Proceedings of the 7th International Conference on

HYDROINFORMATICS 2006

Volume II

Innovate & Share!

4th to 8th September 2006
Nice, FRANCE

Edited by

Philippe Gourbesville
Jean Cunge
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Preface

Innovate & share!

Hydroinformatics, a cross-disciplinary field of study, combines technological, human sociological and more general environmental interests, including an ethical perspective. It covers the application of information technology in the widest sense to problems of the aquatic environment and of the water resources management. Its aim is to equip professionals, practitioners, engineers, managers and decision makers working in water related arenas, with available information and technology, to make rapid and robust decisions as they address the increasing challenge of ensuring a sustainable water environment and adequate water resources for the generations to come. This field is expanding rapidly, as shown by the significant increase in the number of participants and exciting papers presented over the past six conferences (Delft in 1994; Copenhagen in 1996; Zurich in 1998; Iowa in 2000; Cardiff in 2002 and Singapore in 2004).

The 7th International Conference on Hydroinformatics is held from 4 to 7 September 2006 in Nice, France. The conference, returning to Europe after the Asian edition in Singapore, sees a growing interest of the water community for Hydroinformatics. This is a significant step in the continuous effort of three international associations – the International Association of Hydraulic Engineering and Research (IAHR), the International Association of Hydrological Sciences (IAHS) and the International Water Association (IWA) - associated for the first time with the Société Hydrotechnique de France (SHF) to actively promote and accelerate both research and applications of hydroinformatics in the world. This conference, held in Nice on the French Riviera, serves as a perfect venue for practitioners, engineers, researchers, scientists, managers and decision makers from Asian and Americas to meet with their European counterparts to exchange about the most advanced developments in the hydroinformatics field and the urgent water related issues.

The editors and the organizers were honoured to have had the opportunity to organize the conference under the High Patronage of Monsieur Jacques Chirac, President of the French Republic.

The response to the call for abstract for Hydroinformatics 2006 has been overwhelming as over 620 abstracts were received. After a rigorous process of reviewing the abstracts and the full papers, about 400 papers from over 60 countries are published in four volumes of these proceedings.

The papers are grouped in 19 topics covering physical simulation modelling; statistical, correlative and transfer function modelling; rule-based modelling; verification, validation and confirmation of numerical models; management of modelling results uncertainty; advanced applications in real-time control, forecasting systems in meteorology and hydrology; data assimilation techniques; simulators; case studies; web-enabled information and modelling systems; geographic information systems and imaging; data acquisition, modelling and management systems; optimisation techniques; engineering study - decision makers relationships and hydroinformatics support interfaces; decision support and water management systems; uncertainty and risk analysis in decision-making; virtual institutes, collaborative engineering and web platforms experience; international graduate programmes experience; continuous professional education and long life learning experience.

For the first time and in the way to innovate and share, special sessions focused on "hot topics" – *European Water Framework Directive, Experience in Flood Management and Urban Waters Management* - have been introduced to increase and promote the interactions between the practitioners/engineers and the researchers/scientists. The success of this call demonstrates the interest and demand for this needed dialog.

These volumes represent the sum of the efforts invested by the authors, members of the advisory committee, and members of the organizing committee. The editors are also grateful for the assistance of the anonymous reviewers who worked tirelessly behind the scene to maintain the quality of the papers. We hoped that the proceedings will serve as a reference source on hydroinformatics for practitioners, engineers, researchers, scientists, managers and decision makers.

P. GOURBESVILLE, J.CUNGE, V.GUINOT & S.Y. LIONG
Nice, 1st September 2006

Acknowledgements

The editors wish to express their deep appreciation to members of the advisory committee, members of the organizing committee, and reviewers in ensuring high quality papers for HIC2006.

The financial support from the University of Nice – Sophia Antipolis, Région Provence Alpes, Côte d'Azur, the Conseil Général des Alpes Maritimes and the City of Nice is gratefully acknowledged.

Integrated Meeting Specialist Pte Ltd, a professional conference organizer, plays an integral part in the smooth running of the conference. We thank Ms. LEE Fong and Mr. Ivan BOO for their professional work.

The editors would like also to thank all the staff of the University of Nice – Sophia Antipolis and from the Acropolis Conference Center who were involved in the organization and management of the conference.

A special thank is given to the EuroAquae students who have offered a very significant support during the conference.

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7^{th} International Conference on Hydroinformatics
HIC 2006, Nice, FRANCE

NUMERICAL SIMULATION OF THE THREE-DIMENSIONAL FLOW AT THE CONFLUENCE OF THE SAVA AND DANUBE RIVERS

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In this paper, the confluence hydrodynamics at the mouth of the Sava and Danube Rivers in the city of Belgrade is analysed by means of the three-dimensional numerical model. The confluence offers excellent possibilities for such investigation as the two morphological features typical for a river confluence are present: bed elevation discordance at the entrance to the confluence and the scour hole in the post-confluence channel. The results are discussed in terms of the secondary flow pattern. Since the non-deformable bed is assumed, the nature of the river bed – flow interaction is analysed in terms of a non-dimensional bed shear stress and a re-suspension number distributions for different flow conditions in the confluence.

INTRODUCTION

A river confluence has always been a challenging subject for river hydrodynamics and morphodynamics investigations due to complex flow phenomena and processes occurring in both the confluence and the post-confluence channel. The complexity of the phenomena and processes arises from the strong three-dimensional flow effects resulting from the interaction of the incoming flows and the interaction thereof with the river bed. In the last decade, new methods and tools for investigation of complex flows were developed and/or the existing methods and tools were improved, offering opportunities to shed more light on the processes characteristic for a river confluence. The majority of investigations were, however, concerned with the laboratory models of confluences (references can be found elsewhere - Bradbrook et al. [2] and Đorđević & Jovanović [3]). There are only a few field investigations, mostly on the small rivers (Biron et al. [1], Bradbrook et al. [2], Rhoads & Sukhodolov [7], Đorđević & Jovanović [3]).

Unlike a river confluence, a laboratory model of a confluence assumes a simplified plan-form and cross-section geometry of the main river, tributary and post-confluence channels. Hence, not all relevant factors necessary for complete understanding of the confluence hydrodynamics can be encountered for with a laboratory model of a confluence.

The confluence of the Sava and Danube Rivers in the city of Belgrade is a typical example of an asymmetrical confluence with the shallower channel of the Danube River, no significant increase in the post confluence channel width, and presence of the scour hole. With such a complex plan-form and bed morphology it was interesting to investigate the confluence hydrodynamics by using a three-dimensional numerical model. Simulations were performed for various combinations of the upstream hydrologic regimes of the confluent streams.

PROBLEM DESCRIPTION

The confluence of the Sava and Danube Rivers in the city of Belgrade is depicted in Fig. 1. The characteristic shape of the network is caused by the presence of the Great Island which divides the Danube River into the so called "Main channel" with the wider, almost straight channel, and a narrower secondary channel.

The subject of the present study is a portion of the confluence encircled in Fig. 1. It includes the Sava River (the main river in this case), and the branch of the Danube River (the tributary in this case). The confluence-site characteristics are summarized in the Table 1. The confluence hydrodynamics was analysed by covering a range of possible hydrological conditions at the confluence. A set of considered discharge combinations is given in Table 2.

NUMERICAL MODELLING

The three-dimensional numerical model (SSIIM2) used for the modeling is described elsewhere (Olsen [5&6]). The model solves the three-dimensional Reynolds averaged Navier-Stokes equations, with the standard k-ε turbulence-model closure. As this model assumes isotropic eddy viscosity, it should be calibrated when considering strongly anisotropic flows, such as the ones occurring in river confluence (Bradbook *et al.* [2])

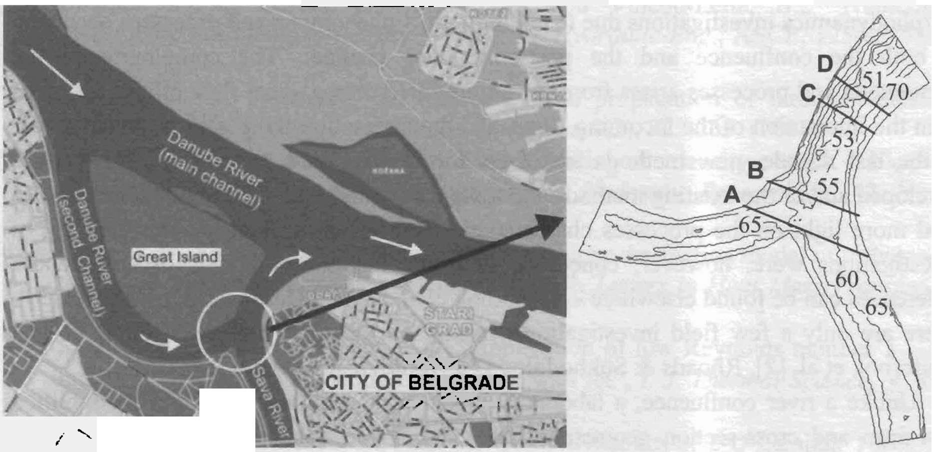

Figure 1. Site location (left) and bed elevation contours (right)

Table 1. Summary of the confluence-site characteristics

River	Bank-full width [m]	Junction angle [°]	Bed elev. discordance [m]
Sava River (Main river)	≈ 290		
Second. channel of the Danube River (Tributary)	275	78	10
Sava River (post confluence ch.)	≈ 290		

Table 2. Analysed combinations of the upstream hydrologic regimes of the confluent streams

	Sava River	Danube River					
p* [%]	Q_{MR} [m^3/s]	Q_{total} [m^3/s]	Q_T [m^3/s]	$D_R = Q_{MR} / Q_T$ [-]	V_{MR} [m/s]	V_T [m/s]	M_R** [-]
0.56	600	5700	1130	0.53	0.21	0.46	0.24
6.59	400	2500	385	1.04	0.17	0.19	0.93
4.53	800	2800	455	1.76	0.32	0.22	2.56
2.60	1300	3500	615	2.11	0.49	0.27	3.84
2.59	1555	2480	395	3.94	0.61	0.18	13.34
0.66	2500	2800	400	6.25	0.91	0.17	33.46

* Probability of occurrence of discharge combination is denoted by p (Group of authors [4])
** The momentum-flux ratio is defined as $M_R = \rho V_{MR} Q_{MR} / \rho V_T Q_T$.

Since the field measurements of the flow field at the confluence of the Sava and Danube Rivers are still under way, no calibration is possible yet. Therefore, the original values of the k-ε model constants (C_μ, $C_{\varepsilon 1}$, $C_{\varepsilon 2}$, σ_k, and σ_ε) were used. For this reason, the presented numerical simulation results could only be used for the qualitative analyses.

The SSIIM2 model solves the governing equations using the finite-volume method on a three-dimensional non-orthogonal unstructured grid. This type of grid allows flow simulation in dendritic channel networks with complex bathymetry, characteristic for river confluences. The model uses SIMPLE method for the pressure term modelling and a second-order upwind scheme for discretisation of the convective terms. A wall law is used along solid boundaries.

In the present study, steady flow conditions were assumed. Symmetric boundary conditions were used for all variables at the surface and the outflow boundary. The water surface was fixed, which can be justified by the fact that the confluence of the Sava and Danube Rivers is under the strong influence of the Iron Gate Dam backwaters and the water level may be considered nearly horizontal. At the inflow boundaries constant fluxes are specified. To ensure mass continuity, a constant flux is prescribed at the outflow boundary.

Computational domain included channels of the main river and the tributary in the length of 1 km each, and 1 km of the post-confluence channel. The length of 1 km along each confluent stream ensured no influence of the upstream boundary condition on the flow pattern in the confluence. The non-orthogonal unstructured grid consisted of two non-orthogonal structured grids – one along the main river and the post-confluence channel (block1) and the other along the tributary (block 2). A grid sensitivity analysis was performed first. Four different grid densities were considered. Blocks with the following dimensions comprised the coarsest grid: 41×11×11 (block 1) and 19×6×11 (block 2). Dimensions of another two meshes of intermediate density were: 81×11×11 (block 1) and 37×11×11 (block 2) for the first and 101×16×11 (block 1) and 46×12×11 (block 2) for the second one. The finest grid consisted of the blocks with the dimensions: 201×31×11 (block 1) and 96×26×11 (block 2).

Since the bed material in the tributary is finer than the bed material in the main river ($d_{50,T}$ = 2 mm, $d_{50,MR}$ = 8 mm), non-uniform roughness was used. The roughness was defined according to the given grain sizes.

RESULTS AND DISCUSSION

The confluence hydrodynamics is analysed by observing the forms of the *secondary circulation* at chosen cross-sections at the confluence and in the post-confluence channel (Fig. 1). Since a non-deformable bed was assumed, changes in the *non-dimensional bed shear stress* and the *re-suspension number distributions* with respect to change in the M_R value are also discussed.

Results of the grid sensitivity analysis shall be presented, first. Cross-section surface streamlines are used to illustrate the secondary flow circulation, A case when two counter-rotating vortices are formed in the post-confluence channel (M_R = 3.84) is used for the comparison. As can be seen from Figure 2, a number of mesh elements in the main flow direction remarkably influences the secondary circulation pattern in the post-confluence channel. In the two coarser grids change in the bed slope in the main-stream direction, responsible for the alignment of the main-flow streamlines and consequently the distribution of the dynamic pressure and the type of the secondary circulation pattern, is not properly resolved (Fig. 2 left). By increasing a number of elements in the main-stream direction, a more realistic flow pattern resulting from the topographic steering is obtained (Fig. 2 right). In what follows, only results pertaining to the finest grid are discussed.

Due to limited space, development of the secondary circulation through the confluence and the post-confluence channel is presented only for four of the six analysed discharge combinations of the confluent streams (Fig. 3). Secondary flow patterns for the M_R values 2.56 and 3.84 are similar. The same holds for the M_R values 13.34 and 33.46. Changes in the M_R value influence the secondary flow pattern in the following. For M_R < 1.0, a single large dominating clock-wise vortex is formed in the upstream part of the post-confluence

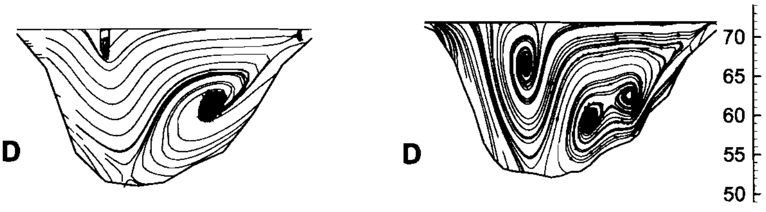

Figure 2. Streamlines showing secondary circulation in the cross-section D – grid sensitivity analysis. Results obtained for the coarsest grid (left) and the finest grid (right)

channel, due to fast realignment of the dominant-flow streamlines, which is in accordance with the similar investigations (Bradbook *et al.* [2]). Further downstream, the vortex gradually diminishes. For the M_R values close to 1.0 and up to, say 13.5, two counter-rotating vortices are formed since the dominant-flow streamlines are not completely aligned along the considerable portion of the post-confluence channel. With further increase in the M_R value (M_R >13.5), the main river dominates and the left vortex gradually diminishes, still leaving a clear dividing line between the two flows, which moves towards the left bank.

Changing flow conditions at the confluence influence the interaction between the flow and the river bed. This also assumes different conditions for sediment load movement including settlement and re-suspension of the sediment particles. The effects of change in the M_R value on the transport competency of the post-confluence channel are presented only for the particle size d = 0.28 mm, which may change between the bed and suspended load. The results are presented for the considered particle size in the form of contour lines of the non-dimensional bed shear stress (Fig. 4) and the re-suspension number u^*/W (Fig. 5). The finer particles are always in suspension, while the coarser ones are always at the river bed in the form of the bed load. As can be seen, particles of d = 0.28 mm are in suspension in the main river and in the central portion of the post-confluence channel (scour hole) only for the highest M_R value (M_R = 33.46), whereas for the M_R values less than, say 30, they move as the bed load. Transition area, in which the change in dominance of the confluent streams occurs ($0.90 < M_R < 2.6$), is characterized by a reduction of the total area available for the bed load movement. For M_R = 2.56 movement is localized in the scour hole of the post-confluence channel and the bar along the right bank of the main river, whereas for the M_R value around 1.0 there is no movement at all. Reestablishment of the bed load transport starts when the tributary takes the dominance over the main river.

CONCLUSIONS

In this paper the confluence hydrodynamics at the mouth of the Sava and Danube Rivers was analysed by means of the three-dimensional numerical model. Comparison of the results obtained for different combinations of the upstream hydrologic regimes of the confluent streams led to the following conclusions.

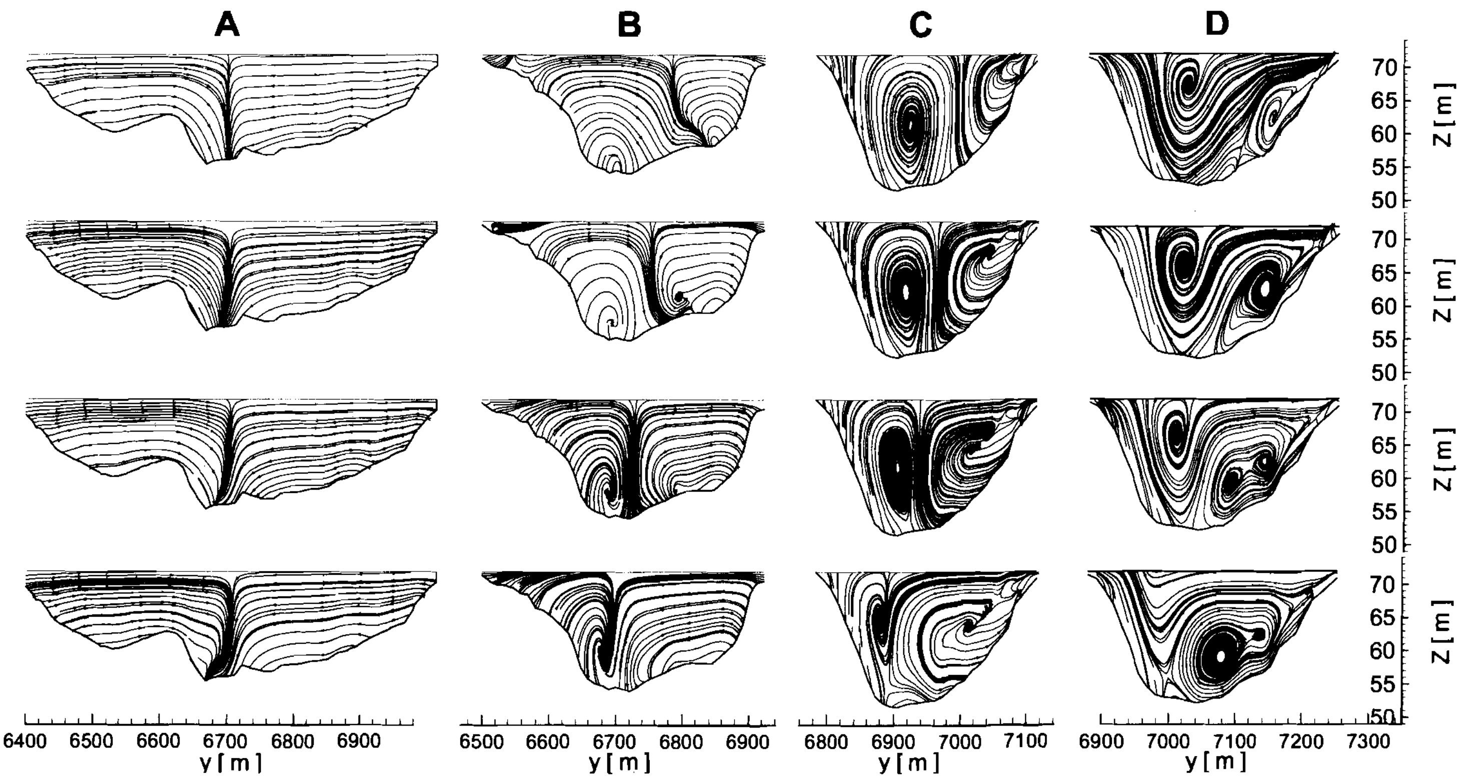

Figure 3. Streamlines showing change in the secondary circulation at the chosen cross-sections with respect to change in the momentum-flux value (M_R) at the confluence

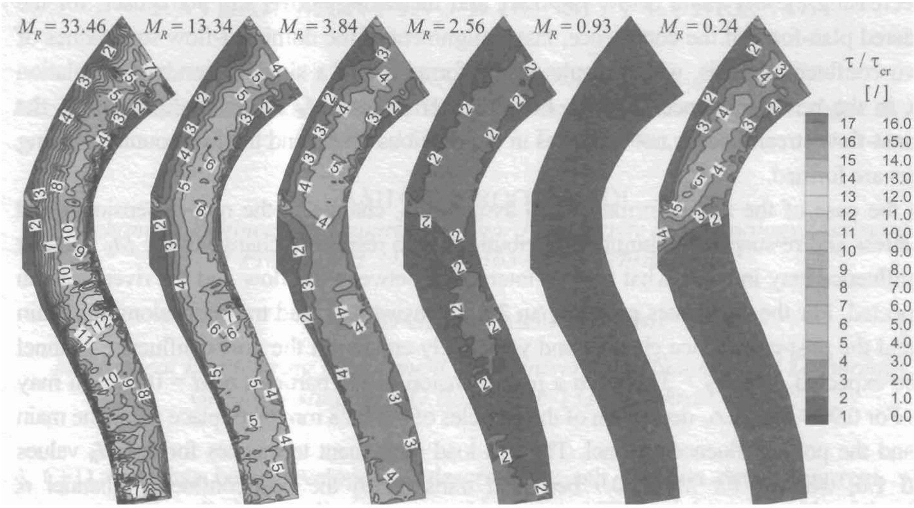

Figure 4. Contour lines showing change in the non-dimensional bed shear stress distribution with respect to the change in the M_R value at the confluence (d = 0.28 mm)

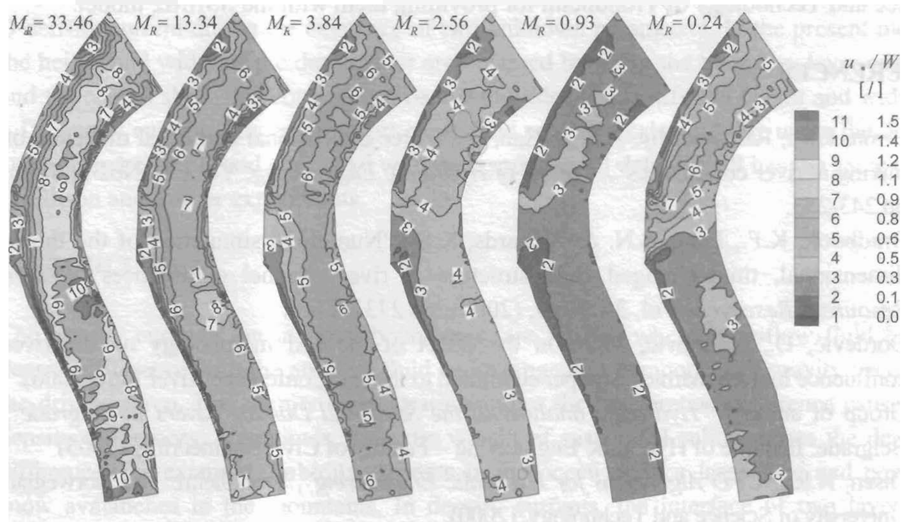

Figure 5. Contour lines showing change in the re-suspension number distribution with respect to the change in the M_R value at the confluence (d = 0.28 mm)

1. Grid density in the main-stream direction remarkably influences the type of the secondary flow pattern. To get a clear picture of the secondary circulation in the post-confluence channel, the number of elements in the main-stream direction must be sufficient to resolve all topographic features which govern the flow in the confluence and the post-confluence channel.

2. Decreasing the M_R value below say 0.90, and increasing above, say 30, causes, for the considered plan-form of the confluence, fast realignment of the dominant-flow streamlines of the two confluent streams, which results in the formation of a single secondary circulation vortex in the post-confluence channel. For the intermediate M_R values realignment of the dominant-flow streamlines is not as fast as in the previous cases, and the two counter-rotating vortices are formed.
3. In the case of the non-deformable bed assumption, change in the non-dimensional bed shear stress and re-suspension number distributions with respect to change in the M_R value at the confluence may indicate what type of interaction between the flow and the river bed can be expected. For the M_R values greater than 3.8, intensive bed load transport along the main river and the post-confluence channel and very likely erosion in the post-confluence channel may be expected. For $M_R > 33.0$ even a re-suspension of the particles of $d = 0.28$ mm may occur. For $0.90 < M_R < 2.6$, deposition of the particles of $d \geq 0.28$ mm takes place along the main river and the post-confluence channel. The bed load movement terminates for the M_R values around 1.0, whereas for $M_R < 0.9$ bed load transport in the post-confluence channel is reestablished.

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Hydroinformatics is a relatively new discipline concerned with the application of Information Technology for the planning, management, and protection of the water environment. Its aim is to allow environmental managers and engineers to make rapid and robust decisions as they address the increasing challenges of ensuring a sustainable water environment and adequate water resources for the future generations.

This publication contains about 400 high quality papers contributed by authors from over 60 countries. The proceedings present many exciting new findings in emerging subjects, as well as their applications, such as: physical simulation modelling; statistical, correlative and transfer function modelling; rule-based modelling; verification, validation and confirmation of numerical models; management of modelling results uncertainty; advanced applications in RTC, forecasting systems in meteorology and hydrology; data assimilation techniques; simulators; case studies; Web-enabled information and modelling systems; Geographic Information System and imaging; data acquisition, modelling and management systems; optimisation techniques; engineering study - decision makers relationships and hydroinformatics support interfaces; decision support and water management systems; uncertainty and risk analysis in decision-making; virtual institutes, collaborative engineering and Web platforms experience; international graduate programmes experience; continuous professional education and long life learning experience.

These proceedings will provide an excellent reference to researchers, practitioners, graduate students and all those interested in the field of water and hydroinformatics.

Hydroinformatics 2006 provided an excellent opportunity for engineers, environmental managers and scientists to meet and exchange ideas in this rapidly developing field.

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