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Rivers flow differently over gravel beds, study finds

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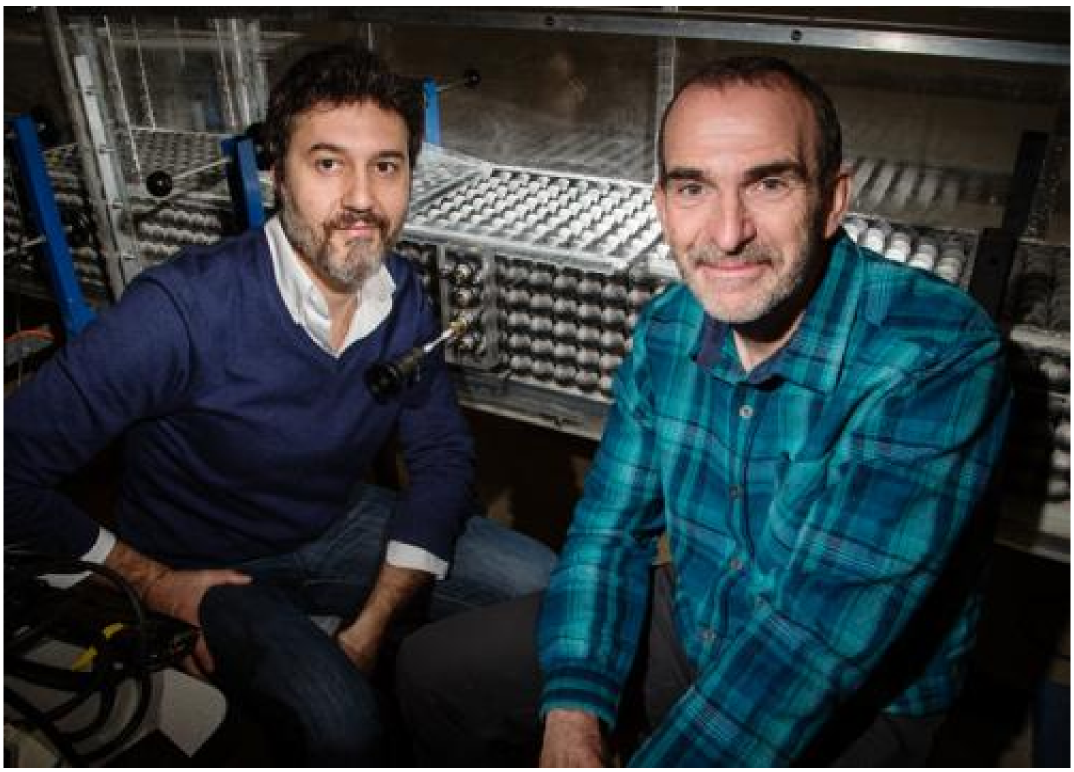

River researchers used a specially constructed model to study how water flows over gravel river beds. Postdoctoral researcher Gianluca Blois (left) and professor Jim Best also developed a technique to measure the water flow between the pore spaces in the river bed. Credit: L. Brian Stauffer

River beds, where flowing water meets silt, sand and gravel, are critical ecological zones. Yet how water flows in a river with a gravel bed is very different from the traditional model of a sandy river bed, according to a new study that compares their fluid dynamics.

The findings establish new parameters for river modeling that better represent reality, with implications for field researchers and water resource managers.

"The shallow zones where water in rivers interacts with the subsurface are critical environmentally, and how we have modeled those in the past may be radically different from reality," said Jim Best, a professor of geology, geography and geographic information science at the University of Illinois. "If you're a river engineer or a geomorphologist or a freshwater biologist, predicting where and when sediment transport is going to occur is very important. This study provides us with a very different set of conditions to look at those environments and potentially manage them."

Best and postdoctoral researcher Gianluca Blois led the study at the U. of I., in collaboration with colleagues in the United Kingdom. The team published its findings in the journal *Geophysical Research Letters*.

The researchers used a specially constructed flume in the Ven Te Chow Hydrosystems Laboratory at Illinois to experimentally compare scenarios ranging from the traditional model of an impermeable river bottom to a completely permeable river bed – a collection of spheres that simulate gravel.

The researchers used a technique called particle image velocimetry (PIV), a widely used method for quantifying how water flows over a model river bed, pioneered at the U. of I. in the 1980s. Best and Blois developed a method to use PIV endoscopically to study, for the first time, fluid flow within the small spaces between the gravel. This allowed them to quantify flow within the river bed and link it to the stream flow above.

They found that, in the scenario that simulates a gravel bed, the patterns of flow velocity above the bed and the distribution of forces on the river bed were dramatically different from the models on which all previous work has been based. Their experimental scenarios also disproved one popular theory that explained the difference between classic models and field observations for the formation of bed topography, such as dunes.

"Bedforms formed in fine sediments are known to be substantially different from those formed in gravel beds, but we just didn't know why," Blois said. "People before us suggested that those differences were due to the roughness of the grains. But we introduced the bed permeability, just like real rivers. This, with our new measurement technique, allowed us to demonstrate that most of the stress variation is actually coming from fluid emerging from the permeable bed, rather than roughness."

The maps of water flow that the experiments produced could lead to better predictive models, so that researchers can more accurately predict and study how nutrients and pollutants travel and accumulate in rivers. These new models also could provide insight into the growth and behavior of organisms that thrive in the narrow zone where river flow meets the river bed.

"For example, when salmon spawn in gravel-bed rivers, they basically make a depression in the gravel, into which they lay their eggs," Best said. "By doing that, not only do they protect the eggs, but they create a bump in the sediment that creates a pressure distribution that would keep fine grains from going into the bed, which would be detrimental to the eggs. It's fascinating that fish actually take advantage of these flow dynamics."

The researchers are working with collaborators around the world to study how permeability affects turbulence above the bed, how this affects the organisms that grow in the pore spaces, and how tiny particles and dissolved substances accumulate in porous riverbeds.

"It's going to change the way we conceptualize these systems and model them," Blois said. "We're trying to raise awareness of the fact that we are now able to measure the complex flow dynamics in these challenging environments, and that's going to open up a new paradigm for river research."

More information: The paper, "Effect of bed permeability and hyporheic flow on turbulent flow over bed forms," is open-access and available online: DOI: 10.1002/2014GL060906/abstract

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