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2D HD model comparison of Particle transport patterns in the río la Miel in Colombia

Using particle tracking and hydrodynamic simulations

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Problem

Particle tracking is very important in for the appropriate management of water resources.

Morphological heterogeneities of rivers make the prediction of the particle motions difficult due to the complex numerical and physical variations in the mathematical formulation.

Data availability in recent years have allowed to extend dimensionality of the problem and even use coupled models for a better understanding of those patterns

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Motivation

The implementation of particle tracking in two-dimensional hydrodynamic models can improve the representation of the transport phenomena in high mountain rivers that present quite complex geometries.
In this particular case of study, the flow characteristic present are even more complex due the construction of the Miel I hydroelectric.

Knowledge of particle transport phenomena in rivers needs to be developed as they can be implemented to describe the movement and behavior of small marine spices, the travel trajectory of a pollutant and other local uses such as forensic investigation in rivers.

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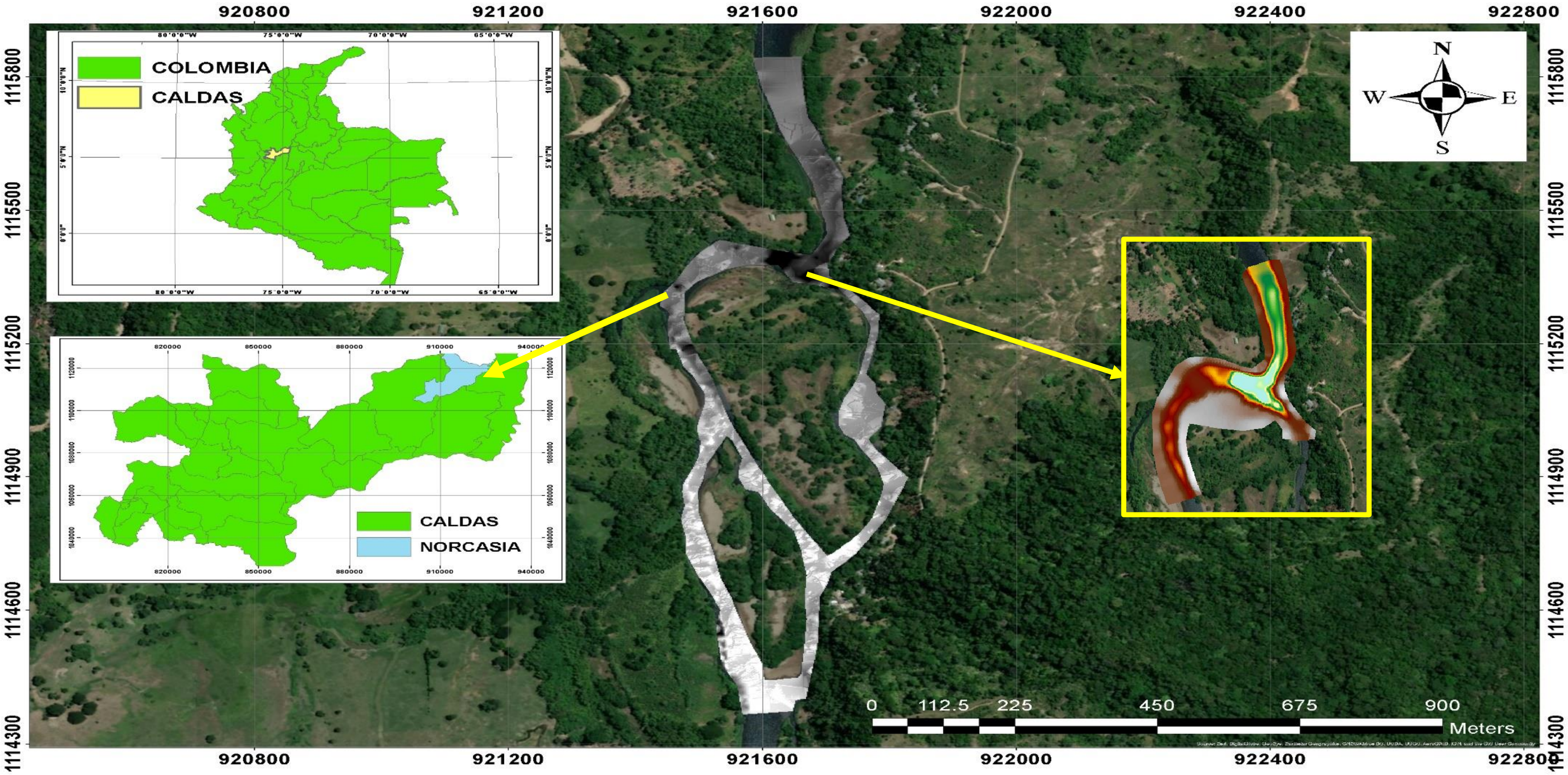
Study Area



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Methodology

Satellite Images

Hydrometeorological Information

Data Collection

Hydroelectric Information

Field Information

Information Processing

Topobathimetry

Initial Conditions

Boundary Conditions

Physical and Numerical Parameters

Analysis of Transport Patterns From Information Taken in Field

Hydrodynamic Model (2D)

Particle Image Velocimetry

Particle Tracking

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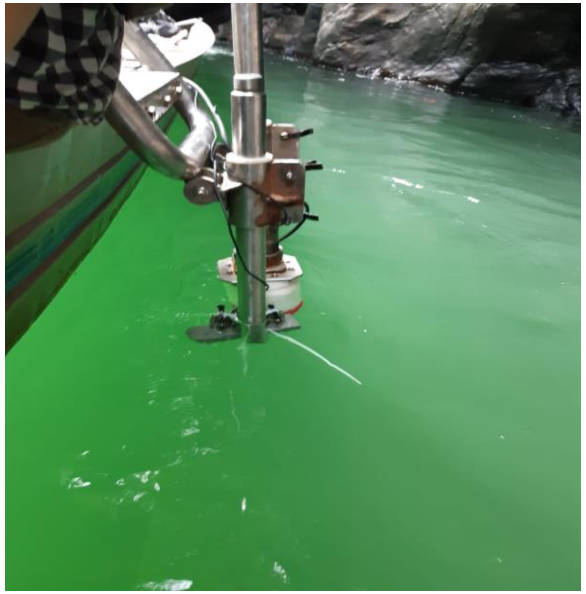
Data Collection

Information Gathering

Hydrophysical recognition in "La Miel" river

Two campaigns

- 21 to 27 of July 2019
- 20 to 23 of February 2020
- Daily time in campaign: 10 hours
- Length of the river downstream of the hydroelectric: 9.8 Km
- Average width: 22 m
- Average Depth: 1.4 m
- Type of river bed: Rock
- The bathymetries were collected using a ECHOMA 54v
- Velocities of the river obtained with and ADCP River Ray, for a 10 km reach.
- The topography was obtained from images taken by phantom 4 drones and a Real Time Kinematic (RTK) equipment.



Particle Tracking Dynamic Data

Helium balloons filled with water so that they could float.

A representative section was selected called "La moya de Jorge".

Hydraulic phenomena of rapids and sudden changes in geometry are presented.

Information Obtained:

-Balloons travel time in control volume defined by the area captured by the drone

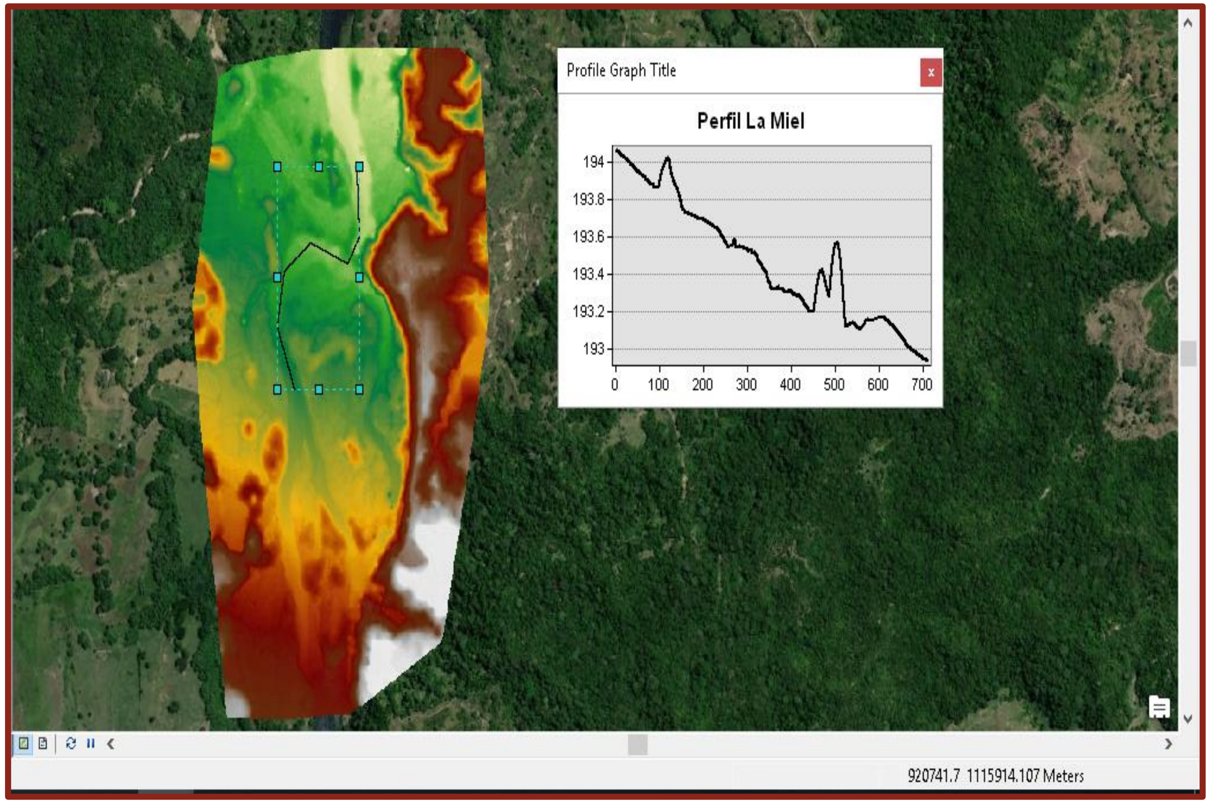
-Displacement of the Balloons through the control volume

-Travel time of the balloons from the beginning to the end of the study section

-Balloons caught by “La Moya”

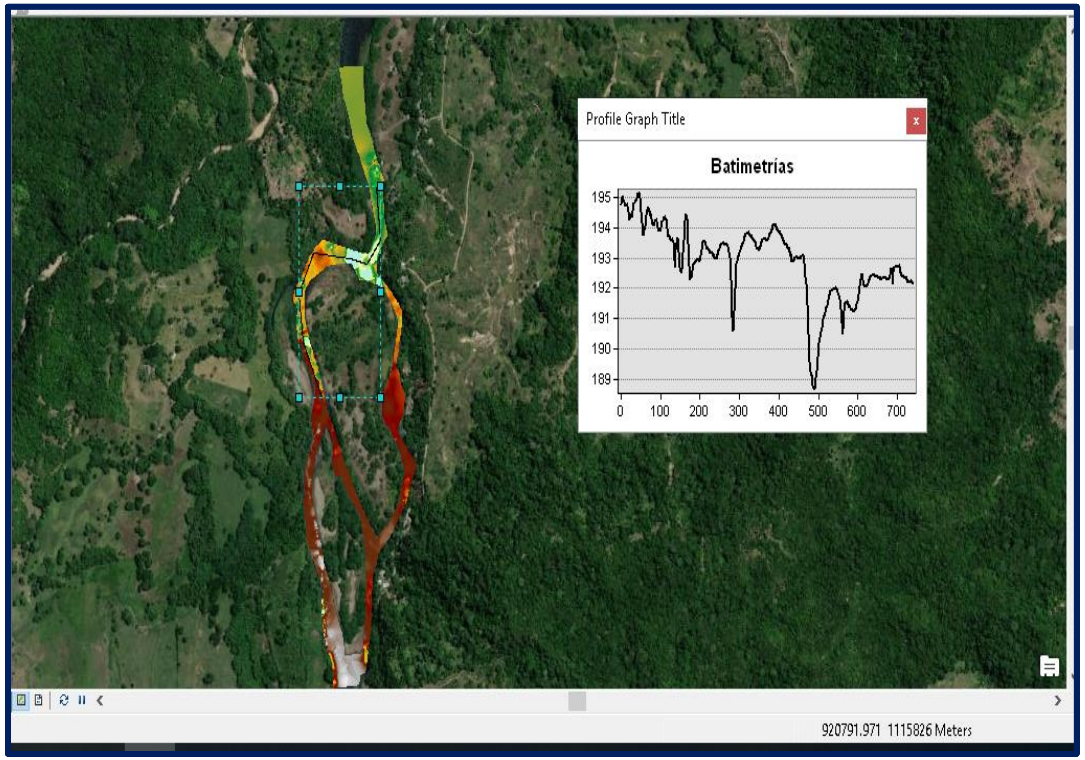
Information Processing

DTM Generation Using Pix4d



The images obtained from drones were used to generate the digital terrain image, which was processed using the Pix4D software.

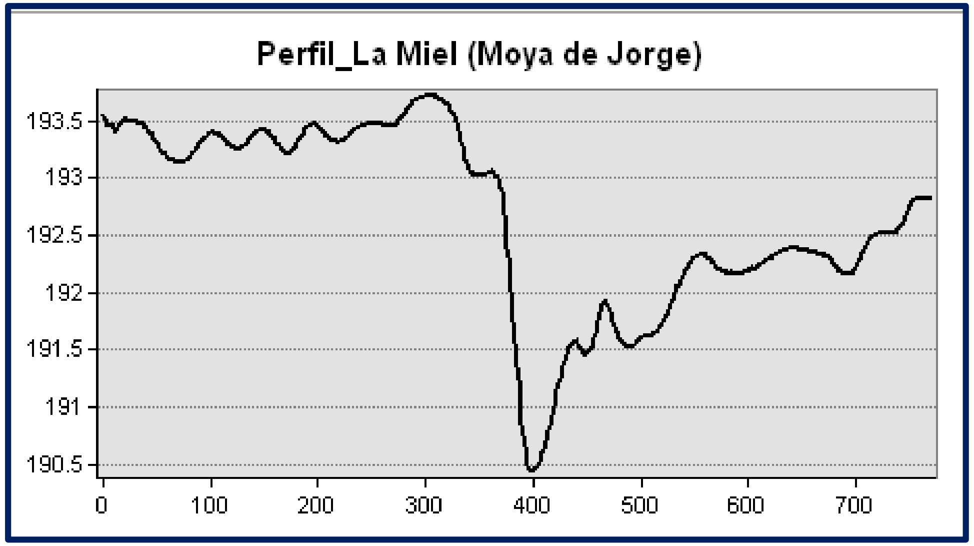
Bathymetry Adjustment



An IDW interpolation Python code was made where the elevation the bathymetries values were obtained from the RTK. The values were then subtracted from the depth of the echo sounder and finally interpolated using the Kriging in ArcMap.

Study Section Final DTM

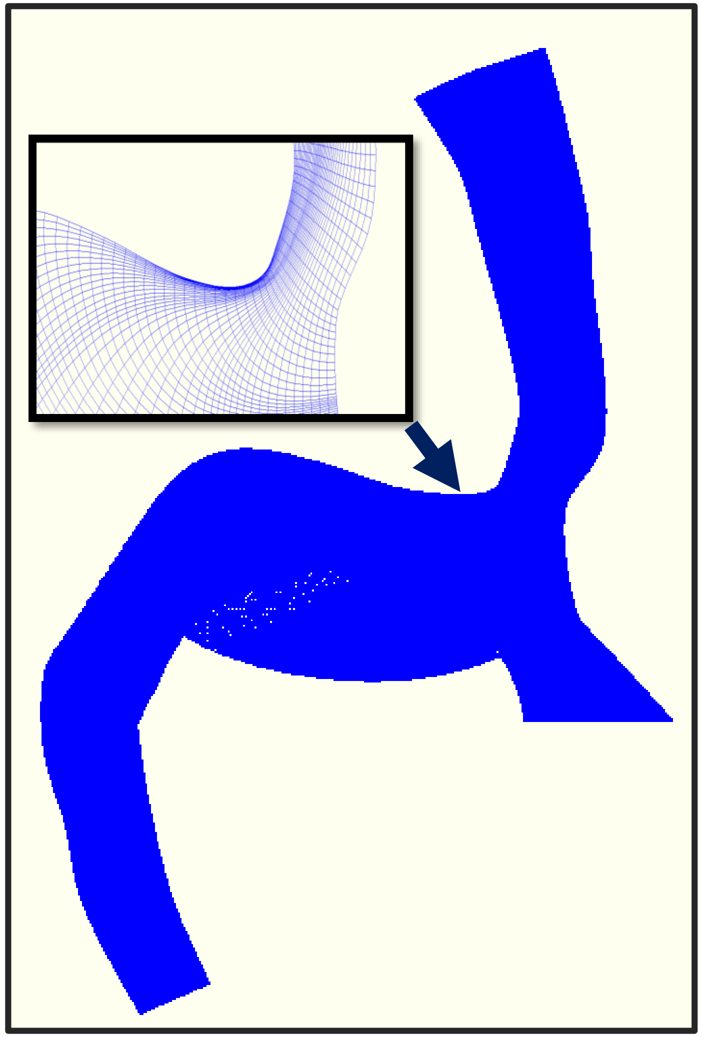
Finally, by using a topobathymetry smoothing technique,we obtained the DTM of the section to be studied (Moya de Jorge)



Hydrodynamic Model (2D)

2D Model (DELFT 3D)- Grid

Curvilinear Mesh



Parameter	Value
Distance X	4 meter
Distance Y	6 meter
Nodes X	1532
Nodes Y	407
Total Nodes	623.524

Parameter	Value
Distance X	1 meter
Distance Y	1 meter
Nodes X	349
Nodes Y	499
Total Nodes	174.151

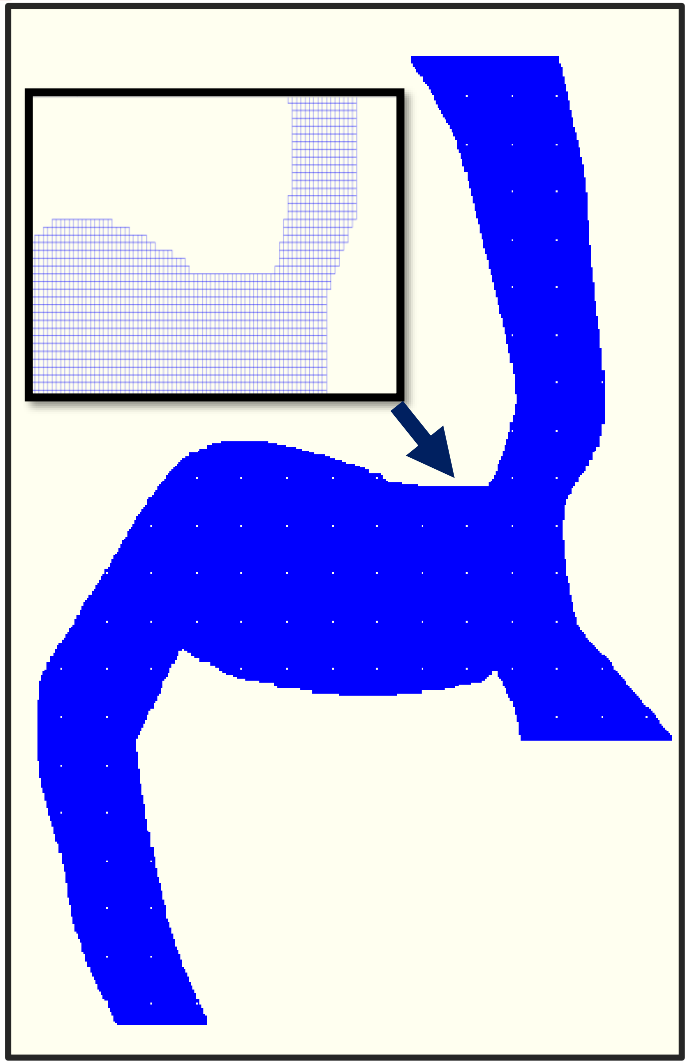
Two meshes were

- non-structured (curvilinear)
- a structured mesh.

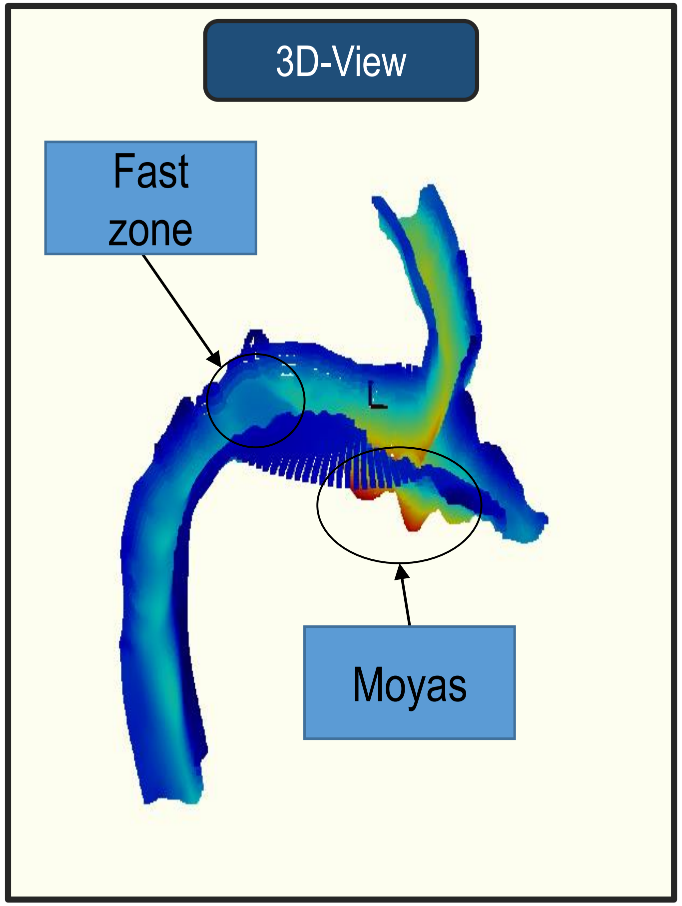
The best mesh was the structured one with a 90° orthogonality

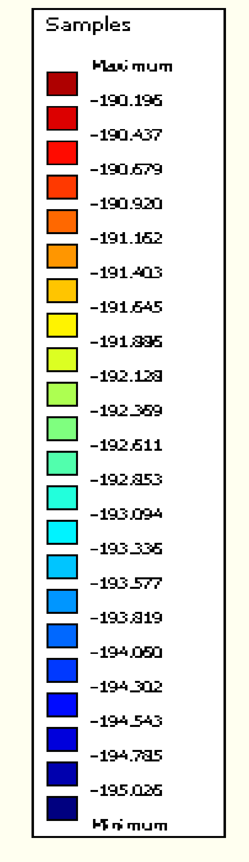
The unstructured mesh generates convergence problems

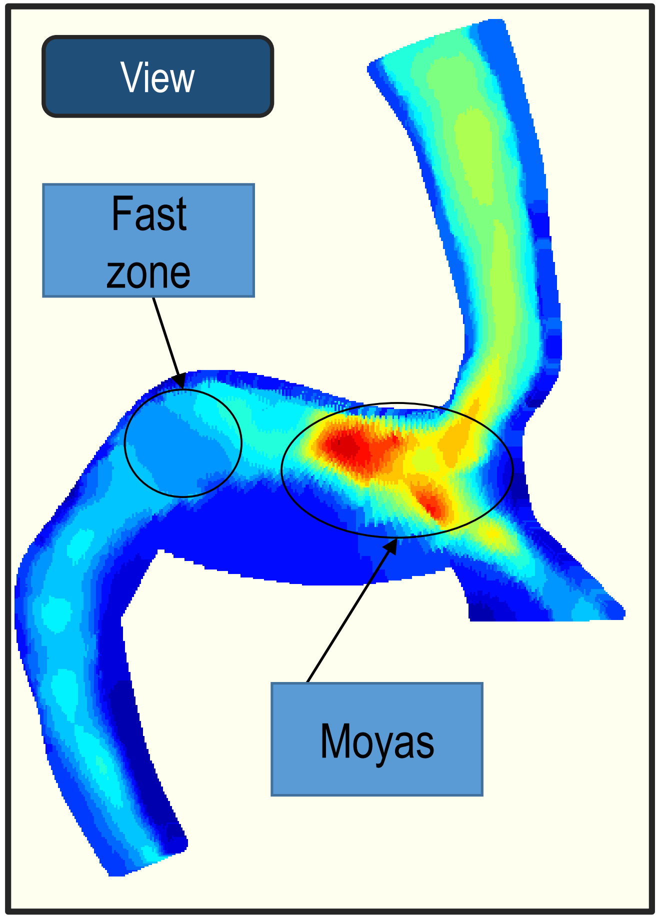
Structured Mesh



Topobathymetry

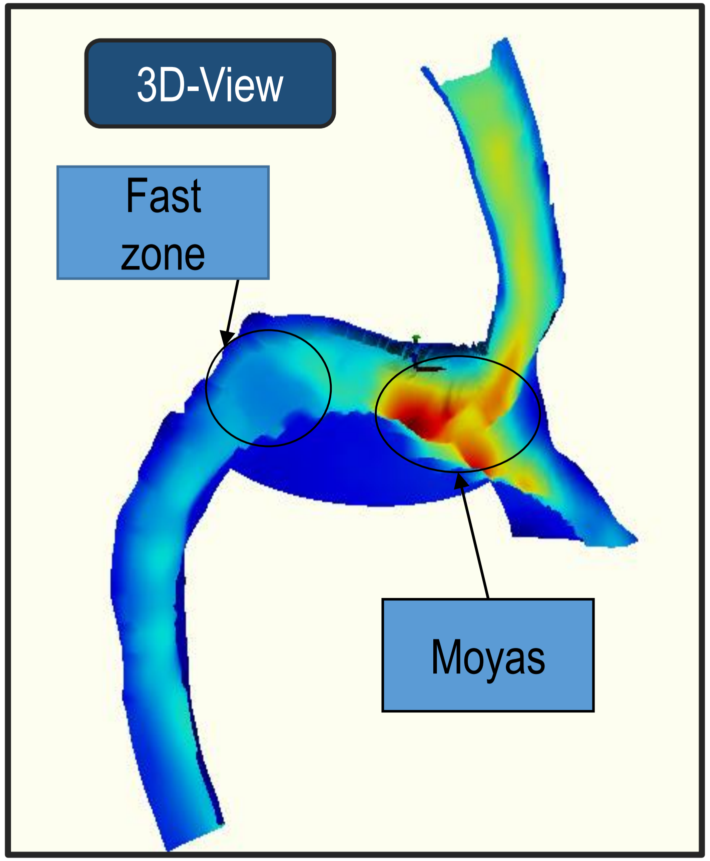


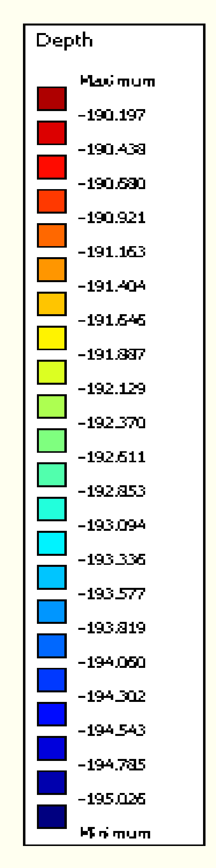


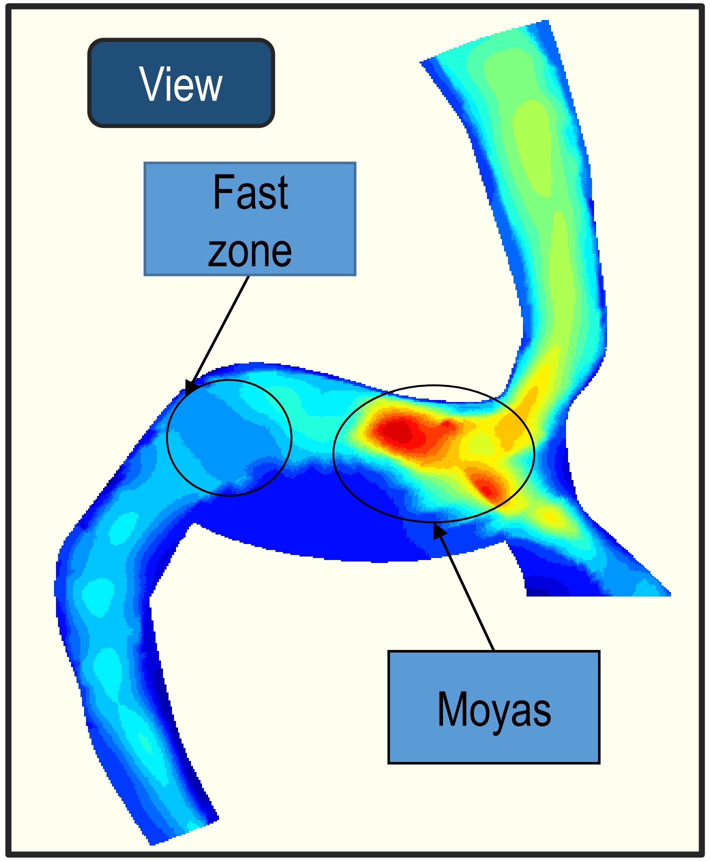


The figures show the 3D and plant view of the XYZ format topobathymetry for the two-dimensional model of the "Moya de Jorge" section in the río La Miel downstream of the Amaní reservoir

Triangular Interpolation

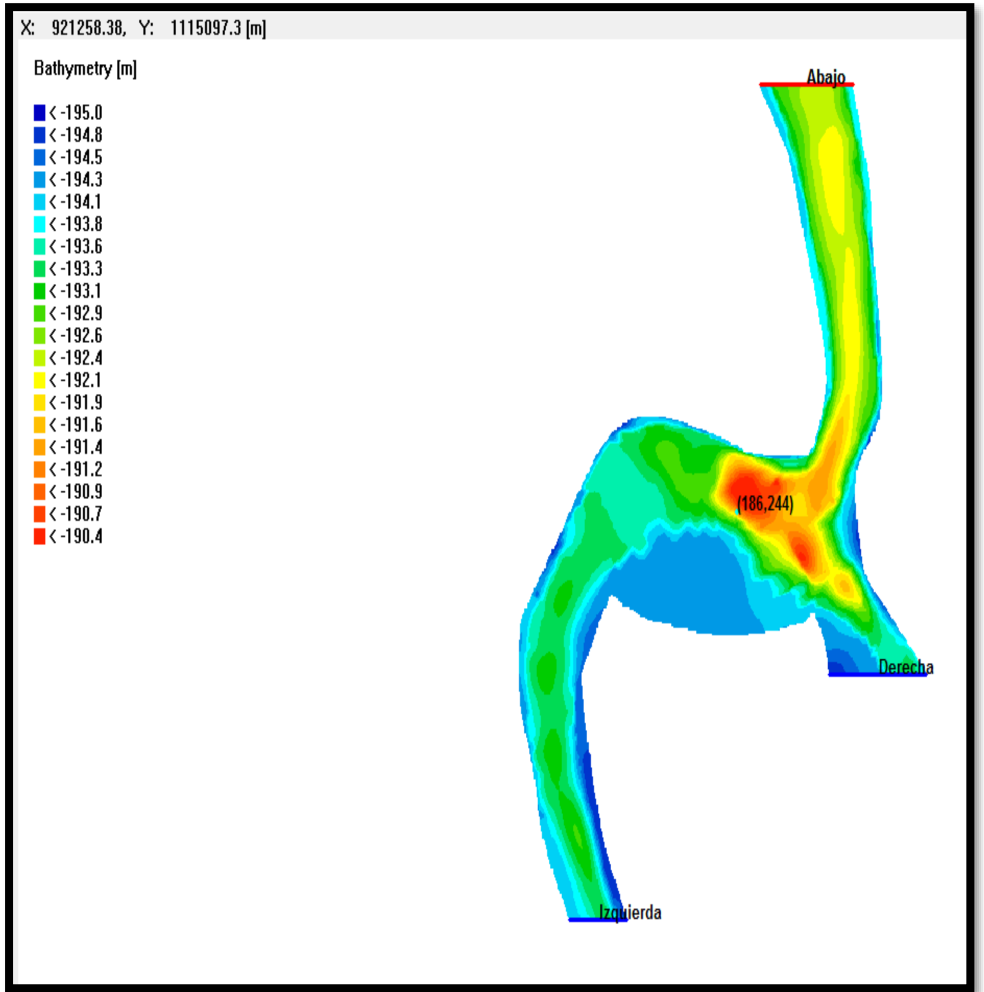






The figures show the plant view of the depth using a triangular interpolation of the topobatimetry of the "Moya de Jorge" section taking into account the mesh.

Final Model



Parameters	magnitude	Units
Simulation start time	15-04-2020 00:00:00	
Simulation stop time	15-04-2020 03:00:00	
Time step	0.001	min
Initial conditions	195.4	m
Boundary upstream (Left)	14	m^3/s
Boundary upstream (Rigth)	4	m^3/s
Boundary Downstream	193.48	m
Manning	0.04	

Results Hydrodynamic Model (2D)

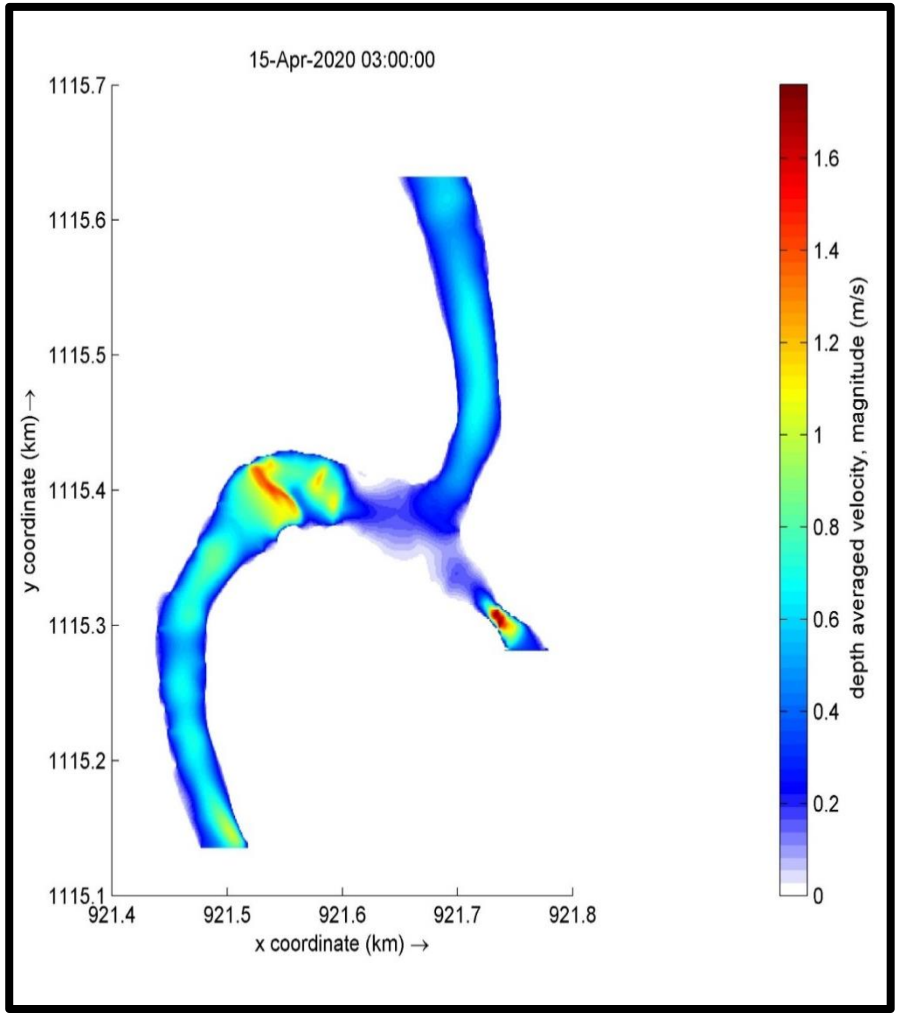
Depth averaged velocity

In the image you can see the results of the depth averaged velocity of the 2D hydrodynamic model.

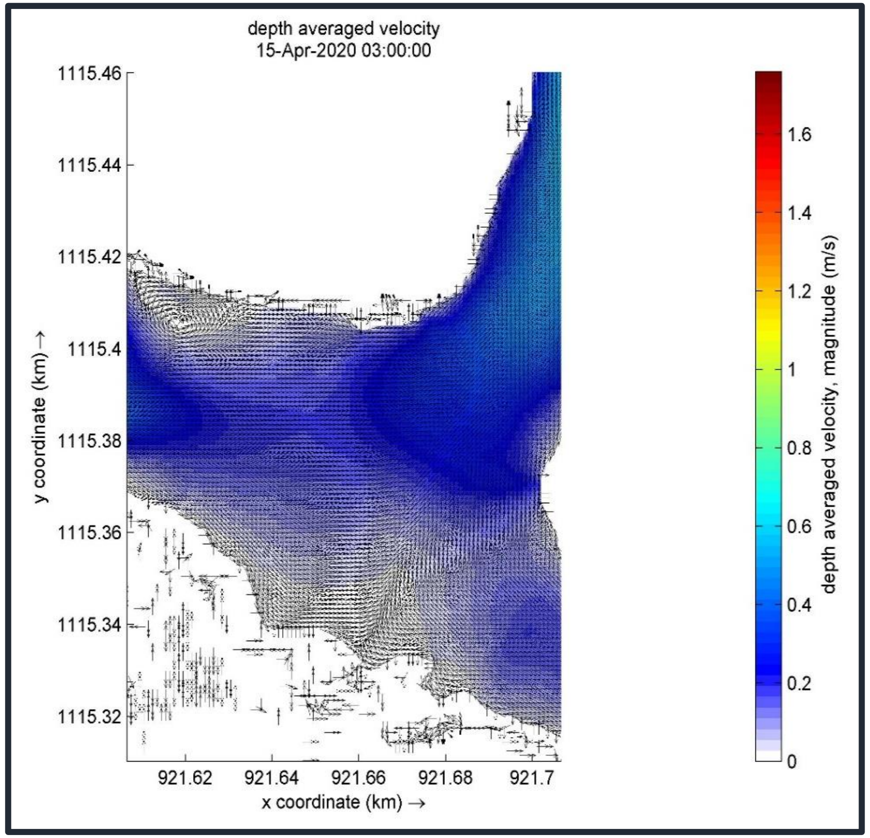
The maximum speeds are in the area of the rapid and at the right entrance before the change of geometry

The minimum speeds are presented in the "moya de Jorge", as in the One-Dimensional model

Regarding the trajectory of the particles , it is expected that the particles will be accelerated in the rapid and slowed down at the moya, where possibly a recirculation phenomena will be generated.



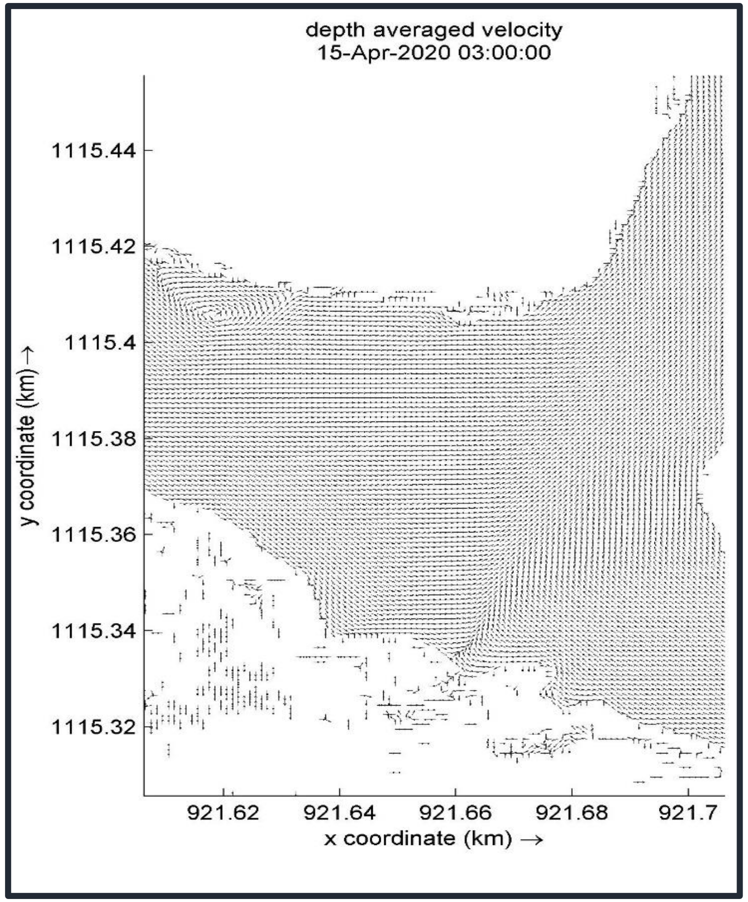
Velocity field – Moya de Jorge



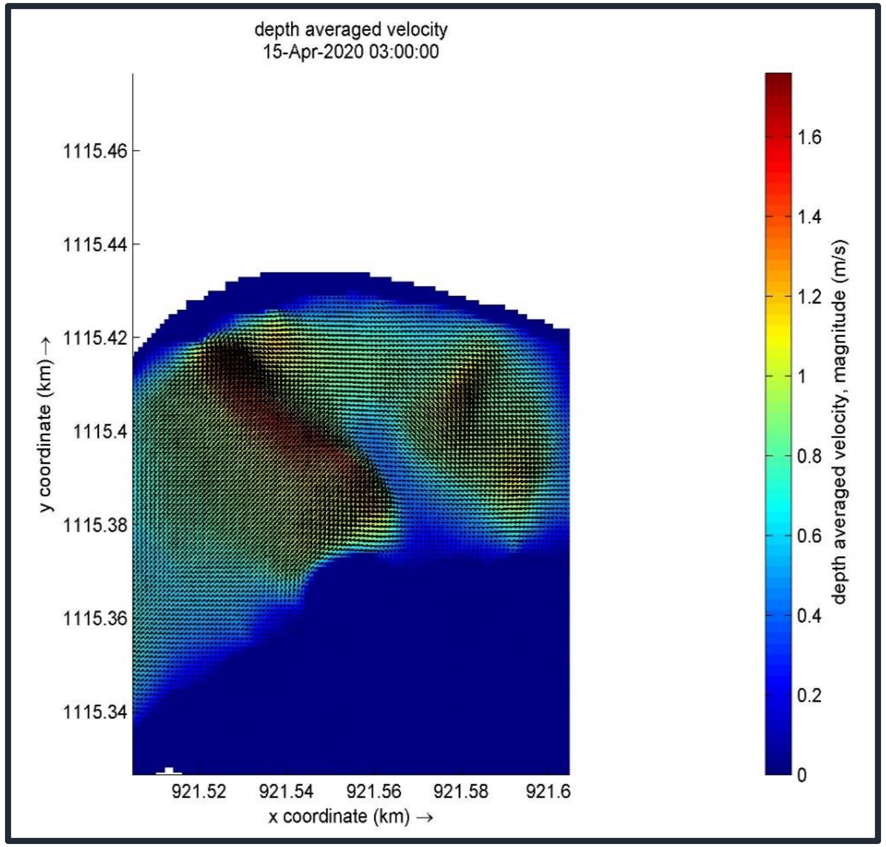
The magnitudes of velocities and the velocity vectors are shown in detail at the "moya de Jorge“.

The influence of the confluence of the two arms of the river on the changes of velocity directions and patterns can be observed.

low magnitudes are presented with an average of 0.2 m/s.

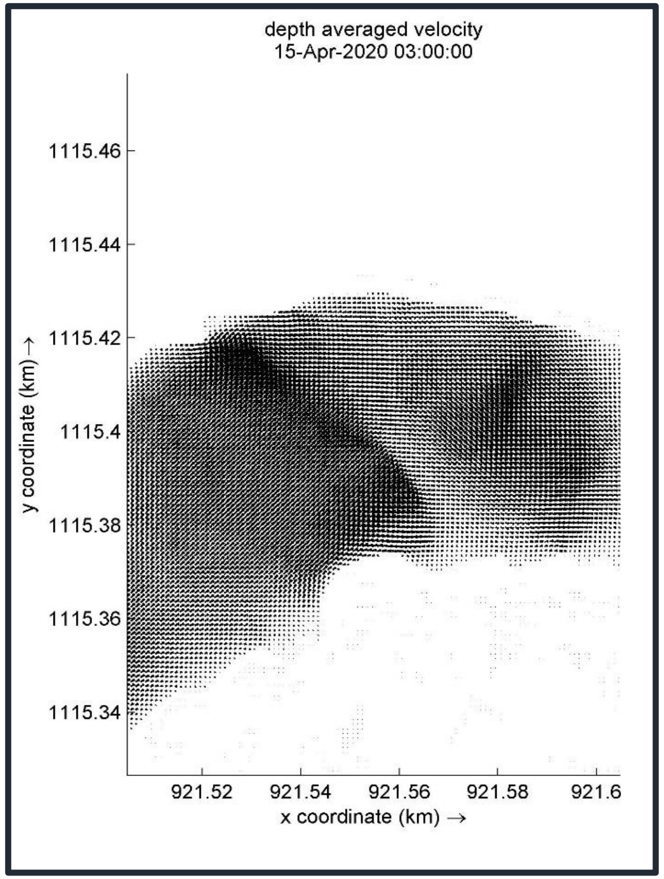


Velocity field – Rapid

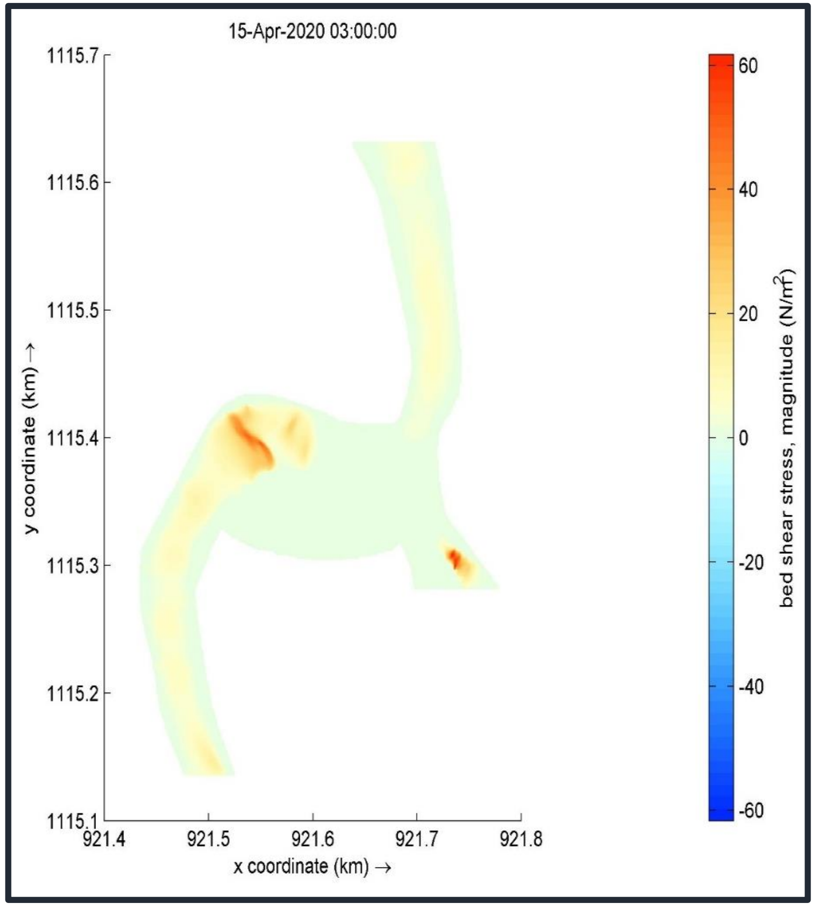


These figures show in detail the velocities magnitudes and the velocity vectors at the rapid

Due to the river bed geometry, the velocities are high, reaching 1.6 m/s, and in the"moya de Jorge“ direction .

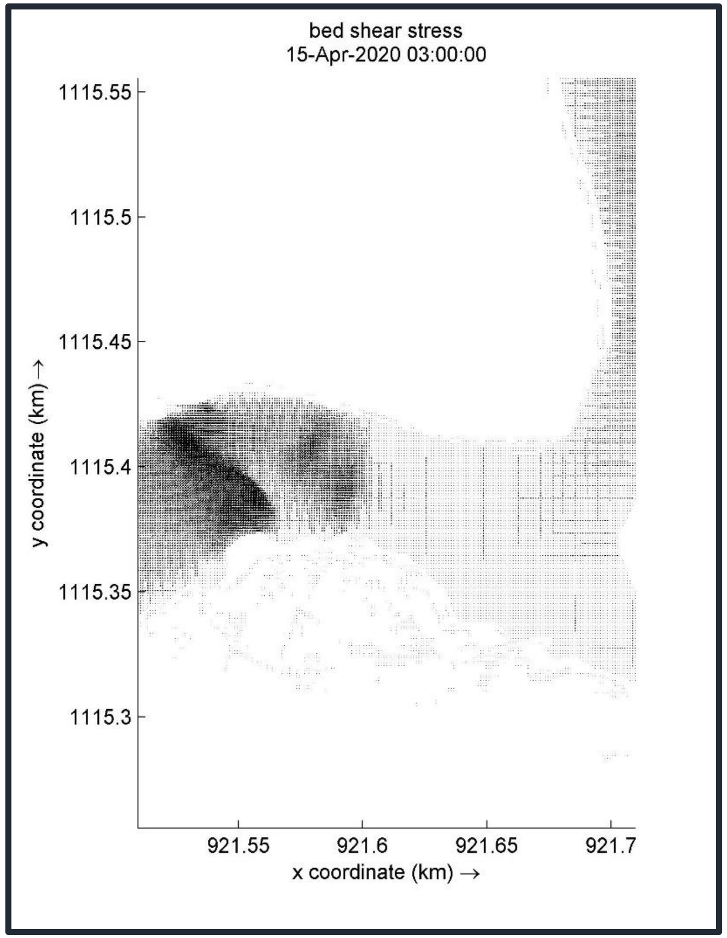


Shear stress

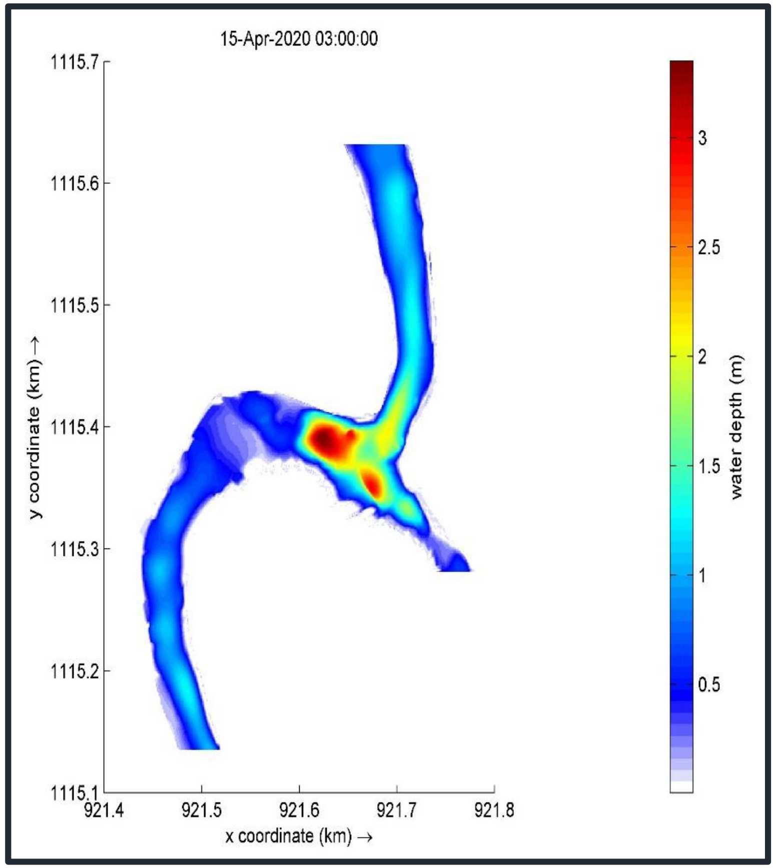


The shear stress in the rapid reach a magnitude of 60 N/m2 and across the section with an average of 20 N/m2.

In the zone of the "Moya de Jorge" where due to the low speeds the forces tend to 0.



Water depth

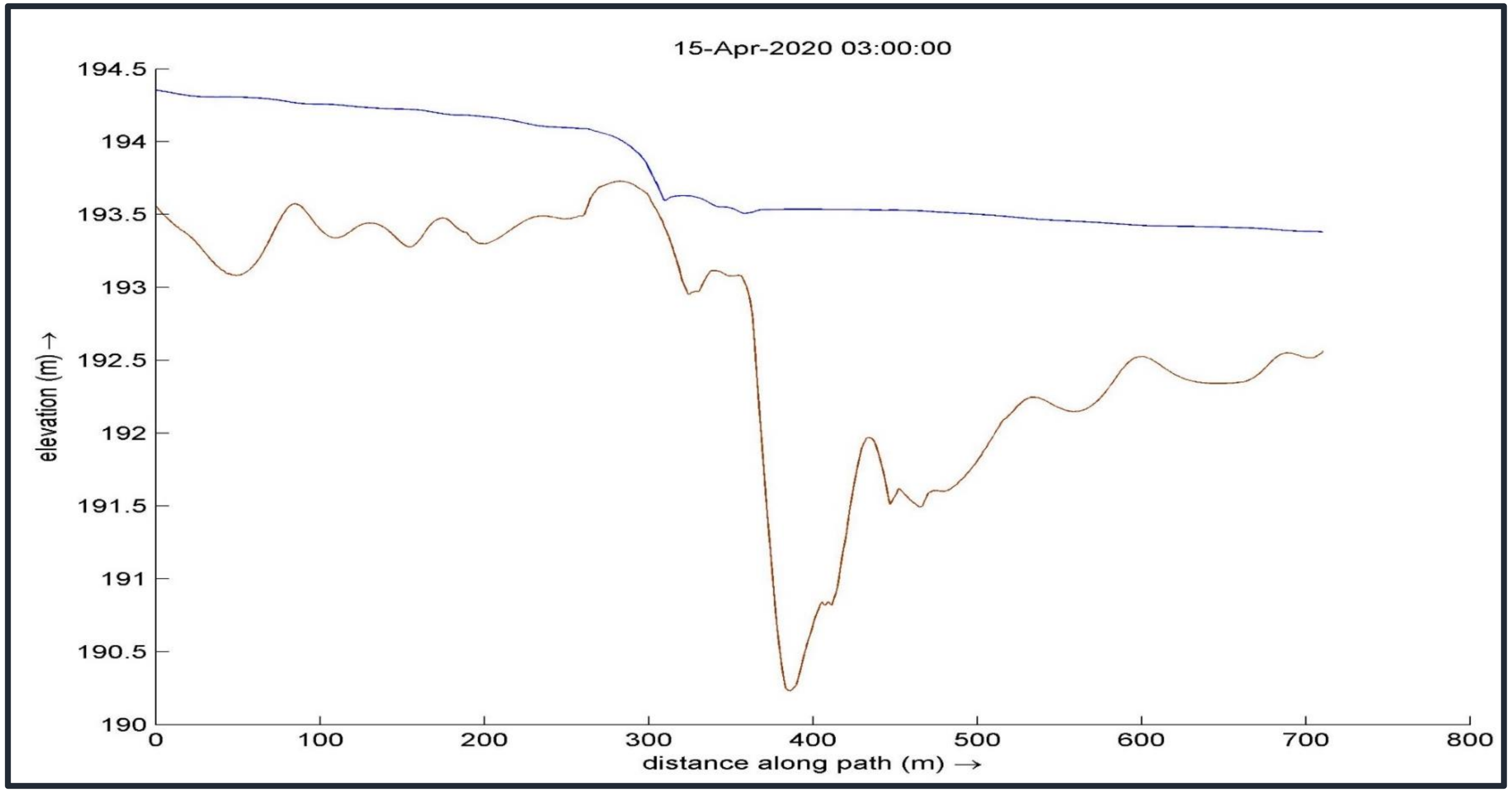


In the area of the rapids the water depth is 20 cm and in the area of the moya water depth depths are more than 3 m.

Inside the moya, there are two changes of geometry or what could be called two moyas, one that is on the left side of the rapid and another one much smaller on the right side

The flow continues at an average depth of 1.3 m.

Longitudinal Profile



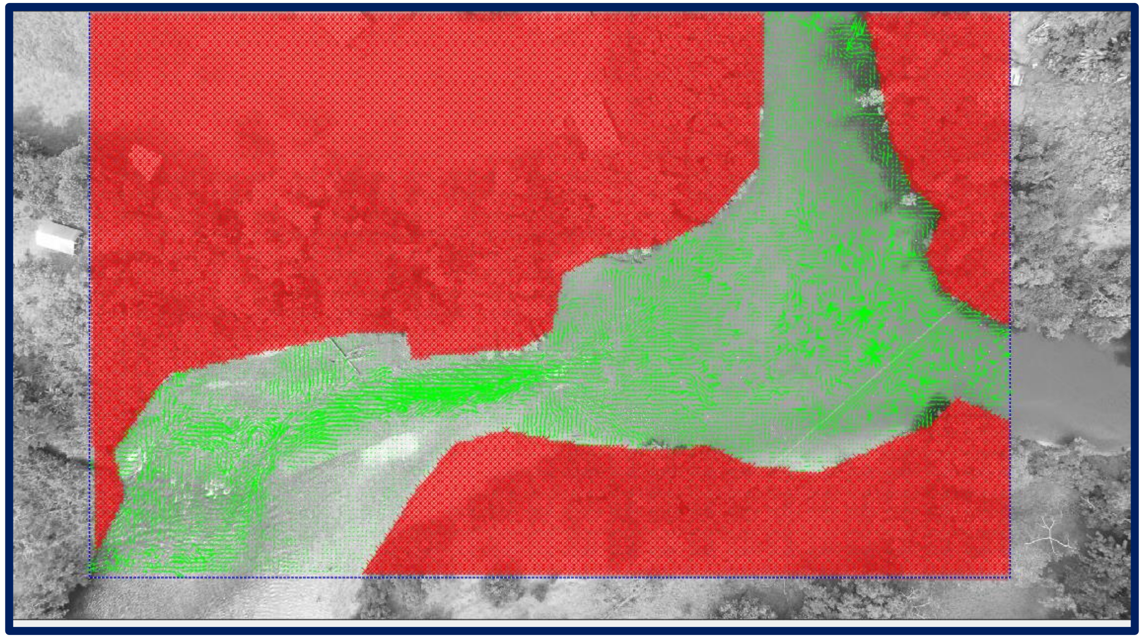
The graph shows the longitudinal profile from upstream to the downstream boundary, passing through the rapids.

The riverbed is compared with the water level, where the influence of the complex geometry on the water depth can be observed.

Particle Image Velocimetry

Particle Image Velocimetry

Rapid- Moya

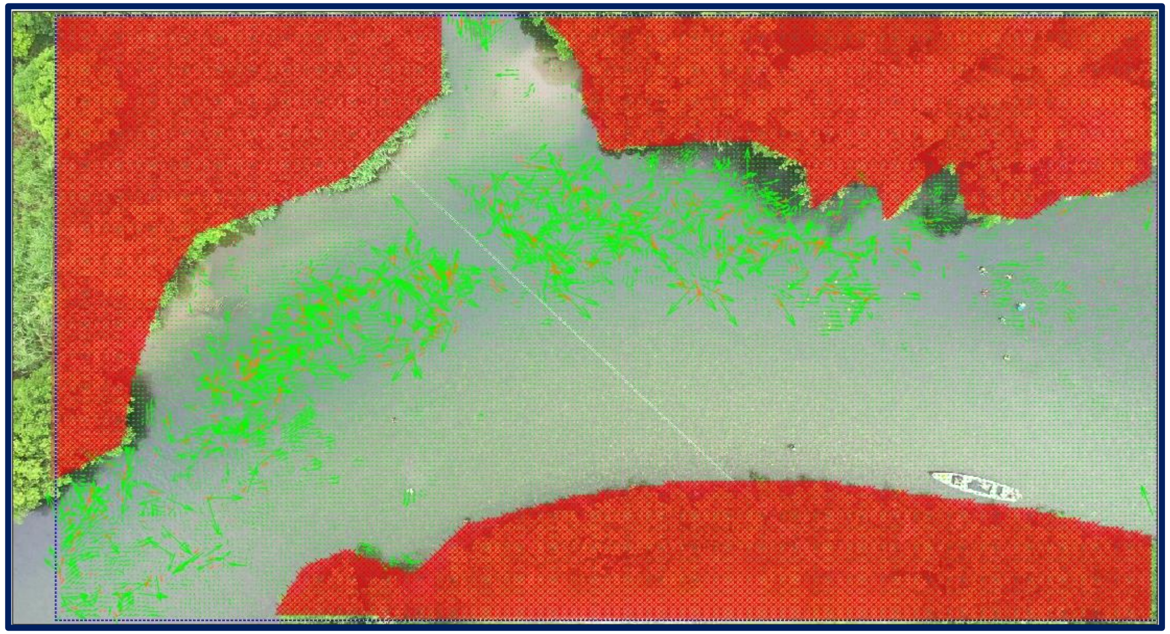


The velocity vectors were obtained processing the drones videos with the River 2.4.3 and PIVlab 2.00 Software using the Particle Image Velocimetry (PIV) technique.

Upstream of this section, the water sheet has a considerable depth and the technique acceptably represents the velocity field. The directions in some places go against the mainstream flow.

Particle Image Velocimetry

Near the upstream boundary



The technique represents well the velocity field.

In general, the vectors show a uniform direction except in a small zone that present a random behavior.

Downstream of the section, the flow continues its normal direction.

CONCLUSIONS AND FUTURE WORK

CONCLUSIONS AND FUTURE WORK

Through the two fieldtrips and the information processing, it was possible to gather good quality topographic and bathymetric information to feed the hydrodynamic models.

The two-dimensional hydrodynamic model developed in Delft-3D was able to capture the hydraulic phenomena associated with the abrupt changes in geometry, water depths and complex velocity fields in the Moya. Velocities, from 0.1 m/s to 1.6 m/s and water depths from 20 cm to 3.5 m in were obtained in the modelling.

It was possible to observe the recirculation phenomena present in the moya from the Particle Image Velocimetry method, that has good precision to capture the direction of the velocity vectors.

We are currently implementing a two-dimensional particle tracking model using the Part module of the Delft 3D software.

References

A.C.E., U. S. (2010). HEC-RAS River Analysis System. User's Manual, Version 4.1. https://doi.org/CPD-68

Adrian, R. J. (2005). Twenty years of particle image velocimetry. Experiments in Fluids. https://doi.org/10.1007/s00348-005-0991-7

Corzo, G. A., Santos, G. R., & Palacios, J. R. (2018). Construcción de un modelo numérico hidrodinámico implementando soluciones basadas en la naturaleza con el software delft3d para la parte alta de la cuenca del río bogotá (villzapinzón). (December).

Delft3D-PART. (2009). Mauel Deltares: Particle Tracking (2.13; Deltares, Ed.). Retrieved from http://www.deltaressystems.com/hydro/product/621497/delft3dsuite

Huang, H. T., Fiedler, H. E., & Wang, J. J. (1993). Limitation and improvement of PIV - Part I: Limitation of conventional techniques due to deformation of particle image patterns. Experiments in Fluids. https://doi.org/10.1007/BF00189883

Jarrett, R. D. (1990). Hydrologic and Hydraulic Research in Mountain Rwers. JAWRA Journal of the American Water Resources Association, 26(3), 419–429. https://doi.org/10.1111/j.1752-1688.1990.tb01381.x

Van Der Molen, J., Van Beek, J., Augustine, S., Vansteenbrugge, L., Van Walraven, L., Langenberg, V., … Robbens, J. (2015). Modelling survival and connectivity of Mnemiopsis leidyi in the south-western North Sea and Scheldt estuaries. Ocean Science, 11(3), 405–424. https://doi.org/10.5194/os-11-405-2015

Willert, C. E., & Gharib, M. (1991). Digital particle image velocimetry. Experiments in Fluids. https://doi.org/10.1007/BF00190388

Sadarjoen, I. A., de Boer, A. J., Post, F. H., & Mynett, A. E. (1998). Particle Tracing in σ-Transformed Grids using Tetrahedral 6-Decomposition. 71–80. https://doi.org/10.1007/978-3-7091-7517-0_7

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Gracias