# Integrated modelling of CSO discharges in the Miño River at Lugo (Spain)

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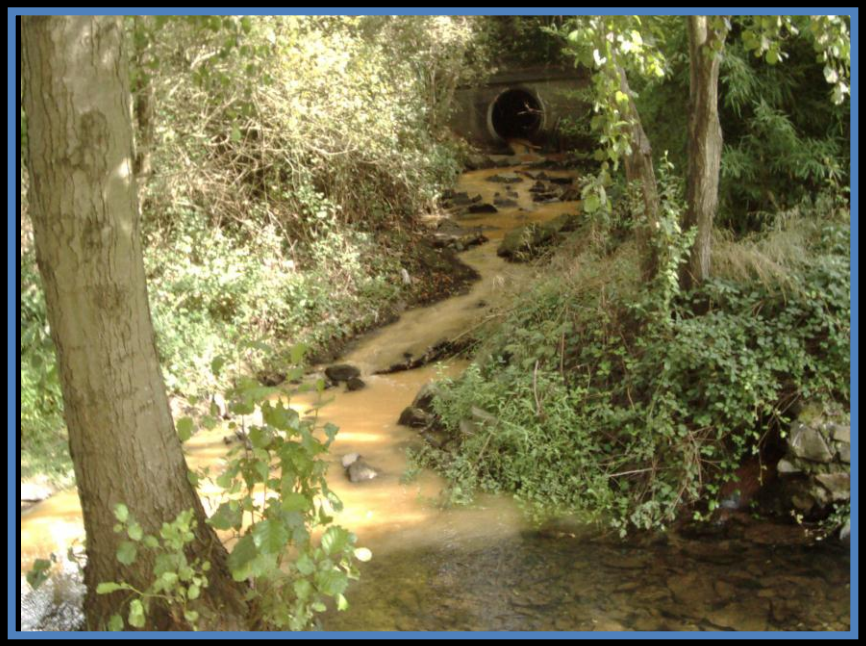
# Galicia


A CORUÑA
A CORUÑA
Santiago de Compostela
LUGO
LUGO
PONTEVEDRA
OURENSE

# INTRODUCTION

- Analysis CSO and SSOs impacts on receiving media



- Integrated modeling of the urban drainage system
  - Sewer
  - WWTP
  - Water bodies

} Long term numerical simulations

**When / How we have to perform ??**

# WQA: SPANISH CONTEXT

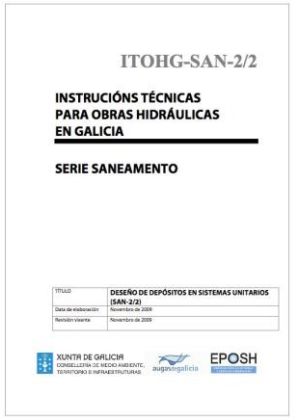
- No national regulation (not yet)
- Local and regional administrations: ES standards
- CHN 1995 regulations:
  - Low specific retention volume: 4 – 9 $m^3$/net ha
  - Wet/Dry weather flow ratios: 7
- Canal Isabel II (2006):
  - CSO tank volume: up to 20 $m^3$/net ha
  - Large Wet/Dry weather flow ratios: 10
- Moving to EQS standards !!!

  Plan de Aguas Pluviales Cataluña:
  UPM procedure (20 to 70 $m^3$/net ha)

# ITOGHs: Galician Regulations

- Technical Regulations for Galician Hydraulic Works : ITOHGs
- OB: planning, design and management of sewers
- Practioners and administration point of view

www.augasdegalicia.xunta.es/gl/ITHOG.htm

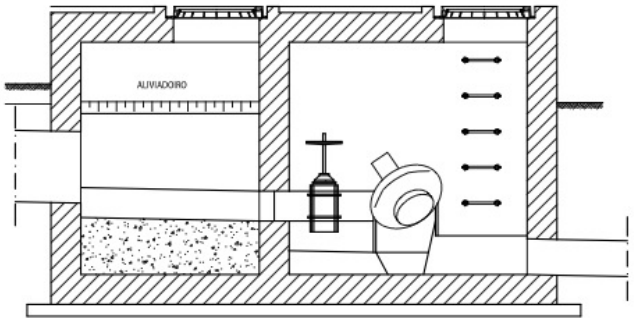

ITOHG-SAN-2/2

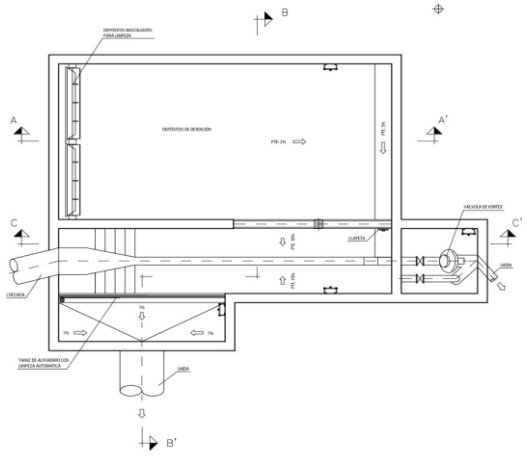
INSTRUCIÓNS TÉCNICAS PARA OBRAS HIDRÁULICAS EN GALICIA

SERIE SANEAMENTO

| | |
|---|---|
| TÍTULO | DESEÑO DE DEPÓSITOS EN SISTEMAS UNITARIOS (SAN-2/2) |
| Data de elaboración | Novembro de 2009 |
| Revisión vixente | Novembro de 2009 |

XUNTA DE GALICIA CONSELLERÍA DE MEDIO AMBIENTE, TERRITORIO E INFRAESTRUTURAS augasdegalicia EPOSH



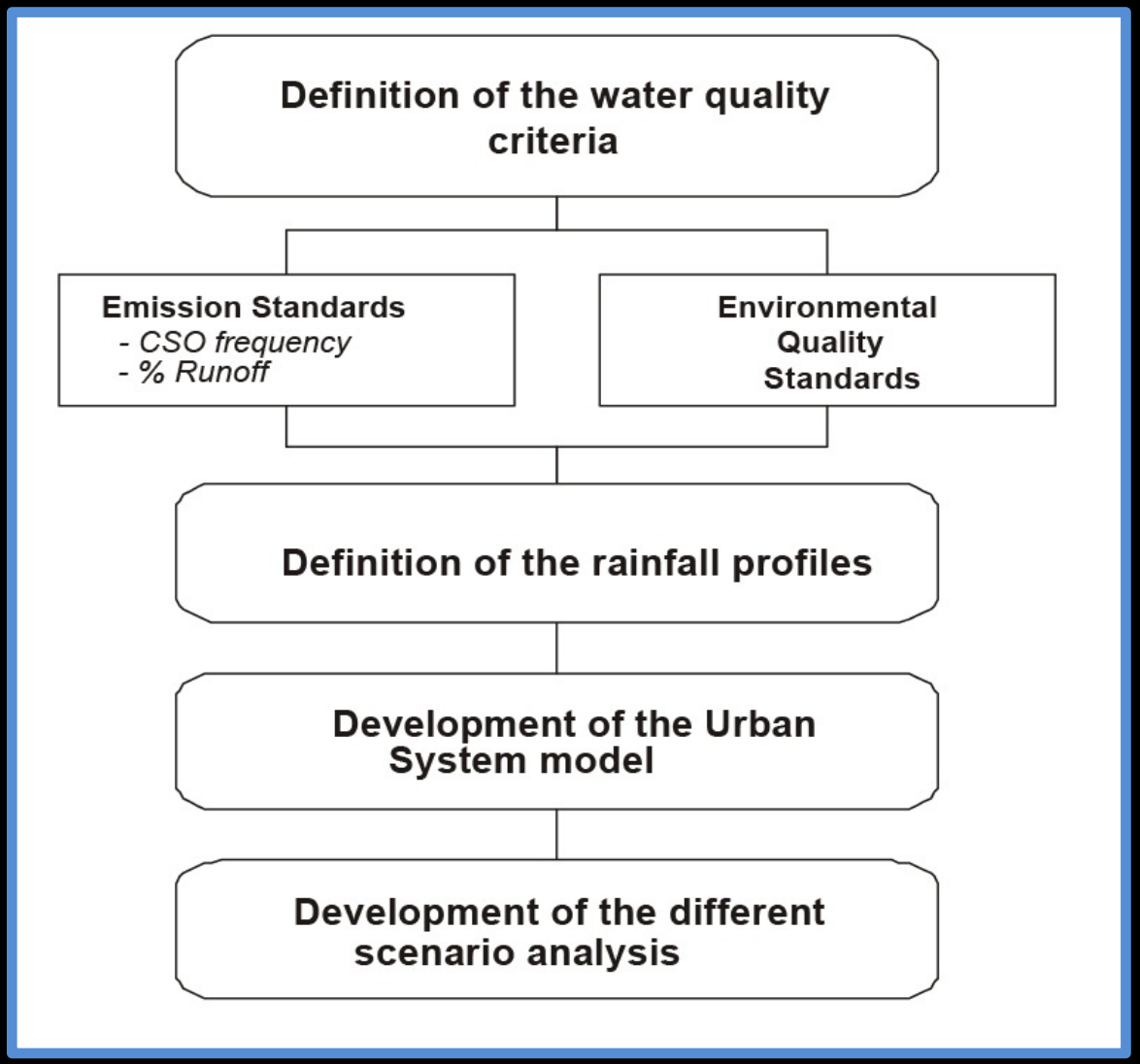
# CSO tank design: SIMPLIFIED CRITERION

- Only for small catchments (<10 net-ha)
- $V_{tank} = SUP_{ImpArea} \cdot V_{spec}$

Minimum specific storage volume ($m^3$/net ha) for CSO tank sizing.
Maximum discharge to WWTP= 3DWF

| **Receiving Media (according to 91/271 EEC)** | **Land Use** | | |
|---|---|---|---|
| | Rural | Urban | Dense Urban |
| Sensitive Areas | 80 | 100 | 110 |
| Non Sensitivity Areas | 60 | 80 | 90 |

# CSO tank design: COMPLETE CRITERION

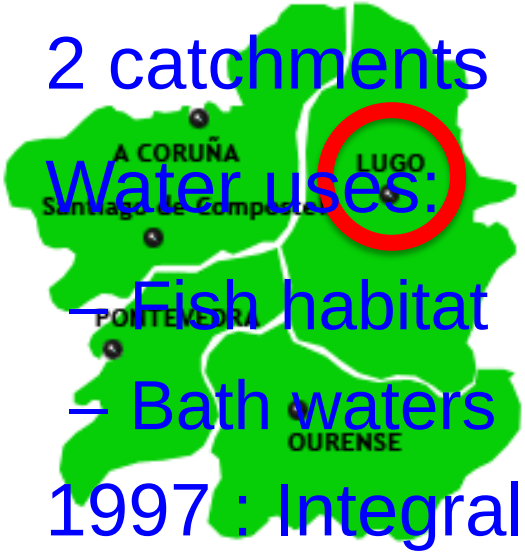


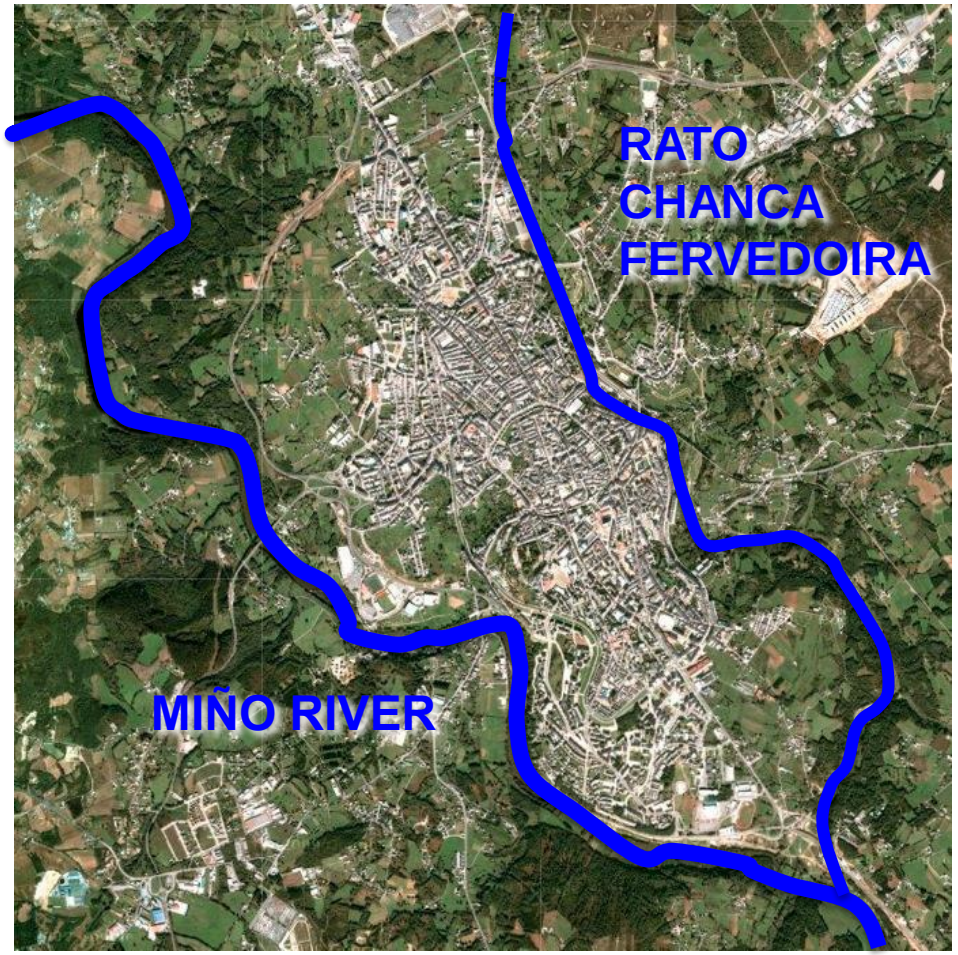

- ES
  - 15 – 20 spills
  - 85 % - 90 %
- EQS (UPM)

- “mean year”
- SWMM modelling

# LUGO SEWERAGE SYSTEM

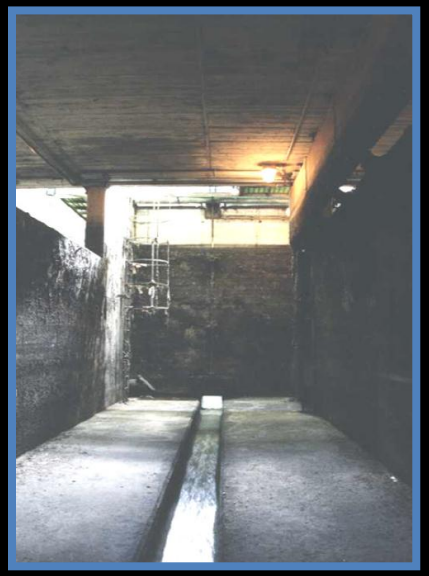
- 2 catchments
- Water uses:
  - Fish habitat
  - Bath waters
- 1997 : Integral sewer system renovation
- CH Miño-Sil
- 100 mill €

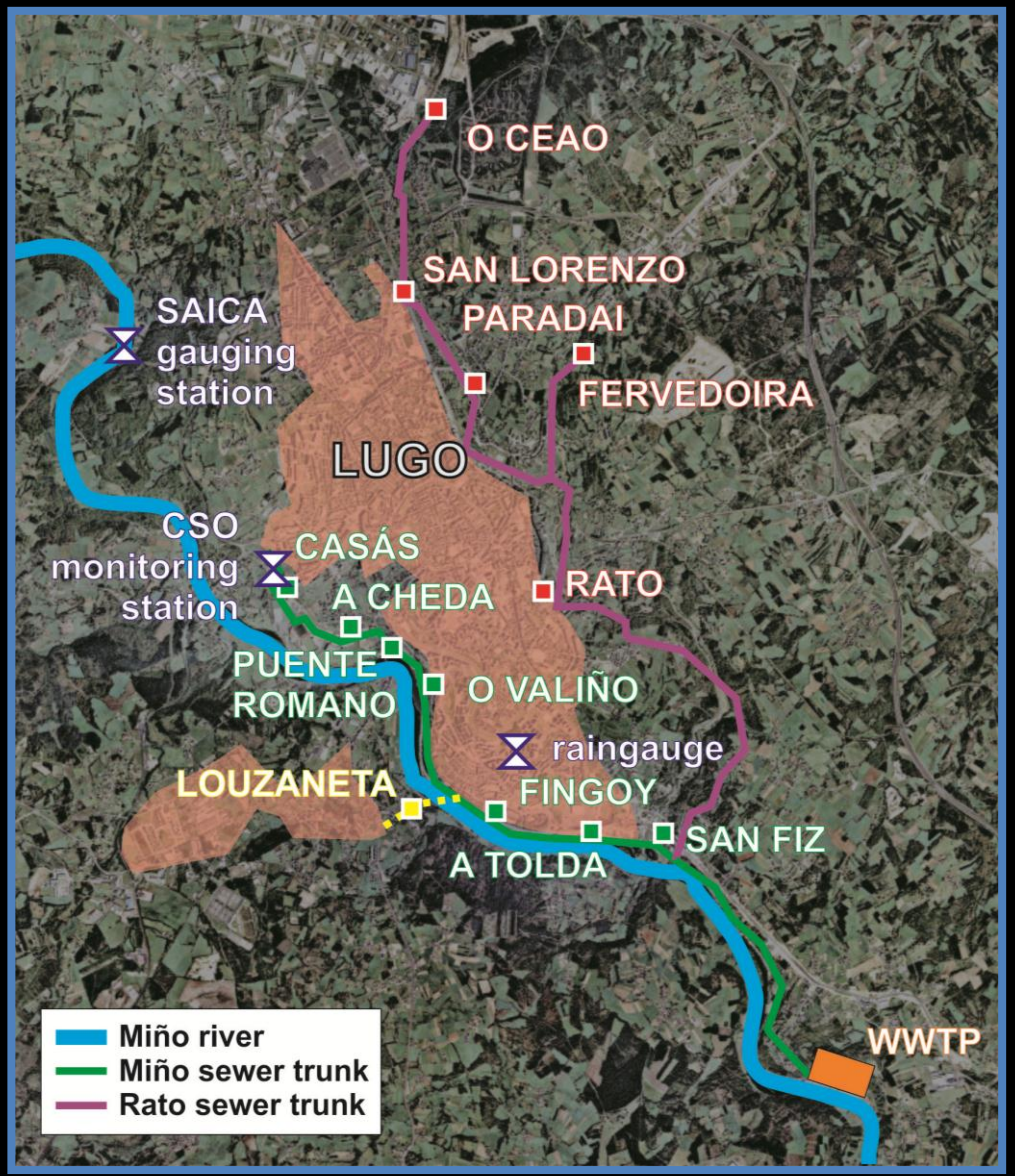


# LUGO SEWER SYSTEM WORKS

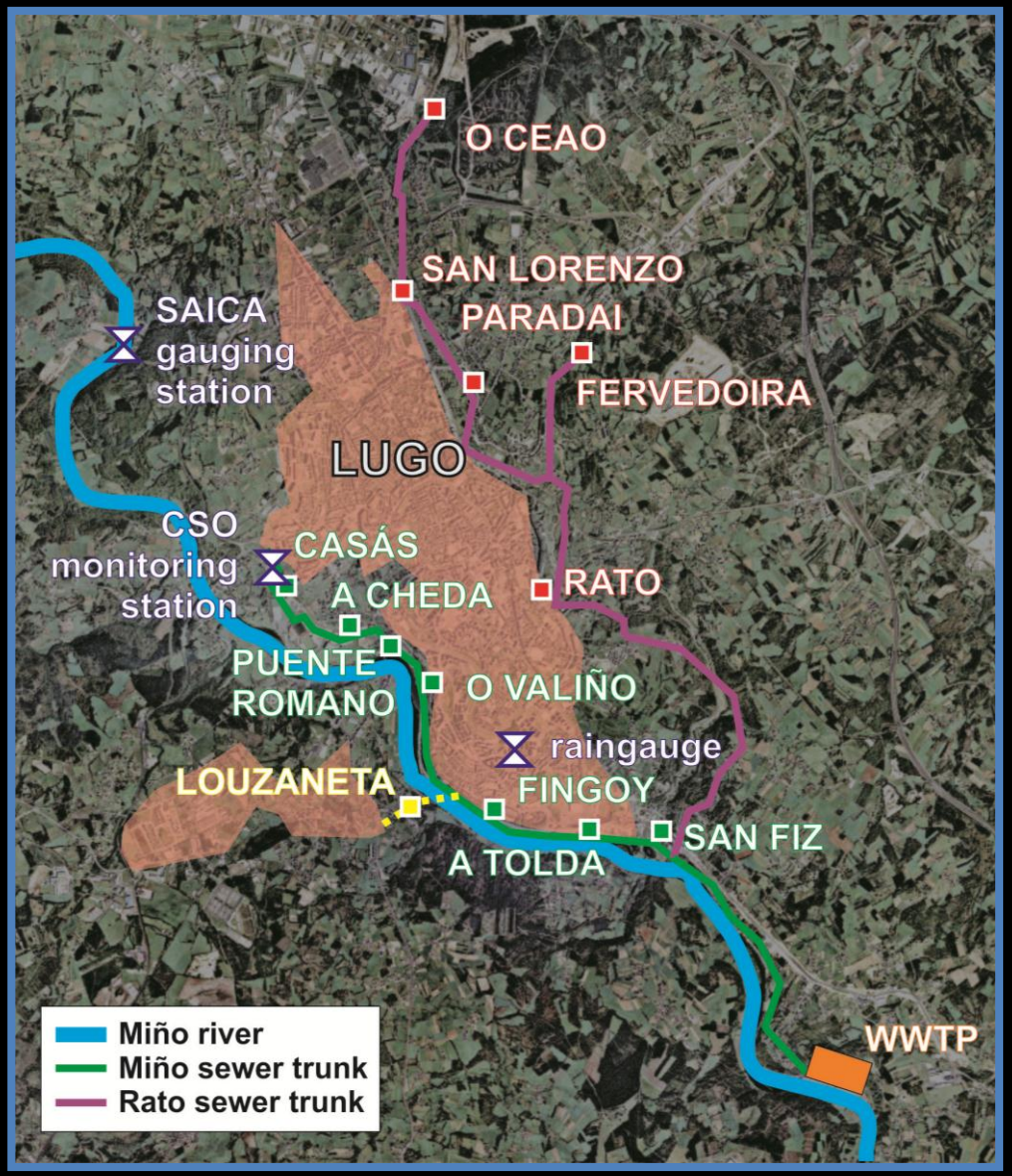
1) Rato, Chanca & Fervedoira works (2004)
   - 12 CSO tanks (CHN criterion)





# LUGO SEWER SYSTEM WORKS

2) Miño River main trunk (2008)

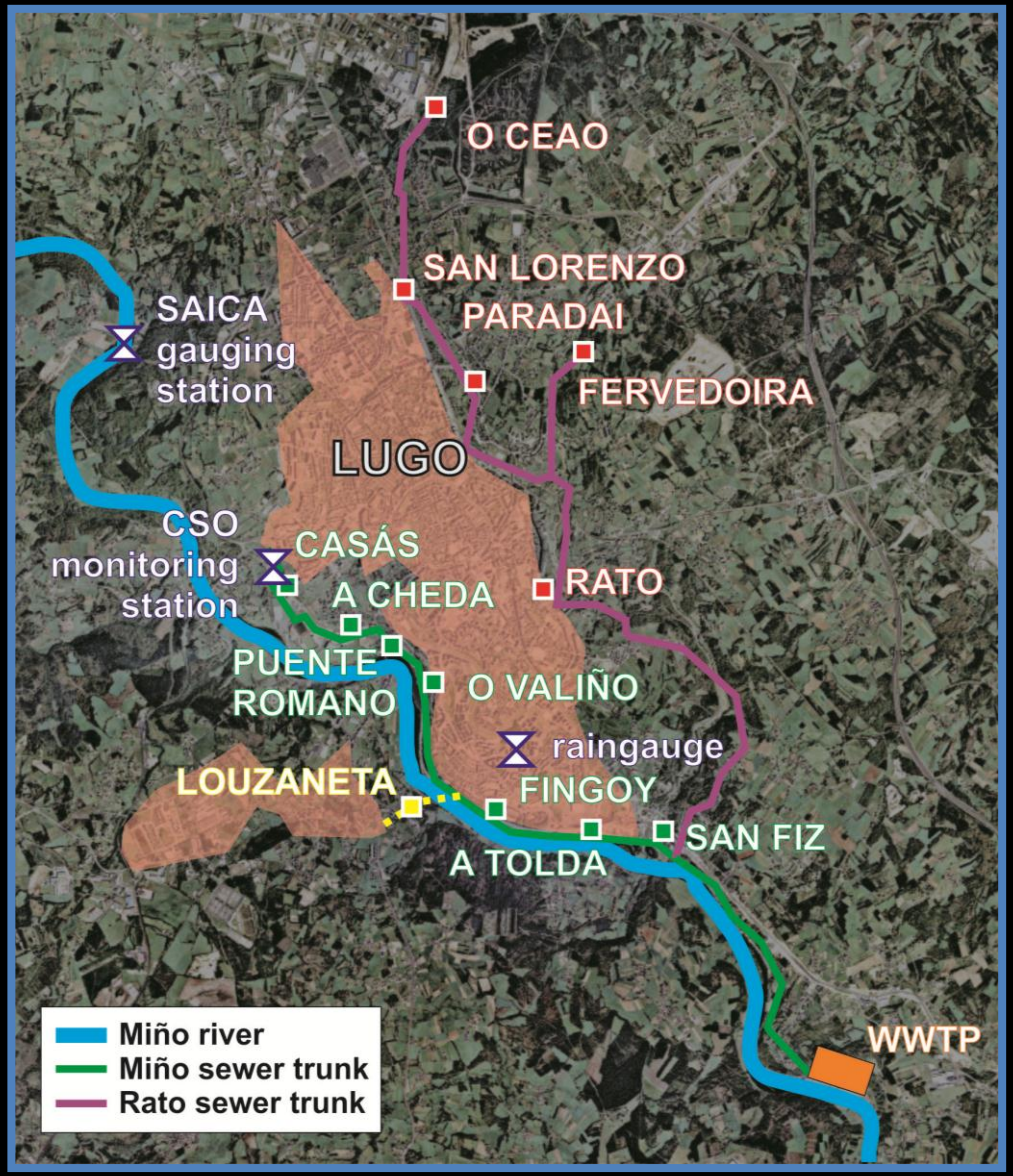


# LUGO SEWER SYSTEM WORKS

2) Miño River main trunk (2008)
   - 8 CSO tanks (ES, 20 – 60 $m^3$/net-ha)
3) WWTP (2011)
4) Louzaneta catchment (under development)

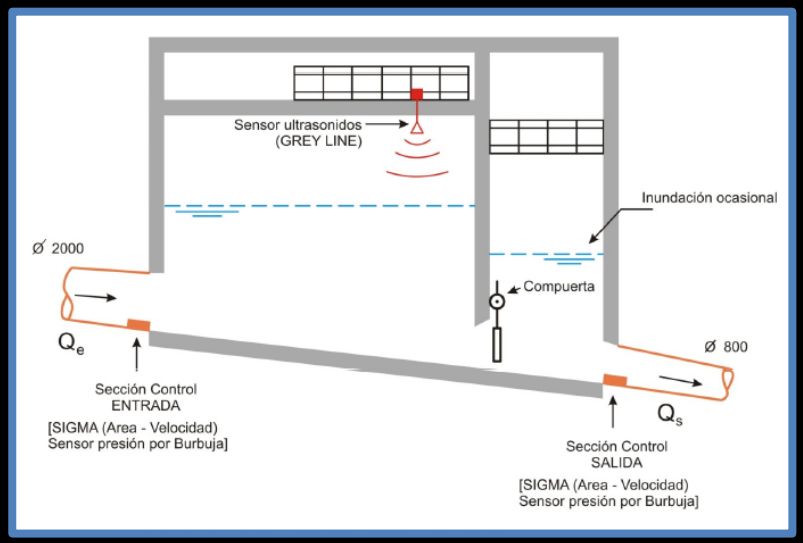
➢ WQA approach

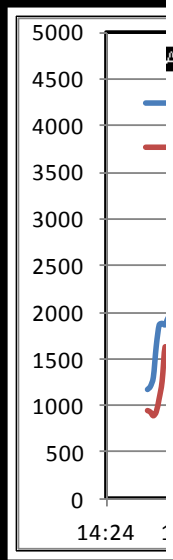
FIS for DO and ammonia (UPM)

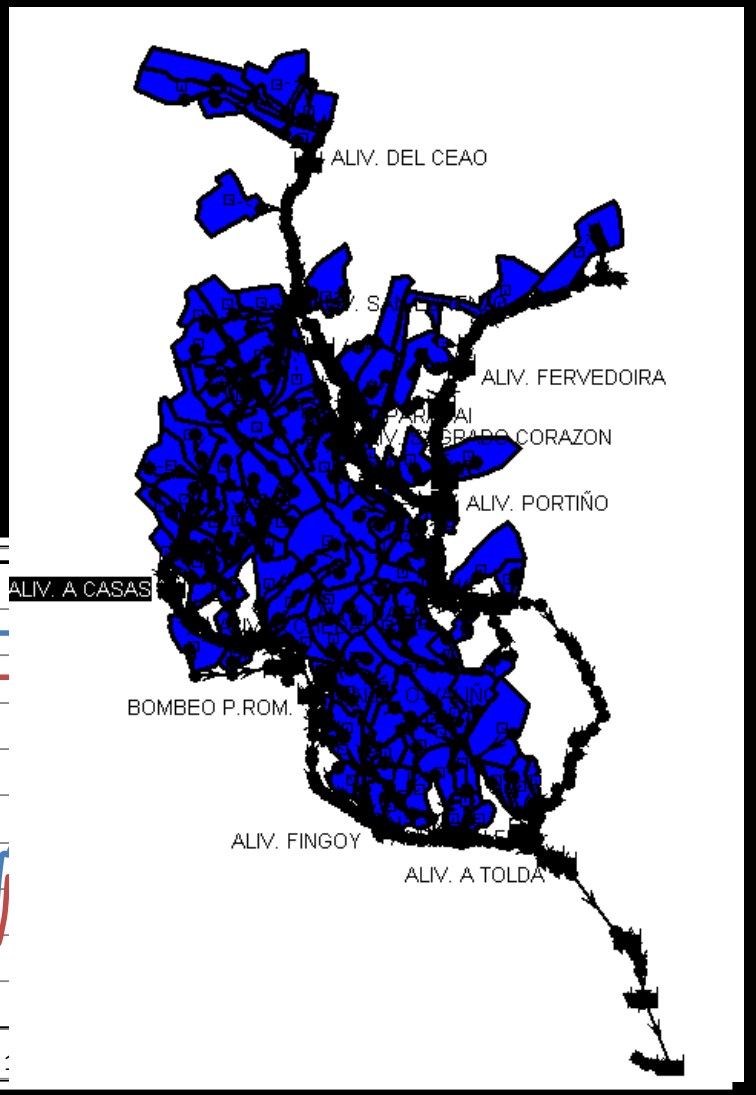


# Sewerage system model

- SWMM semi-distributed model:
  - 21 catchments (153 subcatchments)
  - 21 CSO structures
- Pluviometric “average year” 2008
- Model calibration: Casás CS
- No SWMM quality model



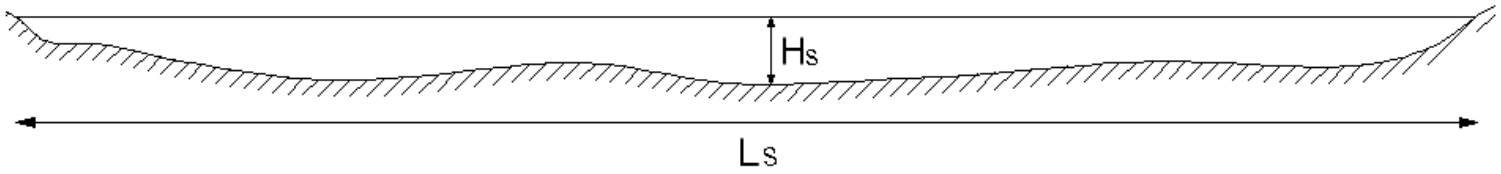



# River Water Quality model

- Turbillón code (GEAMA)
  - 2D shallow water code with turbulence (Cea, 2006)
  - Coupled Water quality model (Chapra 1997, Cea 2011)

$$\frac{\partial h}{\partial t} + \frac{\partial hU_j}{\partial x_j} = 0$$

$$\frac{\partial hU_i}{\partial t} + \frac{\partial hU_iU_j}{\partial x_j} + \frac{g}{2}\frac{\partial h^2}{\partial x_i} = -gh\frac{\partial z_b}{\partial x_i} + \tau_s - \tau_b + \frac{\partial h\tau_{ij}^{eff}}{\partial x_j} + F_C - \frac{1}{\rho}\frac{\partial P_{atm}}{\partial x_i}, \qquad i = 1,2$$



# Water Quality model INPUTS

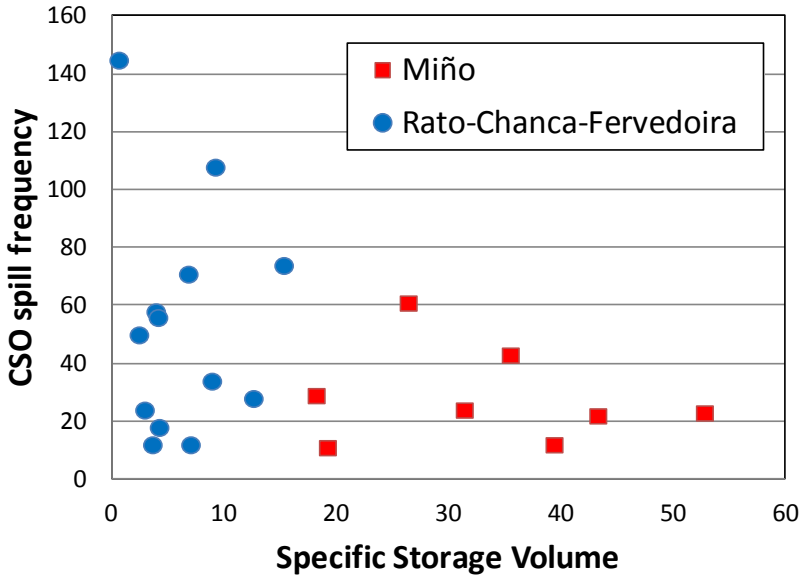
- River bathymetry and roughness (Manning)
- River quantity and quality data SAICA station :
  - daily flow, DO, Tª, $NH_4^+$
- CSO quantity and quality

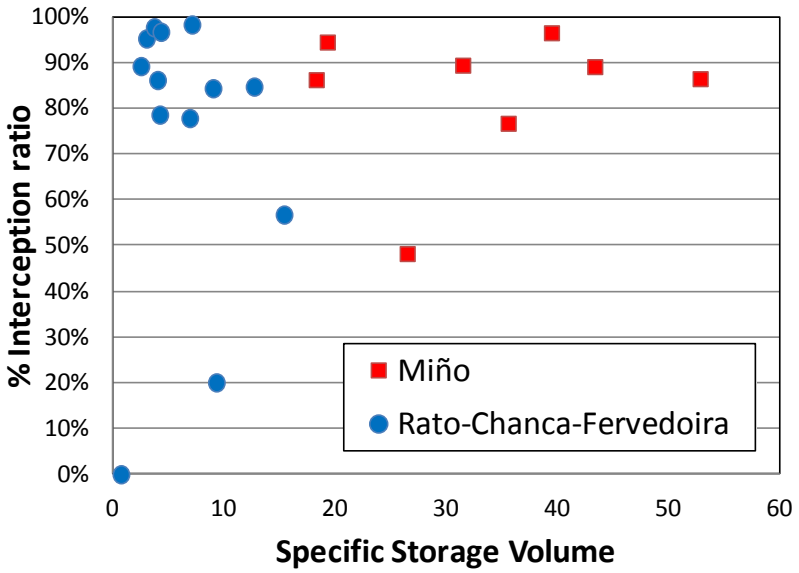

| Sewer system | Values | BOD | NH4+ | Org-N | DO |
|---|---|---|---|---|---|
| Miño & Louzaneta | CASÁS spill EMC | 70 | 1.5 | 5 | 4 |
| Rato, Chanca, … | GEAMA database | 220 | 8 | 18 | 4 |

- Kinetic constants: $k_1$=0.35 $d^{-1}$, $\beta_3$=0.2 $d^{-1}$, $\beta_1$=1.0 $d^{-1}$

# Model results: ES

- Large dispersion of ES values
- No clear correlation with tank volume
- Better performance of Miño river CSO tanks

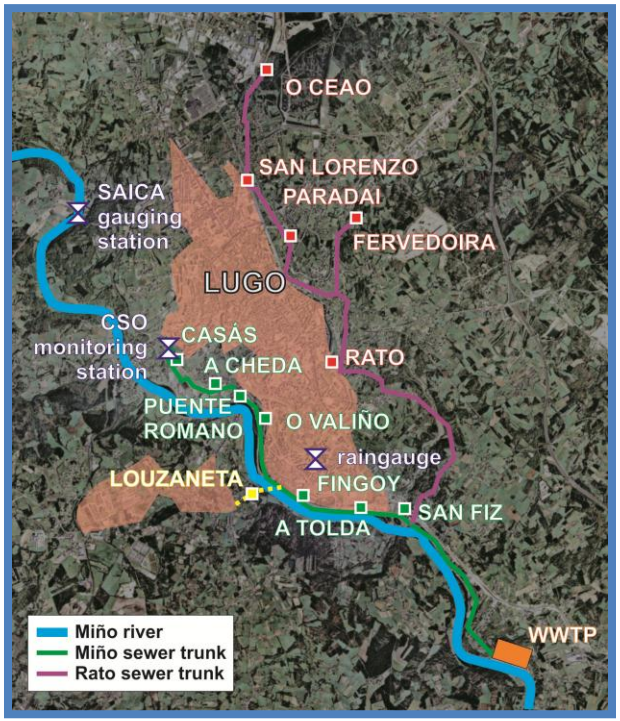


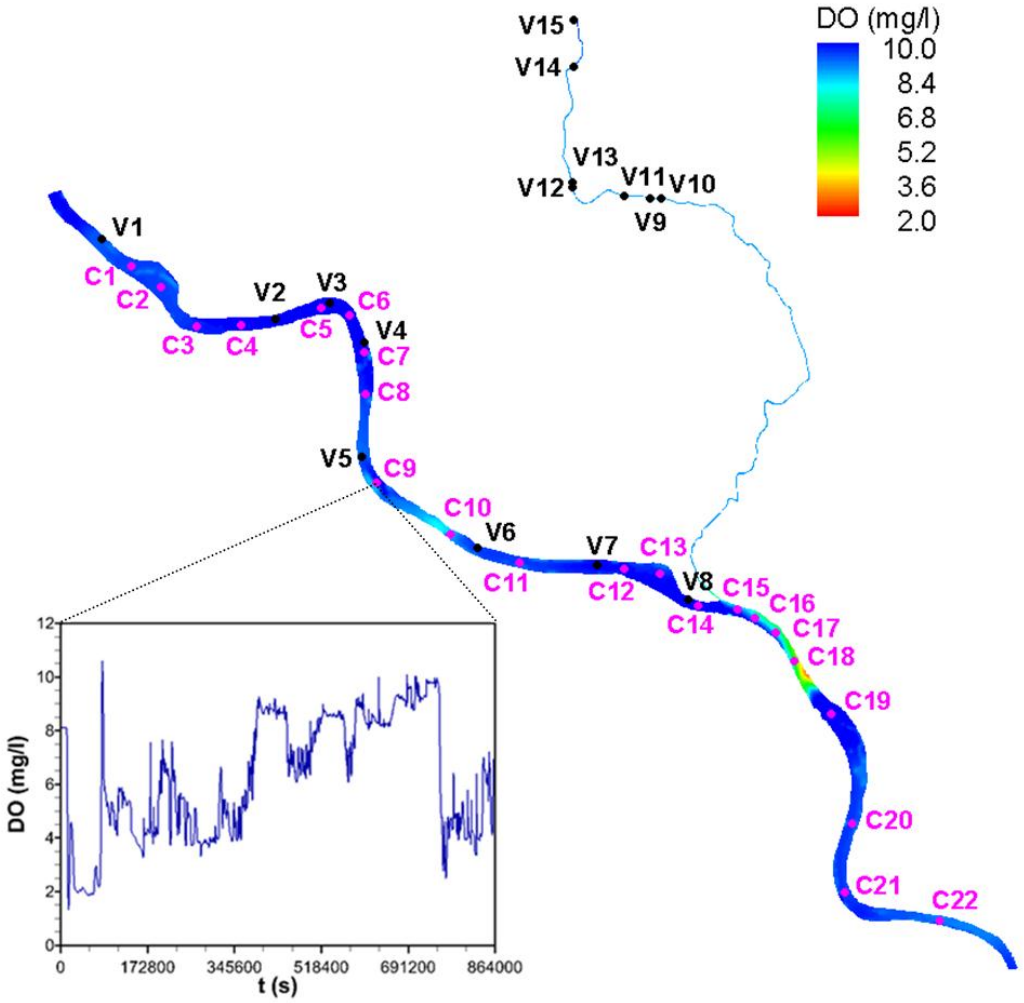



# Model results: water quality model

## River Miño reach

## DO, BOD, $NH_4^+$

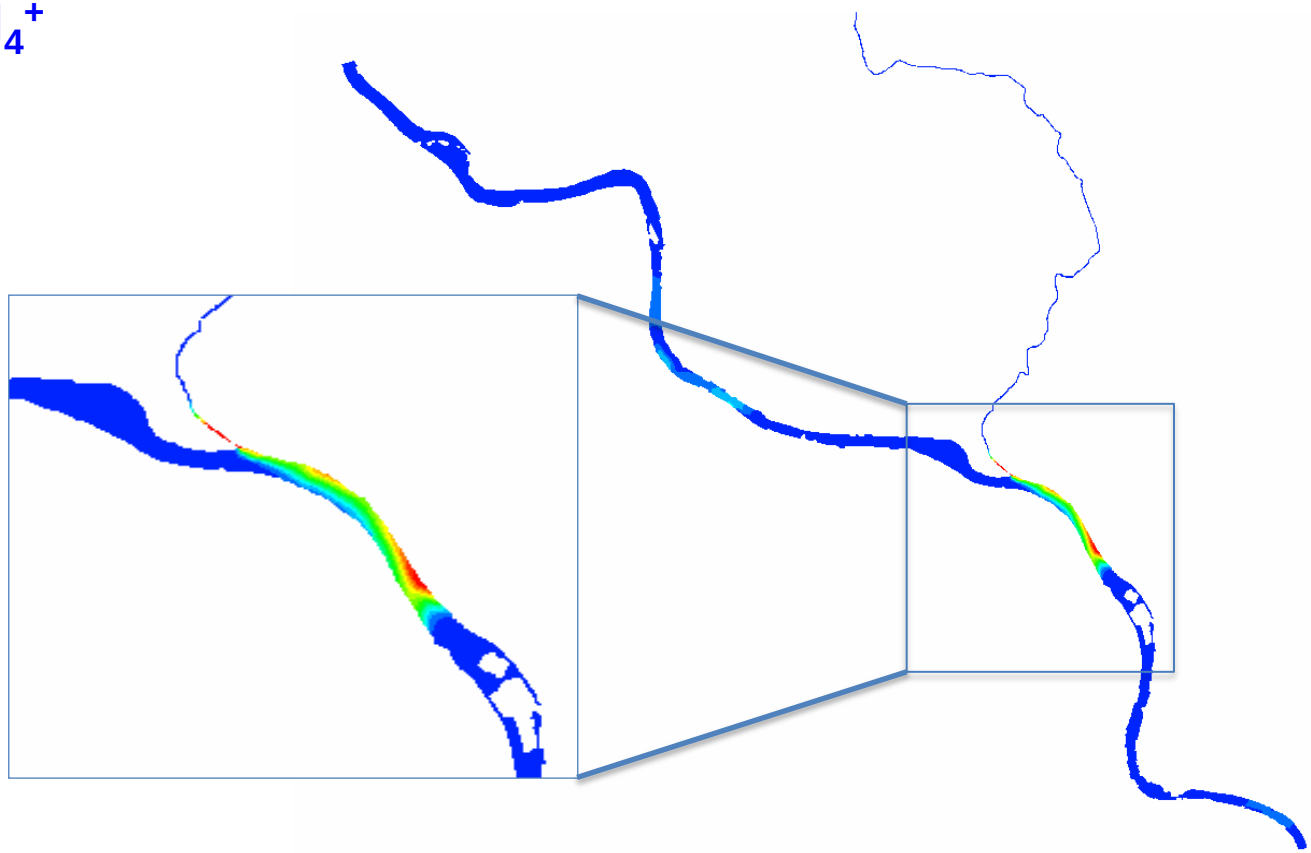


# Model results: water quality model

## River Miño reach

## DO, BOD, $NH_4^+$



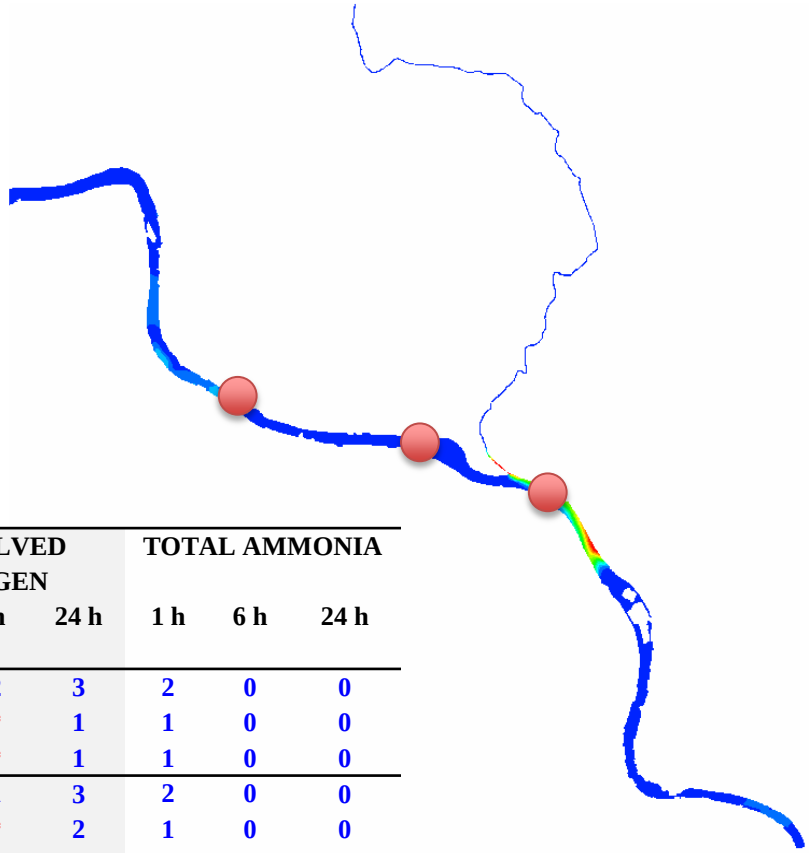
# Model results: EQS

## River Miño reach

## DO, BOD, $NH_4^+$

Detailed analysis 3 points

FIS standard for salmonyd fishery



| | Return period / Duration | DISSOLVED OXYGEN 1 h | DISSOLVED OXYGEN 6 h | DISSOLVED OXYGEN 24 h | TOTAL AMMONIA 1 h | TOTAL AMMONIA 6 h | TOTAL AMMONIA 24 h |
|---|---|---|---|---|---|---|---|
| Control point C9 (Nº exceedances) | 1 month | 43* | 12 | 3 | 2 | 0 | 0 |
| | 3 months | 36* | 8* | 1 | 1 | 0 | 0 |
| | 1 year | 24* | 5* | 1 | 1 | 0 | 0 |
| Control point C13 (Nº exceedances) | 1 month | 37* | 11 | 3 | 2 | 0 | 0 |
| | 3 months | 18* | 5* | 2 | 1 | 0 | 0 |
| | 1 year | 8* | 4* | 2* | 1 | 0 | 0 |
| Control Point C15 (Nº exceedances) | 1 month | 38* | 17* | 4 | 3 | 0 | 0 |
| | 3 months | 19* | 10* | 2 | 1 | 0 | 0 |
| | 1 year | 10* | 4* | 1 | 1 | 0 | 0 |

# CONCLUSIONS

**Successful application of SWMM + TURBILLON to river Miño quality modelling**

**Application of UPM procedure to LUGO**

- DO levels depends on base river and CSO values
- FIS ammonia criterion is fulfilled for salmonid fisheries

**Future research**

- Dual – drainage modelling (Fraga et al, UDM–poster)
- Include river measurements / WWTP / long term simulations (more than 1 year)
- Sensitivity and uncertainty analysis

# THANKS FOR YOUR ATTENTION

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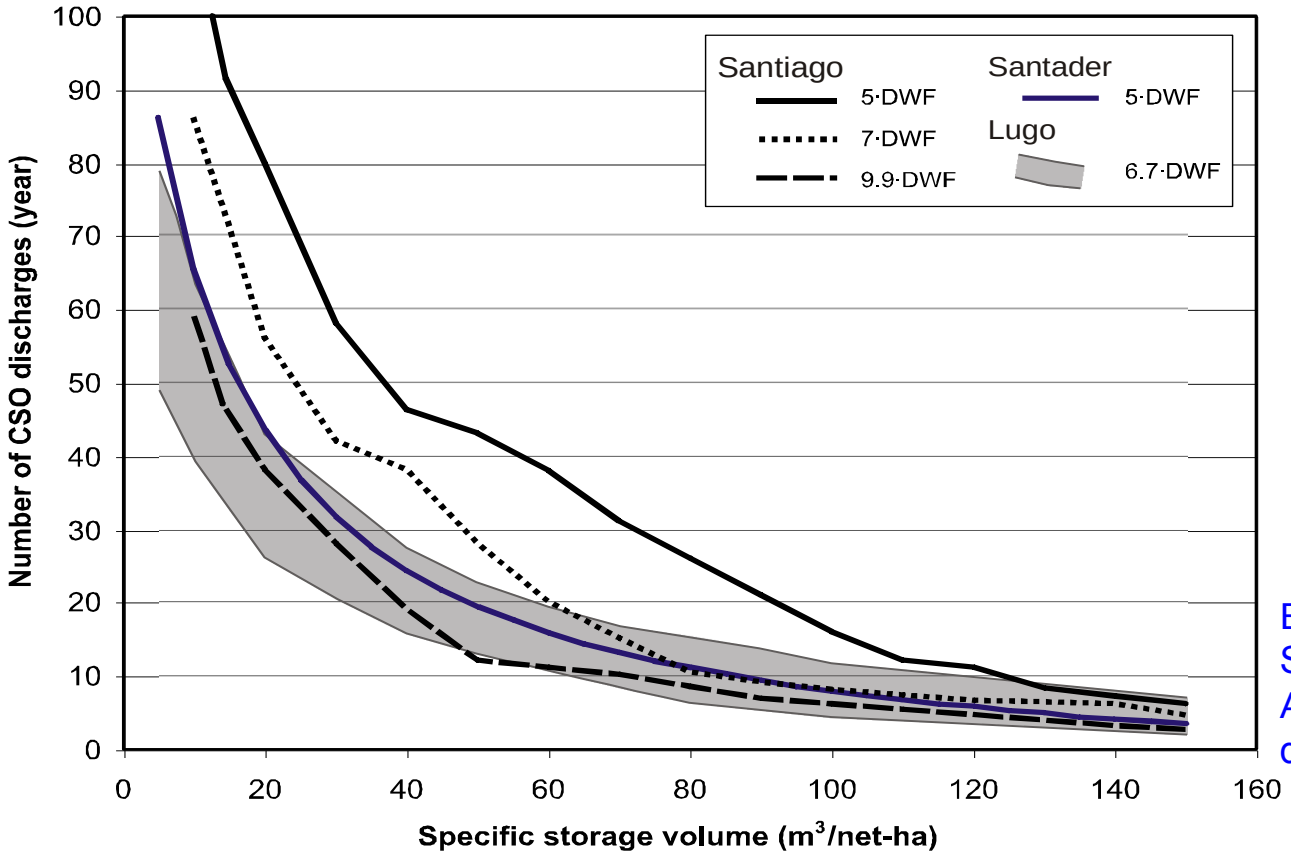
# CSO tank design: SIMPLIFIED CRITERION

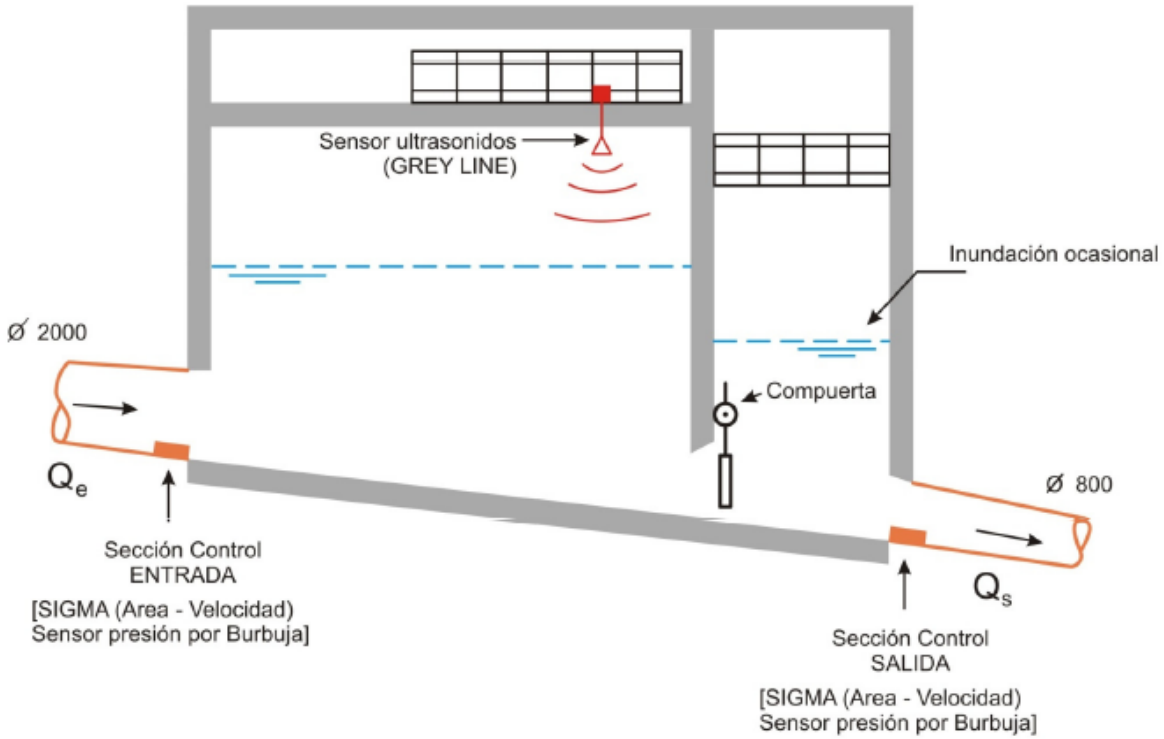
- Specific volumes derived from local studies




Beneyto, 2004
Suárez and Puertas, 2004
Anta *et al.*, 2007
del Río, 2011

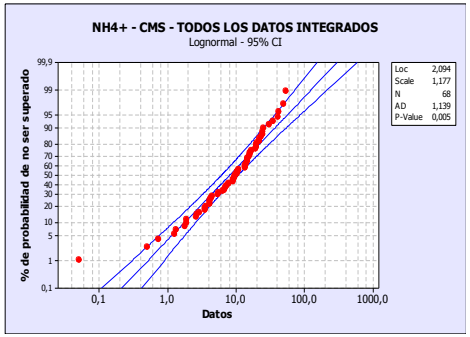
# Casás control section

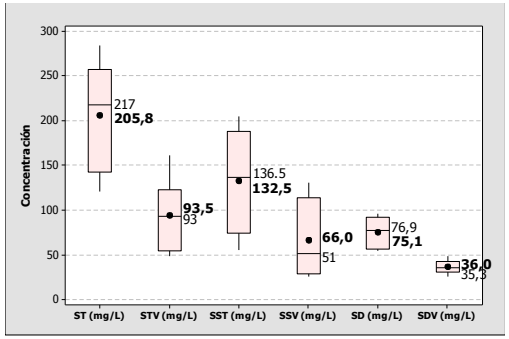
- Flow measurements
- CSO spills pollutant concentration



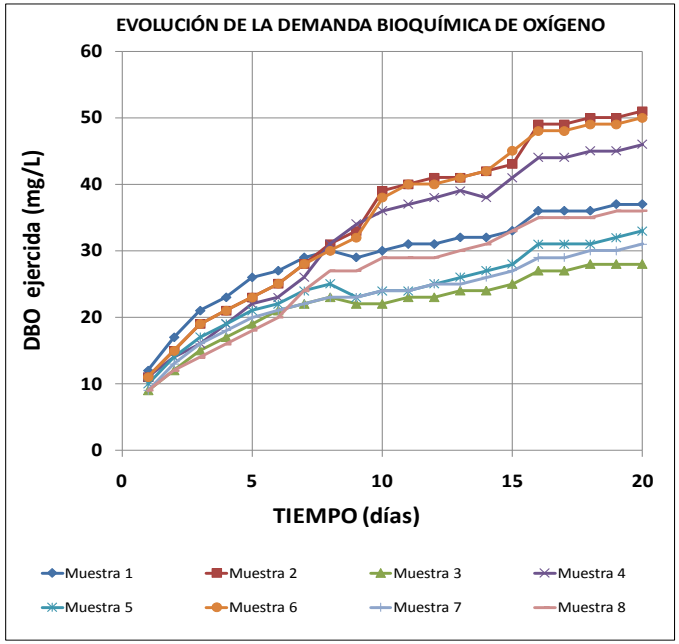

# Casás control section

- GEAMA CS database (>10 sampling sites)
- CSO events: inputs for water quality model



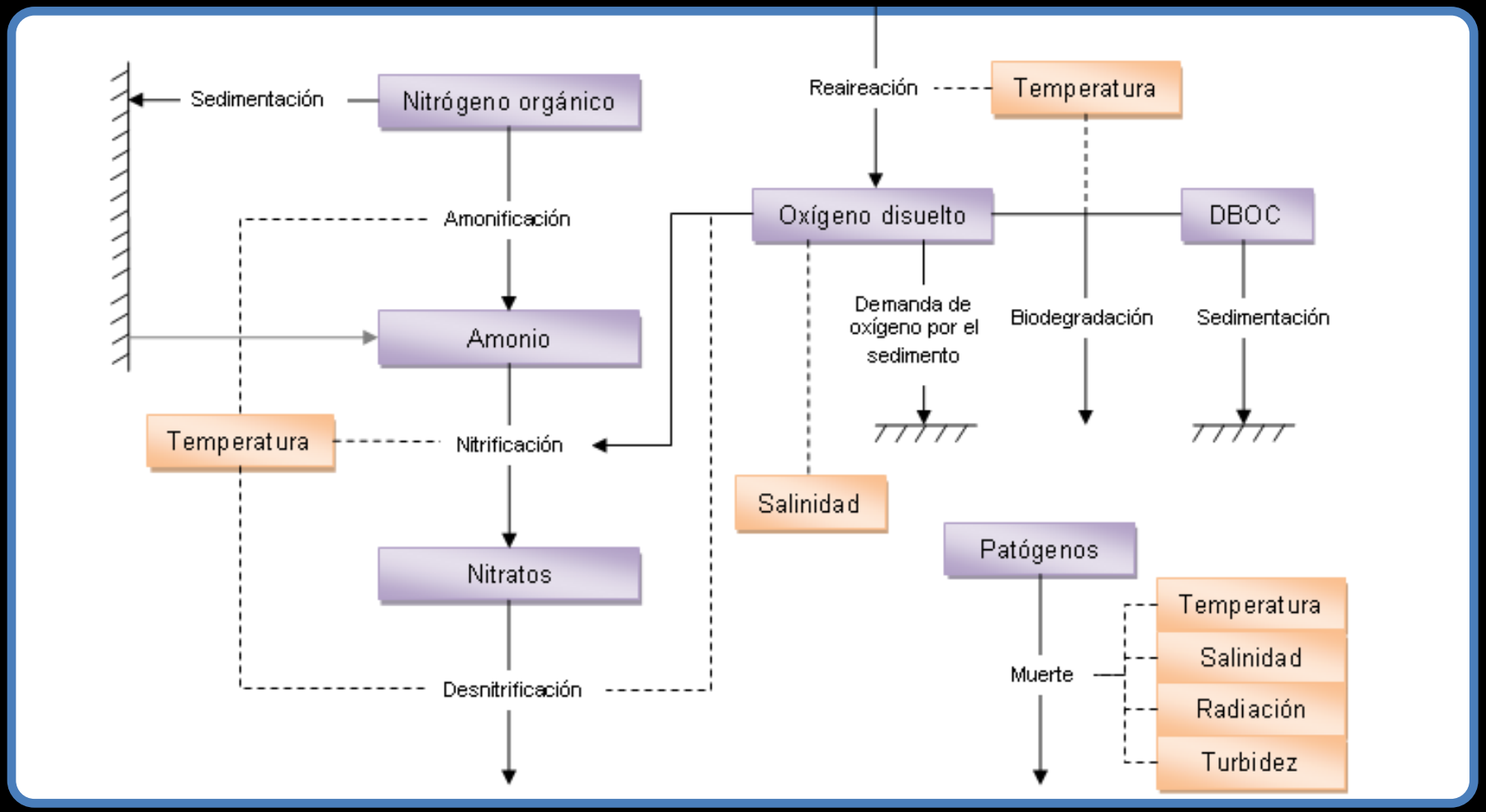




| | COD (mg/L) | $BOD_5$ (mg/L) | $N\text{-}NH_4^+$ (mg/L) | SS (mg/L) | FC (UFC/100 mL) |
|---|---|---|---|---|---|
| EMC - CSO spill | 119 | 58 | 0,83 | 132,5 | 4,10E+06 |
| EMC – Dry weather | 430 | 254 | 26,5 | 118,4 | 2,10E+07 |
| EMC - Database | 593 | 300 | 11 | 471 | 1,60E+07 |
| **EMC reduction** | **80%** | **81%** | **92%** | **72%** | **74%** |

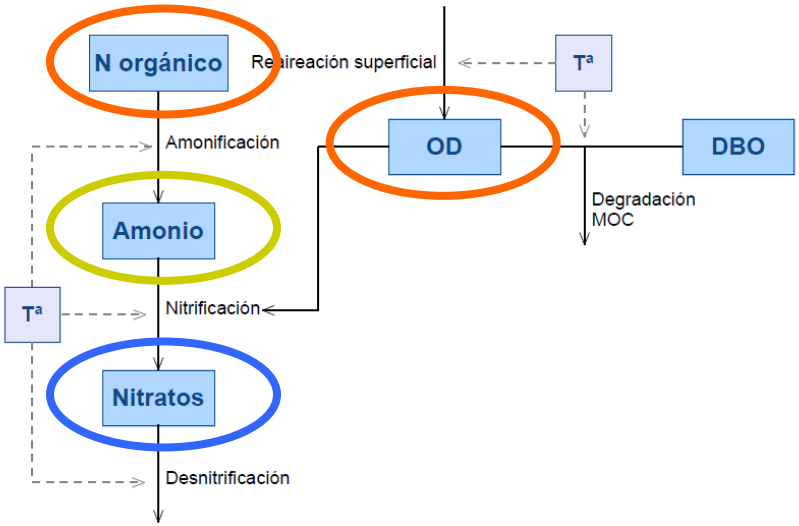


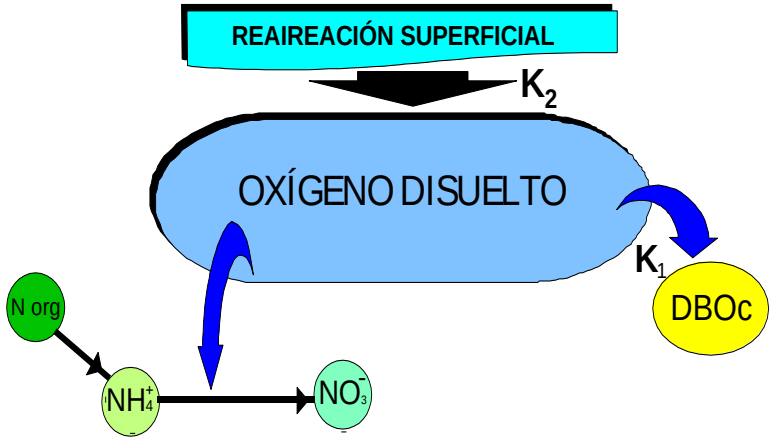
# Water Quality model

## FC + DO + BOD + $N_{org}$ + $NH_4$ + $N0_3$



# Water Quality model




$$\frac{\partial\, h\cdot NH_4^+}{\partial t}+\frac{\partial\, h\cdot U_x\cdot NH_4^+}{\partial x}+\frac{\partial\, h\cdot U_y\cdot NH_4^+}{\partial y}=\frac{\partial}{\partial x_j}\left(h\left(\frac{\Gamma_i}{\rho}+\frac{\nu_t}{S_{c,t}}\right)\frac{\partial NH_4^+}{\partial x_j}\right)+S_{NH_4^+}$$

$$S_{NH_4^+}=k_{amonificacion}\cdot 1.047^{(T_{agua}-293)}\cdot N_{org}-k_{nitrificacion}\cdot 1.083^{(T_{agua}-293)}\cdot F_n\cdot NH_4^+$$

$$S_{OD}=-4.57\cdot k_{nitrificacion}\cdot 1.083^{(T_{agua}-293)}\cdot F_n\cdot NH_4^+ \qquad F_n=\frac{OD}{K_{n1/2}+OD}$$

# Water Quality model: FC

$$\frac{\partial h \cdot C}{\partial t} = -\frac{\partial h \cdot U_x \cdot C}{\partial x} - \frac{\partial h \cdot U_y \cdot C}{\partial y} + \frac{\partial F_{d,x}}{\partial x} + \frac{\partial F_{d,y}}{\partial y} + S_C \cdot h$$

Coliform concentration

Advection

- Tidal currents

Diffusion Dispersion

- Turbulence
- Waves

Death rate

- Temperature
- Salinity
- Solar radiation
- Light extinction