitoring and early warning of water consumption management based on remote sensing.** The project studied the method of rapid interpretation of remote sensing monitoring of regional water consumption, established the method of value conversion from the instant of monitoring to that of the fertility period and proposed the early warning mechanism, control methods and measures in case of regional water consumption exceeding the target volume.

Application

These research findings can significantly improve the efficiency and benefits of water use in the study area, truly reduced the total agricultural water consumption volume and saved the water resources. The applications were as follows:

The results have been applied in the entire Turpan basin, which contributed to the reduction of evapotranspiration of 13.84 million m^3 in the project area accumulatively , significantly slowed down the overexploitation of groundwater under the constraint of stable agricultural production.

The theory and method of agricultural water-saving planning based on water consumption control has been successfully applied to the planning of more than 10 large-scale irrigation districts, such as Hetao, Pishihang and so on (accounting for more than 10% of irrigation districts to be invested throughout the country), which is of great significance to realizing resource-oriented water-saving as well as the ecosystem and environment improvement in irrigation districts.

The results have been widely recognized by experts at home and abroad, and was deemed as highly satisfactory therefore promoted worldwide as a typical case and successful experience by the World Bank.

The project caught the attention of the FAO which entrusted the project experts to prepare the Consumption-Based Agricultural Water Management Manual which will be published on the FAO website and disseminated to Asia-Pacific countries and regions as an example of the Chinese experience and Chinese solutions.

Technology for Simulation and Intelligent Regulation of Urban Water Cycle and Its Application

Main Participants: LIU Jiahong, DING Xiangyi, MEI Chao, YU Yingdong, Jiang Yunzhong, GAO Xichao, LI Xiang, ZHOU Jinjun, WANG Jia, WENG Baisha, SHAO Weiwei, LU Fan, YE Yuntao, KANG Aiqing, SUN Guangdong

Background

Water-related problems in cities and rapid urbanization are the key bottlenecks restricting social-economic development and ecological improvement in China. The underlying surface state, water cycle path, water supply, utilization and drainage modes of urban areas are significantly affected by human activities over past decades. Urban water system is undergoing a rapid evolution process, resulting in multiple effects of resources, economy, society and ecology, and leading to many problems such as flood, water pollution and water ecological degradation.

Supported by the National Natural Science Foundation of China and key team project of the State Key Laboratory, the project has developed technology for simulation and intelligent regulation of urban water cycle, providing basic scientific support for promoting the health of urban water cycle system and scientific prevention and resolution of urban water risk.

Achievements

- **Having systematically revealed the mechanism of runoff generation and confluence on the complex underlying surface of urban area.** According to the underlying surfaces with different permeability, such as highly permeable, permeable, semi permeable and pseudo permeable, which exist in the intensive yet low impact urban development process, the water conductivity and infiltration stabilization time of different types of underlying surfaces were measured, and the infiltration rate variation curves of four types of underlying surfaces were fitted based on Sigmoid function (Fig. 1). On the scale of inner urban district, the confluence modes of traditional development area and low-impact sponge community area were analyzed, and the causes of confluence surge in urban waterlogged area underrainstorm were revealed.

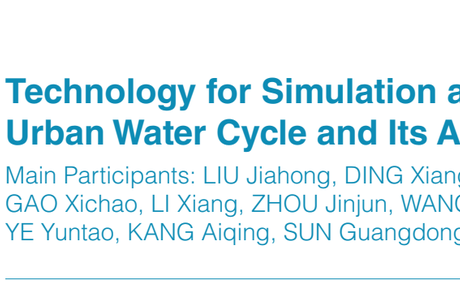


Fig. 1 Fitting Curve of Infiltration/ Evaporation Time History of Different Underlying Surfaces in the Study Area

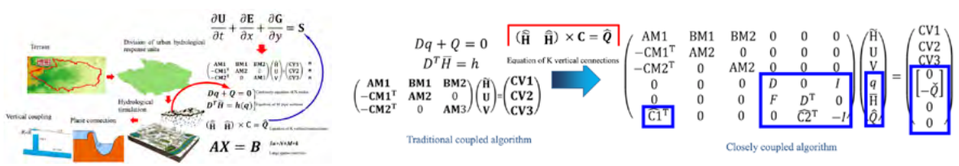


Fig. 2 Improved Technical Route of Closely Coupled Algorithm for Hydrological and Hydrodynamic Model

- **Having developed an urban water cycle model and improved the closely coupled algorithm of hydrological and hydrodynamic model.** Focusing on the key problems such as the vertically coupling of urban one-dimensional and two-dimensional hydrodynamic connection, as well as the urban hydrology-hydrodynamics coupling modelling, the study has improved the mode and connection equation of one-dimensional and two-dimensional vertical connection, and proposed a closely coupled algorithm of one-dimensional and two-dimensional urban hydrodynamics based on equation simultaneous solution, and derived the parameter matrix of simultaneous equations (Fig. 2). This improvement has solved the local "flow field distortion" problem caused by deviation accumulation of traditional algorithm (Fig. 3).
- **Having proposed a coupled equilibrium diagnosis method for urban water cycle system.** Based on the urbanhydrological and hydrodynamic coupled model, this study established the diagnosis method called "three equilibriums of urban water system" respectively regarding water quantity, water quality and water utilization in urban water cycle, and formed the "three-step" progressive water system optimization design paradigm from "problem identification, quantitative diagnosis" to "measure optimization".
- **Having built the monitoring and intelligent regulation system of urban water cycle,** which has been applied to Smart Water System for Dongying City (in Shandong Province) (Fig. 4), as well as the rainwater control of Beijing Daxing International Airport.

Application

The coupled equilibrium diagnosis and optimization design method have been applied to water system planning of New District of Tongzhou City, supporting the construction of subsidiary-centers of Beijing Municipality. The model technology and smart control platform have been integrally applied to the rainwater control system of Beijing Daxing International Airport and the Smart Water System of Dongying City, Shandong Province. Theories, models, and other achievements have also been widely used and applied by large enterprises and institutions such as North China Municipal Engineering Design & Research Institute Co., Ltd. and Beijing Capital Group Company Limited, technologically supporting and leading the national sponge cities piloting in cities of Xiamen, Xi'an, Tianjin, Pingxiang and others.

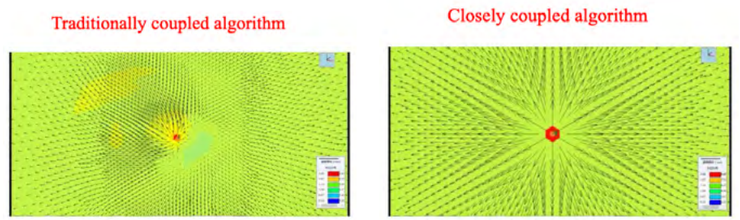


Fig. 3 Comparison of Water Level and Flow Field Distribution Near the Coupling Point between the Traditional Algorithm and Closely Coupled Algorithm

Fig. 4 Urban flood model and interface of Smart Water System of Dongying City

Research and Application of Key Technologies of Remote Sensing Monitoring and Supervision for Soil and Water Conservation

Main Participants: LIU Changjun, SUN Tao, SONG Wenlong, PANG Zhiguo, ZHU He, LI Changzhi, SUN Dongya, LI Lin, JIANG Wei, MA Jianwei, ZHANG Miao, HUANG Shifeng, LI Hui

Background

Closely focusing on the main problems of soil and water conservation monitoring and supervision faced by the central and local governments, based on high-resolution satellite remote sensing, unmanned aerial vehicle (UAV), laser radar and other means, and combined with artificial intelligence, big data, high-performance computing, cloud services, GIS and other high-techs, this project carried out research and application of key technologies for remote sensing monitoring and supervision of soil and water conservation covering the dynamic monitoring of soil and water loss, information supervision of soil and water conservation in production and construction projects, and management of key projects of soil and water conservation.

Achievements

- Having put forward the technology to extract the disturbance patch indicating nature-human induced soil and water loss based on high-resolution satellite images and deep learning and developed the information extraction algorithm regarding vegetation and production and construction projects based on laser radar and the key technologies for monitoring of measures adopted in the key projects of soil and water conservation based on UAV.
- Having proposed a water-soil coupled model of soil and water loss in small watershed based on the temporal and spatial variation mechanism of rainstorm flood and soil erosion mechanism, optimized the calculation method of soil erosion factor in the soil and water loss model and built the benefit evaluation model for soil and water conservation projects based on remote sensing.
- Having independently developed a number of related business application software, such as disturbance patch extraction software for production and construction projects, soil and water loss dynamic monitoring software, UAV soil and water conservation monitoring software, lidar soil and water conservation information extraction software, and big data business analysis, and constructed the soil and water conservation monitoring and supervision application software system.
- Having established the factor index system of remote sensing monitoring and supervision for soil and water conservation, and established the multidimensional cube data model with administrative divisions and small watersheds as the double main lines to form a database of soil and water conservation monitoring and supervision.
- Having developed key technology for the multi-layer dynamic coupling and integration of data, process and model calculation for soil and water conservation monitoring and supervision, formed remote sensing big data storage, resource scheduling and fast processing algorithms based on high performance computing cluster and parallel computing technology and constructed a service platform for soil and water conservation industry.
- Having put forward the increment and decrement extraction model of remote sensing monitoring of human induced soil and water loss changes, formed a soil and water conservation supervision mode covering the whole process from “remote sensing data analysis, rapid field verification, legal punishment and rectification to follow-up benefit evaluation”, and established a nature-human induced soil and water loss dynamic monitoring model featuring “factor extraction, erosion calculation, intensity analysis, and benefit evaluation”.

Application

The project achievements have been applied to the dynamic monitoring, supervision and management of soil and water conservation in more than ten provinces and related watershed institutions, which have improved the information application level of water and soil conservation in relevant provinces and cities and the efficiency of soil and water conservation prevention, supervision and management, and promoted the rapid development of remote sensing technology in soil and water conservation industry and the rapid improvement in the application of information technology in water and soil conservation. They were selected by the 14th Promotion Conference on International Advanced Water Technology and entered the list of advanced and practical water related technologies in 2017 and 2018 and the 2020 promotion list of mature and applicable technological achievements in water sector, and have been disseminated and promoted on multiple occasions such as industry conferences, academic seminars and consultation meetings and also widely applied in flood control and disaster mitigation, river and lake supervision, water environment improvement, flash flood disaster prevention and other fields. Some achievements have even been transformed by universities, research institutions, enterprises and public utilities such as Hohai University, Changjiang River Scientific Research Institute of Changjiang Water Resources Commission and POWERCHINA Beijing Engineering Corporation Limited.

Best Papers

In Journal of IWHR

中国水利水电科学研究院 JOURNAL OF CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH 学报

Comparative analysis of hydrological and hydrodynamic calculation method for flash flood in small watershed

LIU Changjun, WEN Lei, ZHOU Jian, ZHAO Xuantao, GUO Liang and WEI Yongqiang

Abstract: For the fine simulation of flash flood in small watersheds,this paper proposes a spatial and temporal source-variable mixed runoff model in small watershed, and builds a distributed simulation model of stormwater flash flood with small watershed as the unit, The visual distributed hydrological model software FFMS and hydrodynamic calculation software FHMS are developed. Taking the calculation of the storm flood in the small watershed of Baogai Temple as an example, the hydrological and hydrodynamic methods were used respectively to calculate the storm flooding process in the small watershed,and analyzed the calculation accuracy, efficiency and practicability of the two methods. The results of the case study show that:First, hydrological and hydrodynamics can simulate the stormwater flash flood in small watershed, and the simulation results are basically consistent with the actual measurements; Second, for calculation of storm floods in ungauged small watersheds,the hydrological modeling has faster modeling speed and higher computational efficiency compared with hydrodynamic method modeling;Third,when dealing with the formation mechanism and evolution process of storm floods under complex terrain conditions, the hydrodynamic calculation results are more precise and accurate; For flood forecasting and warning in small and medium watersheds in mountainous areas,the hydrological method is more practical.

Keywords: Flash flood; spatio-temporal variable source mixed flow production model; modular distributed hydrological model; hydrodynamic method; flash flood simulation

Application of improved fuzzy comprehensive method to water quality assessment in Erhai

ZHANG Qian, LI Guoqiang, ZHUGE Yisi, YU Xiao, TAN Hongwu and DU Qiang

Abstract: The results of water quality assessment in Erhai using single factor evaluation, do not well reflect the effect of water environment management in recent years. This paper collects the monitoring data of water quality of Erhai systematically in 1992-2016. Based on the improved fuzzy comprehensive evaluation method and several water quality indexes, the trend of water environmental change in Erhai was evaluated from the aspects of surface water quality standard and lake eutrophication, and the results were compared with those obtained by the single factor evaluation method. The results show that the surface water quality in Erhai gradually deteriorated between 1992 and 2003, since 2003, and the water quality of Erhai has been improved year by year and tends to be stable. The quality of Erhai in non-flood season is better than that in flood season (during June to October) during the year, and the water quality in the center of the lake is better than in the south and north. Overall, the eutrophication level of Erhai has gradually changed from oligotrophic to medium nutrition. Compared with the single factor evaluation method, the improved fuzzy comprehensive evaluation method can better reflect the dynamic change characteristics of water quality in Erhai in recent 20 years.

Keywords: Water quality evaluation; eutrophication; improved fuzzy comprehensive evaluation method; single factor evaluation method; Erhai

Study on the engineering measures and prevention effect of Caohai water pollution in Dianchi Lake

YAO Yunhui, MA Wei, CUI Songyun, QI Dexuan and GAN Jiawei

Abstract: Under the joint action of six-key-project management system in Dianchi Lake basin, the water quality of the Waihai and Caohai in Dianchi Lake has been improved significantly in recent years. Caohai, the carrier for pollutant discharge in Dianchi Lake, has been gradually transformed into a place of leisure and entertainment for residents and name card for the city. In order to adapt to the orientation of the functional change of Caohai and accelerate the water quality improvement in the sensitive Lake areas, new eco-project was implemented, such as emergency water supply project of Niulan River-Caohai, new eco-puri-fication project of Laoyunliang River and water replacement channel project of Haigeng levee. The clean and sewage water was physically isolated and separated through new eco-purification project of Laoyunliang River. The emergency water supply project of Niulan River-Caohai provided the necessary water resources conditions for intercepting pollution around the lake and separating clean and sewage water. Water replacement channel project of Haigeng levee shortened the water replacement period in the clean water area and provided hydrodynamic guarantee for water landscape in environmental sensitive areas. As the result, the TN and TP were reduced by 15%~28%. Water replacement channel project will improve the internal accumulation condition and be conductive to the continuous improvement of water quality in Caohai. These combined project managements can improve water quality of Caohai.

Keywords: Water pollution control; engineering measure; sewage diversion; Caohai Lake; Dianchi Lake

Reviews on soil metal pollution in water-level fluctuation zone of Three Gorges Reservoir area

LI Yanyan, XU Dongyu, GAO Li and GAO Bo

Abstracts: At present, the eco-environmental problem in the Three Gorges Reservoir (TGR) area is highly concerned by government and people. The water-level fluctuation zone (WLFZ) is a significant component of ecological environment in the TGR. In recent decades, the heavy metal pollution in soils in WLFZ has attracted much attention from researchers all over the world. However, the comprehensive analysis on heavy metal pollution in soils in WLFZ remains scarce. Through literature review (the last ten years), this study summarizes the content, spatial and temporal distribution characteristics and ecological environmental risks of heavy metal in soils in WLFZ in TGR. The results show that in general, the concentrations of heavy metal in soils in WLFZ are higher in the upper and lower reaches than those in the middle reaches in the TGR. Meanwhile, the distribution characteristics of heavy metal vary with soil layer and elevation. Compared with soils before submergence, the metals concentration in soils in WLFZ exhibit dynamic change with the increase of dry/wet alternation cycle, and heavy metal in soils has the potential to transform into river water. The environmental risk assessment suggested that the studied soil generally belongs to the second-class soil, which is slightly polluted and shows slow ecological risk. The main heavy metals with ecological risks are Cd,followed by As and Hg. However,these metals do not influence human health at present. Finally, this review summarizes future research perspectives on the basis of current research status, which will provide a basis for the development of strategies to prevent soil heavy metal pollution in WLFZ and conserve water ecological environment in the TGR.

Keywords: Three Gorges Reservoir; water-level fluctuation zone; soil; heavy metal pollution; environmental risk; review

Research on the application of Sentinel-1 SAR data in monitoring of landslide disaster in Maoxian County Sichuan

GAO Siyuan, HUANG Shifeng, SUN Yayong and WANG Hui

Abstract: Synthetic Aperture Radar is with observation characteristics of full time, all day, real time and wide coverage, which has unique advantage in fast monitoring of landslide disaster. Therefore, based on the serious landslide disaster in Maoxian County, Sichuan Province on June 24, 2017, this paper conducts the application research of landslide range extraction based on the Sentinel-1 SAR data in the disaster. First,by analyzing the radar backscattering mechanism of forest area and landslide area,the radar ratio index method is proposed based on VV polarization and VH polarization. Then,combining the two-phase Sentinel-1 SAR images before and during the disaster,the features of backscattering intensity change are investigated,and the rationality of extracting landslide mass by the radar ratio index method is verified. Finally, for the Sentinel-1 SAR data in the disaster, the radar ratio index method is adopted for the rapid extraction of landslide range and the monitoring of landslide disaster. The results show that the Maoxian landslide area is 1.3 km² and the inclined sliding distance is about 2378m by performing the rapid extraction of Sentinel-1 SAR data. The landslide caused the serious damage to Xinmo village and the houses were completely destructed. The research shows that the radar ratio index can significantly characterize the image features of the landslide mass. This method presents great potential and advantages in landslide extraction and monitoring by Sentinel-1 SAR.

Keywords: Sentinel-1; landslide; Maoxian County; ratio index

Proportion design and property of cemented artificial sand and gravel material

JIA Jinsheng, LIU Zhongwei, ZHENG Cuiying, ZHAI Jie, WANG Yue and MA Fengling

Abstract: Cemented sand, Gravel and Rock (CSGR) has been developed as an environmentally friendly material in the practice of dam construction in China. Because the CSGR dam was mainly used in the river bed which was rich in natural sand and gravel, the popularization of the CSGR material was limited to a certain degree. For the river bed that lacks natural sand and gravel, artificial sand and gravel can be used to build the Cemented Artificial Sand and Gravel (CASR) dam. The parameters such as water binder ratio, cement dosage, fly ash content and sand rate are studied in the paper, the durability of materials and the design principle of dam section are discussed,and the comparison of dam type schemes is carried out. This research shows:(1) The simple crushing way of artificial sand aggregate, that is, the gravel could directly be smashed by single machine after one break in the hammer crusher. (2) Because the strength of natural aggregate was high,the grading was relatively stable. The intensity of the CASR material was quite uniform. The frost resistance property and impermeability of the CASR was higher than cemented natural sand, gravel and rock material. (3) After the comparison of CASR dam type in the permanent project of Naheng reservoir in Yunnan Province, it saved 10% investment compared with RCC Dam. The CASR dam type has expanded the alternative of damming materials, and provides a new type of dam for the dam construction on the river that has to natural sand and gravel.

Keywords: Artificial sand and gravel; proportion; strength; durability; crushing

In Journal of Hydraulic Engineering

水利学报 SHUILI XUEBAO JOURNAL OF HYDRAULIC ENGINEERING

Influence of the dynamic interaction between high rockfill dam and foundation

KONG Xianjing, ZHOU Chenguang, ZOU Degao and YU Xiang

Abstract: The height of several rockfill dams in China has exceeded 300m with tremendous volume and weight, and the length of dam-foundation interface is over thousand meters along the river. In addition, since rockfill materials have nonlinear property, the influence of dam-foundation dynamic interaction during earthquake causes attention more and more in the engineering,and is necessary to study systematically. According to the several representative high rockfill dams constructed and awaiting construction in China, the wave analysis method is adopted to consider dam-foundation dynamic interaction and study the influence of intercepted range of foundation on the dam dynamic response. Through contrasting the results of vibration analysis and wave analysis, the influence of the dynamic interaction between high rockfill dam and foundation is discussed. The results indicate that the dam dynamic response calculated by wave analysis method conforms to reality better than the vibration analysis method,and suggest that the intercepted range of foundation is equal to 0.3 to 0.5 times of the length of dam-foundation interface along the river. In other words, the range is about 1.0 to 1.5 times of the height of dam for the concrete-faced rockfill dams, and the range is about 1.2 to 1.8 times of the height of dam for the core-wall rockfill dams. Compare with the results of vibration analysis method, the acceleration extreme values of dam calculated by wave analysis method decrease about 10%~40%, the dynamic displacement extreme values of dam decrease about 10%~50%, and the dynamic stress extreme values of concrete face slab decrease about 20%~40% (tensile) and 15%~30% (compressive), respectively. Therefore, the influence of dam-foundation dynamic interaction is significant,and the vibration analysis method will overestimate the dynamic response of high rockfill dam to underestimate the seismic capability.

Keywords: Dam-foundation dynamic interaction; high rockfill dam; vibration analysis; wave analysis; intercepted range of foundation

Preliminary exploration of design flood and control water level of Three Gorges Reservoir in operation period

GUO Shenglian, XIONG Feng, WANG Jun, ZHONG Yixuan, TIAN Jing and YIN Jiabo

Abstract: Considering the impact of joint operation of reservoir group in the upper Yangtze River basin on Three Gorges Reservoir (TGR), the most likely regional composition and typical-year methods were adopted to derive the flood regional composition for each control hydrological station. The multi-inputs single-output (MISO) model was used to simulate the flood process between Xiangjiaba and TGR uncontrolled inter-basin. The design floods as well as the flood control water level of TGR during operation period are derived and analyzed. It is shown that:(1) the design floods of downstream reservoirs are significantly influenced by the operation of upstream reservoirs, particularly the cascade reservoirs in Jinsha River;(2)

The 1000-year design peak discharge, 3d, 7d, 15d and 30d flood volumes of TGR are 81136m³/s, 18.8, 38.6,72.7,132.1 billion m³,decreasing by 18.2%,23.8%,20.6%,20.2% and 16.9%,respectively;(3) the flood control (limited) water levels of TGR are 155(145) m without reducing the original flood prevention standards. The high flood control water level during TGR operation period can not only benefit navigation in the reservoir, sustain reservoir bank stability, and protect eco-environment of reservoir riparian zone, but also can increase hydropower generation, reduce the impact on downstream Dongting and Poyang Lakes during reservoir refill operation period,which has great social-economic and eco-environment benefits.

Keywords: Three gorges reservoir; operation period; design flood; most likely regional composition; flood limited water level; flood control water level

Bedforms, energy dissipation and disaster mitigation mechanism in mountain rivers of Southwest China

WANG Zhaoyin and ZHANG Chendi

Abstract: The continuous uplifting of Qinghai-Tibet Plateau results in the river incision on the margin of Qinghai-Tibet plateu. River incision leads to frequent disasters such as bank failures, avalanches, landslides and debris flows. Based on the field investigations and experiments over the past decade, it is found that natural dams, which are formed after landslides or debris flows block the channel, perform as the negative feedback to river incision. The natural dams are capable to control erosion and incision efficiently, stabilize the riverbed and improve the local ecology. The functions above stem from the bedforms developed on natural dams. The present paper summarizes the mechanism of bedforms and natural dams on energy dissipation and disaster mitigation. The quantification of energy dissipation rate of step-pool, which stands for bedforms, has been put forward. Furthermore, the concept and logic of energy budget in the integrated management of incised rivers is demonstrated in the present paper. The successful application of artificial step-pool system in a debris flow gully is introduced, to illustrate the feasibility and efficiency of artificial energy dissipaters mimicking natural dams in disaster prevention and mitigation. Last but not least, based on the idea of energy dissipation, we suggest that the successive reservoir-dam system consisting of medium-sized dams should be applied in the development and management of the incised river in southwest China, to realize the comprehensive objective including dissipating flow energy, stabilizing the riverbed and promoting the ecology.

Keywords: Natural dam; bedform; energy dissipation and disaster mitigation; barrier dam; step-pool system system

A state-of-the-art review of China's hydropower operations and the recent advances in the era of gigawatts

CHENG Chuntian, WU Xinyu, SHEN Jianjian, LI Gang, LIAO Shengli and LIU Benxi

Abstract: The Three Gorges and West-East Electricity Transfer Projects have brought an unprecedented hydropower boom in China and the world. China's cumulative installed hydropower capacity has been over 100 GW, 200 GW and 300 GW in just 20 years. By the end of 2017, the installed hydropower capacity in China has reached 341 GW, which is more than three times of installed hydropower capacity in the United States, the second largest in the world, and equivalent to the combined installed hydropower capacity of the world's next five major hydropower countries. In the process of rapid development of hydropower in China, it is also the period of speedy development of the entire China's electricity system. By hydropower interconnection, the installed capacity of single regional power grid is more than 100 GW, which is higher than the United States and Brazil, which rank second and third in the world. Two provincial power grids have been built with more than 70 GW and 60 GW of installed hydropower capacity, respectively, ahead of fifth-placed Japan and following the fourth-placed Canada. The unprecedented scale and developing speed of hydropower system in China has greatly changed the existing scheduling management methods at home and abroad, posing a major challenge to the traditional scheduling methods of hydropower system, and a new scheduling method is needed. This paper gives an overview of the development history of hydropower in China, concludes the new changes in hydropower systems and three facing major problems, reviews the theoretical and methodological progress of hydropower in China in the last decade and points out that China's hydropower research under transformation of energy structure needs to be carried out in the future.

Keywords: Power transmission project from west to east; main stream cascade hydropower station group; UHV direct hydropower transmission; interbasin cascade hydropower stations;cross regional coordination

Progresses and challenges in the study of Eco-fluvial Dynamics

FANG Hongwei, HE Guojian, HUANG Lei, LIU Yan, HAN Xu and ZHAO Chenwei

Abstract: The construction and operation of large-scale hydraulic projects cause significant changes in the hydrodynamics and sediment transport in the rivers and lakes, which not only bring about riverbed evolution, but also variations in the interactions among water, sediment and nutrients/pollutants. Accordingly, the bed biofilms, phytoplankton/zooplankton, zoobenthos and aquatic plants in the aqueous environment are also changed. In this paper, the concept and theoretical framework of Eco-fluvial Dynamics are proposed, and the relevant research progresses are reviewed, including the physical processes of turbulence, sediment transport and micro-morphology, chemical processes of nutrients and pollutants transport, and the responses of biological processes in the water and at the bed surface. The coupling between the fluvial dynamics and biological/chemical processes are discussed, and the challenges of multi-disciplinary and multi-scale faced by the study of Eco-fluvial Dynamics are further proposed.

Keywords: Eco-fluvial Dynamics; sediment transport; biological and chemical processes; interactions

Basic theory for urban water management and sponge city—review on urban hydrology

XU Zongxue and CHENG Tao

Abstract: Urbanization has a great impact on natural water cycle system and results in a series of problems such as urban water shortage, degeneration of water ecology and environment and water-induced disasters due to unreasonable urban planning, which brings a great challenge to integrated urban water management. The basic theory and technical support for urban water management are urban hydrology and water-related disciplines. "Sponge city", an advanced urban water management strategy, must take the theory of urban hydrology as its guidance, and should be carried out based on urban water cycle. To lay a foundation for the basic theory development of urban water management, the major progresses and achievements on hydrological response to urbanization, mechanisms of urban runoff process, urban stormwater simulation and management are summarized and reviewed in this paper. It is concluded that further studies should pay more attention to the urban hydrometeorological observation and forecasting, hydrological impact of urbanization, urban runoff generation mechanisms, and integrated urban water system model. It is also pointed out that more researches should be carried out to strengthen the basic theories of urban water management and sponge city technology. In urban hydrology, the changing environment background and complex urban water system pose a great challenge to more comprehensive and elaborate modeling and analysis based on interdisciplinary theories.

Keywords: Urban water management; urban hydrology; hydrological impact of urbanization; runoff process; water system model

Research progress of the intelligent construction of dams

ZHONG Denghua, SHI Mengnan, CUI Bo, WANG Jiajun and GUAN Tao

Abstract: The intelligent construction of dams is essential to comprehensively improve the intelligent management level of dam construction and ensure the quality of dam construction in China. Dam construction in the context of a new era of deep integration and rapid development of new generation information technologies (such as cloud computing, big data, Internet of things, mobile Internet, etc.), artificial intelligence, blockchain, Internet accelerated speed and other technologies Faced with a series of issues such as how to improve the level of intelligent, informationization, digitization and precision, dam intelligent construction is an effective strategic measure to meet these challenges. This paper first analysis the motive force, basic concept and technical connotation of dam intelligent construction. Secondly, it introduces and analyzes the research progress of key theories, methods and techniques in dam intelligent construction. Finally, it discusses the future development direction of dam intelligent construction and trend.

Keywords: Dam; intelligent simulation; intelligent compaction; intelligent grouting; intelligent transportation; intelligent concrete vibration; intelligent temperature control; intelligent integrated platform

The development and prospect of key techniques in the cascade reservoir operation

WANG Hao, WANG Xu, LEI Xiaohui, LIAO Weihong, WANG Chao and WANG Jia

Abstract: Reservoir operation is an important and effective approach to optimal allocation of water resources. It can effectively alleviate natural disasters, such as regional drought and flood. It also plays an important role in supporting sustainable development of water resources strategy. A complete framework on cascade reservoir operation has been formed as a result of theoretical innovation and technological development. The pioneers who are devoted to reservoir operation have carried out plenty of excellent works in both improvement of traditional techniques and theoretical innovations. This paper is aimed to review the development of reservoir operation, summarize the hot issues in the field of reservoir operation at home and abroad, and propose some future potential directions of reservoir operation.

Keywords: Cascade reservoir operation; multi-scale sequential decision; complementation of multiple energies; big data era

Study on safety criteria for the acceptable factor of safety for high earth and rockfill dams

CHEN Zuyu, YAO Shuanxi, LU Xi, YUAN Youren and LI Kangping

Abstract: The current design specification for roller earth-rock fill dams is only applicable to the stability analysis of dam with a height of less than 200m. Based on the current specification, this paper studies the safety factor standards under the normal and seismic conditions for earth and rockfill dams with super height by combining historical experience model and reliability analysis. It has been proved that the safety factor standard of the super height dams should be set between 1.60 and 1.65 in normal conditions and between 1.30 and 1.35 in seismic conditions. Combined with 12 super height dams under construction or being built in China, the feasibility of the above safety criteria is verified. These safety criteria can provide reference and improvement for the revision of the new specifications.

Keywords: Super height dam; safety factor; reliability analysis; safety criterion

Application and optimization of “storing clean water and discharging muddy flow” in the Three Gorges Reservoir

HU Chunhong, FANG Chunming and XU Quanxi

Abstract: The silt problem is one of the key technical problems in the Three Gorges Project. In the demonstration and preliminary design phases of the Three Gorges Project, adoption of the "storing clean water and discharging muddy flow" method was proposed for solving the silt problem. The implementation of reservoir water impoundment in 2003 showed that the reservoir generally follows "storing clean water and discharging muddy flow" scheduling principle and its mode of operation is optimized based on new conditions such as the reduction of upstream water and silt. This study systematically analyzes the advantages and disadvantages of optimization and adjustment of "storing clean water and discharging muddy flow" of operation of the Three Gorges Reservoir, including the effects of the 175m experimental impoundment implemented five years previously, dynamic changes in water level during the flood season, and effects of advanced water impoundment, on reservoir sedimentation and river channel evolution downstream of the dam. In order to providing technical support for the scientific, efficient, and safe utilization of the Three Gorges Reservoir, optimization suggestions for reservoir scheduling aim at forming a new "storing clean water and discharging muddy flow" model and maintaining long term use of the reservoir are proposed.

Key words: Three Gorges Project; silt problem; reservoir scheduling; storing clean water and discharging muddy flow; optimal scheduling

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Management Achievement

The Baise Water Control Project in Guangxi Province, China

Highlights of the Year

1

IWHR took active and effective measures to cope with the COVID-19 pandemic, with several of its departments and individuals praised and awarded by the Ministry of Water Resources for their outstanding contributions to the pandemic prevention and control.

2

IWHR hit another record high of its contract volume in 2020 totaling CNY 1.802 billion (USD 276.49 million), up by 5.1% comparing to 2019, despite the impact of the pandemic, with 1940 new contracts signed. Totally 46 provincial/ministerial-level awards were achieved throughout the year of 2020.

3

iP9000 was successfully applied for the first time in intelligent navigation complex project, marking the expansion of the system's application from a single field of water conservancy and hydropower to more comprehensive fields such as transportation and shipping. SK series and GB series products have been successfully applied in a number of hydropower projects in China and abroad.

4

IWHR is rated Class AAA (the highest class) in the national water conservancy construction market credit evaluation respectively in three categories, namely quality inspection, consultation and goods supply.

5

IWHR provided strong sci-tech support for national development by formulating "China's River Happiness Index Report", conducting soil and water conservation strategy research, undertaking watershed management strategy research and engaging in the preparation of sector and local "Fourteenth Five-Year Plan" on water science and technology.

6

IWHR provided pairing assistance to impoverished areas such as Chongqing municipality as well as Hubei and Sichuan provinces for their poverty alleviation effort in water sector with the provision of professionals and technologies.

7

IWHR were constantly producing outstanding professionals with its professor Chen Houqun, academician of Chinese Academy of Engineering (CAE), winning the honorary title of China's Most Beautiful Scientists in 2020, and another Professor Wang Hao, also academician of CAE, winning the second National Prize for Innovation and Advancement.

8

IWHR made great progress in research platform development. The Test Hall of Flood Control and Disaster Mitigation was officially completed. The field station to observe desert-grassland ecology and hydrology in Inner Mongolia was placed on the priority list of preferred "National field observation and research stations".

9

IWHR remained active in water related international events as it won the bid for the 28th ICOLD Congress and 92nd Annual Meeting in Chengdu, China in 2024, advanced the preparation of the 4th World Irrigation Forum in 2023, and successfully organized IAHR 85th Anniversary Summit.

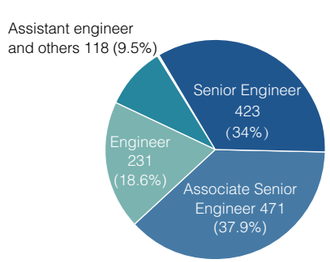
10

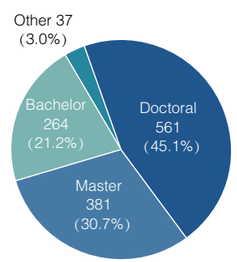
IWHR's international journals kept gaining influence in the global academic community, with its International Soil and Water Conservation Research (ISWCR), got the first official Impact Factor (IF) of 3.770. The Impact Factor for another journal co-hosted by IWHR, International Journal of Sediment Research (IJSR), hit an all-time high of 2.577. Journal of Hydraulic Engineering was chosen as the 2020 Excellent Chinese Academic Journals with International Influence.

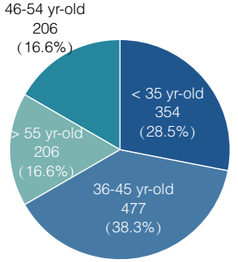
Statistics

Human Resources

By the end of 2020, IWHR has 1243 technical professionals.

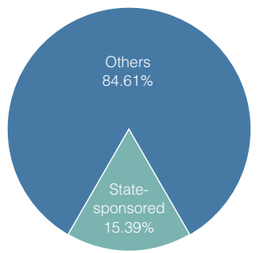




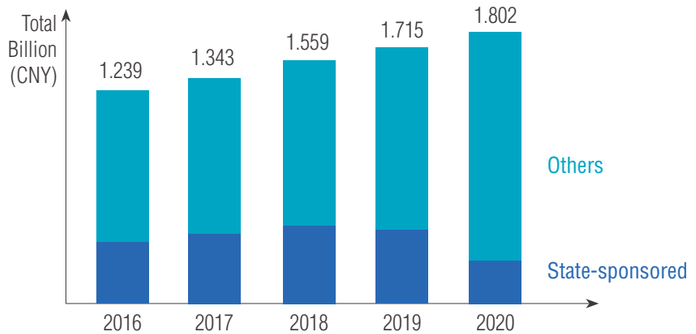


Research Contracts

Research contracts signed in 2020: CNY 1.802 billion in value.



Financial sources of contracts signed in 2020



Awards

In 2020, 46 completed researches are granted provincial/ministerial level prize, including three special prizes.

Type	Amount	Grade
Provincial (ministerial) level	46	Special prize (3)
		First prize (18)
		Second prize (19)
		Third Prize (6)

Some of the prized researches:

- Efficient Operation and Safety Guarantee for Long Distance Conveyance Channel in Alpine Area
- Cloud Computing for Precise Control of Water Environment and Water Ecology in River Basin and Its Application
- Safe and Efficient Construction of High Arch Dam over 300m under Complex Geological Conditions
- Research and Application of Key Technology for Water Ecological Security of the Middle and Lower Reaches of Inland Rivers in Xinjiang
- Hierarchical Allocation and Trading of Water Rights for Coordinated Development of Regional Ecology-Energy-Food
- R&D and Application of Key Technology for Safety Evaluation and Early Warning of Dam Projects
- Safe and Efficient Irrigation with Reclaimed Water and Its Application
- Refined Intelligent Management and Control of Large-scale Water Projects
- Intelligent Tunneling with Rock Tunnel Boring Machine (TBM) and Its Application
- Intelligent Compaction Technology of Embankment Dam and Its Engineering Application
- Key Technology for Houziyan Super High CFRD in High Seismic Area with Narrow Valley and Its Application
- Bed Load Transport Law of Cascade Hydropower Stations in Lower Jinsha River and Its Application
- Evolution Mechanism and Coordinated Regulation of Vegetation-Hydrology in Loess Plateau
- High Stability and Wide Range Operation of Large Francis Turbine and Its Application
- Anti-Cracking Temperature Control of Low-heat Cement Concrete and Efficient Construction of Wudongde High Arch Dam
- Specification for evaluating durability of hydraulic concrete structures
- Dynamic Adjustment of Mix Ratio for Cemented Material Dams with Materials from Extensive Sources and Its Safety Assessment
- Safety Evaluation for Hydraulic Tunnels under the Coupling Effect of High Stress and High Water Pressure
- Movement Mechanism of Complex Saltwater Intrusion and Key Technology for Saltwater Tide Control in Pearl River Estuary
- Key Technology and Equipment for Double Shield Bolt-shotcrete TBM under Complicated Geological Conditions
- Research and Demonstration of System Equilibrium Theory and Key Technology for Sponge City Development
- Measuring Method and Technology for Improvement of Watershed Resources-Environment-Ecology Coordinated Carrying Capacity
- Technology and Application of Risk Simulation and Dynamic Evaluation of Real-time Flood in Complex Flood Control Areas
- Key Technology for Joint Dispatching of Surface Water and Groundwater
- Research and Application of Key Technologies for Water Quality and Water Ecology Risk Response in South-to-North Water Diversion Project
- Research and Application of Key Technologies for Ecological Improvement of Rivers and Lakes in Water-rich Areas in South China
- Theoretical Innovation, Technological Development and Application of Precise Field Irrigation Control

Intellectual Properties

IWHR obtains 421 patents in 2020, including 297 inventions, 112 utility models, 11 new international patents and one design patent, participates in the editing of 28 technical codes, and also publishes 66 books and 686 papers.

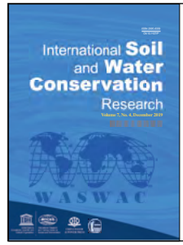
	Patents				Technical codes		Books	Papers
	Inventions	Utility models	International	Design	Chief edited	Co-edited		
Amount	297	112	11	1	19	9	66	686

Journals

Journal of Hydraulic Engineering

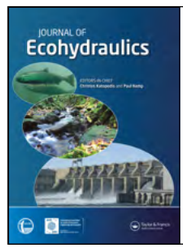
Journal of China Institute of Water Resources and Hydropower Research

International Journal of Sediment Research

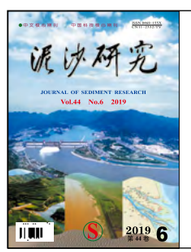


International Soil and Water Conservation Research

China Flood and Drought Management



Journal of Ecohydraulics



Journal of Sediment Research

Mechanical & Electrical Technique of Hydropower Station

International Cooperation

International Exchange

IWHR successfully convened the IAHR 85th Anniversary Summit with participants from over 30 countries online and offline.

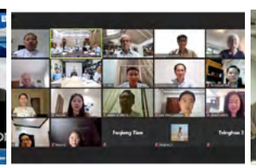
IWHR exchanged warm greetings with its overseas partners and sent medical supplies to those in need during the COVID-19 Pandemic.

IWHR talked with IHA President Roger Gill online on sustainable development of hydropower and two-party cooperation.

IWHR hosted an online conference with the Ministry of Natural Resources and Environment of Laos DPR on deepening bilateral cooperation and promoting Hydraulic Elevator Dam (HED) technology.

Experts successfully organized and implemented the flash flood disaster prevention drill in Xixia County using its new early warning technology.

In honor of the United Nations World Water Day, IWHR and IAHR jointly organized a special online event on Hydro-environment Engineering and Adaptation to Climate Change.



IWHR, together with Tsinghua University, organized an online seminar on the jointly completed project Drought Characteristics of Lancang-Mekong River Basin and the Impacts of Reservoir Regulation on Streamflow.

IWHR organized an online seminar on Flash Flood Risk Management and launched the Flash Flood Prevention Program (FFP) with the joint sponsorship of University of the Cote d 'Azur, France.

The 17th IWHR-KICT Joint Seminar on Construction Technology was hosted in the form of a series of in-person and virtual meetings at the two sides.

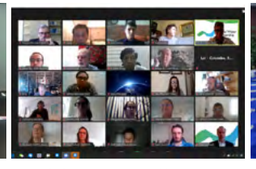
IWHR attended the 71st International Executive Council Meeting during which another four Chinese Irrigation Projects were enlisted as the World's Heritage Irrigation Structures.

IWHR attended the 12th AWC Board of Council Meeting.

IWHR-stationed WASWAC, together with Dalian University of Technology, organized a Webinar on Land Degradation, Soil Conservation and Sustainable Development as preview for the LASOSU2021.

IWHR Professor JIA Jinsheng, also CHINCOLD Secretary-General, made a speech at the Hydro2020 online meeting.

Belt and Road River and Lake Ecological Protection Technology Joint Training Center was established by IAHR in cooperation with several other institutes and organizations.



IWHR Professor JIANG Yunzhong, Secretary General of GWP-China, led the Chinese delegation to attend the First GWP Virtual Regional Days 2020.

IWHR took part in the 12th Joint Steering Committee Meeting of China-Europe Water Platform.

Partnership with Cooperative Agreements

2020 IWHR Global Connections

In 2020, IWHR connected with more than 170 countries and regions virtually.

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HYDROPOWER RESEARCH

The Danjiangkou Water Control Project in Hubei Province, China

Appendix

Organizational Structure

President and Vice Presidents		
Commissions	• Academic Commission • Board of Professional Title Assessment	• Board of Academic Degree Assessment
Administrative Divisions	• General Office • Division of Personnel, Labor and Education • Division of Research, Management and Planning • Division of International Cooperation	• Division of Finance and Assets Administration • Division of Supervision and Audit • Division of Platforms and Infrastructure (Office of State Key Lab)
Research Departments	• Department of Water Resources • Research Center on Flood and Drought Disaster Reduction • Remote Sensing Technology Application Research Center • Department of Water Resources History • Department of Water Ecology and Environment Research • Department of Irrigation and Drainage	• Earthquake Engineering Research Center • Department of Geotechnical Engineering • Research Center for Sustainable Hydropower Development • Department of Structures and Materials • Department of Sediment Research • Department of Hydraulics • Department of Water Resources for Pastoral Areas
Division of Comprehensive Business	• Graduate School • Standardization Research Center	• Information Center • Office of Retirement Services
Enterprises	• Beijing IWHR Corporation • Beijing IWHR Technology Co., Ltd. • Beijing IWHR-KHL Co., Ltd.	• Tianjin Institute of Hydroelectric and Power Research • Beijing Zhongshui Runke Certification Co., Ltd.
Secretariats of International Organizations	• World Association for Sedimentation and Erosion Research (WASER) • World Association of Soil and Water Conservation (WASWAC) • Chinese National Committee on Large Dams (CHINCOLD) • Chinese National Committee on Irrigation and Drainage (CNCID)	• International Association for Hydro-Environment Engineering and Research (IAHR) • Global Water Partnership (GWP) China • China Office of International Hydropower Association (IHA) • International Conference on Flood Management (ICFM) • China River Restoration Network (CRRN)

Research Divisions

Department of Water Resources

Fundamental and applied research on the theories and applications in hydrology and water resources, including the fundamental theories and simulative technologies of water cycle, the assessment, planning, allocation, saving, regulation, management, protection and macro-strategy research of water resources, and the consulting and international cooperation in related fields.

Research Center on Flood and Drought Disaster Reduction

Research on key issues of flood control, drought relief and disaster reduction, including disaster formation mechanism, forecasting and warning, risk assessment, management and rescue technology of risk and emergency.

Department of Water Ecology and Environment Research

Evolution mechanisms and simulation technologies of water environment and ecology; methods and standards of assessment and monitoring, as well as protection and recovery technologies of water environment; guarantee technologies of drinking water safety; environmental impact assessment of projects; theories and information technologies of water environment management.

Department of Irrigation and Drainage

Strategies, planning and related standards of water resources development in rural areas; water. efficiency irrigation and management technologies of farmland water and soil environment; research, equipment development, transfer, promotion and application of water supply technologies in rural areas; quality inspection and product certification of equipment

Earthquake Engineering Research Center

Theories and anaiysis method of earthquake engineering; the arch dam and gravity dam seismic research; dynamic test of stuctures and equipment; monitbring and forecasting of reservoir earthquake; anti-sarthquake analysis and safety assessment of electrical and nuclear power equipment.

Department of Geotechnical Engineering

Property study of geotechnical materials; behavior simlation, safety assessment and centrifugal testing of geotechnical structures such as embankment dams, high slopes and underground tunnels and chambers.

Department of Structures and Materials

Temperature stress and control of hydraulic structures; numerical, visual and digital simulation of projedts; safety monitoring and inspection; anti-seepage, repair and reinforcement of projects.

Department of Sediment Research

River channel evolution and improvement; reservoir sedimentation and regulation; conservation and control of water and soil; sediment issues in estuary, coastal and hydraulic projeds; prevention and control of sediment disasters; fundamental theories and simulation technologies of sediment movement.

Department of Hydraulics

Hydraulics of high-velocity flow, flow-induced vibration and project layout; hydraulic controi and ice dynamics; cooling water and cooling tower research for thermal and nuclear power projects; river and ecological hydraulics; hydraulic prototype observation and equipment development.

Research Center for Sustainable Hydropower Development

Strategies, policies, planning and key technologies of sustainable hydropower development, including the theories, methods and assessment system of hydropower sustainability (green hydropower); strategic planning of hydropower development; ecological protection and reservoir resetlement policies of hydropower projects.

Remote Sensing Technology Application Research Center

Flood monitoring, forecasting and risk management system; drought monitoring evaluation and early warning system based on remote sensing; rivers and lakes monitoring system based on remote sensing; water and soil conservation monitoring and evaluation based on remote sensing; water environment-ecology information extraction and analysis software platform.

Department of Water Resources History

Research on water resources history and water conservancy archives; theoretical and technical research on protection of water resources heritage, survey and design of water works heritage protection; regional water culture; popular science education on water conservancy history, technical consultancy on relevant technical standards, planning and designing.

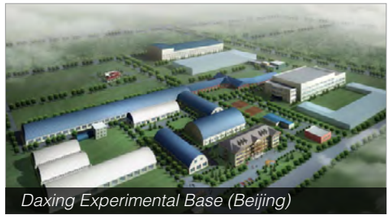
Department of Water Resources for Pastoral Areas

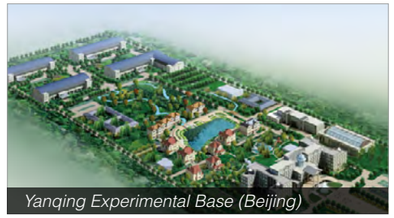
Water resources and water environment for pastoral areas; water-efficiency irrigationo and drainage, conservation of water and soil, and ecological recovery of grasslands; clean energy development and utilization, as well as water supply equipment, for pastoral areas.

Scientific Research Bases


Technology Innovation Base (South, Beijing)


Technology Innovation Base (North, Beijing)


Daxing Experimental Base (Beijing)

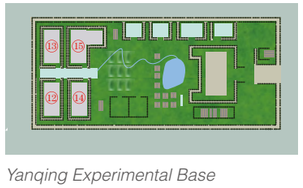

Yanqing Experimental Base (Beijing)


Base of Water Rescources for Pastoral Areas (Inner Mongolia)


Tianjin Institute of Hydroelectric and Power Research (Tianjin)

Laboratories in Daxing and Yanqing bases include:

Daxing Experimental Base



Yanqing Experimental Base

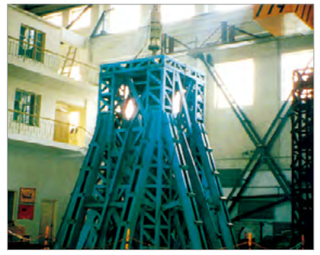
(1) Laboratory of Water Cycle and Deployment
(2) Laboratory of Water-Sediment Regulation and River Training
(3) Laboratory of Soil and Water Conservation
(4) Laboratory of Fundamental Theoretical Research on Sediment Transport
(5) Laboratory of Hydraulics
(6) National Center for Efficient Irrigation Engineering and Technology Research - Beijing
(7) Laboratory of Rural Drinking Water Safety, NCEIR
(8) National Center for Quality Supervision and Test of Agricultural Irrigation and Drainage Equipment
(9) Laboratory of Hydraulic Regulation
(10) Laboratory of River Environment
(11) Hydraulic Machinery Laboratory
(12) Laboratory of Automatic Control and Simulation
(13) Laboratory of Quality Inspection and Simulation for Speed Governing System of Small Hydro
(14) Integrated Laboratory of Engineering Technology on Water Resources and Soil-Water Conservation
(15) Integrated Laboratory of Engineering Mechanics

Large Equipment


Vacuum tank (vacuum percentage 98.7%; flow discharge 1.0 m³/s)


Universal test stand of advanced hydraulic machinery model


LXJ-4-450g-t geotechnical centrifuge


Tri-axial earthquake simulating shaking table with 6 degrees of freedom


15000 KN universal testing machine

Creep testing system for fully-graded concrete


Hydraulic flume and water tank


Eddy covariance system


Multi-functional GC-MS machine

Application Brochure for International Students

Graduate Education

IWHR started its graduate education in the 1950s and has excellent research facilities and equipment, a large number of cutting-edge research projects, adequate research funding, numerous literature resources, a top-notch team of graduate supervisors (172 master's supervisors and 89 doctoral ones). After more than 6 decades of exploration and development, IWHR has established a complete and unique system of graduate education.

Degree Programs in English

8 programs for master's degree and doctoral degree:

- Geotechnical Engineering
- Hydrology and Water Resources
- Hydraulics and River Dynamics
- Hydraulic Structure Engineering
- Hydraulic and Hydropower Engineering
- Hydro-Environment
- Hydro-informatics
- Water Disaster and Security

The applicants must satisfy one of the following language requirements:

- Graduates from universities of English-speaking countries;
- Graduates from universities where English is the official language;
- TOEFL: 80 (internet-based test)/ IELTS: 6.0.

Duration of study:

- At least 2.5 years for master's degree and 3 years for doctoral degree.

Fees

- Application Fee: Free in 2021
- Annual Tuition: CNY 26,000-CNY 39,000
- Annual Accommodation: CNY 24,000
- Annual Insurance: CNY 800

Scholarships

IWHR outstanding international student scholarship

In 2021, scholarships of up to CNY 113,600 per year are available for outstanding applicants, including all or part of the following items:

- Waiver of the fees of tuition, accommodation and medical insurance;
- Living stipend of up to CNY 49,800 per person per year.

Category	Scholarship Grade	Waiver of Tuition	Waiver of Accommodation	Waiver of Medical Insurance	Living Stipend	Total
Master	I	26000	24000	800	38400	89200
	II	26000	24000	800	19200	70000
	III	26000		800		26800
Ph.D.	I	39000	24000	800	49800	113600
	II	39000	24000	800	24900	88700
	III	39000		800		39800

Unit: CNY (1 USD = 6.6 CNY), in Nov. 2020

How to Apply

General information

- Application is open only to non-Chinese citizens who are in good health.
- Educational Background and Age Limit.
- The applicant for a master's program must be under the age of 35 and has a bachelor's degree.
- The applicant for a doctoral program must be under the age of 40 and has a master's degree.

Application Methods

- Applicants for academic degree programs shall submit application documents to iwhrgraduateoffice@163.com.

Required application documents

- See details at http://www.iwhr.com/IWHR-English/index.htm.

Application Deadline

- Applicants for academic degree programs shall submit their acceptable application materials before **May 31, 2021.**

Admission Notice Time

- Between **June 10 and July 15, 2021.**
- Beginning of the Semester.
- In **early September 2021**(See the specific date on the admission notice).

Contact Us

- Office of International Student Affairs, Graduate School
- China Institute of Water Resources and Hydropower Research
- 20 Chegongzhuang West Road, Haidian District, Beijing, P.R.China
- Zip Code 100048
- Telephone: +86-10-68786859
- Fax: +86-10-68785988
- E-mail: iwhrgraduateoffice@163.com

Beijing IWHR Corporation

History

BIC was a wholly-owned subsidiary of China Institute of Water Resourcs and Hydropower Research (IWHR) with 2 million yuan registered capital in 1992. It was just an external window of IWHR. Then, The registered capital increased to 60 million yuan in 2014. With the development, we get six departments, one branch and three holding companies in 2020. The business of our company mainly includes technical product research, contracting projects and producing production and sales.

1992 Begin

2014 Development

2020 Going Global

Main Business

- Engineering Design Research
- Safety Monitoring
- Testing and Evaluation & Anti-seepage
- Consolidation of Special Foundation
- Engineering Safety Information

Beijing IWHR Corporation
Address: 20 Chegongzhuang west Road, Beijing, 100048
E-mail: weixi@iwhr.com
Website: http://www.bic-iwhr.cn/

Main Product

Hydraulic Elevator Dam

Our Hydraulic Elevator Darm mainly uvercame the problems such as safely dischary e, operation inwinter, simple uperation,- flotage, sedimentation, pier, investment, ground settlement and landscape, which occur on steel gate, flap gate, pneumatic gate and rubber dam.

It's widely used in water conservancy and hydropower projects for irrigation, expansion of reservoir capacity and block tidal.

Hydraulic elevator dam technology has obtained more than twenty series of patents for Invention, Utility Model and Appearance issued by the China State Intellectual Property Office.

This technology is widely used in domestic market and Southeast countries, such as Myanmar, Thailand and Bangladesh. There are dozens of completed projects. The highest one is located in Guizhou province, which height is 5m, used for increasing the water head for hydropower generation.

The longest one is in Myanmar, which length is 261m, used for irrigation. In Jilin province, there are 6 sets of HED along Mudan river for cascade development to improve city landscape.

Main Product: Containerized Water Treatment Plant

Consultation, Engineering and Construction For:

•Municipal Sewage Treatment

•Water Supply Projects

•Safe Drinking Water treatment

Gullubag Hydropower Plant in Turkey

Generator Floor of Gullubag Hydropower Plant in Turkey

Generator Floor of Kozbuku Hydropower Plant in Turkey

Kozbuku Hydropower Plant in Turkey

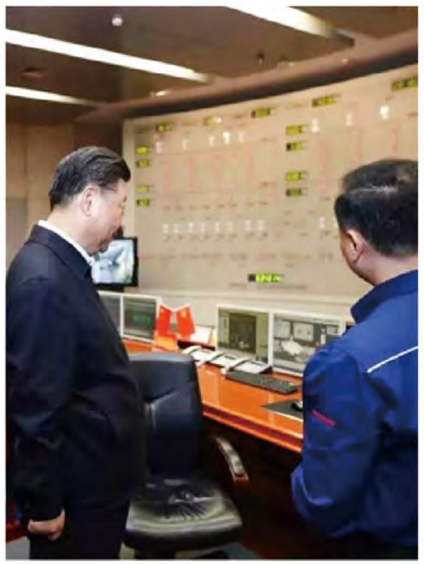
Beijing IWHR Technology Co., Ltd.

History and Business Scope

Beijing IWHR Technology Co., Ltd. is an advanced and new technology enterprise, founded on Dec. 23rd, 2004, a joint venture between China Institute of Water Resources and Hydropower Research (IWHR) and China Three Gorges Corporation (CTGC).The company is formed on the basis of the original Department of Automation and Departrment of Hydraulic Machinery of IWHR, and the staff are the optimum composition of all technical and the management backbones.

By the end of December, 2020, the number of employees in the company is 281, and among which, master's degree or above are 87, bachelof degree are 158, and 87% possess bachelor degrees or above; and 30 are professor engineers, 56 are senior engineers and 44 engineers; 1 person is entitled to the special allowance of the State Council and 1 person was selected for New Century Talents Project. It also has six research and development (R&D) teams in key areas with doctorate and master degrees awarding units on water resources and hydropower engineering.

The company's primary service includes the research, development and manufacture of related technologies on computer monitoring and centralized control for water conservancy, hydropower and new energy, turbine governor and auxiliary control, hydrological monitoring and forecasting system, reservoir dispatching automization, informatization, hydraulic machinery and electromechanical equipment, unit operation support, hydro-mechanical experiment, as well as system integration package, EPC(Engineering、Procurement、Construction), consulting and services, etc.

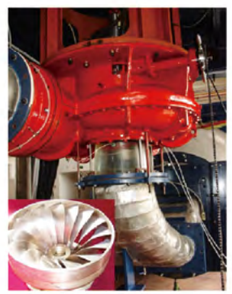


President Xi Jinping Listened to the Report in front of the H9000 System Monitor at the Control Center of the Three Gorges Hydropower Station

Vice Premier Wang Yang Investigated at the Laboratory of Computer Monitoring System

The Cascade Dispatching Center Controlling the Three Gorges, Chengdu City and Jinsha River

Meteorological Telemetry Station for Rainfall and Water Level in Yalong River Basin



Model Unit and Model Runner of Hydraulic Turbine

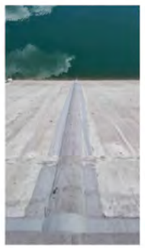
Test Bench for Hydraulic Mechanical Model

Beijing IWHR-KHL Co., Ltd.

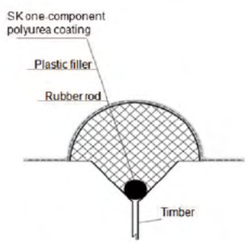
Company Introduction

The Beijing IWHR-KHL Co., Ltd. (IWHR-KHL) was founded in 1993 as a technology-oriented enterprise. With the technical support of IWHR, the Company has developed the GB waterstop structure and the brush-coated flexible waterstop structure as well as a series of GB waterstop materials, which have been successfully applied in more than 100 Concrete faced rockfill dams (CFRDs) in the world, such as Shuibuya, Zipingpu, and Liyuan in China, Bakun in Malaysia, Nam Nugm II in Laos, Mazar in Ecuador, Gelevard in Iran, Merowe in Sudan, Glendoe in Scotland.

Typical Waterstop Structures for CFRDs



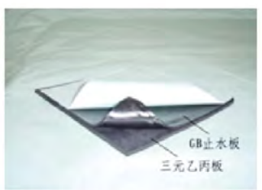
Mechanized installation of GB waterstop materials



Extrusion molding of GB plastic filler

Typical GB Waterstop Materials

GB plastic filler



GB EPDM composite cover

Corrugated rubber waterstop

Integrated construction technology for GB waterstop materials

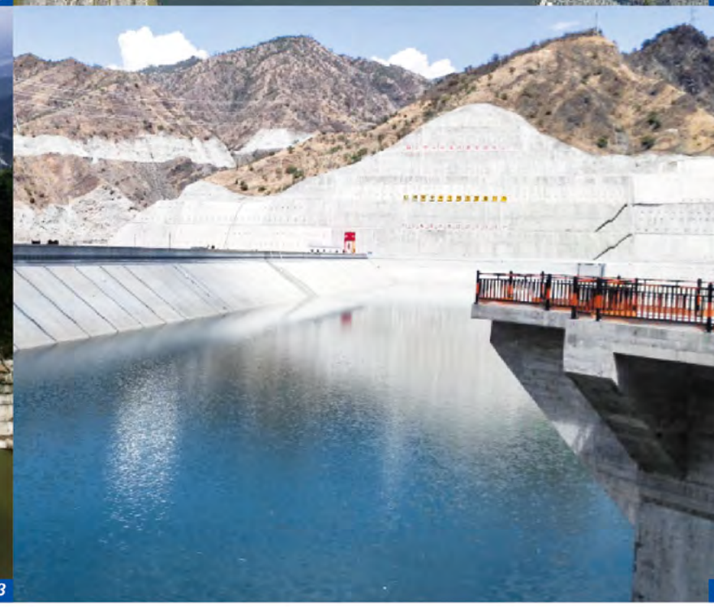
Mechanized installation of GB waterstop materials

Extrusion molding of GB plastic filler

1

2

3



4

Applications of GB waterstop materials at Typical CFRDs

1 *Shuibuya CFRD of 233m high is the highest CFRD in the world. The total leakage is less than 60L/s.*

2 *Bakun CFRD of 203.5m high is the highest CFRD in Southeast Asia. The total leakage is less than 80L/s.*

3 *Zipingpu CFRD of 156m high has successfully withstood the 2008 Wenchuan Earthquake (Ms=8.0). The total leakage after the earthquake is less than 50L/s.*

4 *Liyuan CFRD of 155m high is the first one to use in large scale brush-coated flexible waterstop in the world. The total leakage is less than 30L/s.*

TJINST | Tianjin Institute of Hydroelectricand Power Research

Introduction and Business Scopes

Tianjin Institute of Hydroelectric and Power Research was built in 1979. In 2002, according to the requirements of the reform of the national science and technology system, it was placed under the administration of China Institute of Water Resources and Hydropower Research (IWHR).

Main Business are as follows:

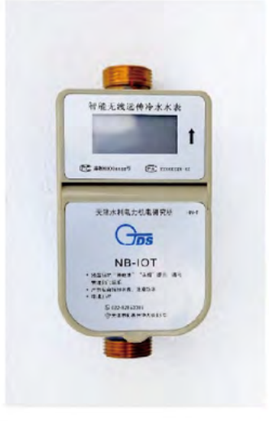
- High efficiency hydraulic machinery (pump) technology
- Intelligent Pump and energy-saving technology
- Intelligent sensor based on IoT (Internet of things) of water conservancy
- Automation components and equipment
- Automation control system
- Network security protection technology of industrial control systems
- Inspection and evaluation of power transmission and distribution equipment, hydraulic mechanical, electrical and metal structure equipment
- Equipment and techniques for disaster prevention and rescue

High efficiency and energy saving laboratory of pump

High efficiency and energy saving laboratory of pump

Network security attack and defense confrontation display platform of industrial control systems

Inspection and evaluation of power transmission and distribution equipment



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IWHR

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AND HYDROPOWER RESEARCH