

COMMISSION INTERNATIONALE
DES GRANDS BARRAGES

VINGT-DEUXIEME CONGRES
DES GRANDS BARRAGES
Norway, 2015

SPILLWAYS DESIGN BY NUMERICAL MODELLING

Carmen BAENA Berrendero

Alberto DUQUE Carrero

Carlos GRANELL Ninot

JESÚS GRANELL Ingenieros Consultores
Calle Cinca N° 34. 28002 Madrid
e-mail: cgn@jgicsa.com, web page: <http://www.jgicsa.com>

SPAIN

1. INTRODUCTION

Traditionally, the design of hydraulic structures in large dams has been carried out based on experimental studies. When it is considered important, a physical scale model is used to check the functioning of the structure.

As in others fields of dam engineering, the development of tools and up to date calculation methods influence the design of these hydraulic structures. Today we have a wide range of tools to be used in the numerical calculation of spillways and outlets.

This article deals with the performance of one of these tools as it is used by the designer, who models and evaluates the results, adapting and improving the initial design in a step by step process until he achieves the optimum hydraulic shape.

JESÚS GRANELL Ingenieros Consultores, a Spanish company, specialized in dam engineering, has been using regularly, since a few years ago, FLOW 3D software in the design of spillways in projects developed in Europe and Latin America. This article summarizes some of these case studies.

2. FLOW 3D SOFTWARE

FLOW-3D® is CFD (Computational Fluid Dynamics) software was originally developed by the Los Alamos National Laboratory in New Mexico and further developed, for over 30 years, by FlowScience Inc.

To solve the Navier - Stokes equations we employ the Finite Volume Method (FVM). This software is especially useful in complex geometries and water free surface calculations since, besides the FVM it has two algorithms [FAVOR ® and TruVOF®] that represent the elements and the free surface, respectively.

By integrating geometry into conservation equations, the FAVOR® algorithm (Fractional Areas/Volumes Obstacle Representation) models the solids inside each control volume. Through the design of a structured mesh, we obtain the accurate geometry of the solids, without having to localize the mesh's nodes on their surface.

The TruVOF® (Volume of Fluid) algorithm is used to represent the interface between two fluids, when said interface is present in the calculations. Thanks to this algorithm, the software is able to correctly localize and indicate the direction of the free surface and follow its movement precisely. Besides, what is more important, the algorithm allows us to impose the boundary conditions on the free surface, avoiding both calculations in the gas phase and the diffusion of the interface.

3. ANALYZED CASES

3.1 - Lateral feeding weir of Bogueira dam (Portugal) for 1900 m³/s

The adequate functioning of lateral feeding to the side channel and jumping towards the riverbed were optimized both in a numerical model and in a scale model.

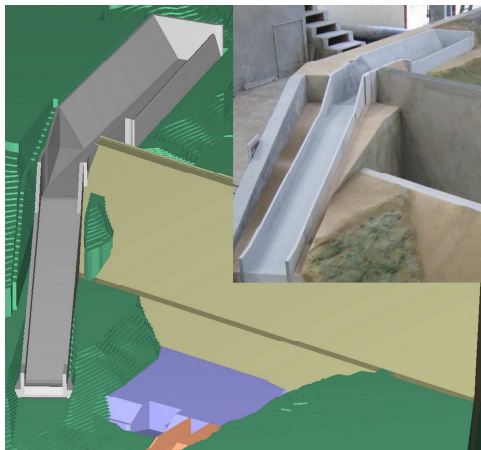


Fig 1

Geometry: Numerical and scale models.

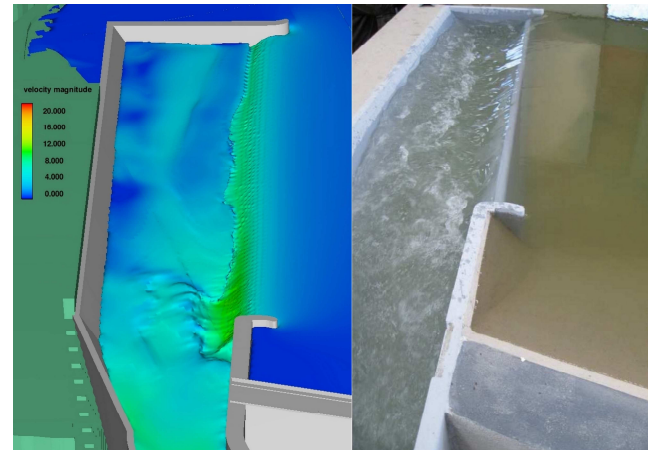


Fig 2

Results: Functioning of the side channel.

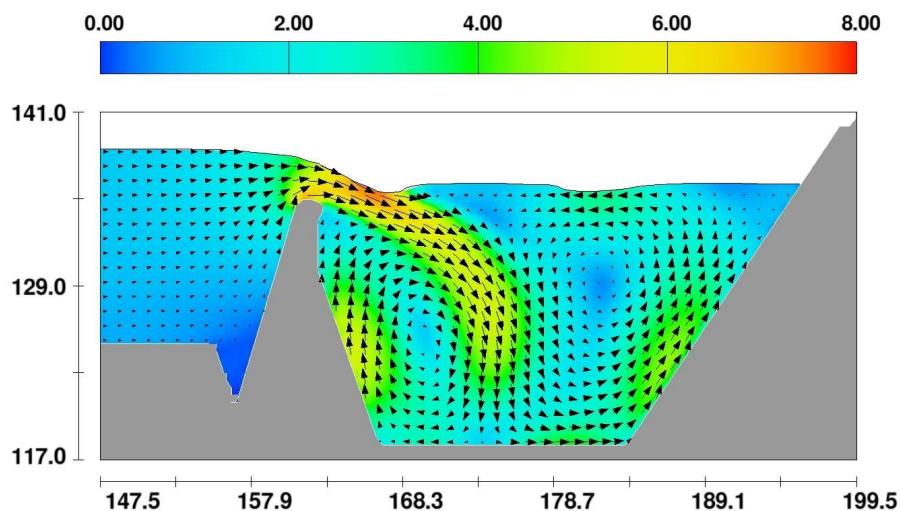


Fig 3

Side channel cross-section. Transversal velocity vectors (in m/s).

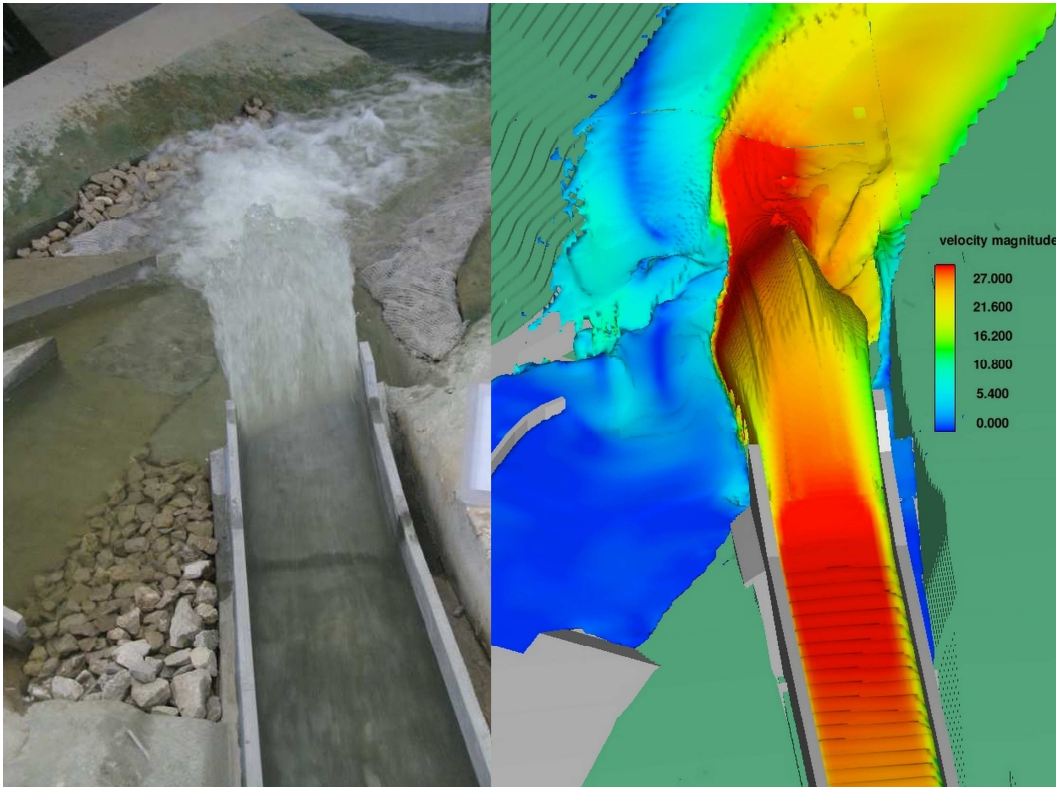


Fig 4

Scale and numerical models. Determining the impact zone on the riverbed.

3.2 - Convergent spillway of Barroblanco dam (Panama) for 2700 m³/s

The enhancement of spillway convergence was analyzed, for several designs of confining sidewall geometry, trying to minimize the effect of the cross waves.

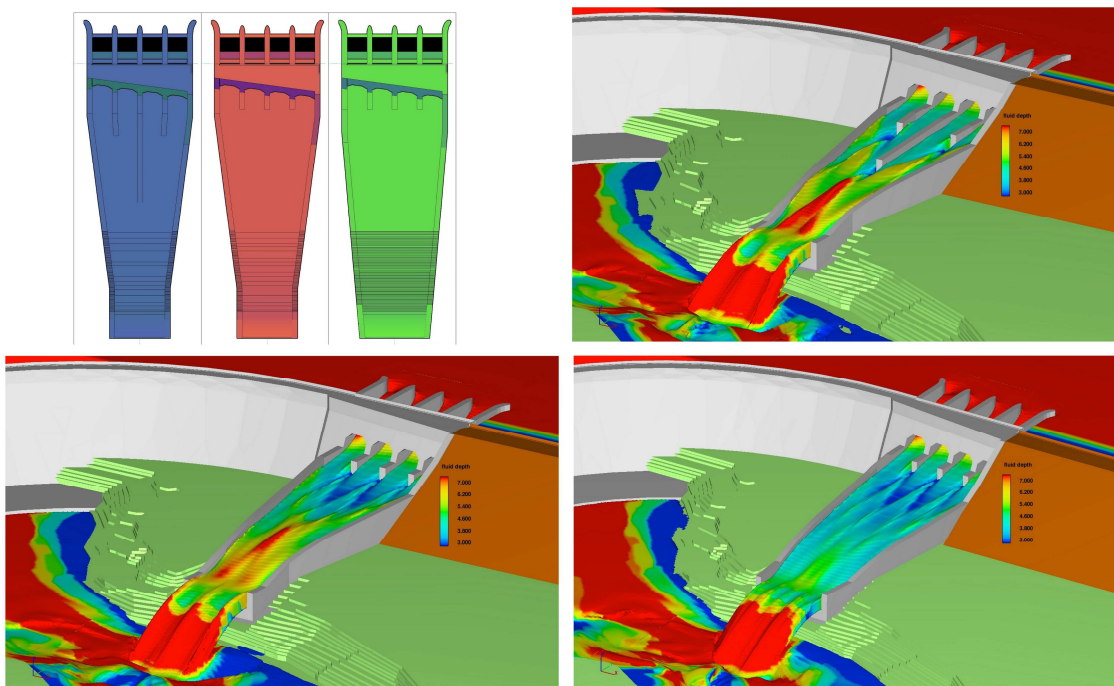


Fig 5

Three designs of spillways with different convergences from those analyzed.

3.3 - Labyrinth weir of Maria Cristina dam (Spain) for 3000 m³/s

Several configurations of the number of labyrinth modules for weir and several designs of stilling basin were studied.

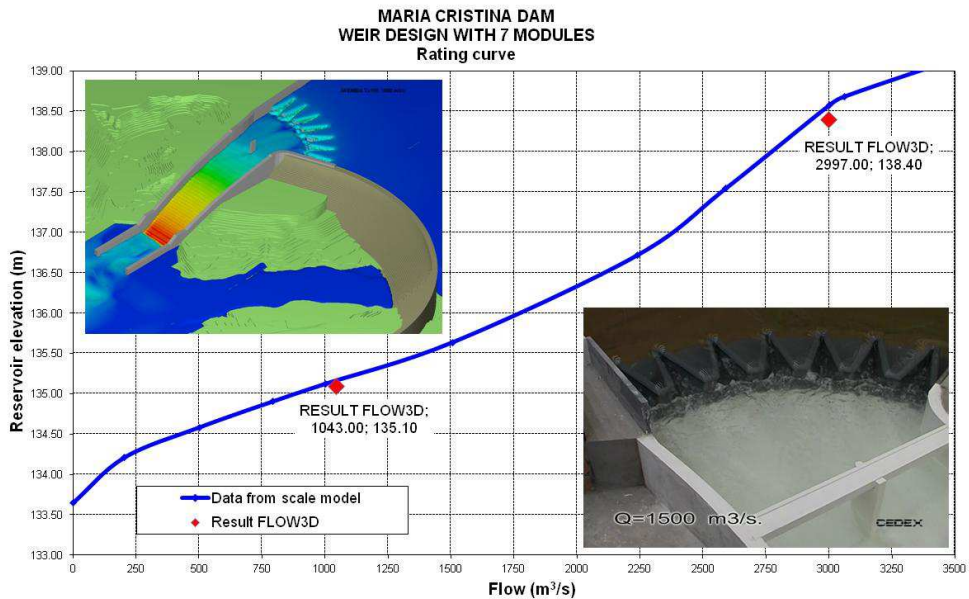


Fig 6

Comparison of discharge capacity for scale and numerical models.

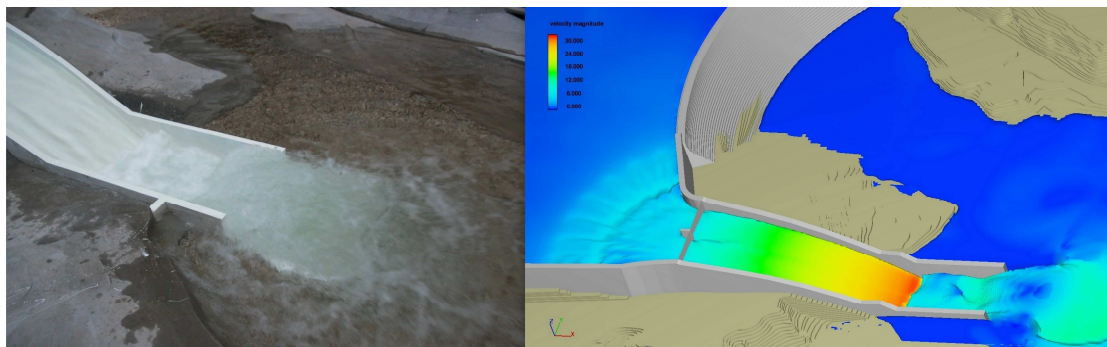


Fig 7

Scale and numerical models. Functioning of the stilling basin for 3000 m³/s.

3.4 - Spillway of Alto Tâmega dam (Portugal) for 915 m³/s on each side

Different shapes and sizes of inner piers, as well as their interaction with the approach channel were analyzed. A study of the different shapes in plan and invert channel of the chute that minimize the rising of the water surface in the curve was carried out.

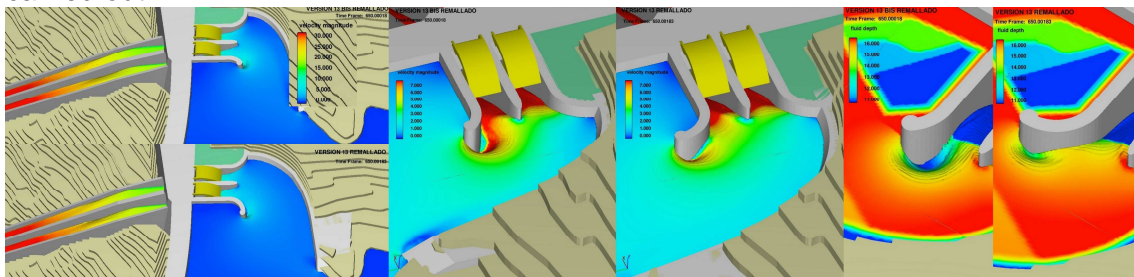


Fig 8

Study of several shapes of piers and approach channels.

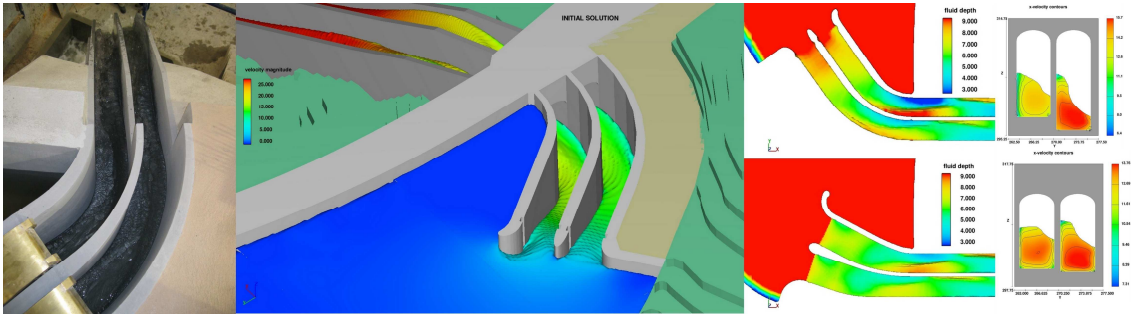


Fig 9

Study of the effect of the shape of the chute in plant and invert channel on the rising in curve.

3.5 - Spillway of Girabolhos dam (Portugal) for 1650 m³/s

The influence on the spillway's hydraulic capacity of the convergence, the curvature and the slope of the first meters of the weir were studied.

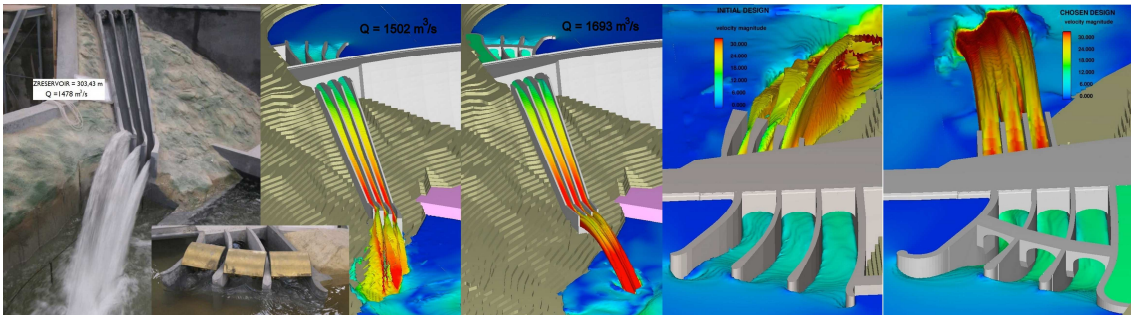


Fig 10

Different shapes of weirs at the same water level were modeled numerically and physically.

3.6- Submerged bucket at Xacbal dam (Guatemala) for 2000 m³/s

Bidimensional numerical study of forms of a submerged bucket with a high unit flow rate-beyond the range of application of the criteria established by USBR.

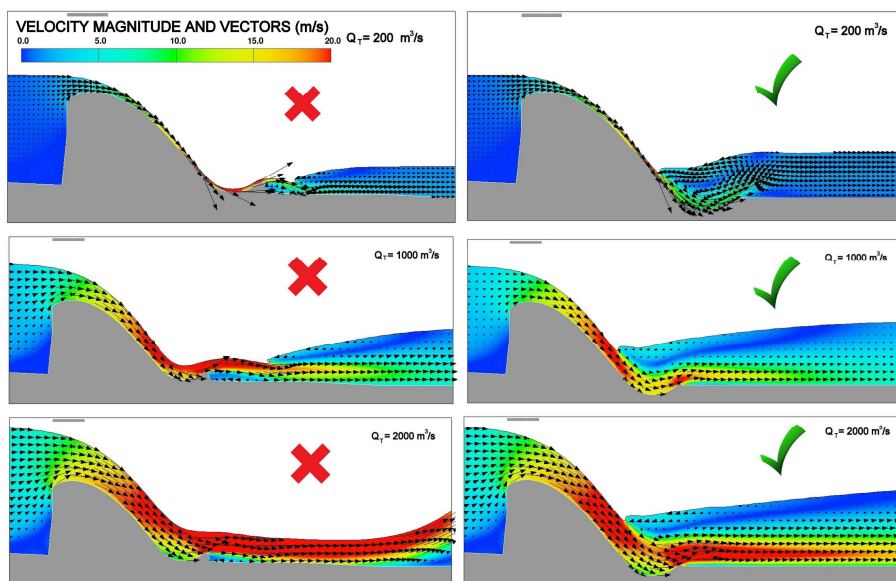


Fig 11

Several designs of submerged buckets. Choosing the best.

3.7- Stepped spillway of Cuira dam (Venezuela) for 1850 m³/s

Studies by means of scale and numerical models of a stepped and convergent spillway and its terminal structure (stilling basin with trapezoidal shape due to geotechnical requirements).

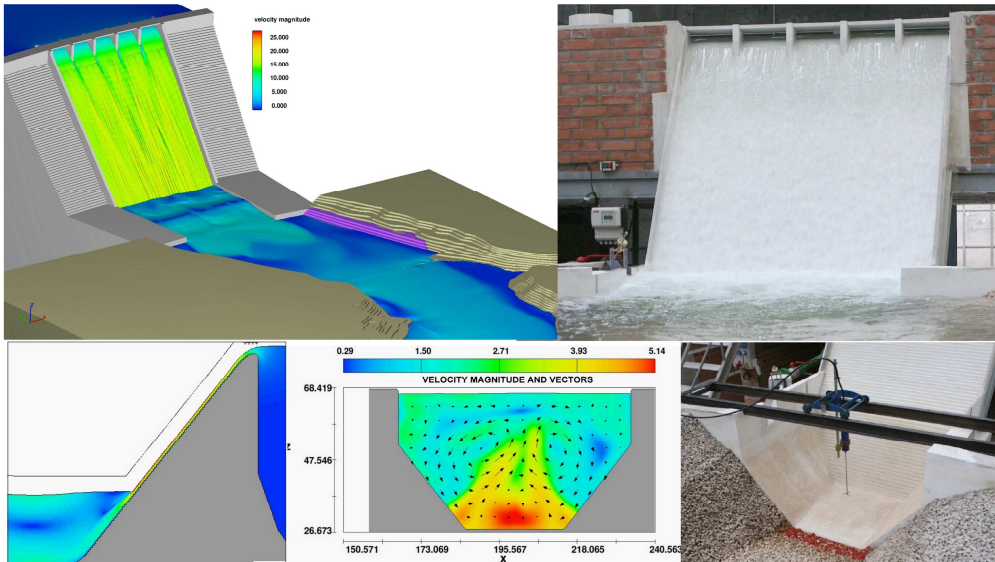


Fig 12

Stepped and convergent spillway of Cuira dam. Scale and numerical models.

SUMMARY

Modern computational numeric models are an efficient tool for designing hydraulic structures. In the last few years, JESÚS GRANELL Ingenieros Consultores have been using FLOW-3D to design different dam spillways, allowing a better approximation to the optimal hydraulic solution of the different parts of the dam: pier-cutwaters, confluences, chutes, hydraulic jumps basins, steps, among others through the creation of specific numeric models and the analysis of their results. It offers a large number of advantages in choosing the best alternative by improving and optimizing the final shapes through a trial and error procedure, reducing costs and saving time. Some examples are presented and the comparison between some of these examples and reduced scale physical models are shown.

RÉSUMÉ

La modélisation numérique à travers des applications informatiques modernes est un outil efficace pour la conception des ouvrages hydrauliques. JESÚS GRANELL Ingenieros Consultores a utilisé l'application FLOW 3D dans les projets récents pour la conception de divers déversoirs du barrage, cette qui permet une plus élevée approximation à la solution optimale hydraulique aux différentes parties: des avant-becs, des convergences, des lancements, des sas à ressaut hydraulique, des gradins, etc. à travers de la création de modèles numériques spécifiques et l'analyse de résultats. Ce qui offre d'innombrables avantages dans le choix de la meilleure alternative, le raffinement et l'optimisation des formes finales, en réduisant ainsi le temps et les coûts. De la même manière, la comparaison de certains exemples est montrée parmi des modélisations physiques à échelle réduite.