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# 水利学报

SHUILI XUEBAO

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

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**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.

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

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

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**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

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

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**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

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

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**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

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## Research progress of the intelligent construction of dams

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**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



## Research progresses and key technologies of CFRD construction

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**Abstract:** The history for the development of concrete faced rockfill dam (CFRD) in China is briefly described. Progresses in the studies of material properties of rockfill and numerical analysis of dam were summarized from the aspects of gradation, strength, deformation, creep and simulation of contact interface, creep analysis and simulation computation, etc. By focusing on dam safety, the key technologies of CFRD construction were analyzed with the consideration of dam seepage, rockfill deformation control and the mechanism of face slab rupture.

**Keywords:** concrete faced rockfill dam; material testing; numerical analysis; seepage safety; deformation control; face slab rupture

## Technical achievement and prospection in irrigation scheme development and management in China

GAO Zhanyi

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**Abstract:** Since the foundation of the People's Republic of China in 1949, remarkable achievement has been realized in the development and management of irrigation schemes during the last 70 years. The irrigated farmland has been developed from 15.93 million ha in 1949 to 67.14 million ha in 2016. With the largest irrigated farmland in the world the irrigated agriculture in China has guaranteed the food security and social economic development for China. The construction and management of irrigation schemes in China have experienced 3 main stages, and various problems have appeared and have been gradually solved with the progresses of science and technology. Next 30 year is the period to realize the modernization of irrigation schemes in China. This paper presents the general introduction on irrigation scheme construction and management in last 70 years, achievement and technical progress, the main problems and challenges and the projection for the modernization of irrigation schemes in next 30 years in China.

**Keywords:** Irrigation scheme development; irrigation scheme management; irrigation technology; irrigation water management; irrigation scheme modernization

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## Progresses and challenges in the study of Eco-fluvial Dynamics

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**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

## Research progress of relation structure-oriented set pair analysis in water resources

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**Abstract:** Intelligent analysis of complex system of water resources–social economy–ecological environment is an important research frontier in the progress of hydro science and socioeconomic development. From the perspective of connection and transformation between certainty and uncertainty, relation structure-oriented set pair analysis provides a basic approach for overall, detailed and dynamic analysis of water resources complex system. That is of great significance to quantitatively deal with the certain and uncertain problems in water resources complex system. Based on the connotation of relation structure characteristics of set pair analysis, this paper pointed out that the set pair analysis in water resources was a developing research field according to bibliometric analysis, which mainly focused on water conservancy project, civil engineering and resources science. Furthermore, the main hotspots were the determination methods of connection degree and connection number in set pair analysis, the prediction and evaluation methods for water resources analysis, and their applications in carrying, utilization and security of water resources, also the coordinated development between water resources and economic society. And then, the research progresses of relation structure of set pair analysis in water resources, set pair prediction, set pair evaluation, and set pair decision-making and control in water resources were summarized. Moreover, the corresponding future development trends were expatiated. This study can promote the development of set pair analysis in water resources, and also can provide an important theoretical support for the analysis and management of water resources complex system.

**Keywords:** water resources complex system; set pair analysis in water resources; relation structure; connection number; prediction and evaluation; decision-making and control

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

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**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

## Summary and prospect of human–water harmony theory and its application research

ZUO Qiting

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**Abstract:** Human–water relationship is one of the most important relationships between human and nature. Human–water harmony is an ideal human–water relationship pursued by human beings. The theory of human–water harmony is a new theory and method to study the issue of human–water harmony. It is of great significance to summarize the development and main contents of the human–water harmony theory systematically. Based on the background and research process of human–water harmony theory, this paper divided the development process of human–water harmony theory into three stages: the pre–2005 embryonic stage; the formative stage from 2006 to 2017; the post–2018 development stage. On the basis of the systematic summary of the existing research results, the system framework of human–water harmony was put forward, including theoretical system, methodology and application practice. The author proposed the basic principles and criteria of human–water harmony by summarizing main contents of the system framework of human–water harmony systematically. Based on that, combined with the analysis of previous research results, the development trend and application prospect of human–water harmony theory was predicted. It provides a reference for further theoretical research and practical application of the human–water harmony theory.

**Keywords:** human–water harmony; human–water harmony theory; human–water system; the development history

## The advances of engineering hydrology in China

RUI Xiaofang

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**Abstract:** Before the 17th century, the observation of hydrological phenomena and the understanding of hydrological cycle by Chinese ancestors were at the contemporary leading level in the world. In the period of quantitative hydrology, China lost the opportunity to develop hydrology synchronism with the world due to the failure to pay attention to and absorb the experimental and theoretical paradigms that promote the rapid development of science. After 1949, with the rapid social and economic development in China, especially driven by the large-scale construction of water conservancy and modern ecological civilization, hydrology in China has not only keep pace development with the world, but also made some innovative achievements in such fields as watershed hydrological model, and design flood theory and method. Nowadays, in the era of deep informatization, big data and intelligence, the simulation paradigm and data-intensive paradigm are triggering a new scientific and technological revolution, and the development of hydrology has entered a good situation. In the future, physical hydrology, random hydrology, simulation hydrology and data hydrology will be complementing and integrating development each other, and its supporting role to socioeconomic development will be more prominent.

**Keywords:** ancient hydrology; engineering hydrology; hydrologic model; Xin'anjiang Model; design flood

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

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**Abstract:** The continuous uplifting of Qinghai-Tibet Plateau results in the river incision on the margin of Qinghai-Tibet plateau. 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