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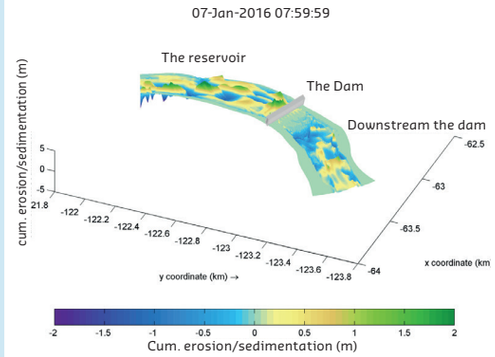
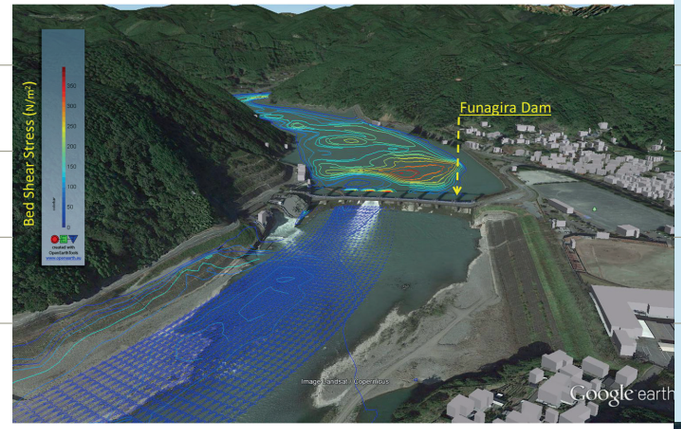
Effect of dam-gate operation on sediment flushing



Total cumulative deposition and erosion upstream and downstream of the dam



Bed shear-stress distribution

Downstream of Funagira Dam. The green lines show an example of coarse grid shape.

A new approach has been developed to investigate different approaches to operating dam gates in the Funagira dam in Japan. This approach consists of quasi-3D-modelling coupled with the real-time control toolbox (RTC), resulting in more efficient reservoir flushing and more sediment transport to the downstream reach.

We applied the approach to the Funagira reservoir, which is located in the Tenryuu river in central Honshū, Japan. This research project is part of a long-term collaboration between Deltares and J-Power, one of the largest power companies in Japan. J-Power is actively seeking to jointly develop knowledge and techniques with the aim of improving gate operation and therefore the management of the sediment trapped in the reservoirs and the spread of sediment downstream. The river downstream of the Funagira dam suffers from bank erosion and point-bar formation due to the present pyramid-shape opening pattern of the gates.

Hydropower dams are major assets for society. Their number continues to increase because of growing demand for water and electricity. However, their presence disturbs river morphology and ecology. The reservoirs behind the dams suffer from a loss of storage capacity and contamination due to sedimentation. The reduction of storage capacity is a challenge for dam operators. The need to maximise storage capacity and preserve the ecosystem downstream at the same time requires the optimisation of operating rules. Sediment management practices for this purpose, such as sluicing and flushing, may generate undesirable morphological changes in the reach downstream of the dam. Gate operation is expected to be a factor in this area.

We developed a modelling approach to simulate flow regulation through a dam in order to establish a picture of how different gate-opening patterns affect morphodynamics. The aim of the approach is to identify possible improvements in the flushing process and to understand how this process affects morphological changes downstream of the dam. We built a quasi-3D morphodynamic model using the Delft3D4 software, which can simulate temporal and spatial variations in hydrodynamics and morphological changes in the reservoir and the river reaches. The Delft3D software was coupled with the real-time control toolbox (RTC) to control different gate openings over time. It should be pointed out here that both Delft3D4 and RTC are open-source software.

Equal-shape openings were introduced as a new pattern. We analysed and compared both patterns in terms of flushing efficiency and sediment distribution downstream of the dam.
The coupling of the quasi 3D-morphological model with RTC was successfully used to establish in detail the differences between different patterns for gate operation. Equal gate operation minimises the formation of eddies downstream of the dam and reduces the erosion of the bed and banks. Equal gate operation is also more efficient in term of sediment flushing than the pyramid approach. Bed shear-stress distribution upstream and downstream of the dam was identified and analysed to determine the expected bed behaviour.

We propose the adoption of the new gate-operation pattern. The ongoing development of Delft3D was addressed in order to use the PID controller. This has been included in the new research questions for 2017. In addition, the reservoir conditions (sediment supply, reservoir bed level, reservoir water level, and dam operation) will be studied with a view to maximising sediment releases to the reach downstream during the low-flood seasons. The results of sediment flushing will be evaluated on the basis of the downstream ecosystem.

Further reading:
https://publicwiki.deltares.nl/display/TKIP/DEL026