Advances in River Sediment Research

Editors: S. Fukuoka, H. Nakagawa, T. Sumi & H. Zhang

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Advances in River Sediment Research

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Local scour & erosion

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Preface

Sediments, which constitute the surface of the Earth, start their journey to rivers with the energy obtained from rainfalls, floods and other natural processes. Due to transport of sediments, rivers develop with various appearances and functions, and play a crucial role in the activities of human beings and the life cycles of other species. The intrinsic values of rivers include disaster mitigation, water resources and riverine environment. Over the past century, a lot of engineering practices have been implemented to control floods and other disasters related to rivers. Later on, efforts have been made to construct new hydraulic structures and to seek more effective operation methods to satisfy the increasing demand on water resources. Since this century, river managers have been increasingly turning from hard engineering solutions to environmental restoration activities all over the world. To take the maximum benefits of rivers, the management of river sediment is one of the most important considerations. On the other hand, sediments carried by flood water may sometimes trigger catastrophic disasters. River sediment, as a conventional topic for river management, has been the topic of continuing research since ancient times, and since then significant progresses in river sediment research has been made. Nowadays, river sediment is much more connected to the activities of mankind and other species, following the increasing awareness of the coexistence of humans and nature. There are significant progresses in river sediment research from a wide spectrum of professionals and disciplines, ranging from fundamental studies in laboratory experiments to applied research in actual rivers, from specific methods to integrated approaches, from local problems to global issues and from academic perspectives to policy implications.

Organized triennial from 1980 under the auspices of UNESCO-IRTCES (International Research and Training Center on Erosion and Sedimentation), the ISRS (International Symposium on River Sedimentation) symposia have been successfully held in China, USA, Germany, India, Egypt, Hong Kong (China), Russia and South Africa. The ISRS symposium series are an official event of WASER (World Association for Sedimentation and Erosion Research) and have become one of the most influential events for the world's sediment professionals and have provided an important forum for scientists, engineers, practitioners and policy-makers to exchange ideas, shear information and make collaborations. As one of the most active research/education centers in river sediment and the world well-known convention city, Kyoto has the honor to hold the 12th International Symposium on River Sedimentation (ISRS2013) and to welcome sediment professionals from all over the world to this ancient Japanese capital.

Japan is covered 70% by mountains and the remaining 30% by plains. High mountain ranges run through the center of the Japanese island and only 5% of its land is suitable for human settlement. Due to its unique natural, geological and topographical conditions, Japan is a country with high rainfalls and steep-slope rivers. A significant amount of sediments are generated and transported during heavy rainfalls, in terms of erosion in the mountains, incision of the valleys and deposition on the floodplains. Rainfalls play an important role in the evolution of the Japanese land topography. Residential areas are widely distributed from mountainous regions to floodplains, in particular, most of the populated urban areas are laid on low lands. Consequently, there are lots of floods and sediment disasters in Japan. Under these natural and social conditions, river sediment research has flourished a long time before and is a main topic in river engineering. Hereafter, an overview of the Japanese research on river sediment is briefed.

Sediment yield and debris flow in mountainous areas triggered by heavy rainfalls are conventional topics in Japanese sediment research. Recently, integrated approaches incorporating rainfall and runoff, sediment yield, sediment transport, channel formation and bed evolution are investigated to predict the movement of sediments, formation and evolution of landscapes. The results are furthermore considered to be used as upstream sediment boundary conditions for rivers in the low land areas. Moreover, researches are in progress on integrated sediment management methods to harmonize the disaster mitigation and environment restoration in river basin scale as well as sediment transport and bed evolution of gravel bed rivers focusing on the transport mechanism of bed materials dominated by boulders. The transport of heterogeneous sediments is a great concern in the bed evolution process and research progresses are also

remarkable with laboratory experiments, field surveys and numerical simulations. Significant achievements are also made on the interaction between sediment transport and hydraulic structures such as the failure process of river embankments and local scour around hydraulic obstacles. The associated mechanisms and underlying processes are gradually understandable with the aid of the studies on fundamental physics to large scale field experiments, the accumulation of a tremendous amount of valuable data as well as the advancement in numerical simulation technologies.

The dimension of rivers is longitudinally dominant, which highly provoked the development of 1D and 2D numerical models. Nevertheless, the plan forms and the longitudinal/transverse cross-sections of rivers exhibit a diverse nature due to different topographic features of various scales and types. There is a strong need to resolve the problem in a framework accounting for the equal importance of the longitudinally dominant reach and the area dominated by local 3D flows. Quasi-3D numerical models have been developed to simulate the flood propagation process and the local flow as well as the bed deformation around river obstacles. The flood water is basically simulated with 2D shallow water equations, while in the 3D flow dominant area, the near-bed velocity and non-hydrostatic pressure responsible for bed sediment transport are obtained without introducing the assumption of the shallow water. The models have been successfully applied to simulate complex flow fields and bed deformations in laboratory flumes. Attempts have also been made to simulate local flow phenomena in actual rivers and the results were much encouraging. Efforts are still ongoing to enhance the model applicability in field situations with a high accuracy. In the field of numerical simulation, the Euler-Lagrange formulation is emerging as a new power in predicting sediment transport in river flows. In this formulation, the turbulent flow is described in the Eulerian frame, while the movement of sediment particles of various properties are described following the basic mechanical laws in the Lagrangian frame. As a result, the detailed flow structure and the behavior of individual particles are resolvable. As the mechanisms of bed changes and sediment movements are not directly obtainable during the floods in rivers, the simulation results provide visible and valuable information. It is expected that the advancements in this method adds new perspective to classic sediment hydraulics and deepens our insight into the mystery of the river sediment.

Monitoring the longitudinal bed changes during flood events is very difficult. Hence, indirect measurement techniques provide an alternative solution. As the temporal variations of water surface profiles are influenced by the evolution of the channel bed, there is a possibility to estimate the bed changes based on the information of the water surface profiles. As is known, the temporal variations of the water surface profiles are readily obtainable with 2D and/or quasi-3D numerical models. If the predicted temporal variations of the water stages are tuned to be consistent with those of the observed data, the corresponding bed elevations and bed changes become available. This method is now adopted in the management of some rivers in Japan.

Sediment management in reservoirs is our challenging issue. In Japan, about 3,000 dams have been constructed for irrigation, municipal water, hydro power and flood control, but the total reservoir storage capacity is only 23 billion m^3. In order to sustain limited storages and achieve sediment passage as much as possible, advanced comprehensive management techniques such as sediment flushing, bypassing, sediment augmentation and hydro-suction sediment removal systems are under developing. These techniques will greatly contribute to both sustainable water resources management and integrated management in sediment routing system.

Research on the environmental and ecological implications of sediment is also a major branch in the Japanese sediment community. Attentions are mostly paid to the sediment problems due to vegetation and forestation, river restoration with neo-natural rehabilitation methods, changing characteristics of bed morphology, substrate and ecosystem downstream of river-crossing structures such as dams, river management methods to enhance environmental diversity and so on. In addition, research results have been widely implemented in actual rivers. The monitoring and post-assessment research are also widely published in the Japanese literatures.

It is noted that the research in Japan is conducted not only to solve problems from the viewpoint of academic advancements, but also to contribute to the management of actual rivers. The results will be intensively presented during ISRS2013, which provides an opportunity for Japan to share its research results and experiences with other parts of the world, and vice versa. The knowledge to be exchanged in the symposium will be a property and contribute to the prosperousness of our river sediment community.

The Local Organizing Committee of ISRS2013 received 448 abstracts from 36 countries/regions, of which 435 were asked to submit their full papers after the first-round of peer review by 50 members of the Review Board. The full papers submitted to the symposium were then peer reviewed for the second round by 185 experts from all over the world. Each paper received reviewing from three independent individuals. Based on the comments of the reviewers, the Review Board finally selected 274 papers to be included in

this book. The accepted contributions, together with 2 keynote papers, cover a broad spectrum of river sediment related issues such as sediment yield, sediment transport and morphology in rivers and lakes, local scour and erosion, reservoir sedimentation and management, sediment in estuarine and coastal area, environmental and ecological aspects of sediment, modeling and measurement techniques, sediment related disasters and integrated sediment management. All papers included in this book are presented by the corresponding authors during the 4-day symposium either in oral or in poster presentations.

A Workshop on International Sediment Advancements is launched on the second day of the symposium. The inter-organizational workshop, organized under the auspices of UNESCO-IHP-ISI, is devoted to disseminate beyond the limits of each membership the most significant progresses attained by several scientific associations operating in the field of sediment research and management. These associations include WASER, IAHR (International Association for Hydro-environment Engineering and Research), IAHS (International Association of Hydrological Sciences), ISI (International Sediment Initiative) and ICOLD (International Commission on Large Dams). The workshop is proposed by Prof. Giampaolo Di Silvio whose enthusiasm and effort are sincerely acknowledged.

We would like to express our sincere gratitude to our colleagues who submitted abstracts and papers to ISRS2013, the paper reviewers who made in-depth reviewing amidst their busy schedule, the advisory, scientific and local organizing committee members who significantly promoted this event and turned it into reality, the secretariat members who were always kept busy in preparation and arrangement of all kinds of detailed matters, and Léon Bijnsdorp, Lukas Goosen, Richard Gundel and other staff members of our collaborating publisher, CRC Press / Balkema (Taylor & Francis Group) who made our proceedings more visible and professional.

Editors
Kyoto, September, 2013

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Keynote lectures

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A reverse flow system for the sediment flushing from large reservoirs

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ABSTRACT: Reservoir sedimentation causes not only the progressive reduction of storage capacity of the reservoir itself but also the sediment interception by the dam causes various adverse effects to the downstream reach such as the riverbed degradation, local scouring, the dense tree growth on the stabilized bars, dirty water stagnation, the aggravation of aquatic habitat and the beach erosion.

The hydraulic flushing that completely drains the reservoir and scours out sediment through the dam's bottom outlets is an effective method to restore the storage capacity. However, for a large reservoir that locates at the uppermost area of the watershed, the securing of the water discharge necessary to flush sediment and the recovery of water storage once after emptying are, in general, difficult. Therefore, the orthodox hydraulic flushing method has not been applied to such a large reservoir.

Here, a reverse flow flushing system that is applicable for a large reservoir at the uppermost area of the watershed is proposed, in which a pool for sedimentation is constructed inside the reservoir near its upstream end by separating it from the main reservoir downstream with a submerged partition weir or by the excavation of a part of the delta deposit that has already been formed in the upstream reach of the main reservoir. The sediment that is newly deposited as a delta deposit in the sedimentation pool is scoured out by the introduction of a reverse flow from the main reservoir and it is flushed through the bypass tunnel whose inlet is set at the bottom of the pool. The numerical simulations confirm this method is feasible.

The large particles mixed in the delta deposit within the sedimentation pool may impede the reverse flow from scouring and flushing the deposited sediment and they may cause an undesirable invert abrasion of the bypass tunnel. Furthermore, they may be deposited in the downstream river causing an unexpected bed aggradation. The open-type check dams are installed upstream of the pool to exclude the harmful large particles before they flow into the pool. The performance of such a check dam is examined by numerical simulations.

1 INTRODUCTION

The control of sediment runoff from an upstream mountain watershed is crucially important for flood control, water-utilization and the maintenance of river environment. In Japan, before 1960s, the riverbeds were generally high due to severe sediment runoff, and the flood and sediment disasters often occurred. The enduring efforts to repress sediment yield by the construction of check dams, afforestation, and others had been made in many devastated watersheds.

The situation changed after the economic growth of 1960s'. The multi-purpose dams for flood control, electricity generation and water-usage and the dams for the exclusive use for the power generation were constructed in the upstream area of many watersheds. In the middle and the lower reaches of the river, enormous gravel mining had been done to obtain concrete aggregate. In addition to the decreased sediment runoff due to afforestation and the deployment of the check dams, the sediment interception by large dams and the massive gravel mining caused the excessive riverbed degradation in the middle and the downstream reaches, which gives rise to the dangerous scouring of the foundations of bridge piers, levees and other structures. The shortage of sediment supply from estuary caused the coastal erosion almost all over Japan.

Gravel mining has been prohibited in the reaches of severe riverbed degradation, and the tendency to degrade is now moderated. However, because sediment supply is still intercepted by dams, the riverbeds downstream are armor-coated and a scarce amount of sediment is transported. This situation is harmful to aquatic habitat. Some rivers transformed their channel pattern from the braided channels to the meandering channel which resulted in the extreme local scouring of the foundations of bridge piers and levees. Reservoir operation reduces the discharge of flood flow. Thereby the stabilization of sandbars is caused. A stable sandbar stimulates the tree growth on it, which diminishes the flood conveying capacity of the river.

A stable sandbar, sometimes, hinders the exchange of water and the stagnant water becomes foul. On the other hand, some upstream reservoirs are about to lose their functions due to severe sedimentation.

To remedy these adverse effects of the reservoir sedimentation, some viable measures must be implemented. These measures should release sediment from the reservoirs and, simultaneously, they must keep sediment transportation downstream as far as to the coastal area in the manner without failure in any standpoint of the flood control, water usage, and environment. Even though their severity is different, similar situations occur worldwide, and therefore, the technology development that solves the problems is an urgent issue. In this context, this keynote focusses on the problems of sediment flushing from a large reservoir which locates in the uppermost reach of the river basin and proposes a promising method which enables the flushing out of comparatively coarse sediment with minimal water consumption, and thereby, the various hazards downstream caused by reservoir sedimentation will be dissolved.

2 EXISTING SEDIMENT MANAGEMENT STRATEGIES AND THE NEED FOR NEW TECHNOLOGIES

Existing reservoir sedimentation management techniques can be divided, as shown in Figure 1, into the following groups (Palmieri 2003):

A. Reduction of sediment inflow to the reservoir;
B. Routing of sediment through or bypass the reservoir;
C. Increasing the reservoir volume by raising dam;
D. Removal of deposited sediment; and
E. Decommission and removal of dam.

Herein, these strategies are briefly overviewed and some shortcomings of them are pointed out to make clear what technology development is needed.

2.1 *Reduce sediment inflow*

Technologies belonging to this category can be divided into two categories:

1. Reducing the sediment production on the mountain slope or the sediment delivery via channel network by the implementation of the deliberate erosion control works, and
2. Checking the runoff sediment at the upstream end of the reservoir by the construction of a sediment storage dam.

In Japan, the erosion control works that are exclusively aiming at the reduction of sediment inflow to a reservoir have never been implemented. However, recently, there is a trend to attach the function of flood control even to a reservoir that was constructed to use exclusively for power generation. Since keeping the effective storage capacity as large as possible is more important for a reservoir aiming flood control than for a reservoir aiming to generate electricity, the governments who are responsible for flood control have begun to plan the implementation of erosion control works within such a reservoir basin.

The large and steep bare-slopes left after landslides in a high mountain watershed are the main place of sediment production. Afforestation to

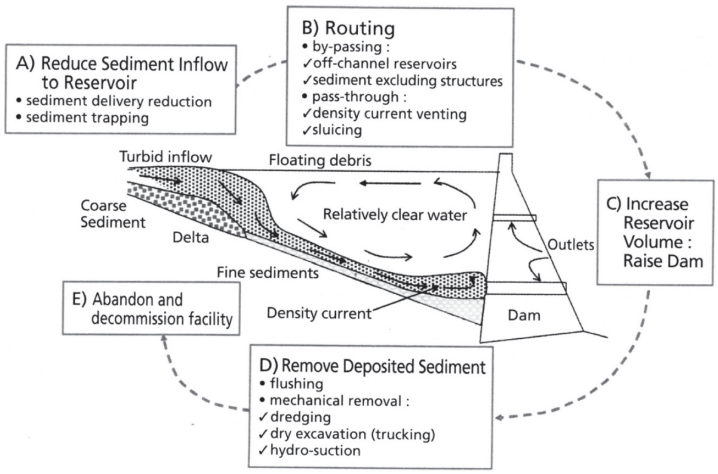

Figure 1. Reservoir sedimentation management options (Palmieri, A. 2003).

reduce sediment production on those slopes is, however, difficult. If check dams are constructed to store the transported sediment in the stream channel system, they can store only a small amount of sediment due to the steepness and narrowness of the channel. Therefore, in general, check dams cannot be very effective measure to reduce sediment inflow to the reservoir for a long time. Thus, the main purpose to install check dams should be to exclude large particles in the runoff sediment so as to make easier the handling of deposited sediment in the reservoir.

The sediment trapping at the upstream end of a reservoir by a check dam and the excavation of the trapped sediment after flood is a popular method. This method would be reliable and economical as long as a carrying out route of sediment is provided and the sustainable demand for the utilization of sediment is guaranteed. Otherwise, some other methods should be implemented.

2.2 *Sediment routing*

This strategy contains the two methods: the sediment bypassing and the sediment passing through the reservoir.

The most effective bypassing method would be the construction of an off-channel reservoir which bypasses sediment laden flow and only sediment-free water is taken into the reservoir and stored. But, this method is not practical for the large reservoirs in which even the heavily sediment-loading water cannot be wasted, and in a steep mountainous area, it is difficult to find a suitable land for the construction of the off-channel reservoir.

One of the practical and effective sediment bypassing methods catches the highly sediment laden flood flow by a weir that is installed in the reservoir. Then, some parts of water and sediment caught by the weir are discharged through a tunnel that is excavated from the immediately upstream of the weir to the downstream of the dam. These kinds of sediment excluding structures were constructed in the Palagnedra dam reservoir in Swiss and in the Miwa dam reservoir in Japan.

In the case of Palagnedra Dam, a bypass tunnel, whose cross-sectional area is 31 m^2, the slope gradient is 2% and the length is 1,800 m, is installed just upstream of a 8 m high submerged dam that is constructed in the upstream part of the reservoir. The gate of the bypass tunnel is gradually opened while in the climbing limb of the flood hydrograph until the discharge attains the tunnel's capacity of 250 m^3/s, and then the flow in the tunnel becomes a pipe flow. The velocity in the tunnel in this stage is 8 m/s. In the recessing limb of the hydrograph, when the discharge in the tunnel decreases to less than 220 m^3/s, the flow becomes an open channel flow and it begins the full-scale sediment release stage. When the river flow discharge becomes less than 30 m^3/s, the tunnel's gate is closed and sedimentation begins in the sedimentation pool that is upstream of the submerged weir. The majority component of discharged sediment is sand, but considerable amount of gravels and stones are contained. The design discharge of the tunnel was determined with insufficient hydrologic analyses and the floods whose discharge is larger than 1,000 m^3/s sometimes occur. In such a case, the highly sediment loading flow overflows the weir and causes the sedimentation in the main reservoir (Martini 2000).

The Miwa dam reservoir is a multi-purpose reservoir of 29.95 million m^3 in the total storage capacity that is completed in 1959. In the period of 43 years after completion the sedimentation volume reached about 20 million m^3 and the functions of the reservoir were managed to maintain by the dredging of about 7 million m^3. Of the total volume of the inflow sediment 3/4 is fine wash load. A countermeasure system based on such characteristic sediment was completed in 2005. This system comprises a coarse sediment trapping dam (10.2 m high and 200 thousands m^3 in sedimentation capacity that is constructed just upstream of the end of the reservoir), a flow branching weir (10.2 m high and 520 thousands m^3 in sedimentation capacity that is installed inside the reservoir) and a bypass tunnel (7.8 m wide, 7 m high, and 4,308 m long that starts from the branching weir). The sediment trapping dam stops the inflow of coarse sediment and the branching weir diverts the flow up to 300 m^3/s through the bypass tunnel. The flood having the return period of 100 years for this reservoir is, however, 1,210 m^3/s.

According to the records of the three floods in 2006 and 2007, of the 1.11 million m^3 sediment inflow to the reservoir, 0.32 million m^3 was bypassed downstream, and the two weirs trapped the total of 0.41 million m^3. Thus, sedimentation was reduced to 0.38 million m^3.

The Asahi dam reservoir is the lower regulating reservoir of a pure pumped-storage-type power plant. Because the storage of flood water is not necessary, the flood flow whose discharge is larger than 5 m^3/s is diverted by a 13.5 m high weir constructed just upstream of the end of the reservoir to the downstream of the dam via a bypass tunnel. The conveyance capacity of the tunnel is 140 m^3/s, so that if the flood discharge is less than 140 m^3/s, all the water and sediment are bypassed. The design flood discharge of the dam is, however, 1,200 m^3/s. Therefore, in the case of a large-scale flood larger than 140 m^3/s, some parts of flow overflow the weir, and so not only the fine sediment that is transported as suspended load but also the coarse

sediment that is transported as bed load and in excess of the volume checked by the diverting weir will be deposited in the reservoir.

The sediment size distribution of the riverbed material at the upstream of the Asahi dam reservoir shows that the maximum grain size is about 30 cm, the median diameter is about 25 mm and the ratio of particles smaller than 1 mm is about 10%. There is no measured data of the bypassed sediment, but the riverbed variation upstream the diversion weir is so small that almost all the particles having the similar composition to that of the upstream riverbed should have been bypassed.

The Asahi dam bypass system was put into use in 1998 and about 83,000 m^3 of sediment was discharged via the tunnel in that year. Because the coarse sediment is transported through the tunnel, considerable abrasion must be taken into account. The survey in 1998 revealed that the tunnel's invert concrete with the designed strength of 36 N/mm^2 wore 46 mm a year and that part with 70 N/mm^2 wore 14 mm a year.

When we consider the feasibility of the bypass tunnel method, we must, of course, care the cost of tunnel excavation and that for the maintenance of the tunnel against the invert abrasion, but even more important problems to be considered would be that how much discharge is allowed to bypass at what timing (A dam aiming at flood control cannot release all the inflow without delay.) and, as in the case of Miwa Dam, how the sediment deposited in the pond of the sediment trapping weir or that in the flow branching weir can be excavated or dredged and how such sediment is disposed.

The sediment sluicing and the density current venting belong to the sediment pass-through methods. Sluicing is the method to discharge flood flow before its loading sediment is deposited in the reservoir. Therefore, the flow velocity in the reservoir must be considerably large, so that the drawing down of the water-stage is necessary. However, if the sediment is very fine suspension, the drawdown of the water stage in reservoir may not necessary be so large. The Sanmenxia Reservoir in China had accumulated far larger volume of sediment than expected and the upstream riverbed aggraded as high as inducing flood disasters within very early time after the completion. A radical improvement of the flood discharging gates and of the strategies for reservoir operation so as to pass through the highly sediment loading flood flows were implemented under the slogan 'Storing the clear and releasing the turbid'. The Three Gorges Reservoir in China also adopts this strategy. If highly sediment loaded floods arise only in a comparatively short period of a year and the quantity of the flow-in water during the rest period of the year is enough to fulfill the reservoir's objectives, they can wait for the highly sediment loaded flood flows with lowered water stage. It may be economically feasible only if the ratio of reservoir storage capacity to annual water inflow is less than 0.1 or so and the sediment size is fine.

When the inflowing flood flow has a conspicuously larger density, by loading very highly concentrated sediment, than the stored water in the reservoir, the flow crawls forward as a density current along the bed of the reservoir to the dam as illustrated in Figure 1. The method of density current venting discharges the density current through the lower outlet from just after its arrival at the dam. The Xiaolangdi Reservoir that locates 125 km downstream of the Sanmenxia Dam is a large multi-purpose dam whose storage capacity is 12.6 billion m^3 of which 7.5 billion m^3 is allotted to sedimentation. The fundamental management strategy of this reservoir is the same as those at Sanmenxia and Three Gorges, but Xiaolangdi applies the density current venting. The material that composes the density current in this reservoir is the very fine silt of 0.004 to 0.008 mm in diameter. A trial to produce an artificial density current by stirring up the deposit in the reservoir with a high pressure water jet is implemented. The number of reservoirs which the density current venting is effectively applicable is, however, limited.

2.3 *Flushing*

The hydraulic flushing is a method to flush sediment by completely draining the reservoir and scouring out the sediment from a low-level outlet using the action of the tractive force of restored riverine flow. If an adequate tractive force throughout the impound reach as well as the downstream of the dam can be produced, this method is applicable for even a coarse sediment and, in some cases, it is economical in comparison to the mechanical sediment removal that necessitates high cost dredging, the acquisition of sediment disposal area, land transportation and the associated engineering. Attention should be paid to the possible very high sediment concentrations downstream that might cause several hazards.

The representative example of hydraulic flushing in Japan is the coordinated sediment flushing at Dashidaira Dam and Unazuiki Dam in the Kurobe River. This coordinated sediment flushing is made possible by their small reservoir index, RI, that is the ratio of the storage capacity to the mean annual water inflow. Sumi (2000) gave a criterion for the feasibility of the hydraulic flushing as a function of RI and the dam's life span that is defined as the ratio of the storage capacity to the mean annual sediment inflow. According to him, if the life span is 200 years RI should be less

than 0.08, and if the life span is 20 years RI should be less than 0.034. The RI of Dashidaira Dam is 0.007 and that of Unazuki Dam is 0.014 and these values are well below the criterion.

For many large-scale reservoirs that locate at the most upstream part of the watershed RI values are not rare to exceed 0.2 and in some cases it is more than 1. In such a reservoir the hydraulic flushing cannot be applied, because once the reservoir is emptied the refilling of it needs very long time, during that period the functions of the reservoir are much deteriorated. Furthermore, the natural inflow rate during the flushing operation is often too small to flush all the sediment that is accumulated in a long period. In this context, a new effective method to discharge sediment in such a reservoir is needed.

3 THE IDEA OF THE SEDIMENT FLUSHING SYSTEM USING THE REVERSE FLOW FROM THE DOWNSTREAM RESERVOIR

Generally, a reservoir is constructed to be able to carry out its purposes for at least a hundred years even under a severe sedimentation. In Japan, more than 50 years have passed since the vigorous dam construction age began, and some of the reservoirs are about to filled-up by the sediment yield more than that was expected. Many difficult problems caused by the reservoir sedimentation become obvious. Especially for a rock-fill-type dam the filling-up of the reservoir by sediment might cause the destruction of the dam and endangers the downstream reach, so leaving them to take their own course is not allowed. Thus, the effective methods to cope with the reservoir sedimentation problems are urgently needed.

As mentioned earlier, the hydraulic sediment flushing can be an advantageous method if the reservoir is under a favorable condition because it is applicable even for the coarse particle deposit. But, for a large reservoir with large RI value, emptying the reservoir is not practical. The methods to bypass the inflowing water and sediment by the installation of a partition weir (diversion weir) inside the reservoir are implemented in Palagnedra Reservoir and Miwa Reservoir, but they can bypass only a part of the naturally inflowing water and sediment and the considerable amount of sediment is still accumulated at the downstream of the partition weir. The system at the Asahi dam reservoir directly bypasses all the flow to the downstream of the dam if the inflow rate is less than the capacity of the bypass tunnel but if the inflow rate surpasses the tunnel's capacity the situation becomes similar to Palagnedra Reservoir.

Moreover, there are many reservoirs whose inflow sediment is too coarse to pass-through by the mere drawing-down of the lake water level so that the sediment sluicing is impossible, the peak flood rate is too large to discharge all the water and sediment via a bypass tunnel so that the Asahi dam method is not applicable, and mechanically removed sediment by excavation or dredging cannot be taken out due to various restrictions.

Overviewing the above mentioned existing methods to cope with the reservoir sedimentation, the lack of the method that is applicable to a large reservoir with large RI value is clear. In particular, it is true for a reservoir that locates at the uppermost part of the watershed and whose sediment is coarse. Here, I propose a new system that is applicable to such a reservoir. The system is comprised of the following facilities:

A sedimentation pool is constructed near the upstream end of the reservoir by installing a partition weir if the reservoir is newly constructed or by the excavation of the delta deposit if sediment is already accumulated considerably in the reservoir. The crest height of the partition weir or that of the downstream bank of the excavated pool is set around the high water level of the reservoir. The sedimentation pool can store the sediment that runoff within about a year or with some conspicuous floods. This capacity is, of course, far less than the sedimentation capacity allotted to the entire reservoir, i.e. the sediment runoff volume in a hundred year. Therefore, the hydraulic flushing from such a sedimentation pool would be feasible if only the sufficient water discharge to flush sediment that is accumulated in the sedimentation pool can be supplied. This may sound the similar system to Palagnedra's, but the source of the water supply is different. The system herein uses the water that is stored in the main reservoir downstream. First, the water stored in the sedimentation pool is drained using the bypass tunnel whose entrance is at the upstream foot of the partition weir or the bank, and the tunnel guides the flow to the designated place downstream of the dam. Next, the reverse flow, from the reservoir to the sedimentation pool in the opposite direction to the river flow, is introduced via a pipe line that is connected to an aqueduct hanging on the side slope of the sedimentation pool. The reverse flow overflows from the aqueduct and erodes the delta deposit in the sedimentation pool. Then, the reverse flow together with the eroded sediment is drained via the bypass tunnel. It is noticed that this system is devised for the case that the majorities of inflowing sediment are coarse and the volume of fine material that overflows the partition weir (or the bank) and is deposited in the main reservoir is small. A conceptual diagram of the system is given in Figure 2.

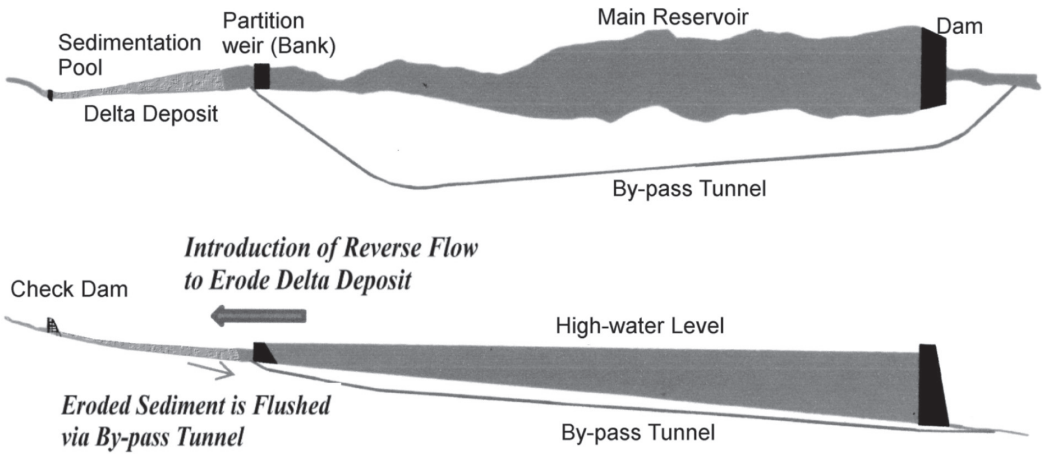

Figure 2. Concept of a reverse-flow sediment flushing system.

The key points of the idea are as follows:

1. For the sake of checking the inflow sediment, a sedimentation pool is set near the upstream end of the reservoir with the capacity to be able to store at least an annual sediment runoff volume;
2. The sedimentation pool is separated from the main reservoir by a partition weir or a bank. A bypass tunnel is installed from the sedimentation pool to the downstream of the main dam. If the deposited delta already proceeded well inside of the main reservoir, the sedimentation pool and the partition bank may be constructed by excavating the top-set bed part of the delta deposit;
3. To store water as plenty as possible in the main reservoir, the entrance gate of the bypass tunnel should be closed during the normal flow as well as amid the flood. Thus, sedimentation takes place in the sedimentation pool under a high water stage and water overflows the partition weir (bank) when the water stage of the sedimentation pool becomes higher than the crest of the weir (bank);
4. The unsuitably coarse particles in the runoff sediment should be checked by the open-type check dams before flowing into the sedimentation pool. Such particles' size is determined by considering the ability of the reverse flow to erode delta deposit, the risk of the invert abrasion of the bypass tunnel, and the sediment transporting capacity of the downstream river. When the check dam becomes filled-up, that sediment must be mechanically removed and disposed around the reservoir or crushed so as to be suitable to be dropped inside the pool and then flushed via the bypass tunnel;
5. It is desirable to use no power to introduce reverse flow into the sedimentation pool. To meet this requirement the crest height of the partition weir (bank) is set equal to the high water level of the main reservoir and the reverse flow is produced by the head difference between the main reservoir and the sedimentation pool. Therefore, the water stored in the sedimentation pool must be released and the pool must be nearly dry before the flushing operation. Making the pool dry before the introduction of the reverse flow guarantees the full efficiency of the delta erosion by the reverse flow. If the water supply line to introduce reverse flow is left open during the normal flow, the water stored in the sedimentation pool can be used as a single entity with that stored in the main reservoir;
6. Sediment flushing operation is desirable to do in the last stage of flood because the high turbidity and large flow rate in the river flow downstream just before the flushing operation may moderate the adverse effects of sediment flushing. However, as long as the quantity of water in the main reservoir is sufficient, the timing and the flow rate for flushing can be chosen freely considering the various circumstances of the downstream reach of the river. In the case that the sediment concentration in the flushing flow exceeds the allowable level downstream, additional flow should be released from the main reservoir or from the other reservoirs to dilute the sediment concentration in the river flow downstream;
7. The desultory introduction of reverse flow into the sedimentation pool cannot fulfill the expected function. An aqueduct to guide reverse flow is set near the bottom of the sedimentation

pool along the side bank diagonally to the direction of the delta motion. The delta deposit proceeds downstream in the sedimentation pool burying the aqueduct. When the reverse flow is introduced, it spills over the side wall of the aqueduct at the in-tersection with the front-set slope of the delta deposit and spreads over the deposit to erode it forming a large horizontally rotational flow that is swallowed down through the bypass tunnel. Thus, a highly sediment loaded flow is formed and discharged via the bypass tunnel.

4 PERFORMANCE OF THE REVERSE FLOW SYSTEM

A reservoir that is located in the one of the severest sediment yielding watersheds in Japan was selected as the site of the performance study. Among the tributaries of the reservoir, S is the steepest and most actively sediment yielding watershed with the area of the bare-land slopes left after landslides amounts to 21% of the entire watershed area. In winter, all the area is covered by snow and the sediment production on the bare-slopes by the action of freezing and thawing cycles is extremely active and this is one of the main causes of extreme sediment yield. Figure 3 shows a part of the reservoir's basin. As is evident in Figure 3, the A and B Ravines were the independent tributaries of the reservoir before the completion of the reservoir, but, due to the severe sediment yield, the delta deposits of the both tributaries are now unified to form a compound alluvial fan, so the watersheds A and B are now considered as the sub-watershed of S.

Here, the performance of the reverse flow system is examined under the assumption that the system is constructed by the excavation of this compound fan.

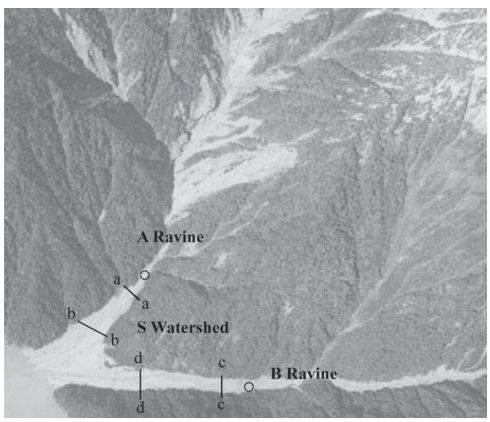

Figure 3. Some parts of S watershed.

4.1 *Estimations of sediment graphs and particle size distributions in the runoff sediment*

The sediment runoff volume data based on the sounding survey in yearly basis from the S watershed exist since the beginning of water storage in the reservoir. The design of the sediment flushing system and its operation plan, however, needs the sediment runoff volumes and their particle size distributions for every conspicuous flood. Therefore, at first, the method to predict the sediment runoff in respect to both over a long time period and for a single-event is explained. This method predicts not only the volume of sediment but also the temporal changes in the particle size distributions in the flow as well as on the riverbed.

Here, a recently developed sediment runoff model named SERMOW ver. 2 is used. This is the modification of SERMOW (Sediment Runoff from Mountainous Watershed) model (Takahashi *et al.* 2001 Takahashi 2006). The SERMOW considers the debris flows that possibly occur in the watershed are the typical stony debris flows or the typical turbulent muddy debris flows, and in the calculation the specific resistance formulae applicable for stony-type mature debris flows or immature debris flows and for turbulent-type debris flows are switched depending on the relative depth (= flow depth/mean particle diameter in the flow) and the coarse particle concentration in the flow. However, the sediment compositions in the A and B Ravines are widely distributed from large stones to silt size material in which the majority composition is sand, and the flow may change its mode from stony debris flow to individual particle's motion via the hybrid-type and the turbulent-muddy-type debris flows during its motion down the river channels successively depositing larger particles. SERMOW ver. 2 changes its fundamental equations from those of SERMOW to that for the generalized inertial debris flow (The inertial debris flow is a general term indicating stony debris flow, turbulent muddy debris flow, and the flow that is intermediate between these two typical type flows.), thereby no switching of the equations is necessary throughout the mode changes during the course of run down (Takahashi and Satofuka 2002 Takahashi 2007 Takahashi 2013) except the switching from the inertial debris flow equation to the equation of the individual particle motion. In the SERMOW ver. 2 model, for the individual particle motion that occurs after the stopping of the debris flow or after the gradual phase change due to the deposition of coarse particles, a Brown-type total load formula is used considering that a

large amount of suspended sediment is contained in the flow.

SERMOW and SERMOW ver. 2 calculate flood runoff discharge hydrograph at an arbitrary site in the stream channel system within a watershed using the kinematic wave method by giving a time series of rainfalls. The same rainfalls produce and move sediment on the bare-slopes that are left after landslides and the moved sediment is once deposited on the taluses existing at the foot of the slopes. The amount of sediment produced and moved on the slope is assumed to be proportional to the rainfall intensity in excess of a threshold value, where the threshold rainfall intensity is determined as a decreasing function of an increasing cumulative rainfall, so the larger the cumulative rainfall the larger the supply of sediment to the talus becomes under a certain rainfall intensity.

The flood flow that appears in a stream channel increases its sediment concentration by eroding the riverbed and the taluses on the way or decreases its sediment concentration by depositing the loading sediment on the riverbed. If the sediment concentration in the flow is less than the equilibrium value, the flow erodes the channel bed and the taluses, and on the contrary, if the sediment concentration in the flow is larger than the equilibrium value, the excess sediment is deposited on the bed. The equilibrium sediment concentrations in debris flow and in bed material load flow are the functions of channel slope and other hydraulic conditions. After repeating such erosion and deposition processes, sediment runs off the watershed.

Because the origin of sediment is limited to the bare-lands, the estimation of particle size distributions in the talus deposit is crucially important in getting reliable results in SERMOW or SERMOW ver. 2 calculations. But, the field survey apt to estimate unreasonably large sizes because the fine particles sink deep in the talus or they are washed away in the process of accumulation on the talus. Therefore, taking both the data obtained at the taluses by the field surveys and that obtained by the boring of the delta deposit at several points in the reservoir into account, the representative size distribution in the sediment deposited on the talus is determined.

Figure 4 compares the calculated annual sediment yields from the S watershed with those obtained by sounding the delta deposit, in which the sediment volume is given in bulk volume. The calculated results well reproduce the sediment runoffs in the annual basis and the total volume in thirty years is calculated 106% of the measured data. The largest annual sediment yield in thirty years was 1.4 million m^3 that was produced by the large-scale floods of five times a year. As opposed to this, the third largest annual sediment

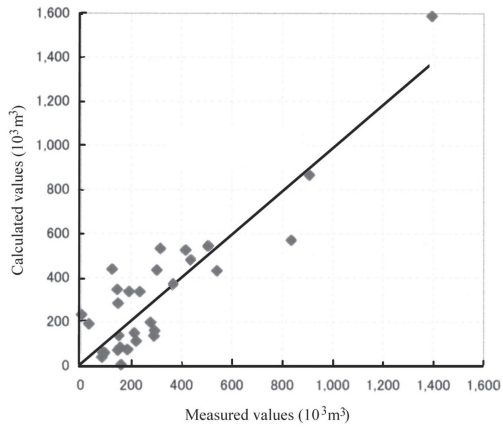

Figure 4. Comparison of the calculated annual sediment yields with the measured data.

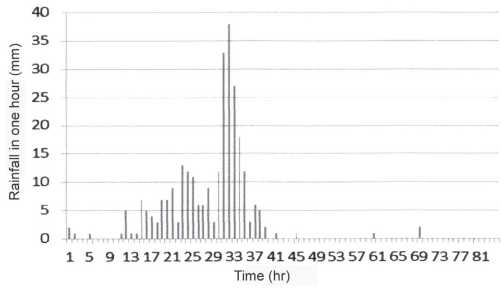

Figure 5. Hyetograph of a rainfall event selected to estimate the hydrograph and sediment graph by the SERMOW ver. 2 model.

yield was 0.8 million m^3 that yielded with only one large flood. The total runoff sediment volume in thirty years amounts to 9.27 million m^3 and this gives the annual mean sediment yield is about 0.31 million m^3. The yearly variation is, however, significantly large and the largest annual sediment yield was about 4.5 times larger than that of the annual mean value. This fact should be taken into account in the design of the sedimentation pool.

As an example, the rainfall event of which hyetograph is shown in Figure 5 is chosen to show the runoff hydrograph and sediment graph in the A Ravine. This event has the 9th largest cumulative rainfall amount and the strongest in the rainfall intensity within one hour during these thirty years. Figure 6 shows the calculated hydrograph and sediment graph at the outlet of the basin (left-hand side) and the sediment graph for each particle size group (right-hand side). The total of water plus sediment runoff volumes amount to 2.18 million m^3 and the total sediment runoff

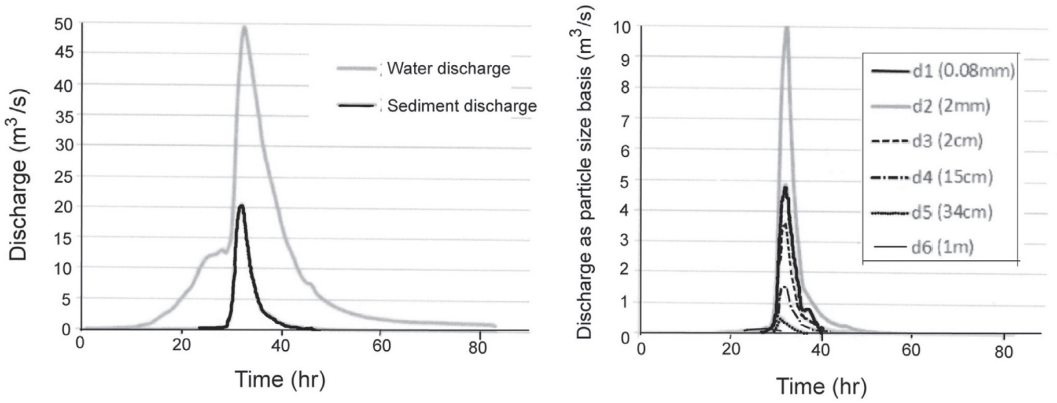

Figure 6. Calculated hydrograph and sediment graphs.

volume amounts to 0.325 m^3 in the substantial volume (about 0.52 million m^3 in bulk volume). The total sediment runoff volume from the B Ravine by the same rainfall event is calculated as 0.247 million m^3 (0.395 million m^3 in bulk volume). This is the second largest annual sediment runoff in these thirty years, so it is seen from Figure 4 that almost all sediment runoff in this year was due to this rainfall event.

The particle size group written as d4 (15 cm) in Figure 6 is that belongs from 7 cm to 24 cm in diameter, and the results of calculation show that the particles larger than or equal to d4 group occupy about 9.6% of the total runoff sediment. If very coarse particles are deposited in the sedimentation pool, a large water discharge becomes necessary to flush out such coarse particles and the flushing may cause the severe abrasion of the invert of the bypass tunnel and, in addition, the sediment transportation in the river downstream of the tunnel will be hampered. For the sake to exclude these disadvantages, here, the installation of the open-type check dams upstream of the sedimentation pool is planned. These check dams should prevent the inflow of the particles of 10 cm or larger into the sedimentation pool.

4.2 *Checking harmful coarse particles by the open-type check dams*

To stop the debris flow front that is comprised of coarse particles 1 m or larger in diameter, the grid-type 10 m high check dams whose spacing between the grid pipes is 1 m are installed at the positions a-a and c-c shown in Figure 3, respectively for the A and B ravines. The ledge-type check dams are also installed at the downstream positions b-b and d-d, respectively, whose net spacing between the ledges is 10 cm and the dam height is 12 m. These ledge-type dams check the particles of 10 cm or larger in diameter.

A grid-type dam can stop the debris flow front by checking the constituting particles larger than 0.7 times of net space between the grid pipes (Takahashi 2007), so the particles larger than 70 cm are expected to be checked by the upstream grid-type dam. When coarse particles are checked at the grid face, the finer particles involved in the succeeding flow are also checked forming a rebounding deposit that goes upstream. That part consumes the storage capacity of the dam uselessly, but by making the grid face perpendicular to the river channel (dam length) as wide as possible than the width of the debris flow, the retrogressive deposit would be mitigated since the wide river width allows the deflection of the successive flow which contains many particles that are passable through the grid. Thus, the majority of particles less than about 70 cm arrive at the face of the ledge-type dam, where the particles larger than 10 cm are checked and only the finer particles pass through the dam to be deposited in the sedimentation pool. The retrogressive deposition of particles finer than 10 cm may also be mitigated by making the ledge face as wide as possible.

Figure 7 shows the calculated sediment graphs of all the particles and of the individual particle groups in the A Ravine for the rainfall event explained above. The left-hand side graph is the sediment graph of the inflow at 200 m upstream of the grid dam whose position is designated by a circle in Figure 3, the middle graph is that at 10 m downstream of the grid dam, and the right-hand one is that at 10 m downstream of the ledge dam. The particles larger than d4 were completely checked by these two dams and the discharge of the sediment that passed through the dams was also decreased by the storages upstream.

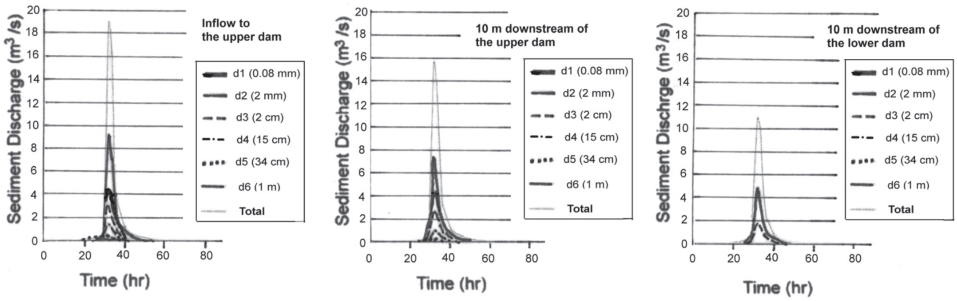

Figure 7. Sediment graphs at various points along the A Ravine.

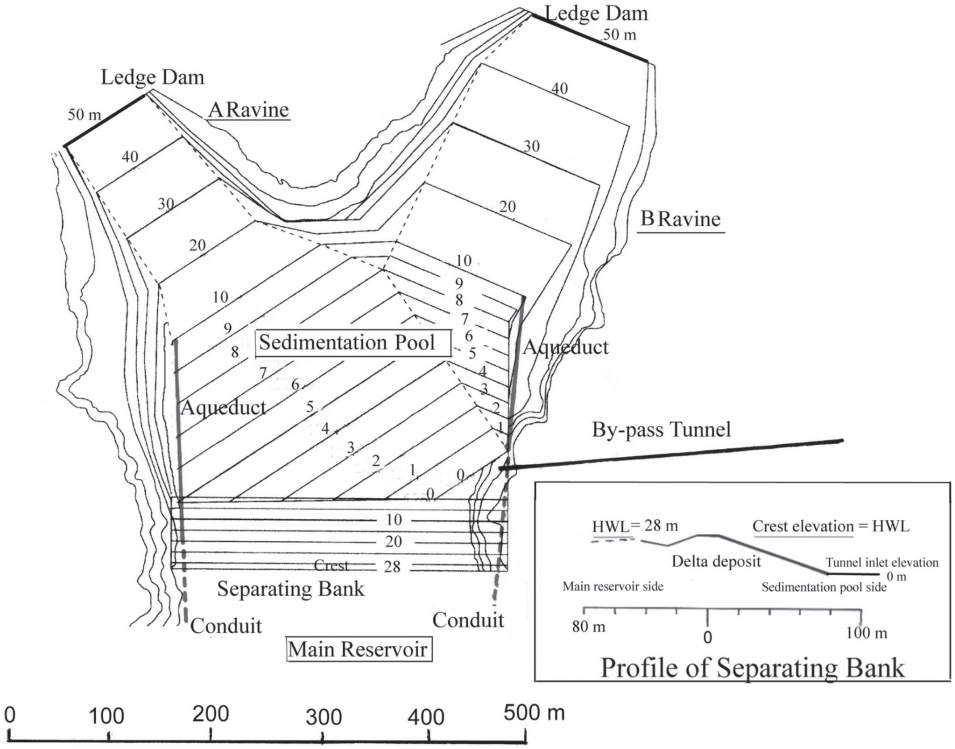

Figure 8. Plan of the sedimentation basin.

Of the total sediment volume of 0.325 million m^3, 0.171 million m^3 was stored upstream of the check dams and 0.154 million m^3 was stored in the sedimentation pool. The mean diameter of the deposited sediment in the sedimentation pool except the wash load is about 2 mm. The technology development to decrease the deposit of particles less than 10 cm upstream the check dams is necessary. Anyway, particles larger than 10 cm must be disposed around the dam site or crushed into less than 10 cm to make them flushable via the bypass tunnel.

4.3 *Design of the sedimentation pool and the reverse flow channel*

The downstream end of the A and B Ravines forms a compound alluvial fan, where it was originally a part of the water surface of the reservoir. A sedimentation pool is made by excavating that fan as illustrated in Figure 8. The partition that separates the sedimentation pool from the reservoir is, as shown on Figure 8, a bank slope constructed by a slight reform of the present delta deposit. The crest height of the bank is at the High Water Level (HWL) of the reservoir. The bottom

of the sedimentation pool is tilted towards the entrance of the bypass tunnel so as to concentrate the flow on the tunnel, whose bottom elevation at the entrance is 28 m below HWL.

The entrance gate of the bypass tunnel is assumed to be closed when a flood flows into the pool. The water stage of the sedimentation pool will rise in harmony with the inflow of flood flow, and soon, the flow gets over the partition bank. Therefore, some reinforcements of the surface of the separating bank are necessary to prevent from the scouring by the overflow. When the main reservoir controls flood by using the surcharge capacity, the water stages in the main reservoir and in the sedimentation pool become equal height and rise in harmony, thereby the separating bank is submerged. Meanwhile, the delta deposits are formed within the sedimentation pool by the sediment runoffs from the respective A and B Ravines that proceed downstream and are combined into one in due time.

Approaching the terminal stage of the flood or by the beginning of a normal stage, the entrance gate of the bypass tunnel is opened. Then, the water stage in the sedimentation pool gradually descends. At that time, because the water inflow rates from the A and B Ravines are neither sufficient to largely erode the delta deposit nor sufficient to flush the sediment out of the pool, some other considerable amounts of water flow must be supplied from the significantly upstream parts of the deposit. There is no source of water usable for this purpose except that of the main reservoir. To make the water supply possible, a reverse flow system that is composed of a conduit and an aqueduct (reverse flow channel) is installed.

The arrangement of the reverse flow system is shown by the fat solid lines and the fat broken lines on Figure 8; the two aqueducts are installed along the both sides of the sedimentation pool and to the respective aqueducts the conduits are connected to supply water from the main reservoir. The longitudinal profiles of the respective aqueducts and a representative cross-sectional shape of the aqueduct are shown in Figure 9.

The reverse flow flushing is assumed to start at the time when the delta deposit is near at the position shown by the broken lines in Figure 9. At first, by the opening of the entrance gate of the bypass tunnel, the water stored in the sedimentation pool is released together with the river flows coming from the A and B Ravines. This release is not mere

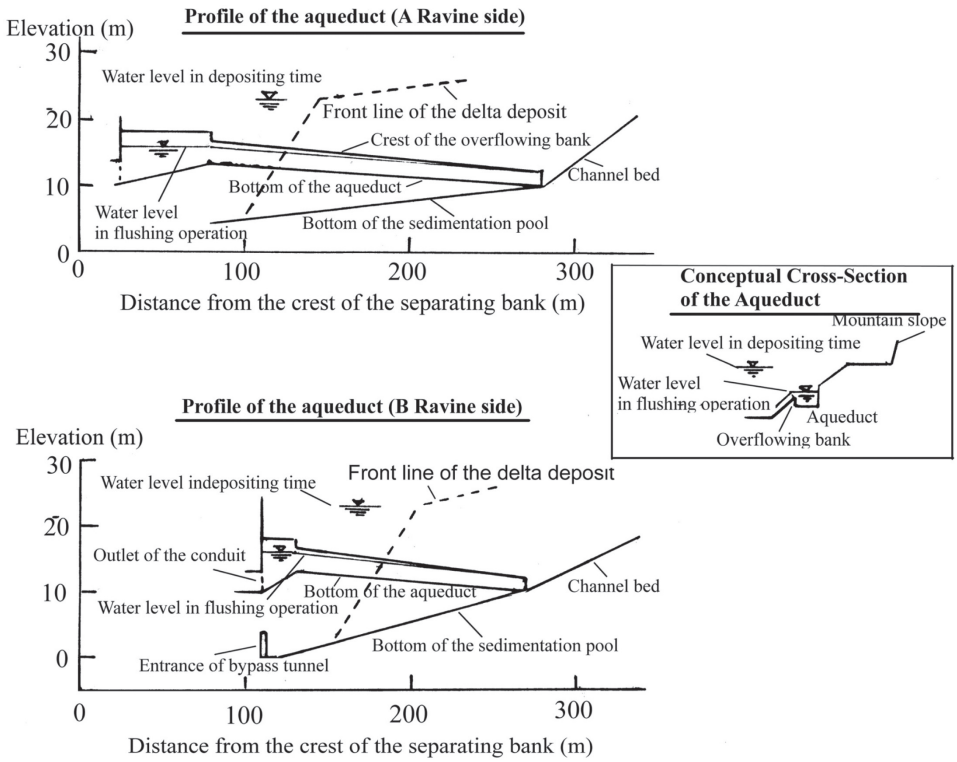

Figure 9. Profiles and cross-section of aqueduct.

waste of water but effective for the flushing out of the fine sediment that was deposited ahead of the delta deposit and for the preparatory actions of the aquatic lives in the downstream river against the sediment flushing. After draining almost all the stored water in the sedimentation pool, a reverse flow is introduced. Because the aqueduct is burrowed into the delta deposit as shown in Figure 9, the reverse flow spills over at the intersection with the front-set slope of the delta deposit. Being the aqueduct set as oblique to the front-set slope of the delta, the high speed flow that spills over the aqueduct makes a curved flow with a large radius of curvature and it violently scour the delta and entrains thus scoured sediment into the flow to be finally flushed out of the sedimentation pool via the bypass tunnel. The overflowing wall of the aqueduct is tapered down towards the tip of the channel and so no overflow takes place upstream the intersection point. As time goes by, the intersection point proceeds towards the downstream of the aqueduct and the erosion of the delta deposit proceeds. After a considerable degeneracy of the delta deposit becomes evident and the efficiency of sediment flushing decreased, the reverse flow is stopped and the entrance gate of the bypass tunnel is closed.

The maximum designed reverse flow discharge for the A ravine side is, in this case, 100 m^3/s, and the aqueduct is 7 m in width, 200 m in length, 1.5% in slope, and the maximum designed reverse flow for the B ravine side aqueduct is 50 m^3/s, and the aqueduct is 3.5 m in width and 140 m in length. The highest and lowest levels of the B ravine side aqueduct are the same to those for the A ravine side, hence the longitudinal slope is 2.1%. The largest velocities in the aqueducts are 7.1 m/s and 7.0 m/s for the A ravine side and B ravine side, respectively.

The storage capacity of the sedimentation pool below HWL is about 2.15 million m^3 that is sufficient volume capacity for the severest sediment yield in a year.

The effectiveness of the reverse flow system to flush sediment was confirmed by the previous fundamental experiments (Takahashi *et al.* 2002).

4.4 *Effectiveness examination of the reverse flow flushing system by numerical simulations*

The effectiveness of the designed reverse flow flushing system is numerically examined by the horizontally two-dimensional simulations, in which the initial condition of the delta deposit in the pool was formed by giving the steady flows of 10 m^3/s in water discharge and 0.07 in sediment concentration from the respective A and B ravines. For the sake of simplicity, the existence of the check dams was ignored except that they control the sediment size to be less than 10 cm in diameter and so the mean particle size of the deposit excluding the wash load component is 2 mm. The algorithm for the deposition and erosion analyses can be found elsewhere (Takahashi *et al.* 2002), in which, as the sediment transport equation the Brown-type total load equation is used considering the fact that much fine sediment is included. Figure 10 shows thus made delta deposit just before the flushing operation, in which the relative surface elevations of the deposit measured from the tunnel base level are given by the different brightness in the gradational expression.

The flushing operation began with the sudden supply of the steady 100 m^3/s reverse flow to the A ravine side aqueduct under the situation of no water in the pool. After six hours, the reverse flow was shut down and, in turn, the steady reverse flow of 50 m^3/s was given to the B ravine side aqueduct. Figure 11 shows the topography of the sedimentation pool after the twenty-four hours' flushing operation. No river flow was given from either of the ravines. Although the calculation was carried out under the assumption of the uniform material of 2 mm, a separate consideration on the maximum transportable particle size in the sedimentation pool revealed that all the particles smaller than 10 cm could be transported. Thus, the sediment having the same composition to the delta deposit could be flushed out.

The sediment discharge and the cumulative volume of sediment ejected from the bypass tunnel are shown in Figure 12. The sediment discharge produced by the A ravine side flow began to decrease after about three hours and it became about 60% of the peak discharge after six hours. Although the reverse flow supply was switched to the aqueduct of the B ravine side, for some time, sediment discharge continued to decrease and after eight hours it changed to increase. At about ten hours the sediment discharge reached a peak again, then, it tended to decrease. Therefore, in this operation, an effective flushing was accomplished in about twelve hours from the beginning. Notwithstanding the flow rate from the B ravine side aqueduct was half of that from the A ravine side, the sediment discharge by the former was as large as that by the latter. This was presumably due to the closeness of B ravine side aqueduct to the deposited delta and due to steepness of the slope gradient to the bypass tunnel.

The total flushed out sediment volume in the initial twelve hours was about 0.3 million m^3 in the substantial volume, so about 0.46 million m^3 in bulk volume. This value is well over the yearly average runoff volume of 0.31 million m^3. The total water quantity that was necessary to flush this volume of sediment was 3.24 million m^3, so the average sediment concentration was about 9%. The consumed water quantity was about 20% of

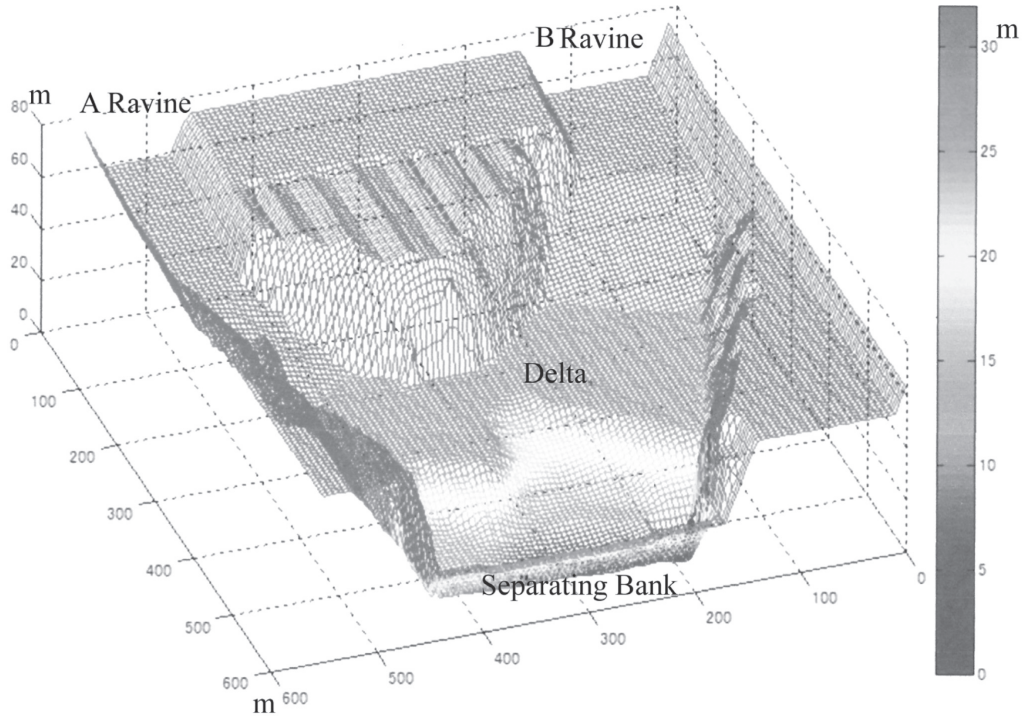

Figure 10. Initial delta deposit before flushing.

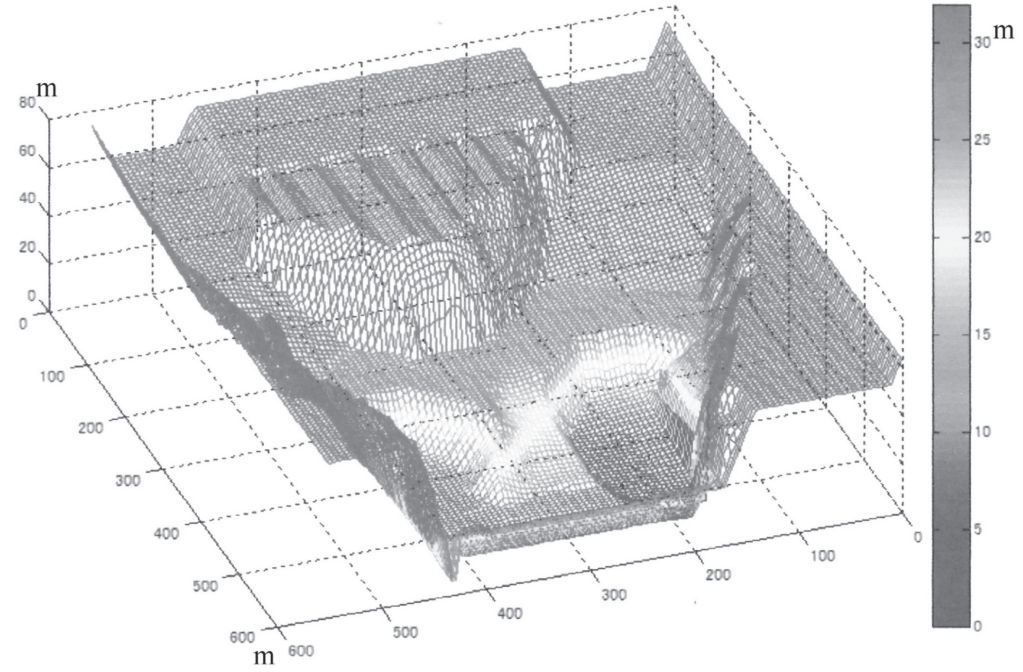

Figure 11. Delta deposit after 24 hours' flushing.

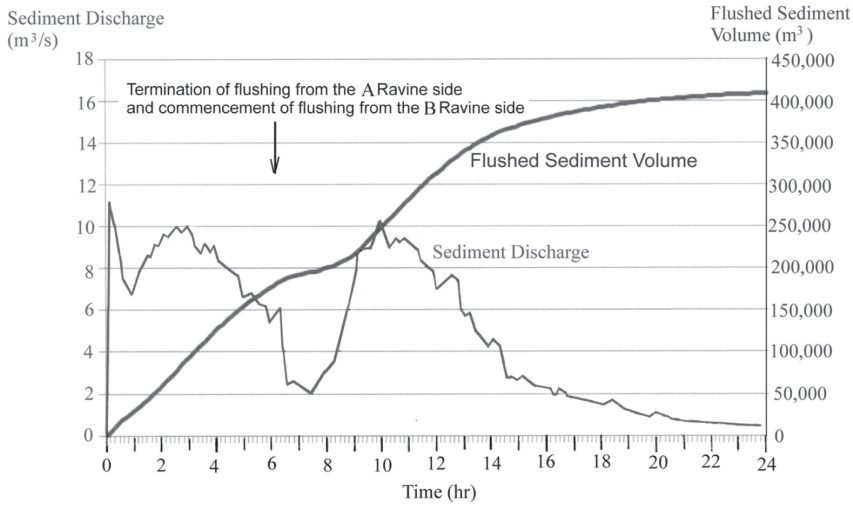

Figure 12. Temporal variation of flushed out sediment discharge and volume.

the main reservoir's effective storage capacity, and it is only 0.79% of the average yearly inflow. The consumption of this amount of water may not be a problem. In addition, the RI value for this reservoir is 0.18. This means that the sediment flushing by emptying the main reservoir is not feasible. In comparison to this, the RI value of the sedimentation pool is as small as 0.005.

The maximum sediment concentrations in the flushed out flow from the A ravine side and B ravine side are 9% and 18%, respectively. The concentration of 18% is too dense from the restrictions of the tunnel's capacity for this particular case, so that the dilution by the supply of 50 m^3/s from the A ravine side aqueduct after six hours is recommended. Thus, the water consumption increases to 4.32 million m^3 but the maximum solids concentration decreases to 9%. This value of solids concentration causes no problem in the downstream river as far as the physical capacity of sediment transportation is concerned, but, in the ecological point of view, it may cause some problems even though the suspended sediment concentration in the downstream river may become about half since the other particles are transported as bed load. In this context, the highly sediment loaded flow that is released from the tunnel outlet should be diluted so as to achieve the ecologically safe concentration. In this particular case, there is another reservoir downstream whose stored water could be used to fulfill such an object.

4.5 *Design of the bypass tunnel*

The sediment and water flushed from the sedimentation pool must be transported and released safely to the downstream river via the bypass tunnel. Because the inlet and the outlet altitudes of the bypass tunnel are fixed, the slope gradient of the tunnel is given. For the above mentioned case, the gradient of the tunnel bed is 0.029 and the alignment of the tunnel has to insert curves due to the topographical restriction. Taking these conditions and the unstable oscillations of flow due to high Froude number into account the tunnel cross-section is set as a horseshoe-shape of 4 m in width and 4 m in height as shown in Figure 13. The hydraulic analyses reveal that the ability of the tunnel is given as shown in Figure 14. According to Figure 14, the ability to transport sediment under the flow rate of water that is equal to 100 m^3/s is more than 17 m^3/s, but for 50 m^3/s it is about 8 m^3/s, so that the peak sediment discharge of about 10 m^3/s that will occur with the introduction of the reverse flow of 50 m^3/s from only the B ravine side (see Fig. 12) cannot be sluiced. This is the reason why the dilution by keeping the water supply of 50 m^3/s from the A ravine side even after the switching of flow to B ravine side is recommended.

Although the capacity of the tunnel guarantees the safe sluicing of the flushed water and sediment under normal condition, an abnormally large amount of sediment might happen to inflow and so the flow in the tunnel could not keep an open channel flow; in the worst case the tunnel might be clogged. For the sake to avoid such a hazardous situation the similar inlet structure to that of the Asahi dam bypass system can be adopted. The sketch of the inlet structure is given in Figure 13. Confronting abnormally extensive sediment inflow the conveyance ability of the tunnel is extremely

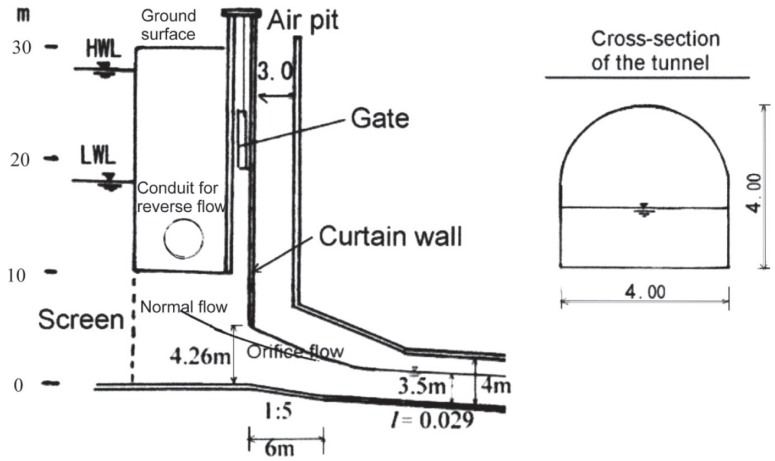

Figure 13. Longitudinal profile of the entrance of the by-pass tunnel and the standard cross-section of the tunnel.

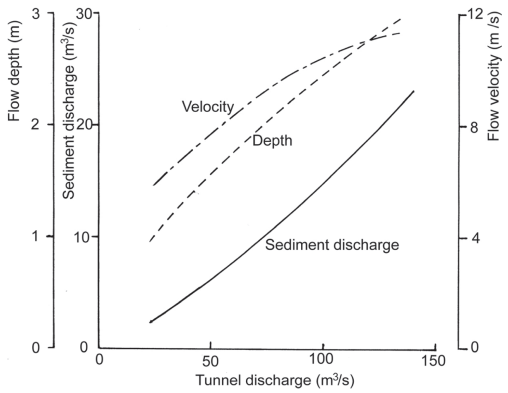

Figure 14. Flow depth, velocity and sediment discharge versus the total discharges in the tunnel.

decreased, then the water stage just upstream of the inlet rises. When the water stage becomes well higher than the opening of the curtain wall, the curtain wall forcibly produces an orifice flow and controls the amount of inflow to the tunnel. Simultaneously, due to the rising of water stage upstream of the inlet, sediment inflow is decreased. In due time, sediment accumulated on the bottom of the tunnel is naturally removed and the conveyance ability of the tunnel is automatically revived (Harada *et al.* 1997).

5 EFFECTS TO THE PROLONGED TURBIDITY

The fine sediment that is involved in flood flow causes some adverse effects to the reservoir such as the prolonged turbidity and eutrophication, and so various countermeasures against such problems have been implemented at many reservoirs. The Asahi dam bypass tunnel system was first planned as a countermeasure for the prolonged turbidity. For the case of Asahi dam, if the inflow rate to the reservoir is less than the tunnel capacity, the entire flood flow is bypassed and no turbid water flows into the reservoir. However, if the inflow rate exceeds the tunnel capacity, highly turbid water overflows the separation weir and goes into the reservoir.

The reverse flow system herein proposed is equipped with a comparatively large sedimentation pool that is able to store at least a normal annual sediment runoff. It is not only able to store all the coarse particles but is expected to reduce the inflow of fine sediment to the main reservoir that causes turbidity of the reservoir.

Consider the sedimentation pool having the scale given in Figure 8 as an example. Although this pool has a complicated form with two tributaries, it is simplified as a rectangular basin with 200 m in width, 250 m in length and 20 m in average depth into which only one ravine pours.

When small—to medium-scale flood with 15 m^3/s in discharge flows into the pool and no density current is formed, the fine material (the representative diameter d = 0.08 mm) that might cause turbidity in the main reservoir is transported downstream with the mean velocity of 0.0038 m/s, meanwhile it settles down with the velocity of 1 cm/s. Because the time necessary for the fine particles to vertically fall 20 m is 0.56 hour while the residence time for a particle within the pool is 18 hours. A back analysis to get the size of a particle that falls 20 m within 18 hours gives 0.02 mm in

diameter. Therefore, all the fine particles less than about 0.02 mm are settled down onto the bottom of the sedimentation pool in front of the front-set bed of the delta deposit. Thus deposited fine sediment together with the coarser sediment that forms the delta deposit is flushed out via the bypass tunnel with the introduction of the reverse flow.

When a large-scale flood flows in, the turbid water within the flow becomes dense enough to generate a density current in the sedimentation pool. According to the sediment runoff analyses of which results are given in Figure 6, the concentration of fine sediment in the interstitial fluid that behaves as a unified body with water (the representative diameter d = 0.08 mm) is about 0.045 in volume. Then, the interstitial fluid has the density $\rho' = 1.075$ g/cm^3. So, the density difference of this fluid with the ambient fluid is $\Delta\rho = 0.075$ g/cm^3. The effective gravity g' (= $g\,\Delta\rho/\rho$) is, therefore, 0.733 m/s^2. Previous experiments and field measurements confirm that the flow depth at the plunging point approximately satisfies (Wan and Hu 2009):

$$\frac{q^2}{g' h_p^3} = 0.6 \tag{1}$$

where q is the discharge per unit width and h_p is the depth at the plunging point.

Although Figure 6 was obtained for the peak discharges of 50 m^3/s in the A Ravine and 30 m^3/s in the B Ravine, respectively, the same sediment concentration is assumed to be applicable for the total inflow of 100 m^3/s, so when a flood of 100 m^3/s flows into the sedimentation pool, q is equal to 0.5 m^2/s and h_p is given as 0.83 m. The depth of the density current, h_d, in the pool approximately satisfies the conjugate depth relationship with the depth at the plunging point:

$$\frac{h_p}{h_d} = \frac{1}{2}\left(\sqrt{1+8F_i^2} - 1\right) \tag{2}$$

where $F_i^2 = U_d^2/(g'h_d)$; and U_d is the velocity of the density current. Then, after some trial calculations, U_d = 0.86 m/s, h_d = 0.58 m, and the density current discharge Q_d = 100 m^3/s are obtained. Therefore, if the bypass tunnel's gate is kept open during the flood, the water stage in the sedimentation pool is kept at the high water stage and the entire fine sediment that causes the reservoir's turbidity can be bypassed.

If a much larger scale flood, say 500 m^3/s, flows into the sedimentation pool with the same fine sediment concentration as the former example, we obtain h_p = 2.42 m, h_d = 1.7 m, U_d = 1.47 m/s, and Q_d = 500 m^3/s. Since the capacity of the bypass tunnel is 100 m^3/s, the discharge in excess of the tunnel capacity will overflow the separation bank of the sedimentation pool even the tunnel's gate is kept open during the period of flood. The density current, here, is assumed to flow along the bottom of the sedimentation pool with the full width of the pool, i.e. 200 m. When it arrives at the neighborhood of the tunnel gate, some parts of it contract the width to be swallowed into the tunnel but the other parts collide with the partition bank and deflect their direction vertical or rebound upstream. The velocity of the density current is, however, not so large and the height of deflection or reflection should not be high enough to be able to overflow the bank. Thus, the rebound part gradually forms the horizontal density current bed in the vicinity of the partition bank and the less turbid water overflows the bank. The density current bed together with the coarse delta deposit must be flushed out after the termination of flood by introducing the reverse flow.

The discussion above is only a rough estimate of the function of the reverse flow system to mitigate the turbidity of the reservoir. The phenomena in the sedimentation pool are highly complicated and a detailed three dimensional analysis is necessary.

6 CONCLUSION

Previously, there is no effective method to exclude sediment from a large and coarse sediment storing reservoir that locates at the most upstream part of the watershed. Thence, not only the lives of the reservoirs themselves are faced with a crisis but, by the cutoff of sediment transport downstream, it becomes evident that the rivers are going to have many problems in view of flood control, water utilization and environment.

The reverse flow sediment flushing system, which authors have invented, was proved, through the numerical simulation under an actual situation, to be a method to return from the brink of death of reservoirs and downstream rivers.

The appropriate scale, form, deployment of the respective system's facilities, operation method and the timing to implement the flushing will be different case by case, so the specific design is necessary for the specific cases. But, there should be many reservoirs suitable to apply this method.

ACKNOWLEDGEMENT

The reverse flow sediment flushing method is an idea which the author has been nursing long and some basic examinations have done occasionally.

Recently, we had a chance to examine the feasibility of this method for an actual case. The author appreciates the collaboration of Profs. Yoshifumi Satofuka and Motoyuki Inoue.

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Mechanism and prediction of bank failure

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ABSTRACT: In this paper, we introduce a new norm, stable slope, to make alluvial riverbank stability assessment. The definition and calculation of stable slope is demonstrated, followed by the analysis of stable slope variation with bank composition. Accordingly, a new bank stability model in terms of stable slope is proposed. The primary advantage of this model is its independence on field data which is required for calibrating some essential geotechnical parameters attached to most bank stability models. Then this new model is incorporated into traditional flow-sediment models to simulate river evolution with bank failure. The results indicate that the proposed model is capable of both making large-scale riverbank failure prediction and simulating small-scale channel evolution with width adjustment subject to bank collapse.

1 INTRODUCTION

Bank failure typically happens in alluvial rivers, adversely affecting embankment safety, river regime stability, function of hydraulic structures and normal life of residents along the river. Furthermore, bank failure induced sediment loss also threatens to local ecological environment. Therefore, effective prediction and prevention of bank failure is urgent.

Bank collapse is triggered when the gravitational forces that drive soil movement exceed the frictional and cohesive forces that resist soil movement. At present, bank failure investigations are mostly based on forces analysis of soil block above potential or prescribed failure surface, using the safety factor that is the ratio of resisting forces to the driving forces to assess bank stability (ASCE Task Committee 1998a,b). The main factors that affect bank stability include riverbank geometry (Dapporto et al. 2003, Rinaldi et al. 2004), bank material properties (Simon et al. 2000), bank stratigraphy (Thorne & Tovey 1981), pore water pressure (Casagli et al. 1999, Rinaldi & Casagli 1999), water stage fluctuation (Dapporto et al. 2003, Luppi et al. 2009, Rinaldi et al. 2004), seepage (Chu-agor et al. 2008, Fox et al. 2007, Shields & Simon 2009), riparian vegetation (Pullen et al. 2009, Simon et al. 2006, Van-De-Wiel & Darby 2007, Hubble & Rutherfurd 2010), tension cracks (Darby & Thorne 1994, Taghavi et al. 2007). These factors have been taken into consideration in some available bank stability models of which are capable of replaying detailed collapse processes, such as collapse time and shape of failed blocks (Darby et al. 2000, Langendoen & Simon 2008, Luppi et al. 2009, Osman & Thorne 1988, Rinaldi et al. 2004, Simon et al. 2000). At the same time, several complex mathematical models that combine bank stability models and sediment-flow models are developed to simulate the river evolution with bank erosion and show effective performance to some extend (Chen & Duan 2008, Darby & Thorne 1996, Langendoen et al. 2009, Nagata et al. 2000, Wang et al. 2004). However, most bank failure models require large detailed field data to calibrate key parameters incorporated, especially geotechnical parameters to which these models are sensitive (Langendoen & Simon 2008, Parker et al. 2011, Samadi et al. 2009, Samadi et al. 2011), and their application are confined to local riverbanks where bank material properties show not much spatially variability and can be generalized by situ investigation. Consequently, these models are incapable of predicting bank failure with respect to large-scale natural riverbanks with both lack of field data and highly inherent geotechnical variability. The traditional methods based on extreme hypothesis are able to predict large-scale bank retreat, but they are merely applicable to homogenous non-cohesive riverbanks (Chang 1990). Furthermore, the extreme methods only provide the overall retreat instead of the detail distribution at left and right bank (ASCE Task Committee 1998b).

According to the summaries of characteristics and reasons of several alluvial riverbank failures, this paper points out it is the lower bank instability due to slope steepening by flow scouring that leads to bank failure. Then the stable slope of lower bank is conceptually introduced. Based on

the field topography data with respect to bank failures along the middle and lower Yangtze River, we present the statistic method of stable slope and demonstrate the stable slope variation with riverbank materials. Accordingly, a new model in terms of stable slope is proposed to make rapid bank stability assessment. The primary advantage of this bank stability model over traditional models is its independence on field geotechnical data, and hence large-scale bank failure prediction is potentially practicable. Then two complex mathematical models are developed by incorporating the proposed model into one-dimensional and two-dimensional flow-sediment models, respectively. The one-dimensional complex model is used to predict the bank failure along the middle and lower Yangtze River after the operation of Three Gorges Project since 2003, and the two dimensional models is employed to simulate the bank retreat in Jianli reach located in the middle of Yangtze River. The results indicate the proposed bank stability model not only is able to predict large-scale riverbank failure but also can simulate small-scale channel evolution with bank collapse.

2 BANK FAILURE MECHANISM

Alluvial riverbank compositions are formed primarily by fluvial deposition and are typically stratified with fining materials overlaying relative coarse materials (ASCE Task Committee 1996a). Table 1 lists bank composition, bank failure characteristics and bank failure causes of several alluvial rivers. It is obvious that these riverbanks are basically stratified except the Arno River (Dapporto et al. 2003) and Missouri River (Simon 2002, Simon et al. 1999) where part riverbank materials are primary cohesive soil in contrast to coarse bed materials. When water flows by near-bank zone, the fluvial erosion of lower bank is more effective than the upper bank due to less cohesive resistance to flow scouring and higher frequency of water stage up to lower bank, and the faster erosion rate gets lower bank steep to the point of triggering upper bank collapse, which is consistent with the collapse causes listed in Table 1. Consequently, the stability of alluvial riverbank is closely related to the lower bank slope steepening by flow scoring.

The bank failure types, listed in Table 1, are mostly cantilever failure and planar failure. Cantilever failure typically occurs in stratified bank with thick non-cohesive layer underlain by thin cohesive layer, such as the bank failures along Yangtze River (IGSNRR 1985), Gangs River (Bela 2011, Bhaskar et al. 2012) and East Fork River (Andrew 1982). The cause of cantilever failure mainly depends on the contrasting cohesion between the upper and lower layer. The upper layer needs to be cohesive enough to maintain overhanging, while the lower layer is easily entrained by flow. Cantilever failure usually happens during the later stage of falling limb when the bank toe erosion is accumulated to some extend (Luppi et al. 2009). Planar failure usually happens in stratified bank with steep cohesive

Table 1. Bank composition and bank failure characteristics.

River	Bank materials	Characteristics and causes of bank failue
Yangtze river	Cohesive soil overlaying sandy bed	Cantilever failures due to bank oversteepening by flow scouring.
Ganges river	Micaceous sand underlying silt-clay layers	Bottom layer retreat due to flow scouring leads to upper layer collapse and seepage after flood also triggers bank instability.
Nile river	Cohesive layer overlying sandy bed	Planar failures due to toe and near bank scouring, crack, seepage and water stage fluctuation.
Arno river	Homogeneous banks being composed of silty sand and stratified banks with sitly sand overlaying sandy gravel	Dominant planar and cantilever failures are triggered by a complex combination of bank materials, bank geometry and flow characteristics.
Sieve river	Silty sand layer overlying sandy gravel layer	Planar and rotational failures dominate, which occur due to lower bank oversteepening by scouring.
Missouri river	Homogeneous banks being composed of silt and clay and stratified banks with silt and clay overlaying silty sand or fine sand	Planar failures due to bank toe oversteepening by fluvial bank erosion are primary.
East fork river	Gravel layer underlying sand and silt	Upper layer collapse due to the removal of base layer by flow entrainment.

upper layer, such as the bank failures along Nile River (Ahmed et al. 2010), Missouri River (Simon 2002, Simon et al. 1999), Sieve River (Rinaldi et al. 1999) and Arno River (Dapporto et al. 2003). The upper layers of these banks can keep steep due to matric suction developed in upper unsaturated layer, increasing the apparent cohesion and allowing the upper layer to maintain a large angle. So the reduction of matric suction and development of pore water pressure due to prolonged high water stage, rainfall infiltration through tension cracks and lateral seepage unfavorably affect upper bank stability and can further trigger planar failure in coincidence of bulk volume increase and rapid removal of confining pressure at drawdown stage. Accordingly, planar failure typically occurs during the early stage of falling limb (Luppi et al. 2009).

In fact, the detail failure type and time depend on the comprehensive interaction of inner soil physical properties and outer hydrological processes. No matter what kind of bank failure happens, the lower bank deformation due to fluvial erosion always accompanies. The lower bank is composed of primary non-cohesive materials which keep stable at an angle no more than angle of repose, so the slope angle to maintain stable under flow scouring is definitely smaller than repose angle and exists an upper limit, called critical slope. If the lower bank slope exceeds critical slope, the lower bank will adjust slope to critical slope, equivalent to the retreat of lower layer, which leads to the upper layer overhanging and weakens the upper layer stability. As this kind of retreat goes on, the upper layer will collapse in combination with other adverse factors related to bank stability. On the contrary, if the lower bank slope doesn't exceed critical slope after flow scouring, the shaping of lower bank focuses on slope adjustment in the range from zero to critical slope rather than treat, which negatively triggers the upper bank instability.

3 STABLE SLOPE

3.1 *Stable slope definition*

The critical slope is defined as the maximum slope of lower erodible bank during the process of bank failure. Considering both the occasion of bank failure episode and lack of field data, the quantification of critical slope seems impossible, so the stable slope is introduced instead. The stable slope is defined as the maximum observed slope of all riverbanks with basically the same lower bank materials. In theory, the stable slope is less than the critical slope. However, if the field topographical data is sufficient enough to cover mostly instable banks subject to bank failures over years, the calculated stable slope will be viewed as an approximation to the critical slope in time and space.

The following statistics of stable slope are limited to the middle and lower Yangtze River from Yichang to Datong, but this method is available for other alluvial rivers. The field data used for stable slope definition includes the complete situ investigations of cross sections in 1996, 1998, 2002 and partial investigation in 1981, 1993 and 2008. The locations of overall 62 cross sections are marked by triangles in different colors (Fig. 1) according to bank composition (Fig. 2). The red triangles denote banks of Type A with clay overlaying fine sand (Fig. 2-(1)), which dominate in the middle and lower Yangtze River. The triangles in cyan, blue and green represent banks of Type B, C and D (Fig. 2-(2)–(4)), respectively. The black means protected banks with revetment (Type E, Fig. 2-(5)). For the sake of simplicity, the bank material only refers to lower bank in following content.

3.2 *Stable slope calculation*

Prior to stable slope calculation, it is essential to define the location of upper interface, denoted as (x_1, z_1), and location of lower interface, denoted as

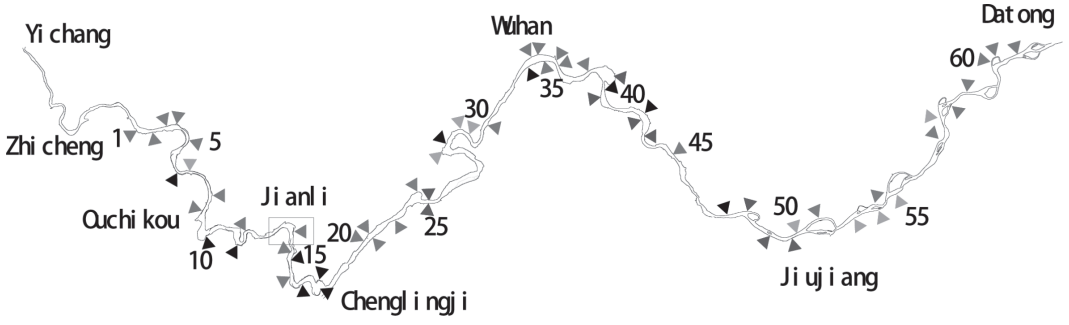

Figure 1. Sketch of the middle and lower Yangtze river.

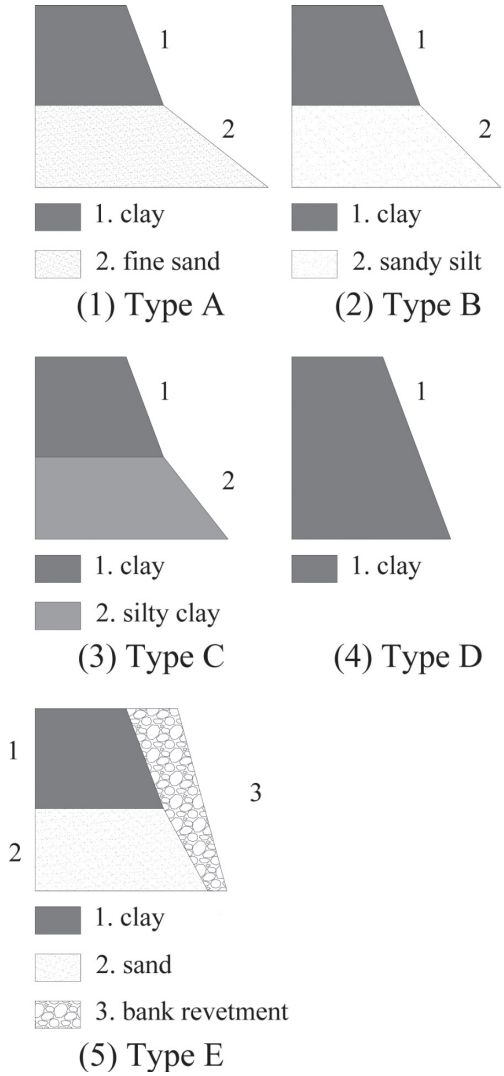

Figure 2. Bank types of Yangtze river.

(x_2, z_2). Then the slope equals to $(z_1 - z_2)/(x_1 - x_2)$. Generally, the instable banks subject to mass failure suffer from intensive flow scouring, and there usually exists a near-bank thalweg which can be chosen as the lower interface. With respect to the upper interface, the ideal choice is the interface between the cohesive layer and non-cohesive layer, but the definition of such interface along the reach over 1000 km seems unrealistic. In fact, the interface between cohesive and non-cohesive layers is typically higher than the low water level (IGSNRR 1985), and the slope from the low water level downward to the near-bank thalweg is smooth enough to represent the overall lower bank slope. Consequently, the low water level is selected as the upper interface. When the upper and lower interfaces are determined, the slope is obtained, and the slopes of other banks with identical soil composition are analogously determined. Then the stable slope is obtained by maximizing.

3.3 *Stable slope analysis*

Table 2 lists the observed maximum slopes for banks being composed of fine sand (Type A). The channel configuration (the second column in Table 2), denoted as the flat form of local reach to which each section belongs, are mostly meandering and bifurcated, which are typically common in the lower and middle Yangtze River. The observed maximum slope ranges from 0.302 to 0.363, corresponding to the maximum angle between 16.804° and 19.951°. The stable slope (angle) is, defined as the maximum of observed slopes, 0.363 (19.951°). In general, the fine sand layer is very thick and can be viewed as the same as near-bank bed materials. The available size gradation of near-bank bed materials indicates that the fine sand contains very little cohesive soil and hence is non-cohesive. With respect to fine sand, the corresponding repose angle is about 26°–30°

Table 2. Observed maximum slope of bank composed of fine sand.

Section	Channel configuration	Maximum slope	Stable slope
1	Meandering bifurcated	0.324	0.363
2	Straight bifurcated	0.302	
3	Straight bifurcated	0.318	
4	Meandering bifurcated	0.333	
5	Meandering bifurcated	0.335	
8	Meandering bifurcated	0.340	
9	Straight	0.305	
12	Meandering	0.333	
13	Meandering bifurcated	0.315	
14	Meandering	0.356	
16	Straight	0.312	
20	Straight bifurcated	0.307	
21	Straight bifurcated	0.305	
22	Straight bifurcated	0.307	
23	Straight	0.313	
24	Meandering bifurcated	0.363	
35	Meandering bifurcated	0.313	
38	Straight	0.324	
45	Straight bifurcated	0.304	
51	Meandering bifurcated	0.317	
53	Straight bifurcated	0.318	
56	Straight bifurcated	0.333	
59	Meandering bifurcated	0.329	
60	Meandering bifurcated	0.347	
61	Meandering bifurcated	0.363	

(Zhang 2007), greater than the stable angle. This difference depends on the following three reasons: the actual bank slope right before bank collapse, definitely larger than the observed slope in Table 2, is hardly to be recorded due to occasion of bank failure; the lower bank is usually immersed by water, and the higher moisture content reduces the repose angle (Li 2004), and sometimes the repose angle of saturated fined sand used in engineering application is conservatively set to about 20° (Zhang 2007); the repose angle is defined as the maximum stable slope in hydrostatic case rather than hydrodynamic condition in which stable slope is determined.

The observed maximum slope for banks being composed of sandy silt (Type B) is listed in Table 3. The slope (angle) falls into the range of 0.311 (17.276°) to 0.368 (20.204°), and the stable slope (angle) is determined as 0.368 (20.204°). Similarly, the stable slope and stable angle for banks being made of silty clay (Type C) is 0.376 and 20.606°, respectively (Table 4). Compared to fine sand, the sandy silt or silty clay is cohesive to some extent, so the corresponding stable slope seems to be larger than that of fine sand. It is noted, however, that the observed stable slopes of three kinds of bank materials are basically identical, since the dominant constituent is still non-cohesive sand and the higher moisture content due to longtime soak reduces the limited cohesion.

In Table 5, the stable slope (stable angle) is 0.452 (24.323°) for banks being composed of clay (Type D). It is significantly larger than that of the above three bank materials, because the content of cohesive soil with grain size less than 0.005 mm reaches to about 30% (Bureau of Hydrology 1983), which greatly increases the cohesion as well as resistance to flow scouring.

It is obvious in Tables 2–5 that the lower bank composition almost determines the corresponding stable slope. As the content of cohesive particle increases, the stable slope increase accordingly.

The statistics listed in Tables 2–5 are based on the cross sections without or before bank revetment. In fact, bank revetment reinforces the bank stability, consequently increasing bank slope, and steeper bank tends to be protected more, which greatly limits the number of unprotected banks used for statistics.

Table 6 lists the observed maximum slope of several protected bank composed of composed of fine sand, clayed loam and clay. No matter what kind of bank materials, it is worthy noting that the maximum slope of bank with revetment is always larger than that of bank without protection (Tables 2, 4 and 5). In fact, the common revetment is riprap protection in Yangtze River. The riprap changes the lower bank material composition and effectively weakens the fluvial entrainment, so the protected bank can maintain a higher slope.

Based on the above analysis of stable slope, a new model is proposed for bank stability assessment as follows: (1) defining the stable slope for a specified bank material through the available sectional topographic data; (2) estimating the bank stability by making a comparison between the actual lower bank slope and the stable slope: the bank maintains stable with the actual slope less than the stable slope, otherwise the bank is instable with respect to mass failure. Compared to most bank stability model at

Table 3. Observed maximum slope of bank composed of sandy silt.

Section	Channel configuration	Maximum slope	Stable slope
31	Straight bifurcated	0.316	0.368
33	Meandering bifurcated	0.329	
34	Meandering bifurcated	0.324	
36	Meandering	0.345	
37	Meandering	0.333	
58	Meandering bifurcated	0.368	
62	Straight	0.333	

Table 4. Observed maximum slope of bank composed of silty clay.

Section	Channel configuration	Maximum slope	Stable slope
25	Straight	0.361	0.376
26	Straight	0.315	
39	Meandering bifurcated	0.376	
41	Straight	0.306	
43	Meandering bifurcated	0.332	
44	Meandering	0.334	
47	Meandering bifurcated	0.373	
48	Straight bifurcated	0.321	
49	Meandering	0.346	

Table 5. Observed maximum slope of bank composed of clay.

Section	Channel configuration	Maximum slope	Stable slope
7	Meandering	0.442	0.452
27	Meandering bifurcated	0.452	
29	Meandering	0.439	
30	Meandering	0.440	
50	Straight	0.400	
52	Straight	0.395	
54	Straight bifurcated	0.400	
55	Meandering bifurcated	0.417	
57	Meandering bifurcated	0.430	

Table 6. The observed maximum slope of protected bank.

Section	Channel configuration	Maximum slope	Bank materials
6	Meandering	0.555	Fine sand
10	Meandering bifurcated	0.528	Fine sand
11	Meandering	0.501	Fine sand
15	Meandering	0.490	Fine sand
17	Meandering bifurcated	0.563	Fine sand
18	Meandering	0.597	Fine sand
19	Meandering	0.516	Fine sand
28	Meandering bifurcated	0.604	Clay
32	Meandering bifurcated	0.689	Clay
42	Meandering bifurcated	0.413	Silty clay
40	Straight	0.499	Silty clay
46	Straight	0.502	Silty clay

present, the new model needs the support of topographic data rather than geotechnical data which is only available in special location, so the model is preferable to make rapid bank stability estimation for the riverbank free of detail geotechnical data.

4 COMPLEX FLOW-SEDIMENT MODEL

4.1 *Governing equations*

Incorporating this new bank stability model into traditional flow-sediment models, we can develop complex models to simulate the channel evolution with bank failure. In this paper, a one-dimensional complex model and a two-dimensional complex model are established, respectively. For the sake of simplicity, only the two-dimensional complex model is present.

The two-dimensional flow-sediment equations in orthogonal boundary-fitted coordinates (ξ, η) are as follows (Wang 2004).

Continuity equation

$$\frac{\partial Z}{\partial t}+\frac{1}{C_\xi C_\eta}\frac{\partial}{\partial \xi}\left(UhC_\eta\right)+\frac{1}{C_\xi C_\eta}\frac{\partial}{\partial \xi}\left(VhC_\xi\right)=0 \quad (1)$$

Momentum equation in ξ direction

$$\begin{aligned}&\frac{\partial U}{\partial t}+\frac{U}{C_\xi}\frac{\partial U}{\partial \xi}+\frac{V}{C_\eta}\frac{\partial U}{\partial \eta}+\frac{UV}{C_\xi C\eta}\frac{\partial C_\xi}{\partial \eta}-\frac{V^2}{C_\xi C_\eta}\frac{\partial C_\eta}{\partial \xi}\\&=-\frac{g}{C_\xi}\frac{\partial Z}{\partial \xi}+\frac{\nu_t}{C_\xi}\frac{\partial}{\partial \xi}\left(\left(\frac{\partial C_\eta U}{\partial \xi}+\frac{\partial C_\xi V}{\partial \eta}\right)/C_\xi C_\eta\right)\\&-\frac{gn^2\sqrt{U^2+V^2}}{h^{4/3}}U-\frac{\nu_t}{C_\eta}\frac{\partial}{\partial \eta}\left(\left(\frac{\partial C_\eta V}{\partial \xi}-\frac{\partial C_\xi U}{\partial \eta}\right)/C_\xi C_\eta\right)\end{aligned} \quad (2)$$

Momentum equation in ξ direction

$$\begin{aligned}&\frac{\partial V}{\partial t}+\frac{U}{C_\xi}\frac{\partial V}{\partial \xi}+\frac{V}{C_\eta}\frac{\partial V}{\partial \eta}+\frac{UV}{C_\xi C\eta}\frac{\partial C_\eta}{\partial \xi}-\frac{U^2}{C_\xi C_\eta}\frac{\partial C_\xi}{\partial \eta}\\&=-\frac{g}{C_\eta}\frac{\partial Z}{\partial \eta}+\frac{\nu_t}{C_\xi}\frac{\partial}{\partial \xi}\left(\left(\frac{\partial C_\eta V}{\partial \xi}-\frac{\partial C_\xi U}{\partial \eta}\right)/C_\xi C_\eta\right)\\&-\frac{gn^2\sqrt{U^2+V^2}}{h^{4/3}}V+\frac{\nu_t}{C_\eta}\frac{\partial}{\partial \eta}\left(\left(\frac{\partial C_\eta U}{\partial \xi}+\frac{\partial C_\xi V}{\partial \eta}\right)/C_\xi C_\eta\right)\end{aligned} \quad (3)$$

where C_ξ, C_η = Lami coefficients determined by the following equations

$$C_\xi=\sqrt{x_\xi^2+y_\xi^2},\quad C_\eta=\sqrt{x_\eta^2+y_\eta^2} \quad (4a,b)$$

Z = water level; h = water depth; Z_b = bed elevation; $U=uy_\eta-vx_\eta$, $V=vx_\xi-uy_\xi$, contravariant velocities in ξ and η directions, respectively; n = roughness coefficient; $\nu_t=0.067u_*h$, turbulent diffusion coefficient; u_* = shear velocity; g = gravitational acceleration.

Suspended load transport equation

$$\begin{aligned}&\frac{\partial}{\partial t}\left(hS_k\right)+\frac{1}{C_\xi C_\eta}\left(\frac{\partial C_\eta UhS_k}{\partial \xi}+\frac{\partial C_\xi VhS_k}{\partial \eta}\right)\\&=\frac{1}{C_\xi C_\eta}\frac{\partial}{\partial \xi}\left(\nu_t\frac{C_\eta}{C_\xi}\frac{\partial hS_k}{\partial \xi}\right)+\frac{1}{C_\xi C_\eta}\frac{\partial}{\partial \eta}\left(\nu_t\frac{C_\xi}{C_\eta}\frac{\partial hS_k}{\partial \eta}\right)\\&+\alpha_{*k}\omega_k\left(S_{*k}-S_k\right)+S_{0k}\end{aligned} \quad (5)$$

where subscript k = index to size group of suspended load; S_k = suspended sediment concentration of the kth size group (kg/m^3); S_{*k} = sediment carrying capacity of the kth size group(kg/m^3); ω_k = effective setting velocity (m/s); α_{*k} = saturation recovery coefficient for the size group k; S_{0k} = lateral suspended sediment input for the kth size group.

Bed deformation equation of suspended load

$$\rho_s\frac{\partial Z_{sl}}{\partial t}=\sum_{k=1}^{N_s}\alpha_{*k}\omega_k\left(S_k-S_{*k}\right) \quad (6)$$

where ρ_s = dry bulk density of suspended load; N_s = total number of suspended load size group; Z_{sl} = scouring or deposition depth due to suspended load transport.

Bed deformation equation of bed load

$$\rho_b\frac{\partial Z_{bl}}{\partial t}=-\sum_{j=1}^{N_b}\left(\frac{1}{C_\xi}\frac{\partial g_{b\xi,j}}{\partial \xi}+\frac{1}{C_\eta}\frac{\partial g_{b\eta,j}}{\partial \eta}\right) \quad (7)$$

where

$$g_{b\xi,j} = \frac{g_{bj}U}{\sqrt{U^2+V^2}}, g_{b\eta,j} = \frac{g_{bj}V}{\sqrt{U^2+V^2}} \quad (8a,b)$$

subscript j = index to size group of bed load; ρ_b = dry bulk density of bed load; N_b = total number of bed load size group; Z_{bl} = scouring or deposition depth due to bed load transport; g_{bj} = unit width bed load transport rate of the jth size group.

The criteria for classifying wash load, bed load and suspended load is based on suspension index (Zhang 1989). The suspended sediment carrying capacity calculation and its graduation distribution refer to the refined Zhang Rui-jin formula (Li et al. 2001) and Li Yi-tian formula (Li 1987), respectively. The Dou Guo-ren formula (Dou et al. 1987) is employed for bed load transport rate calculation, and the Wei Zhi-lin model is used for bed materials graduation adjustment (Wei 1997).

4.2 *Boundary conditions and moving boundary treatment*

At inlet, the discharge, suspended sediment concentration and bed load transport rate are specified. At outlet, the water level is defined. At solid walls, the velocities, sediment concentration and bed load transport rate is set zero.

The initial flow field is set to zero. The water level is specified the same as water level at outlet. The suspended load concentration is set to zero or observed data.

The interface between water and land always moves as the water level fluctuates, and the "freezing" method is employed to deal with moving boundary (Cheng 1988). When the water depth drops below a prescribed dry threshold (0.05 m), this node (or control volume) is viewed as dry, and the velocities is set to zero and this node is kicked out of computation.

4.3 *Bank erosion model*

In section 3, we have proposed the bank stability model. Prior to applying this mode to modeling bank retreat, we need to make the following assumptions: a. The riverbank is stratified with the cohesive layer overlying non-cohesive layer, and the soil properties of both layers can be generalized by averaging; b. the upper bank materials are fine enough to be defined as wash load; b. the bank failure type limits to planar failure sliding through bank toe; c. the influence of pore water pressure, crack, confining water pressure, vegetation and seepage is out of consideration.

The bank erosion model includes two steps: lateral fluvial erosion calculation and bank stability analysis. First, the lateral erosion distance is determined as follows (Osman 1988)

$$\Delta B = c_l \Delta t \frac{\tau - \tau_c}{\gamma_b} e^{-1.3\tau_c} \quad (9)$$

where c_l = erodibility coefficient related to soil properties and needs to be calibrated by field data; γ_b = bulk weight of bank materials; ΔB = the lateral erosion distance during time interval Δt; τ_c = critical shear stress of bank materials; τ = flow shear stress that is determined as follows

$$\tau = \gamma_w n^2 \frac{U^2+V^2}{h^{1/3}} \quad (10)$$

where γ_w = bulk weight of water.

The lateral erosion calculation is followed by bank stability analysis. Figure 3 depicts the bank retreat with respect to mass failure. ΔB is the lateral erosion distance determined by Equation 9. ΔL is the retreat distance of the upper cohesive bank. β is the stable slope resting with bank materials, channel form and earthwork of bank revetment. θ is the slope after fluvial erosion. The water level sigh denotes low water stage which corresponds to the upper elevation subject to definition of stable slope. In Figure 3, the upper cohesive layer, denoted as *HEFG*, is to collapse immediately after the retreat of lower layer, denoted as *ABEH*. *AIHG* represents the initial bank shape. After fluvial erosion, the bank deforms as ACIHG. When the bank slope θ exceeds the stable slope β, the bank will collapse and adjust its slope to stable slope, denoted as *BLEF*. Consequently, the overall retreat of both fluvial erosion and mass failure is equivalent to bank retreat from *AH* to *BE*. Then the retreat distance of upper layer, ΔL, can be figured out on the basis of conservation of

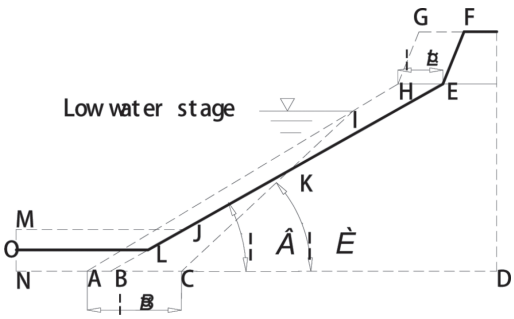

Figure 3. Sketch of bank erosion inducing mass failure.

sediment volume, the identical area of triangle *ACI* to quadrangle *ABEH*, and initial bank geometry *AIHG*. When the bank slope is less than the stable slope, the bank will keep stable.

The sediment derived from bank erosion or both bank erosion and bank failure partially translates into suspended load, equivalent to the lateral suspended sediment input in Equation 5, while the rest accumulates at bank toe as bed materials and changes bed elevation of bank toe. When the amount of the accumulated sediment is determined, the bank toe elevation can be updated. Supposing MJBN denotes the whole sediment yield from riverbank and MJLO stands for the transportable suspended sediment, the final bank toe after bank retreat is defined as OL.

4.4 *Numerical solution and computation procedure*

4.4.1 *Velocity field solving*

The SIMPLE (Semi-implicit Method for Pressure Linked Equations) algorithm formulated on collocated grid is employed for updating velocity field (Tao 2001). Equations 1–3 are discretized by finite volume method. The power-law scheme, central difference scheme and forward difference scheme are used for discretizing convection-diffusion items, water stage gradient and temporal derivatives in Equations 2 and 3, respectively. The discrete equations are solved by ADI (alternating direction iteration) method. In order to prevent the occurrence of chessboard pressure, the MMIM (Modified Momentum Interpolation Method) is used to maintain pressure-velocity coupling (Majumdar 1988).

4.4.2 *Bank erosion modeling*

According to the updated flow condition, we use Equation 9 to figure out the lateral erosion distance. Then we assess the bank stability and record the deformed bank geometry as well as overall sediment yield from bank.

4.4.3 *Lateral sediment input calculation*

In step (2), we have obtained the sediment yield of which is transported into suspended load. The lateral input of suspended load is determined as follows

$$S_{ok} = \frac{M_b P_1}{0.5(\Delta x_1 + \Delta x_2) B \Delta t} \Delta P_{bk} \tag{11}$$

where $M_b = V_b \rho_{bk}/(1 + e)$, the mass of eroded sediment; $V_b = 0.5 A_b(\Delta x_1 + \Delta x_2)P_2$, the volume of eroded sediment; A_b = the area of eroded sediment for a given cross section; ρ_{bk} = bank materials density; e = soil moisture content; Δx_1 = distance between the referred section and its adjacent section forward; Δx_2 = the distance between the referred section and its adjacent section backward; P_2 = longitudinal erosion range; P_1 = percent of suspended sediment in the eroded sediment; B = the river width. ΔP_{bk} = bank soil graduation.

When the lateral input is figured out, the sediment accumulated at bank toe is also determined. Accordingly, the bank toe elevation can be updated.

4.4.4 *Suspended load transport solving*

The discretization of Equation 5 is the same as that of Equation 2 and the discrete equation is also solved by ADI method.

4.4.5 *Longitudinal riverbed deformation and bank geometry adjustment*

After solving Equations 5 and 6, we can obtain the updated bed elevation. If the bed elevation of control volume attached to bank toe changes, the bank toe elevation is set to be the same as that of the bank toe attached control volume, and the bank toe is relocated at the intersection of bank surface and bed surface. In Figure 3, OL represents the bed surface close to the bank surface denoted as LE. When the bed elevation descends from *O* to *N*, the bank toe is at *B*. When the bed elevation ascends from *O* to *M*, the bank toe is at *J*.

5 APPLICATION

5.1 *Bank failure prediction of the Jingjiang reach*

The one-dimensional complex model is used for predicting the bank failure along Jingjiang reach from Zhicheng to Chenglingji (Fig. 1) after 20 years operation of TGP (Three Gorges Project) since 2003.

According to the bank stability model proposed in Section 3, the bank stability depends on the comparison between the actual lower bank slope and stable slope. Since the upper interface (lower water stage) is easily obtained through field data of water stage over years, the actual bank slope mainly relies on the lower interface (near-bank thalweg) variation including vertical depth change due to erosion-deposition and lateral adjustment. Since the one-dimensional model fails to quantify the lateral adjustment, the vertical depth change is only concerned.

The water depth of thalweg, denoted as H_{max}, usually increases as the sectional average depth, denoted as H_{av} increases, and vice versa. The empirical relationship between H_{max} and H_{av} is expressed as follows (Li 2009)

$$H_{\max} = kH_{av} + H_1 \tag{12}$$

Equation (12) in form of increment is

$$\Delta H_{\max} = k\Delta H_{av} \tag{13}$$

where k = the ratio coefficient, depending on the channel configuration of local reach, the bank materials, and the reference water stage with respect to H_{max} and H_{av}; H_1 = coefficient which is calibrated by field depth data; ΔH_{max} = water depth change at thalweg; ΔH_{av} = sectional average depth variation.

The detail procedures of large-scale bank stability assessment are as follows: a. we use the one-dimensional flow-sediment model to simulate the channel evolution of Jingjiang reach (Ge 2007), and obtain the correspondingly sectional average depth variation below low water stage, ΔH_{av}; b. Based on Equation (13), we figure out the lower interface variation subject to lower bank slope calculation; c. Calculation of the actual slope and estimation of bank stability by the model proposed in Section 3. Figure 4 depicts the predicted bank failures along Jingjiang Reach after 20 years operation of TGP, denoted as triangles. The red circles denote the observed bank failure happening during the time from 2003 to 2007. Apparently, the whole observed bank failures are predicted. Considering the lower bank slope calculation refers to the elevation of thalweg in 2023, definitely lower than the elevation of thalweg before 2007, so the observed bank failures, of course, fall into the range of prediction. The triangles in black color represent the predicted bank failures which don't occur actually. This discrepancy results from the fact that the revetments largely strengthen these banks for maintaining stable to a steeper slope. In addition, the triangles in magenta color denote the bank failures which don't happened during the time from 2003 to 2007, but it is quite possible that these banks will collapse in future and need to be monitored and protected in advance.

5.2 *Simulation of Jianli reach evolution with bank failure*

The Jianli reach, a typical minor bending bifurcated reach, locates at the tail of Jingjiang (Fig. 1). It starts from Tashiyi and ends at Hengling. Wuguizhou bar divides the channel into left Jianli branch and right Wuguijia branch (Fig. 5).

The dominant fluvial processes perform as the alternating development of left or right branch accompanied with the deposition-erosion of Wuguizhou bar, and the detail are shown in Table 7. When the left branch dominates, the left bank (from Laohexiakou to Taiheling) retreats significantly (Fig. 5). When the right branch becomes main branch after 1989, the right side of Wuguizhou Bar has fallen back substantially.

The left bank is composed of deposition formed in Holocene. The upper layer consists of silt loam, silty clay and clay, and the lower layer consists of relatively homogeneous fine sand. The right bank is mainly composed of clay except bedrock. The riverbed primarily consists of relatively homogeneous fine sand, the Wuguizhou Bar is composed of fine sand, sandy loam and silty loam.

The computation domain starts from Tashiyi to Hengling (Fig. 5). The computation grid is orthogonally boundary-fitted and its layout is as follows: 240 cross sections along riverbank with an adjacent distance about 75 m; 120 nodes along sectional direction with an adjacent distance about 8–26 m.

The model calibration includes fixed bed verification in terms of water stage and lateral velocity distribution and movable bed verification in terms of cross section erosion-sedimentation. The calibration data refers to field data observed in 2008–10 and 2009–10.

Table 8 lists the calculated and observed water stage with inlet discharge of 16370 m^3/s in 2008–10. The absolute difference doesn't exceed 5 cm.

Figure 6 shows the calibration of velocity distribution of section 0-0 in 2008–10 (inlet discharge

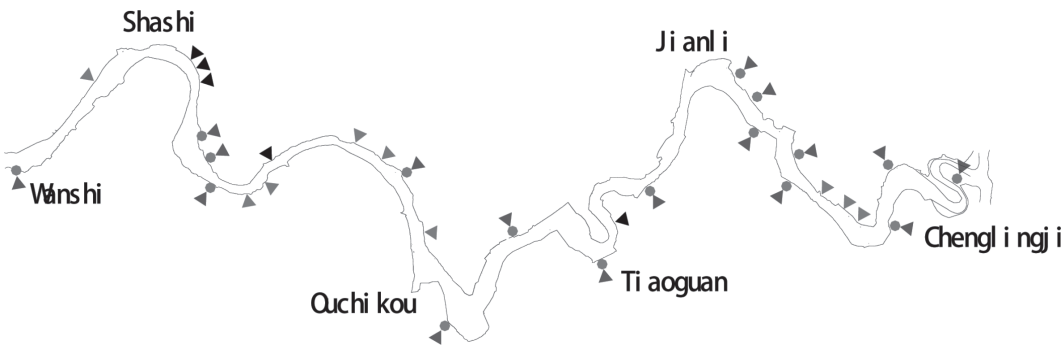

Figure 4. Prediction of bank failures along Jingjiang reach from 2003 to 2023.

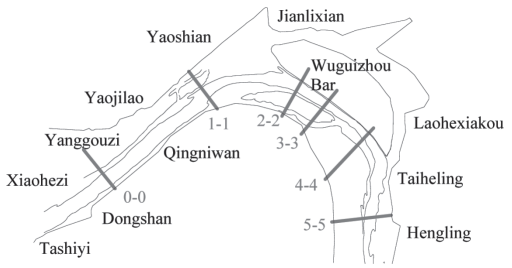

Figure 5. Sketch of Jianli reach.

Table 7. Fluvial processes of Jianli reach since 1945.

Time	Fluvial evolution characteristics
1945–1971	The left Jianli branch develops with left bank retreats, while the right Wuguijia branch deterio-rates due to sedimentation. The Wuguizhou Bar is attached to the right bank as the convex side bar.
1971–1975	The left Jianli branch gets narrow and curved due to continuous deposition at left margin of Wuguizhou Bar. The right Wuguijia branch turns into main branch after the cutoffs downstream.
1975–1989	As the Wuguizhou Bar retreats substantially, the sidebar attached to right bank develops and the entrance of left Wuguijia branch gets shallow. The left Jianli branch changes back into mian branch.
After 1989	The head of Wuguizhou Bar shrinks, which improves the flow conditions of left Wuguijia branch. After two major floods, the entrance of left Wuguijia branch gets deeper and the left branch becomes the dominant branch.

Table 8. Water stage calibration.

Section	Observed (m)	Simulated (m)	Difference (m)
0–0	29.77	29.75	0.02
1–1	29.65	29.66	–0.01
2–2	29.57	29.58	–0.01
4–4	29.30	29.32	–0.02
5–5	29.17	29.16	0.01

of 16370 m^3/s), and Figures 7 and 8 corresponds to sections 1-1 and 5-5, respectively. Obviously, the simulated results coincide well with the observed.

Figures 9–11 depicts the sectional erosion and deposition calibration for section 0-0, 1-1, and

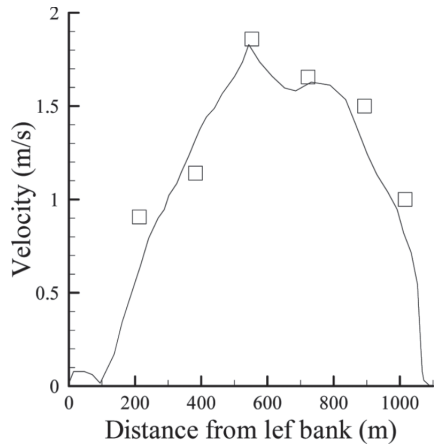

Figure 6. Velocity calibration for section 0-0.

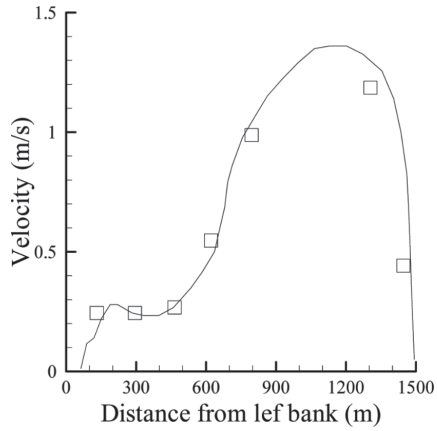

Figure 7. Velocity calibration for section 1-1.

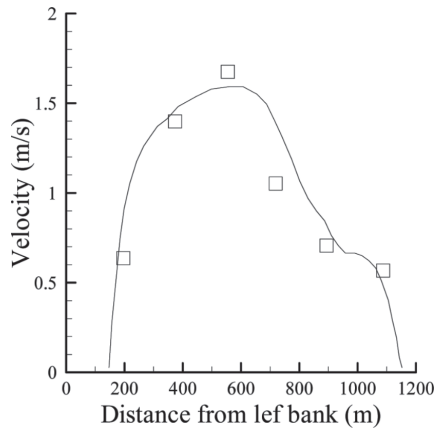

Figure 8. Velocity calibration for section 5-5.

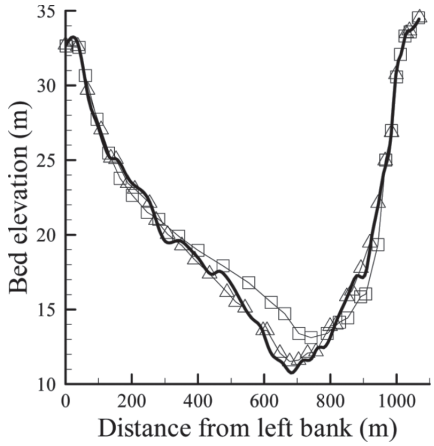

Figure 9. Topography calibration for section 0-0.

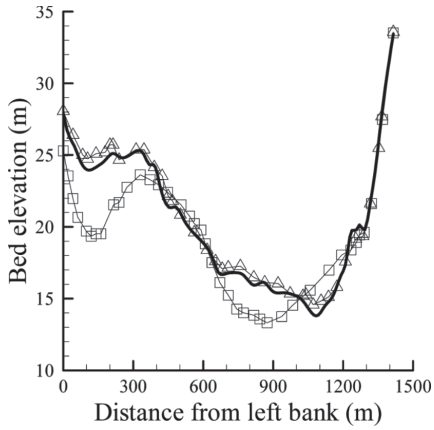

Figure 10. Topography calibration for section 1-1.

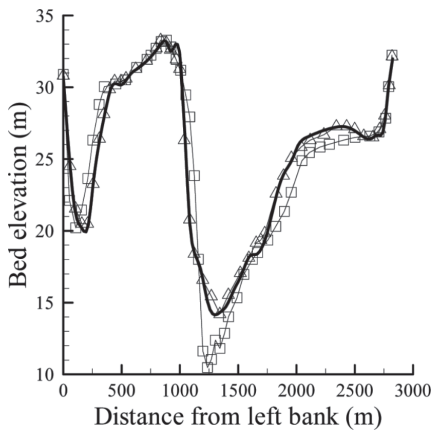

Figure 11. Topography calibration for section 4-4.

4-4 during the time from 2009–10 to 2010–10, respectively. The simulated terrain variations are basically consistent with the observations.

The satisfying calibrations of water stage, velocity distribution and sectional deformation indicate the two-dimensional complex model is capable of modeling flow movement and riverbed evolution.

The calibrated two-dimensional model is applied to simulate the right bank retreat of Wuguizhou bar during the time from 2007–7 to 2009–10, and the simulated results are shown in Figures 12–14.

Figure 12 depicts the retreat process of section 2-2, located at the head of Wuguizhou. The simulated retreat is slightly less in 2008–10 but relatively more in 2009–10. Figure 13 corresponds

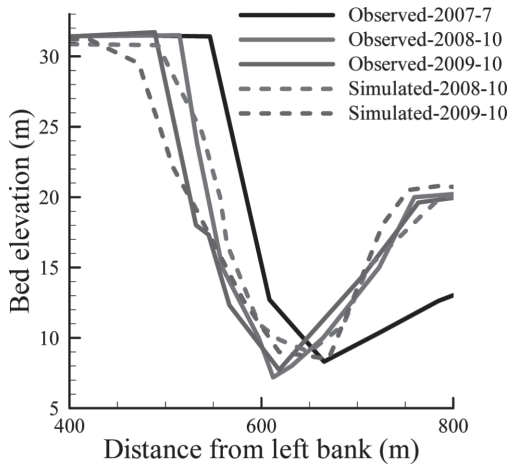

Figure 12. Bank retreat simulation for 2-2.

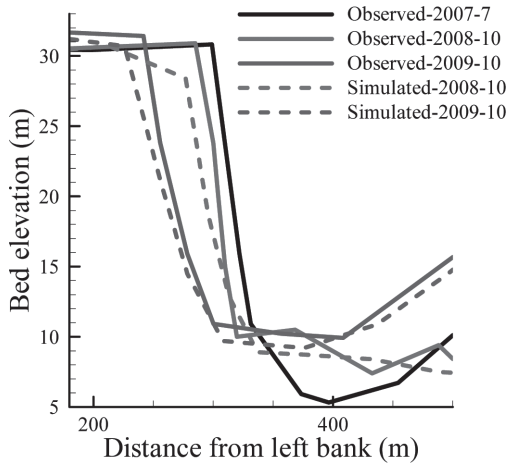

Figure 13. Bank retreat simulation for 3-3.

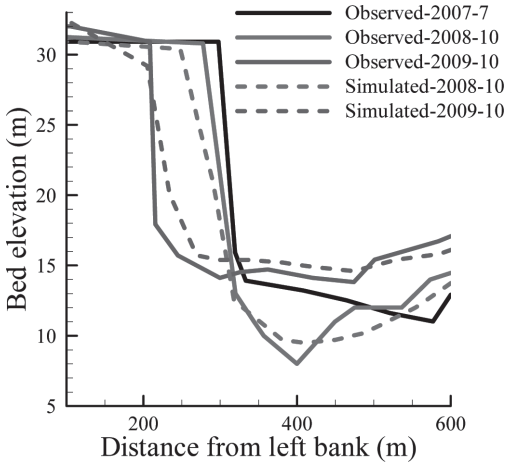

Figure 14. Bank retreat simulation for 4-4.

to 3-3, located at the middle of Wuguizhou, the simulated bank retreat is more than that of observed. The retreat at the tail of Wuguizhou is shown in Figure 14, the comparisons between simulation and observation is quite the reverse of that of section 2-2. On the whole, the simulated bank retreat generally coincides with the actual bank retreat and this means the proposed bank stability model is also applicable to small-scale channel evolution with bank failure.

6 CONCLUSION

The alluvial riverbank collapse is closely related to bank stratification. In this paper, we analyze the bank failure characteristics and causes of bank failure in several alluvial rivers, and the stable slope is introduced as a criterion for bank stability estimation. Based on the field date with respect to bank failure along Yangtze River, the analysis of stable slope is followed by its calculation. The analysis indicates that it is the lower bank composition basically determines the stable slope and the stable slope increases with the increase of content of cohesive particle. Then a new bank stability model is proposed, and two complex models are developed by incorporating the proposed bank stability model into the traditionally one-dimensional and two-dimensional flow-sediment models, respectively. The one-dimensional complex model is used to predict the bank failure along the Jingjiang reach from 2003 to 2023, and the two dimensional models is employed to simulate the bank retreat in Jianli reach. The results indicate the proposed bank stability model not only is able to predict large-scale riverbank failure but also can simulate small-scale channel evolution with bank collapse.

This new model can assess bank stability in a simple but effective way. However, this model doesn't take into account enough factors that affect bank stability, and hence it fails to show better performance than the dominant mechanical models in terms of failure type, failure time and geometry of failure block. In future work, we need to refine this model by enhancing its mechanical basis.

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Technical papers

Sediment yield

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Sediment source: A key parameter of catchment sediment yield

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ABSTRACT: The suspended sediment yield of a catchment or river basin is a key measure of its sediment response. It can be usefully complemented by additional information on, for example, the physical and geo-chemical properties of the sediment. Information on sediment source could add another important dimension. Attempts have been made to generate such source data from the sediment load record, but the methods employed and the data produced are of questionable reliability. Recent advances in the use of sediment source fingerprinting techniques now provide an effective means of assembling information on sediment source and this approach is being increasingly used. The basis of sediment source fingerprinting techniques is outlined in this contribution and the results from a study of two contrasting sets of catchments in Britain are presented. Available information on the sediment sources of catchments and rivers in Britain is reviewed and the potential for developing a global typology of fluvial systems based on the relative contribution of surface and channel sources is explored.

Area method in landslide depth estimation for slate and shale hillslopes

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ABSTRACT: Sediment yielded from a watershed is usually generated from various sources. Nowadays numerical models at different spatial scales are available to estimate soil loss from a watershed. Nevertheless sediment yield from slump or landslide still depends on empirical relationships to estimate the likely sediment production that often calculated landslide depth. Total of 108 landslide sites acquired from three watersheds situated in southeast corner of slate and shale geological formation of Taiwan, with the drainage areas of 102.65, 102.46 and 145.16 km^2, respectively, constitutes the field data domain. The results of this study indicate landslide depth is poorly correlated with average slope of the landslide extent. It is better correlated with the projected area of the landslide extent. A regression equation is generated that provides acceptable landslide depth estimation for the projected area of landslide extent up to 1 km^2.

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Sedimentation study of Putah South Canal, California, USA

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ABSTRACT: The 53-km long Putah South Canal (PSC) is a vital source of agricultural, municipal, and industrial water supply for over 400,000 people in Solano County, California, USA. Large amounts of sediment are carried into and deposit in the canal every year, impacting water quality and creating significant operational and maintenance problems. The study involved identification of major sources of sediment in the canal, measurements of annual sediment deposits, field monitoring of turbidity and suspended sediments during storm events, and development of sediment budget components. The data collected provide valuable planning and management information for PSC operators and users. Results of this study may also be of interest to those concerned with operation and maintenance of canals located in similar environments.

Using $^{210}Pb_{ex}$ measurements and the SEdiment Delivery Distributed (SEDD) model to estimate erosion rates in a small agricultural catchment in southern Italy

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ABSTRACT: In the study reported in this paper, $^{210}Pb_{ex}$ measurements are used to calibrate and validate the SEDD model for a small catchment (ca. 0.8 ha) located in Sicily (southern Italy), where high rates of soil loss have been observed during recent decades. The sediment delivery ratio estimated using the $^{210}Pb_{ex}$ measurements has been used to calibrate the SEDD model and the estimate of net erosion from the catchment provided by the model has been compared with that provided by the $^{210}Pb_{ex}$ measurements. The results confirm that the SEDD model provides estimates of erosion rates similar to those provided by the $^{210}Pb_{ex}$ technique and indicate that in combination the two approaches provide an effective means of estimating soil erosion rates on agricultural land in southern Italy.

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Numerical modeling of soil erosion on DEM-based systems

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ABSTRACT: Soil erosion usually results in agricultural losses and environmental disasters. Since soil erosion phenomenon is complicate, estimating watershed erosion during storms is practically difficult. Although empirical equations for soil estimating have been applied in practice, the applications of these equations have still limited in some specified geomorphologic and hydrologic conditions. The objective of this study is to develop a fully distributed soil erosion simulating model based on erosion mechanics and watershed geomorphologic conditions. Watershed topographic figure was firstly developed based on a Digital Elevation Model (DEM), and diffusion-wave approximation was used to simulate the runoff processes. Mechanics for rainfall detachment and flow detachment on soil were included in the numerical modeling.

Geomorphologic and hydrological information from the Goodwin Creek Experimental Watershed in the United States and Shihmen Reservoir Watershed in Taiwan were collected to demonstrate the applicability of the proposed model for sediment-yield estimation during storms. Good agreements between the simulated and recorded sedimentgraphs have shown the capability of the numerical model for runoff and sediment yield simulations in these two watersheds. The results indicate that the numerical model can perform a good simulation for sediment yield because the detail mechanics of soil particles transport and deposition from overland to downstream channel have been included in the modeling.

Experimental analysis for fine-grained and large-grained soils involved in debris flow at the solid-fluid transition

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ABSTRACT: A laboratory experimental techniques has been presented for determining the viscous properties of materials that are involved in fast landslides (i.e., mud flows and debris flows). An inclined plane and a rotational rheometer have been used. Water-soils mixture have been arranged at different solid concentration and different grain size distribution, reproducing a mixture having characteristics close to the samples of real debris-flow. In the studied range of solid concentration (in which the material behaves like an homogeneous fluid), the typical rheological behavior of these suspensions is that of a yield stress fluid exhibiting a static yield stress larger than the dynamic yield stress. The stresses widely increase from very low to very large values. It has been also observed that the rheological behavior of the materials is strongly influenced by the particle size in the mixtures. These results suggest that during a fast landslides motion a small variation of the solid fraction content or of the particle dimensions may lead to changing from "solid like" behavior to "fluid-like" behavior and vice versa.

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Simulation of suspended sediment load using data-driven models: A comparative study

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ABSTRACT: This study is aimed at comparing four data-driven models: Sediment Rating Curve (SRC), Modified SRC (MSRC), Artificial Neural Network (ANN) and singular spectrum analysis coupled with ANN (SSA-ANN), for simulating monthly average suspended sediment load of four catchments in the Lower Mekong Basin. Three different input combinations were also taken into account for model simulation. As a result, SRC and MSRC which are more dependent on the average relationship, require larger sample size than ANN and SSA-ANN do, for statistical stabilization and at the same time the high quality results. The model performance was improved successively while advancing the method from SRC to MSRC, ANN and SSA-ANN. Based on the best input combination of each model and catchment, all the corresponding results were considered acceptable with Nash-Sutcliff Efficiency ranging from 0.85 to 0.99 in calibration stage and 0.57 to 0.86 in validation stage.

Study on multi-stages landslide due to rainfall

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ABSTRACT: In the mountainous area of the world multi-stages landslides in series may occur due to rainfall events. So, this study attempts to develop a numerical model to investigate this landslide mechanism. A two-dimensional (2D) seepage flow numerical simulation model was coupled with a one-dimensional (1D) surface flow and erosion/deposition model for the seepage analysis. Pore-water pressure, moisture-content, and surface-water head data obtained by the coupled model were used to analyze the stability of the slope. The Spencer method of slope-stability analysis was incorporated into dynamic programming to predict the time of a landslide and its failure surface. The down slope movement of the landslide mass was analyzed using 1D sliding block model as that of a rigid body. The data obtained from the numerical simulation results and experimental measurements are comparable.

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A study on mechanism of large-scale landslides and the prediction

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ABSTRACT: Recent researches indicated that the large-scale landslide induced by rainfalls usually occurred at the end of the rainfall, and the occurring conditions usually were attributed to the high accumulated rainfall. However, the researches which explore the relation of rainfall-runoff and the scale of the large-scale landslide are rare. This study used the integrated Rainfall-Infiltration-Slope stability model to simulate the process of rainfall-runoff and predict the occurring time and the scale of the large-scale landslide. The simulation showed that the runoff had a double peak pattern in weathered granite slopes with steeper bedrock, but ladder recession pattern in volcanic debris slopes. The bedrock locations had influence on the peak timing and decreasing pattern of the runoff. It is expected to have the possibility of the large-scale landslide evaluation if the relation between the runoff and bedrock locations is further studied.

Numerical simulation of debris flows induced by deep-seated catastrophic landslides

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ABSTRACT: It has been proposed previously that the fine sediment in large-scale debris flows behaves as a fluid rather than a solid. In order to link this concept to a model for the numerical simulation of debris flows, we presented governing equations and methods of setting parameters. Then, we conducted numerical simulations of four deep-seated catastrophic landslide (DCL)-induced debris flows that occurred in Japan. We found that the method described in this study could be applied to predict runout processes of DCL-triggered debris flows. Moreover, we found the volume concentration of fine sediment behaving like a fluid to be similar for four different debris flows, despite large differences in the volumes and grain size distributions of these debris flows. This suggested that there may be a limit to the volume concentration of fine sediment in the interstitial water of debris flows.

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Case study on 2006 flash flood disaster in Putih River of Jember, East Java, Indonesia

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ABSTRACT: On January 1, 2006 flash flood disaster (in Indonesia is known as *banjir bandang*) occurred in Putih River, Jember District of East Java Province. This disaster resulted in more than 80 people were killed and hundreds were injured. The disaster was caused by natural dam break. The natural dam was formed by landslide due to heavy rainfall. After the January 2006 disaster, new cracks and crevices were found in the upstream area of Putih River. Based on this condition, repetition of similar disaster in the future is likely to occur. Therefore, it is required to conduct mitigation efforts in order to reduce the probable casualties in the future. One of the mitigation efforts is conducted by simulation of the past event. The understanding of past event from the simulation result can be used as reference to arrange plan and action of mitigation efforts. Modeling simulation of the January 2006 flood was conducted by 1-D models. Flood hydrograph was approximated by using Nakayasu method. The daily rainfall data recorded from the neighboring rainfall stations were transformed to hourly rainfall data by implementing the Alternating Blok Method. The rainfall intensity was calculated using the Mononobe formula. The natural dam model was interpreted from field observation and related references. Flood hydrograph induced by dam break process was approached by modeling flow over a growing opening. Model calibration was conducted by varying roughness coefficient, height of dam and breach parameters. Two marks of maximum elevation of flood at 5.996 km (RS 6+984) and at 12.980 km (RS 0+000) downstream of the natural dam were used for control points in the model calibration. The calibration process has shown that the height of natural dam was significantly influencing to the changes of flood flow surface elevation at the control points. The result of flood simulation in reconstructing the January 2006 flood showed that the simulations are able to approximate the disaster event both for water surface elevation and the flood arrival time.

The changes of annual mean suspended load at up reach of Changjiang River after the Wenchuan earthquake

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ABSTRACT: The serious earthquake induces secondary geological disaster like landslips, debris flows, barrier lakes and so on, accumulates mass sediments in land surface and damages erosion control structures, which changes the underlying surface condition of river basin erosion, so the serious earthquake can influence sediment yield in river basin distinctly. Based on the observed data in recent 60 years, the quantities of water and suspended load in main control station of Changjiang River upstream was statics analyzed, and the changes of annual mean suspended load at Changjiang River upstream after the Wenchuan earthquake was discussed. Results of this study can be shown that, after the Wenchuan earthquake, the suspend load at Pingshan station (Changjiang River) decreased, the trend was consistent around Wenchuan earthquake. The suspend load at Gaochang station (Minjiang River), Fushun station (Tuojiang River) and Beibei station (Jialingjiang River) increased, it was contrary to the trend before the earthquake. The suspend load at Wulong station (Wujiang River) had no distinct changes. So the whole upstream of Changjiang river sediment runoff appeared different trend with the period of 1990 to 2008. The changes of sediment transport may affect some reservoirs and process of maintain river, especially, the increase of suspended load in some stations may cause more deposition at the fluctuating backwater area of the Three Gorges Project, so related department should be prepared by observation and research.

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Depositional process of wood-sediment-water mixture flows at an open type of check dam

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ABSTRACT: Experimental investigation into the depositional process of debris flows (wood-sediment-water mixture flows) trapped by an open check dam model shows that the behavior of wood pieces determines the sediment deposition by the open check dam model. In the laboratory flume experiments, some wood pieces were placed on the initial movable bed, and the other wood pieces were dropped on the surface of the subsequent flow part. This condition resulted in the concentration of the former pieces at the flow front and the latter pieces on the subsequent flow surface. The latter pieces trapped by the check dam model were piled up on the former pieces trapped by the check dam model. Trapping pieces by the check dam model requires sufficient number and volume of wood pieces at the flow front. The accumulation depth of the trapped pieces determines sediment deposition behind the trapped pieces.

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Sediment transport

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Development mechanism of sand bars in anabranching rivers

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ABSTRACT: The development and stability of sand bars resulted in anabranching rivers. This paper studies the development mechanism and growth direction of bars by using the evidence of vegetation development on the bars. Sandbars develop in alluvial rivers following sediment deposition in the upstream end and the bars grow upstreamward, which is very different from the delta development in estuary and reservoirs. The friction head loss of sand bars is derived based on the principle of the minimum flow resistance, in which sandbars are generalized in a diamond form. Theoretical analysis proves that the sand bars grow upstreamward. In the bar head the flow velocity is low and suspended load deposits. In contrast, two anabranching channels converge at the sand bar tail, flow velocity and the sediment carrying capacity of the flow is high. Sediment is prevented from depositing at the tail zone. The sand bar tail is shaped into a sharp triangle. Vegetation develops well and high at the bar tail, and very poor and low at the bar head. Moreover, the vegetation succession occurs at the bar tail and only pioneer species occur at the bar head. The phenomena prove the upstreamward growth of sand bars in alluvial rivers.

Linear stability analysis of meander formation originating from alternate bars

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ABSTRACT: There are two theories about the origin of river meanders: One is based on bed instability theory and the other on bend instability theory. According to bed instability theory, meanders develop as a result of alternate bar formation. However, this theory is not applicable for wave numbers where alternate bars develop, because the bend instability with such wave numbers is in a resonance condition. Meanders induced by alternate bars are often seen in natural rivers, so theoretical verification of this meander generation type is required. In this study, linear stability analysis is applied to a straight channel with erodible banks, in order to obtain the characteristics of meanders. The results indicate that some meanders are induced by alternate bars and these meanders have longer wavelengths than those determined by the previous bar theory. It was also found that Froude number is the most important parameter affecting the wavelength of this meander type.

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Study on method to determinate the gravel shoal regulation water level in the straight transition section of the upper reaches of the Changjiang River

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ABSTRACT: Gravel shoals in the straight transition section is one type of the main obstacle shoals in the Chuanjiang River. The determination of regulation water level is a key to success in the regulation of these gravel shoals, and yet the empirical and semiempirical methods are mostly used at present. In this paper, depending on gravel shoal at the straight transition region of the upper reaches of the Changjiang River, the relations between regulation discharge Q and scour indexes (average water depth H, waterway slope J, and velocity V) are obtained through numerical simulation combining the regulation scheme for actual shoals; finally the method to determinate the regulation water level is proposed.

Study on morphological process in gravel-bed river driven by vegetation

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ABSTRACT: The extension of relative elevation between bed in low-water channel and bar surface is one of the typical figures in gravel-bed river with much vegetation and that makes strong meandering flow and bank erosion in medium-size floods. In this study, such a morphological change in gravel-bed river is investigated from a view point of interaction between wood land expansion and alluvial process with alternate bars. A depth-averaged flow and bed-variation analysis is carried out considering the events of invasion and destruction (wash-out) of riparian vegetation. Results of the simulation model show extension of relative height due to bed degradation in low-water course and immobilization of forested bars which can be seen as resent channel characteristics with alternate bars in gravel-bed river.

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An explicit finite-volume depth-averaged 2-D model of morphodynamic processes near marsh edges and vegetation patches

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ABSTRACT: A depth-averaged 2-D model has been developed to simulate sediment transport and morphological changes near marsh edges and vegetation patches induced by rapidly-varying transient flows, such as strong storm surge, tsunami wave and dam-break flow. The model uses the generalized shallow water equations that take into account the effects of sediment concentration and bed change on the flow. The vegetation drag and inertia forces are added in the momentum equations. The sediment transport model simulates the non-equilibrium transport of total load. The governing equations are solved using an explicit finite volume method with the HLL approximate Riemann solver to handle the mixed-regime flows and the wetting-drying problem efficiently. A specially designed avalanching algorithm is adopted to consider different repose angles for submerged and emergent materials. The model has been tested using several experiments, and the simulated flow patterns and bed changes are in good agreement with the measured data.

Bed morphological changes near a finite submerged patch of vegetation in open channel flows

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ABSTRACT: This laboratory experiment described the sediment patterns of erosion and deposition in response to a patch of submerged cylinders in open channel flows. For flows below the threshold of sediment motion, the erosion took place primarily opposite the patch and near the leading edge due to accelerated velocity and the diversion of flow, respectively. The degree of scour observed at both regions increased as the flow blockage, which was the non-dimensional parameter (λW_v). For flows above the critical value of sediment, sediment was deposited near the patch due to reduced bed shear stress, and as the flow blockage increased the deposition in and behind the patch decreased because of higher diversion of flow. A two-dimensional model employed the empirical relationship for submerged conditions applied to the experiments performed in present study. The model simulated well the flow and sediment patterns of erosion and deposition with the patch. From comparisons with experimental data, the degree of scour was under-predicted due to additional turbulence and vortex motions caused by cylinders, and the simulated amount of deposition in and behind the patch agreed well with experimental data.

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Simple 1-D model for dune development in a closed conduit under the previous experimental conditions

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ABSTRACT: The numerical simulation of dune development in a closed conduit is conducted under the previous experimental conditions. A simple 1-D model with Boussinesq equation for pressurized flows and non-equilibrium sediment transport model proposed by the authors is applied to reproduce the dune development. Simulations are conducted under the experimental conditions by changing the several hydraulic parameters and conditions such as diameter and step length of sediment particles. Focusing on the temporal change of amplitude and length of the dunes, the simulated results are compared to the experimental results. Through the examination of simulated results it is pointed out that the dune development processes in a closed conduit can be reproduced to some extent by means of the proposed numerical model. However it is observed that the temporal change of amplitude and length are dependent on step length.

Effect of oblique dunes on flow field and sediment transport

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ABSTRACT: Bedforms play an important role in the sediment transport of a river. Therefore many experiments have been carried out to better understand bedforms. Most experiments concern transverse bedforms. However, bathymetry measurements show many instances of oblique dunes. Oblique bedforms induce flow and sediment transport in the transverse direction.The mechanisms involved in the formation of oblique dunes are investigated in a simplified environment.The results of show a dune orientation that eventually finds an equilibrium. Two explanations were given. (1) A gradient in transverse sediment transport can decrease or increase the dune migration rate. (2) Dune crests break up, and merge before reaching a larger angle.We analysed the flume experiments carried out by Arno Talmon. Furthermore, we carried out detailed three-dimensional flow simulations. The main finding of this analysis is that the relation between dune angle and crest parallel flow velocity appears to be exponential.

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Quasi 3D numerical simulation for flow and bed variation with various sand waves

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ABSTRACT: This paper presents a quasi-3D numerical computation method for sand waves varying with hydraulic conditions. To calculate depth scale flow structures interacting with sand waves, we developed the general Bottom Velocity Computation method (general BVC method) based on a depth integrated model, in which bottom velocity and pressure acting on bed surface are calculated semi-directly without taking the assumption of the shallow water flow, such as the hydrostatic pressure distribution. The flow separation behind the dune crest, which has been found to play an important role of the dune formation, is evaluated by the production terms of the depth integrated vorticity equations. Non-equilibrium sediment transport is calculated by using momentum equation of the sediment motion with the lag distance. We applied the model to experimental results on sand waves in a narrow channel and discussed the performance of the model.

Bedload transport direction induced by bed form orientation: Large scale modelling

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ABSTRACT: The oblique feature of the dunes can be associated with the effect of the river bends as well as three-dimensional nature of the bed forms. The dune crest might be skewed in one or multiple directions, i.e. directed towards one bank or both banks. The experiments and some basic studies have shown that it has an effect on sediment transport direction. To our knowledge, this effect has not been considered so far in any existing morphological models. An attempt has been made to incorporate a dynamic bed-form orientation model, proposed by Sieben and Talmon (2011) with further improvement, into the open source of Delft3D morphological solver. The approach is rather simple, i.e. the changes in bed-form orientation are associated with transverse gradients in the bed-form migration rate. The effect of bed form orientation mainly reflects on the bed load transport direction, in turn, on morphology. In this study, some basic tests have been carried out to assess the behaviour of the numerical model in predicting the effects of the dune orientation angle on bed load transport direction and, in turn, on the bed level changes.

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Growing and decaying processes and resistance of sand waves in the vicinity of the Tone River mouth

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ABSTRACT: The long-term growth and decay processes and resistance of sand waves of the Tone River mouth from 1961 to 2007 are clarified in this paper. At first, we examine characteristics of the arrangement of dunes which are seen in the downstream of the Choshi Ohashi Bridge. Next, the long-term growth and decay processes of dunes are indicated by the variation of cross-sectional bed forms surveyed from 1961 to 2007. The variation of sand waves resistances and bed elevations during the floods in different years is evaluated by a numerical unsteady flood flow and bed variation analysis based on the observed temporal changes in water surface profiles. At last, characteristics of the sand wave resistances in the Tone River mouth are clarified by comparing with the previous studies on sand wave resistances in alluvial rivers.

Numerical study of dissipation and regeneration of fluvial sand dunes under variable discharges

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ABSTRACT: This work presents detailed morphodynamics modelling of the bedform under variable discharges and simulates the conditions in which the bed of the river is flattened out in upper plane bed regime. This scenario is simulated by detailed hydrodynamics, sediment transport and morphodynamics models, which is an extension for the model developed by Nabi (2012). Several discharge hydrographs are examined here. In the first case, the discharge increase linearly, and then stay constant. We found that dunes are generated before the condition reaches the upper plane bed regime. As the flow condition fall in the upper plane bed regime, high frequency ripples generate and they flattened the bed out. As the discharge stay constant, the bed remains smooth with small high frequency ripples. Later, four different scenarios are simulated, in which the discharge decreases again after a certain period. It is observed that the bed regenerates again in the case the discharge decreases. The model shows its capability in simulating the flood wave events.

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Analysis on trends of runoff and sediment load of the Yellow River

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ABSTRACT: As the second longest river in China, the Yellow River flows through varying natural and geographical regions, with the prominent imbalance of water and sediment sources. Meanwhile, the Yellow River is one of the rivers that have suffered the dramatic impacts of human activities since 1960. The spatial and temporal distributions of water and sediment load in the Yellow River have been changed owing to climate change and man-made projects also, such as the reservoirs, the soil and water conservation projects and the irrigation projects along the River. It is of vital for the management of water and sediment load in the Yellow River basin to probe into the trends of variations in runoff and sediment load as well as their abrupt changes.

According to the characteristics of water sources and sediment load in the Yellow River basin, the main hydrologic stations along the stem stream are selected to analyze the trend of variations in runoff and sediment load of the River. Based on nearly 60 years of field data of these stations, the Mann–Kendal trend test is adopted to check the tendencies of variations in annual runoff and annual sediment load; the rank sum test is selected to find the particular years when abrupt changes took place. The results indicate that both of runoff and sediment load manifest a sharp downward trend at most hydrologic stations, except Tangnaihai Hydrologic Station. Furthermore, the Yellow River has started to witness abrupt changes in runoff since 1986, and has started to go through abrupt changes in annual sediment load since 1980.

Suppression of alternate bar migration in a straight river due to vegetation enlargement

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ABSTRACT: Instability analysis was performed on suppression of alternate bar migration in a straight river due to vegetation enlargement. Vegetation areas were arranged alternatively on a flat bed, and linear approximation was applied to the governing equations assuming that sand bar development and flow resistance due to vegetation are very small. Analytical results could explain the tendencies in experimental results of migration velocity and wave height of the sand bars and velocity field and river bed variation around the vegetation areas. Finally, criteria diagram was obtained with respect to sand bar mobility, showing additional effects of vegetation enlargement to conventional regime criteria with no vegetation.

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Problems for the long-term use of the Three Gorges Project

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ABSTRACT: It was introduced the basic principles, the influencing factors, the research process as well as the main research results of the Three Gorges Reservoir's long-term use in the paper. The Three Gorges Reservoir was a river-type reservoir with rich flow and low sediment concentration upstream. The incoming flow and sediment came mainly in the flood period. It was beneficial to the long-term use of the reservoir. The managing methods of "storing clear and releasing muddy" were useful to control the sediment aggregations in the reservoir. The reservoir would be used for a long term when the sediment aggregation and degradation were equal as well as most of the effective storage capacity was kept in the reservoir. From now on, in order to bring the reservoir's comprehensive benefits into full play and make sure of its long-term use, the methods of the Three Gorges Reservoir's management should be optimized whereas it should be accompanied with the operation upstream the reservoir.

Study on the sedimentation and operating level in the Three Gorges Reservoir

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ABSTRACT: Sedimentation is one of the key technical issues concerned during the construction and operation of the Three Gorges Project (TGP). During the period from June 2003 to December 2010, a total amount of 1169 million t sediment has been deposited in the reservoir, and its impact were less than that predicted in the demonstration phase. According to the design, normal water level at dam of the Three Gorges Reservoir (TGR) is 175 m, and the limited water level in flood season is 145 m. However, due to the less sedimentation than that predicted, a suggestion of rising the limited water level in flood season was raised, which can increase the comprehensive benefits of TGR. This paper analyzed the sedimentation in TGR, studied the relationship between the flood control level and the reservoir sedimentation using mathematical model, and indicated that sedimentation is not the most important limitation preventing the rise of limited water level in flood season under the current condition of sediment inflow.

Keywords: the Three Gorges Reservoir, Reservoir sedimentation, Operation Mode, Mathematical Model

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Human impact on morphology and sediment budget in the Tedori River, Japan

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ABSTRACT: The present study uses a 58-year topographic survey data and related data on human impacts to quantify the change in the morphological characteristics and sand and gravel budget in the downstream Tedori River, Japan. We pursue these goals by comparatively analyzing the survey data and applying morphologic method to derive the sediment budget for the study area. The results indicate that riverbed degraded in excess of 0.5–3.5 m in the entire study area over the period 1950–2007. The riverbed experienced four phases of adjustment: first three phases strongly depended on the rate of sediment extraction from the river while the final phase was dominated by Tedorigawa Dam operation. An overall decrease in channel width of the downstream Tedori River (d.T.R) was observed. Prior to 1991 sand and gravel mining induced a considerable reduction in sediment budget along d.T.R; after 1991sediment budget slightly recovered.

Influence of Jamuna Bridge on river morphology

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ABSTRACT: Present study intends to evaluate influences of Jamuna bridge on river morphology by means of data analyses, numerical simulations, and to develop countermeasures against side bank erosion. The channel morphology of the study reach is discussed based on the criterion proposed by Kuroki et.al. in terms of the flow discharge/channel geometry, on satellite images and on numerical simulations. The numerical computations are conducted by means of a 1-D and a depth integrated 2-D models. The 1-D model describing a relation between the flow width and the flow depth is applied to estimate bed elevation macroscopically. The 2-D model proposed by Takebayashi et. al. is employed to simulate forms/changes of the channel morphology in the river reach where suspended sediment dominates. The numerical model successfully generated the braided channel with multiple row bars, and calculated the both case including a bridge structure as well as a counter measure.

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Hydro-morpho-bio-dynamic interactions in river modelling

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ABSTRACT: Riparian vegetation is a fundamental component of fluvial processes. On one side it determines the hydraulic resistance of water flow and therefore the water velocity and sediment transport. On the other side, vegetation dynamics (generation, growing and mortality) is controlled in various ways, either positively or negatively, from water discharge and cross-section morphology. In the presentation this complex interactions are described in terms of "carrying capacity", which accounts for different riverine actions on vegetal population; in particular: anoxia, wilting, extirpation and bank erosion. The carrying capacity concept has been incorporated in a quasi 2-D morphodynamic model and applied to river of various sizes in different climate conditions (Adige River in Europe, Parana River in South America and Zambezi River in Africa).

Numerical simulation of the natural processes of river meandering over realistic time scales

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ABSTRACT: In this study, the numerical flow and sediment-transport model including sub-models for bank erosion considering slump block, land accretion and cut-offs, is developed. And its validity has been investigated by calculating the meandering evolution process. It has been conducted under an unsteady discharge condition using experimental scale flume. Result shows that the bank erosion expands the channel width at along outer bend. On the other hand the land accretion narrows it along inner bend. Due to repetition of big and small discharge both phenomena have been repeated, and a meandering shape is developed and migrate from upstream to downstream. Further, the channel shape is changed drastically at the time when bank lines are crossed so called as cutoff. Results of this study indicate that a variation of discharge is key role to create complex a meandering shape which can be seen in a natural river.

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Three-dimensional gravel motions in numerical movable bed channel with particles of various shapes and sizes

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ABSTRACT: Sediment transport rate and bed variation in gravel-bed rivers are strongly affected by gravel sizes and shapes in streams. However, measurements of forces acting on sediment particles in active are difficult, especially for rapid gravel-bed rivers. To investigate the dynamic mechanism of gravel moving in streams, we have developed a numerical movable bed channel in which three-dimensional motions of various shape and size gravel particles are calculated individually. The dynamic interaction between particles motions and hydrodynamic forces on movable bed surface in numerical experiment is investigated. It is demonstrated that large gravel particles form static clusters and they have an important role to stabilize gravel-bed surface against hydrodynamic forces of flows.

Pre- and post-construction geomorphological studies of the partially closed Ackerman's Cut near RM 614, the Mississippi River

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ABSTRACT: Twenty seven locks and dams were constructed along the Upper Mississippi River upstream from the confluence with the Missouri River in 1930s. The upper part of Pool 11 just downstream from Lock and Dam 10 in Guttenberg, Iowa has a very unique geomorphic feature in which the main navigation channel flow along the right bank tends to bifurcate by cutting through an island and to feed substantial flows to the old channel along the left bank which existed prior to the construction of Lock and Dam 10. Significant reduction in the main-channel flow due to this bifurcation was considered to cause expensive dredging operations downstream from the cut, and to impact the environmental quality of the slough due to increased sediment loads from the main channel. The federal government, therefore, constructed partial closure structures to reduce bifurcation flows into the slough. This paper describes field data collections prior to and after installation of two submerged dikes in the cut, and numerical efforts to predict head drops across the cut. Using field data collected, head drops through the cut were predicted for different Mississippi River discharges and for different Manning's coefficients in the slough.

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Variational data assimilation for parameters estimation of suspended sediment transport

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ABSTRACT: Coefficients of saturation recovery and sediment carrying capacity are the key parameters in suspended sediment transport model, which are identified using historical hydrological data. However, those static values, not changing with the flux of the water-sediment environment, finally decrease accuracy of predicted sediment concentration. Four dimensional variational algorithm is one of the most popular data assimilation methods for parameter's optimization. This paper constructs a variational data assimilation system to estimating the parameters of suspended sediment transport model. A cost function is used to measure the distance between the predicted data and available observations, here the sediment concentration, and to calculate gradients for each parameter. Sediment transport equation is considered as a constraint of the cost function. A steepest descent algorithm is then used to minimize the cost function and to get optimal parameter either. As an application of the data assimilation technique, the water and sediment regulation of the lower Yellow River in 2009 is investigated. The variational assimilation method gets a process of the parameters changing with the variation of water-sediment environment, at different time and different cross section. Moreover, the method reduces the error of sediment concentration between the predicted values and the observations.

Assessment of pollutant routing method for quantification of trapped sediment in a reservoir

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ABSTRACT: Changes in land use have significant impact on the hydrology of a catchment, causing more surface runoff, less base flow and less infiltration. Erosion driven by water increases to generate more sediment being transported by river downstream, changing the river equilibrium to cause more deposition in a receiving lake, delta or estuary. For a lake, increase of sedimentation reduces the storage, either for flooding control or for power generation, besides affecting its natural ecology. Conventional methods of estimating sediment deposition in a lake are bathymetry survey and continuous monitoring at the inlets. The application of pollutant routing algorithm has been wide spread in design of a detention basin for storm water management and pollutant removal, but it has never been tested on a storage reservoir, especially under varied inflow conditions as per Manual Saliran Mesra Alam of Malaysia, MSMA (MSMA, 2000). Ellis et al (1994) developed a procedure of pollutant routing algorithm for a reservoir, but did not prove its suitability for a reservoir under varied pollutant load and inflow. Under this study, the equations by Ellis et al are used to calculate the trapping efficiency of a reservoir thus investigating the equation's suitability. The origin of the equation is continuity equation that relates Inflow and Outflow from a lake to the change in lake storage. The methodology involved combination of field sampling and laboratory analyses. By applying the routing equation, the concentration of the outflowing sediment is calculated and relates to the amount of sediment trapped in the lake. The values of trap capacity for the representative particle sizes are then weighted according to the assumed size distribution to give an overall trapping capacity of the lake. Under this study, the estimated sediment trapped in Ringlet Reservoir, after taking into dredging works at the settling basins upstream of both inlets is 20,000 m^3/yr.

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Simulation and prediction of morphological changes of the All American Canal

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ABSTRACT: The All American Canal was constructed to transport water to the San Diego area in southern California, USA. The original canal without lining resulted in significant amount of water loss due to seepage. Because water is precious in the area, a new canal with concrete lining was constructed parallel to the original canal to eliminate seepage. During the construction of the new canal, excavated sediments were piled on the right and the left banks of the original canal. The piled sediment slipped into the original canal and caused channel morphologic changes. Sediment inputs from either side of the bank caused lateral migration of the channel thalweg with flow meandering and formation of middle bars. GSTARS4 computer model was used to simulate and predict the formation and movement of the meandering thalweg. The stream tube concept and the minimum energy dissipation rate theory were applied to GSTARS4 to simulate and predict lateral variation of sediment scour, transport and deposition. Lateral migration of the channel thalweg and formation of middle bars were found by the GSTARS4 modeling. Steady and unsteady simulations have similar channel changes. However, simulated and predicted results with the application of minimum energy dissipation rate theory provided more lateral migration of the channel thalweg and flow meandering than those without the application of minimization theory.

Analysis and research on riverbed evolution and morphological relationships of Guan He River

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ABSTRACT: In this paper, hydrology and sediment characteristics of Guan He River are introduced. River bed evolution is analyzed using measured underwater terrain data. Historical evolution shows that coastal erosion happens on both sides of the Guan He Estuary area. Since the implement of bank revetment, shoreline has become generally stable. Main channel changes a little in recent years. Slight erosion happens on the concave bank and deep groove gets a little deeper. Transition area changes a little, coastline is relatively stable, river phase relation has small changes, thalweg changes a little and riverbed is relatively stable. The results of the present work show that proposed bridge zone has good condition of bridge building and deep waterway development.

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Case study: Movable-bed model scaling for bed load sediment supply in the Old Rhine (France)

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ABSTRACT: To improve the morphodynamic and biodiversity of the Old Rhine (France) which is a stable, armoured bed channel, a project aiming at supplying sediment to the bed through bank erosion has been initiated by EDF (Electricité de France). This technique consists of removing embankment revetment, allowing bank erosion and retreat, thus releasing sediment into the riverbed. In this paper, results of a laboratory modeling study are presented for a specific pilot site. On the left (French) bank, the river exhibits an alternating sequence of pools and shallow riffles with a well-developed gravel bar. To achieve model similitude, sand material is used to model the prototype bank material in a 1:40 undistorted, Froude complying model. A specific scaling approach for multi-grain size mixtures that ensures similitude of initial motion for each grain size is used but strict similitude of Shields parameter is relaxed. However, the similitude of bank mass failure between the model and prototype is preserved. More than thirty configurations have been studied, where modification to the existing groyne, adding of walls (deflectors), digging of a lateral channel and lowering of riverbed upstream of the bar were tested to find the best performing way to deflect fast-moving flow towards the left bank. Two independent deflectors with specific dimensions and form, combined with bed lowering at upstream of the bar, are recommended, combined with bed lowering. This strategy has been found to cause bank erosion for flow rates below the 1-year return period flood.

On the flow resistance and bed variations during Hii River flood

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ABSTRACT: Main channel of the Hii river divides into braided channels, and large sand waves are formed on the bars. It is considered that the flow resistance changes with bed elevation of the main channel during a flood. Therefore, evaluating the temporal variation in the flow resistance is important to understand the flood flows and bed variations in the Hii river. In this study, first, the temporal variation in the resistance during the 2011 May flood of the Hii river is evaluated by the Manning's roughness coefficient in quasi-steady flow analysis. Next, the unsteady flow analysis is conducted using the temporal variation in the roughness coefficient determined by the quasi-steady flow analysis to investigate the mechanism of bed variation in the Hii river. From these investigations, we conclude that the analysis method presented in this study is useful for the flood flow analysis in the Hii river.

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Correlation between flow-sediment regime and mainstream planform of Jingjiang reach

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ABSTRACT: To unify the variation of mainstream planform to braided and single bends in Jingjiang reach, the middle stretch of Yangtze River, this paper presents a dimensionless coefficient: sinuosity eigenvalue *r*. Correlation between *r* and hydrological eigenvalues (such as dispersion of flood flow, sediment transport index etc.) reveals that less of average flood discharge, uniformity of incoming flow and sediment will reduce height difference between beach and groove, which is favorable to formation of wide-shallow streambed, weakening the bounding effect of channels, and minish the sinuosity of thalweg. Thereby, the main streamline straightened, otherwise curved.

Equilibrium state of river bed with three grain size groups of sediment

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ABSTRACT: The objective of this study is to clarify the mechanism of the sediment transport in a reach of the river whose bed is composed of an extremely wide range of the grain size. In this study, we assumed that the bed was composed of three grain size groups of sediment: the larger stones which cannot move at all, the medium gravels which move as bed load, and the finer sand or silt which moves as suspended load. Fundamental experiments were conducted by changing the condition of bed shear stress and the sediment composition of bed. Static equilibrium state of bed was focused on. It was found in the void space of the larger stones that the vertical sorting of sediment occurs clearly. The influence of the arrangement of the larger stone was also investigated. As a result, it was concluded that the effect of the arrangement can be neglected.

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Response of reach-scale bankfull channel geometry to discharge and sediment load in the LYR

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ABSTRACT: Significant variation of bankfull channel geometry has occurred on different reaches of the Lower Yellow River (LYR) since the flow and sediment regime entering downstream has been altered by the operation of the Xiaolangdi (XLD) Reservoir. This paper presents a study on the response of bankfull channel geometry to discharge and sediment load, based on observed profiles of sedimentation sections and hydrological data. Reach-scale bankfull channel parameters (bankfull width, depth, area) were calculated using a composite method which integrates the geometric mean based on the log-transformation with the weighted average based on the distance between two consecutive sections. Relationships between the reach-scale bankfull channel geometry and the preceding 4 years' flow-sediment regime were developed in different reaches. The proposed equations can predict further change in reach-scale bankfull channel geometry in response to flow-sediment condition in the LYR.

The changing relationship of the Jingjiang River and Dongting Lake after operation of the Three Gorges Project

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ABSTRACT: Based on the field data since operation of the Three Gorges Project, the changes in Jingjiang River water level, changes on runoff three diversions from Jingjiang Reach to Lake Dongting, water level at Chenglingji station, the changing relationship of the Jingjiang River and Lake Dongting have been studied, the results show that, medium & low water level decreased to some extent in Jingjiang River, the flood water level increases slightly, the flow of the three diversions is little changes recently, changes in water level in Chenglingji decrease slightly, however, the role of the Three Gorges Reservoir regulation leads to change in above factors during median & lower water period, in essence, the relationship of the Jingjiang River and Lake Dongting will maintain the existing pattern of now after operation of the Three Gorges Project.

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Erosion-deposit variation of the river channel in Wuhan reach after the operation of Three Gorges Project

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ABSTRACT: After the completion of the Three Gorges Project, conditions for incoming water and sediment of the Yangtze river channel downstream from the Three Gorges reservoir will change, the sediment transport capacity of the river channel will be in an unsaturated state, and riverbed scouring will take place along the river channel, which may bring about adjustment of the Wuhan river regime and have some influence on the flood control. Based on the new research of 1D flow and sediment mathematic model, through computation by mathematic models and analysis of observed data, preliminary researches were conducted on the variation of water and sediment on the evolution of the river channel erosion and deposit in the Wuhan river regime after the Three Gorges project. The 50-year operation of the Three Gorges Reservoir brings minor impact on the river regime and thalweg of the WuHan reach. The two braches of the Baishazhou are kept. However, the left branch of the Tian-xin bottomland continues to become weaker, with the right one growing. At last, the effect and sediment problems related to the blocking of right branch of Baishazhou which maybe implement in recent years were studied in the paper.

On the modelling of sediment saltation mechanism under unidirectional turbulent flows

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ABSTRACT: This paper describe the computational modeling of sediment transport under turbulent flow regime. The aim is to calculate the average saltation length, height and speed of sediment in the bedload sediment transport. The sediment transport is calculated in a Lagrangian framework under turbulent flow, which is simulated by a detailed three-dimensional hydraulic model developed by Nabi et al. (2012). The hydraulic model is based on Large Eddy Simulation (LES) techniques using Cartesian grids with local refining. The sediment is considered as sphere particles and the forces are derived from the flow field. The sediment pick-up, transport, sliding and deposition models proposed by Nabi (2012) are applied. The results show that the saltation length is a function of sediment diameter and local bed shear stress. The results are compared with the previous experimental studies and a good agreement is found.

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Large eddy simulation for vertical sorting of graded sediment in sheet-flow regime

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ABSTRACT: A sheet-flow regime gives a considerable impact on a beach change. In the present study, a large eddy simulation for the vertical sorting process under the sheet-flow regime has been performed to inspect of the mechanism in the sheet-flow layer in detail. The validity of the simulation results has been verified by comparison with the previous experimental results. Then the inner structure of the sheet-flow layer has been investigated computationally. Consequently, the significant development of the vertical sorting is found in the acceleration phase, and there, the intensive turbulent-energy production rate is generated in the vicinity of the movable bed. And also the upward intensive contact force acting on large particles is found.

River sedimentation research by integrated modeling

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ABSTRACT: This paper is intended to present some recent progresses in developing better research tools for conducting research, engineering, planning and management of water resources in the world today. This need is to meet the challenges of the ever-increasingly complex and multi-disciplinary problems of maintaining sustainable, quality water supply, protecting environmental and ecological quality, and in the meantime, achieving these objectives cost-effectively. To meet this difficult challenge, the research methodology has been greatly improved, especially in the applications of newly developed computational modeling and its integration with the improved technologies of physical or hydraulic modeling and field monitoring. New applications of the integrated modeling are discussed to encourage the younger research professionals to join forces to speed up the progress for the betterment of this research approach, so that our scarce water resources system can be better understood and managed for our society. River sedimentation problem is one of the most important and complicated problems of water resources. Newly integrated modeling research examples are introduced to demonstrate the usefulness of the Integrated Modeling Approach.

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Numerical simulation of river channel processes with bank erosion in steep slope curved channel using unstructured grid system

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ABSTRACT: Accurate estimation of sediment inflow to reservoir is extremely significant for an efficient dam management. Although behavior of eroded sediment has to be investigated for a proper dam management, detailed information is not available at present. In this study, hydraulic experiments regarding bank erosion for a steep slope curved channel were conducted. And a numerical model based on the unstructured grid system was developed to simulate the bank erosion processes. It was noted that, even for an upper regime flow condition, the general feature of local bed variation is similar to the results for lower regime flow obtained by other researchers. It was also found that the experimental results can be simulated fairly well by the numerical model using appropriated submerge angle of repose of sand and the critical tractive stress at the trapezoidal slope.

Hydrodynamic forces on saltating particles in turbulent channel flow

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ABSTRACT: This paper numerically investigates the hydrodynamic forces on saltating sediment particles in a turbulent channel flow having a rough bed consisting of 2–3 layers of densely packed spheres. To solve this problem, three numerical technologies, i.e., the large eddy simulation of turbulent flow, the combined finite-discrete element modelling of the deformation, movement and collision of the particles, and the immersed boundary method for the fluid-solid interaction problem, were combined and a computing program was developed. The hydrodynamic forces on saltating sediment particles, together with the particle velocities, flow velocity profiles and turbulence intensities, were investigated. We found a velocity lag between the moving particles and the surrounding fluid and also other modifications on flow velocity profiles and turbulence intensities. The mean lift force on the particles is generally less than the particles' gravitational force in the full channel depth and its maximum is about 0.6 times the particles' submerged weight for all three cases with different Shields numbers. However, the fluctuation of the lift force cause by the turbulence coherent structures is much larger than its mean value. This, in our opinion, is the real reason for the upward motion of the sediment particles.

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Bar instability accompanied by bank erosion

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ABSTRACT: Linear stability analysis of fluvial sand bars involving bank erosion is performed with the use of the shallow-water equations. We employ simple assumptions that the bank erosion takes place with the average channel width kept constant, and that the bank erosion speed is a function of the non-dimensional bed shear stress in the vicinity of the bank. The analysis provides the growth rate of perturbation as a function of the wavenumber, the aspect ratio, and the bank erodibility. It is found that the flat bed becomes unstable in a wider range of wavenumber with increasing bank erodibility. This implies that the bed instability is intensified by bank erosion.

Experimental and numerical study of long term sedimentation in a secondary channel: Example of the Beurre island on the Rhône River, France

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ABSTRACT: Two numerical models (1D and 3D) have been used to reproduce significant deposits that have been observed in two secondary channels located next to the Beurre island on the Rhône River, France. Both models yield relatively good results compared to the measurements but are sensitive to the upstream boundary condition for the concentration, which is poorly understood. Several issues also arose thanks to this modelling. Computation of discharge repartition in the two secondary channels appeared to have a strong impact on long-term estimation of fine sediment deposits, and is an interesting challenge for 1D modelling. Discharges in the Rhône River above the one year return period flood yield approximately 50% of the fine sediment mass transiting in the secondary channels, which represents approximately 1% of the total SSM fluxes. And 1 to 10% of these fine sediments appeared to settle down. Also, erosion and deposition laws that are implemented in 1D and 3D models induce different strategies for calibration and validation.

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Loess step-pools in an ephemeral Gully in Loess Plateau, Northwest China—morphologic features and possible development mechanism

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ABSTRACT: Loess step-pools often develop in ephemeral gullies of Loess Plateau, Northwest China. The configuration of this morphology is almost totally absent with boulders, cobbles or Large Woody Debris (LWD) which normally necessary for development of step-pools in perennial mountain streams. The configuration features of the loess step-pools were surveyed and contrast with non-loess step-pools. The development mechanism for the loess step-pools is different from those non-loess step-pools. The loess step-pool morphology may firstly form from small washing holes on the loess slope due to flow scouring. With the washing holes gradually become larger, headward erosion occurs and loess steps forms. With headward erosion development, some loess steps may integrate together to form bigger ones. Vertical joint, loose structure and permeable properties of the loess and headward erosion play significant role for the development of loess step-pool morphology.

Effect of cross slope behind stream-wise groins on the ship wave and sediment transportation

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ABSTRACT: Field investigations at three locations in the Arakawa River were conducted. At each field investigation site, the wave height, distribution of bed material particles, and accumulated weight of sediment in a sediment sampler for one ship passing through the river near the groin were measured. When the variations of the average change of river bed topography at Location C1 (with milder slope (1/80)) and Location C2 (with steeper slope (1/30)) were compared, the change at Location C1 (–0.9 m^2) was around 2 times that at Location C2 (–0.4 m^2), even though the reduction of ship waves by the groin is almost identical. This result indicates it is very important to consider not only the configuration of groins but also the effect of the cross slope on sediment transportation to prevent bank and bed erosion behind groins.

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Soil erosion process and hydraulic characteristics in sloped grass plots

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ABSTRACT: It is important to study soil erosion process of grass plot so as to use them effectively to control soil and water losses on the Loess Plateau. Soil erosion, infiltration and hydraulic parameters characteristics of grass plot with 20° slope gradient were studied under rainfall intensities of 45, 87 and 127 mm/h. The results showed that cumulative runoff and cumulative sediment yield of grass plot had an obvious positive correlation with rainfall time. Under rainfall intensity of 45 and 87 mm/h, runoff and sediment yield of grass plot kept a constant level. Under rainfall intensity of 127 mm/h, runoff kept a fluctuant increase trend. Runoff infiltration of grass plot had a negative relation with runoff and sediment yield. Hydraulic parameters such as average flow velocity, runoff depth, Reynolds number, Froude number and Darcy-Weisbach coefficient were derived and analyzed based on hydraulic theory.

Investigation of sediment effects on the velocity contours in the curved open channel with rigid and mobile bed

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ABSTRACT: In the present study, based on the Computational Fluid Dynamic (CFD) a three-dimensional model was used in order to simulation of flow field in curved open channel with rigid and mobile bed in 2 & 3phases, respetively. For this purpose, commercial ANSYS-CFX software was used. Also k - ε turbulence model was used to solve turbulence equations. Simulation data were verified using experimental data obtained in an experimental analysis in hydraulic laboratory of TarbiatModares University of Tehran. Finally using Tec plot software velocity contours in different sections of both channels was plotted and compared with each other.

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Bankfull discharge prediction in the lower Wei River

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ABSTRACT: The main channel of lower Wei River is dramatically shrinking, along with a markedly decreasing of bankfull discharge in recent period. Observation data of Huaxian station in the lower Wei River is collected to study the adjustment of bankfull discharge. The response of bankfull discharge to the changes of incoming water and sediment in flood season and the Tongguan Elevation is analyzed. The result shows that the bankfull discharge of lower Wei River is not only affected by incoming water and sediment, but also by the erosion base level of downstream (the Tongguan Elevation). The delayed response model of bankfull discharge is applied and a calculation method of bankfull discharge for Huaxian station in the lower Wei River is represented in this paper, in which effect of average flow discharge in flood season, average incoming sediment coefficient in flood season, peak discharge and Tongguan Elevation are considered. Test against measured bankfull discharge at Huaxian station shows that the proposed method can accurately describe the adjustment of bankfull discharge, and the calculation results agree with the observation data very well.

How the river improvement works have been conducted in the Lower Tone River and how effective they are

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ABSTRACT: In the Lower Tone River, channel dredging and widening have been conducted to accommodate large flood discharge. However, the current river channel has still insufficient capacity for the design flood. It is therefore required to implement the appropriate river improvement works. However, effectiveness of the past channel dredging and widening has not been assessed so far. In the present paper, we carry out the assessment of the past improvement works in the Lower Tone River and clarify by investigating changes of channel shape and longitudinal distributions of hydraulic quantities in the river how the river improvement works have played important roles. The results of the past river improvement works demonstrated that the sediment deposition tended to vanish away at the downstream from 18.5 km and bed scouring near the outer bank in the river bends nearly disappear from 40 km to 18.5 km.

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The fluvial evolution characteristics and its influence on deep water channel regulations in Tongzhou Shoal river reach of Yangtze estuary

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ABSTRACT: Tongzhou Shoal river reach is one of key navigation obstructions in the extending deep water channel regulation project in Yangtze estuary. In this paper, based on multi years of field sedimentation and hydrology data, the recent flats and shoals evolutions were studied about Tongzhou river reach, the fluvial evolutions of Tongzhou Shoal river reach was predicted. The factors, formation and its effects of navigation obstruction characteristics were pointed out based on analysis of channel and riverbed evolution. It is concluded that Tongzhou Shoal is regular shoal located in the transient section of upper and lower deep troughs, sediment is silted because deep trough is bended and widened, which forms navigation obstruction shoals. Based on the analytical results, the strategy of reinforcing flats and stabilizing troughs has been brought up. The research results have also provided key technical support for channel regulation design and practice.

Study on representative tide type in lower Yangtze River

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ABSTRACT: Due to the distortion rate and time scale variation, controlling boundaries of physical model are usually conceptual and empirical. In experiments of lower Yangtze Estuary, the lower boundary of topography variation physical model is difficult to choose because the lower tidal boundary is varied with river discharge and tides. It is worth a further study in view of hydrodynamics. In this paper, one-dimensional sediment loaded flow model is setup to calculate the instant tide levels. The high and low tide level is correlated to the river discharge of Datong station. The lower controlling boundary is calculated based on the representative tide type of different accumulation rate of tide difference. The adaptive tide type is analyzed with comparison of field topography variation. It is concluded the middle and larger tide difference of lower boundary in combination with the upper river discharge can agree with the field topography variation for the river reach in engineering.

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Study on recent evolution and channel regulation schemes of Hechangzhou braided channel

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ABSTRACT: Based on the collected field hydrological and topographic data of Hechangzhou braided channel, fluvial process of this river reach and the main problems of the navigation channel were analyzed. The regulation schemes for the navigation channel were then proposed considering the requirement of shipping development and the regulation target of this navigation channel. Results show the navigation condition of the right branch can be further improved if two variable-slope submerged dikes are built in the downstream of the existing submerged dikes and the back-beach of the Zhengrunzhou is cut and the strait middle and lower channel of the right branch channel is dredged. This specific combination scheme is then studied further in next stadge. The fluvial process feature, characteristic of navigation obstruction and scheme comparison results in this study provides a good reference for navigation channel regulations in Hechangzhou braided channel.

Cumulative sediment reduction to the Lower Mekong River from planned dams

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ABSTRACT: The Mekong River is undergoing rapid development, with eight dams under construction in China and 133 proposed for the Lower Mekong River Basin (LMRB). We delineated nine distinct geomorphic regions, for which we estimated sediment yields based on geomorphic characteristics, tectonic history, and the limited sediment transport data available. We then applied the 3 W model (Minear and Kondolf 2009) to calculate cumulative sediment trapping by these dams, accounting for changing trap efficiency over time and multiple dams on a single river system. Under a 'definite future' scenario of 38 dams (built or under construction), the net sediment reduction to the Delta would be 51%. Under full build-out of all planned dams, cumulative sediment trapping will be >90% of the pre-dam sediment load will reach the Delta. This scenario would have profound consequences on productivity of the river and persistence of the Delta landform itself, and suggests that strategies to pass sediment past dams should be explored to reduce the sediment starvation.

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A study on wave equation and solutions of shallow water on inclined channel

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ABSTRACT: Viscous debris flow in China is well known as lots of intermittent surge flows. These intermittent surge flows are observed not only in China of viscous debris flow but also in the European Alps and other mountains region. But the characteristic of wave motion has not been made clear. It is important to obtain wave equation for wave motion of intermittent surges. We obtain mathematically the wave equation of shallow water with sediment on inclined channel which include intermittent debris flow. Using non-dimensional basic equation as Laplace equation, bottom boundary condition, surface condition (conservation condition of flow surface), and equation of momentum. Using a method of perturbation, Gardner-Morikawa (G-M) transfer, we obtained wave equation of shallow water on inclined channel, and we solved the wave equation on periodical boundary and initial conditions of rectangle and sin function.

Creation of meandering configuration in straight rivers by using groynes on either bank

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ABSTRACT: Continuous groynes can provide diversity of flow by creating riverbed configurations with riffles and pools. While urban rivers are often straightened and smoothed, a meandering flow condition is desirable for ecological aspects. In order to create meandering configurations in straight rivers, groynes located alternately on either bank are promising by controlling sediment transport around them. In this study, the bed deformation was measured in the various conditions of the groyne length, the longitudinal interval of each groyne and the flow rate. Generally, scour holes are generated around the groyne tip and eroded sands are transported behind the groyne. The longer groynes cause larger bed deformation. The relative flow depth and the interval of groynes are related to the deposition areas downstream and total bed form shows different patterns. To evaluate the magnitude of meandering configuration an inclination factor and a bias ratio are proposed. Using these parameters, the results of bed deformation were evaluated.

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Sediment transfer in the extreme volcanic environment (case study of the Kamchatka peninsula)

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ABSTRACT: Rivers of active volcanic territories in Kamchatka have a range of hydrological features which determine the extreme amounts of washed sediments. Sediment transport in and to river channels in volcanic mountainous terrain is strongly influenced by climate condition, particularly when heavy precipitation and warmer climate triggers a mud flow in association with snow melting in the catchment volcanic area. High porosity of the channel bottom material leads to the interactions between surface and ground water which causes temporal variability of water and sediment flow. This study provides a quantitative measure of such sediment transport. The small tributary (river length 20 km) of Avacha river was modeled based on the river.

A numerical model for sediment transport and bed change in rivers with ice

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ABSTRACT: The existence of ice has important effects on river morphology in regions with annual occurrences of an ice season. This paper presents a two-dimensional numerical model on sediment transport in river channels coupled with ice and thermal processes. The ice component of the model considers the dynamics of ice transport and cover evolution, as well as thermal related processes, such as water temperature, frazil ice, anchor ice, and thermal growth and decay of ice cover. The sediment model considers the effect of surface ice and water temperature on the sediment transport capacity. Numerical examples illustrating the ice effects on sediment transport and bed changes in alluvial channels are presented.

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The hump phenomenon and its formation mechanism in the Lower Yellow River

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ABSTRACT: The bankfull discharge of the Lower Yellow River appeared the most remarkable hump phenomenon during 1994–2002. After then, the hump phenomenon was weakened gradually. The peak of the Hump was situated in the reach between Gaocun and Sunkou stations. The formation of the hump reach reflected the scour and siltation of the channel. For example, from October 1994 to October 1999, the siltation between Jiahetan and Sunkou stations was larger than the other reaches. The hump reach also has the characteristics of easy siltation and difficult erosion. After analyzing the historical background and geographical environment of the hump reach, the paper points out indicated that the formation and development of the hump reach are mainly due to the changes of water and sediment conditions, then the water and sediment conditions for formation and important of the hump reach are given in the papers.

Study of flood flow and gravel riverbed variation analysis in the Satsunai river

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ABSTRACT: In the Satsunai river with gravel-bed, stones and gravels have moved violently during floods and severe bed scouring and bank erosion occurred. To clarify flow and sediment transport during a flood is important to design a stable longitudinal and cross-sectional form. The authors have developed a new method of two-dimensional riverbed variation analysis focused on bed surface unevenness and the mechanism of sediment transport in gravel-bed rivers. We applied the new model and the conventional model to riverbed variation of 2011 flood whose data of water surface profiles were observed in detail. We showed that the new model is a useful method for flood flows and riverbed variation in the Satsunai river with gravel-bed.

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Experimental study on sediment transport characteristics of dry dams

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ABSTRACT: Since dry dams excel at regulating floods while having little adverse effect on the natural environment, many such dams have been planned in recent years. However, the characteristics of sediment transport at dry dams are not sufficiently understood. The purpose of this research is to obtain basic data for hydraulic model experiments and to understand the sediment transport characteristics of dry dams. The experiments found that sediment is flushed from the dam at the discharge increase period and the latter discharge decrease period, and that the grain size distribution changes with time. Moreover, it was suggested that the flushing mechanisms of sediment from the dam differ in the discharge increase period and the latter discharge decrease period. The meandering talwegs that formed immediately upstream of the dam are thought to play an important role in sediment transport.

Linear stability analysis of channel bifurcation by seepage erosion

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ABSTRACT: In the previous analysis, a linear stability analysis of the inception of stream incision by seepage erosion had been performed, and the theoretical results were compared with the laboratory experimental results. The Cartesian coordinate system was used. Recently, we had conducted a new experiment. In the new experiment, a small channel was made before running at the center of the scarp line where seepage emerges. Thus, groundwater flow convergence into the small center channel was promoted. In some cases, channel bifurcation of the centered channel was observed, and in some cases, another channel was initiated. Thus, two phenomena should be considered separately. To study channel bifurcation around the channel head, we introduce a new simple linear stability analysis using the polar coordinate system in this study.

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Interaction between waves of alluviation and incision in mixed bedrock-alluvial rivers

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ABSTRACT: In the Sklar-Dietrich model of bedrock, incision is caused by wear as alluvial clasts collide with bedrock. The rate of wear is related to a cover factor expressing the areal fraction of the bedrock surface covered by alluvium. This cover factor is related to the ratio of sediment supply to the capacity sediment supply necessary for complete alluviation. This model cannot capture time-varying sediment supply. Here a variant of an earlier model due to Struiksma is used to describe alluvial waves migrating over a bedrock surface. It is shown that even with the same mean sediment supply rate, different patterns of cyclic variation can lead to the evolution of very different equilibrium long profiles in balance with constant base level drop or uplift rate.

Estimation of critical discharge at the failure of loose rock chutes

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ABSTRACT: Rock chutes are structures used in river restoration as grade stabilization structures. They pass stream flow to a lower level with high dissipation of energy and also a low environmental impact structure as fish easily move in either direction over the chutes. Aeration of flow over the chute due to high turbulence improves the water quality by increasing the dissolved oxygen. In order to ensure functionality of rock chute, it is important that the rocks remain stable during design flood events. Tests were performed in a rectangular channel where rock chutes of different slopes were modeled. The chute instability occurs at different stages viz. incipient, local, global and ultimate failure, however the local failure has been considered as critical condition of instability. The critical discharge increases with non-dimensional boulder size while decreases with chute slope. The critical discharge also increases exponentially with uniformity coefficient of the boulders. The available data were used to arrive at a specific relationship for critical discharge estimation at local failure. The proposed relationship satisfactorily estimates the critical discharge at local failure within 30%.

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Cyclic steps by bedrock incision

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ABSTRACT: In rivers flowing in mountain areas, a series of steps are often observed on bedrock. This is called "cyclic steps by bedrock incision" in this study. They are thought to be cyclic steps formed due to erosion of bedrock, which should be driven by abrasion due to bedload sediment transport. We demonstrated a series of flume experiments of the formation of cyclic steps on bedrock by abrasion due to bedload transportation using weak mortar as the model bedrock. Cyclic steps are developed on the harder model bedrocks in this study and their shapes are consistent with that predicted by the analysis, i.e., a short upstream-facing slope and a long downstream facing slope. The maximum erosion rate occurred at moderate sediment supply, which might due to the tradeoff between abrasion and the partial alluviation of bedrock. The result is consistent with previous studies.

Research on channel improvement scheme of the Shipai reach by three-dimensional flow mathematical model

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ABSTRACT: The reach has five famous navigation-obstructing shoals between the Three Gorges and the Gezhouba Reservoir. And they are respectively four shoals and one bend. This bend is Shipai reach. Generally, the flow is gentle and has no complex flow pattern with small discharge. But flow velocity is rapid and flow pattern is out of order when the discharge is larger than 25,000 m^3/s in the flood season. It is dangerous for ship navigation and difficult to guarantee navigation safety. The flow conditions for navigation urgently need to be improved. Despite the improvement of navigation management, it is also necessary to build the engineering for channel improvement. Based on analyzing the navigation-obstructing characteristics, the principles and ideas are obtained for channel improvement engineering. In order to contrast the effects for different improvement schemes, the three-dimensional mathematical model is proposed. It uses the orthogonal-grid in horizontal and sigma-grid in vertical direction respectively to fit the irregular distribution of channel plane, bed topography and water surface. It is well validated by measured data from the physical model, including water level and velocity in three directions. Then it is used to simulate the flow characteristics without and with the channel regulation. The flow pattern is contrasted with different schemes, including backflow and circulation flow. The simulated results show that it is effective by reef blasting and dumped fill which may obtain good flow pattern. The research results will have a good preference for designing of channel regulation in the Shipai reach.

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Suspended sediment movements as 2D Poissonian models

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ABSTRACT: This research initializes a sequence of studies for the development of stochastic models of sediment movements in open-channel flows. A longitudinal and vertical trajectory of single particle results of two chronologic series of movement periods: (i) an alternate series of longitudinal downstream steps intercalated by time periods when the particle does not move in this sense, and (ii) an alternate series of fall vertical steps, intercalated by time periods when the grain does not move vertically. These series are defined by four density functions of mobility, which characterize the particles group random movements. The objectives of this work are: (i) to present the longitudinal and vertical models; (ii) to calibrate and validate them, using data from laboratory channels experiments. Radioisotopes were used to measure the bed and suspended-load movements. The results show that the Stochastic Theory may be applied to evaluate the 2D sediment and pollutant movements in open-channel flows.

Morphological variations of different sections in Jingjiang river after TGR operation

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ABSTRACT: The characteristics of flow and sediment, erosion and deposition, and morphological changes in the cross section of Jingjiang river channel was investigated on the basis of measured data after the Three Gorges Reservoir (TGR) operation. Factors causing the morphological changes were also analyzed. Results suggest that the erosion mainly happens in channels of low water level, among which the shallow shoals in lower Jingjiang reach are subject to severe erosion. Morphological change varies in different river patterns: for braided channels, branching braids developed at the convex bank; for curved channels, deep grooves were silted at the concave bank while side shoals were eroded, and the morphology of the cross section transformed from approximate V-shape to W-shape; and as for straight channels, the side shoals at both banks were eroded alternately, and the cross section developed to be wide and flat with the thalweg changing frequently. Furthermore, Factors leading to the morphological changes were concluded as flow stage, incoming sediment, and bed's plane morphology.

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Analysis on runoff and sediment changing of the Jialingjiang River basin

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ABSTRACT: The runoff of the upper reaches of the Yangtze River mainly derives from the Jinshajiang River, the Minjiang River, the Tuojiang River, the Jialingjiang River and the Wujiang River, while the suspended load sediment is mainly originated from the Jinshajiang River and the Jialingjiang River. In recent years, with the development of economy and the exploitation of water resources, the condition of sediment yield and transportation in the upper Yangtze River have been greatly changed. The Jialing River Basin is one of the primary sediment-yielding areas in the Yangtze River, where a large number of hydraulic constructions have been built for the past few years, resulting in significant sediment blocking effect. Studying the characteristics of runoff and sediment in the Jialingjiang River is of great importance for researches on the runoff and sediment changes of the upper Yangtze River, as well as the comprehensive management of the Yangtze River. In this paper, a long hydrological sequence of runoff and sediment observations from 1950s to 2010 in the Jialingjiang River Basin is used for trend, breakpoint and cycle analysis, using statistical analysis technique, such as Accumulated Anomaly analysis, Mann Kendall rank correlation test, and Fisher ordered clustering method. The results show there is no tendentious variation for the runoff, while the sediment load is reducing significantly, especially after the year of 1980.

Characteristics of riverbed deformation along the estuary reach of Huaihe River

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ABSTRACT Based on long-term measurements of flow and sediment transport along this river reach, features of sediment transport and riverbed deformation have been studied. Considering the features of this estuary river reach, one 2D numerical model has been developed to simulate flow along the river reach from the Fushan to Laozishan.The developed model can be used to simulate flow under different alternatives in river regulation/construction process of the estuary reach downstream of the Fushan. Based on the findings, considering the development of the flood retention zones of the Huaihe River, some countermeasures for flood protection along the estuary reach of the Huaihe River have been proposed, such as, 1) the excavation of the Fengtieying diversion channel, and 2) dredging and straightening of the estuary reach of the Huaihe River.

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Experiment on channel formation process using wide width flume

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ABSTRACT: Channel network configurations are changed by hydraulic conditions. The characteristic of a river channel network configuration is directly connected with river channel disasters and a river ecosystem. For this reason, the relation between the form characteristic and the hydraulic conditions needs to be grasped. In this study, hydraulic experiments on channel network configurations were conducted. Sufficiently wide flume was used for the experiments so that the influence of side walls might not appear in the channel network formation. Although few channels were formed in the hydraulic condition that the bed shear stress was near the critical bed shear stress, multi-row bars were formed in the condition that the bed shear stress is to some extent large. As a result of conducting linear stability analysis, it is found that a channel formation is strongly affected by bar formations.

Experimental research on the sand waves variation of compound plastic sand of physical model

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ABSTRACT: the resistance of sand waves is an important part of resistance in movable bed. And in River Physical Model, it is key problem to learn the variation of model sand wave for resistance similarity in movable bed. The compound plastic sand is new model sand which was developed to need the Changjiang river flood control model's research. The compound plastic sand has the advantages of stable and adjustable in physical property, and easy to mass production. The study of this plastic sand waves is basis for mobile-bed simulating of Changjiang river flood control model. In this article the flume experiment was done to study the variation of plastics sand waves. The results show that: under a certain depth of water, with the flow intensity increasing the sand waves goes through three stages: ripples, dune, and plane movable bed. Wave height and length firstly increases and then decreases with flow strength increasing. The metric of sand waves increased with increasing of median grain size of the plastic sand. When the sand waves fully developed, the bed resistance can increase from 0.013 (plane bed) to more than 0.03.

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Computational study of roll waves in shallow flow over erodible bed

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ABSTRACT: A computational study on erodible-bed hydraulics of roll waves with sediment transport and morphological evolution is presented. The governing equations of the model comprise the shallow water hydrodynamics equations closed with the Manning formulation for the boundary resistance. The second-order Total-Variation-Diminishing version of the Weighted-Average-Flux method, along with the HLLC approximate Reimann Solver, is used to solve the governing equations, which can properly represent shock waves. It is applied to reproduce Brock's laboratory experiments of roll waves in a fixed bed channel. Numerical simulations are performed to illustrate the evolution of roll waves over erodible bed. The results show that the morphological evolution considerably affects the dynamic characteristics of roll waves, as the infiltration. It is therefore essential to incorporate sediment transport and morphological changes in mathematical modeling of overland flows featuring roll waves in arid areas.

Impacts of operation on navigation conditions in Middle and Lower Yangtze River (MLYR) of the Three Gorges Reservoir (TGR)

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ABSTRACT: The flow and sediment condition in MLYR was changed after the impoundment of TGR, and further, the deformation of sandbars and shoals were affected, both of which have an influence on the navigation in MLYR. Based on the field data, the analysis shows that the changes of flow and sediment favored the waterway condition, which includes elevation of the lowest water level, time extension of shoals scour, speed increase of shoals erosion caused by less sediment. After the operation of TGR, bank collapsed and beach was cut with increasing frequency, and the shoal tended to shrink. However, not all the deformation of sandbars and shoals will obstruct the waterway, only the Width of Water Retaining to Channel (WWRC) is more than the critical width, the channel will not be smooth. The critical WWCR is about 900~1900 m and varies with the navigation base level and the channel scale.

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Sediment resuspension distinction after dredging project due to wave

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ABSTRACT: A wave flume test was conducted in conditions of different bulk densities and wave dynamics in order to reveal the sediment resuspension characteristics. There were three findings. *Firstly*, in the static state, suspended sediment concentrations exhibit slight vertical difference. While under wavelet condition, sediment particles do not move on a big scale and suspended matters' in each of the three layers do not increase noticeably. *Secondly*, with an increase of wave height up to 9 cm, shear stress becomes far greater than critical shear stress and suspended matter concentrations increase abruptly and show marked vertical layers. To be specific, the concentration after ten minutes is 10~15 times higher than that in wavelet period and resuspension quantity within 60 minutes is 80 percent of resuspension gross in 120 minutes. *Thirdly*, the flume test, including four densities of 1.34, 1.47, 1.55, and 1.59 g/cm^3, also indicates that resuspension gross has a negative significant linear correlation with bulk density of sediment.

Changes of navigational channel and its regulative strategies on the middle Yangtze River after the Three Gorges Project impoundment

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ABSTRACT: After the impoundment of the Three Gorges Project on the Yangtze River, ongoing changes of channel evolution are obvious in long distance downstream the dam, so that the navigational water depth and stability of water way are difficult to maintain and regulation measures should be taken to guarantee the channel unobstructed. In this paper, the changes of channel evolution and the compensative strategies are presented comprehensively. It is proposed that the base level of erosion should be protected in the gravel bed reach, so that the process of water surface gradient increasing could be stopped. However, in the sand bed reach the sandbars should be protected from erosion to keep the stability of channel planform, so that both the position of main stream and width of channel cross section could be controlled.

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Riverbed evolution trend of Laijiapu riverbend downstream from Three Gorges Project

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ABSTRACT: The Laijiapu riverbend located in Jingjiang River Reach downstream from the Three Gorges Project, whose bank collapses and sandbar changes frequently. So the position and depth of channel trough in Laijiapu riverbend are unstable, which are not conductive to shipping. The article collects the measured terrain data for nearly 40 years, by contrast riverbed evolution characteristics in different periods, combining logical reasoning and numerical simulation, discusses influence factors of riverbed evolution, reveals the trend of riverbed evolution and channel navigation condition change. The research shows that the point bar of the convex bank will continue to erode, being cut during greater flooding, and the Zhongzhouzi flood plain on the left side of the transition section will collapse severely. These changes will cause the entrance and transition section of Laijiapu riverbend widen, deep troughs interleaving, and channel navigation condition worse.

Fluvial evolution causes and regulation of Dongliu braided reach

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ABSTRACT: In this paper, the flow-sediment mathematical model is employed to check the influence factors related to the rapid increases of diversion ratio of Donggang Branch in Dongliu braided reach. The simulating results indicate that the dominant influence factor is the adjustment of diverting point due the retreat of the head of central bar by scouring. Accordingly, a regulation scheme is proposed in terms of protecting the head of central bar to suppress the diversion ratio increase of Donggang Branch. Similarly, the numerical model is used to check the effect of regulation project and the results denote that the proposed project is able to control the further increase of Donggang diversion ratio so as to solve the navigation problems of Dongliu Reach.

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Analysis on bed evolution and channel regulation of Madangnan reach of the Yangtze River

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ABSTRACT: Madang South reach, located in the lower reaches of the Yangtze River, is a typical braided channel. Based on the observed data of he hydrology and sediment over years, this paper analyzes the evolution and navigation-obstruction characteristics of the waterway, and proposes the regulation idea, which is "maintaining the existing pattern of two branches, guarding against the scouring of Mianwai sandbar head, keeping the shrink of the right reach within limits, and maintaining the channel navigation condition. The waterway regulation scheme is discussed based on the moving bed model test, and the test result shows that the project layout of the longitudinal dam in the head of Mianwai sandbar and the bottom protection mattress in left channel are reasonable, and the project can achieve the anticipated effect after the implementation of the project. This project can provide reference for the similar branching channel management in the middle and lower reaches of Yangtze River.

The diffusion coefficient of suspended sediments based on two-fluid model of two-phase flows

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ABSTRACT: Suspended sediment plays a dominate role in fluvial rivers. In this paper, the theoretical expression of the diffusion coefficient for suspended sediment based on the two-fluid model of two-phase flows is obtained by introducing the concept of dispersion velocity. The advantages of the result are as follows. First, the model considers several factors including gravity, the lift force, the turbulent diffusion, and the inter-phase forces, and thus we can describe the mechanism of suspended sediments better than empirical relations. Second, it is noted that the suspension of sediment in open channels is the result of three different actions, which are the turbulence diffusion of mixture, particle turbulence, and collisions among particles. Furthermore, the concentration and the grain size of sediments have different effects on the three actions, their influences are derived by comparing between different experimental runs.

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Dynamic changes in water depth, velocity and resistance of flow during flood at steep mountain stream

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ABSTRACT: Understanding flow characteristics and flow resistance of steep mountain streams are essential; however field data is limited especially for large floods. This study aimed to measure flow depth, velocity and resistance intensively in the field and captures dynamic temporal changes in flow depth, velocity and resistance during large flood. We could measure water depth and surface velocities at the step and the downstream pool section at one minute intervals during large flood with total precipitation of 288 mm. Flow behaviors during peaks were different between the step and the pool section; increase in water depth was significant at the step while dramatic increase in velocity drained same amount of water at the pool section. Manning's roughness coefficient dramatically decreased with water depths up to about 1.1 m, while changes in coefficient were small when water depths were over 1.2 m at the both section. The coefficients at the high flow condition were similar at the step and the pool sections. Our results suggested that dominant component of flow resistance changed from spill and grain resistance during base flow to form resistance during peaks of large floods.

A field survey on the bathymetry and bed sediment in a multi-spur-dyke field

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ABSTRACT: This paper presents a field investigation result on the bathymetry and bed sediment composition in a multi-spur-dyke field in a reach of the Min River near Chengdu City, China. The typical bed morphological features such as local scour, wake deposition, mainstream degradation and thalweg shifting are confirmed with the field data. The sediment size distribution in the spur dyke field is completely different from that in a channel without any hydraulic structure. In general, the fine sediment intends to set down in the bay area formed by the spur dykes and this kind of sediment is hardly found in the main channel area. The low elevation area in the spur dyke bay works as a sink tank for the finest sediment particles.

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Suspended sediment transport in the Kiso River basin

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ABSTRACT: In order to estimate the amount of suspended sediment transport from the Kiso River basin to the Ise Bay, we investigated the relationship between observed river discharge and suspended sediment concentration at several points in the basin. The relationship was applied to a distributed hydrological model (Hydro-BEAM) for the long-term simulation. Then, the amount of suspended sediment transfer from the Kiso River basin to the Ise Bay was estimated using an L-Q equation. The results obtained in this study will be utilized for river sedimentation management or as an input variable for the ocean circulation model.

Low-flow channel variation due to sediment augmentation

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ABSTRACT: For the conservation and restoration of river environment, a sediment replenishment technique, which conveys a part of the sediments excavated and/or dredged in reservoirs to the river below dams, is developed and has been implemented tentatively in several dams in Japan. Sediments placed for replenishment will be flushed out and transported downstream by floodwater or dam discharge. The flushed sediments are expected to contribute to the control of degradation and the variation of low-flow channel. However, this technique is in the development stage because there are many unknown factors. Therefore, systematic investigations are necessary for practical management of the technique. In this paper, the effects of the location of replenishment sediment on sediment flushing and on control of degradation are investigated through the flume tests. The differences of these phenomena between uniform sediment and non-uniform sediment are also discussed.

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Study and application on diffusion character numerical model for the abandon sediment emission during the construction of water-related project

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ABSTRACT: Hyper concentration sediment released during the construction of the near-shore projects will pollute the nearby river area. So it has important environmental and engineering significance to forecast the incidence of the sediment pollution. An unsteady two-dimension (2D) horizontal mathematical model for flow and sediment in generalized curvilinear coordinate is employed to simulate the contaminated zone induced by side-discharged dense slurry in Wuhan reach of Yangtze River. Calculated results indicate that the model can reflect the movement of flow and sediment exactly, and also it can provide the necessary reference for the production and domestic water consumptions.

Analysis on bottom tearing scour in Xiaobeiganliu in the Yellow River in July 1977

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ABSTRACT: In July 1977, there occurred a strong bottom tearing scour in the reaches of Xiaobeiganliu in the Yellow River. After the flood flowed, the deepest and average river bottom elevation both rapidly decreased in sections of Longmen and Tongguan. The river scouring process developed from the general scouring of big floods to the bottom tearing scour. During the process of bottom tearing scour, a narrow and deep channel first formed because of local scouring and then the whole section scour formed as the channel developed on both sides.

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A case study—evolution mechanism on bending braided river of Wuhan Tianxingzhou reach under the variable condition of incoming flow and sediment

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ABSTRACT: The flow dynamic axis of braided river reach influenced by flow, sediment and river bed boundary sways commonly, which provides power to translocation of beaches and grooves in the downstream. Impoundment of the Three Gorges reservoir causes greater variations of flow and sediment and hence more substantial and influential swaying of the mainstream path. This paper analyzes the evolution of bending braided reach as example of Wuhan Tianxingzhou reach, based on the existing summary of evolution characteristics of the Tianxingzhou reach. The interactional relationship of river bed boundary and hydraulic sediment condition is deeply analyzed, the mechanism of fluvial processes is revealed. The river evolution tendency are forecasted according to change of flow and sediment after operation of Three Gorges reservoir.

Influence of water level change of Yangtze River on storage process of Dongting Lake

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ABSTRACT: Based on the measured data, this article analyzes the relationship between the water level changes in the Yangtze River and the storage capacity of the Dongting Lake, identifies the critical water level at the outlet of the Dongting Lake under different inlet flow and Jianli discharge, which could reflects the influence of the water level changes in the Yangtze River on the storage and the water level of the Dongting Lake, and estimates the influence of the water level fall caused by the impoundment of the Three Gorges Reservoir. According to the practical scheduling process of the Three Gorges Reservoir, using the data in 90 s, at the end of the impounding period, the water level of Chenlingji would fall by 1.64 m compared with the natural state, the inlet flow of the lake reduces by 2.42 billion m^3, and the outlet flow increases by 1.68 billion m^3, that means the water quantity of the Dongting Lake reduces by 4.1 billion m^3 altogether compared with the natural state.

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Numerical experiments on characteristics of braided streams observed in Satsunai River

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ABSTRACT: The typical bed configuration of the Satsunai River, which meanders continually and is well known to have double-row bars and braided channels, can be observed in the channel. Levee construction on the Satsunai River started in 1950. It has been reported that bank erosion occurred in the river in 148 places for the 15 years from 1960 to 1975, which was the time just after the levee construction. In this study, numerical experiments with a full-scale channel were performed in order to reproduce the characteristics of bed deformation observed in the Satsunai River at that time. The characteristics of bed deformation and braided streams observed in the river were found to be strongly affected by the meandering river channel.

Forced bars in a meandering channel with variable width

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ABSTRACT: In natural river channels, meanders and variable widths are often both found. However, as the phase difference between the two has not yet been elucidated, its impact on riverbeds is unknown. Against such a background, this study was conducted to analyze the impact of this phase difference on riverbeds through numerical experimentation using a planar 2D calculation model for riverbed elevation changes. The results indicated that the wave height of forced bars and riverbed scouring locations can depend on this difference.

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Modeling of fluvial processes and waterway regulation for braided channel in the middle Yangtze River, the Jianli reach

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ABSTRACT: A plane two-dimensional mathematical model is used to simulate hydrodynamic and sediment transport of the typical braided channel in the middle Yangtze River. The model is established based on grasping the fluvial processes characteristics of the Jianli reach. Observed hydrologic and topographic data have been compared with model results to calibrate roughness coefficient and sediment transport capacity coefficient. Comparisons of water level, velocity and suspended sediment concentration of several different flow discharge calculated by the mathematical model and the field data at all observation cross sections show good agreement. The validated model is applied to predict the evolution trend and the effect of waterway regulation works of the Jianli reach in the next decade. The model results show that the Xinhekou point bar could very likely be cut, while the low channel bar can keep steady under the protection of the first phase project. However, the first phase project still cannot prevent the deterioration of the waterway condition, the shoal at the inlet of branching will deposit to obstruct navigation once the Xinhekou point bar shrunk dramatically. After implementing the Xinhekou point bar protection works, river boundary on both sides of the shoal which located in the inlet of branching will be true stability, thence the waterway of the Jianli reach can be kept in good condition.

Fluvial process of braided channel in the middle Yangtze River after the impoundment of Three Gorges Reservoir

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ABSTRACT: The water-impoundment of Three Gorges Reservoir has affected the channel of the middle Yangtze River by significantly changing the flow and sediment discharge. As the middle Yangtze River is widely distributed with braided channels, which also are the key factors restricting the development of the Yangtze River waterway, this paper selects the branching channel to examine dam impact on channel evolution and fairway conditions in the middle Yangtze River. Field data, including channel topographic maps, split ratio and hydrological data were employed to demonstrate branching channel changes. The result indicates that the braided channel, which under the constraint of levees along the riverbanks, underwent widespread increase of split ratio of the tributaries, decrease in size of the low sandbars due to the substantially reduction of sediment discharge. The sandbars erosion caused the widening of low flow channel and reduction of velocity at the inlet section of the branching, in which shoals commonly appeared. Meanwhile, decrease of the split ratio of the main branch also reduced the erosion intensity around shoals region. Furthermore, two of conjunctions between the Yangtze River and Dongting Lake are distributed in braided reach, the erosion and deposition of riverbed near the estuary will affect the discharge of tributary and then change the relationship between river and lake.

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Application of 1D finite volume model of unsteady flow in Wubu-Tongguan Reach, Middle Yellow River

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ABSTRACT: The requirement of flood forecasting at Tongguan Hydrology Station needs the simulation of Wubu-Tongguan Reach. The one-dimensional model with HLL format was used to simulate the sediment propagation in the Wubu-Tongguan Reach, and the format will benefit the simulation of supercritical flow in Wubu-Longmen reach. The flood propogration in the Lower reach of lower Weihe River is also simulated nore than providing lateral inflow. The flood of 1986 in Wubu-Tongguan Reach and 2007 in Longmen-Tongguan Reach were simulated. Besides, the influence of discharge of the Weihe River on the simulating the Longmen-Tongguan River is also analyzed. Analysis shown that, the numerical model can be used to simulated the flood in Wubu-Tongguan reach, including the lower Weithe River.

Fluvial processes and regulation of the transitional reach in bifurcated rivers

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ABSTRACT: The Xinzhou-Jiujiang reach, located in the middle of Yangtse River, is characterized as a transitional straight bifurcated channel and is confronted with the difficulty of regulation due to its complex flow characteristics in response to upper meandering reach. Based on analyzing the fluvial process of Xinzhou-Jiujiang reach in recent decades, the paper summaries the corresponding fluvial evolution and navigation-failure characteristics, and puts forward the following guidelines for regulation: strengthening bars, protecting riverbed and stabilizing main stream. At the same time, a horizontal two-dimensional model is developed to check the effectiveness of undergoing regulation projects. The results indicate that the Xinzhou-jiujiang reach is classified as a typical meandering transitional channel and the upstream and downstream evolution is deeply linked. When the sink flow structure of Xinzhou channel changes, the hydrodynamic power of meandering reach strengthens, and this gives rise to the degradation and retreat of Xujiawan sidebar and Bianyu bar, worsening the navigation status at Xinzhou and upper Jiujiang consequently. So the regulation of Xinzhou-Jiujiang reach mainly focuses on protection rather than adjustment and the detail lies on appropriately adjusting the main flow of shoal areas in transitional reach to maintain enough navigating depth in dry season by using regulating structures to stabilize and elevate the bars. The modeling results prove the validity of the proposed regulation which aims at solving the navigation failure problems.

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Local scour & erosion

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Flow structure at downstream side of two sequential bridge piers

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ABSTRACT: The bridge piers in rivers are normally installed in the form of two sequential piers in the flow direction. The flow structure between two bridge piers is important and very different from a single pier. In this study, the three dimensional flow structures at the downstream side of two sequential bridge piers have been investigated under no scouring condition. The results, obtained from a series of laboratory tests with both a single pier and two pier arrangements, are presented. Furthermore, the detailed results for two pier arrangements including the effects of different pier spacing on turbulence characteristics of the flow have been provided. Three dimensional flow velocities were measured at different grid points and different depths within the flow using a micro Acoustic Doppler Velocimeter (ADV). The velocity was measured at a frequency of 50 Hz. The results indicated that substantial flow structure interactions were generated with increasing the spacing between two piers. Moreover, the flow structure at the downstream side of the piers varied significantly. It was observed that when the spacing between bridge piers was greater than three times of the pier diameter, the effect of the upstream pier on flow structure at downstream side decreases and eventually piers acted as individual piers.

Physical model study on scour hole near hydraulic structures

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ABSTRACT: Scour Hole is defined as a kind of significant localized erosion phenomenon near hydraulic structures. In order to prevent infrastructure failure caused by flow, many research methods are applied to solve varieties of scour problems. Among these methods, the most authentic method is three-dimensional water-sediment physical model. In this paper, two case studies with different physical model technology were presented. The first method was large-scale undistorted movable-bed model which was widely used these years, and it can give reasonable scour morphology. The second was vertical turbulence velocity was surveyed using ADV around the structures, so vertical turbulent intensity can be calculated, and also two dimensional current field was detected. This method can give coverage range about soft mattress. Also result of the experimental method was compared with traditional movable bed physical model. At last, developing insight of scour processes was given and also physical methods were summarized.

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Characteristics of bed deformation around submerged groins with various angle

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ABSTRACT: Numerous spur dikes and groins had been built for the purpose of preventing stream bank erosion, or stabilizing channel alignments. In each purpose, groin angle and arrangement has been studied comprehensively through past studies. It is known that plane angle of groin has different influence on riverbed deformation. In this study, flume experiments with movable-bed were conducted in order to discuss characteristics of bed deformation around submerged groins for different plane angle for the purpose of finding the fundamental shapes of the submerged groin which are suitable for capture bedload and form a point bar. Tested groin models were set to various plane angles against the sidewall, from a right angle to an angle pointing upstream of nearly 80°. In results, the fundamental effect of groin angle is observed. As the angle becomes large, local scour around the tip of groin decreases. The scour volume increases because the scour holes formed on the downstream side increase in size due to flow passing over the groin model at an angle. Furthermore, it is shown that scour volume is considerably reduced by devising the shape of the groin.

Oscillating-tray experiments on local scour around piles

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ABSTRACT: This paper reports a series of experiments on local scour around single piles with different cross sections and around twin-pile groups with different configurations. The effectiveness of seabed scour collars as a scour-prevention measure has also been investigated. The experiments were undertaken in an oscillating-tray facility, where a tray of sand moves back and forth in a tank of water, so that the relative motion between the sand bed and water is similar to that in the wave and tidal situation. The present experimental setup was first verified against an empirical formula for the equilibrium scour depth around isolated circular mono-piles. The variations of scour depth with the cross-sectional shape, angle of attack and separation of pile group members have been illustrated graphically.

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Mitigation of local scour hazard at the foot of single spur dike by using optimum footing

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ABSTRACT: Bed deformation characteristics and flow structure were investigated around single porous spur dike with and without footing in a movable bed flume. Effects of footing extension to the spur dike upstream, downstream and front side under clear water emerged and submerged conditions were noticed in this study. In the case of spur dike without footing, the scour hole was generated around the spur dike, and the maximum scouring depth located at the tip of the spur dike. In the case of spur dike with footing, the scour hole was shifted to the downstream of spur dike in the main channel. With an increase of the upstream width of the footing, the scour hole around the spur dike was diminishing. The existence of spatial correlation between the areas of highest bed shear stress and where the maximum scour occurred was observed.

Local scour and sediment sorting around an impermeable spur-dike with different orientations

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ABSTRACT: This paper presents an experimental study on the impacts of orientation of spur-dike on the bed topography and sediment sorting process of bed surface around a single impermeable spur-dike. The importance of one of the governing parameters, the orientation of the spur-dike, was emphasized through quantitative and qualitative evidences. It was found that each case of the spatial progress patterns of scour-deposition and sediment sorting were different in comparison with different types of orientations. Compared to the deflecting and attracting types of spur-dike, the repelling type has the property of promoting deposition in the wake region of the spur-dike. This property is caused by the difference of flow structure in the vicinity of spur-dike. The coarsened longitudinal region and fine sediment regions were observed, and it was indicated that the repelling type of spur-dike has the strongest intensity of sediment sorting of the three orientations of spur-dikes.

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Investigation of the formation of scour hole around groynes with different head shapes

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ABSTRACT: In the present study, the formation of scour hole around two types of groynes with different shapes of head was investigated. Two case studies were considered: a simple straight groyne and a groyne with T-shape head. The equilibrium of bed variation in both spur types was shown and the differences and similarities of the pattern of scour hole were investigated. Finally, an in-depth discussion about the evolution of the scour hole and the deposition area around these types of groynes was studied in order to evaluate the performance of the special geometrical features of T-shape groyne (its wing) to the formation and extension of scour hole toward the downstream. Results indicated that the wing of T-head groyne can push away the extension of scouring area toward the main channel.

Scour and deposition around spur dykes with head works

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ABSTRACT: Spur dykes have a variety of types in materials and shapes etc. In this paper, shapes of spur dykes, especially their head works which are installed parallel to the main flow direction is studied. The laboratory experiments were conducted for 10 spur dykes in a straight flume with a movable bed and 10 spur dykes. Effects of the length of the head works on bed configurations and the flow were determined and discussed. The equilibrium bed configurations and the velocity on surface flow were also measured. How the shapes of the spur dykes make geometric diversity in the embayment, and possibly diversity of habitats, is highlighted.

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Application of steady flows for simulating the local scour depth under time varying flows

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ABSTRACT: Local scouring in the vicinity of bridge piers which are implemented in the natural streams is the subsequent of 3D complex flow patterns. During the local scour process the accelerated flow develops the local scour depth and if it is not predicted correctly the bridge failure occurs. Local scouring around bridge piers is a strictly time dependent phenomenon and subsequently the evolution of local scour depth under the unsteady flow condition is essential for both structure safety and ecological issues. In the present study, development of local scour depth around a circular pier under time varying flows of the three different types of step-wise hydrographs has been simulated by using a fully 3D numerical program SSIIM along with applying a superposition scheme. Results show good agreement between predicted numerical results and experimental data whereas the error rates of the maximum simulated local scour depths were less than 10%.

Temporal evolution of a scour hole upstream of a slit in a vertical wall

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ABSTRACT: The temporal evolution of a scour hole upstream of a dam gate under free surface overflow is experimentally investigated. A total of 18 experiments is conducted for different flow discharges, movable bed particles, and geometries of gates. The scour length, maximum scour depth, scour width, and scour volume are evaluated to clarify the temporal evolution of the scour hole topography. Experimental results show that the features of the temporal evolution of scour hole topography under different experimental conditions show similarities. In addition, two dimensionless hydraulic parameters—the relative flow velocity and the ratio of discharge distribution—are found to have a positive correlation with the dimensionless scour volume. The influence of the ratio of discharge distribution on the dimensionless scour volume is found to vary with the elapsed time, whereas the influence of the relative flow velocity is constant with time.

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Study of circumfluence sediment deposition in downstream approach channel of Three Gorges Project

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ABSTRACT: The mechanism of sediment deposition in downstream approach channel of Three Gorges Project and the method to compute sediment deposition in the approach region are studied. The research results indicate that there exists circumfluence in the approach region of the downstream approach channel which is the reason of sediment deposition. The density flow in the channel induces sediment deposition there. The sediment deposition amount in the approach region is related to the length of the circulating region, water depth, longitudinal velocity, sediment concentration and duration of inflow. It is appropriate to apply Xie Jianheng's expression to compute sediment deposition in the approach region of the downstream approach channel, and the key parameters such as the circumfluence length and so on are presented. Comparison between the calculated and measured sediment deposition amount caused by the circumfluence is made. The calculated sediment deposition amounts caused by the circumfluence are in good agreement with the measured values.

Translation of meander bends at a bridge site: A case study of the Old Brahmaputra River

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ABSTRACT: The study is intended to understand the translation processes of the meander bends at the proposed bridge site based on which effective river training works would be adopted in order to ensure the safety of the bridge. The main channel of the Old Brahmaputra river is sinuous with variable sinuosity. The study bend falls within the zone of non migrating bars indicating the adjacent bar is stationary and would guide the flow towards a fixed point of the opposite. But as the water level rises, the effect of sand bars for flow diversion to a stationary point would be decreased and erosion would move towards the downstream. It is found that the upstream bend along the right bank has significantly translated (around 2500 meter) towards the longitudinal (valley) direction for the last 20 years, while the scale of lateral translation within the river corridor is relatively smaller (50 to 100 meter). Such phenomenon indicates that the rate of longitudinal translation of the upstream bend in average is 125 meter per year. If bank protection or river training work along the upstream of the right bank is not adopted, then within 4–5 years, the bend may be translated towards the proposed bridge section which may endanger the right abutment of the proposed bridge. The adopted river training work comprises of three components: permeable groins at the upstream to provide gentle diversion of the approach flow away from the right bank, construction of a 1500 m long dredged channel starting together with 250 m long bank revetment at the bridge site. It is expected that the proposed river training works would effectively protect the proposed bridge site against erosion. It is also recommended to monitor the morphodynamic response of the proposed river training works during the monsoon of 2013 and onward.

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Soil composition and stability of riverbanks in the middle Yangtze River

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ABSTRACT: A field survey and indoor tests of soil samples were conducted at 4 typical riverbanks in the Upper Jingjiang Reach, and the composition and mechanical properties of riverbank soils were obtained. Experimental results indicate that there exists a close relationship between water content and shear strength indicators. Different methods for predicting riverbank stability were then proposed respectively during the periods of low and high water level, and the recession period. Safety factors for two riverbanks were calculated during different periods, based on the soil properties from the indoor tests. Calculated results indicate that the stability of riverbank is relatively high at low water level, and it is low at high water level. The safety factor during the recession period is significantly lower than that during the period of low or high water level, which indicates the change of water level has an important effect on the degree of riverbank stability.

Soil erosion risk potential with regards to rainfall erosivity

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ABSTRACT: Rainfall erosivity is an important index that refers to the potential of rainfall to mobilize soil particles away from their original place to another location. The purpose of this study is to evaluate the degree of rainfall erosiveness along Langat River, Malaysia which can be used as a tool in indicating the degree of river bank erosion. To get the erosive properties of rain, the following parameters have to be considered namely rainfall intensity, energy and 30 minutes maximum rainfall amount. With rainfall data records from the year 2000–2010 for 8 rainfall stations along Langat River, Daily Rainfall Amount analysis and 'ROSE' (after the name of researchers) index software application were used to determine the degree of rainfall erosivity. The results indicate that as the degree of rainfall erosivity is critical, the soil erosion risk potential along the Langat river bank is also critical and vice versa. The soil erosion risk potential with regards to rainfall erosivity assessment is very significant and valuable to be used as a quick indicator for immediate preventive action to be taken in mitigating serious river bank erosion along the Langat River.

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Comparative study of different calculation methods on measured amount of riverbed erosion and deposition

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ABSTRACT: A number of mathematical models, physical models and wading engineering sediment test, study, are based on the measured data of riverbed erosion and deposition. At present, cross-section topographical method, grid topographical method and sediment balance method are widely used. In practice, the amount of riverbed erosion and deposition in the same reach or in the same period is often significant differences with different calculation methods. The amount of riverbed erosion and deposition in the reach from Yichang to Jianli of Yangtze River downstream of Three Gorges Project from 2003 to 2008 is calculated based on topographic map, cutting cross-section on topographic map and sediment data of import and export stations using the three methods in this paper. An analysis as to the reason of amount differences is made. The optimum arrangement of channel cross-sections and sediment measurement are presented in this paper.

Soil properties and erosion mechanisms of composite riverbanks in the Lower Jingjiang Reach

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ABSTRACT: After the TGP operation, the Lower Jingjiang Reach (LJR) has experienced a process of continuous channel degradation, with the phenomenon of bank erosion occurring frequently. Therefore it is necessary to investigate the soil properties and erosion mechanisms of composite river bank. A field survey and indoor soil tests were conducted at 6 typical riverbanks in the LJR, with riverbank soil composition and mechanical properties being obtained. A new method for calculating the safety factor of overhanging block was proposed using the principles of cantilever stability. Based on the computed near-bank hydrodynamic conditions and the soil properties, stability degrees and influencing factors of a typical composite riverbank in the LJR were investigated quantitatively. The calculated safety factors for riverbank stability have lower values during the flood season and the recession period, and a high value during the dry season, which corresponded to the recent statistics of field survey of bank erosion in the LJR.

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Study on density flow sediment deposition located inside the lower approach channel of Three Gorges Project

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ABSTRACT: This study focuses on the exploration and discussion on formation mechanism and calculation method of density current sediment deposition inside the entrance area of lower approach channel downstream the Three Gorges Project, comprehensively compares the calculation results of several calculation formulas and compares them with the measured data. The study shows that inside the lower approach channel, the sediment deposition is caused by density current, the longitudinal decay process of sediment concentration and the amount of sediment deposition calculated with Han Qiwei's formula are relatively consistent with the measured data, and Han's formula can be applied to predict the amount of sediment deposition when the flow and sediment conditions near the lower approach channel are known.

Secondary flow structure and its effect on bed variation at a small-angled confluence

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ABSTRACT: Combining flows at an open-channel confluence generate local scour along the mixing zone between the descending helical flow increase the local bed shear stress along the dividing line. However, detailed examination of three dimensional flow structures has not been conducted so far because of the complexity of the flow. In this research, the authors firstly performed detailed measurement of three dimensional flow structures for a fixed bed channel by using PIV methods. Secondly, we measured surface flow velocity distribution by PIV and bathymetry by stereoscopic measurement method for a movable channel. It was made clear that a couple of spiral flows are actually generated at the confluence through the direct measurement. It was verified that the spiral flow becomes the cause of local scour at the confluence for the movable bed condition.

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Characteristics of fluvial channel processes due to bank collapse in the upper Yellow River

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ABSTRACT: Bank collapse in the upper Yellow river behaves three kinds of collapse patterns such as wash, stripe and arc collapsing, various bank material grain size, and nonuniform spatial and temporal distribution. Wuhai and Dengkou reaches (WH and DK for short) are typical of collapsed bank reaches of sand-bank and silt-bank respectively in the upper Yellow river, and the fluvial channel processes in the two study area were studied based on interpretation of remote sensing imagery and Arcgis9.2.The result showed that the characteristic of fluvial channel processes is different from whether the channel is straight or bend. In terms of WH reach, the evolution magnitude in straight channel is greater than that in bend channel because of sand involvement. However, the DK reach exhibits the opposite characteristics, for instance, the erosion and accretion rate of bend channel is 12.25 times and 2.89 times of straight channel respectively in right bank, besides the bend channel has changed into straight channel from 2003 to 2009 with a remarkable swing rate of river regime. In addition, the siltation exceeds erosion for all the cross sections in two reaches. The measurements were consistent with the study results. Thus, some effective measures are to be taken to protect the upper Yellow river reach from getting further deposited, and the study is aimed at providing evidence for flood control and river management.

Characterization of seepage erosion from alluvial river banks

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ABSTRACT: Seepage erosion occurs simultaneously with other fluvial erosions and mass failure processes in large alluvial river courses during the recession period of flood hydrographs. However, in many alluvial river courses the seepage erosion may be a significant contributor. In this study a functional relationship between seepage erosion rate and its controlling variables is established for a composite riverbank using lysimeter experiments. This experimental relationship can be used to formulate a mathematical seepage erosion model, which can predict the daily seepage erosion rate from a composite riverbank. Soils collected from the Brahmaputra River banks were repacked in a lysimeter in horizontal stratification as similar to the actual bank stratification. A total of 76 lysimeter experiments have been conducted with various combinations of the controlling variables. The results indicate that the seepage gradient has dominating effect on the time taken in developing undercut, which finally leads to the bank collapse. Moreover, increase in the number of silt layers increases the time to collapse significantly.

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Hydrodynamic relation between sedimentation and large-scale horizontal gyres in side-cavity zone

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ABSTRACT: We can see consecutive groins and embayment form dead water zones, where sedimentation and congestion of pollutants are often observed particularly, there exists spanwise gradient of streamwise velocity near the junction, and it produces small-scale turbulent vortices owing to shear instability. Furthermore, large-scale horizontal circulations are also generated in the embayment zone. These coherent turbulent structures play significant roles on mass and sediment transfers through a mainstream / embayment boundary. However, the relation between the turbulence and mass transfers is still poorly understood. Thus, we conducted PIV and LIF measurements, and compared exchange properties of dye concentration and effects of sedimentation on them among different bed configurations. The both of primary gyre and secondary one are observed in the flat-bed and downward slope conditions, and in contrast, the primary gyre is prevalent in the upward slope condition. It was found that these formations of the horizontal circulations have striking impacts on the mass transfer properties through the boundary between the mainstream and the side-cavity.

Levee breach observation at Chiyoda experimental flume

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ABSTRACT: The authors conducted large scale experiments in which levee breach caused by side overflows from an actual river channel were reproduced using a full-scale levee model, and flooding flow was created with the floodway channel beside the experimental flume used to resemble a floodplain. Use of this specially designed flume allowed the progress of levee breach and other processes to be monitored under highly precise conditions relating to flow rate and other variables with various observation devices. Four experimental cases were performed with variations in flow rate, levee material and levee shape to enable observation of the levee breach process under different conditions, and the related collapse phenomenon was quantitatively monitored using acceleration sensors to clarify its relationship with hydraulic quantities. The authors identified four characteristic breach processes, focusing on levee breach processes and side overflow, as well as sedimentation in the flume and overflow area.

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The side overflow through river levee crevasses

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ABSTRACT: Devastating disasters such as extreme heavy rains have increased by global scale climate change, and flood damage has been increasingly severe all over the world. It is important to enhance the safety of river levees, and minimize the damage caused by floods. In this study, we proposed a method to estimate the side overflow discharge through river levee crevasses based on De Marchi's formula. There are two distinct regimes of side overflow. In both regimes, the side overflow discharge can be estimated by given hydraulic parameters: the Froude number upstream of the overflow reach, the overflow reach length divided by the channel width, and the overflow reach height divided by the critical depth.

Modeling of sand/mud mixtures hindered settling

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ABSTRACT: Mixtures of non-cohesive and cohesive sediment are frequently involved in natural environments such as estuaries. Depending on the concentration of both species, mixed sediment can record segregation effect or not, behaves like non-cohesive sediment or like cohesive sediment. The present study deals with the segregation effect between mud flocs and sand grains during hindered settling. Simulations of this process under various conditions of mixture are proposed by using two coupled mass conservation equations which are solved by a high order numerical model. Specific closure equations are proposed herein for the hindered settling of sand-mud mixed sediment. Comparisons between simulations and experiments are presented on vertical concentration profiles during the segregation process. The model also describes the hindered settling for pure non-cohesive (or pure cohesive) case and the segregation for bi-disperse non-cohesive suspension.

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Scour depth during flow event

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ABSTRACT: Worldwide, bridges across rivers or coastal waters collapse because of scours at their foundations. Scour design criteria are generally referred to estimations on maximum scour depth which are based on scour measurements. Such measurements are mainly gained from laboratory tests. Some additional measurements could also be taken in prototype. Typically, from practical reasons, the scour depths in laboratory as well as in prototype are measured after the flow event in nature and after stopping the flow in laboratory experiments respectively. In this paper it is pointed out that in case of current velocities of more than say twice the critical velocity, scours at foundations may become significantly deeper during flow event than that what is measured after stop of flow. This way, many scour depth data given in the literature may underestimate the maximum scour depths and scour dimensioning criteria based on those measurements may be the reason for many bridge failures. In this paper, the mechanisms which are responsible for the possibility of scours being deeper during flow event than after flow event are explained and the difference between the maximum scour depth under flow attack and after flow event respectively, is quantified based on laboratory experiments.

Study of various arrangements of pile groups scouring due to waves

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ABSTRACT: Regarding the complexity of the scouring of piles due to waves, existing models do not always provide acceptable results in predictions of scour hole properties. This study addresses two alternative approaches to estimate the wave-induced scour depth around vertical piles. To assess the performance of two data mining approaches: Artificial Neural Networks (ANN) and Support Vector Machines, data sets collected in the filed or laboratory were used. Controlling parameters of scouring such as Keulegan-Carpenter, pile Reynolds number, etc. were used as inputs and the amounts of scouring around each set of pile data were predicted as outputs of the models. Results of data mining approaches were compared by those of empirical approaches to assess the applicability of data mining models. Results indicate that data mining models provide better prediction than other models.

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Evaluation of canal stability and sediment transport behavior: A case study of New Fuleli Irrigation Canal in Sindh, Pakistan

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ABSTRACT: Many sediment approaches developed to evaluate sediment transport behavior in the canals and rivers still do not fit with field conditions, because field conditions vary time to time and space to space. This study was carried out on perennial controlled irrigation canal in Lower Indus Basin. Findings show that sediment concentration varies from 50 mg/l in January to 1255 mg/l in October, because of dry to monsoon period in Pakistan. The canal regime parameters were determined and found that the shear velocity varied from 0.05 m/s to 0.044 m/s and bed shear stress from 0.51 kg/m^2 to 0.448 kg/m^2, critical mobility index from 0.055 to 0.061 along the canal length. Further, the fall velocity varied from 0.0081 m/s to 0.0036 m/s—almost 50%; this acknowledges the sediment deposition at upper reach of canal which was substantiated thru bed level observation along the canal, thus these findings conclude the stability of canal.

In addition, vertical sediment distribution was determined and found the concentration in ripple bed is more than dune and plane bed. The computed and observed suspended concentration profiles are not matching with each other. It is therefore suggested the Rouse approach should be tested at upper and lower Indus Basin Irrigation System and its application be advised accordingly.

A new method for measuring and calculating flows and bed forms around river banks

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ABSTRACT: Three-dimensional velocity distributions and bed-forms were measured around flow attacking zones in the experimental meandering channel in the Jyoganji River by using the Acoustic Doppler Current Profiler (ADCP). This paper presented a measuring method for accurate velocity and bed profiles using individual beam data for current profiles. We proposed a numerical analysis method for the local three-dimensional flow configuration around the revetment using bottom velocity computation method without the shallow water assumption. We validated the accuracy of new analytical method through the comparison with velocity distributions measured by the experiment. Results demonstrated that combined use of the measuring and calculating method presented here was useful to understand three-dimensional flows around structures.

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An investigation of coherent vortical structures of flow at a circular piled pier

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ABSTRACT: Detached Eddy Simulation is used to study the vortical structure of the flow at a circular piled pier. The paper focuses on the dynamics of the large-scale coherent structures forming around the piled piers and their role in controlling the sediment entrainment and transport mechanism at conditions corresponding to the flat bed and the clear-water scour. Simulation results show that the solid volume fraction plays an important role on the formation of the horseshoe vortex system, the separated shear flows and the wake flows. In addition, a semi-empirical approach for estimating sediment entrainment fluxes is employed. The result shows that if the SVF is small enough, the sediment entrainment ability at a piled pier does reduce significantly. Otherwise, the penetrating flow within the piled pier may play an important role on the sediment entrainment for the mediate SVF case.

Study of stagnation point of water and sediment in north passage of Yangtze estuary

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ABSTRACT: According to the data of North Passage in Yangtze estuary from 1978 to 2007, the study of change range, trend and reason has been done. Results show that the stagnation point of water moves down when the quantity is about 50000 m^3/s. The stagnation point of water moves down and then sails upstream from 2000 to 2006 when the quantity is about 40000 m^3/s. In dry season, it moves down from 1997 to 2004 and sails upstream in 2007. The stagnation point of sediment didn't change much. The change of stagnation point is related to the waterway regulation engineering. The increase of bed resistance and decrease of split ratio make the main channel erode, groin field of spur dike deposit, the channel volume decrease, the water level decrease, intertidal zone area decrease and the advantage of flood tide becomes obvious which lead to the change of the stagnation point.

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Reduction of local scour around side-by-side piers using bed sill

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ABSTRACT: The main cause of failure of bridges is local scour around piers. Due to the geotechnical and economical reasons, group piers used in bridge design, so controlling the scour around these structures should be considered. Flow-altering countermeasures such as bed sill reduce the strength of horseshoe and wake vortices. In this study the efficiency of bed sill was investigated for two circular piers which are located normal to the main flow (side-by-side piers) with different spaces between piers. The bed sill was located at two positions downstream of the piers. The experiments were conducted in a rectangular flume under clear-water conditions. The results showed that the maximum scour depth occurred at downstream and far away from piers and bed sill and bed sill is effective structure for reducing the scour depth around side-by-side piers.

Turbulence dynamics and mass transfer in side-cavity zones aligned in streamwise direction

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ABSTRACT: It is well known that groynes navigate mainstream effectively to protect a river basin. An associated dead water zone can be a valuable space for various aquatic eco-system. In contrast, such a closed water environment reduces water quality rapidly, and it is therefore of vital importance to consider not only hydrodynamic properties but also mass transfer mechanism beneath the mainstream and the dead water zone. We conducted turbulence and dye concentration measurements in a laboratory flume by using PIV and LIF techniques, respectively, and based on the present results, a phenomenological flow model was developed which describes comparison of large-scale gyre structure and mass transfer coefficient among the different rank number.

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Numerical study on 3-D currents structure and coherent events in side-cavity zone for prediction of scour and sedimentation process

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ABSTRACT: In natural rivers, open-ended side-cavity zones are often observed. Many pollutant clouds and suspended sediments are conveyed and trapped in the cavities, and it is thus very important in environmental hydraulics and river management to predict accurately mass and momentum exchanges through mainstream/side-cavity interface. It is well known that small-scale shedding vortices are generated due to a shear instability induced by velocity differences between high-speed mainstream and low-speed embayment flow. A large momentum in the main-channel causes large-scale horizontal gyre in the cavity zone. We highlighted three-dimensional current properties and turbulence structure by using a LES which is also compared with PIV measurements. Scientific knowledge of significant relation between instantaneous vertical flows and the momentum & sediment transfers could be obtained.

PIV measurements of coherent turbulent flow structure and bursting process around a scour hole

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ABSTRACT: The results of a series of experimental tests related to the flow characteristics in a scouring hole are presented in this paper. The experimental tests were carried out for five different stages of development of a scour hole. These stages are defined on the basis of experimental observation. The mechanisms of the development of the scour hole and flow characteristics were investigated in this study. The flow velocities were measured using Particle Image Velocimetry to characterize the mean velocity field and turbulent characteristics of flow in the scour hole. The measurements reveal a good understanding of the flow characteristics and bursting process and a strong recirculation in the hole. The results showed that upstream of the orifice, the transition probabilities of the stable events were higher than other transition probabilities. Therefore, the events of P11, P22, P33 and P44 were dominant when compared to others. This can be interpreted as an expectation that entrainment should occur at this location. These expectations are consistent with scour hole development and were confirmed by measuring scour hole depth upstream of the orifice.

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Study of coherent turbulent flow over the ripples using Particle Image Velocimetry

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ABSTRACT: The structure of turbulent flow over ripples is important to understand initiation of sediment entrainment and transport. The focus of this study is the measurement and analysis of the dominant bursting events and the flow structure over the ripples in the bed of a channel. One type of ripple with sinusoidal form was tested in this study. The velocities of flow over the ripples were measured in three dimensions using Particle Image Velocimetry (PIV). These velocities were measured at different points within the flow depth from the bed and at different longitudinal positions along the flume. It was found that upstream of the ripple crest, transition probability of stable organization (P44) were dominant when compared to other 15 transition probabilities. This can be interpreted as an expectation that entrainment should occur at this location. However, downstream of the ripple crest, transition probability of zone 2 to zone 3 (P23) and transition probability of zone 3 to 4 (P34) were more dominant than others. Therefore would be expected sedimentation to occur at this location.

Numerical simulation of landslide dam deformation caused by erosion

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ABSTRACT: Three types of landslide dam deformation processes have been reported: erosion due to overtopping, instantaneous slip failure, and progressive failure caused by infiltration flow. However, the exact mechanisms were not fully elucidated in previous studies. In addition, no study has modeled the processes of both erosion-induced infiltration and deformation of landslide dams, even though it has been reported that the dam moisture content affects deformation. We observed the deformation of and outflow discharge from a small artificial landslide dam. These experimental results were then compared to a two-dimensional numerical model under conditions in which overtopping erosion occurred. We also used the model to calculate the moisture content in landslide dams during erosion to investigate the effects of infiltration.

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Numerical modeling of erosion of unsaturated river embankment due to overtopping flow

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ABSTRACT: A numerical model which can compute the erosion of river embankment by flow overtopping considering the effects of shear strength due to suction on an unsaturated sediment bed had already been developed in our previous research. The erodible bed thickness of embankment at each calculation time step may be partly saturated and partly unsaturated. Usually top surface close to flowing water is saturated. In saturated region, there is no effect of suction in the soil mass. However, in the computation we have to use very small grid size to represent such condition. Therefore, in the model, total erosion rate was calculated under the supposition that the thickness of saturated part is a half of total eroded thickness for simplicity. In this paper, new erosion model, in which sliding procedure was also newly incorporated, was developed and the model was tested for erosion of river embankment with different hydraulic conditions and different sediment sizes. The numerical results of temporal variation of embankment surface erosion and moisture movement in the embankment were agreeable with the results obtained from the hydraulic model experiments.

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Reservoir sedimentation

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A study on the density current at Xiluodu and Xiangjiaba hydropower stations in the downstream of Jinsha River

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ABSTRACT: Xiluodu and Xiangjiaba Hydropower Stations are important large-scale key water control projects in Jinsha River Basin, it is necessary to study the laws of density current movement of the two hydropower stations, the research findings indicate that: under the power generation operating conditions of the normal pool level, Xiluodu reservoir is difficult to form a stable moved density current, but the density current is likely to occur in the flood season of June and July. Xiangjiaba reservoir is also difficult to form a stable moved density current under the power generation operating conditions of the normal pool level, but under the flood season operating conditions when the sediment concentration of the muddy inflow suddenly increases by more than 1.0 kg/m^3, and the flow is within 5000 m^3/s ~ 9000 m^3/s, a relatively stable turbid water with density current will be formed in the reservoir area.

Reservoir sedimentation and sediment management techniques in the Nile River basin countries

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ABSTRACT: Currently, there are thirteen large dams on the Nile and around thirteen future dams planned. The Nile has been the major supplier of suspended sediment to the eastern Mediterranean Sea until the construction of the Aswan High Dam (AHD). The objective of water and sediment incorporation is to manipulate the river-reservoir system to achieve sediment balance while maximizing the beneficial storage and minimizing environmental impacts and socioeconomic costs. The paper aims at reviewing the current state of Nile Basin reservoir sedimentation and sediment yield. It also summarizes the response of AHD to reservoir sedimentations of the newly constructed or planned dams in the upstream regions. As the Ethiopian Highlands are the main source of sediment, the river systems draining this region have witnessed severe sediment management problems since the construction of large dams. Coordinated sediment management and dam operation are highly recommended for the cascade dams along the Blue Nile.

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Sustainable management of sediment fluxes in reservoir by environmental friendly flushing: The case study of the Genissiat Dam on the upper Rhone River (France)

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ABSTRACT: This paper focuses on the case of the Genissiat dam on the Rhone River (France), which specific design allows environmental friendly flushing. The 2012 sediment flushing operation organized to prevent extra flood hazard in the lowest parts of the Geneva City is presented. This situation results from bed aggradation due to Verbois reservoir sedimentation (Switzerland). Thanks to the Genissiat dam regulation, sediment concentration released from Swiss dams are moderated and largely reduced to limit the impact in the downstream part of the river. The monitoring network deployed to pilot the operation and prevent thereby possible damages on environmental stakes is described, as well as the advantages of the operation. A comparison between the previous flushing events is also provided.

Influence of reservoir sedimentation on power generation

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ABSTRACT: Reservoir sedimentation is one of the most important problems for securing sustainable hydropower plant operation in the future. We have already classified the sedimentation problem regarding the reservoir types and proposed some effective sediment control measures for regulating reservoirs. On the other hand, sedimentation problems in storage reservoirs need to be more studied. In this paper, we have evaluated the influence of sedimentation progress in storage reservoir on power generation by analyzing long-term operation record, and predicted the future influence of storage reservoir sedimentation assuming active storage capacity decreasing.

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Cost-benefit analysis of sediment management in Sutami Dam, East Java, Indonesia

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ABSTRACT: The impacts of global climate change have been recognized as the main threat of the sustainability of water resources infrastructures. In the basin level, reservoir is the most susceptible infrastructure to the impacts, particularly to sedimentation. Sediment management is one of the techniques to enhance the economic life of reservoir. However, most of sediment management projects were conducted based upon the necessity to remove the sediment only without considering the profitability of the project itself. Departing from economic analysis will cause some consequences to the project, such as project cost overrun and other budget-related problems. Thus, this study aims to determine the economic feasibility of sediment management project in Sutami dam by using the Cost-Benefit Analysis. A basic framework of the Cost-Benefit Analysis application in sediment management, particularly in Brantas River Basin has been also developed in this study.

Sedimentation and its mitigation strategies: A case study of the Ethiopian highlands

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ABSTRACT: The aims of this study are (1) to analyze the spatial variability of sediment yield and to identify the factors explaining the sedimentation rates and (2) to prioritize sediment mitigating options on selected dam-catchments in the Ethiopian highlands. The sediment yield was assessed through reservoir surveys (n = 14) and the prioritization of sediment management options was done with a multi-criteria decision analysis (MCDA) approach. A large spatial variation in area-specific sediment yield (SSY) was observed among catchments with an average value of 1013 (± 735) t km^{-2} y^{-1}. This variation is attributed to both human and environmental factors. About 50% of the reservoirs were found under extreme siltation problem. A combination of curative and preventive sediment management strategies was proposed: (1) removal of sediment and hence making use of the sediments for farmland reclamation, and (2) implementation of specific area-targeted catchment management interventions.

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Study on sedimentation in medium and small reservoirs and solutions to mitigate sedimentation in Northern mountain of Vietnam

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ABSTRACT: Study was carried out in the 3 sub-catchment that its water flowing directely to the natural lake of Ba Be. Data collected at the experiental station located in the Bac Kan province with using common methods used in the world as well as in Vietnam now. Results show that at present the soil erosion at study areas is seriously and resultant sedimentation at the Ba Be natural lake is also dramatically. Number of solutions is suggested and applied in order to reduce sedimentation at Ba Be and outlets flowing directly to the lake.

Importance of selection of processes for modeling long term reservoir sedimentation

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ABSTRACT: Reservoir sedimentation is a very complex process where both hydraulic conditions, such as flow depth and velocity, as well as sediment properties, such as settling velocity of transported sediment or bed composition, change for orders of magnitude both in space and time. Several processes are involved, such as sediment transport, deposition rate, compaction of deposited sediment, resistance to erosion of the deposits etc. While these processes are important to assess sediment dynamics in a reservoir, not all of them are well understood and their mathematical descriptions may not always give accurate predictions. Accuracy of numerical simulations also depends on the availability of input data. To obtain accurate field data is often difficult or, before the dam has been built, not possible to the full extent. From an engineering perspective, a balance between the complexity and efficiency of the model must be sought. This is particularly the case for long term simulations when the run time and the number of scenarios that need to be simulated is a constraint. In addition, it is often difficult to select proper values of model parameters. Often, not much calibration data is available. If the number of the parameters to be calibrated is high in comparison to the available data, this can result in over-calibration of the model. This paper discusses the importance of including various reservoir sedimentation related processes in a model and the increase in accuracy of model results obtained by increasing its complexity, that is adding more parameters or processes. To illustrate this, a one dimensional long-term reservoir sedimentation model RESSASS is used and applied on the particular case of Tarbela reservoir in Pakistan. The analysis showed that for the particular case, the optimum number of fractions is about seven, and that compaction process should be taken into account for modeling sedimentation of the reservoir.

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Numerical simulation of sediment supply from dam reservoirs to downstream by the placed sediment

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ABSTRACT: Sedimentation is one of the important problems of a reservoir. In recent years, for the purpose of recovering river environment and solving sedimentation problem, the number of trials to place the sediment to the downstream river has been increasing in Japan. To make appropriate sediment supply plan in consideration of river environment, it is required to develop a prediction method to estimate erosion process. In this paper, the numerical simulation of flow and bed deformation under the field observed conditions was carried out to verify the applicability of numerical models to erosion phenomena of placed sediment. In order to simulate the placed sediment erosion, bed load and suspended load sediment transport and bank erosion were taken in account for modeling. As a result of comparison between observation and calculation, it was indicated that the model could reproduce the erosion process of the placed sediment and estimate the eroded volume quantitatively.

Sediment management on the Arase Dam Removal Project

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ABSTRACT: Sediment management during and after dam removal involves extremely important flood control and environmental challenges, including the outflow of reservoir sediment and its effects downstream. The Arase Dam is the first dam to be completely removed in Japan. To assist in sediment disposal planning and to predict both upstream and downstream changes after dam removal, riverbed change simulations and environmental monitoring have been employed. Herein items to consider in sediment control for dam removal are discussed.

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Real-time sediment inflow prediction for sediment bypass operation at Miwa Dam in Japan

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ABSTRACT: Reservoir sedimentation has been an important issue at dams in the world. Evacuating sediments with sediment bypass tunnels, which allow sediments from upstream of reservoirs to pass through the reservoirs without being captured by the reservoirs, is expected to be an effective countermeasures against the issue. In this paper, real-time prediction models of sediment inflow are developed for efficient operation of a sediment bypass tunnel at Miwa Dam in the Mibu River basin in Japan. Two kinds of prediction models, namely a Multivariable Linear Regression (MLR) model and Artificial Neural Network (ANN) models, are respectively developed in order to predict sediment inflow for the coming three hours with hourly time resolution. Through application of developed prediction models, it was demonstrated that the ANN model showed better performance than MLR model, especially in terms of time series predictability.

Sediment flushing operations of Pulangi Hydropower Plant IV Reservoir, Philippines

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ABSTRACT: Pulangi Reservoir in Central Mindanao, Philippines with a 255-MW hydropower plant has experienced accelerated sedimentation thus prolonging the life of this reservoir would require proper sediment management and control. It is found that reservoir sediment flushing operations is the most economical, long-term sediment control strategy. This paper presents results of the study to develop reservoir sediment flushing operations rules. A two-dimensional reservoir, flow-sediment hydraulic model is used to evaluate the effectiveness and impacts of different reservoir sediment flushing rules (schedules and schemes) conditional on current or forecasted hydrologic and hydraulic conditions as well as reservoir conditions and hydropower objectives.

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Computational Fluid Dynamic (CFD) modelling in 3D of turbulent suspended sediment transport processes in reservoirs

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ABSTRACT: Sediment deposition in reservoirs can affect flood levels, drainage from agriculture land, the firm yield of a dam, hydropower operation and navigation. Turbulent suspended sediment transport is the dominant mechanism of sediment transport through most reservoirs. This paper focuses on the simulation of flow and sediment transport patterns utilising a fully coupled 3D numerical model based on Navier-Stokes equations which include both sediment transport and hydrodynamic parameters. With the aid of a finite volume procedure the coupled 3D model aims to determine a detailed spatial and temporal pattern of the sediment concentration and also the extent of sediment deposition and erosion in the reservoir. A three dimensional hydrodynamic CFD model can be used to simulate the stream lines and sediment transport accurately. This paper discusses model validation using laboratory data under sediment deposition and sediment erosion conditions. The transport of non-cohesive (coarse sediment) considering suspended sediment transport is addressed.

Simulating turbidity current in reservoirs with a layer-averaged 2D model

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ABSTRACT: A two-dimensional layer-averaged model is developed to simulate turbidity current characteristics and sediment sluicing in reservoirs. The governing equations consist of mass and momentum conservation laws for the turbidity current mixture, equations for the suspended sediment transport and bed dynamics, and auxiliary relations for the interactions among clear water, turbidity current and bed. A finite-volume, unstructured, hybrid-mesh numerical method is adopted so that reservoirs with complex terrains may be simulated. Special algorithms are developed to model the movement of the turbidity current front through a dry bed and to simulate the sluicing of the turbidity current through bottom outlets. The developed model has been tested and verified with both conservative and non-conservative turbidity currents ranging from simple to complex reservoir terrains. Comparisons of the model results with the available data show that the developed turbidity current model, with appropriate calibrations, predicts well the turbidity current movement, the sediment deposition in the reservoirs and sluicing through bottom outlets.

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Sediment relocation trial by Ejector Pump Dredger System (EPDS) in a dam reservoir

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ABSTRACT: The Ejector Pump Dredger System (EPDS) is able to pick the sediment up from the bottom of reservoir by means of the pressure gradient generated by jet water. In this system, the maximum expected size of gravel which can be transported is approximately 150 mm. The field tests on this newly developed system was very successful as approximately 3,500 m^3 sediment was dredged by ejector pump from different depths in the reservoir, 3 to 15 m deep, and then the sediment relocated to the disposal site, 400 m upstream from the suction point, by floating transportation pipeline. The sediment transportation rate was equal to approximately 70 m^3/h.

Numerical study of flushing half-cone formation due to pressurized sediment flushing

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ABSTRACT: Pressure flushing cleans up the hydropower plant entrance from the sediment deposition. This technique results in localized scouring, that is called flushing cone. In this study, the flushing cone formation is simulated by implementing a RANS based 3D numerical model that consists of two successive stages: hydraulic flow and sediment erosion simulation. The velocity distribution profiles and the final geometry of the flushing cone were used to verify the numerical model outcomes. The results obtained by the hydraulic flow simulation revealed that the calculated velocity distribution profiles were comparable with the experimental data and the universal wall equations with roughness, k_s = 10 mm as a sediment boundary condition was adequate for the application. However, when considering the simulation of the sediment erosion process using the moving boundary method the model should be improved for better accuracy in predicting flushing cone geometry.

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Experimental study of driftwood sinking into turbid water

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ABSTRACT: Lots of driftwood was often found in reservoir after typhoon and flood in Taiwan and even impeded reservoir operation. Driftwood density increases because of water absorption and sediment attachment. Eventually driftwood sank into water, as driftwood density was more than ambient water density. This study experimentally discussed several influences on driftwood sinking into water in the Shihmen Reservoir, including sinking time, driftwood kind, driftwood size and ambient sediment concentration. The object of this study was to provide manager information to understand driftwood sinking behavior. In this study, 4 coniferous samples, 4 broad-leaved samples, 4 size cylindrical driftwood samples and 4 ambient sediment concentrations were considered. Driftwood sinking time, temporal driftwood density variation and sediment attachment were recorded in the experiment. Results showed more broad-leaved samples sank than coniferous samples. Overall, driftwood sinking time increased with increasing length-to-diameter ratio of driftwood and decreasing ambient sediment concentration. This study also suggested manager of the Shihmen Reservoir salvaged driftwood in 10 days. Sediment attachment greatly increased driftwood density and then speeded up driftwood sinking into water. Actually, influence of sediment attachment in field was greater than that in the experiments.

Sediment model verification of dam area of Three Gorges Project

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ABSTRACT: Sediment model verification tests for the Three Gorges dam area were carried out using the measured hydrological and topographical data for the river reach around the dam in the early impoundment period (2003 to 2006). According to the verification tests the results of the sediment model for the dam area are consistent with the prototype data; the flow velocity and regime of the model match the prototype; the sediment deposition and distribution are similar to the prototype, and generally, modeled sediment deposition amounts are equal to those of the prototype, with only slight differences. The main channel, downstream approach channel, and entrance to the 3.5 km river reach upstream of the dam have the greatest differences.

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The restriction of sedimentation on the advance impoundment of Xiluodu and Xiangjiaba reservoirs in the flood recession period

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ABSTRACT: Sedimentation is one of the key problems that restricts the scheduling optimization of Xiluodu (XLD) reservoir and Xiangjiaba (XJB) reservoir. This paper adopts a one-dimensional unsteady numerical model of flow and sediment to study the relationship between final silt-stable deposition and the impoundment time of a reservoir in the flood recession period and then clears the restriction interval of sedimentation on the optimization of the impoundment time. The results show that the amount of sediment accumulation decreases with the delay of the impoundment time in the flood recession period, however, the change trend has a critical point. It means further postponed of storage time won't reduce the sediment accumulation significantly when the flood control level lasts for a certain time. However, as for different water silt conditions, the required sediment discharge time will be different. Under the natural circumstance, a 10-day advance impoundment gives a little influence on the equilibrium sedimentation in XJB, but this is not suitable for XLD; Considering the influence of the upstream Baihetan reservoir (BHT), a 10-day and 20-day advance impoundment in XLD and XJB, respectively, won't have significant influence on sedimentation. The results of this study can be used for enactment of the operation scheme of XLD and XJB.

The research on optimal operation of reservoir on account of reduction of upstream sediment load

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ABSTRACT: Sedimentation is a crucial problem which influences the comprehensive benefits and long term operation for Three Gorges Project. In recent years, sediment from upstream to Three Gorges Reservoir has decreased rapidly, which indicates the sedimentation is better than anticipation. On the basis of measured hydrological data, the variations of inflow and sediment deposition in Three Gorges Reservoir area are analyzed. It's put forward that, according to the inflow situation in October, reservoir impoundment in advance is necessary. Furthermore, the feasibility of reservoir optimum operation is discussed based on relative results and medium and small flood control practice in the flood season in 2010. It's presented that the water level could rise to 150 m in flood season, and the medium and small flood could be regulated according to actual conditions, which can accumulate experience for future operation.

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Sediment flushing efficiency of empty storage—A case study for shaft spillway

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ABSTRACT: Sediment deposition decreasing and sediment flushing are critical for reservoir management. In this study, a Physiographic Soil Erosion–Deposition (PSED) model is used in conjunction with GIS, to simulate sediment flushing efficiency of empty storage in Agongdian Reservoir. This PSED model is verified using Typhoon Morakot and then compared to the historic data, which shows close agreement between the simulated and recorded values. The PSED model is then applied to calculate the sediment flushing efficiency of empty storage under one-day and two-day storms of seven return periods (2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year). The simulated results indicate that the average efficiency is 54.32% in one-day storm and 55.72% in two-day storm. The results are correspond to the result obtained from the hydraulic model test in the laboratory. Sediment deposition decreasing and sediment flushing are critical for reservoir management. In this study, a Physiographic Soil Erosion–Deposition (PSED) model is used in conjunction with GIS, to simulate sediment flushing efficiency of empty storage in Agongdian Reservoir. This PSED model is verified using Typhoon Morakot and then compared to the historic data, which shows close agreement between the simulated and recorded values. The PSED model is then applied to calculate the sediment flushing efficiency of empty storage under one-day and two-day storms of seven return periods (2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year). The simulated results indicate that the average efficiency is 54.32% in one-day storm and 55.72% in two-day storm. The results are correspond to the result obtained from the hydraulic model test in the laboratory.

Study of shape modeling of high alluvial flats and deep trench in Xiaolangdi Reservoir in Yellow River

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ABSTRACT: In the last exit of gorges in middle reach of Yellow River lies Xiaolangdi reservoir, with design total storage capacity of 12.65 billion m^3, which is one of key projects in system of Yellow River harnessing and development and water-sediments regulation and control, and an irreplaceable key project to resolve flood prevention and sedimentation reduction in downstream of Yellow River for its important strategic position in Yellow River comprehensive control. Multiple study methods used, prototype observation and experience during operation period combined, some results are obtained as below: (1) The characteristics and developing trend of water and sand are analysed, and the condition of water and sediments going into Xiaolangdi reservoir is carried out. (2) The deposition forms in either main channel or branches are systematically analysed since Xiaolangdi reservoir utilized. (3) The utilization style of elevating riverbed progressively to block coarse sands release fine sand is compared with the style of multi-year regulating and flushing sedimentation via water-sands adjustment by mathematic model and entity model. The difference of age limit of reservoir to block sediment, process to model deposition forms in main channel and branches, and change of storage capacity between the two styles are researched and utilization form in later stage of blocking sediment in reservoir is recommended also. (4) The effective capacity and capacity for storage sediment in Xiaolangdi reservoir are analysed and proved further.

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Sediment delivery ratio on flood event scale in Three Gorges reservoir

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ABSTRACT: Relationship of Sediment Delivery Ratio (*SDR*) vs. its influencing factors were analyzed based on flood events after the impoundment of the Three Gorges reservoir (TGR), and stepwise regression were used to find the main influencing factors of *SDR*, then a new formula of *SDR* was established. Results show that the main influencing factor of *SDR* was the Flood Retention Coefficient (*FRC*), and an idea was put forward that the priority should be given to the regulation of the reservoir inflow and dam front water level in sediment management of TGR during flood season. In order to be used easily for real-time operation decision in flood reasons, another formula of SDR was established based on the SDR formula which was established before, furthermore, the relationship graph of SDR vs. water level before dam and reservoir inflow was given in this paper at last. The research results can give reference for sediment management of TGR in flood season.

Sediment in estuarine & coastal area

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Study on the characteristics of tidal flow and sediment transport of Hangzhou Bay and numerical simulation analysis

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ABSTRACT: Abundant of literature discussed the tidal flow characteristics of Hangzhou Bay. However, the study on the characteristics of sediment transport is relatively few, or the study on the organic connection between the two is even less. On the basis of field data of hydrology, sediment, and so on in Hangzhou Bay, 2D mathematical model with unstructured triangular mesh has been established to simulate tidal flow and sediment transport in Hangzhou Bay. The model has been validated according to the measured hydrologic and sediment data. A lot of numerical analysis has been carried out with the model, which explains qualitatively and quantitatively that the evolution trend of north scouring and south silting in Hangzhou Bay is caused by the hydrodynamic characteristics of the outside sea tidal wave propagation from south to northwest. The North-South coastline contraction of the Hangzhou Bay induces the flood velocity increasing gradually in the northern coast and scouring to form the northern deep groove, and the southern coast is an easily silt area with the flood current hiding and the ebb flow diffusing.

Current- and wave-induced non-equilibrium sediment transport model based on MACS algorithm

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ABSTRACT: A depth-averaged morphological model has been developed to calculate bed level changes in alluvial sand beds under current and wave actions. This model is based on MAC on collocated grid for shallow water equations (MACS) algorithm with unstructured collocated grid using the distributed memory system to increase the computational efficiency. MACS algorithm is used to handle the model system, which includes a hydrodynamic module and a sediment transport module. The sediment transport module is describing bed deformation assuming that scouring is taking place in the non-equilibrium form of bed-load and suspended-load sediment transport. Flow and sediment transport are simulated using two different time scales using parallel computation to shorten scouring prediction time. Numerical simulations are carried out and compared with two sets of experimental results. Comparison between experimental and numerical simulation results shows good agreement. Also, it is verified that the parallel efficiency of the proposed method is satisfactory in large-scale problems.

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The experimental analysis of evolution on Lingdingyang Beach after building the Hong Kong-Zhuhai-Macao Bridge

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ABSTRACT: The main characteristics of the Pearl River Estuary tidal current and sediment physical model are introduced in this paper. Through the experiment by fresh water with fixed bed, local movable bed and suspended sediment deposition, the evolution of the Lingdingyang beach after building the Hong Kong-Zhuhai-Macao Bridge are studied. The result shows that the flood protection and drainage in the riverway have to some influence and the mainstream of Lingdingyang sea area hasn't significant changed after building the project. The local river bed near the mainstream section of bridge site has visible erosion after building the project. Compared with non-project, the thickness of accumulated sediment through ten years at the Lingdingyang beach has increased after building the project, but the increased thickness is small; the rate of development at main beach is increased too, but it changed slightly. The entire configuration of the three beaches and two grooves will be maintained after building the project.

Topographic changes of tidal flats in the Ota River estuary by flood flows

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ABSTRACT: In the Ota River estuary, there are tidal flats along the riverside in the Ota River floodway. Since emergency transportation road along the riverside is to be constructed on the tidal flats, a part of the tidal flats will be lost by the road constructions. Therefore, understanding bed variations on the tidal flats by flood flows is important for minimizing loss of the tidal flats. So, we investigated changes over time in bed profiles of tidal flats by using surveying data. The observed data indicates that the tidal flat elevations become lower due to alternate bar movements and a series of flood events. We estimated effects of floods and the road constructions on temporal and spatial changes in bed profiles of the tidal flats by applying numerical model for flood flows and bed variations. Finally, this study gives the concept of riverside design to preserve tidal flats in the floodway.

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Identification of sediment sources and deposition characteristics in the Fitzroy River Estuary, Queensland, Australia

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ABSTRACT: The Fitzroy River Estuary (FRE) is located on central Queensland coast, Australia. The adjoining Fitzroy River Basin (FRB) is Australia's second largest (144,000 km2) seaward-draining catchment. Annual sediment yields from the FRB typically vary from 4–9 M tonnes per year. As a major sediment source to the nearby Great Barrier Reef (GBR), understanding the sources, cycling and deposition of sediment and associated nutrients and contaminants is pivotal to the management of the fragile GBR ecosystem. Increased sediment exports since European settlement threaten to degrade inner shelf reef and benthic ecosystems of the central and southern GBR. In this study, contemporary sediment sources to the FRE coastal zone have been identified and quantified using an integrated geochemical and modelling approach comparing the compositions of major catchment soils and FRE sediments. The FRB geology is complex, comprising five major catchment units with >100 rock types. Sediment geochemistry indicates a sediment composition consistent with derivation from mixed sources, dependant on flows from particular sub-catchments. Coastal sediments display little geochemical variation as a result of homogenisation due to hydrodynamic mixing. However, sediment actually deposited within the FRE and adjacent coastal zone has a substantially different composition to that transported in rivers, particularly during flood events which dominate FRB hydrology. Longitudinal variations in sediment composition deposited in the FRE are also apparent. Variations in rainfall in different catchment regions due to intermittent cyclonic activity and catchment clearing following European settlement have affected the relative contributions of material delivered to, and deposited in, the FRE. Basaltic soils, although representing <10% of the catchment, are more readily mobilised and are also transported further within freshwater flood plumes that penetrate from the FRE and deep into the adjacent coastal zone. In large flood events basaltic material may even reach the GBR. This study demonstrates that a multi-faceted approach can be used to identify sources of sediment transported to, and deposited within, a large estuarine system. This approach also allows for the implementation of improved land management practices to reduce sediment, nutrient and contaminant loads by targeting key catchment areas.

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Numerical and experimental investigation of velocity field of breaking waves

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ABSTRACT: Numerical and experimental investigations were carried out to study velocity fields of breaking waves. In this paper, mainly, plunging wave breaking condition was considered. A Particle Image Velocimetry (PIV) was used as an experimental approach and a 3D Large Eddy Simulation (LES) was used as a numerical approach. The numerical results of velocity fields were verified by the experimental results. In the numerical approach, the effects of different flume widths on velocity fields were also discussed. The free surface distributions at several locations along the flume were compared with the numerical results prior to comparison of the velocity fields. The results revealed that both free surface distributions and velocity fields obtained by numerical and experimental approaches were consistent. It was also observed that change of flume width has no effects on velocity until waves break. However, after waves break, reaching to a concrete conclusion was difficult due to turbulence and complex fluid motion.

Tidal river management: An innovative approach for terminating drainage congestion and raising land through sedimentation in the Bhabodaho area, Bangladesh

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ABSTRACT: Drainage congestion and sedimentation on the riverbed have been crucial problems in the southwest region of Bangladesh for some time. The entire river system of the southwest region is vulnerable to excessive sedimentation by incoming silts from upstream rivers and, to a lesser extent from the sea during high tide especially in dry season. This continuous siltation process, has reduced the conveyance of the peripheral rivers reduced significantly leading to large-scale Water-logging problems inside the peripheral embankments or polders. Tidal River Management (TRM) is one initiative taken to address this problem. TRM involves breaching polders to allow tidal flow during high tide. At low tide, clear water erodes the river bed, increasing the depth of the river while simultaneously depositing sediment on the low-lying land within the polder easing drainage congestion. TRM has been applied in Bangladesh to varying degrees of success. This study assesses the effectiveness of TRM for solving the long-term drainage congestion problem and raising the low lying lands through sedimentation. This study assessed the effectiveness of TRM for solving the long term drainage congestion problem and raising the low lying lands through sedimentation using hydro-morphological data and questionnaire survey. Since TRM is technically feasible, environment friendly and socially acceptable that it could be an excellent solution to the menacing problems of south west region of Bangladesh.

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Quasi-three dimensional analysis on the flushing mechanism of sandbar at a river mouth

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ABSTRACT: The river mouth bars in the Aganogawa River estuary extend toward the center of river from both banks. The sandbar causes the discharge capacity to decrease and the water level to rise. Therefore, it is important to understand flushing mechanism of river mouth sandbar during a flood event. The authors' studies on river floods showed that the flow and bed variation during a flood could be explained by means of a suitable numerical analysis method using temporal changes in observed water surface profiles. The objective of this paper is to clarify the extension process of channel through the river mouth due to the sandbar flushing during a large flood by the quasi-three dimensional numerical analysis, which is capable of estimating the bottom velocity and the non-hydrostatic pressure distributions of flows.

Sediment siltation analysis for a navigation channel project in Jiangsu Coast, China

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ABSTRACT: This study presents a numerical investigation of the sediment siltation for the optimal scheme design of a navigation channel project in the northern Lanshayang Waterway in Jiangsu Coast of China. A two-dimensional numerical model is developed to simulate the tidal current field around the project area. The model is verified by the observed tidal level and tidal current velocity. Based on the model results, the change of tidal current velocity in the channel is studied. An empirical formula is employed to predict the sediment siltation intensity in the channel after the project construction. It is shown that the channel dredging does not significantly change the feature of current field and the maximum cross-flow velocity is less than 0.5 m/s. The sediment siltation analysis indicates that the optimal scheme outperforms the other by reducing the annual siltation intensity by 33%.

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Sandy beach development in association with fluvial sediment supply

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ABSTRACT: This paper is concerned with the development of an extensive sandy beach on an initially rocky coast facing the Sea of Japan, to which a diversion channel of the Shinano River was excavated and opened in early 1920s. From its completion, a significant volume of sediment has been discharged into the sea through the mouth of the channel, forming a sandy beach of 300 ha over a period of nearly 100 years. This study focuses on how the sandy beach has been developed in association with the fluvial sediment inputs. Results of GIS analysis indicated an increase of the total subaerial beach area by 230 ha in a period up to 1965. The sedimentary architecture of the beach was identified through comprehensive geophysical/sedimentological approaches. The subaerial and subaqueous sediment budgets are then discussed, emphasizing the importance of precisely grasping the fluvial sediment inputs to the sea through the diversion channel.

Study on river mouth erosion process due to tsunami waves

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ABSTRACT: The 2011 off the Pacific Coast of Tohoku Earthquake generated a huge tsunami wave. Severe erosion in many areas was caused by the tsunami wave. The erosion due to the tsunami was affected by morphologic and topographical features and estuarine environments. Furthermore, the erosion is closely related to the tsunami scale and tsunami propagation time. In this study, video data, aerial photography and topography data were evaluated to assess the influences of these factors on the erosion process due to the tsunami wave. In case of the massive tsunami event, the initial tsunami flows have been determined by the river mouth morphology and topographic feature. The effect of the estuarine environments has been confirmed that the estimated erosion distances differed depending on the types of environments.

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A saving, economic and safe measurement on the dynamic state of urban river mouth

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ABSTRACT: In this study, we propose a saving, economic and safe measurement on the topography change and the spatial distribution of water temperature and salinity at urban river mouth. Study site is Akashi river mouth in Hyogo prefecture, JAPAN. From the observations by camera monitoring and portable GPS survey, it is clarified the shape of river mouth bar has been drastically changed by the flood. The results of observation by the radio control boat show that the existence of water-route at the site of right bank and deposition trend of river bed after the flooding. In addition, the relationship between salinity behavior and river mouth closure is confirmed by continuous monitoring at the right bank.

Estuary sedimentation control using a tidal reservoir

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ABSTRACT: The authors study on riverbed sedimentation control using a tidal reservoir. In this method, a tidal reservoir is connected to the river in the tidal area, and riverbed is scoured by the flow caused by the tidal reservoir which saves water at the flood-tide and this saved water is discharged from the tidal reservoir at the falling tide. In this study, we studied the riverbed sedimentation control of the estuary part using a tidal reservoir by numerical analysis. The obtained result of this study is summarized as follows.

- The longer the distance between the connecting point and estuary, the bigger the effect of the tidal reservoir to the upper stream reaches of the river as long as the tidal reservoir is affected by tide.
- On the other hand, the size of the tidal reservoir is needed to be big when the connecting point is far from estuary.

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Assessment of the morphological changes at the Samegawa River mouth, Japan

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ABSTRACT: The river mouth morphology changes at Samegawa River after The Great North East Japan Tsunami of 2011 was investigated in this study by analyzing the water level data. The correlation coefficient (R) and the gradient of the linear regression (a) from the relation of the water level data in the river and the tidal level were used to assess the river mouth condition. It was found that both parameters show similar behavior, reflecting the river mouth condition, which was verified with the available aerial photo. The water level analysis as presented in this study is very efficient and useful in assessing river mouth condition.

Experimental study on sediment deposition and scouring in water intake pipelines of power plant at macro-tidal estuary

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ABSTRACT: To decrease sediment deposition in pipeline, characteristic tests of sediment movement and overall model tests of water intake tunnel were carried out. When the sediment concentration is 3–9 kg/m^3, the critical non-silting velocity of pipeline is 0.54–0.57 m/s and the flow velocity of pipeline with sediment suspension is 0.64–0.67 m/s. The initial motion velocity of siltation increases with time and the velocities at 4th, 7th and 21st day are 0.69 m/s, 0.80 m/s and 1.23 m/s respectively. Under normal condition, the average velocity for the pipeline of 5.5 m diameter is 2.24 m/s and sediment will not silt in the pipeline. During maintenance period, one pipeline does not take water for a long time that the intake head silts seriously. The maximum siltation height for 30 days is 0.80 m. It is necessary to scour pipeline with water every 15 days to avoid silt consolidation in pipeline.

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Water flow and sediment exchange model and its application in channel regulations about shoals and flats in tidal and bifurcated river estuary

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ABSTRACT: Tongzhou Shoal river reach of lower Yangtze estuary is bifurcated and bended type with many flats and shoals, influenced by river discharge and tides. The riverbed silts are fine and easy to initiate. This river reach is one of key navigation obstructions in the deep water channel regulations from Nanjing downstream. In this paper, based on field sedimentation and hydrology data, ADCP and multitask bottom mounted flow and sediment measurement system was applied to measure ditches over flat surface, flow and sediment movement in branches. Flow and sediment motions and exchange model were studied about water flow and sediment motion characteristics in flats and shoals. Semi-rotary flow of middle Tongzhou Shoal river reach was studied by analytical method and physical model. Flow and sediment obstruction ratios under different top levels of regulation structure were calculated. The analytical results have provided key technical support for channel regulation design and planning.

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Modeling of resuspension mechanism of deposited organic mud in the tidal estuary

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ABSTRACT: Organic mud existing in coastal area is transported to the upstream of river by tidal currents. It is expected that the variation of resuspension amount of organic mud in tidal river is caused by fluctuations of river water salinity. However, modeling of resuspension phenomena of deposited organic mud is difficult because it due to various chemical properties of organic mud and complex deposition behavior. In this paper, salinity effect on resuspension characteristics of organic mud is clarified through laboratory experiments. Moreover, the results compares with proposed resuspension model.

The monitoring of the evolutional processes of the sand bar in Modaomen Estuary with remote sensing technique

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ABSTRACT: The Modaomen Estuary is one of main channels of flood water and sediment in the Pearl River, and it makes the largest runoff distribution among eight river mouths in the Pearl River Delta. Since 1980s the Modaomen Estuary has been subjected to massive artificial regulations and the original pattern at the entrance has gradually been transformed from the multiple branching into the dual branching, with the Modaomen as the main channel and Hongwan Waterway as the secondary. This has brought dramatic changes in the water regime including the hydrodynamic characteristics and sediment transport, deposition, erosion and accretion trend. In this paper, the sandbar evolution process has been analyzed with the application of the satellite remote sensing technology and the development trend has been predicted from the aspects of the wind and tidal force with the remote sensing analysis and hydrology and terrain analysis.

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Total sediment flux entering the sea from major Chinese rivers and rough estimation for global land-ocean sediment flux

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ABSTRACT: Changes in total runoff and sediment loads from 10 major Chinese rivers to the Pacific Ocean are presented in the paper. To assess these changes, 17 most downstream gauging stations has been selected and the length of the data series of these stations used for the analysis has been standardized as from 1955 to 2010. The missing data have been interpolated by different approaches according to specific conditions. Over the observed 56-year study period, there is a slightly declining tendency in the runoff. Results show that the mean annual runoff flux entering the Pacific Ocean from these major Chinese rivers is about 1424 billion cubic meters. However, the mean annual sediment flux carried into the Pacific Ocean from these 10 studied major rivers decreased from 2026 million tonnes to 499 million tonnes with 4 clearly steps of decreasing phase over the 56-year period. The total mean annual sediment flux was 1285 million tonnes. Referencing available sediment data of the seaward-most gauging stations on 90 rivers of the world with high sediment loads, and using the contemporary pre-dam land-ocean flux as a baseline, the post-dam or recent global annual land-ocean sediment flux was roughly estimated with value of about 13.2 gigatons.

Relation between sediment conditions of river basin and evolution of front sand islands in Yangtze Estuary

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ABSTRACT: According to the data from 1958 to 2009, the relation between rate of erosion/deposition of the front sand islands and sediment conditions of river basin is established in order to study the process and the trend of evolution of the front sand islands in Yangtze estuary. The results show that front delta above -5 m deposited from 1958 to 1989 and the rate slowed down from 1989 to 1997. From 1997 to 2000, the delta deposited because of the flood around the whole basin. But the delta kept on eroding from 2000 to 2009. The relation between rate of erosion/deposition and volume of water and sediment towards sea is also established. The critical volumes of water and sediment that keep balance of erosion and deposition are respectively 2.83×10^8 tons per year and 0.318 kg/m^3. If the volume of sediment keeps the low degree after Three Gorges running, the sand islands will erode to the degree of 1958 and the wetlands' protection, natural resources and urban safety in Yangtze estuary will be seriously threatened.

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Cross-shore bottom profile change during a decade in Joetsu-Ogata coast

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ABSTRACT: The present paper shows some observed results on bottom profiles change and wave observation results, and the relationship between bottom profile change and wave conditions is discussed. The cross-shore bottom profiles along the observation pier of Ogata Wave Observatory have been measured once a month, and both erosion and deposition processes exist from 1998 to 2006. Incident wave conditions have been observed at Naoetsu, which is the west of the observed area. Wave conditions from 1998 to 2006 have similar seasonal variation. Although incident wave conditions is similar in each year, the drastic profile changes occurs twice in 2001 (erosion) and 2005 (deposition) and the magnitude of the profile change is not so much bigger except the timing of both drastic profile change. This result means that both quasi-stable state and the drastic change of bottom profile exist under similar incident wave condition.

Study on siltation and flood control for channel regulation project of Guan he Estuary

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ABSTRACT: Tongzhou Shoal river reach is one of key navigation obstructions in the extending deep water channel regulation project in Yangtze estuary, where the water depth of estuary sand bar is around 3 m, shallow flat consists of fine silt with strong wave actions. Aimed to evaluate effects of outer channel regulation project on siltation and flood control, physical model test about wave and current interaction was carried out to study siltation of channel dredging under normal waves and storm waves, flood control by Xinyi River and flood discharge capacity of Guan he Estuary. It is concluded the sea dike regulation method can reduce siltation under complicated wave and current dynamics, channel dredging may increase the cross section area of flood discharge, the annual siltation under normal waves is 1.90~3.30 million m^3 of channel, about 1.80 million m^3 under storm waves, and it is suggested to raise the level of dike tail to reduce siltation near estuary mouth.

Environmental & ecological aspects of sediment

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Integrated sediment management along a river—lesson in the Yahagi River, Central Japan

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ABSTRACT: River management composed of flood mitigation, water resources utilization and ecosystem conservation cannot be achieved without proper management of sediment. The importance of "integrated sediment management" has been recognized in these days, but it is not easy to make a plan which must be compliment to the master plan of river management. Integrated sediment management plan suggests the proper sediment flux along a river where it is degenerated by the changes in river basin particularly such as dam construction, elaborate sabo works as well as sand mining. While, the sediment flux along a river governs its morphology, bed topography and successively it is related to flood control, access to water resources and river ecosystem. It is time to discuss integrated sediment management related to river management with recent development of fluvial hydraulics and ecohydraulics. Yahagi river in central Japan is a typical sandy river with a big dam (Yahagi dam) at the upstream, and there are 5 hydropower dams in mountain area then it flows in an alluvial plain with high human activities. In particular, after heavy rainfall in 2000, the reservoir of Yahagi dam lost the effective capacity, and removal of sedimentation and sustainable releasing of sediment input there to the downstream became an emergent topic. While proper sediment supply is required to restore the river ecosystem in the downstream. This study aims to figure the framework of the integrated sediment management plan for the Yahagi river under the above situation as one of lessons.

Study on changes in fluvial geomorphology and riparian vegetation along a sand-bed river after dam closure: Pre-dam stage

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ABSTRACT: In this paper, preliminary result from investigation on past and present status of the Naesungcheon River was briefly provided as a first step of the long-term research project before analyzing changes in fluvial morphology and vegetation after dam closure. Hydrological (including water quality) data of last decades of years were reviewed with land use change. Changes in river geomorphology were addressed. Present vegetation distribution was briefly described. Finally, discussion concerning the causes of changes in river morphology and vegetation in the rivers without dams was given with future research direction.

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Vegetation encroachment on lower reach of a regulated river in an altered sediment regime

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ABSTRACT: When sediment is released from dams, its huge flux results in deposition in downstream channels and bars and those are followed by an intensive colonization of plants. An investigation was carried out to elucidate the factors responsible for vegetation encroachment in association with sediment release in downstream active river channel areas of the Kurobe River in Japan. Herbaceous plant biomass was strongly correlated ($p < 0.01$) with the thickness of surface sandy layer. It had also a high correlation with a fraction of fine sediments ($p < 0.01$). However, higher plant biomass due to fine sediment was associated with its Total Nitrogen (TN) concentration rather than Total Phosphorus (TP) or moisture content levels. The comparison of TN:TP ratio of substrate and plant tissues indicated that the lack of nitrogen (N) was the primary factor for limiting plant growth. Following sediment release, N was no longer a limiting factor and as a result, vegetation growth was promoted. The increased depth of fine sediment in these areas also favored vegetative encroachment. After initial colonization, the encroachment of vegetation was accelerated by the intensified accumulation of fine sediment during inundation and added nutrients through litter mineralization. The history of sediment release in the Kurobe River and the rate of channel vegetation had a similar pattern. The results of this study support the hypothesis that the downstream river channel morphology and ecosystem shift considerably due to multiple dam releases and create a substantial amount of sediment deposition that favorably change the nutrient stoichiometry and allow for vegetative encroachment. Therefore, sediment release program should consider the consequences of change in soil stoichiometry and possible vegetation encroachment.

Channel response prediction for abandoned channel restoration and applicability analysis

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ABSTRACT: As channel evaluation for abandoned channel restoration design, this study sought to exam channel changes from the past to the present and predict subsequently occurring river responses. For the methodology, channel geomorphology changes were evaluated through image analyses of annual aerial photographs to complement the limited river data. Channel responses were predicted using an analytical stable channel model, the SAM (Stable Channel Analytical Model) program, based on a stability theory as well as empirical equations for equilibrium channel. The results of the geomorphological channel changes showed that channels became narrower and bed levels became lower, whereas vegetated bars expanded. The channel response prediction results, narrower channels with deeper depths and mild slopes, were expected compared with the current condition. The channel response, obtained by the field measurement data, image information, and stability theory, are in relatively good agreements showing the reliability of the application suggested in this study. Consequently, the comprehensive channel evaluation approach is expected to be applicable to abandoned channel restoration designs from the aspects of channel geomorphology and hydraulics.

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Deposition mechanisms for particulate organic matter and suspended sediment in riparian vegetation

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ABSTRACT: The transport and deposition of Particulate Organic Matter (POM) in river streams has recently received much attention as one of important ecological process in rivers. We focused on interacted behaviors of suspended sediment and POM in vegetated area on sand bars. The purpose of this study is to clarify the characteristics of deposition of suspended sediment and POM on sandbars with riparian vegetation through field observation and laboratory experiments. The main results of this study are that the spatial changes in thickness of sediment deposition for respective size and specific weight have differences from the upper to lower part of riparian vegetation of sandbar. Also, it was clearly showed that the behavior of suspended sediment and that of POM have significant differences under the same condition. These results indicated that hydraulic and geomorphic roles of vegetation and suspended sediment.

Missing link of coarse sediment augmentation to ecological functions in regulated rivers below dams: Comparative approach in Nunome River, Japan and Trinity River, California, US

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ABSTRACT: This study investigated gravel augmentation activities undertaken in Nunome River and Trinity River in relation to ecological functions of instream geomorphological features from the empirical perspectives of habitat diversity and organic matter interactions. It was found that riffles supplemented by high-flow stockpile in Nunome River functioned as an important natural filter for removing reservoir-derived plankton, and then subsequently contributed to macroinvertebrates species richness and functional feeding group. In the Trinity River, we found that an island and a point bar, which recreated by high-flow injection and direct placement respectively, had a distinct retention capacity for suspended particulate organic matter, and played an important role in inducing hyporheic flows providing simplified habitat with hydrological and thermal heterogeneity. These findings of the ecological roles of inchannel riffles and gravel bars could yield insights that will inform environmental management of design, implementation of rehabilitation activity and their maintenance.

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Numerical simulation of long-term trend of bar morphology and vegetation distribution with consideration of interspecific competition and expansion of riparian vegetation

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ABSTRACT: The expansion of riparian vegetation on floodplain has been reported in many Japanese rivers, and it would be necessary to understand vegetation dynamics for both flood protection and ecological conservation. In this study, a numerical simulation model was presented to describe river-bed evolution and vegetation dynamics with interspecific competition and expansion of riparian vegetation. The numerical simulation was performed under conditions at the downstream reach of the Yahagi river. The results of the simulation show that the present simulation model can predict the long term trend of vegetation coverage and the rates of immigration and destruction fairly well.

Analysis of the basin turbidity reduction effects on the reservoir and downstream river

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ABSTRACT: This study analyzed the various alternatives regarding the degree of turbid reduction in reservoirs and downstream by the installation of turbidity reduction facilities such as barriers, check dams and land use change. There are many measures for the turbidity control in the view of basin-wide management, which include a detour watercourse, a channel improvement plan, a check dam, and a debris barrier that controls the inflow from streams. The channel improvement measure shows a control effect of 20% which can be improved. In conclusion, for further turbidity reduction effect analysis of reservoirs in Imha basin, accurate field survey, long-term accurate flow and sediment observational data as well as comparative analyses of various measures are necessary. In addition, such studies should be continuously conducted to improve the water turbidity problems of Imha basin in Nakdong river, Korea.

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Effect of basin geology on riverbed configurations formed upstream and downstream of a dam

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ABSTRACT: Dam construction alters the riverbed configuration both up and downstream of it, but the condition is quite different among rivers. In this study, the relationship between basin characteristics and riverbed configuration around a dam was investigated. Through the field measurements, following characteristics were clarified. Riverbed configuration upstream of a dam is determined by water level fluctuation and existence of a sub-dam as well as sediment transport rate that depends of basin geology and riverbed slope upstream. The material of a delta also depends on basin geology. Downstream of a dam, armoring is observed in rivers with volcanic rock, although it is not clear in other rivers. In the area where landslides occur, the fine material in the thick sediment layer and coarse material remains. This is not armoring but coarsening. In the area without landslides, thin sediment layer was washed out and only fine materials are supplied from surroundings.

Need for analyzing spatiotemporal patterns of river-corridor habitat structure in sediment management

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ABSTRACT: Spatiotemporal patterns of river-corridor habitat are determined by flow and morphological regimes and they should be integrated in the ecological evaluation. Existing habitat evaluation tools, however, lack this perspective. Even though some recent studies highlighted spatiotemporal patterns, e.g., shifting habitat mosaic steady state concept and habitat age, they do not address processes of changing patterns of each habitat unit, e.g., riffles, side pools, and back waters. We propose a habitat diversity hypothesis, defined as: spatiotemporal patterns of habitat structure determine biological diversity, which can be characterized by a function of intensity and frequency of disturbances and age of each habitat unit from its disturbances. In order to prove our hypothesis, we started a case study in a middle reach of the Tenryu River Japan. Data collected by several interval recording cameras enable to transform into 2D and 3D data and to quantify spatiotemporal patterns.

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Habitat effect on scour hole around low drop structure types

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ABSTRACT: This study sought to review whether large-scale experimentation can apply to actual rivers concerning the effect of topographical change by scour in the downstream area of natural-type low drop structures on the fish habitat. The large-scale applicability experiment performed in this study installed low drop structures as the study object within the experiment channel and precisely surveyed topography in the downstream area of drop structures along with the hydraulic amount including water level and flow velocity under certain flow conditions. Based on topographical data acquired through the survey after the experiment ended, this study reviewed the change of suitability index and difference of weighted usable area by performing 2D habitat simulation. Ultimately, through the habitat simulation results in cases of considering and not considering scour in the downstream area of drop structures, this study analyzed the effects of topographical change in actual rivers on the habitat.

Characteristics of stabilized gravel bars and their determining factors focusing on riffle-pool structures

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ABSTRACT: This study aims to reveal the characteristics and forming process of stabilized and vegetated gravel bars, focusing on the characteristics of riffle-pool structures. Based on field measurement for riffle-pool structures in three rivers, in the area where sediment layer is thin, the water surface width is constant. However, in the Nakatsu river, where sediment layer is thick, constant width riffle-pool is seen. As a result of flume experiment, these constant widths are created due to the accumulation of large materials on the upstream edge of dry riverbed. The results of field observation in five rivers as for grain size and dominant vegetation type on the bar shows that tree expansion is found only where large materials exist. It can be concluded that the existence of large materials is a key factor for the stabilization of gravel bars because they accumulated on the upstream edge of stabilized dry riverbed.

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Transport characteristics of nourished sand in Song-do, Busan, South Korea

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ABSTRACT: The research zone of this study, Songdo Beach, a pocket beach, is directly affected by wave activity. During the First Coastal Repair Project (2000–2009), two submerged breakwaters were installed to reduce incoming wave energy and trap the nourished sand eroded from the beach. In this study, the changes to sediment transport due to the Nourished sand and submerged breakwater installed were monitored over a 5 year period. It is important to investigate both artificial structures submerged breakwaters are changing to the topography (shoreline and water depth) of the zone beyond the submerged breakwater to the shore. Therefore, the response due to waves and flow that occur from the inherent characteristics of the placement of the submerged breakwater installed in the Songdo Beach region will be evaluated and on the basis of the accumulated data, we analyzed the characteristics of wave and shoreline, bathymetry at Songdo Beach to predict beach erosion. We also analyzed the flow patterns behind the submerged breakwaters to provide the preliminary data for long-term stability of the shoreline.

Assessment of reservoir sedimentation using quasi two-dimensional model

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ABSTRACT: This paper presents a numerical model that is capable of predicting sedimentation and flushing process in the reservoir. The model first computes one-dimensional continuity and momentum equations and Exner's equation with the quasi-steady assumption, that is justified due to that the time scale of changing channel morphology is much larger than that of changing flow. Then, the model solves the momentum balance equation in each cross section, distributing the flow based on the geometry and flow dynamics. So the model is quasi two-dimensional, providing lateral distributions of depth-averaged velocity, bed shear stress, and lateral shear.

The proposed model is applied to Xiaolangdi Reservoir in China during a period of May, 2003-October, 2006. The reservoir has carried out flushing processes periodically to mitigate sedimentation in the upstream reach. Simulated results of longitudinal thalweg profiles are compared not only with measured data but also simulation results by GSTARS4. Computed shapes of cross sections are also given and discussed.

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Laboratory testing of nutrient adsorption on sediment and integrated modelling of nutrient distributions in the Loughor Estuary, UK

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ABSTRACT: Field survey and laboratory experiments have been conducted to investigate the adsorption capacity of nitrogen and phosphorous compounds on sediment samples collected from the Loughor Estuary in the U.K. The partition coefficients between the adsorbed and dissolved nutrients, and their dependence on salinity, have been obtained. The experimental results have been utilized in developing an integrated model for the nutrient process in the Loughor Estuary, which receives considerable amounts of nutrients from inflowing rivers and sewerage treatment works. The nutrient flux changes associated with advection, diffusion, biochemical reaction and exchange between the water column and bed sediments were considered in the model. Reasonably good agreement has been achieved between the model predictions and field surveys.

Aquatic invertebrate monitoring in least developed areas in Myanmar—effect of shifting cultivation on water quality

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ABSTRACT: In this study, we present the results of the first investigation of the water and sediment properties and macroinvertebrate community at a 2nd- order stream in Chin State, Myanmar. The concentrations of inorganic nitrogen and phosphorus measured in the rainy season are very high compared with those measured in the dry season. Shifting cultivation has been performed traditionally in least developed areas. Its distributions are analyzed using Landsat data and GIS. The results show that the area of forest burning increased within 4 years. Although more replications and long-term sampling are necessary, there is a close relation between shifting cultivation and water quality.

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Estimation of the detachment rate of algae due to sediment blasting using a spectral image analysis

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ABSTRACT: The growth and detachment of attached algae are key processes in riverine ecosystems. The transportation of sediment particles is a key factor for the detachment of attached algae. In this paper, the detachment rate of attached algae due to both sediment blasting and substrate rolling was evaluated using a spectral image analysis technique. In this work, to evaluate the attached algae density on gravel in a nondestructive and continuous way, a method for converting NDVI to Chl-a was developed. A quantitative analysis of the detachment rate of attached algae indicated that the detachment ratio was closely correlated with work performed by sediment impinging on the algae.

Study on sedimentation and turbulent flow structure in compound water channels with vegetated floodplain

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ABSTRACT: This study was focused on the effect of vegetation on floodplain towards sediment deposition with change of momentum transport behavior on compound water channels. The turbulent flow structure of the compound channel was investigated with PIV technique and results were further verified by comparing with sediment deposition profiles obtained with sedimentation experiments. Due to the vegetation on floodplain, momentum exchange from low channel towards floodplain is increased so that sediment deposition is also increased on floodplain. It is also identified that in vegetated floodplains; with low water depths sediment deposition would be distributed along the floodplain while in case of large water depths sediment deposition would be concentrated on the middle of floodplain.

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Validation of a 1D computational model to predict biological flocculation sediment transport in open channels

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ABSTRACT: Prediction of flow and sediment transport in open channels and rivers, in particular the biological flocculation sediment induced by microbial biofilm, has gradually become a research focus in the last decades, which is of critical importance in many river engineering applications due to the possible effects on the river eco-system, structural integrity of hydraulic structures, navigability, etc. This paper focuses on the validation of the suspended sediment transport module and its coupling with the mechanistic model (BFLOC) to predict the water level and sediment concentration of biological flocculation sediment aggregates in nutrient-rich aqueous ecosystems. In the model, the biological flocculation of sediment is the main reason for the particle size changes of suspended sediment. Biological flocculation sediment transport is simulated through the unsaturated non-uniform sediment transport method. The flow is calculated by solving the Saint-Venant equations for one-dimensional unsteady flow. Validation of the suspended sediment module is accomplished through simulation of one test case in straight open channels. The agreement with measurements is generally good.

The environmental impacts of Aswan High Dam

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ABSTRACT: Impacts of High Aswan Dam (HAD) were to create a new body of water; change the amount and timing of low water downstream; and generate electric power at the dam site. Initial evaluation indicates that AHD represented a general safeguard for Egypt against high and low floods more than fifty years. This paper reviews some of AHD impacts upstream and downstream the Dam basing on field monitoring over the past five decades and on the results of many studies and mitigation measures. The most significant impacts are channel encroachments, water quality deterioration, and characteristics alterations. A multi-actor character of societies through new process and mechanism should evaluate the dam impacts. These processes should lead non central actions as they should be decided upon among multiple actors in the process. The main focus is to restore the water quality and master plan for river integrated management and development should be suggested.

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Effects of groin installation on gravel bed restoration in the Tedori River

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ABSTRACT: Although gravel beds create a good environment for river ecosystems, reduction of the gravel supply from upper streams has caused severe bed degradation problems in recent years in Japan. Under these circumstances, the gravel bed area has gradually disappeared and soft rock exposure has progressed. Once the soft rock appears, gravel bed recovery is extremely difficult. It is therefore important to establish a gravel bed restoration method. In the Tedori River, groins using natural stones were installed experimentally to restore the gravel bar. To advance the river restoration project, new groins will be emplaced. Therefore, in this paper, the effect of groins was assessed using two-dimensional flow analysis. Simulation results demonstrate that groin installation achieves gravel bed restoration.

Effect of flood impact on wash-out of vegetation and bed deformation in the Asahi River

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ABSTRACT: Forestation in rivers causes several problems because it reduces river flow capacity. Furthermore, forestation by invasive species sometimes affects endemic species and biodiversity in a river habitat. The wash-out of vegetation during a flood is known to be a reasonable measure for preventing forestation. However, the relation among the wash-out condition, a river discharge and bed deformation has not been clarified. This paper describes the vegetation growth rate and the wash-out condition of vegetation during flooding in the Ohara area of the Asahi River in Japan, based on field observations and numerical simulations. The observation results show that the large discharge during flooding induced bed deformation and wash-out of vegetation. The simulated results indicate that the non-dimensional bed shear stress for specific grain diameter d_{85} can evaluate the washed-out condition more suitably.

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The assessment of effects of flush discharge and sediment replenishment focused on growth types of periphytic algae and filamentous green algae

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ABSTRACT: In the downstream of the Miyagase Dam, a large amount of periphytic algae and large filamentous green algae has been developing in recent years. In expectation for the control of nuisance growths of these algae, flush discharge and sediment replenishment experiment have been implemented. We conducted quantitative assessment of the effect of these measures based on the impact response in the local site. Flush discharge could detach and separate the periphytic algae including mainly filamentous cyanobacteria and creeping/attaching diatoms and remove silty soil captured in the periphytic algal community. In other hand, the distribution rage of large filamentous green algae was not changed remarkably. However, reduction in cover degree and separation of these algae was confirmed only for filamentous lengthened to more than 5 cm.

Development of the Kuzuha Embayment, the Yodo River

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ABSTRACT: This paper concerned with the Kuzuha Embayment, which are the artificial ponds beside the low flow channel of the Yodo River. Historical and ecological reviews of the embayment were conducted, and the reconstruction of 8 embayments in 2000's was also presented, and it was summarized that the present status of the nature restoration in the Kuzuha Embayment. Results of hydraulic observation and topographical survey in the first period of 2 embayments concluded that the intruded flows from the main river during a flood eroded the riverside area of the embayment, but caused the sedimentation along the bank-side area, where the flows became stagnant, and deposited fine particles. Results of the second period of 8 embayments concluded that the flood uni-directionally flowed over the embayment, and caused the disappearance of the silt deposition in the first period, but the sand deposition in wide area. Biological monitoring in the first period concluded that the number of fish species observed in 2 embayment was similar to the old ones at 28, but its contents were different because of the increase of alien species of the fish. The number of the fish species in the second period was reported to be decreased at 18, because the lentic environment has not been yet restored.

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Investigation of vegetation flow for prediction of sedimentation process

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ABSTRACT: In many natural rivers, aquatic vegetation occurs in patches of finite length. In such vegetated flows, the shear layer has not formed at the upstream edge of the vegetation patch and coherent motions develop downstream. However, there is almost no detailed information about the developing process of large-scale coherent structure within the vegetation patch. So, in this study, we consider the effect of the limited length vegetation patch. Flow images were taken by CCD and the instantaneous velocity vectors are analyzed by PIV techniques. The results showed that (i) the 3-D diverging flow occurs at the vegetation patch edge and (ii) as the coherent structures develop downstream in nonwake zone, the rate of the vertical momentum transport by Sweep motions becomes larger.

The Impact of sediment to the Xiangxi River algal bloom process of China

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ABSTRACT: A three-dimensional unstructured-mesh eco-dynamic model was developed for simulating temporal and spatial variations of water quality with respect to phytoplankton, nutrients, dissolved oxygen and suspended sediment based on ELcirc model. Four major interacting systems were simulated, including phytoplankton dynamics, nutrients cycles, dissolved oxygen balance and suspend sediment. The effects of suspended sediment and bed sediment on the water quality processes were also considered. Then the model was applied to simulate the algal bloom processes in Xiangxi River (XXR), which was a tributary of Yangtze River and was affected by impounding of Three Gorges Project (TGP), and the model was calibrated and verified by the field data during the periods of XXR algal bloom. The simulated time serial concentrations of phytoplankton (chlorophyll) and nutrients were generally in good agreement with files observations.

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Roles of disturbance in structuring geomorphology for riverine animal communities

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ABSTRACT: Local species diversity is maximized when ecological disturbance is the intermediate disturbance. However, artificial impacts such as dam, excavation and levee caused decreasing dynamism and activity of sediment and biological habitats, and thereby biodiversity by disturbance less than intermediate. This paper aims at showing the effects of decreasing disturbance on changes of landscapes and geomorphic habitat diversity. Hierarchical structure of aquatic habitats in the lower reaches of the Kizu River, a tributary of the Yodo River, central Japan, was investigated using the aerial photos taken in 1948, 1961, 1971, mid 70s, 1979, 1990, 2002, 2008, 2010 and 2012. Results of the landscape changes showed that water surface and bareland significantly decreased with increasing bushland and woodland. Average channel width, braided index and shoreline index as geomorphic parameter decreased gradually. According to changes of landscapes and geomorphic parameters, habitat diversity increased gradually between 1948 and 2012. Increase of habitat diversity during the period indicated that the increase of vegetation area contributed to raising habitat diversity to some extent. Therefore, vegetation expansion derived from stabilization of flow regimes and reduction in sediment dynamics fascinated the environmental heterogenety in there 60 years in the Kizu River.

Sediment discharge measurements in a dam reservoir by means of detailed bed profile measurements

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ABSTRACT: Sediment discharge is one of the key parameters in considering river management, such as flood alleviation and environmental conservation. Sound measurement methods for the discharge applicable to real rivers have, however, not yet been established. This definitely comes from lack of sediment discharge data in real rivers. In this paper sediment discharge out of a dam reservoir is estimated by measuring bed geometry in the reservoir several times throughout 2 years, then relation between flow and sediment discharges are examined.

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Estimation of increased stage in river restoration by vegetation freeboard equivalence

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ABSTRACT: The application of vegetation freeboard equivalence is carried out from the comparison between the rise in stage with/without vegetation and the freeboard height under design discharge conditions. A vegetation safety factor is defined as a function the ratio between the rise in computed flood stage with vegetation to the design stage without vegetation plus freeboard. The applicability of the *VFE* and SF_V in this study, two models are used for this analysis of flood stage with and without vegetation: the 1-D model HEC-RAS and the 2-D model RMA-2. Both models are applied to three study sites of the Han, Seomjin and Geum. River systems in South Korea as representative of a urban, flatland and mountain river reaches. The analysis shows that without vegetation, both models provide comparable results. When vegetation is added for river restoration, both model results are also comparable and lead to the following conclusions: the numerical models showed a similar design flood stages before vegetation modeling; and no embankment overflow was shown from the urban river at a vegetation density of 25%, despite the 0.20 m rise in flood stage. The vegetation freeboard equivalence is therefore useful in the analysis of river stages during design floods with floodplain vegetation.

Long-term changes of riffles as habitat for benthic invertebrates in Kizu River, Japan

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ABSTRACT: To understand qualitative and quantitative changes of riffles as habitat for invertebrates with channel degradation, field surveys of riffles and aerial photo analyses were conducted in the Kizu River, Japan. Riffles of converge and traverse types had steeper water surface slopes and coarser bed materials than riffles of diverge types. The former two types also had higher biomass and taxonomic richness of invertebrates than the latter two types. Riffles were dominated by diverge types in 1945 to 70's, and riffles of converge and traverse types have increased in 2000's. Thus, although total area of riffles in the channel may have been more in earlier periods when channels were more aggraded, invertebrate biomass and taxonomic richness of riffles at reach-scale seem to have increased along with the channel degradation in the Kizu River.

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Experimental studies on channel evolution due to dam removal in Taiwan

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ABSTRACT: This study focused on No. 1 Check Dam on Chijiawan creek in Taichung County, Taiwan, which was removed in May 2011 due to habitat restoration for landlocked salmon. We conducted scaled experiments on scenarios of different flood conditions, and removal sizes and shapes. We compared our experimental results of riverbed elevation profiles with the analytical solutions derived from the diffusion equation. Besides, we conducted the long profile survey after the dam was removed to compare with the experiment results. The findings indicated the experimental results fit better with the theoretical solution near the dam site when the simulated discharge was larger. The comparison between experimental and field longitudinal profiles suggest the experimental predictions provided solid information but also highlight discrepancies at some places.

Flow structure and bed deformation around a group of spur dykes in a curved channel

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ABSTRACT: This paper presents the flow structure and the bed deformation characteristics in a 90° curved channel with a group of spur dykes installed on both sides of the curve. The spur dykes on the convex side are effective in promoting local scour pools and pool-riffle morphologies as well as varieties of flow fields. With proper design and co-working with the spur dykes on the concave side, their negative impacts on the sand bar development and the concave erosion can be controlled. An aspect ratio of 2–4 is suggested for the spur dyke groups on the convex side to achieve the maximal benefits to the ecosystem and the channel stability.

Modeling & measurement techniques

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Hydrophone observations of bedload transport in mountainous rivers of Japan

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ABSTRACT: The difficulties in directly monitoring traction processes, such as bedload and mass movements, have been recognized and have prompted research into surrogate monitoring technologies, including acoustic and seismic methods. Over the last decade, the hydrophone, an acoustic method, has become widely used in mountainous rivers in Japan to monitor bedload. However, since the results of acoustic measurements must be converted to bedload data using empirical and/or theoretical relationships, calibration is still a key issue for acoustic bedload measurements. Recently, we proposed a new method for calibration of sound pressure data, which are collected by hydrophones, with the volume of bedload transport. Here, we examine the accuracy of this new calibration method by comparing direct measurement data and estimation results. Our results show that the data evaluated by hydrophone agree well with direct sampling data. Then, we analyze hydrophone data at around 20 observation stations in Japan. We compare the bedload discharge data, evaluated by hydrophone, with the sediment deposition rate at sediment control dams. These comparisons indicate that the general trends in sediment discharge observed by hydrophone agree with the deposition rates at the sediment control dams. These results indicate that the combination of the hydrophone and our new calibration method is effective for clarifying bedload dynamics in mountain watersheds.

Monitoring of suspended sediment—laboratory tests and case study in the Swiss Alps

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ABSTRACT: There is an increasing demand for continuous real-time monitoring of Suspended Sediment Concentration (SSC) and Particle Size Distribution (PSD), e.g., for sustainable operation of hydraulic schemes. Most optical and acoustic devices need to be calibrated with respect to the properties of the suspended particles. Prior to a field study in the Swiss Alps, various turbidimeters, a portable laser diffractometer (LISST) and an ultrasonic system were tested in suspensions made of various mineral particles in a mixing tank. Significant influences of particle size and shape on the SSC estimation were observed and quantified. The data from the devices that have subsequently been installed in the headwater of a hydropower plant confirm temporal variation of PSD and allow cross-comparing the measuring capabilities of the devices under field conditions. LISST has the advantage to provide not only SSC but also PSD, and SSC data is less or not affected by varying size of suspended particles.

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Discussion on bedform data recording, post processing and analytical suitability

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ABSTRACT: Acoustic sensors, and more recently laser and photographic methods, are often used to obtain topographic information of underwater features in the laboratory. This physical quantity can vary with time or space. As with every signal, limitations of the measuring device or unfavorable environmental conditions can influence the quality of the signal. Studies undertaken by the authors in recent years highlight the new challenges that modern high-resolution datasets provide for identifying geometric bedform features. There is a need for a unified automatic post-processing methodology guideline. In the past, bed elevation datasets had a low data range, often allowing straightforward determination of discrete bedform parameters by observations only, or limited analysis. Examples from experiments undertaken in a narrow flume with 0.44-m width and a wide flume with 1.5-m width, highlight the new post-processing requirements needed for modern high-resolution datasets, which can easily exceed 1-million data points per bedform profile. Finally, a discussion is presented on the data specification needs for bedform analysis.

Bamboo forest estimation concerning land stability by ground temperature and water temperature

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ABSTRACT: In the Kidzu river, when the Izumi bridge built in 1951, the around 25 km left banks were narrowed and a stream was buried. Around the stream there is a national bamboo forest since 1888's old map. By the 1 m depth ground temperature and the river water temperature survey, the buried stream under the bank and the river plain was detected. In the Kidzu river's second sub-stream Ohtani river's basin, at Ishidera, Watsuka-town, suffered debris and water hazards in 1953, the stream was mended with continuous 3–5 m high small dams, many pipe holes are seen in landslide cliffs, the 5 m high dam downstream about 20 m of the both sides deserted lands have made bamboo forests.Abundant ground water is welled up in the next neighbor old stream valley. By the 1 m depth ground temperature, the river water and the well temperature survey, probability of a shallow ground water stream was detected.

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Study on changes of incoming runoff and sediment load of the Three Gorges Project and influence of human activities

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ABSTRACT: The Three Gorges Project is the largest and most important hydro junction in the Yangtze River Basin, which has huge benefits in flood control, power generation and shipping. Changes in the runoff and sediment load of the upper Yangtze River will affect the operation of the Three Gorges Project and the reservoir sedimentation. Variations of water and sediment during the period from 1956 to 2011 in the main tributaries of the upper Yangtze River and the Three Gorges reservoir were investigated in this paper with the cumulative curve analysis method and the Mann-Kendall test method. It is pointed that there is no obvious changing trend for annual runoff in tributaries of the upper Yangtze River and the Three Gorges reservoir. Except for the Jinsha River, annual sediment load of the other tributaries and the reservoir significantly reduces. The impacts of human activities such as soil and water conservation, sediment trapping by reservoirs, sand mining in river, and over construction on water and sediment changes of the river are analyzed according to the characteristics of water and sediment variations. It is pointed out that the different human activity plays a different role in the changes of river runoff and sediment.

User guide to gravelometric image analysis by BASEGRAIN

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ABSTRACT: BASEGRAIN is a MATLAB-based automatic object detection software tool for granulometric analysis of top-view photographs of fluvial non-cohesive gravel beds. It is handled via a graphical user interface, which enables post- and preprocessing as well. The core of the software code is a sophisticated five step object detection algorithm that separates interstices from grain areas. A quasi grain size distribution is derived from the *b*-axes of the detected grain top view area following a line-sampling methodology. Results are exported to common spreadsheet-file and GIS-file formats. If geotagged photographs are analyzed, georeferencing is done automatically. BASEGRAIN is freely distributed over the Internet in binary form, but the source code remains closed. The present paper contains background information on the object detection methodology used and focuses on how to apply BASEGRAIN in the most efficient way.

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1-D numerical model of sediment transport for pumped storage power station

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ABSTRACT: The rapid development of pumped storage power station challenges its sediment computations. The paper develops a 1-D numerical model simulating non-uniform sediment transport in pumped storage power station. The model also considers such properties of pumped storage power station as its special composition, complexity of operating conditions, dramatic changes of reservoir water level and complicated flow patterns near the inlet/outlet of pumping conduit. For example, the unsteady flow is enhanced by setting virtual inflows and outflows near the inlet/outlet. Furthermore, the model can respectively estimate the sediment concentration through the turbine both in dynamoelectric status and pumping status. Taking Tianchi pumped storage power station as an example, the detailed simulating method and results output methods are introduced on its sediment computation.

Three-dimensional numerical modeling of bed level in an open channel with 90° bends

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ABSTRACT: The main purpose of this study is investigation of the longitudinal variations of bed level in an open channel with 90° bend. For this purpose, numerical study was carried out for 3D simulating of the flow field in considered bend in 3phases (air+water+sediment). In the first step of this study using ICEM software, physical simulation and gridding of the channel was done. Then using ANSYS-CFX commercial code, 3D simulation of the channel with 90° bend was done. It should be mentioned that the Eulerian-Eulerian homogeneous multiphase flow was applied. In the third step of this paper an experimental investigation was performed on a laboratory flume to verify the numerical results. Finally, longitudinal profile variations of channel bed in different distances from outer bank of the channel were investigated.

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Numerical analysis of flood flows and bed variations at river confluences of the Go River

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ABSTRACT: In confluences of rivers having a comparable drainage area, a strong mixing of a mainstream and tributaries flows which have a large momentum in a different direction induces complex three-dimensional flow structures. In this study, the Bottom Velocity Computation (BVC) method consist of shallow water equations, depth-integral vorticity equations and water surface velocity equations was extended by introducing the flux integral method considering a non-orthogonal direction of a grid line for properly evaluating flood flows and bed variations in the confluences. The extended model was applied to recent large floods in the Go River confluences to investigate the flood flows and bed variations during the flood events. From the calculation results, we clarified that separation zones formed at the confluences have pronounced effects on the three-dimensional flow structure and bed variations for the downstream channel.

Study on flow and sediment routing model system in flood diversion and storage area based on Google Earth software

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ABSTRACT: In the past 10 years, geographical information technology changes with each passing day. Numerous geographic information platforms are founded, among which the software of Google Earth is the most widely used one. In this paper, a flow and sediment transport model based on Google Earth software is developed for using in flood diversion and storage area. This model interpolates data based on the Digital Elevation Database (DEM) to ensure fast and simple data processing. The finite volume method is adopted to ensure mass and momentum conservation. The unstructured grids are employed for adapting to the complex boundaries in practical situations. For post processing, the simulation results are also presented on Google Earth. This provides vivid three-dimensional and virtual views. The developed platform is applied in the Jingjing flood diversion area. Results show that this platform is highly efficient and suitable for urgent condition simulations. The developed platform can provide good predictions for flood and emergency controls in the flood diversion area.

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Finite element simulation of sediment transport: Development, validation and application of model to Potho minor of Jamrao West Branch, Sindh, Pakistan

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ABSTRACT: In this paper, a vertical two-dimensional finite element model was developed, validated against analytical solutions and laboratory observations available in open literature and applied for predicting suspended sediment concentrations in Potho minor of Jamrao West Branch, Sindh Pakistan. The model was developed using hydrodynamics equations coupled with transient suspended sediment transport equation. The semi-implicit Taylor-Galerkin scheme was applied to resolve the temporal behavior. The main feature of the model is the use of an innovative non-dimensional parameter, Diffusion Reynolds Number, which demonstrates fairly in terms of stability while dealing with sediment-laden flows. The model was validated against analytical solutions, which shows a good matching. Then it was compared with laboratory observations of Wang & Ribberink (1986), results reveals that model predictions are accurate; predicted concentration profiles at 3, 6 and 12 m downstream show a better match than other researchers. To check versatility of the model, observed concentrations, measured at various locations of selected Potho minor, are compared with the predicted results which show a good sign of conformity. This proves the robustness, accuracy and reliability of the present model.

Dam break on a movable bed by elastoplastic particle method

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ABSTRACT: The paper presents an applicability of an elastoplastic model based on a particle method to dam break simulation on a movable bed. In a riverbank, an undermining due to river flow can cause a collapse of riverbank. In order to simulate this series of phenomenon from sediment transportation to soil failure, a material of riverbank should be regarded as an elastoplastic body, and the numerical model should be required to treat a large deformation of soil and fluid-soil two-phase flow. In this paper, a numerical model based on a particle method has been developed. A dam break flow on a movable bed is simulated to examine the new two-phase flow model in which a movable bed, or a soil, is treated as an elastoplastic body, and its applicability is investigated by comparing the calculated result with a previous experimental one about behaviors of fluid and bed materials.

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Evaluation of critical shear stresses of cohesive sediments by using PIV compared with vane strength measurements

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ABSTRACT: In reservoirs flow velocities, turbulences and bed shear stresses are reduced, leading into settlements of the transported sediment load. Depositions in reservoirs often contain fine sediments like silt and clay. The occurring cohesive forces increase the critical bed shear stress and the Shield curve is no longer valid. Additional data is required in such cases to estimate the cohesiveness and as consequence the valid critical shear stress. In this study the critical shear stress was evaluated for cohesive sediment samples taken from a reservoir in Austria and from one located in Costa Rica. The sediment samples were placed in a flume and the discharge was varied until mass erosion took place. A 2D PIV device was used to measure the velocity profile and the turbulences at the same time. These values were used to calculate the bed shear stress for the specific discharge where erosion took place. Additional vane strength measurements have been carried out in the reservoirs to test the transferability of the measured vane strength values from the field into useable values for the estimation of erosion rates.

The relationship between downstream channel siltation and diversion canal length

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ABSTRACT: This paper introduces the relationship between downstream channel siltation and diversion canal length. Through field investigation, data analysis, mathematical model, physical mode and other technical means, it can be concluded that longer downstream canal leads to larger total sediment siltation quantity and smaller siltation intensity, sluice bottom elevation also has obvious influence on riverbed siltation.

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Two dimension velocity distribution in straight open channel under the effect of flow obstruction

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ABSTRACT: This paper investigates the velocity distribution around spur dikes using physical models. The scale model simulates two sites located at 34 kilometer and 104 kilometer downstream Aswan Dam. The two sites are straight reaches and spur dikes are needed to minimize local erosion in banks. Two cases were tested in the physical model under low and high flow rate using a single and triple spur dikes. A 2 dimensional numerical model was applied at Elgaafra to simulate low and average flow rate conditions. The physical and mathematical models concluded that for average flow rate, the triple configuration of spur dikes is effective in reducing flow velocity near the bank and bank erosion.

Supercritical flow in sediment bypass tunnels

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ABSTRACT: This paper deals with an experimental investigation of the mean and turbulence characteristics of supercritical quasi-uniform and gradually varied open-channel flows over a transitional rough bed. These conditions are typical for sediment bypass tunnels. The results show that the log-law holds well in the inner region across the channel. The roughness shifts the velocity profiles downward by an amount of ΔU^+. The velocity-dip phenomenon and strong secondary currents exist in the channel for narrow open-channel flow. These currents cause the Reynolds shear stress distributions to deviate from the linear distribution and an undulation on the transversal distribution of the bed shear stress, which matches with the bed abrasion pattern. The streamwise turbulence intensity profiles deviate from the semi-empirical universal function whereas the vertical turbulence intensity profiles fit well with it only at the centerline of the channel. A strong wall effect exists on the turbulence intensities in the outer region.

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Survey on relationship between the river topography and water level fluctuation at Kotogawa River

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ABSTRACT: The flood occurs and it becomes a problem in the river especially. It is necessary to manage usually so that the river shape may influence at the flood. However, in order to obtain frequent topography data at a river, it is necessary to expend large amounts of time and cost. Therefore, if it is possible to estimate river topography information from water level data, it will be practically effective for river management. Thus, it is necessary to clarify the Kotogawa River characteristics. In this study, river characteristics were investigated from river topographical and measured water level. Especially, each point were confirmed the large topographical fluctuations in the flood season. However, in comparison with water level and river topographical survey data, measured station 1 and 4 had a tendency to erosion. On the other hand, measured station 2 and 5 had a tendency to deposition.

Review of techniques for automatic measurement of suspended sediment concentration

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ABSTRACT: Sediment pose great challenges in the development of hydropower projects in Himalayan Rivers. Measurement of suspended sediment must therefore be an integral part of the planning, design and operation of any hydropower projects built on such rivers. Traditionally, Suspended Sediment Concentration (SSC) measurement is done by manual method. Although the manual method is reliable and reasonably accurate, the results are not quickly available. Moreover, the sediment concentration varies largely with time and the low frequency manual sediment sampling cannot cover such events. In order to cope with the need for high frequency sampling, techniques for indirect measurement of suspended sediment concentration have been gradually developing. All of the techniques developed to date have been trying to indirectly measure the SSC in water flow. Some of the techniques developed have only limited application. This paper presents a review of different sensor based techniques used for suspended sediment measurement.

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Development and application of a 2D flow and sediment transport numerical model on tidal reaches

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ABSTRACT: The flow and sediment transport in tidal reaches shows unsteady and non-equilibrium characteristics. This makes the theory study in these reaches difficult. In this paper, a depth-averaged two-dimensional mathematical model under curvilinear coordinates is developed. This model accounts for both the suspended sediment and bedload transport. The finite volume method is adopted for discretization with the SIMPLEC algorithm to address the water-lever and velocity coupling issue on non-staggered grids. This model is well validated by using of the measured data in Kouanzhi and Yizheng tidal reaches.

A large time step scheme for 2-D free surface shallow water equations on unstructured grids

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ABSTRACT: An effective numerical scheme can raise the efficiency of simulation of the river sediment. This paper will introduce the LTS (Large Time Step) scheme which is firstly by LeVeque to unstructured 2-D grids to obtain high resolution and efficiency. Exact Riemann Solver, and projection ratio method are adopted to assure the LTS scheme feasible. With the LTS scheme, CFL number can break through traditional restriction (CFL < 1) which will enhance the computational efficiency. Comparing to traditional Roe scheme, the results are acceptable when the CFL number is less than 2. When CFL number is larger than 2, the scheme will lost stable.

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Solve one dimensional river networks flow by using directed graph

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ABSTRACT: The definition of directed graph is introduced in this paper, and the depiction of river networks' loop-graph and tree-graph are expounded. The incidence matrix of one dimensional river network is constructed, and the mathematical essential of different type river networks' structure is revealed. The definite problems of various river networks flow and their solution strategies are given. Through generalized example, the reasonableness of solve river networks flow by directed graph is validated.

Physical model experimental investigation on riverbed evolution trend prediction with different model sand

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ABSTRACT: In the river model design, model sand selection is directly related to the sediment movement of model, similarity of riverbed deformation and reliability of the model test results, so it has always been the important and difficult job therein. Based on the summary of former model sand characteristics, selection rules and application effects, independent test is conducted in two sets of river model in Shashi river reach by selecting different model sand (pulverized coal, plastic sand); and then suitable hydrology series is chosen for the prediction research on the evolution trend of riverbed of Shashi river reach. The result shows that the overall prediction effects in Shashi river reach are almost the same either the pulverized coal or plastic sand is taken as the model sand; however, silting and scouring variation of riverbed of Shashi river reach is relatively complex, and plastic sand is easier to be started compared with pulverized coal, so it is more sensitive to the change of local flow condition; therefore, there are still differences in the regions where the local flow condition is complex. This research result not only underlies the study of riverbed evolution and waterway regulation engineering design of Shashi river reach, but also gives reference to the model sand selection in the river model of riverbed with complex sandiness.

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Application of two-dimensional mathematical model in the Yangtze River waterway management

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ABSTRACT: In order to better serve for shipping, in recent years, many waterway regulation projects in key navigation-obstruction channels have been launched. And the numerical models are widely used in the research on waterway regulation in middle and lower reach of Yangtze River, because of the short period and easily used characteristics. This paper introduces the basic theory, basic equation and calculating method of 2D flow and sediment models. What's more, the analysis and discussion of the numerical practice model are carried out based on the Jiepai river regulation project, for the middle and lower reaches of Yangtze River and other rivers of similar problems to provide reference. Research shows that, numerical simulation basing on accurately reflecting the actual water and sediment transport characteristics, by changing the hydrological conditions and boundary conditions, can be realized on prediction of riverbed evolution trend and different projects' effect, so as to guide engineering design.

Numerical modeling of sediment erosion and deposition in the lower approach channel on Pak Beng hydropower station

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ABSTRACT: Pak Beng hydropower station is the first grade of the cascade power stations in the mainstream of Mekong River. In order to research the problem of sediment erosion-deposition at the entrance area in lower approach channel as well as the scouring effect and operation mode of channel scouring sluice, a plane two-dimensional flow and sediment mathematical model was used in the paper. Erosion-deposition process in the lower approach channel was obtained, and it shows that there will be accumulated deposition in the approach channel after the power plant runs. Besides, suggestions for optimizing the operation mode of channel scouring sluice are proposed based on the calculated results. In order to improve the scouring effect of channel scouring sluice, it's recommend to flush sand at small discharge.

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Sediment transport from the Kiso River to Ise Bay using coupled river and ocean models

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ABSTRACT: A coupled river runoff and ocean circulation model is developed. The model consists of distributed hydrological model Hydro-BEAM and ocean circulation model RIAMOM, along with advective diffusion model of sediment. These models are connected through the boundary conditions. We apply the model to a heavy rainfall case around the Kiso River basin and Ise Bay during April 2003. It is found that the calculated suspended sediment distribution is qualitatively consistent with that of muddy water from MODIS satellite observation.

Application of sediment mathematical model for plan and design of Dongzhuang Reservoir in Jinghe River

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ABSTRACT: Hyperconcentrated flows have a significant influence on sediment carrying capacity and settling velocity of sediment particles, which leads to the sediment transport problem being more complex than common sediment-laden flows. Taking the influences above into account, packet sediment carrying capacity formula reflecting different states of riverbed erosion and deposition is established, and a mathematical model of reservoir sediment scour and deposition for silt calculation of hyperconcentrated flows is developed by applying correction method for settling velocity proposed by Zhang Hongwu to revising free settling velocity of a sediment particle and utilizing corresponding saturation recovery coefficient for different particle size based on the condition of erosion and deposition. The mathematical model is verified with measured data of Xiaolangdi reservoir on the Yellow river and Bajiazui reservoir on the Puhe river, the calculation of the reservoir siltation and deposition features agree well with measured data, and the process of sediment scour and deposition on the high sediment-laden river with reservoirs built is also well reflected. The mathematical model is adopted on the Dongzhuang reservoir scheduling of water and sediment regulation for the calculation of reservoir sediment scour and deposition with using data of three series of flow and sediment. The results provide essential technical support for Jinghe river basin planning and reservoir planning and design.

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Sediment related disasters

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Study on the function of a closed-type Sabo dam with a flap for debris flow

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ABSTRACT: In recent years, many research studies have examined efficient function of sabo dams, which have a great impact on ecology and landscape. In that research, attention to the aspect of analysis of impact force associated with debris flow is still lacking. Therefore an alternative design and its resistance against debris flow impact force deserve investigation. In this study, a new closed-type dam with flap is designed to capture more debris and effectively control the total pressure compared to without flap dam. The laboratory experiments are performed to clarify the improved functions of the new dam and the effect of debris flow impact pressure on it. The results from the experimental data clearly show that the proposed dam type has the ability to capture more sediment sustaining less force than the without flap dams under the same debris flow. This comparison demonstrates the future importance of the proposed sabo dam.

Characteristics of recent urban flood damage and its mitigation—examples in Kyoto and Uji City area

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ABSTRACT: In the summer season of 2012, several heavy rain falls around Kyoto City areas caused severe hazard like flood inundation in the populated areas. The hazard types were the inundation by rainfalls, local flood by break of river dikes and sink of motorcars in highway underpass. The study of detail mechanisms of such dramatic hazards is necessary to propose countermeasures against local heavy rainfalls which often occur these days. The paper describes the characteristics of the hazard obtained mainly in the field survey and discusses the origin to raise the hazard level. Several simple ideas to mitigate the hazard are proposed.

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Study on flow and sediment balance of flood in Saba River occurred on July, 2009

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ABSTRACT: A flood occurred in the Saba river which passed through Hofu City, Yamaguchi, Japan due to heavy rainfall on 21st July, 2009. The rain induced slope failure and caused a large quantity of sediment to flow into the river. In this study, estimation of the flow balance and sediment balance were conducted by using numerical simulation and the river bed elevation data observed before and after the flood at two stations (Shinbashi and Manao). The numerical simulation for the flow balance in which the inflow discharge from the tributaries and the overflow from a bank are considered is in good agreement with the observed hydrograph at the Shinbashi station. Although the numerical simulation overestimates the volume of the sediment accumulated in the river, the accumulation properties in the river can be simulated qualitatively.

Characteristics of sediment disaster phenomena in Mimikawa River Basin

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ABSTRACT: In the Mimikawa River Basin, located in Miyazaki Prefecture, in southeast Kyushu, Japan, there are seven hydroelectric power stations (total output: 341MW) operated by Kyushu Electric Power, (KEPCO) which comprise an important hydro-energy source in the region. In September 2005, Typhoon No.14 brought heavy rainfall exceeding 1,000 mm, and caused a severe sediment disaster attributable to mountain slope failures in approximately 500 locations. This experience raised awareness of the future risk of sediment disasters which might occur in this basin. To carry out appropriate facility maintenance in the future, KEPCO carried out a survey of the river basin, and analyzed the sediment disaster. In addition, from the points of view of topography, geology, and amount of rainfall, we analyzed the characteristics of the sediment disaster in the river basin, and identified areas susceptible to sediment disaster as well as the level of rainfall that creates a high risk of sediment disaster.

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A basic study on the snowmelt process by the pyroclastic flow and the discharge estimation of the snowmelt-type mud flow

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ABSTRACT: This research detailed the mechanism of eruption-induced snowmelt and the relationship between heat quantity exposed to the snow covered slope and the amount of heat output on the downstream end. We conducted flume experiments to investigate the process of fresh or corn snow melting in high-temperature conditions and that of hot-material flow and accumulation and accompanying snowmelt water discharge. It was revealed that there are some regimes for the process of snowmelt according to the falling materials and significant differences were found in time histories of weight of falling materials. In addition, an indicator for potential snowmelt amount was defined and it is verified that this was effective in estimating patterns of snowmelting caused by hot materials.

Characteristics of woody debris deposition during the Yabe River Flood in Yame City, Japan: Northern Kyushu Flood Disaster in July, 2012

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ABSTRACT: Field survey along the Yabe river was performed to examine characteristics of woody debris deposited on flood plain during the flood event. The flooding woody debris was restrained by obstacles, such as houses, utility poles and barriers with various irregular shapes and then yielded woody debris jam on the flood plain. Two types of woody debris deposition can be distinguished; one is the deposition of individual wood pieces, and the other is the accumulation or jam of woody debris. It is found that the volume of woody debris jam depends on the scale of an obstacle on the flood plain. On the other hand, 50% of individual wood pieces has a length from 2 m to 6 m and 80% of individual wood pieces has a diameter from 0.1 m to 0.3 m.

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Experimental study on accumulation processes for non-homogeneous debris flow

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ABSTRACT: By means of the grain size gradation of debris flow from Chenjiaba area of Beichuan county in Sichuan Province, China, 12 runs of experiments for non-homogeneous debris flow had been carried out to get some meaningful parameters including the accumulation geometric parameters and water-sediment parameters. Furthermore, based on the statistical correlation analysis, both the accumulation geometric parameters vary by changing of unit weight, flow velocity and hydraulic gradients in the accumulation processes. If the topography of accumulation plate is not changed, energy dissipation rate in the accumulation area keeps constant in experiments. Otherwise, energy amount of accumulation processes increases by increasing of moving hydraulic gradient. These results above are significant for investigating mechanism of non-homogeneous debris flow and designing of the disaster control projects.

Keywords: non-homogeneous debris flow, accumulation process, geometric parameter, energy dissipation

Calculation technique for evaluation of bed variation in mountain rivers: Effects of methods describing erosion and deposition processes

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ABSTRACT: We conducted numerical simulations of the sediment discharge of Haruki-gawa, central Japan, to predict riverbed variation due to high sediment supply to mountain rivers from hillslopes and hollows. We used the theory proposed by Takahashi et al., to describe deposition and erosion processes. We analyzed the effects of the deposition rate coefficient in Takahashi's theory, the runoff ratio and sediment supply conditions at the upper boundary of the studied areas. We found that the deposition rate coefficient exerted the most significant impacts on sediment transport volume and riverbed variation. When the deposition rate coefficient was set to 10^{-3}, we found that the simulated pattern of sediment transport volume and riverbed variation was almost consistent with that observed. Therefore, ours results indicate that sediment dynamics in mountain rivers can be described by a model of non-equilibrium sediment transport conditions.

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Study on the width of rivers in valley bottom plains

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ABSTRACT: Flood disasters caused by torrential rainfalls have recently been increasing in Japan. One of the representative disasters is Yosasa River flood disaster in 1998. Far exceeding capacity of flow made river widths and channel shape change by severe bank erosions. But, there are few observation data such as discharge and the water level hydrographs of flood disasters in the middle and small-scale rivers. Quantitative investigations on appropriate river width and water depth have not been conducted sufficiently.

In this study, we applied two-dimensional flood flow analysis for the 1998 flood occurred in the Yosasa River and proposed a decision method of river width required for large floods in rivers flowing valley bottom plains.

Levee breach and successive disaster depending on landscape management on floodplain

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ABSTRACT: The disaster is caused by the levee breaches are not equal all over the floodplain, which depends on landscape management. Thus, the research is important to recognize the disaster effect on the floodplain in order to understand the characteristics disaster because of the levee breach and we have attempted to evaluate them through numerical schemes. As for the simulation scheme; from the Satellite Image Analysis, tentatively five kinds of typical model flood plains (rural to urban) are considered with the conformity of the Sirajganj district in Bangladesh. And, an excellent solver RIC-Nays as a two-dimensional simulation model for flood flow and morphology is utilized of which confirmation was checked through small-scale laboratory experiments. An initial condition for the overflow breach is provided with a partial crest opening. The inundation flow pattern and the process of sedimentation over the floodplain are analyzed to understand the disaster effect on the various model flood plains.

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Dangers of levee breach in river with higher relative river bed suggested by small-scale laboratory experiments and numerical analysis

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ABSTRACT: Rivers with large amount of sediment transport often have higher river bed from the floodplain level, and more dangerous risk may be expected if such rivers are suffered by levee breach. In addition to the fact that aggradations decreases the flood capacity and increases the risk of over topping the levee under such situations, outflow from the breach is more rapid, and more sediment is transported from not only from the levee but also from river bed to deposit on the floodplain causing more serious disaster. Furthermore, outflow of sediment from the levee breach causes degradation in the upstream river reach of the breach. It makes the foot of levee there unstable, while the gap of the bed elevations between upstream and downstream at the breach obstructs the main flow to promote more outflow diversion to the floodplain. In this paper, small scale laboratory experiments and numerical simulations of flow and bed-morphology of an area including river and floodplain as well as levee embankment are conducted by comparing them each other to complement the weakness in applying them independently.

Jingjiang River and Dongting Lake relation modulating and its influence on flood situation

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ABSTRACT: The relationship between Jingjiang River and Dongting Lake has varied greatly in recent decades, channel of Jingjiang River has been continuously scoured, the three diversion rivers from Jingjiang to Dongting Lake have shrunk by deposition, runoff and sediment from Jingjiang to Dongting Lake decreased greatly. It is revealed that these changes mainly owe to the bends cutoff of the lower reach of Jingjiang River during 1967–1972. Because of sedimentation and reclamation, the area and volume of Dongting Lake decreased, and the flood regulation ability weakened. Hydrographic data reveal that annual flood and annual flood stage of Yangtze River below Dongting Lake were increasing with time in recent decades, and the maximum flood stage increment appears near Chenglingji by 2.0 m. Increment of annual flood by 7000 m^3/s raised the flood stage by 1.5 m, deposition of the Yangtze River channel from Chenglingji to Wuhan raised the water stage by 0.5 m.

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Influence of river bed evolution on inundation processes at Narayani River in Nepal

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ABSTRACT: Numerical simulations were conducted to estimate the inundation area at the area where sediment deposition takes place actively. Two different conditions were configured as the rigid bed condition; simulating only flood flow, as well as erodible bed condition; simulating flood flow with bed variation. The inundation processes were discussed in terms of effects of flood discharge, river bed evolution, and sediment supply conditions at the upstream boundary. The results obtained from numerical computations show that the inundation areas computed with erodible bed condition are much larger than those predicted with rigid bed condition, and increasing of sediment supply from upstream significantly contribute to the increasing of inundation area. These results were validated partly with Modified Land Surface Water Index (MLSWI), which was obtained from satellite information, and indicate the importance of river bed evolution to the inundation processes.

A theoretical treatise of drainage and seepage in bottom land areas adjacent to incised channels: The J.J. van Deemter analysis

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ABSTRACT: Saturated groundwater flow research on agricultural land in early times was mainly concerned with drainage of excessive rain. The key issue then was the spacing of drains or ditches to provide the efficient and effective removal, within a given time, of excessive water for a given soil. The focus was almost exclusively on flat land areas and for homogeneous, isotropic soils. In this context, the analytical and experimental works by Hooghoudt, Kirkham, Gustafsson, Childs, and others in the 1930s and 1940s come to mind in which various aspects of this problem were studied. Since those days, drainage research has shifted to a host of other issues involving soil profile heterogeneity, soil layering, drainage technologies, etc. Perhaps the most significant, but least recognized, contribution to drainage theory under steady flow regimes through homogeneous isotropic soils during those early years was the work by J.J. van Deemter (1950) in the Netherlands. His work represents an analytical approach of finding exact solutions for a host of situations of 2-dimensional flow using conformal theory. His work represented a major advancement at that time but never received the recognition it deserved because: (1) it was written in Dutch; (2) upon completing his work, Dr. van Deemter joined the Royal Dutch Shell and did not continue or publish this work; and (3) the mathematical complexity of his work was beyond the competency of many drainage practitioners. This paper revisits his work and the analytical solutions obtained for a number of scenarios involving drainage by drains, ditches, and stream channels. The significance of this work today is that it allows the evaluation of seepage forces in streambank instability issues, sediment production in stream channels, and water quality source problems from land adjoining streams.

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Study the evolution of JianLi reach and the impact on stability of revetment in scouring situation

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ABSTRACT: The flow and sediment load flowing into JingJiang river reach downstream of the Three Gorges Reservoir (TGR), either the process or the amount, have significant changes after the impoundment of TGR. Conspicuous erosion has occurred in JingJiang river channel resulting in river regime changes in some locations. Which will consequently affect embankments, bank protection works along both sides, river regulation projects and the stabilities of river bed at different levels, and then will affect the flood control, navigation, ecology, environment and the integrated function of the river in these areas for a long time. Based on the analysis of the characteristic of incoming water and sediment in JingJiang river reach after the impoundment of TGR, the feature of the fluvial process in JianLi reach, the changing tendency and the effect to stability of existing revetment work are studied mainly in this paper.

Numerical study on the flow and the sedimentation during 2008 flood in the Koshi River in Nepal

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ABSTRACT: This study has attempted to replicate the flooding and the sedimentation during the 2008 flood by using a numerical model. A two-dimensional morphodynamic model, which can treat the bed-load and suspended load transport of non-uniform sediment, has been applied to simulate the flood flow and the sediment transport induced by the levee breach. By using this model, we have investigated how this flood propagates on the floodplain and how much sediment was supplied from the levee breach point. The volume of the flood flow and the sediment transport into the floodplain has been estimated. In addition, we have conducted a case study, which focuses on the effect of the bed level difference between the riverbed and the floodplain to the volume of the flooded sediment and the bed evolution dynamics in the Koshi River. The proposed model predicts the flood discharge due to the levee breach reasonably well; however, the amount of the floodplain sedimentation appears to be under-predicted. The result also reveals that the bed level difference between the riverbed and the floodplain strongly affects the sedimentation volume on the floodplain and the channel evolution dynamics in Koshi River.

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The impacts of climate and land use change on soil erosion risk in the Mae Nam Nan Catchment, Thailand

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ABSTRACT: This study predicts the impacts of climate and land use change on soil erosion in the Mae Nam Nan Sub-Catchment in Thailand. CA Markov model and HadCM3 were used to characterize future land use and climate changes. Soil Loss Modeling in IDRISI software was employed to estimate potential soil erosion risk and total soil loss generated at a 10 year interval. Results indicate that the percent of the study area in very severe class (erosion rate > 100 Mg/ha/yr) decreased under A2 scenario. While mean soil loss rate in very severe class and the amount of soil loss increased moderately under A2 scenario compared to 2010. The increase in the amount of soil loss was 2.33, 6.05, and 18.19% for A2 scenario from the year 2020, 2030, and 2040, respectively. The high amount of soil loss in 2020, 2030 and 2040 can be attributed to high rainfall erosivity under future climate. Moreover, land use changes have significant effect on soil erosion in the future periods.

Wavelet analysis of the retrogressive erosion process of tailings dam-break

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ABSTRACT: Tailings dam is a man-made potential source of debris flow, which will cause a disaster once the dam being broken. An experiment of physical model of molybdenum mine tailings dam was conducted, which included the first stage dam and the second stage dam. During the experiments, the volume of dam-break was measured by a topographic measurement system (contour style 3D laser scanning system). Then, the wavelet analysis was adopted to process the variations of dam-break volume. The results showed that (1) the dam-break volume of the retrogressive erosion of tailings displays periodic fluctuations; (2) the peak dam-break volume occurs accompanying the liquefaction of depositions which come from the disintegration and collapse; (3) Flow of high frequency in the first stage dominates the erosional process while flow of low frequency in the second stage plays a main role in dam-break process. This study investigated the dam-break phenomenon from a different way and the results have significant meanings for both theoretical and practical applications.

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Integrated sediment management

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Water and sustainable development of Macau

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ABSTRACT: Water resource has an important impact on the sustainable development of Macau. In recent years, the problem of saltwater intrusion is very serious in Pearl River estuary, which affected seriously water supply safety of Macau. The Central People's Government attaches great importance to the Macau's water problem, which has become the first living issue of people. In order to guarantee Macau's water supply safety, the key points include the establishment of long-term mechanism and engineering measures, and the construction of water-saving society. In spite of the hot issues on water supply safety, Macau also faces other issues on water: 1) Development and protection of beach. 2) Prevention and reduction of flood or tide disasters. 3) Water pollution prevention and water ecosystem protection. 4) Modern management of water resources, and suitable layout of water engineering and so on. To make a comprehensive and systematical research to these issues, we should not only aim at the prominent contradiction in reality, but also relate with the sustainable development of Macau, as well as the Pearl River Delta environment and the periphery urban area. Based on the long-term research for Macau's water problem, the paper try to make a sketchy review to our works, and put forward some advises.

Utilization of the Yonmenkaigi system method for sand mining management of community building at the local community level of Merapi Volcano, Indonesia

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ABSTRACT: This paper introduces the implementation of the Yonmenkaigi System Method (YSM) to develop sand mining management of local communities for disaster management in Merapi Volcano of Indonesia. A participatory workshop method called YSM, originally developed in a local community of Japan, is presented as a case study carried out under the Pilot Project at the local community level in Yogyakarta, Indonesia. YSM consists of the four main steps: carrying out SWOT analysis, completing a Yonmenkaigi Chart, win-win debating between groups, and presenting the action plan. A case study implemented in the Kemiren village, Yogyakarta in July 2010, demonstrates how residents who are interested in disaster mitigation and management can collaboratively develop an action plan for sand mining management of local community. YSM can be utilized as a useful tool to improve motivation for community building and understanding of disaster management activities for enhancing the disaster coping capacity of local communities.

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Research on comprehensive harness of the river near the city based on harmonious idea

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ABSTRACT: Through researching the impact factors and basic requirements of the river health, finding the correspondence of maintaining the function of flood discharge and restoring the ecological environment. The view river restoration means restoring its functions gradually in a new environment has been made, and several restrictive relations of the comprehensive harness of river have been pointed meanwhile. The article highlighted research on the comprehensive harness mode, which was mainly about making windbreak and sand fixation realized on the floodplain of the river near the city and then improving the ecological environment. The author analyzed a few typical reaches of Luanhe River, and raised the training principles that solving not only the river control but also the development construction of the city near the river, and forming a harmony and mutual promotion relationship between the urban sustainable development and river health.

Discussion of Yellow River water and sediment regulation and control system

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ABSTRACT: In this paper the situation and existing problems of the Yellow River water and sediment regulation and control system were analyzed based on the root problem of Yellow River, which is summarize as insufficient water, excessive sediment and imbalance of the two. The overall arrangement of Yellow River Water and Sediment Regulation and Control System was presented here according to the demand of the storm flood and ice flood control, sediment deposition reduction and water resource configuration of the Yellow River. The regulated sediment-laden flood characters and operated ways of Yellow River water and sediment regulation and control according to the demand to maintain the capacity of release the flood and sediment, to assure the safety of the storm flood and ice flood control and to realize the effective management and configuration of Yellow River water resource. The built order of key projects was determined by analyzing the development tasks, the status and role in Yellow River Water and Sediment Regulation and Control System and the urgent requirements of the regulation and development of Yellow River. Besides, the role of Guxian Reservoir in the Yellow River was analyzed, the result shows that it occupies a Strategically important position in the regulation and development of Yellow River and plays an important role in the flood control, so it is vital necessary and urgency to accelerate the construction of Guxian Reservoir.

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Sediment budget of the scarce monitored transboundary Selenga river system

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ABSTRACT: Paper aims at understanding sediment budget of the Selenga river system which is the largest tributary of Baikal Lake. Sediment loads were measured in August 2011 and June 2012 at 90 sites in north-central Mongolia and rep. Buryatia (Russia), focusing on the main stem of Selenga River and its tributaries where mining, agriculture, and urban populations are concentrated. Sediment budgets illustrate main sediment fluxes and erosional/deposition rates which are crucial for floodplain and channel sediment pollution of the downstream reaches and recipient water body (Lake Baikal). We argue that transported sediments are mostly deposited along Selenga downstream during high water period, whereas during low water period due to channel erosion in the downstream reaches longitudinal increase of sediment load occurs. The results are useful for transboundary pollution assessment and implementation of the river system model.

Water scarcity and its impact on the social and economic national projects in Egypt

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ABSTRACT: The management of the Egypt's water resources, which are mostly (about 95%) contributed by the Nile River, to face the increase in the water demand is considered extremely difficult, especially in the near future after implementing Upper Nile Projects. This study includes the impacts of the reduction of the flows downstream Aswan High Dam on projects of economic and social dimension. In this research, GSTAR3.0 numerical model was selected for simulating the flow of water and sediment transport in the fourth reach in the Nile River (i.e., which extends from the downstream of Assuit Barrage to the upstream of the Delta Barrage. The model was, primarily, calibrated. It was, then, used to predict the probable river bed morphological changes that might prevail due to the release of the variation of discharge according to the strategic water plans. Locations of navigation bottlenecks were identified. In addition, the efficiency of drinking pump stations was evaluated. Results were obtained, analyzed and were presented. The results could support decision-makers to plan mitigation measures to limit the complications of water scarcity.

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Expected fluvial sand supply from a river for reforming a river mouth delta—an example of the Sagami River

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ABSTRACT: The Sagami River flowing into Sagami Bay is the main source of sand of the Shonan coast of 16 km length extending between Oiso Port and Enoshima Island. In the upstream basin of this river, large dams were constructed and riverbed mining was extensively carried out to obtain construction materials before 1967. These activities resulted in the decrease in sediment supply from 1.5×10^5 to 5000 m^3/yr and the shoreline recession around the river mouth. In this study, the expected fluvial sand supply to recover a river mouth delta of the Sagami River was investigated, using the contour-line-change model considering changes in grain size. It was concluded that the expected sand supply from the river necessary for recovering the river delta within 30 years from the present was $(1.0–1.5) \times 10^5$ m^3/yr.

A complex sediment yield and transportation model for mountain area

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ABSTRACT: In Taiwan, the catastrophic typhoon is an important factor to trigger serious landslides in mountains. For example, Typhoon Morakot in 2009 caused 39,492 hectares for landslide areas. The sediments yield from landslides triggered the mass movement in the mountains and caused serious hazards. In order to make the manage plan for watersheds, an applicable numerical model is needed to estimate the mass movement. In this study, the purpose of this research is to establish a model for sediment yield and transportation in a watershed. The process of sediment yield and transportation in a watershed could be simulated during rainfall. The processes of sediment yield and transportation, which including several major mechanisms, runoff, soil erosion, groundwater, shallow landslide, channel flow, bed load, suspended load, river bed and sediment size variation are established in this model. The scheme of the model is setup as quasi-two dimension model and based on mass conservation. This scheme can shorten lots time in simulation, and shows more detail terrain characteristic in special scale, resulting in sediment yield and transportation can be accurately assessed. The numerical analysis of this model are also preceded in this research. Finally, the Blackstone watershed in Central Taiwan is selected to simulate the process of sediment yield and transportation during 2005 to 2011 by this model. The simulation shows this model could provide good result at sediment movement in watershed. So the model is effective in watershed management.

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Technical consultation and exchange on sediment management of Korea Gyeong-in Ara Waterway

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ABSTRACT: Invited by K-Water of Korea, engineers from CRSRI of China provided technical consultation on sediment management for Korea Gyeong-in Ara Waterway in 2010. Firstly, techniques, researches and practices on sediment management of China waterways of water resources and hydropower projects have been summarized as five aspects: causes of sediment deposition in waterway, measures to reduce waterway sedimentation, methods of sediment observation for waterway, measures to prevent and control sediment yield of watershed, and researches on sediment issues of the Three Gorges Project. Then, four major sediment problems of the Waterway have been pointed out, which include observation and estimation of sediment yield and transport rate from Han River, Gulpo River and West Sea, re-checking of sediment carrying capacity and monitoring of sediment transport, engineering and non-engineering measures to prevent sedimentation around headwork, and design of the Waterway dredging and estimation of sediment deposition recovery. Finally, comprehensive suggestions of sediment management on observation, measures and researches for the Waterway have been proposed.

Importing and exporting sediment management strategies: Challenges and opportunities

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ABSTRACT: Mitigating increasing reservoir sedimentation in the United States is challenging due to the many environmental regulations passed and multiple oversight agencies created during the period when dams were being built. Limitations on the suspended sediment concentration of discharged sediments effectively rules out such management alternatives as flushing and sluicing with the exception of a very few projects that have been operating in this mode for decades. Sediment bypassing that matches sediment concentration in the discharge to that in the inflow appears to be amenable to regulatory agencies. A few brief examples illustrate the point that necessity and collaboration are the key to successfully managing the sediment issues related to U.S. reservoirs.

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Limitations of institutional management and socio-economic barriers of Tidal River Management, a semi-natural process to save bhabodaho from water-logging problem

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ABSTRACT: Perennial water-logging due to the excessive riverbed sedimentation has become the most menacing crisis to the people of South-West region of Bangladesh. Peripheral embankments, polders, made in 1960 have turned out to be curse while it had been built to save the area from natural disasters and to augment agricultural yield. Later on Bangladesh Water Development Board (BWDB) implemented Khulna-Jessore Drainage Rehabilitation Project (KJDRP) to solve this long-standing water-logging problem during 1994–2002. After that, a popular indigenous concept Tidal River Management (TRM) was adopted which allows the tidal flow during high tide where in low tide, clear water erodes the river bed and increases the depth of the river as well as deposits sediment on the low lying land. As the tidal flow is allowed to enter in low lying areas or natural depression (locally known as beel) the land remains drowned during the application of TRM for 5–6 year. So locals can do nothing with their land that they suffer and starve. Due to institutional limitations, mismanagement as well as long appliance period the process of TRM operation the area still needs further attention to solve institutional conflicts and disputes among farmers, fishermen and land owners because of shrimp firming and loss of indigenous varieties of fish and crop biodiversity. The study explains that TRM could be the best solution to menacing water-logging if it is made socially acceptable.

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Comprehensive sediment management model in Yahagi River basin based on Yahagi Dam sediment Bypass project

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ABSTRACT: This study examines measures for the effective and efficient management of sediment in connection with the operation of the sediment discharge bypass (BP) being considered for the Yahagi Dam, including merits and demerits in the downstream river. Specifically, based on the area where excavation for maintenance will be required for flood control after the sediment discharge facility (BP) starts operation and the amount of sediment to be excavated, examination was made on the measures for effective use of sediment resources by the development of tidal flat at the river mouth and shallow bottom/tidal flat in the port area and the recycle of excavated sediment (for material etc.). As a result, development of a stockyard as an adjustment base for sediment management in the mid-stream area proved to be effective. Further examination was made as a case study on potential sites for stockyard leading to optimum cost effectiveness and "sediment management" (draft) for optimizing flood control, water utilization, and environment for the overall river system.

Study on the role of GuXian Reservoir in Yellow River management and development

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ABSTRACT: Guxian Reservoir is a very important project in the Water & Sediment regulation and control system of Yellow River, because it has special geographical advantages for sediment retention, water & sediment regulation and control when together with XiaoLangdi Reservoir. The plan of combine GuXian with XiaoLangdi was put forward according to the operation experience of XiaoLangdi Reservoir and studies on the characteristics of water & sediment in Yellow River. Analyses on the role of Guxian Reservoir in the Yellow River management were carried out by the observed data and mathematical model. The results of the analyses show that Guxian Reservoir which operated with the existing reservoir projects will significantly improve the relationship between water and sediment, reduce the sediment deposition in the lower yellow river, maintain the normal channel whose bank full discharge is about 4000 m^3/s, decrease Tongguan elevation by about 2 m, cut down the flood discharge in Xiaobei main stream and let down the level of detention flood in SanMenXia Reservoir. And at the same time, it can significantly improve the water supply conditions of the surrounding areas and promote regional economic and social development. Therefore, we should accelerate the construction of Guxian Reservoir to perfect the Water & Sediment Regulation and Control System in order to keep healthy life of the Yellow River.

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Sediments, which constitute the surface of the Earth, start their journey to rivers with the energy obtained from rainfalls, floods and other natural processes. Due to transport of sediments, rivers develop with various appearances and functions, and play a crucial role in the activities of human beings and the life cycles of other species. River sediment, as a conventional topic for river management, has been the topic of continuing research since ancient times, and since then significant progresses in river sediment research has been made. Nowadays, river sediment is much more connected to the activities of mankind and other species, following the increasing awareness of the co-existence of humans and nature.

Advances in River Sediment Research comprises the proceedings of the 12th International Symposium on River Sedimentation (ISRS2013, Kyoto, Japan, 2-5 September 2013). The book contains two keynote papers and 274 peer-reviewed regular contributions from all over the world, and covers recent accomplishments in theoretical developments, numerical simulations, laboratory experiments, field investigations and management methodologies of river sediment related issues. The book may serve as a reference book for graduate students, researchers, engineers and practitioners in disciplines of hydraulic, environmental, agricultural and geological engineering.

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