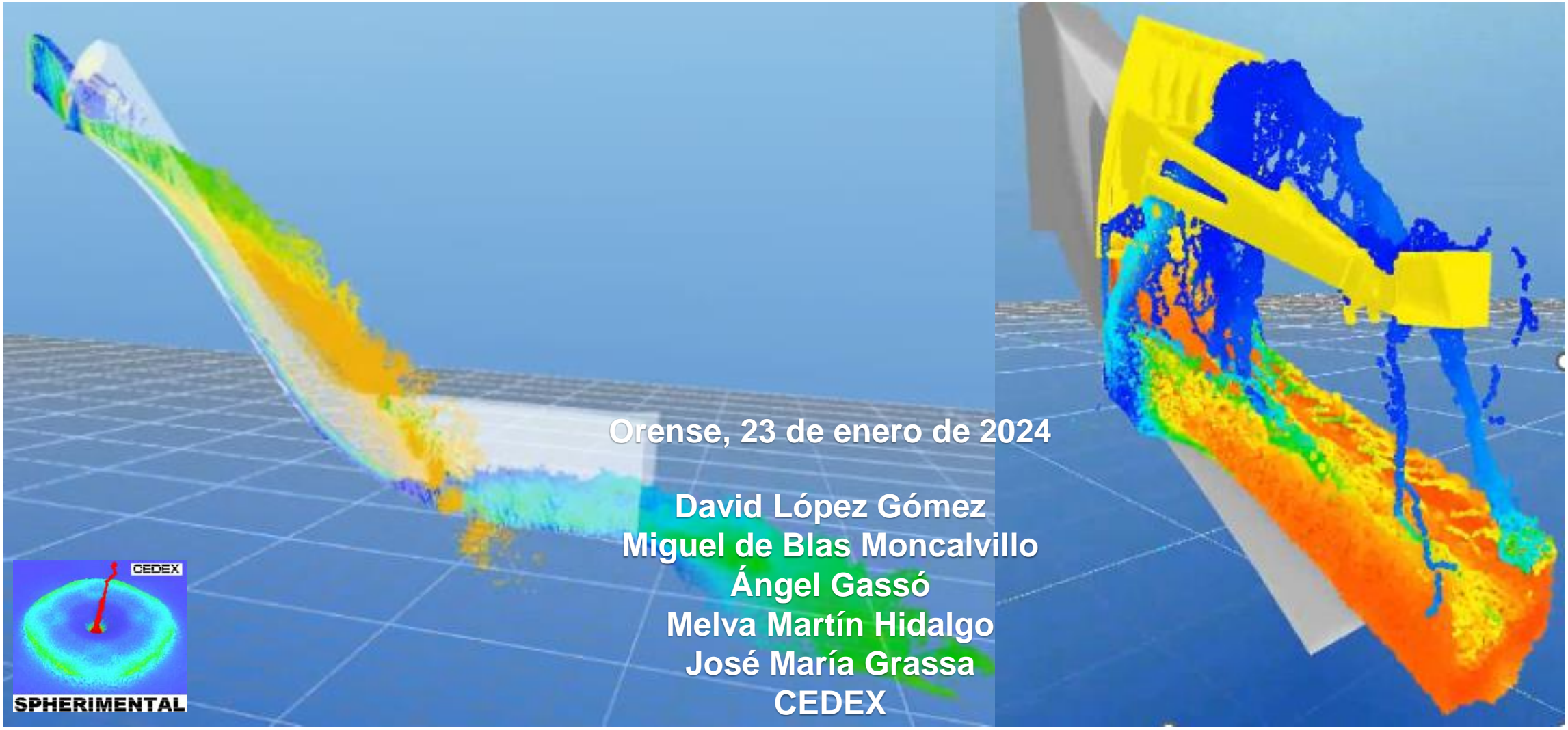
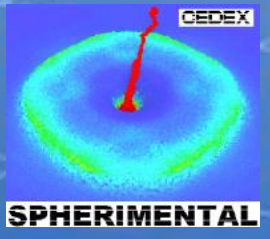


SPHERIMENTAL MODEL: DEVELOPMENT AND NEW CAPACITIES



Orense, 23 de enero de 2024

David López Gómez
Miguel de Blas Moncalvillo
Ángel Gassó
Melva Martín Hidalgo
José María Grassa
CEDEX



HYDROGRAPHICAL STUDIES CENTER.

SPHERIMENTAL model: development and new capacities

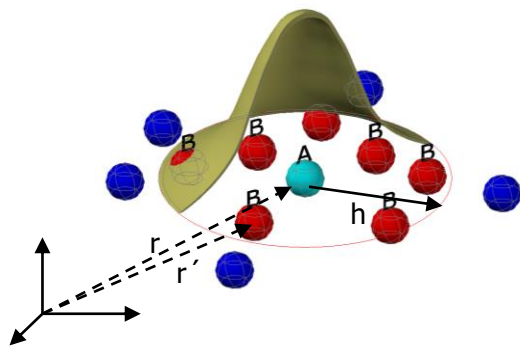


HYDRAULIC LABORATORY



SPH METHOD

Kernel: smoothed function.



➤ SPH solves 3D de Navier Stokes equations:

$$\frac{d\rho_a}{dt} = -\rho_a \sum_b \frac{m_b}{\rho_b} (v_b - v_a) \nabla W_{ab}$$

$$\frac{dv_a}{dt} = -\sum_b m_b \left(\frac{p_b}{\rho_b^2} + \frac{p_a}{\rho_a^2} + \Pi_{ab} \right) \nabla W_{ab}$$

➤ Weakly compressible flow:

$$P = \frac{\rho c_s^2}{\gamma} \left(\left(\frac{\rho}{\rho_0} \right)^\gamma - 1 \right)$$

➤ Turbulence Model for free surface flow (Monaghan)

$$\Pi_{ab} = \begin{cases} \frac{-\alpha \bar{c}_{ab} \mu_{ab} + \beta \mu_{ab}^2}{\bar{\rho}_{ab}}, & v_{ab} \cdot r_{ab} < 0 \\ 0, & v_{ab} \cdot r_{ab} > 0 \end{cases}$$

$$\mu_{ab} = \frac{h v_{ab} \cdot r_{ab}}{r_{ab}^2 + (0.1h)^2}$$

➤ Alfavor improvement:

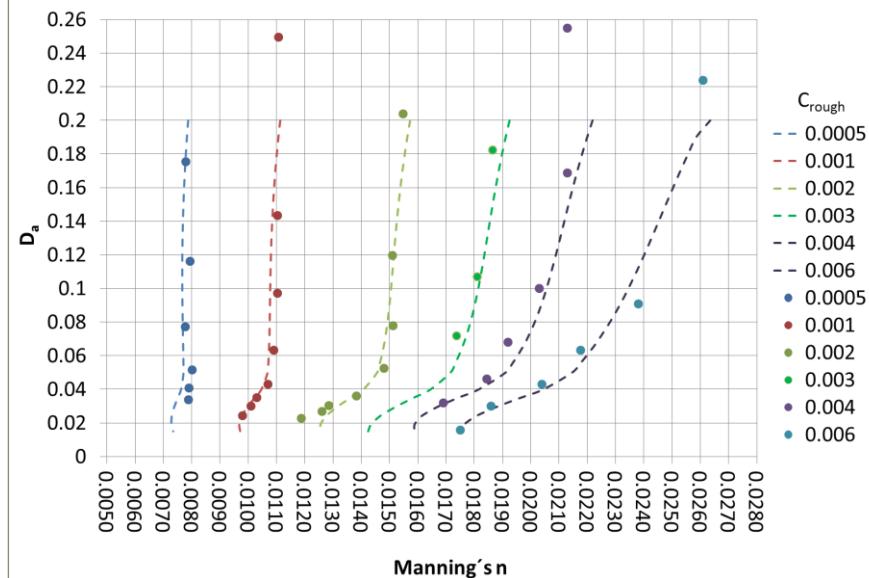
➤ $\alpha = \alpha(\text{vorticity})$ if Froude > 5

➤ Boundary condition

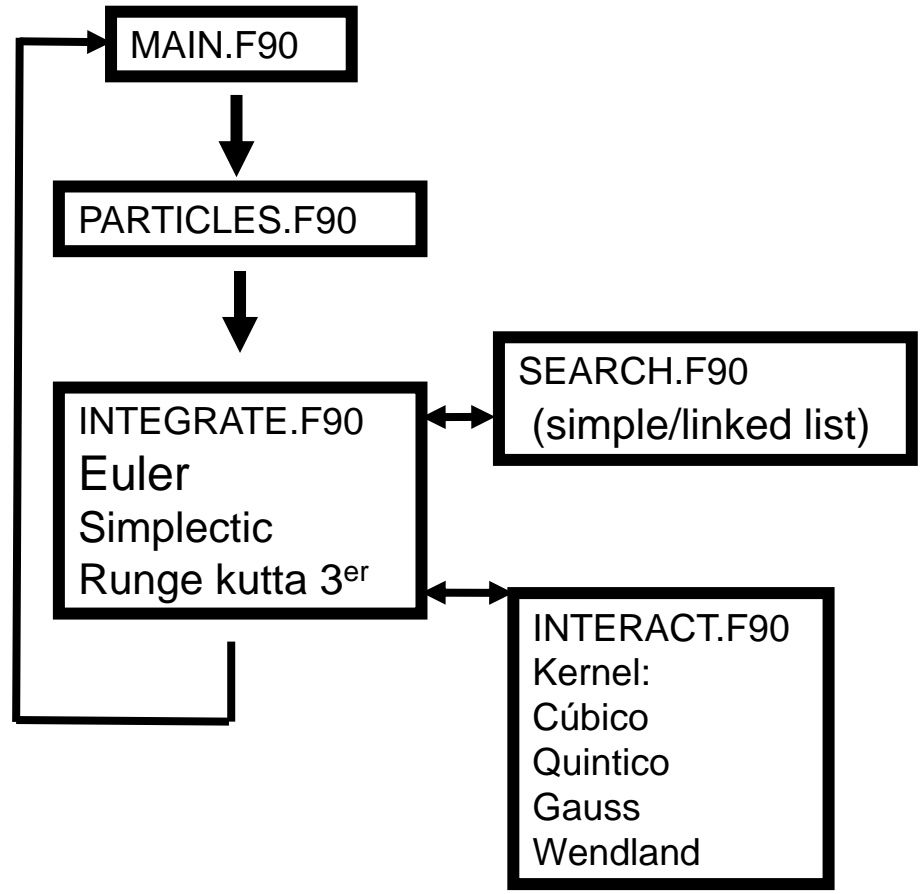
$$f(r) = d_0 \left(\left(\frac{r_0}{r} \right)^{p_1} - \left(\frac{r_0}{r} \right)^{p_2} \right) \frac{\vec{r}}{r^2} - \frac{C_{\text{rough}}}{dx} v_{\text{part}}^2 \frac{\vec{r}}{r}$$

Lenard Jones Forces (d_0) Friction Forces (d_0)

$$C_{\text{rough}} = \frac{g(H - C_e d_x)}{H^{4/3}} n^2 \left(\frac{a \left(\ln \frac{H}{k_s} - 1 \right) + b}{a \left(\ln \frac{C_e d_x}{k_s} \right) + b} \right)^2$$



SEQUENTIAL FORTRAN CODE STRUCTURE

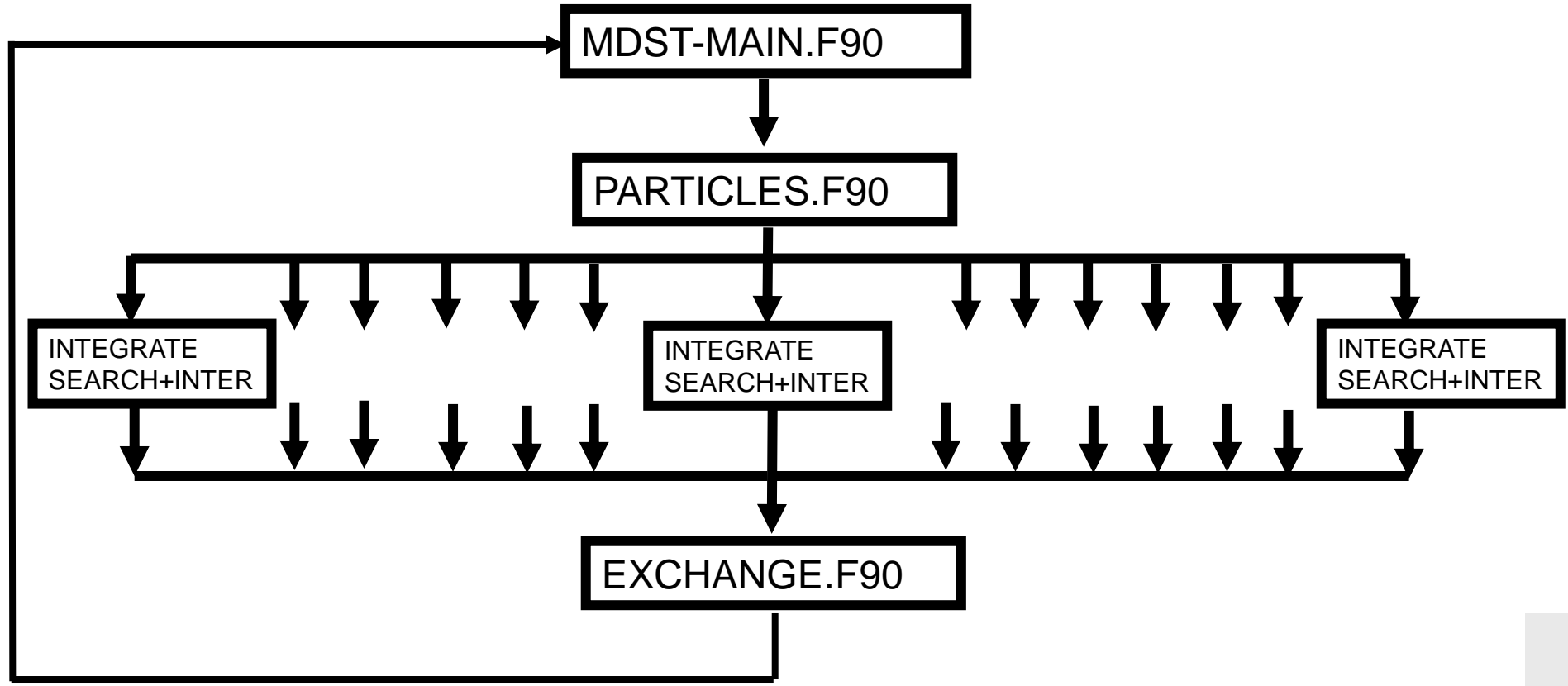


PGI FORTRAN 90



CODE EVOLUTION: MDST MPI

STRUCTURE FORTRAN MPI CODE



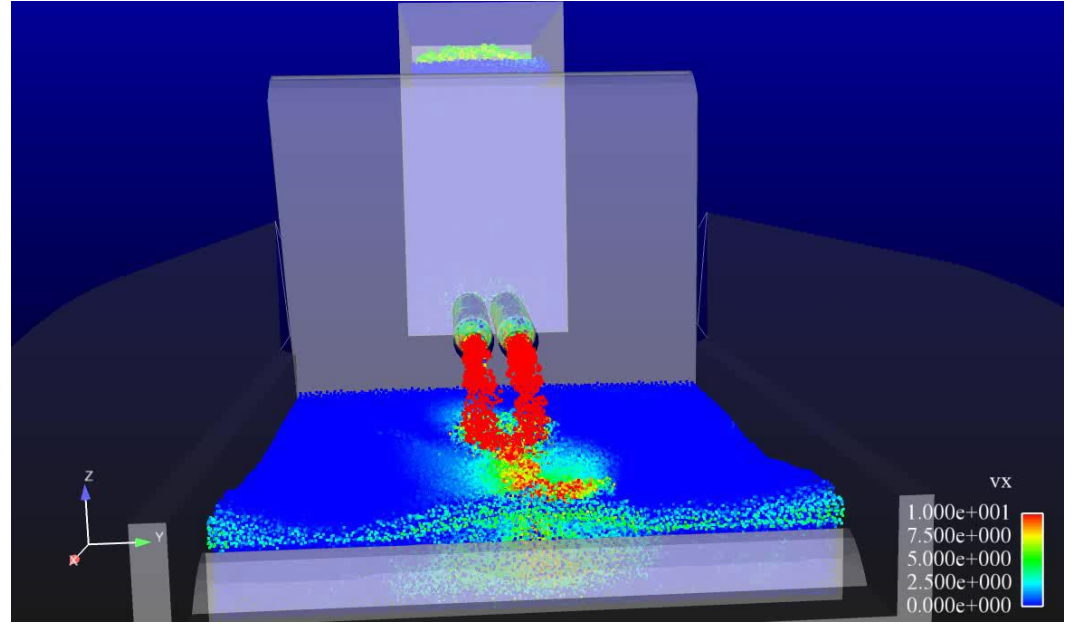
PGI FORTRAN 90 -MPI

PUERTOS (2008)

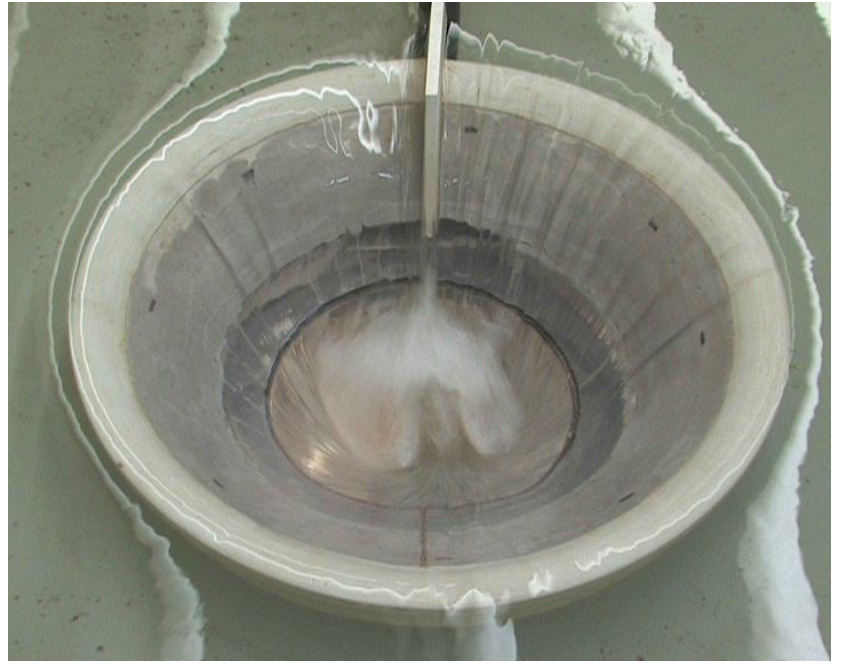
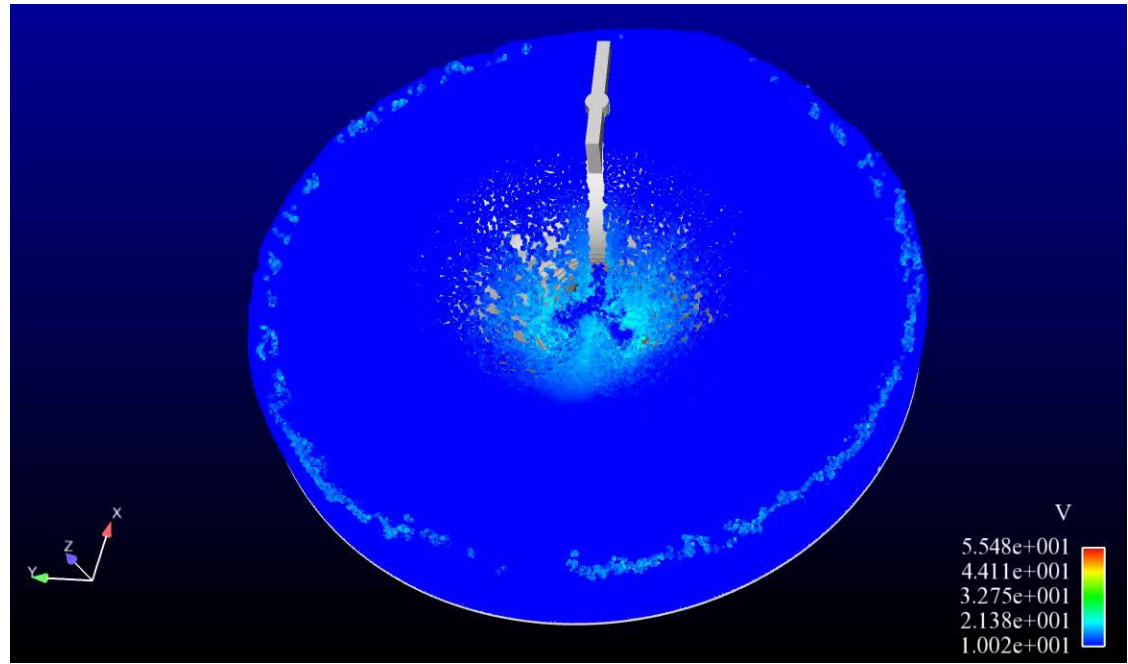


12 blades	4porc.
CPU. Opteron AMD 885. Dual	32 GB
Memory frecuency	1000 Mhz
Memory cache	1 Mb

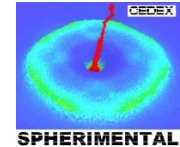
Villar del Rey dam outlet bottom



Calanda dam spillway



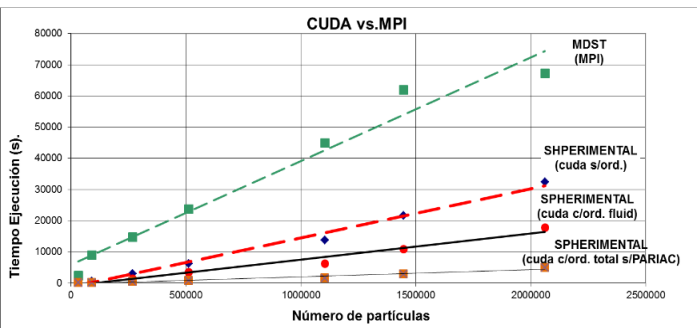
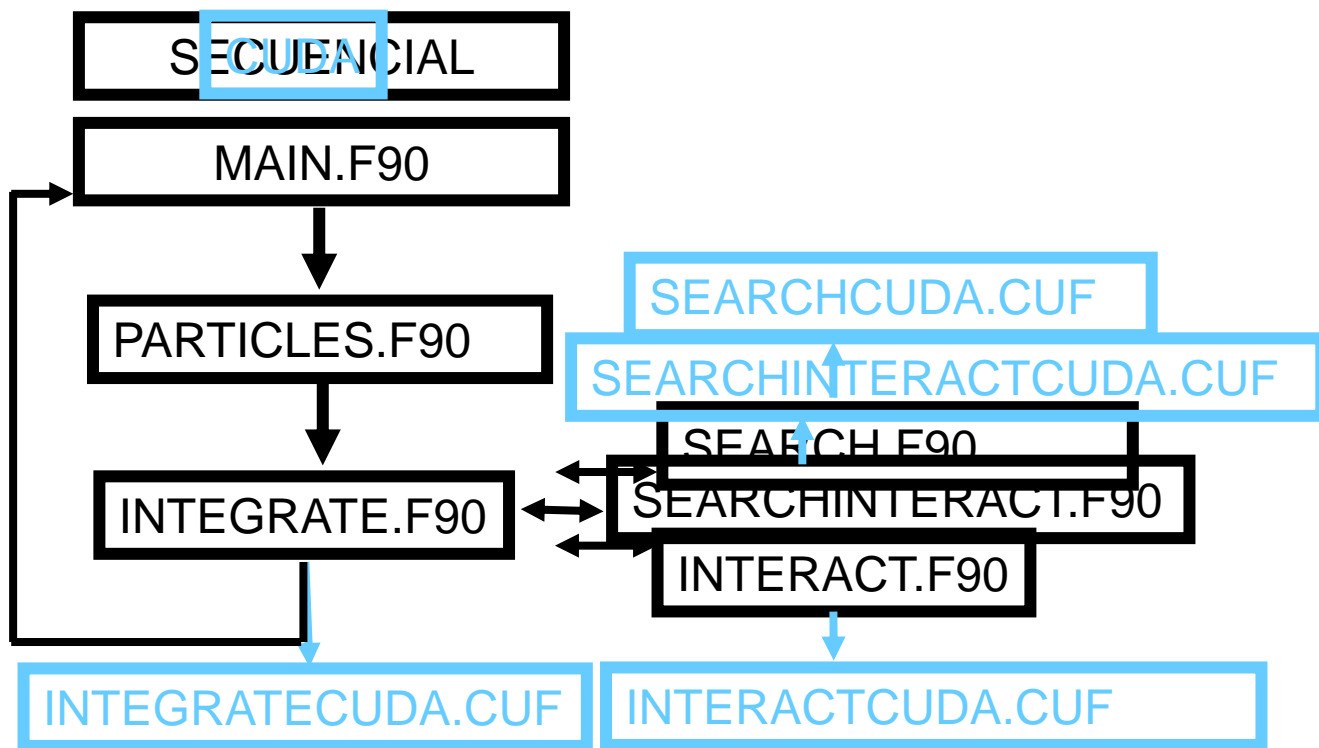
CODE EVOLUTION: SPHERIMENTAL



CODE OPTIMIZATION

- Memcpy device to host only for results
 - Texture memory
 - Search method of linked list changed for spatial hash
 - Coalescence: Reordering of particles by spatial criterion.
 - Single precision: local coordinates
- Secuential data structure: $0.14 \cdot 10^6$ particles/Gb
- CUDA data structure: $4 \cdot 10^6$ particles/Gb RAM

CODE STRUCTURE FORTRAN CUDA

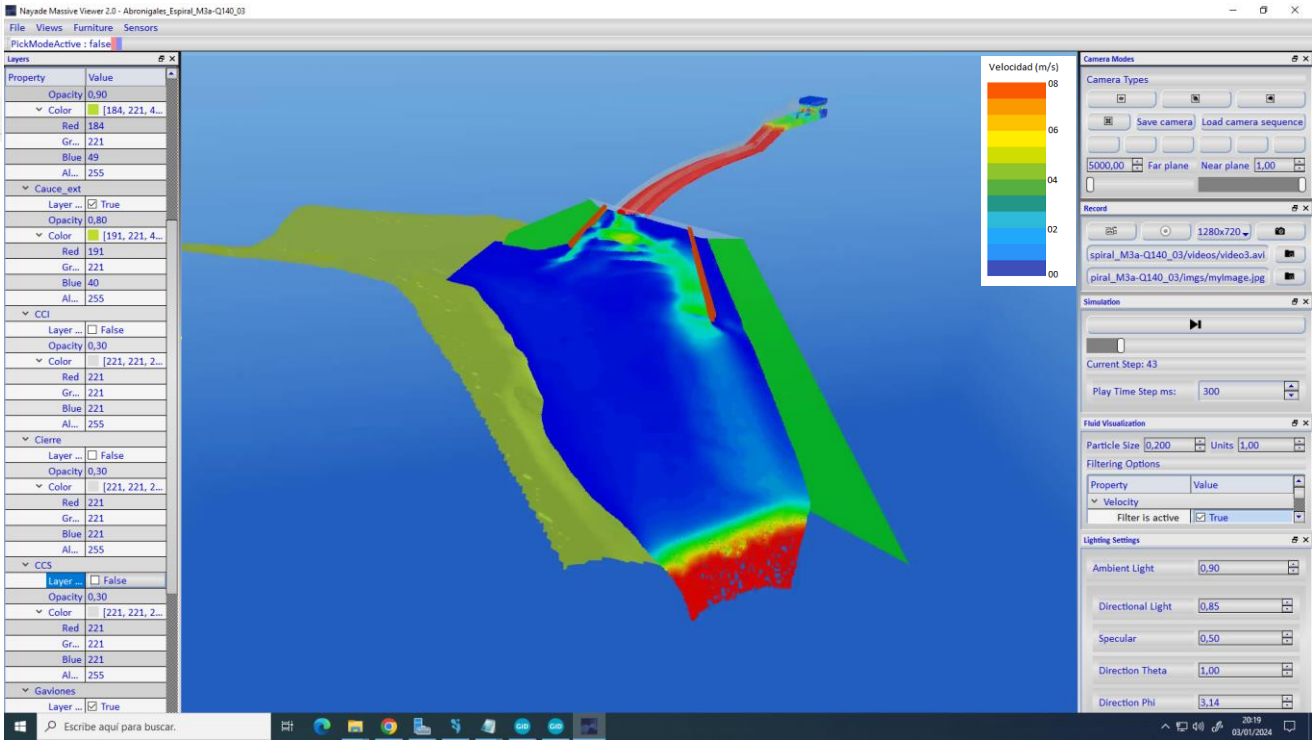
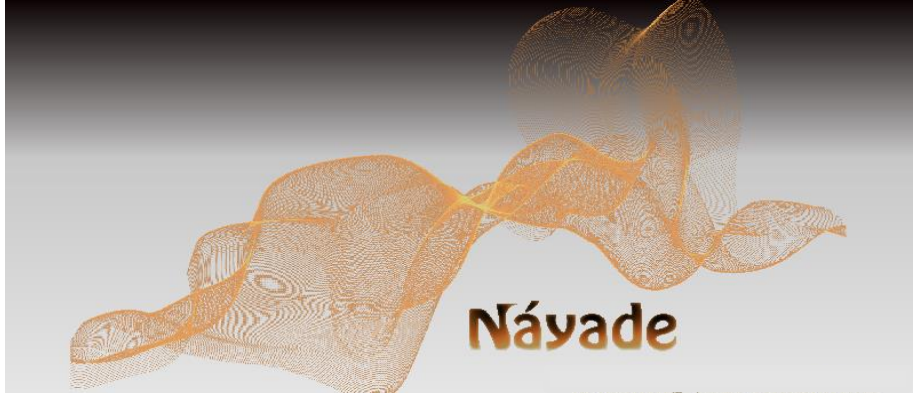
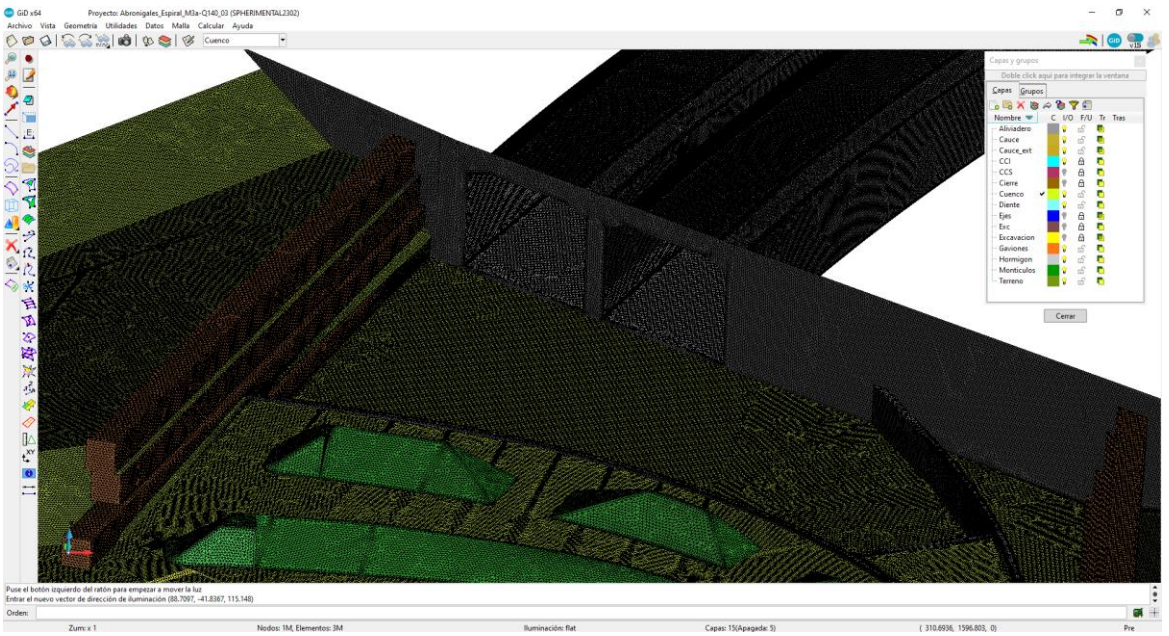
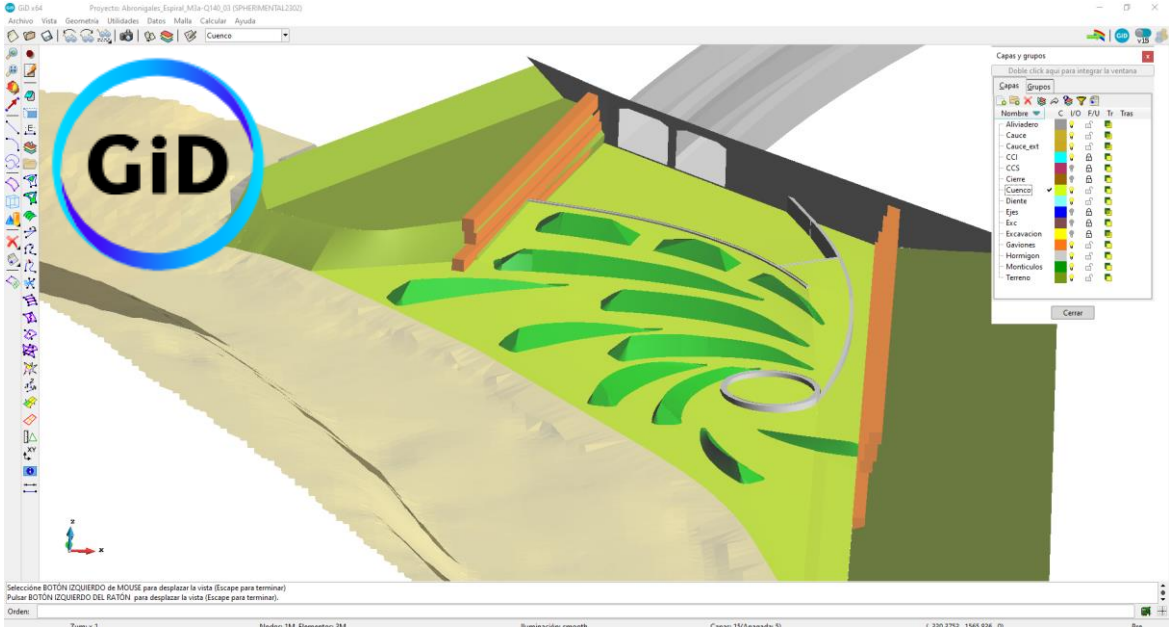
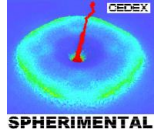


PGI VISUAL FORTRAN - CUDA

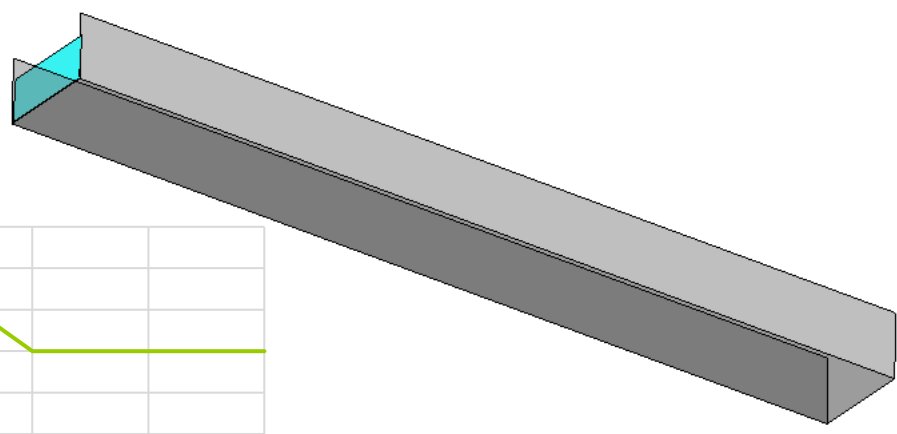
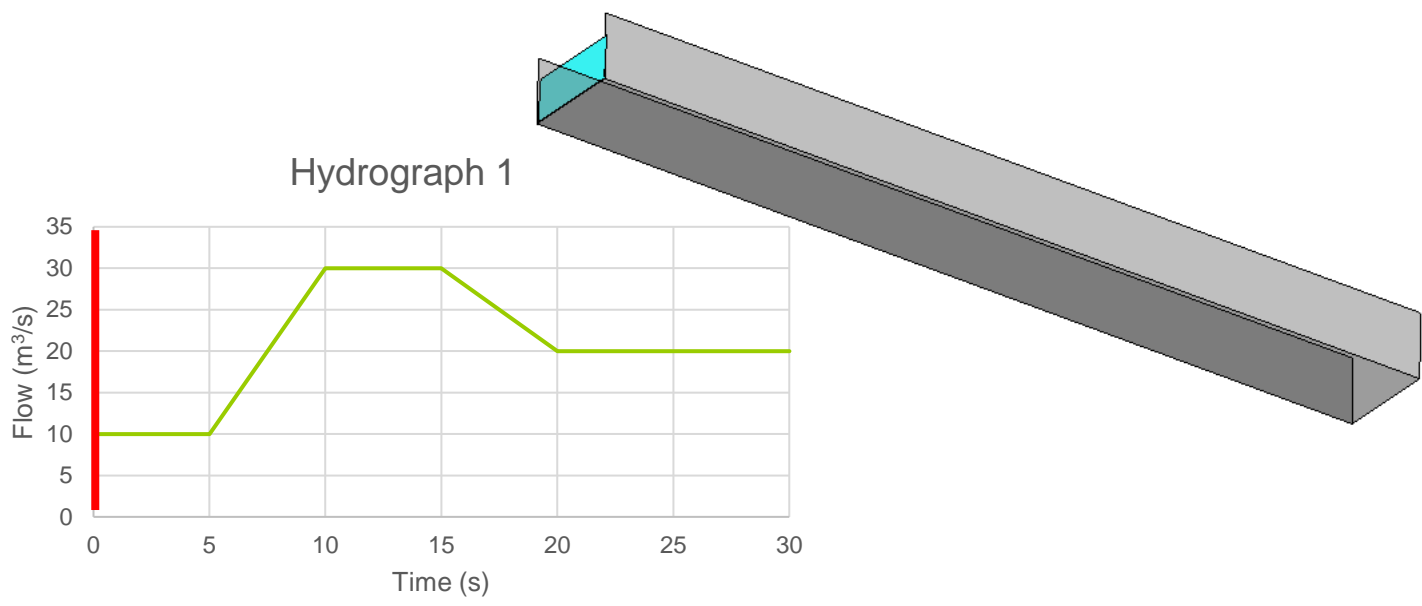
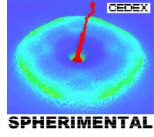
Docker
NVIDIA HPC SDK Linux

- Computation performance: $1000 \cdot 10^6$ interactions/s Nvidia GTX1080 (model of 10^6 particles and time step : 10^{-3} s)
- Computation performance: $2650 \cdot 10^6$ interactions/s Nvidia V100 (model of $9 \cdot 10^6$ particles and time step : 10^{-3} s)

PRE & POST PROCESS TOOLS



INPUT BOUNDARY CONDITION

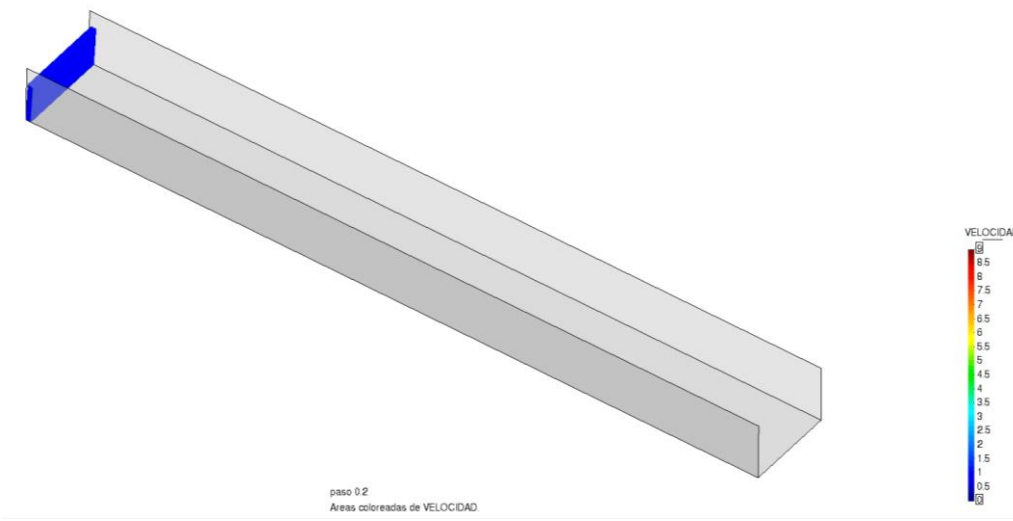
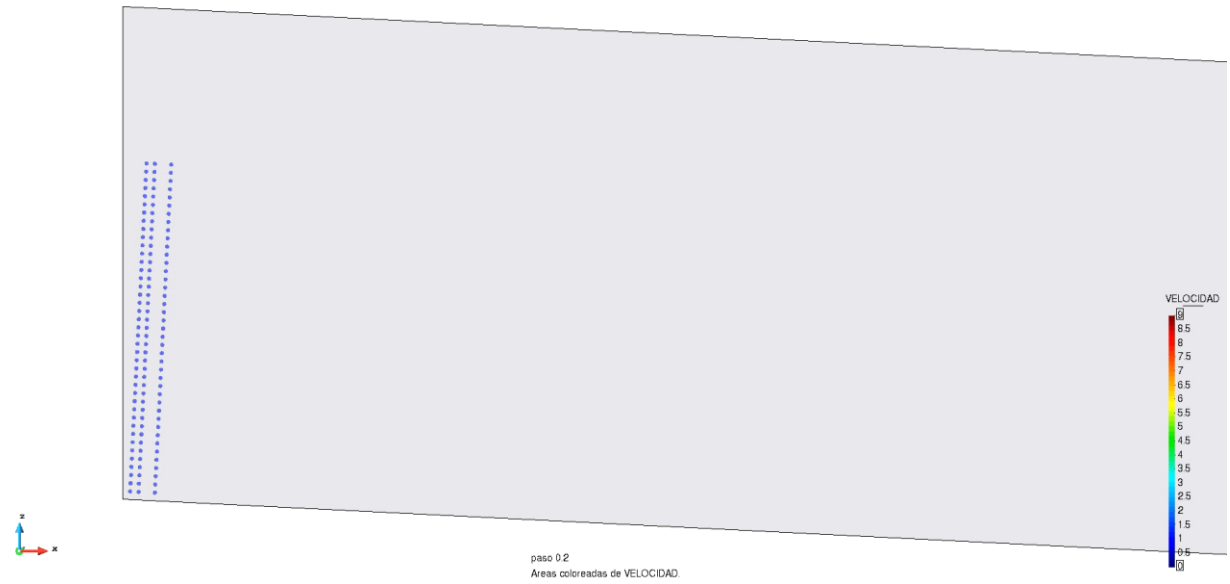


Datos

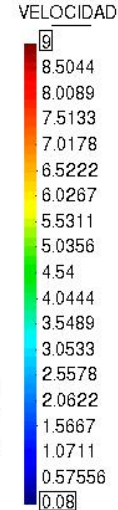
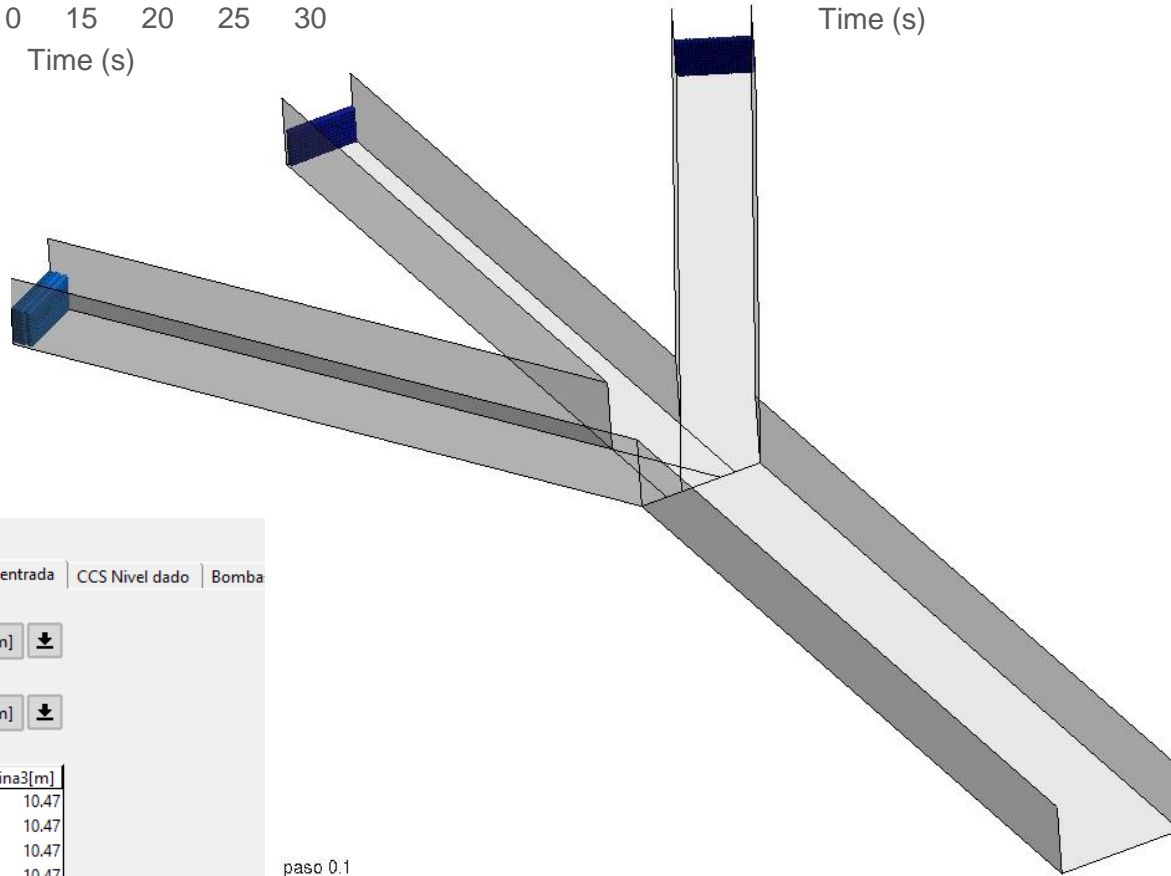
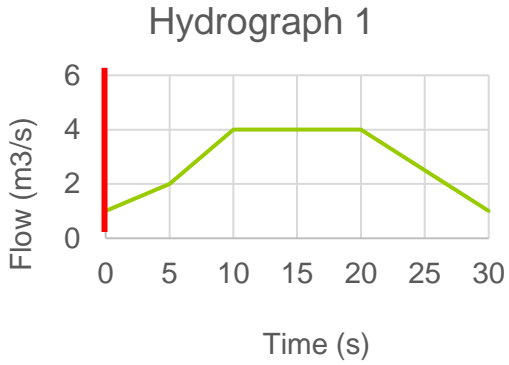
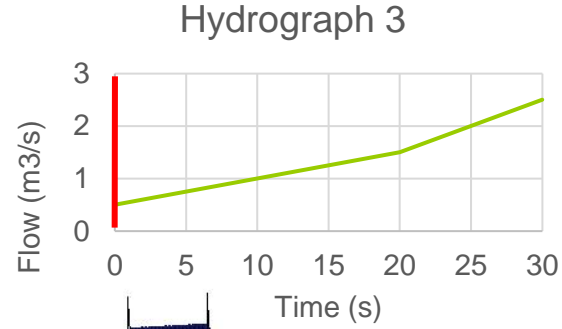
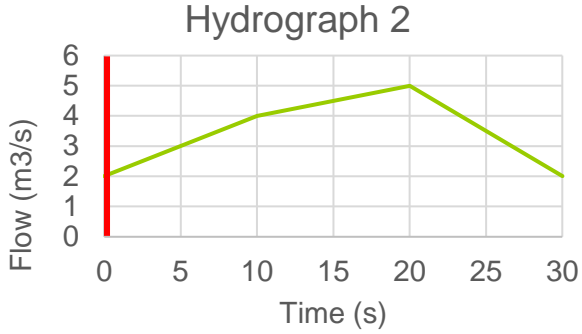
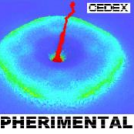
Turbulencia |
 Solidos |
 Difusión |
 Flujo Térmico |
 Transporte de sedimentos |
 Flujo con aire |
 Caudal de entrada |
 CCS Nive

Caudal Entrada 1

Hidrograma 1	Tiempo [s]	Q1[m3/s]	Cota Lamina1[m]
<input type="checkbox"/> Caudal En	0.0	10	12.05
<input type="checkbox"/> Caudal En	5	10	12.05
<input type="checkbox"/> Caudal En	10	30	12.05
<input type="checkbox"/> Caudal En	15	30	12.05
<input type="checkbox"/> Caudal En	20	20	12.05
<input type="checkbox"/> Caudal En	30	20	12.05



INPUT BOUNDARY CONDITION: MULTI INFLOW



Datos

Flujo Térmico
 Transporte de sedimentos
 Flujo con aire
 Caudal de entrada
 CCS Nivel dado
 Bomba

Caudal Entrada 1
 Hidrograma 1: Tiempo [s], Q1[m3/s], Cota Lamina1[m]

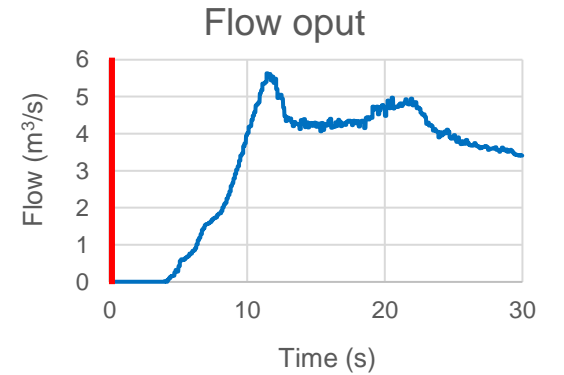
Caudal Entrada 2
 Hidrograma 2: Tiempo [s], Q2[m3/s], Cota Lamina2[m]

Caudal Entrada 3
 Hidrograma 3:

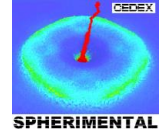
Tiempo [s]	Q3[m3/s]	Cota Lamina3[m]
0.0	0.5	10.47
10	1	10.47
20	1.5	10.47
30	2.5	10.47

Caudal En

paso 0.1
 Areas coloreadas de VELOCIDAD.



OUTPUT BOUNDARY CONDITION (CONTROLLED LEVEL)



Datos

Transporte de sedimentos
 Flujo con aire
 Caudal de entrada
 CCS Nivel dado
 Bombas
 Condición de salida forzada
 Sloshing
 Compuerta vertical

Caudal Entrada 1

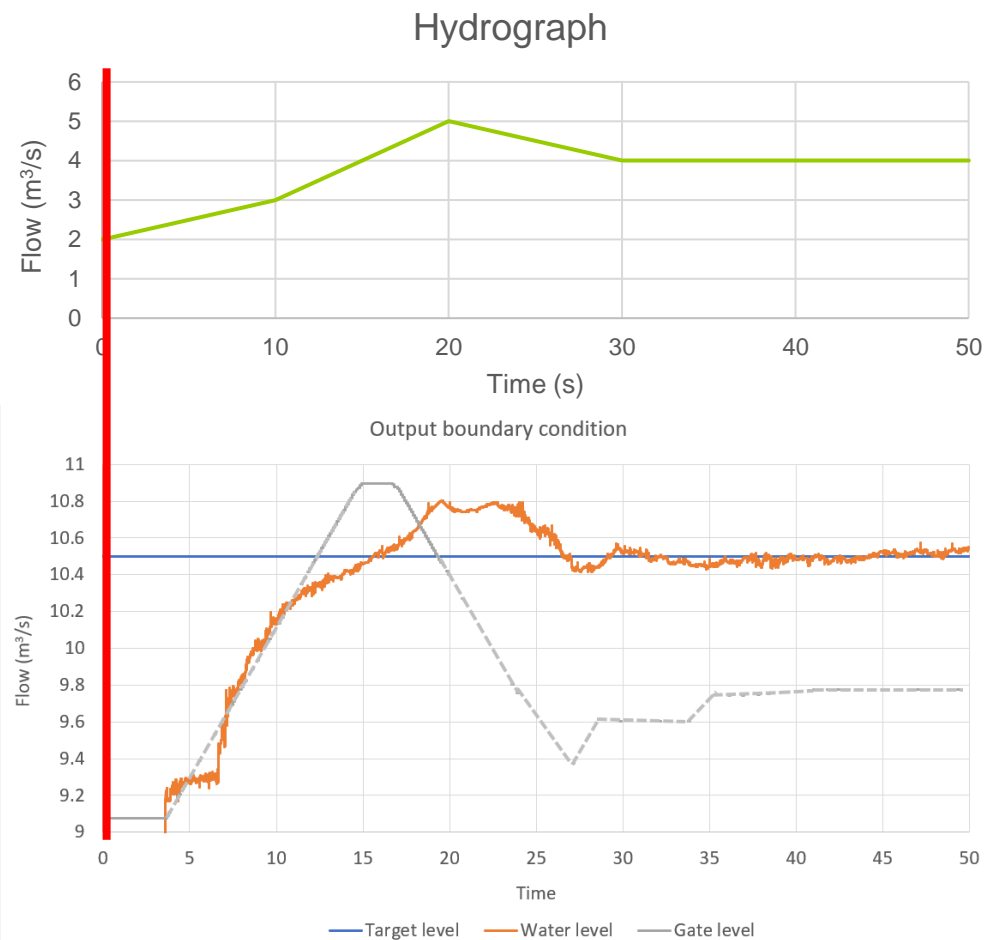
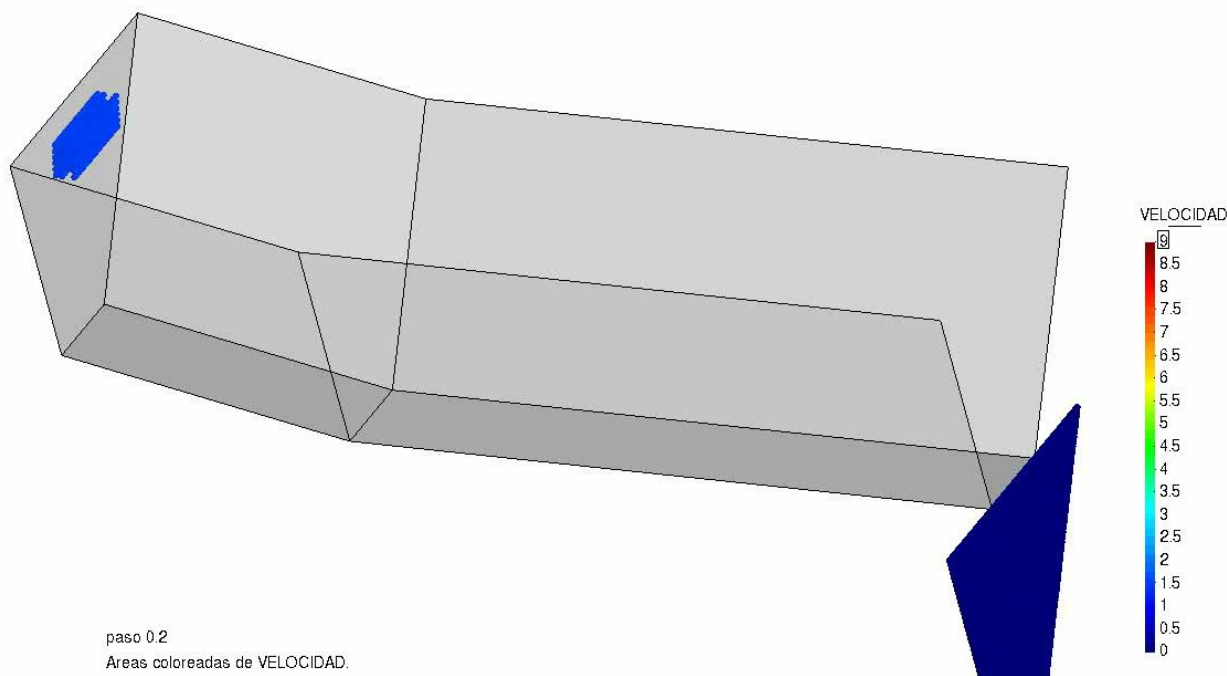
Hidrograma 1	Tiempo [s]	Q1[m ³ /s]	Cota Lamina1[m]
<input type="checkbox"/> Caudal En	0.0	2	13.5
<input type="checkbox"/> Caudal En	10	3	13.5
<input type="checkbox"/> Caudal En	20	5	13.5
<input type="checkbox"/> Caudal En	30	4	13.5

CCS Nivel Dado

Nivel de lamina objetivo [m]

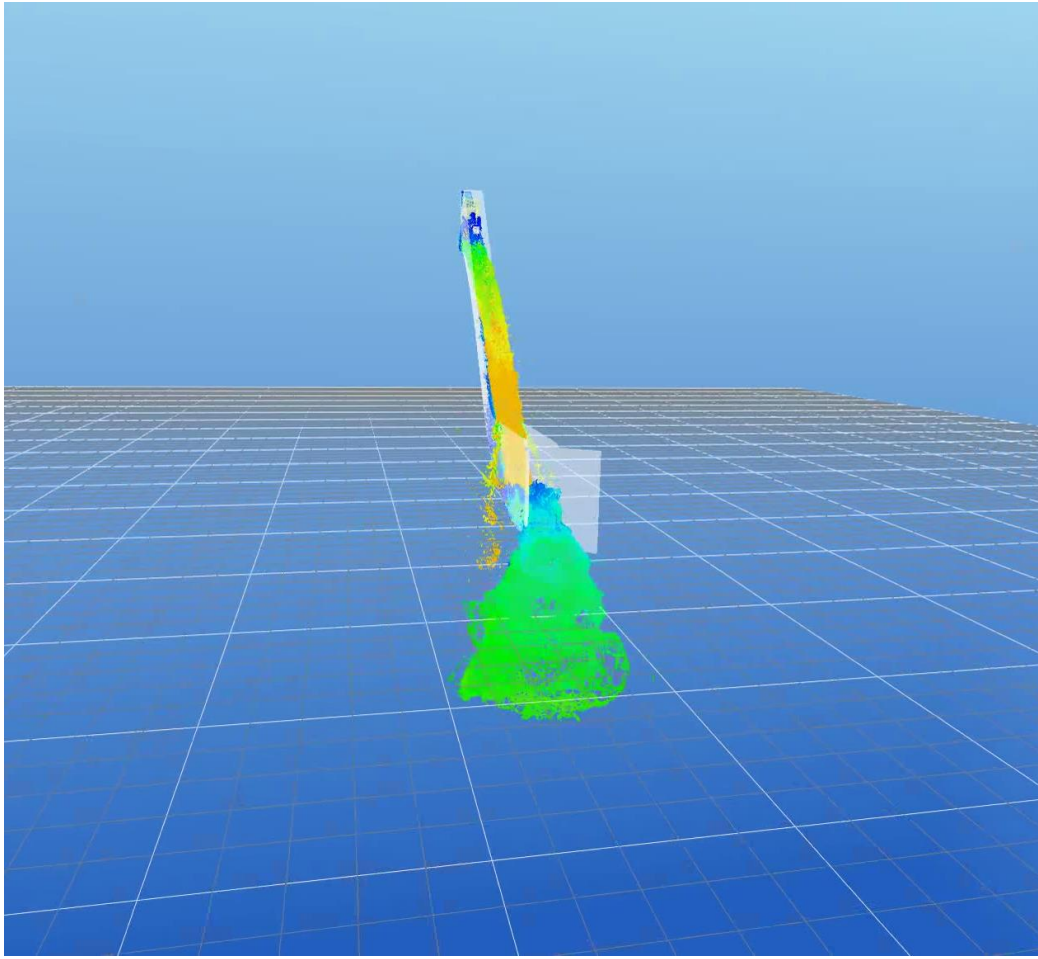
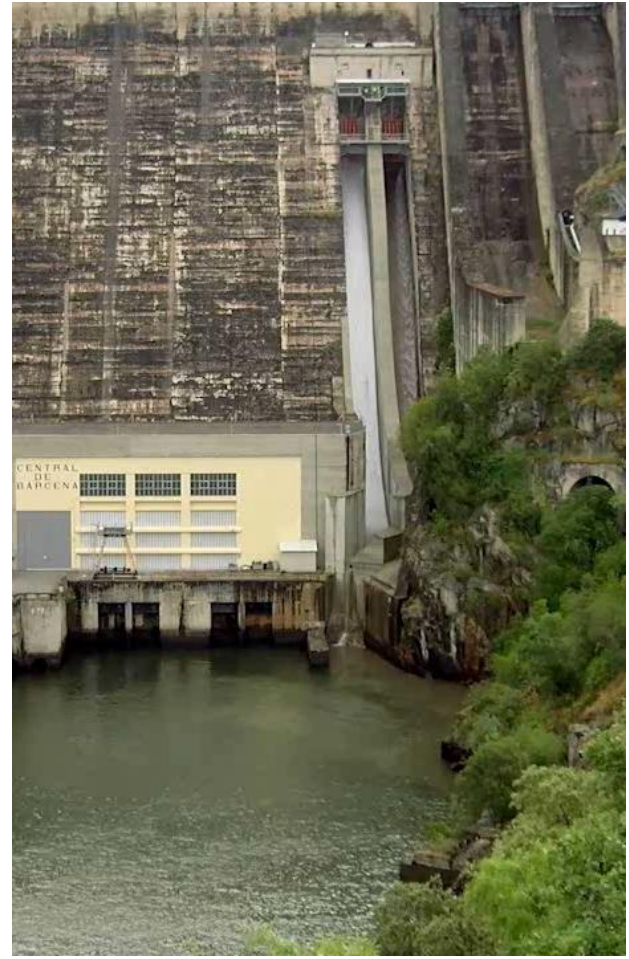
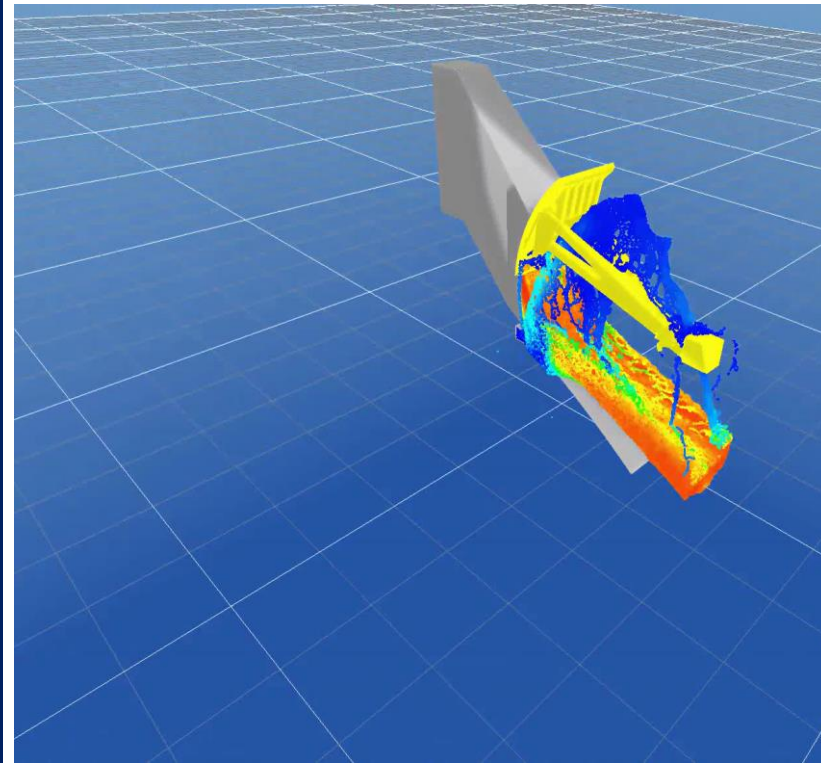
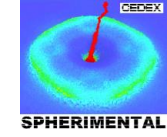
Punto control de nivel X[m]

Punto control de nivel Y[m]



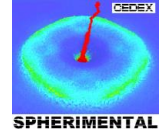
SPHERIMENTAL. HIDRODINAMICALS STUDIES

Bárcena dam intermediate outlet

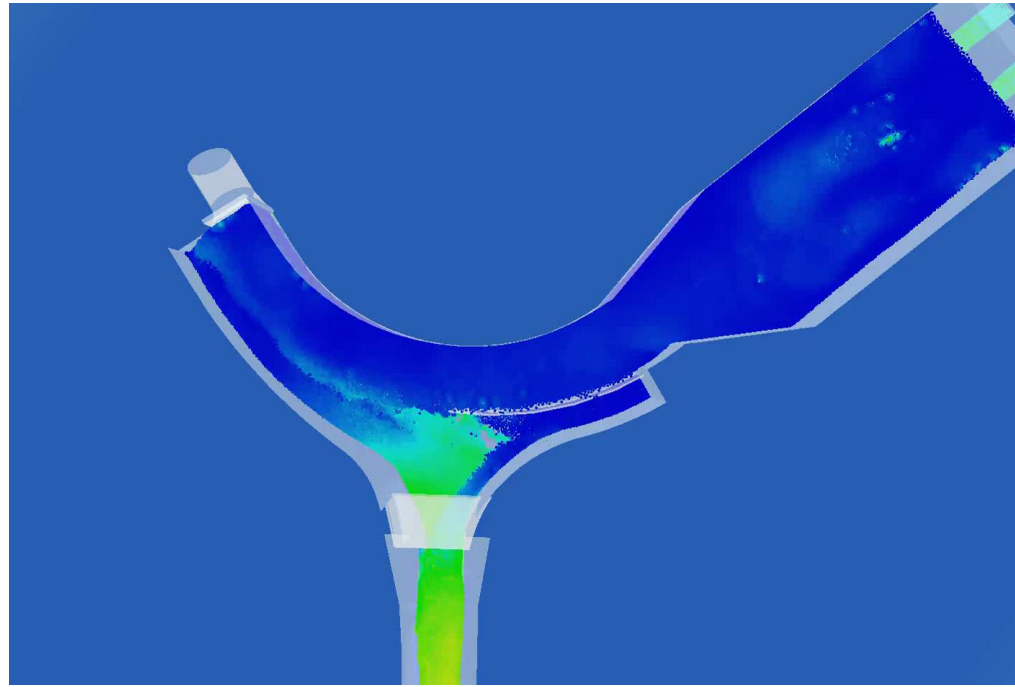




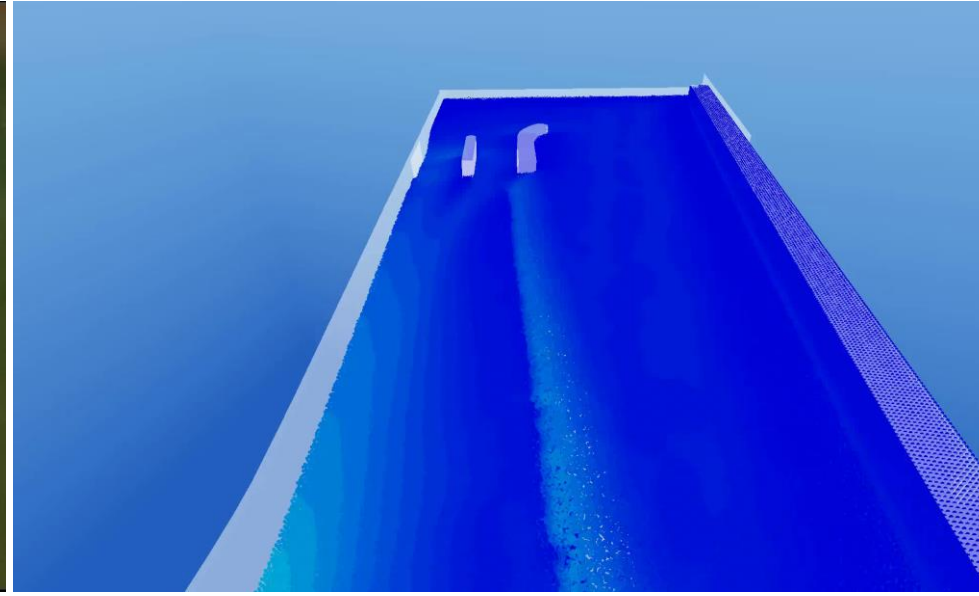
SPHERIMENTAL. HIDRODINAMICALS STUDIES



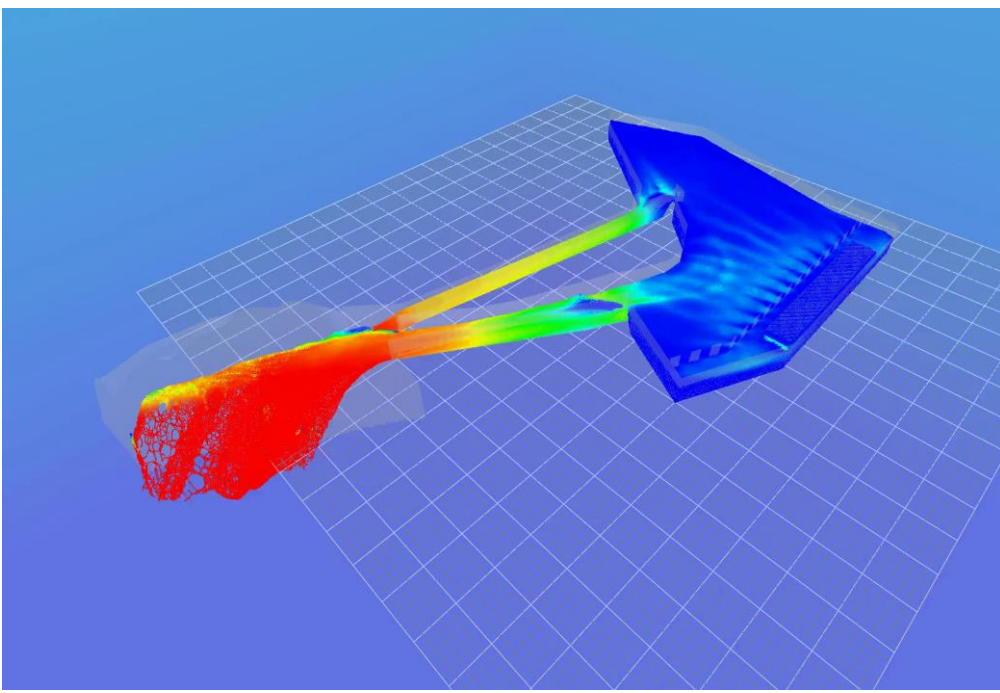
Angostura dam Spillway
(Arequipa, Perú)



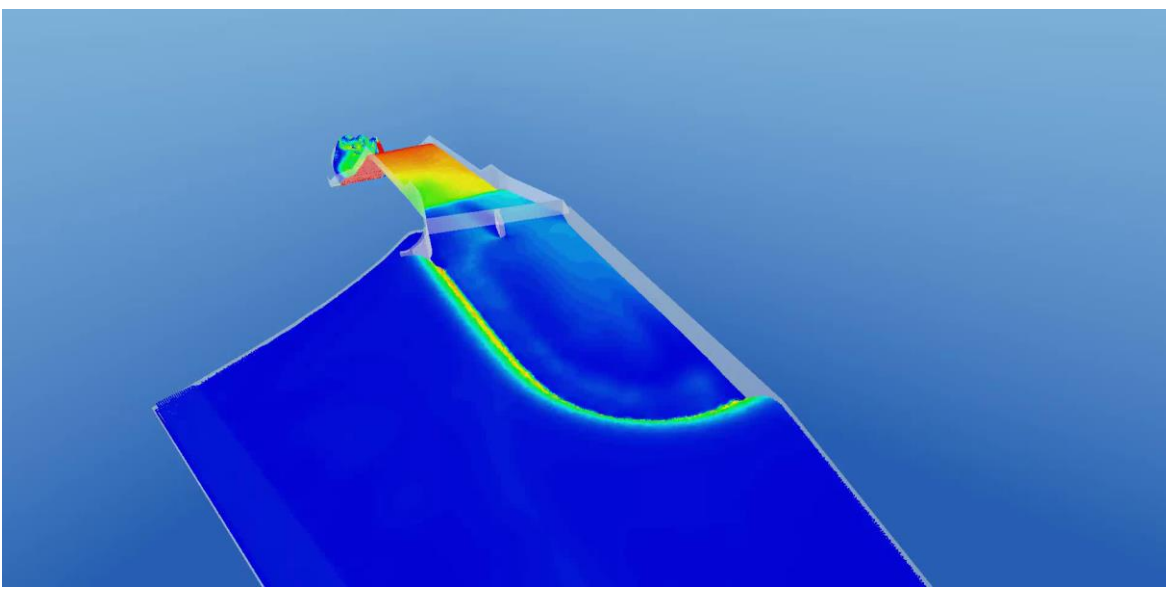
Rumblar dam Spillway
(Jaén, España)



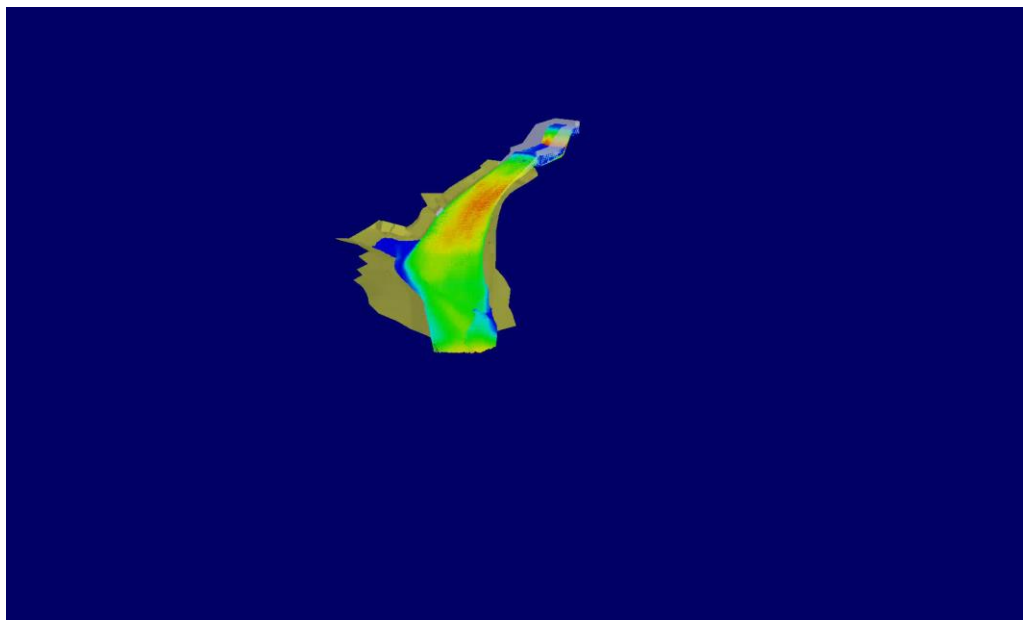
Jándula dam Spillway
(Jaén, España)



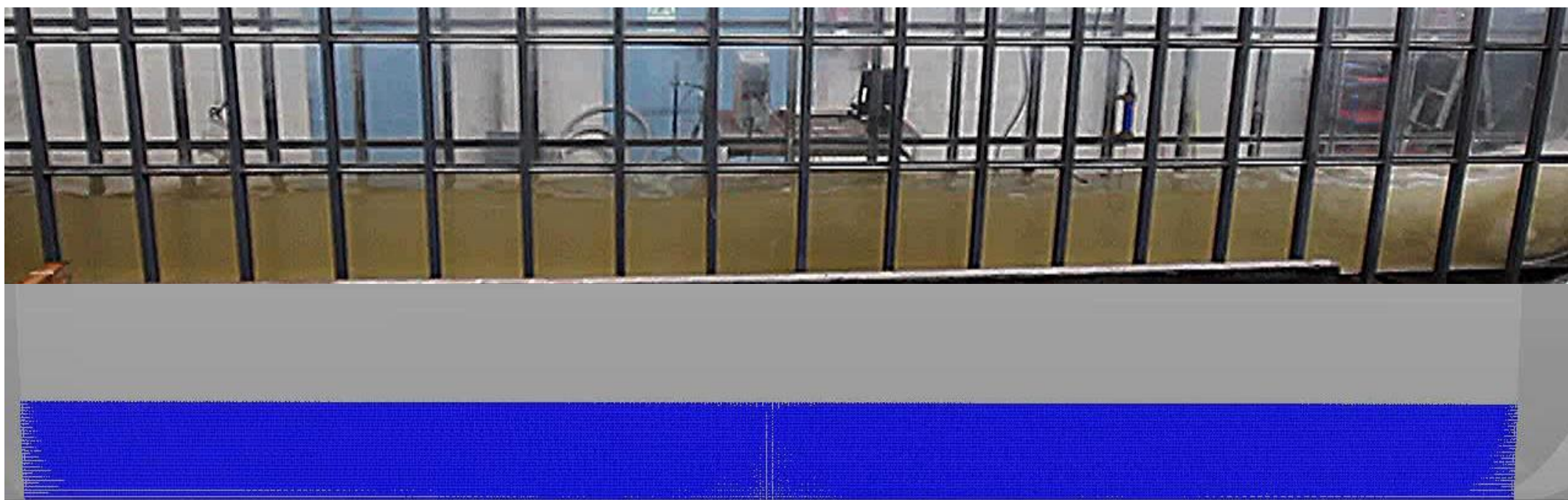
Tranco dam Spillway
(Jaén, España)



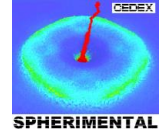
Andévalo dam Spillway (Jaén, España)



I+D EMULSIONA



PUMPS: OUTPUT BOUNDARY CONDITION



GID x64 Proyecto: CB-SMD-DEF10-5B-01 (SPHERIMENTAL203)

Archivo Vista Geometría Utilidades Datos Malla Calcular Ayuda

CCI-MDETS

Datos

Bombas

Datos bombas	x[m]	y[m]	z[m]	Fi[m]	QB[m3/s]
380.6253629839559	22.08890575733558	93.42	0.6	1.3	
382.9415333362054	20.60386202082120	93.42	0.6	1.3	
385.0583658528779	17.9177086193272	93.42	0.6	1.3	
386.4138814117998	16.1976279324055	93.42	0.6	1.3	
387.9179466210145	14.289045252396669	93.42	0.6	1.3	

Aceptar Cerrar

$V = f(Q, D)$

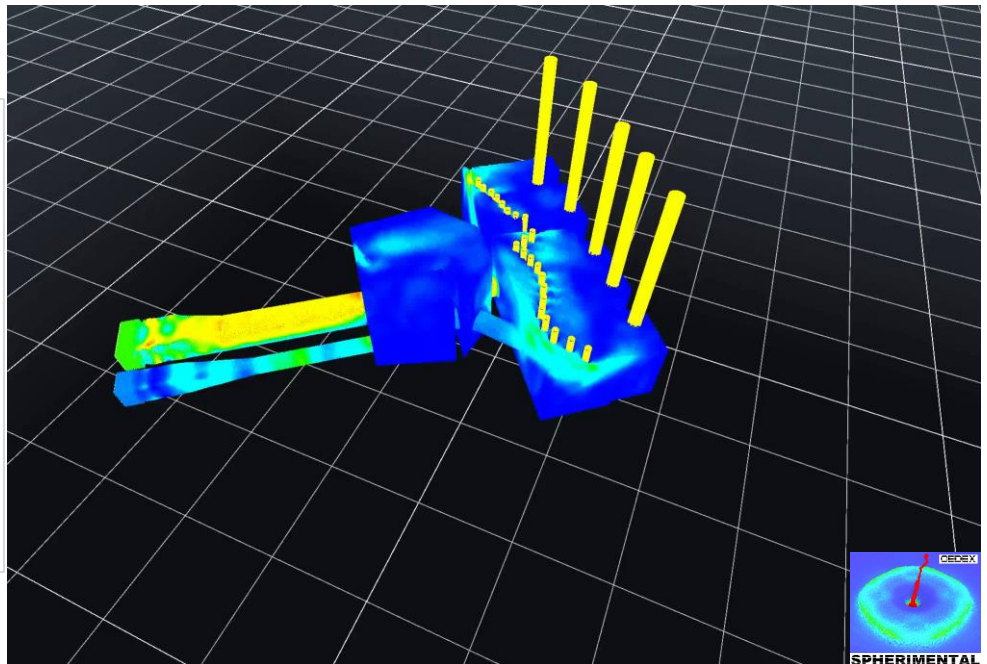
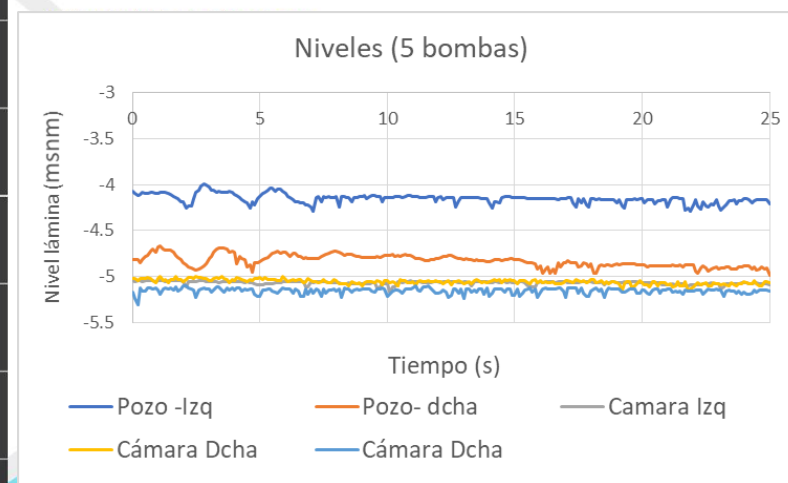
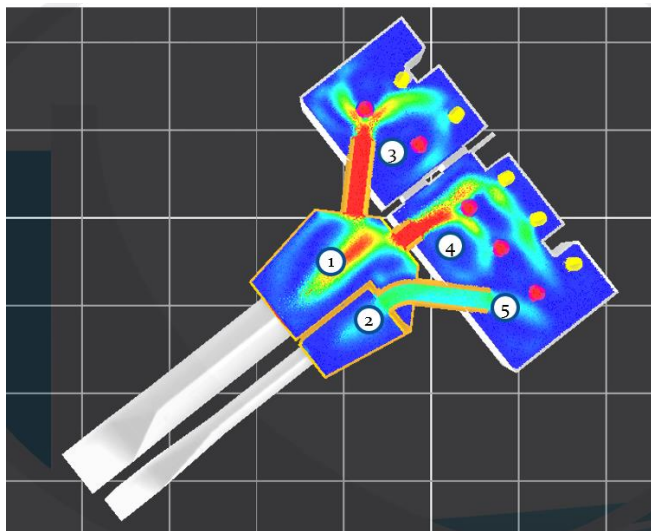
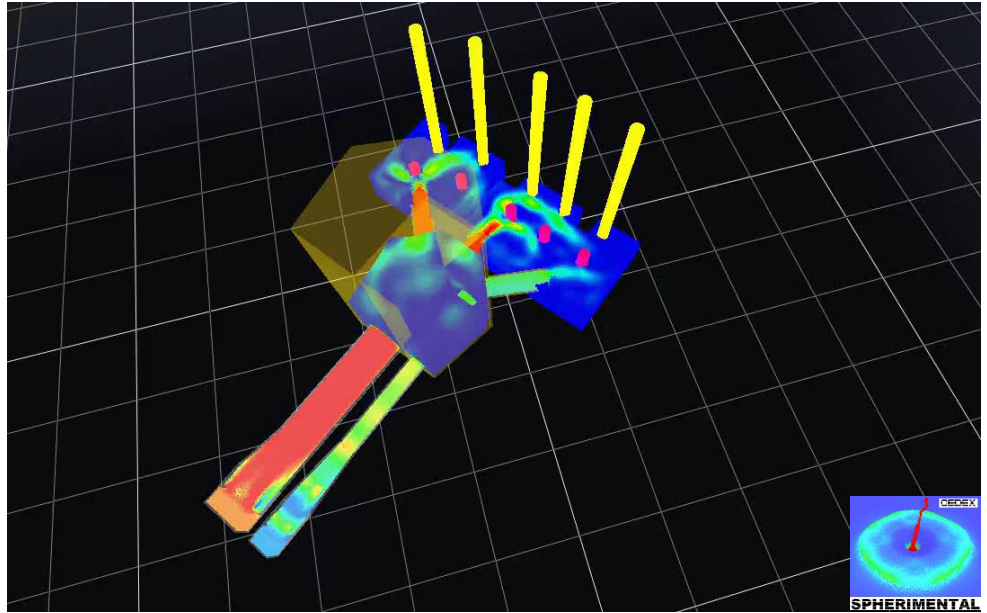
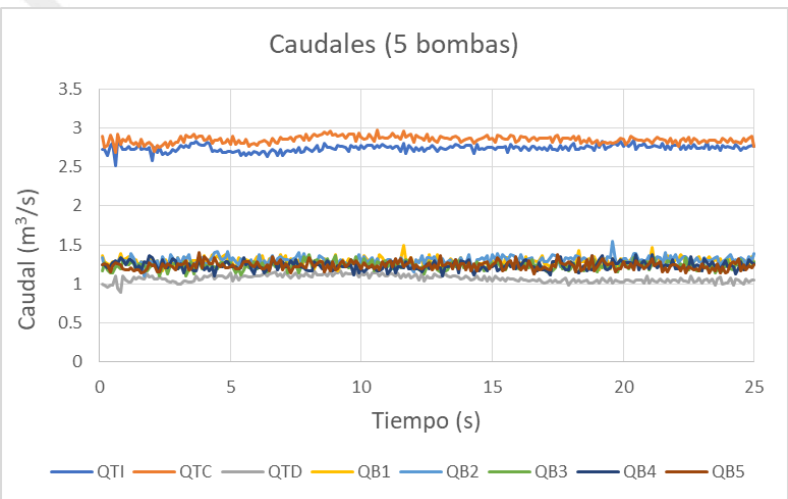
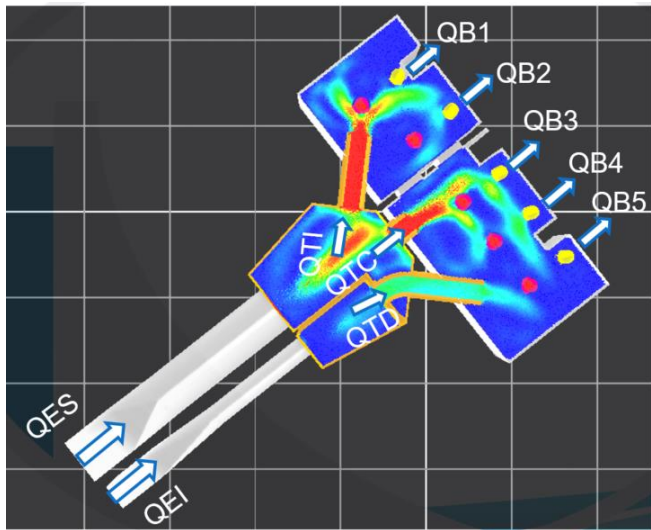
Orden: Zum: x 0.74 Nodos: 1M, Elementos: 2M Iluminación: flat Capas: 19(Apagada: 12) (308.0054, 156.6025, 0) Pre

Escribe aquí para buscar.

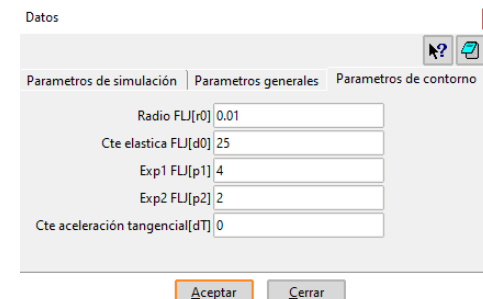
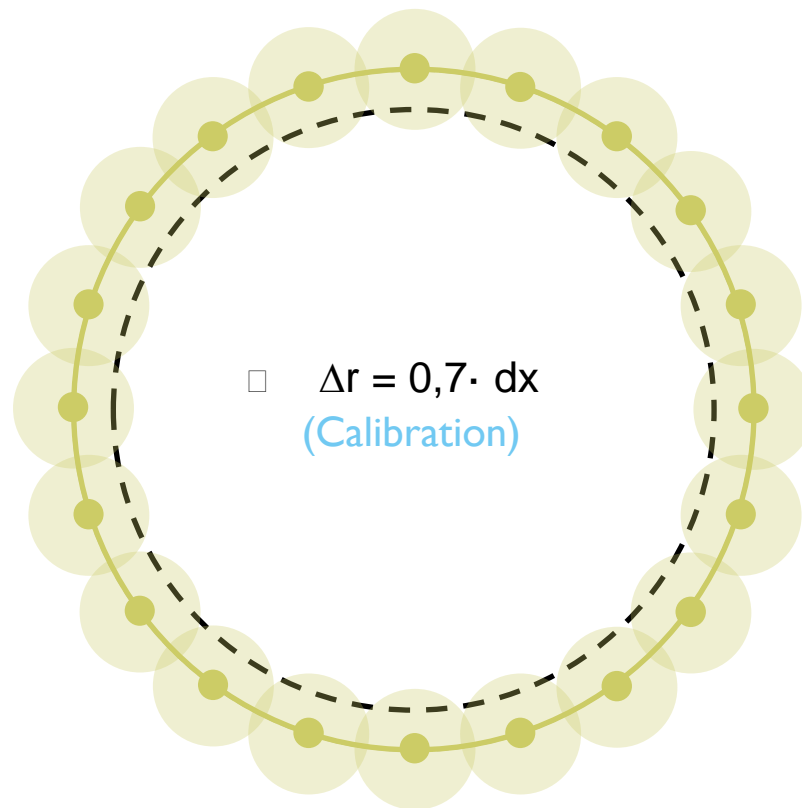
14:15 29/12/2023

PUMPS: OUTPUT BOUNDARY CONDITION

Casa Blanca Pump Station (La Habana, Cuba)



Boundary resizing



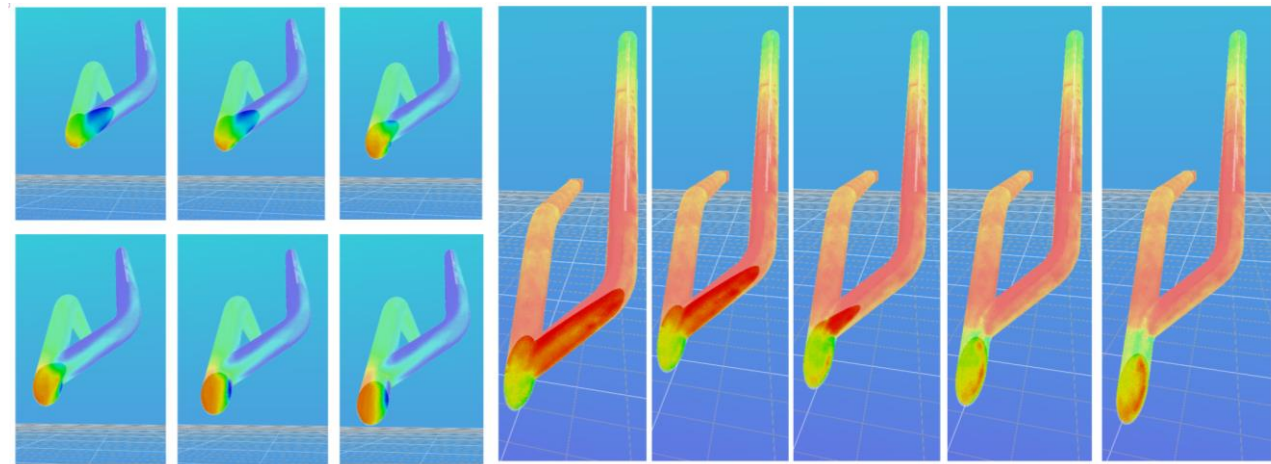
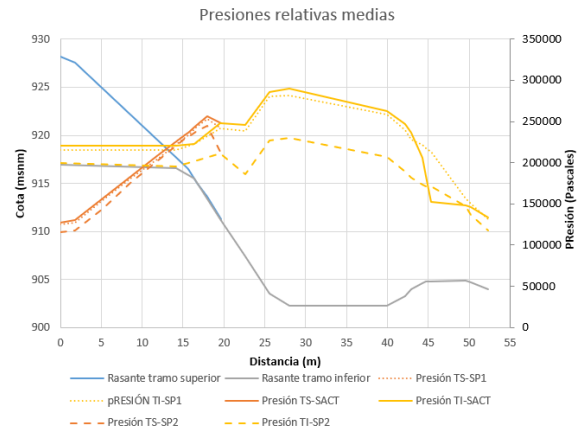
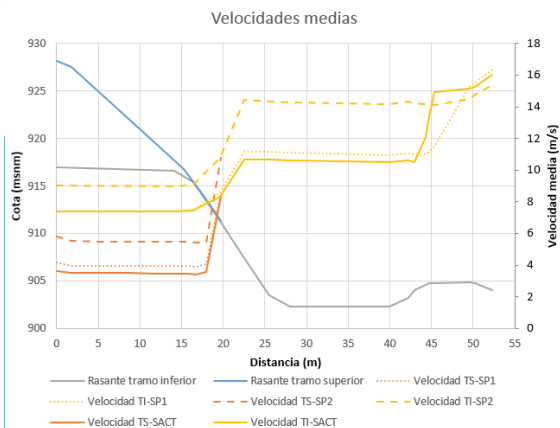
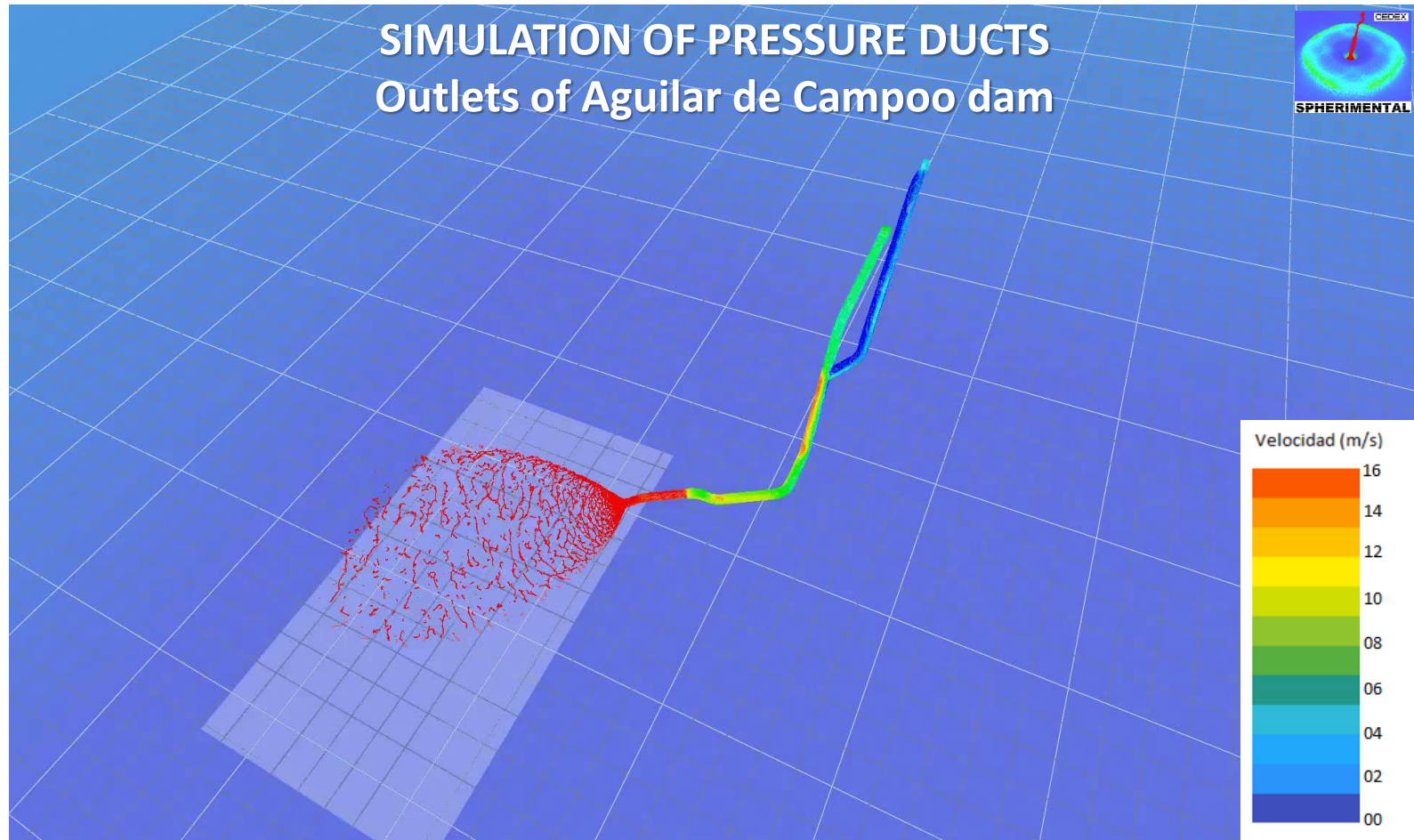
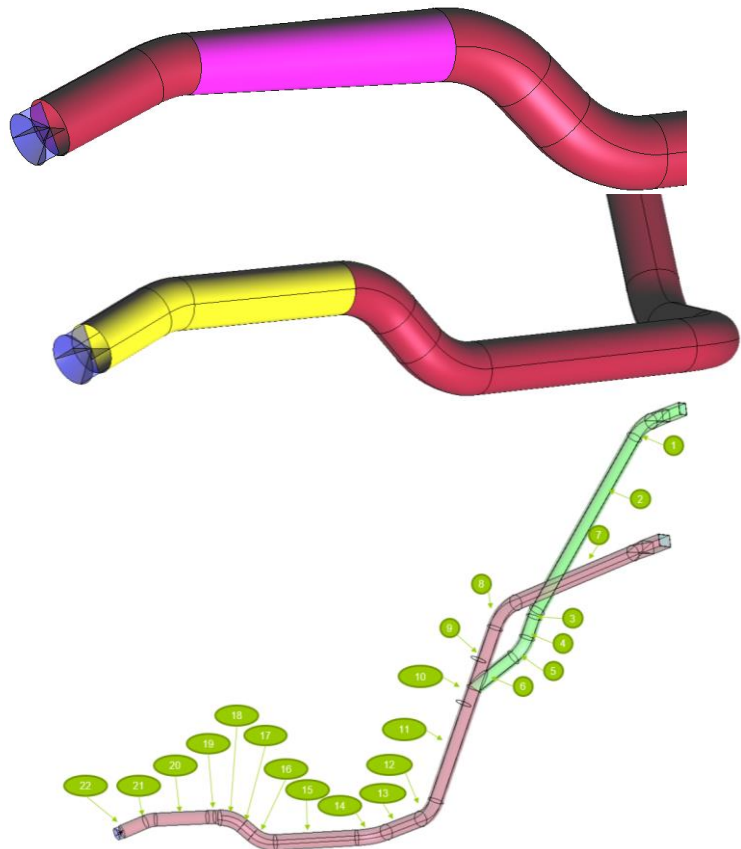
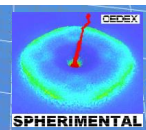
Braking effect on boundaries

$$f(\vec{r}) = \underbrace{d_0 \left(\left(\frac{r_0}{r} \right)^{p_1} - \left(\frac{r_0}{r} \right)^{p_2} \right) \frac{\vec{r}}{r^2}}_{\text{F. Lennard-Jones}} - \underbrace{C_{rough} \frac{v_{part}^2}{dx} \frac{\vec{v}_{part}}{v_{part}}}_{\text{F. friction}} + \underbrace{a_{acel} \frac{\vec{v}_{part}}{v_{part}}}_{\text{F. lubrication}}$$

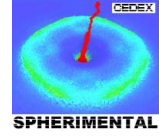
If $\vec{r} \cdot \vec{v} > 1$
 $a_{acel} = 0,05 \cdot g$
 (Calibration)

SIMULATION OF PRESSURE DUCTS

Outlets of Aguilar de Campoo dam



ROTATIONS IN MOVING BOUNDARIES. Application to Sloshing



Datos

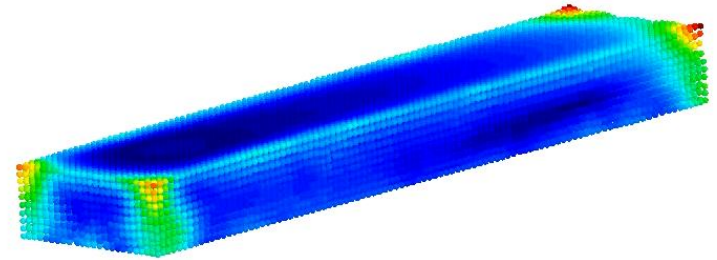
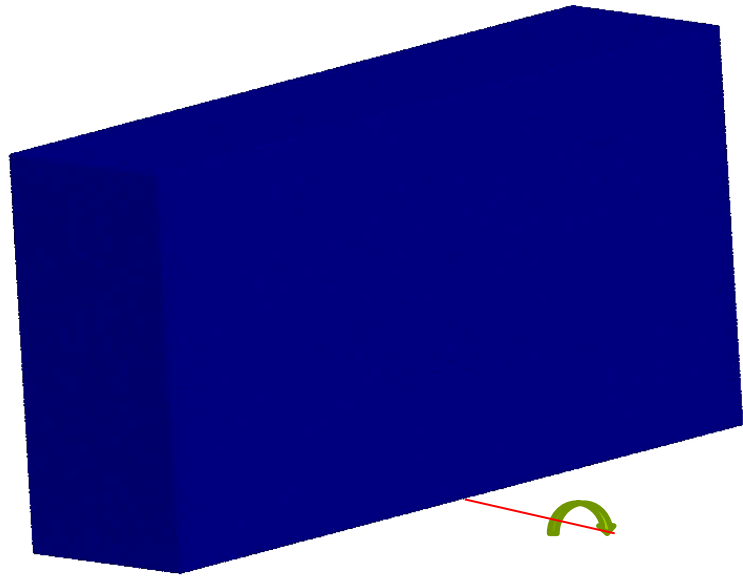
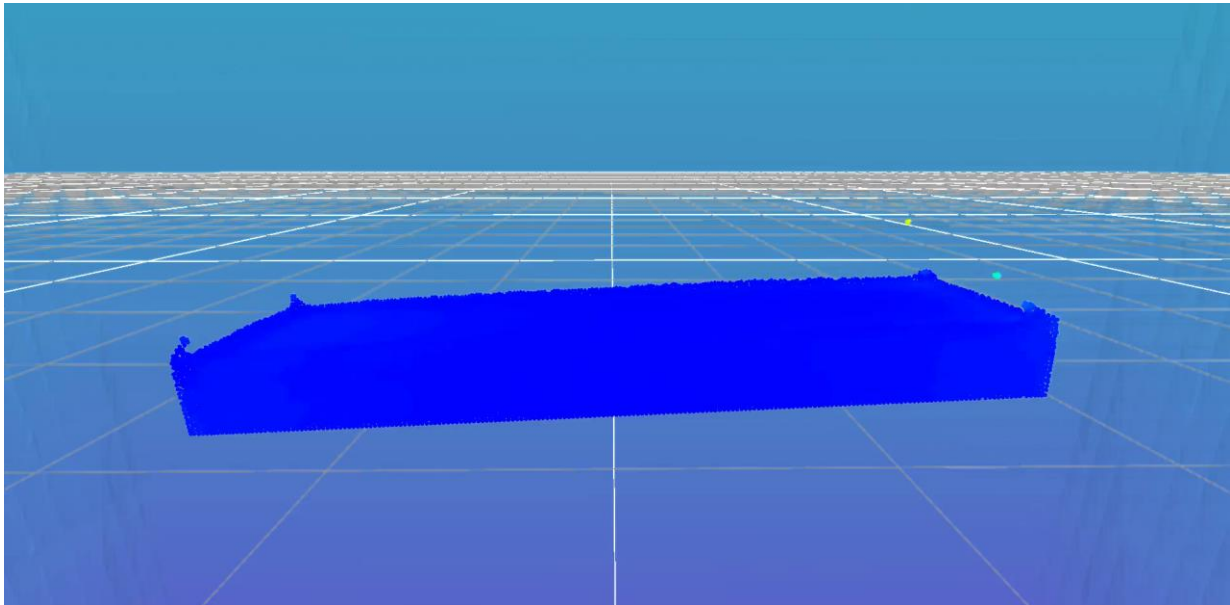
Sloshing

Dirección eje x: 0
Dirección eje y: 1
Dirección eje z: 0
Punto eje x: 0
Punto eje y: 0
Punto eje z: 0

Velocidad Angular constante
Tiempo de inicio del movimiento [s]: 1
Velocidad angular [rad]: 0.1
Angulo maximo[grados]: 10

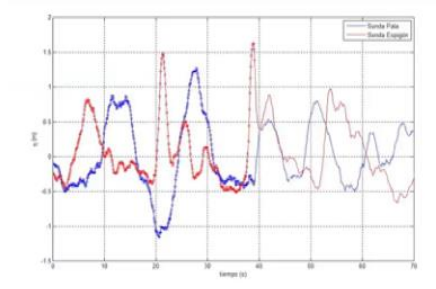
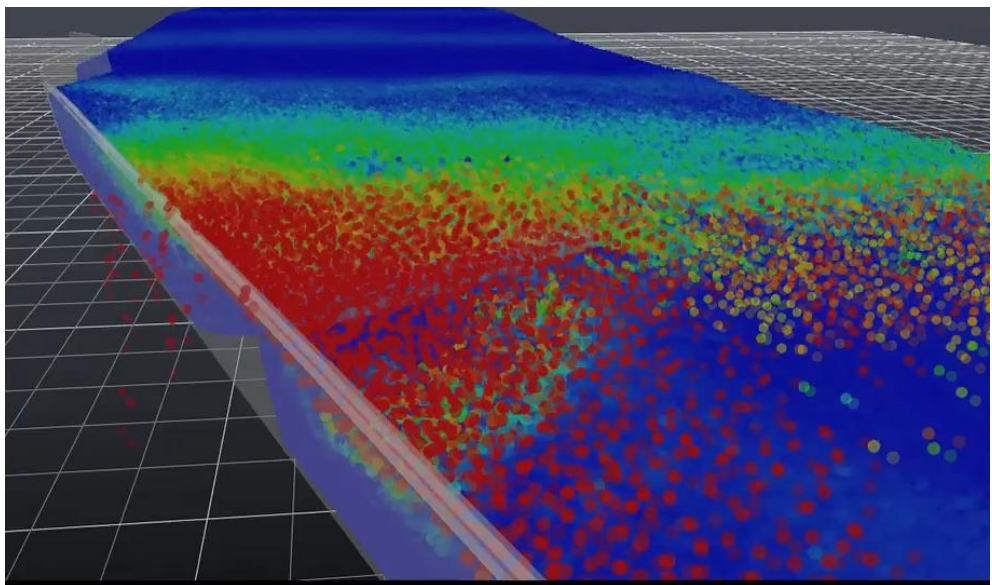
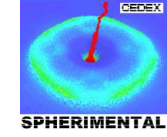
Serie temporal sloshing
Serie angular: Tiempo [s] Angulo [grados]

Aceptar Cerrar



COASTAL ENGINEERING APPLICATIONS

Study of wave overflow on the Sardinero promenade



Datos

Bombas
 Condición de salida forzada
 Sloshing
 Compuerta vertical
 Paleta oleaje
 Auto Llenado

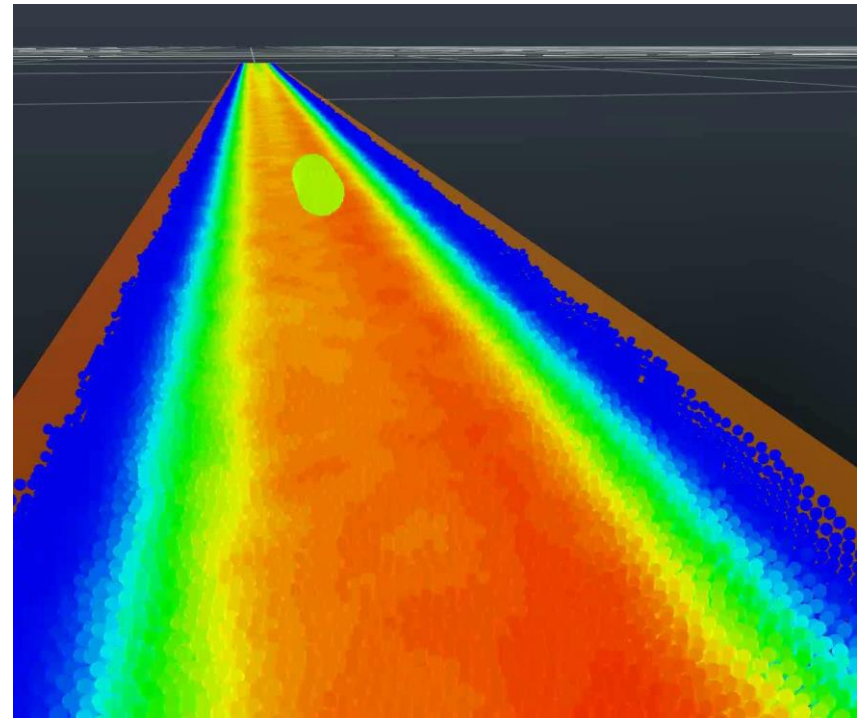
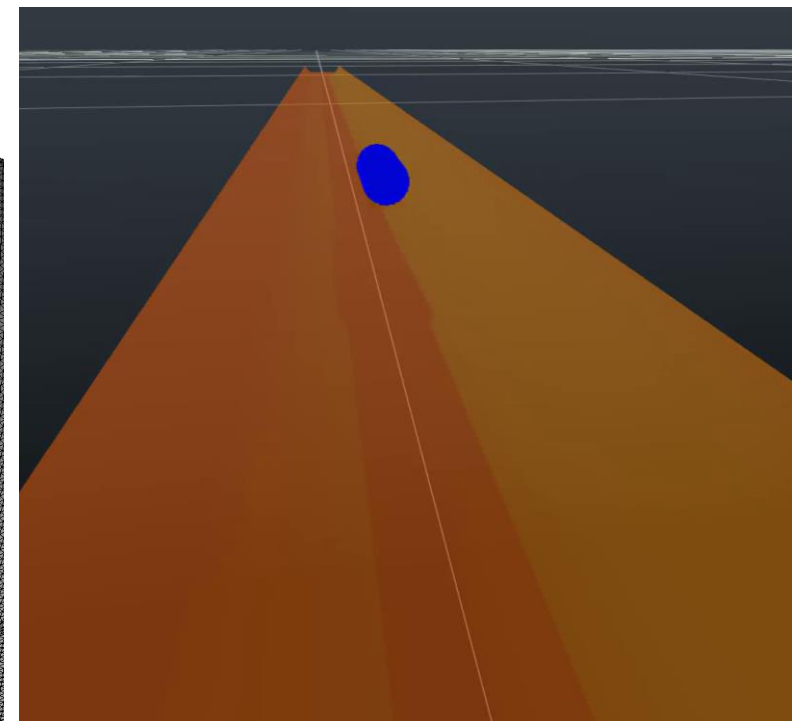
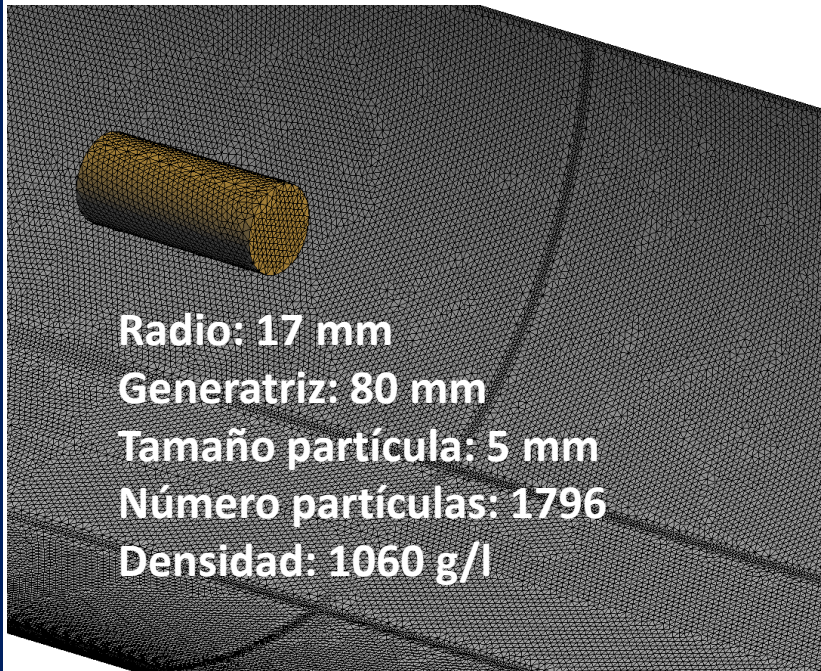
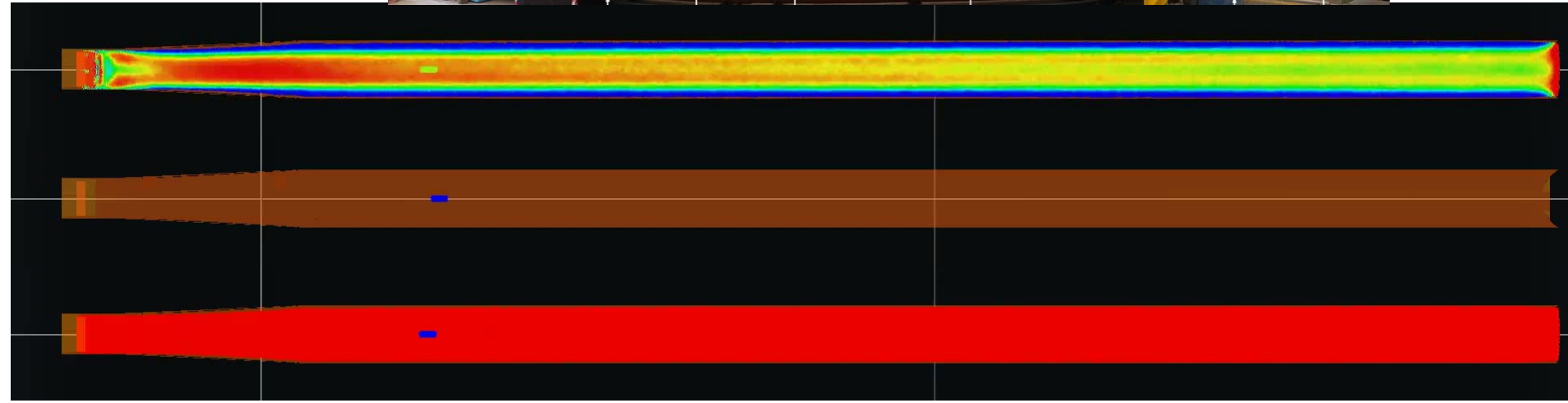
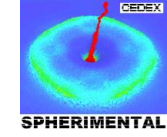
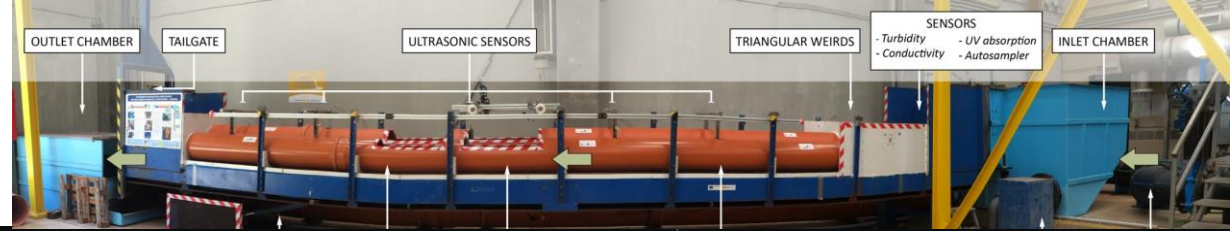
Serie periodica
 Semiamplitud[m]
 Periodo[s]

Serie Temporal
 Serie

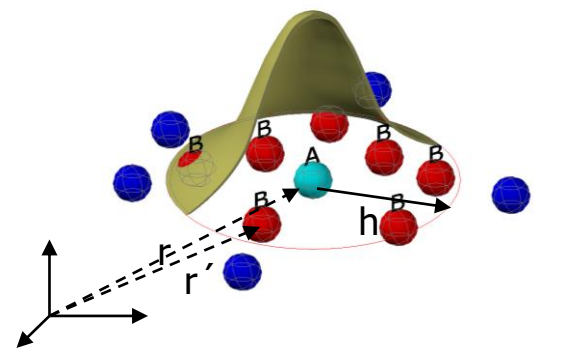
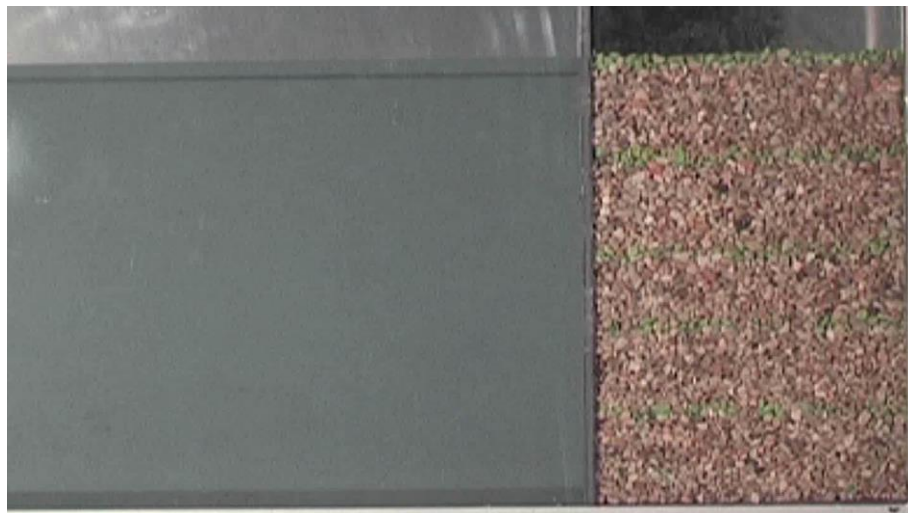
Tiempo de estabilizacion[s]



SOLIDS APPLICATION TO GROSS SOLIDS



TWO-PHASE FLOW. WATER-SEDIMENT BEGINNING OF MOVEMENT



If (Tipo A = Tipo B) Tipo 1 -> (NS+Viscosity)

If (Tipo A = Tipo B) Tipo 2 -> (NS+internal friction)

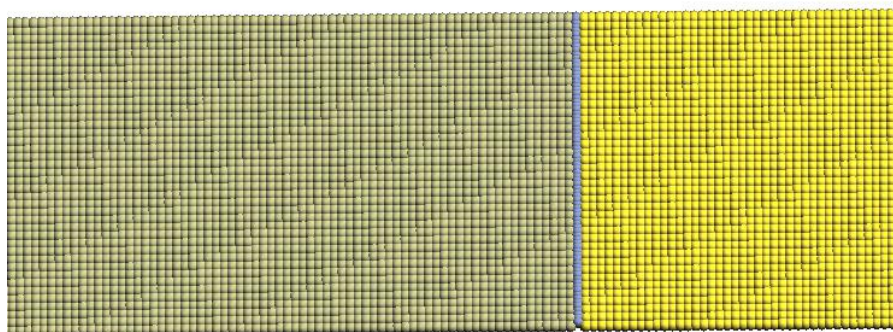
$$Acel_{fricción} = -g \operatorname{tg} \varphi \frac{\bar{v}}{|\bar{v}|}$$

¿ Drag start? = f(acceleration)

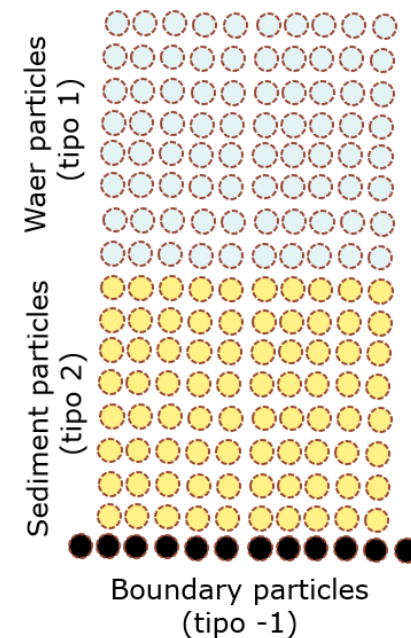
$$Acel_{critica} = Coef_{Shields} \left(\frac{\rho_s - \rho_w}{\rho_w} \right) * I_{porosidad} \frac{D_*}{dx} g$$

$Acel_A < Acel_{crit}$ -> Sediment particle no movement

$Acel_A > Acel_{crit}$ -> NS+internal friction

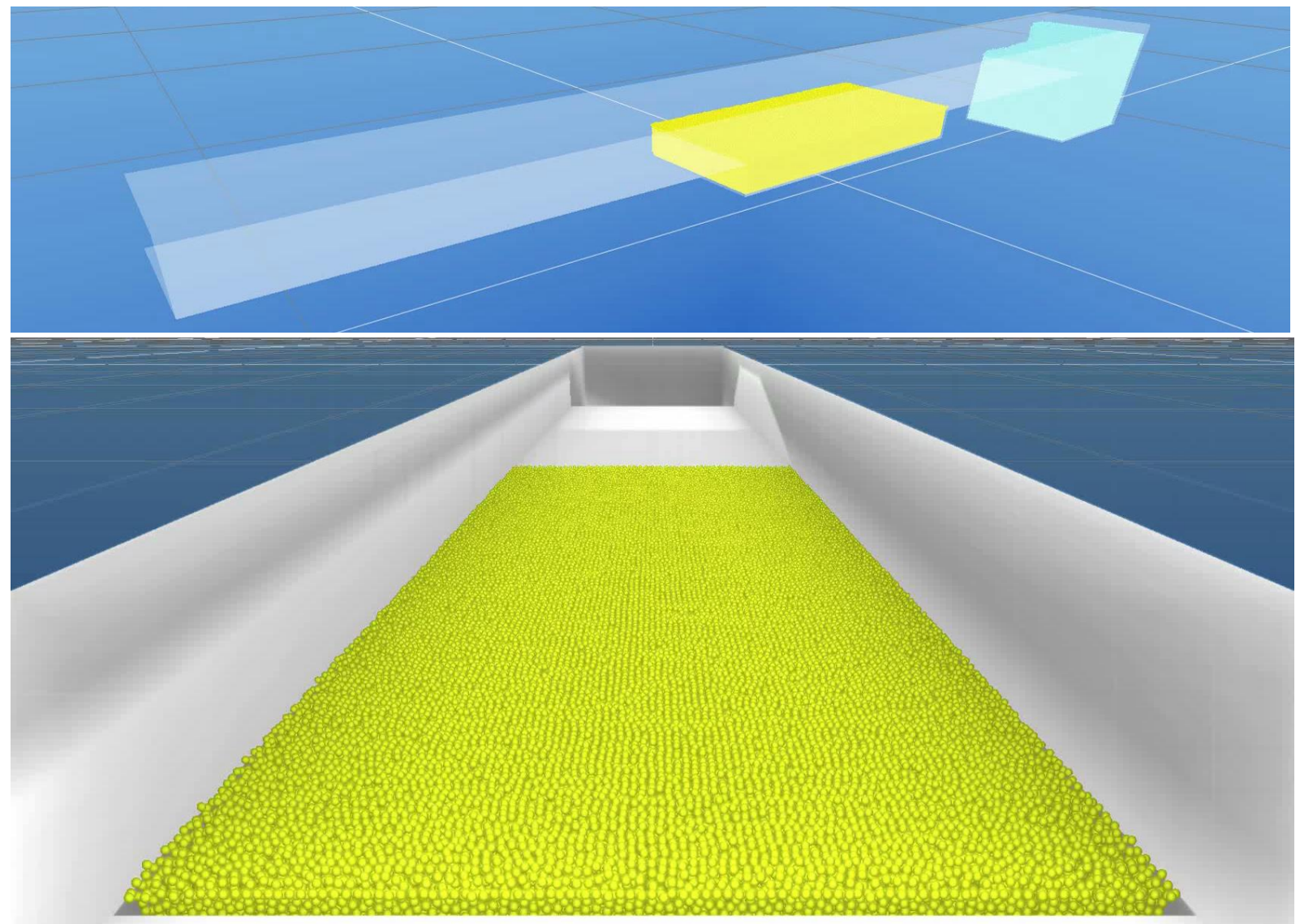
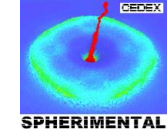


$$\rho_{water} = 1000 \text{ kg/m}^3$$

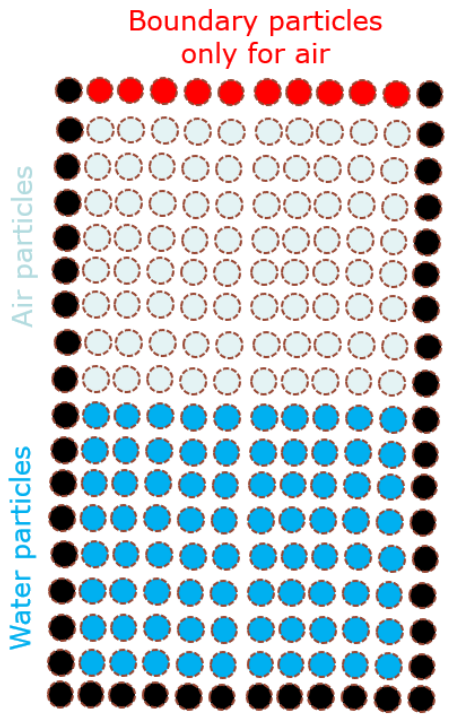
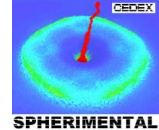


$$\rho_{sediment} = 2650 \text{ kg/m}^3$$

TWO-PHASE FLOW. WATER-SEDIMENT SEDIMENT TRANSPORT



TWO-PHASE FLOW. WATER-AIR



$$P = \frac{\rho c_s^2}{\gamma} \left(\left(\frac{\rho}{\rho_0} \right)^\gamma - 1 \right)$$

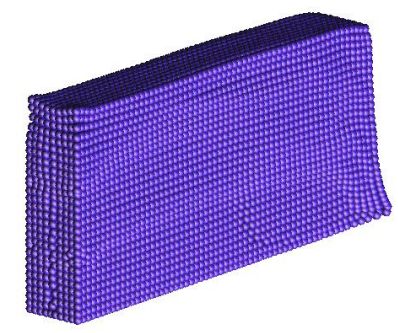
$P_{atm} = 101300 \text{ Pascales}$
 $\rho_{aire} = 1.5 \text{ kg/m}^3$
 $c_{aire} = 340 \text{ m/s}$
 $\gamma_{aire} = 1.4$
 Water surface

$$\frac{d\rho_a}{dt} = -\rho_a \sum_b \frac{m_b}{\rho_b} (v_b - v_a) \mathcal{N} W_{ab}$$

$$\frac{dv_a}{dt} = -\sum_b m_b \left(\frac{p_b}{\rho_b^2} + \frac{p_a}{\rho_a^2} + \Pi_{ab} \right) \nabla W_{ab}$$

$\rho_{agua} = 1000 \text{ kg/m}^3$
 $c_{agua} = 1500 \text{ m/s}$
 $\gamma_{agua} = 7$

$$\frac{dv_a}{dt} = -\sum_b m_b \left(\frac{p_a + p_b}{\rho_a \rho_b} + \Pi_{ab} \right) \nabla W_{ab}$$



Fixed boundary particles

Condiciones de contorno ✕

Contorno Fijo ? 📄

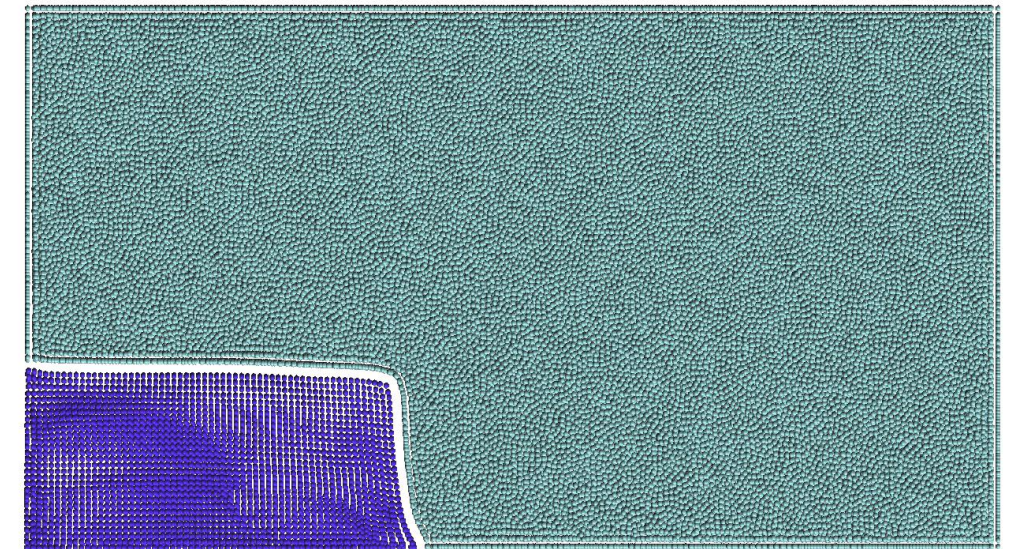
DIMENSION 3D

Coefficiente Rugosidad Crough 0.000

Contorno solo para aire

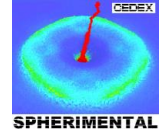
Asignar
Entidades ▼
Dibujar ▼
Desasignar ▼

Cerrar



TWO-PHASE FLOW. WATER-AIR

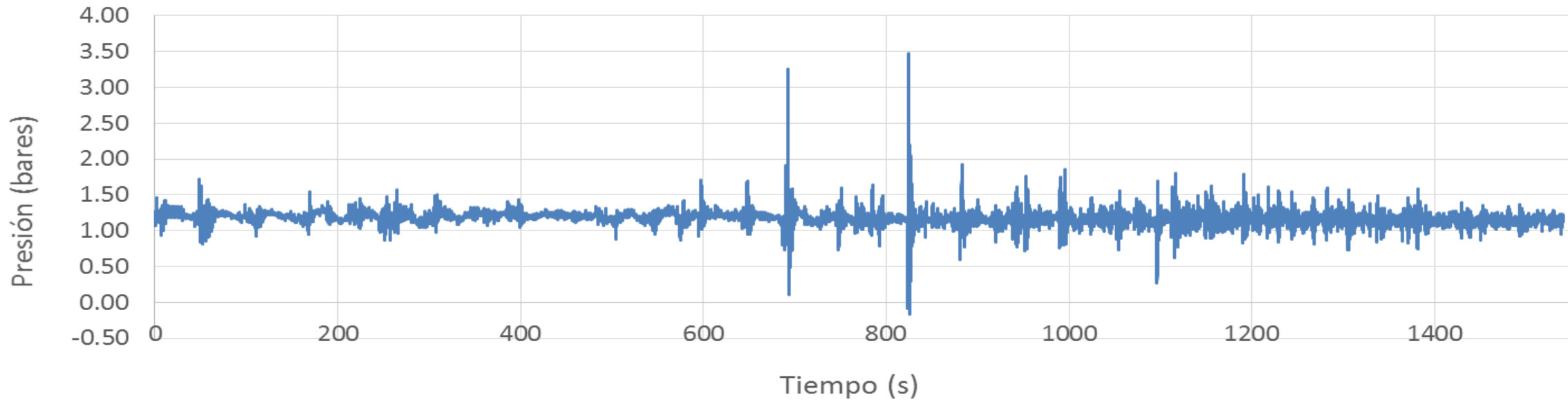
Nagore spillway



Nagore. Flow in head. Air bags in the outlet duct

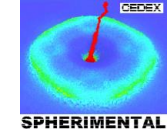


Presión en clave de galería (Valores de prototipo)

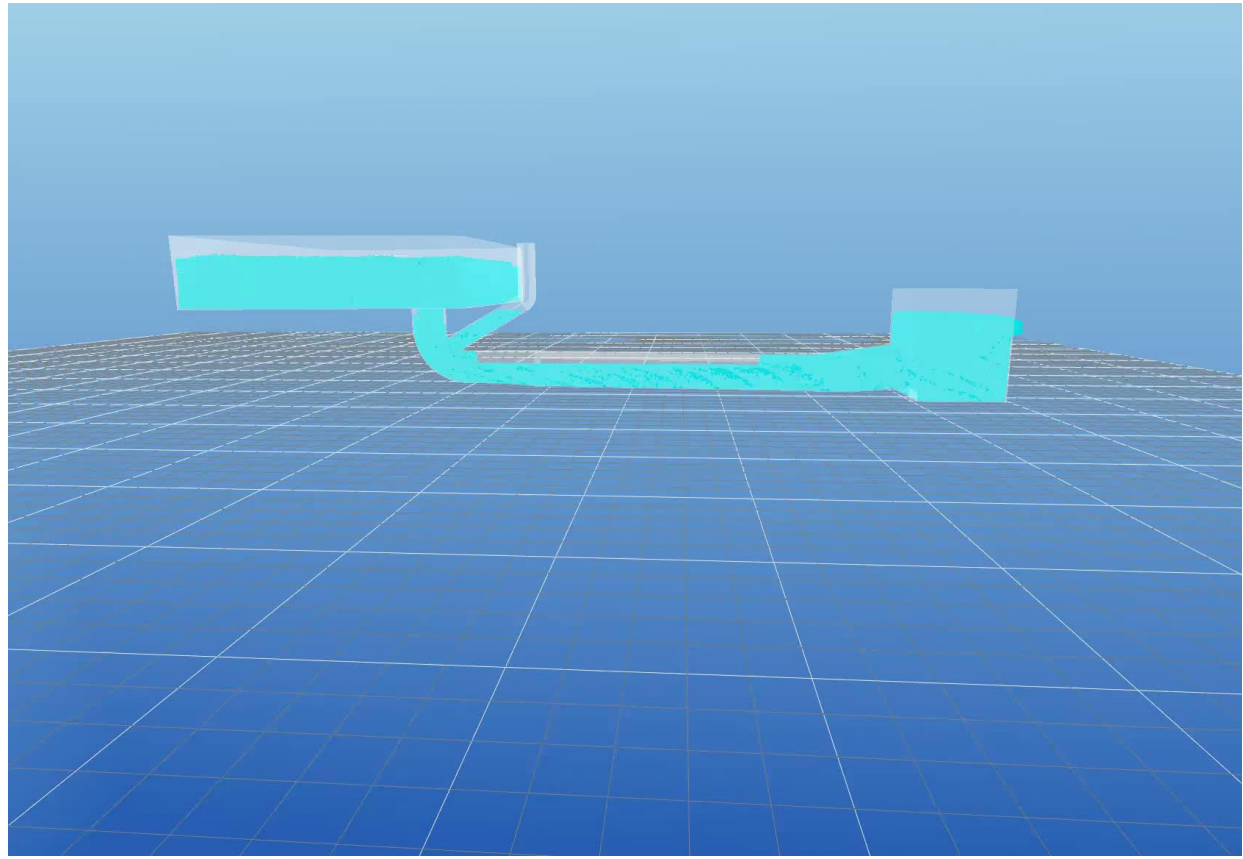
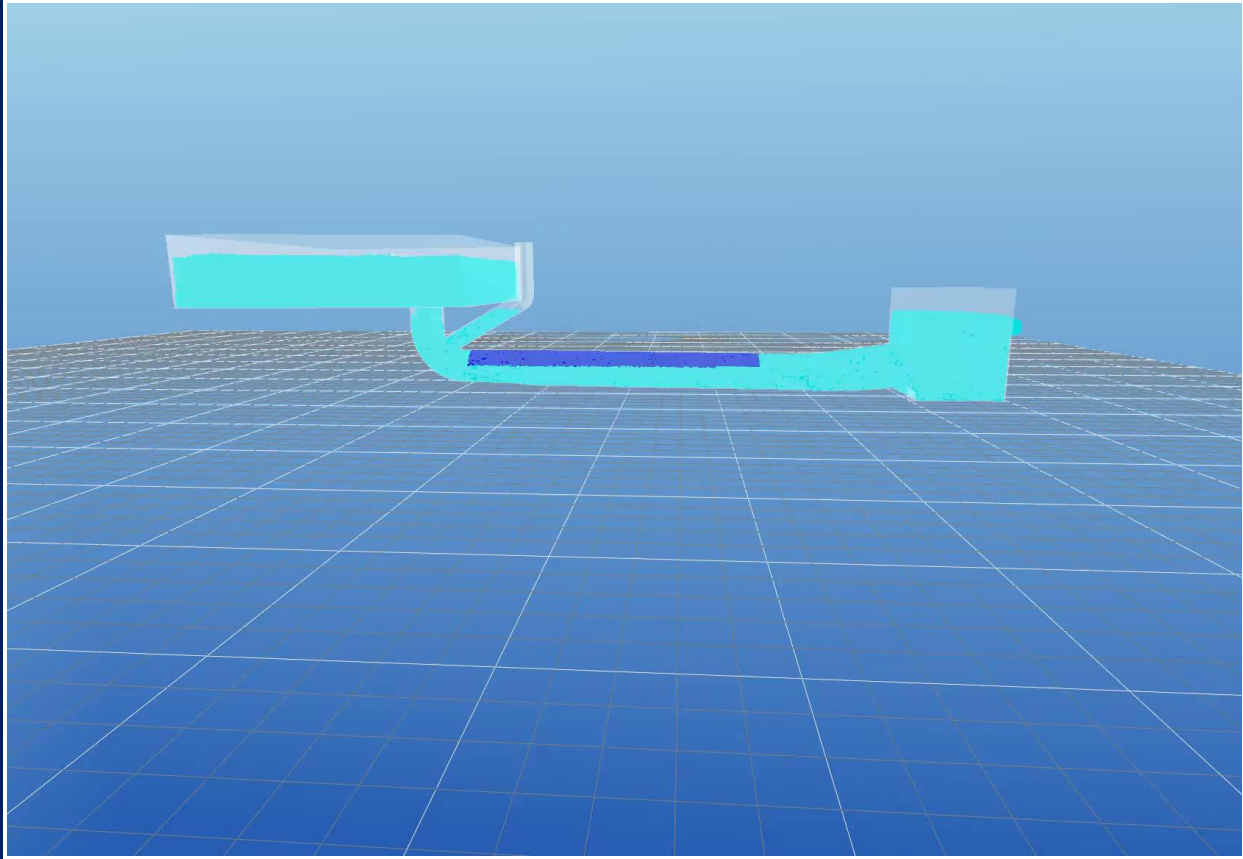


TWO-PHASE FLOW. WATER-AIR

Nagore spillway



Pressure due to air bags



TWO-PHASE FLOW. WATER-AIR

Nagore spillway

AIR OUTLET DUCTS



Thanks for your kind attention