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Numerical Investigation of Sediment Transport and Bedmorphology on a Stretch of Nakdong River

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Abstract

In this study, we modified and applied an open source CFD software package, the TELEMAC, to simulate sediment transport and bed morphology on a meandering stretch of Nakdong River, between Gangjeong and Dalsung Weirs, whose length is about 20km. The numerical simulations have been carried out on a High Performance Computing Cluster (HPC) with the real river bathymetry and with different operation scenarios of the weirs. The hydrodynamic parameters and bed evolutions obtained from the numerical results have been validated against field observation data. In addition, this study is to figure out a magnitude of bed evolution and the location where the erosion or deposition taking place under the weir operating conditions.

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1. Introduction

After completion of the Four Major Rivers Restoration Project, several new weirs have been built on the Han, Nakdong, Geum and Yeongsan Rivers. As a result, the hydrodynamics and river morphology have been changed. Unfortunately, there are a few studies on bed morphology in a long river stretch caused by the weir operating systems. Due to physical scales and fluid properties, lab-scale models of a long river stretch cannot be derived from experiments according to the Hydraulic Similitude Laws. However, Computational Fluid Dynamics (CFD) tools can perform using real temporal and spatial scales under various operating conditions to predict turbulent flows and bedmorphology in any

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natural river stretch. In recent years, with the increasing capabilities of computational technology, CFD has been widely used to determine fluid flow behavior in environmental and river engineering. A number of applications using CFD simulations to study the flow and scouring process in a natural river have been achieved. Due to the large temporal and spatial scales, in dealing with morphology problems in natural river flows, mainly 1D or 2D models are used to perform the simulations. Regarding 2D models, it should be mentioned such as TAB-2 (Thomas et al., 1985), MOBED 2 (Spasojevic, 1988), TELEMAC-2D (Galland et al., 1991), CCHE2D (Wu, 2001), River2D (Steffler and Blackburn, 2002), MIKE-21 (DHI, 2007), etc. However, most of available 2D models are commercial or shareware, the users cannot have a chance to modify and adapt the source code for their specific applications. Recently, TELEMAC has been released as an open source, which can give us an opportunity to modify the code to fit into our applications, therefore in this study we choose the open source TELEMAC-2D to simulate hydrodynamics, sediment transport and bed morphology on a stretch of Nakdong River located between two weirs, Gangjeong and Dalsung Weirs, whose length is around 20 km. The real bathymetry of the river stretch have been implemented in the numerical model. Numerical results have been validated against available field observation data, and thereafter the numerical model can be applied to answer the "what-if" questions following the practical water level management.

2. Methodology

As mentioned above, a 2D-numerical simulation is based on the TELEMAC 2D combined with SISYPHE model. This software uses finite element method and is capable to deal with complicated geometries by the use of unstructured grids.

2.1. Hydrodynamic calculation: TELEMAC 2D

The hydrodynamic calculations is based on TELEMAC 2D by solving depth averaged Reynolds Averaged Navier-Stokes Equations (k-ε model), as follows:

$$\frac{\partial h}{\partial t}+\frac{\partial (hU)}{\partial x}+\frac{\partial (hV)}{\partial y}=0 \tag{1}$$

$$\frac{\partial (hU)}{\partial t}+\frac{\partial (hUU)}{\partial x}+\frac{\partial (hUV)}{\partial y}= -h\cdot g\frac{\partial Z}{\partial x}+h\cdot F_x+\mathrm{div}\left(h\cdot \nu_e\cdot \vec{\nabla}(U)\right) \tag{2}$$

$$\frac{\partial (hV)}{\partial t}+\frac{\partial (hUV)}{\partial x}+\frac{\partial (hVV)}{\partial y}= -h\cdot g\frac{\partial Z}{\partial y}+h\cdot F_y+\mathrm{div}\left(h\cdot \nu_e\cdot \vec{\nabla}(V)\right) \tag{3}$$

$$\frac{\partial k}{\partial t}+U\frac{\partial k}{\partial x}+V\frac{\partial k}{\partial y}= \frac{1}{h}\,\mathrm{div}\left(h\cdot\frac{\nu_t}{\sigma_k}\vec{\nabla}(k)\right)+P-\varepsilon+P_{kv} \tag{4}$$

$$\frac{\partial \varepsilon}{\partial t}+U\frac{\partial \varepsilon}{\partial x}+V\frac{\partial \varepsilon}{\partial y}= \frac{1}{h}\,\mathrm{div}\left(h\cdot\frac{\nu_t}{\sigma_k}\vec{\nabla}(\varepsilon)\right)+\frac{\varepsilon}{k}(c_{1\varepsilon}P-c_{2\varepsilon}\varepsilon)+P_{\varepsilon v} \tag{5}$$

Where *h* is the water depth, *U* and *V* are the depth averaged velocity components, *Z* is the free surface elevation, F_x and F_y are source terms, and ν_e is the effective viscosity, and a summation of the molecular viscosity *ν* and the turbulent viscosity $\nu_t = c_\mu k^2/\varepsilon$, $(\nu_e = \nu + \nu_t)$.

The depth averaged kinetic energy *k*, and its dissipation rate ε are defined by: temporal fluctuation of

$k=\frac{1}{h}\int_{Z_f}^{Z}\frac{1}{2}\overline{u_i'u_i'}dz$ and $\varepsilon=\frac{1}{h}\int_{Z_f}^{Z}\frac{\nu}{2}\overline{\frac{\partial u_i'}{\partial x_j}\frac{\partial u_i'}{\partial x_j}}dz$

where u_i' is the fluctuating velocity, and U_i (*i=1, 2, 3*) are the average over time of velocity components; P is the production term: