Webinar Q&A: For those about to rock scour (we compute you)

Question #	Question	Answer(s)
1	Can rocscar be coupled with other CFD software like OpenFOAM or ANSYS too?	It is only coupled with FLOW-3D
2	Are the existing scour calcualting equation used in industry are 3-dimensional? Why we need CFD to calculate scour?	There is a wide range of approaches, but in general most scour approaches will be based on 1D/2D or simplified hydraulic assumptions. In cases, where there is a significant veritical components to the flow field, 3D CFD can provide a more detailed representation of near bed hydraulics driving the scour process.
3	How do you present the logs and tires in the water? Are they floating on the surface?	There is a Moving Objects module in FLOW-3D. This allows you to place any geometry shape into the mesh for a coupled simulation with fluid. Each moving object has specified mass properties which will impact how it behaves in the simulation.
4	What is the method used for water-air interface capturing in Flow-3D? Is the Flow-3D solver a compressible or incompressible solver please?	FLOW-3D used the Volume of Fluid (VOF) method to capture the air-water interface. It can handle both compressible nad incompreessible flow.
5	Do you think we can model rock scouring not due to fluid flows but due to wave actions. This is applicable to coastal structures rather than hydraulic structure?	Currently the coupling technically would probably run, but the rock block break-up methods and criteria may have to be adapted to the coastal structure. If peeling off of blocks by interface velocities is relevant this may work. However, the fracturing process of rock joints would have to be adapted to the characteristics of an impinging wave instead of a jet.
6	For the 2D/3D model coupling -- Does it interface with the results of existing 2D models (such as those built in RAS)? Or would Flow 3D have its own 2D model set-up / runs?	FLOW-3D has its own 2D shallow water model embedded within the software. Currently, this internal shallow water model is the only option available to couple with 3D.
7	How important is the detail of CAD model, is an approximation sufficient, or do surface imperfections matter?	It depends on the goals of the simulation. If you need to understand the interaction between these surface imperfections and flow, then yes it will be important to have that feature represented in CAD. You will also need a mesh cell size small enough to capture these features.
8	As well as scour, can the CFD take material transport/deposition into account?	Yes, in certain cases.
9	How does the mesh dynamically change according to the scour? Can you please expand on that?	The mesh does not change during scour formation. The mesh is preconfigured to contain mesh elements inside the rock mass at start of the run. During progressive scour, these elements progressively become relevant.
	... also is the mesh or unstructed, or could be either in the scour region	The mesh is structured. FLOW-3D's preprocessor automatically embeds the geometry into the mesh using a method called FAVOR. It essentially interpolates the surface intersection in the cell as a flat plane. It makes for a very fast and easy meshing process.
10	Any chance of a calibrated Rocscor-Flow 3D Kariba modelling example?	Maybe one day…
11	Is there a database the results can be validated against? How do we ensure our numerical results are correct please?	A database of case studies has been used to calibrate and validate the different parameters of the rock break-up criteria, see the handbook on digital rock scour Bollaert (2024)
12	Thanks for your presentation.. i have an Q... The mesh shapes are rectangular. How can we apply them to a curved channel, as we saw before at the beginning of this presentation?	FLOW-3D's preprocessor automatically embeds the geometry into the mesh using a method called FAVOR. It essentially interpolates the surface intersection in the cell as a flat plane. It makes for a very fast and easy meshing process.
13	Is it necessary/recommended to carry out mesh convergence studies when developing these coupled models, considering that pressure fluctuations are critical in dislodging blocks? Can RANS models represent peak pressures with sufficient accuracy?	In general, I think it is always a good idea to test mesh and parameter sensitivity. I will let Erik B comment further on specifics related to the rock scour coupling during the Q&A. Erik B answer: peak pressures are not being modelled by RANS models, but RMS values are reasonably well modelled and are used to estimate peak pressures, based on the fracture mechanics model.
14	Are the results relevant for the final steady state with the maximum scour happenning? What is the durarion of scour simulation to give us the long-term scour depths please? Could you expand on these too please? Thanks	When using block uplift or peeling off models, or erodibility index methods, only the ultimate scour depth is obtained after a certain number of coupled iterations. Computational run times are typically of tens of minutes in 2D, and a few hours in 3D coupling. In case of fracture mechanics, the user provides the total time duration of the real flood event, and the computed scour will correspond to the real scour that is expected for that time duration.
15	How do you account for te resistance of movement as a result of angular & irregular rocks as well as the fact that rock riprap consists of a range of rocks in a grading envelope?	Frictional forces along the contact faces with neighbours can be added by the user based on a friction angle.
16	Do you find much difference in the scour profile outcomes between the fully coupled approach (i.e. using Flow 3D with Rocsc@r to dynamically vary the bed profile) vs. entering the hydraulic jet parameters directly?	For similar flow parameters the results are quite similar, and in the same range. Only, the coupling allows to model the flow in 3D, and thus also the scour of the rock in 3D, which is not the case for the 2D approach with jets in rocsc@r directly. As such, one gets more details.

17	Is there consideration of scour by abrasion from sediment impacts in any of the modules?	No.
18	Obviously some great work to be able to calculate scour and couple it with the hydraulic model. My question/comment is, like with all scour problems, we don't have an accurate 3d model of the rock/soil profile due to limitations on the discrete sampling/boreholes. I imagine the program needs to have the location, frequency, size of fractures etc that may significantly dominate the calculations and solution. How does this information get input (in a 3-dimensional sense) and what are the things that need to be considered to not inadvertently influence/skew the results of the scour estimates?	The more details you provide as input, the more detailed becomes the output. Rock mass is modelled by a series of 2D numerical grids respresenting the different layers, lithologies and blocks. Combining these 2D grids allows obtaining a full 3D model with depth. Relevant information is UCS strength, block size and shape, degree of fracturing, RQD, etc.
19	How do you account for the effect of debris (sediment, trees, houses, shipping containers, etc) that is too often entrained in flood flow?	This is not included.
20	Does remoteScour work with Flow-3D too?	Yes, it is developed to couple rocsc@r to FLOW-3D.
21	Also, in most of my attempts to simulate the local scour around pridge pier, I reach a equilibrium scour phese in the CFD model before it reaches the laboratory experiment. is it normal!	This is probably done with small grain size sediment transport options. For rock scour, the time dependency is dictated by the degree of fracturing and the resistance to fracturing of the rock mass and not by the CFD.
22	How does Rocscor calculate lateral erosion and slumping, at an embankment toe for example?	Lateral erosion is computed based on the 3D turbulent flow characteristics, slumping effects are not included.
23	Is rocsc@r applicable to very weak weathered rocks (i.e., rocks potentially better described as very dense soils) as well?	Yes, good experiences have been obtained. More info on the influence of rock quality can be found in the handbook on digital rock scour Bollaert (2024)
23	Is rocsc@r applicable to very weak weathered rocks (i.e., rocks potentially better described as very dense soils) as well?	see above
24	Is there a way to integrate non-newtonian fluids such as tailings into a odel such as this? I know F3d hydro has the option to use one, but does it interact well with these models?	While the hydraulic outputs could probably be passed from FLOW-3D to rocsc@r, the coupling has not been validated for tailings the main fluid.
25	is there a coupling period between Hydro and Scour i.e. 5 time steps for hydro and then 1 step for scour etc.	Yes, there are a number of options to control this.
26	Which turbulence models do you recommend for these coupled models? Are results sensitive to the turbulence model selected?	Turbulence models that have been successfully applied are k-eps, k-w, RNG, LES. The settings of the turbulence models may influence the hydraulic parameters and a sound check of the hydraulic results is necessary before starting the coupling, especially for RMS pressures.
27	How do you determin the initial scoured bed area? Is is for the sake of computational time saving consideration that you don't start from a flat bed?	I got my answer from Eric and Erik's explanation. Thanks.
28	Is it possible to get the profile the centerline of a curved channel?	Currently only linear profiles between 2 gridpoints may be defined in addition to longitudinal or transversal profiles, but the module is still under development and continuously enhanced, and will certainly provide these features in the future. FLOW-3D POST can be used to extract data along a spline, so it is possible to plot the erosion along a centreline of a curved channel.
29	For the example you provided, how much did having access to the rock properties post-event contribute to the accuracy or the model? Do you think that you would be able to get an equivalent result just from a bore hole based geotech assessment?	Knowledge of the post-event scour hole of course allows fine-tuning the model parameters. Without such knowledge, a plausible range of parametric values can be defined based on the rock quality and provides a range of scour results (min-max).
30	Eric L - by 'mounding downstream' do you mean deposition of the scoured material ejected and transferred downstream? How would you have altered your CFD model to make allowance for the change in hydraulics resulting in the change in channel geometry?	The channel geometry may be altered for example.
31	The flow is (logically) not symmetric. So we should not expect a symmetric scour.	In the CFD model, the spillway geometry, plunge pool, and downstream channel were symmetric along the centreline. As a result, the modelled rock scour was also relatively symmteric along this model centreline. However, the observed scour after the flood event was not symmterical. This could be due to different rock properties within the plunge pool (we considered homogeneous rock properties in the model) or some other factor causing the hydraulic and scour conditions to be uneven.
32	When selecting the area for scour analysis, are you able to take into account side/wing walls/rock armouring and undermining of adjacent structures?	Non-erodible areas can be defined at start of the computations. Undermining is accounted for by comparing runs with and without non-erodible parts. rocsc@r_2D on its own allows regressive scour by automatically displacing towards upstream the point of issuance of the flow.
33	How do the CFD results compare with the experimental/theoretical formulae I assume should exist for the scour depth please?	As experimental equations are very unprecise, no time has been allocated to making this comparison.
34	The bridge example would have been more of interest... Can you please share the slides of that?	The video of the webinar will be made available if I am not wrong. More information is given in the handbook on digital rock scour Bollaert (2024).
35	What about a layered bed example for a bridge scour problem?	No problem to handle this, the 3D rock mass lithologies and characteristics with depth are automatically implemented during the computations.

36	Is there any progress in getting the CFD calculations in a format where the models can be run utilising a GPU rather than a CPU?	This is certainly a topic of interest, but at the moment, our initial testing indicates that 3D free-surface models to not scale well on GPU when compared to the current CPU approach.
37	All of the presented models show that the hydraulic structure itself is a solid- immovable object, unaffected by the flow of water. Is it possible for Flow 3D to model a mobile structure (i.e. breakwater, modular weir) to calculate its resistance to the force of flowing water and/or its predicted behaviour due to water flow?	Yes, you can define any solid object to be a "Moving Object" where its motion is fully coupled with the fluid.
38	If there is a good reference for the design of baffle blocks you suggest being used, could you please reference them? Many thanks for the presentation	HEC-14 is a useful guide for that topic: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/hec14.pdf
39	It's a pity that you didn't run the bridge scour examples long enough to show the development of the classic "horse shoe" shaped scour hole. But that is the key evidence that the scour portion of the software works appropriately for bridge scour.	Sorry, we can follow up with more detail on this case if wanted. For the sediment transport module, FLOW-3D HYDRO has been validated for pier scour where this horseshoe phenonmenon is present: https://www.semanticscholar.org/paper/CFD-Analysis-of-Local-Scour-at-Bridge-Piers-Fox/84bac36985ce6551fada752db82059ea39dea7d4?p2df