14th International HCH and Pesticides Forum

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AECOM

MASS DISCHARGE TEMPORAL EVOLUTION IN A TRANSECT LOCATED IN THE DISCHARGE ZONE TO THE GALLEGO RIVER IN BAILIN LANDFILL, SABIÑANIGO (HUESCA)

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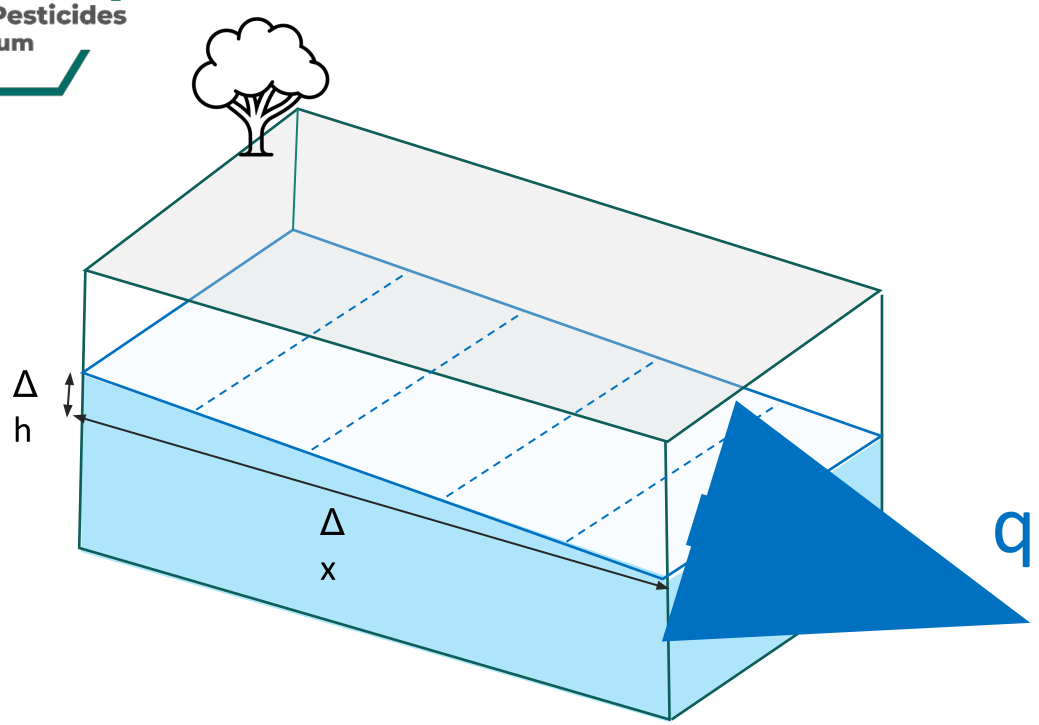
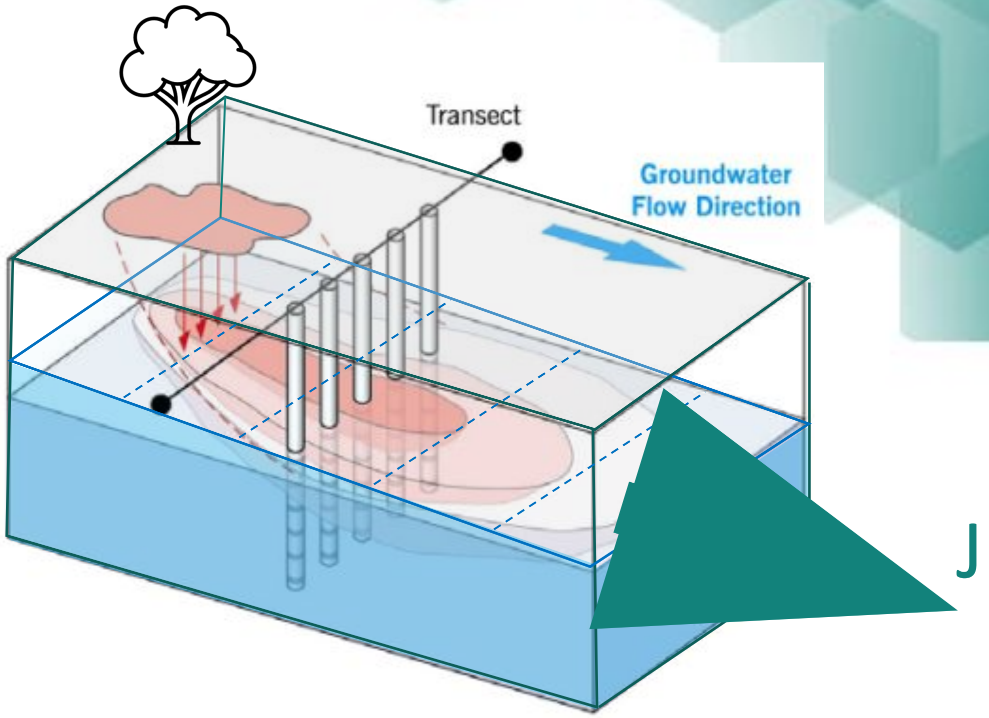
GOBIERNO DE ARAGON

ROADMAP

- Mass Flux / Discharge concepts
- Bailin site: Why Mass Flux matters?
- Selected method: Passive Flux meters
- Results: mass discharge & mass balance
- Conclusions

GROUNDWATER & MASS FLUX CONCEPT





Groundwater Flux = Darcy velocity

$q = K \times i$ (m/d)

i: Hydraulic gradient (dimensionless)
K: Hydraulic conductivity (m/d)

Expresses how fast water flows through the soil voids in the saturated zone

Mass Flux = Groundwater flux x Concentration

$J = q \times C$ $(mg/d/m^2)$

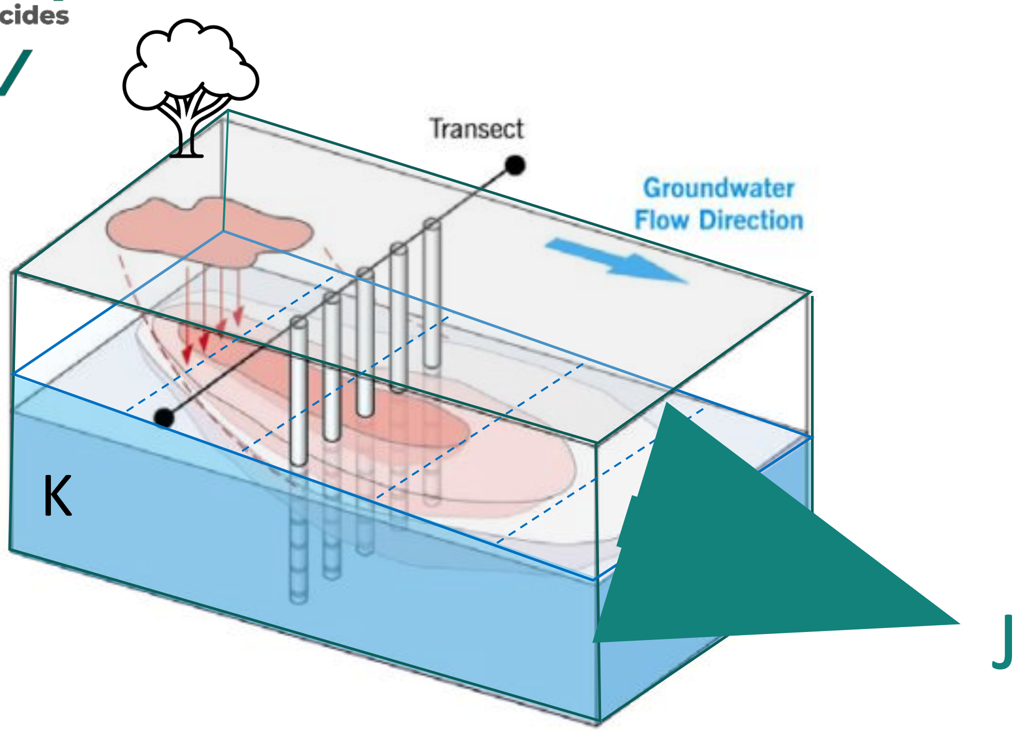
C: Groundwater concentration (mg/l)
q: Groundwater flux (m/d)

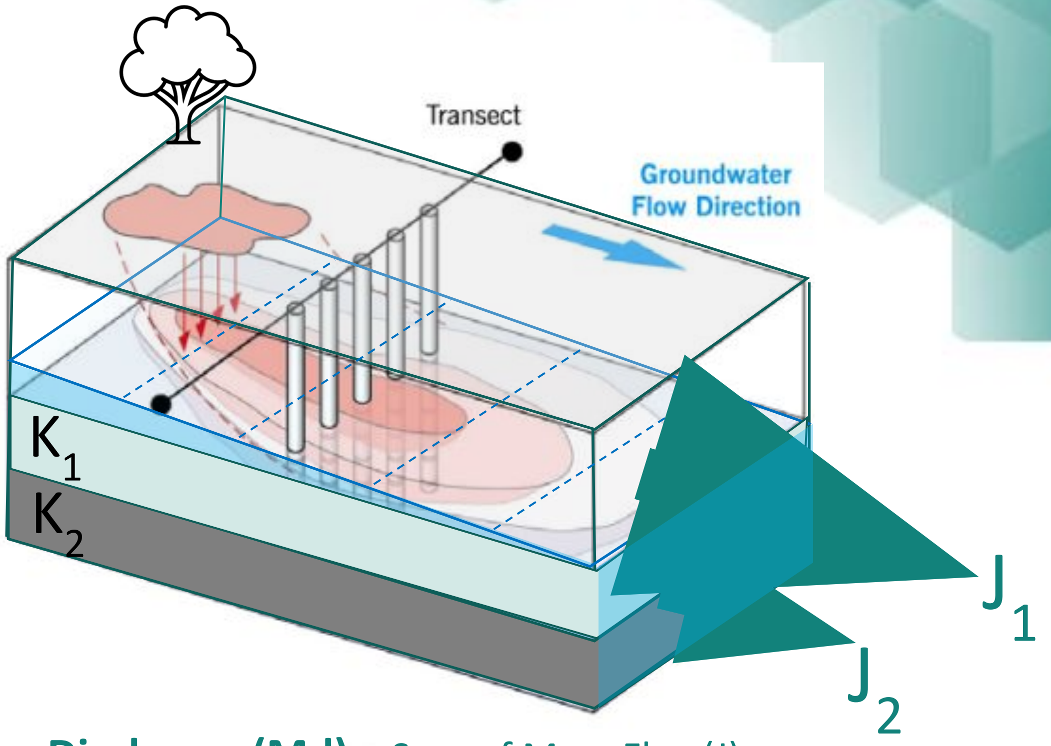
$J = K \times i \times C$ $(mg/d/m^2)$

i: Hydraulic gradient (dimensionless)
K: Hydraulic conductivity (m/d)

Amount of a contaminant mass moving in the groundwater based on the groundwater flow velocity, and it´s delimited in a defined area.

MASS FLUX & MASS DISCHARGE CONCEPTS





Mass Flux = Groundwater flux x Concentration

$J = q \times C$ (mg/d/m²)

C: Groundwater concentration (mg/l)
q: Groundwater flux (m/d)

$J = K \times i \times C$ (mg/d/m²)

i: Hydraulic gradient (dimensionless)
K: Hydraulic conductivity (m/d)

Amount of a contaminant mass moving in the groundwater based on the groundwater flow velocity, and it´s delimited in a defined area.

Mass Discharge (Md) = Sum of Mass Flux (J)

$$Md = \int_A J \cdot d_A$$ (e.g., g/d; g/year)

where A = control plane area

Mass Discharge is the integration of the contaminant mass fluxes across the selected transect → Total mass of the whole plume cross section.

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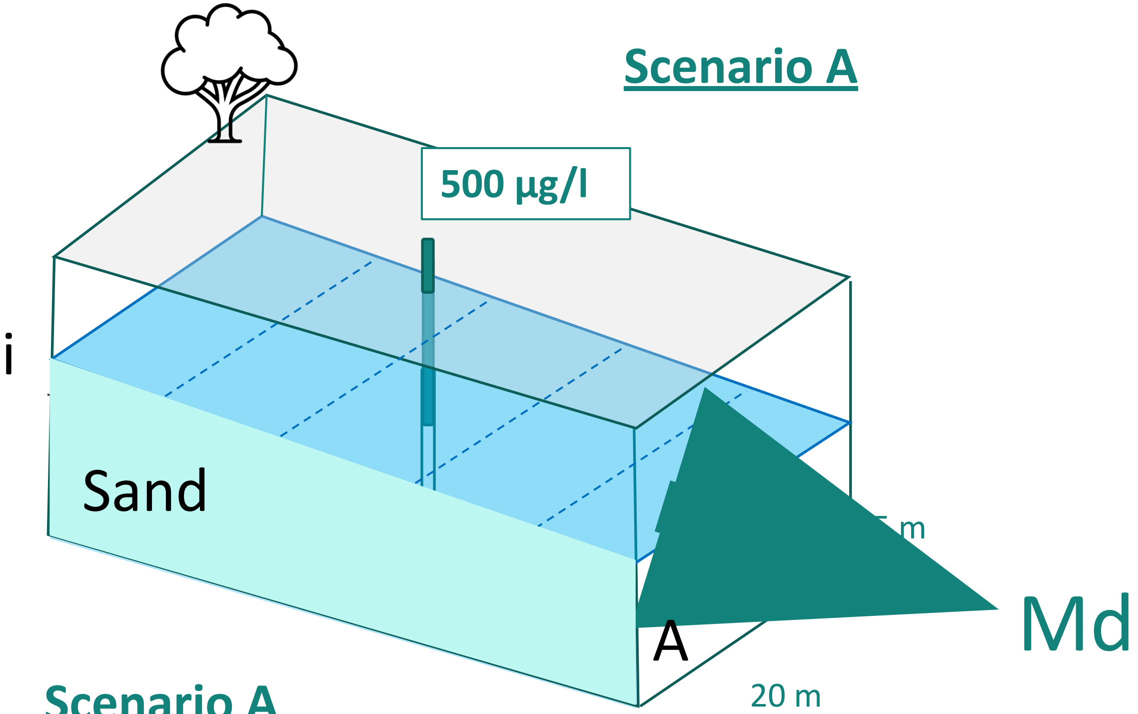
GROUNDWATER CONCENTRATION *vs* MASS DISCHARGE

Descarga de masa = caudal x concentración

Scenario A



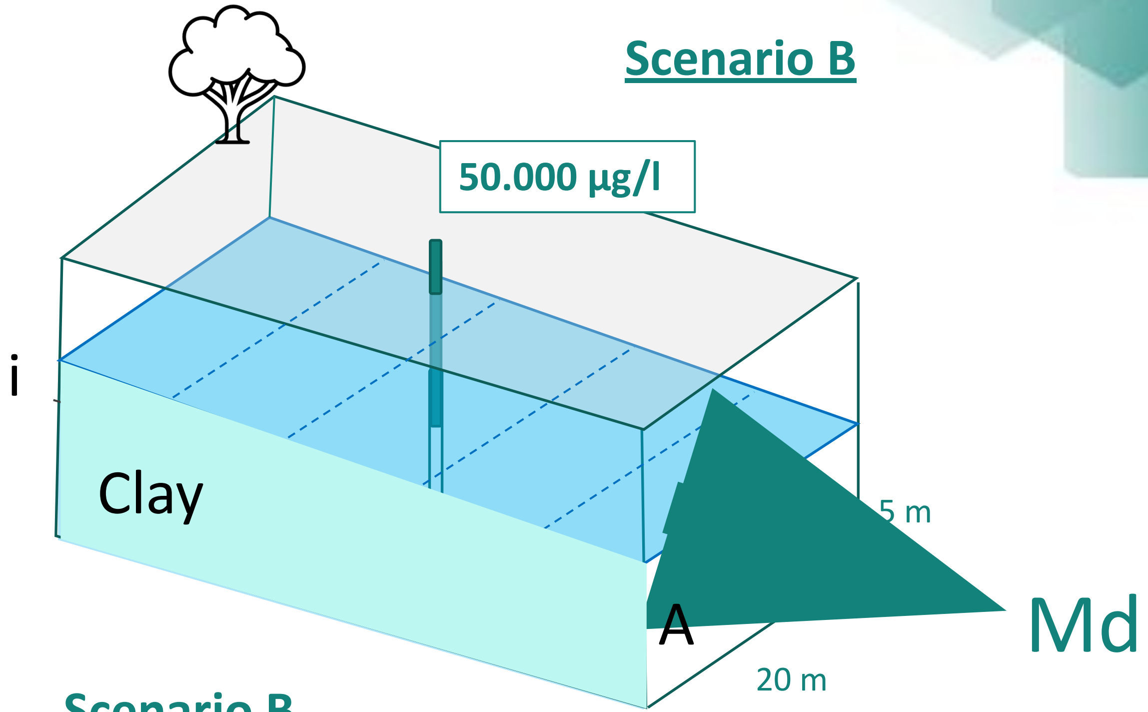
Scenario A

Area: 100 m^2
i: 0,01
K_{Sand} = 10 m/d
C= 500 µg/l

Flow 10.000 l/d

5 g/d

Scenario B



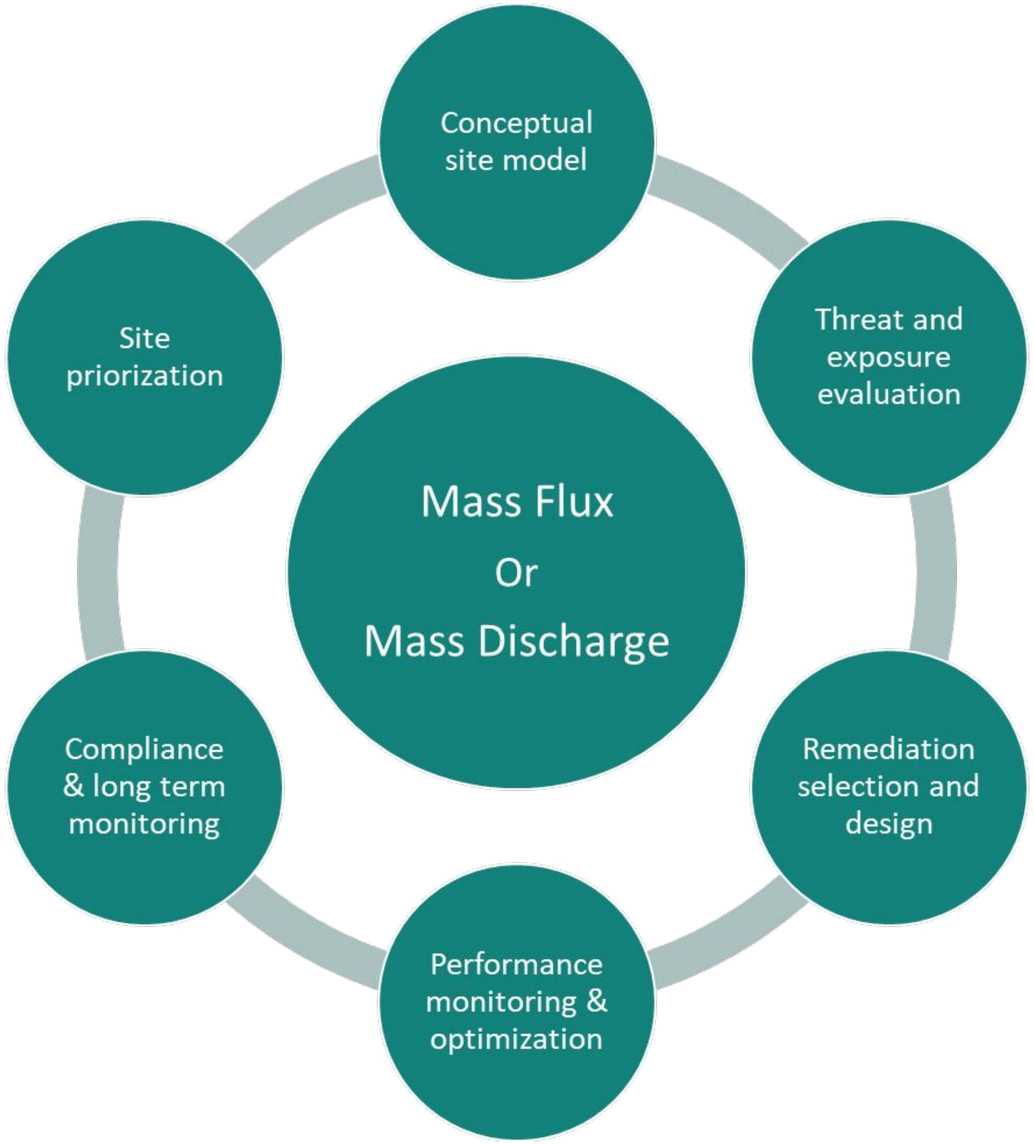
Scenario B

Area: 100 m^2
i: 0,01
K_{Clay} = 10^{-5} m/d
C= 50.000 µg/l

Flow 0,1 l/d

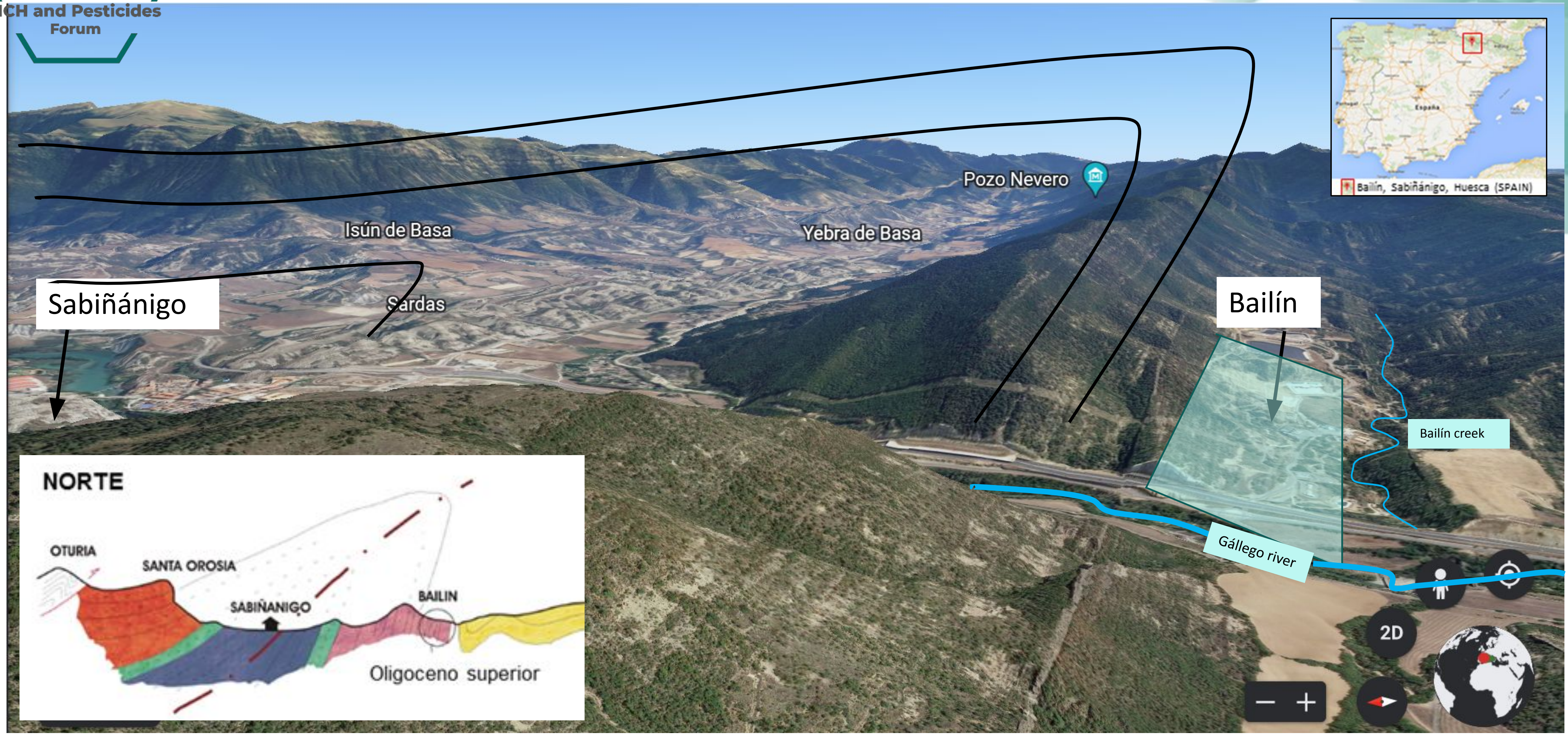
0,0005 g/d

POTENTIAL APPLICATIONS FOR CONTAMINATED GROUNDWATER MANAGEMENT



ITRC (Interstate Technology & Regulatory Council). 2010. Use and Measurement of Mass Flux and Mass Discharge. MASSFLUX-1

BAILÍN SITE: LOCATION

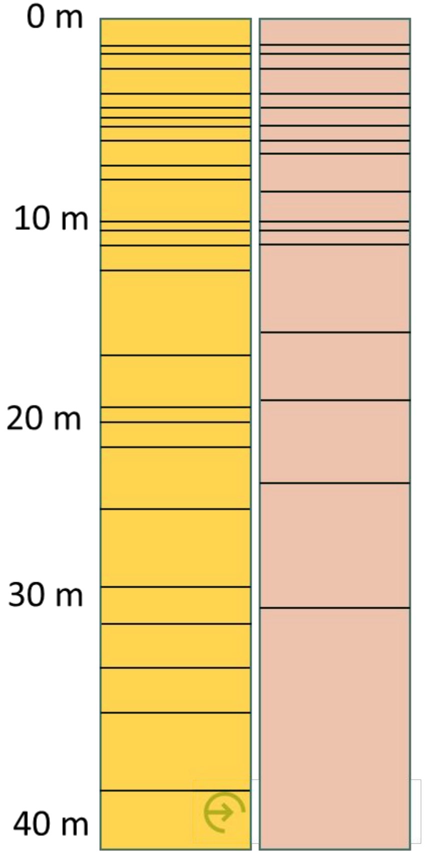


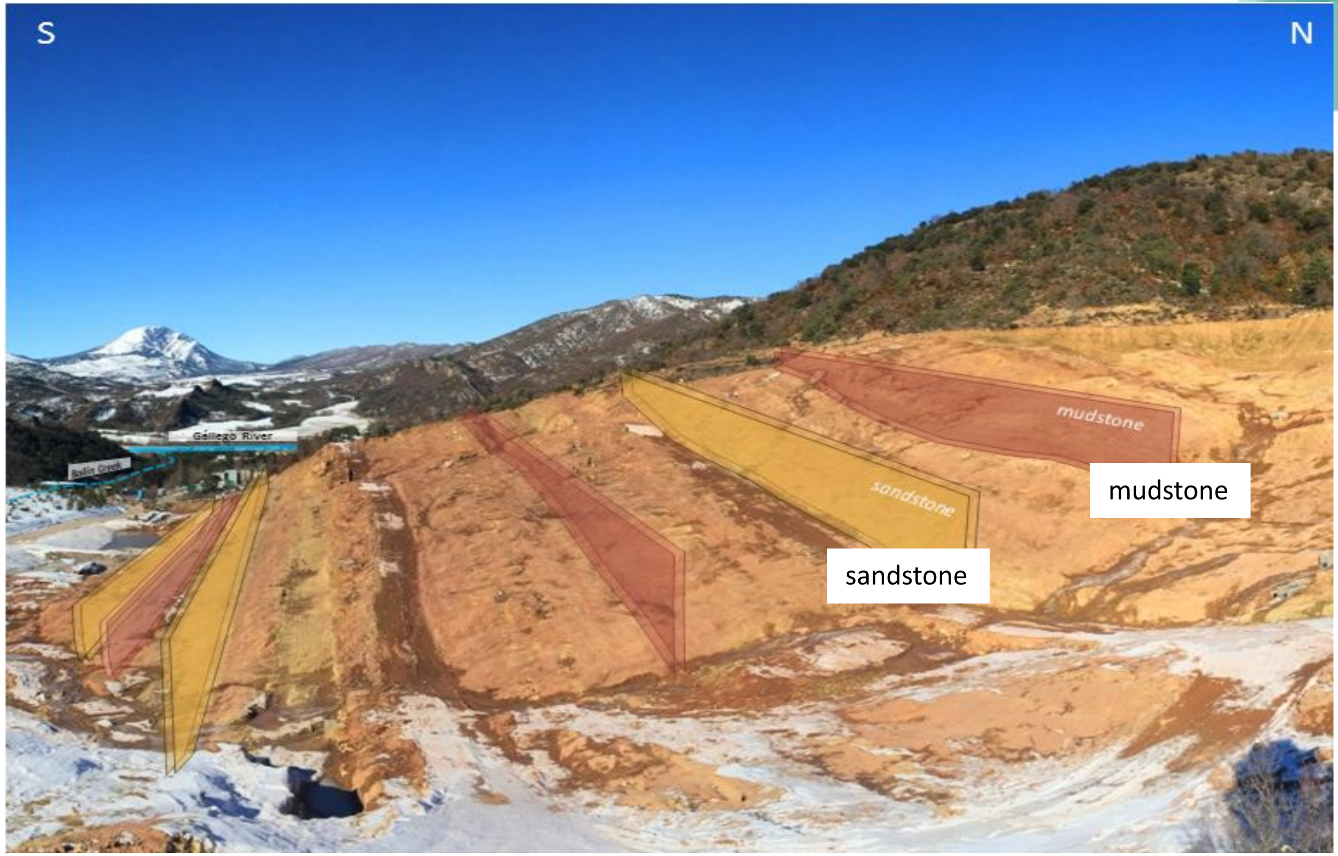
BAILÍN SITE: GEOLOGY RULES

- Rock fractured media: an alternance of vertical sandstone and mudstone layers
- Fractures distribution in depth and lithology controls groundwater flux and direction

sandstone mudstone

sandstone mudstone





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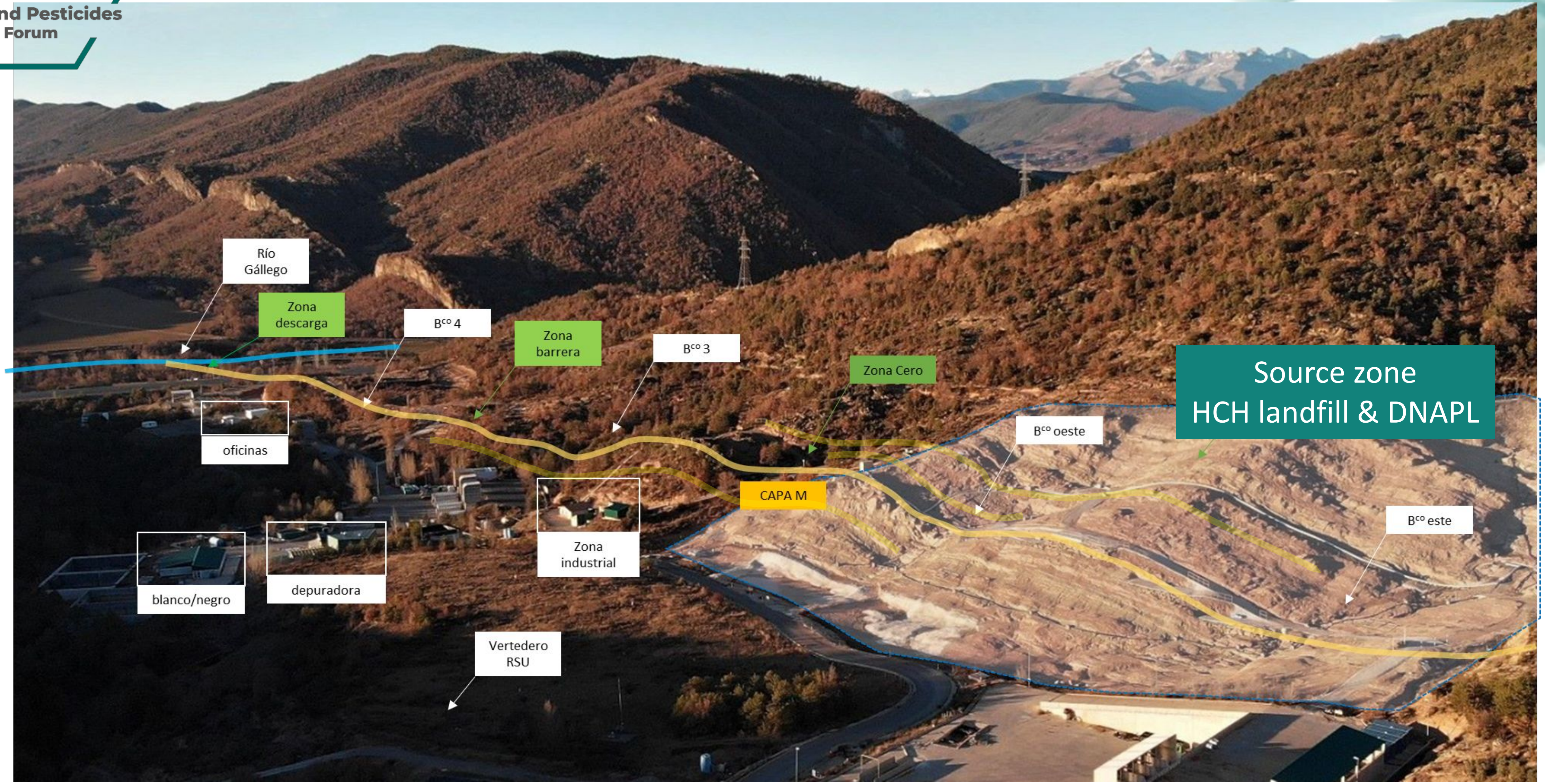

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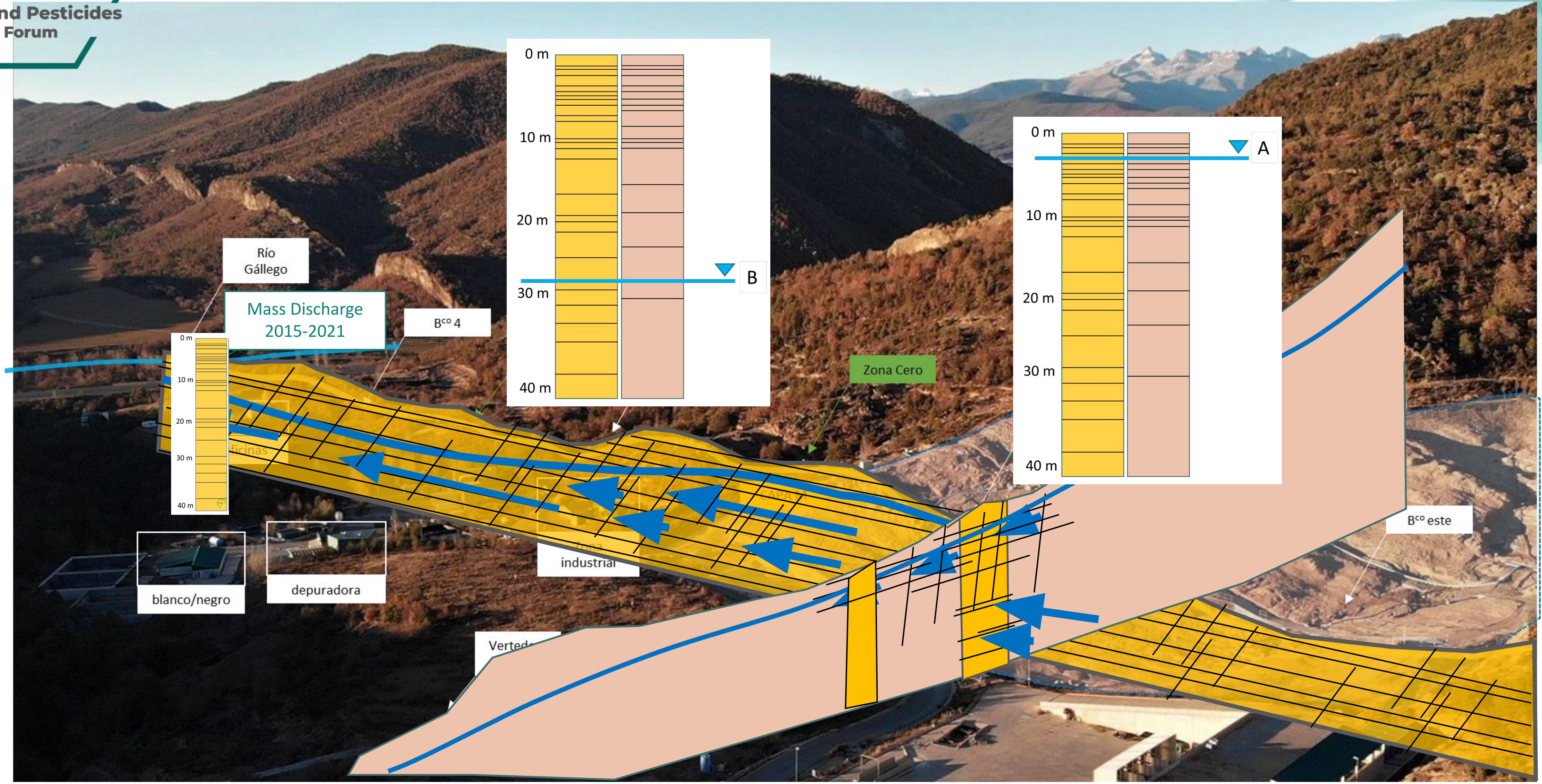
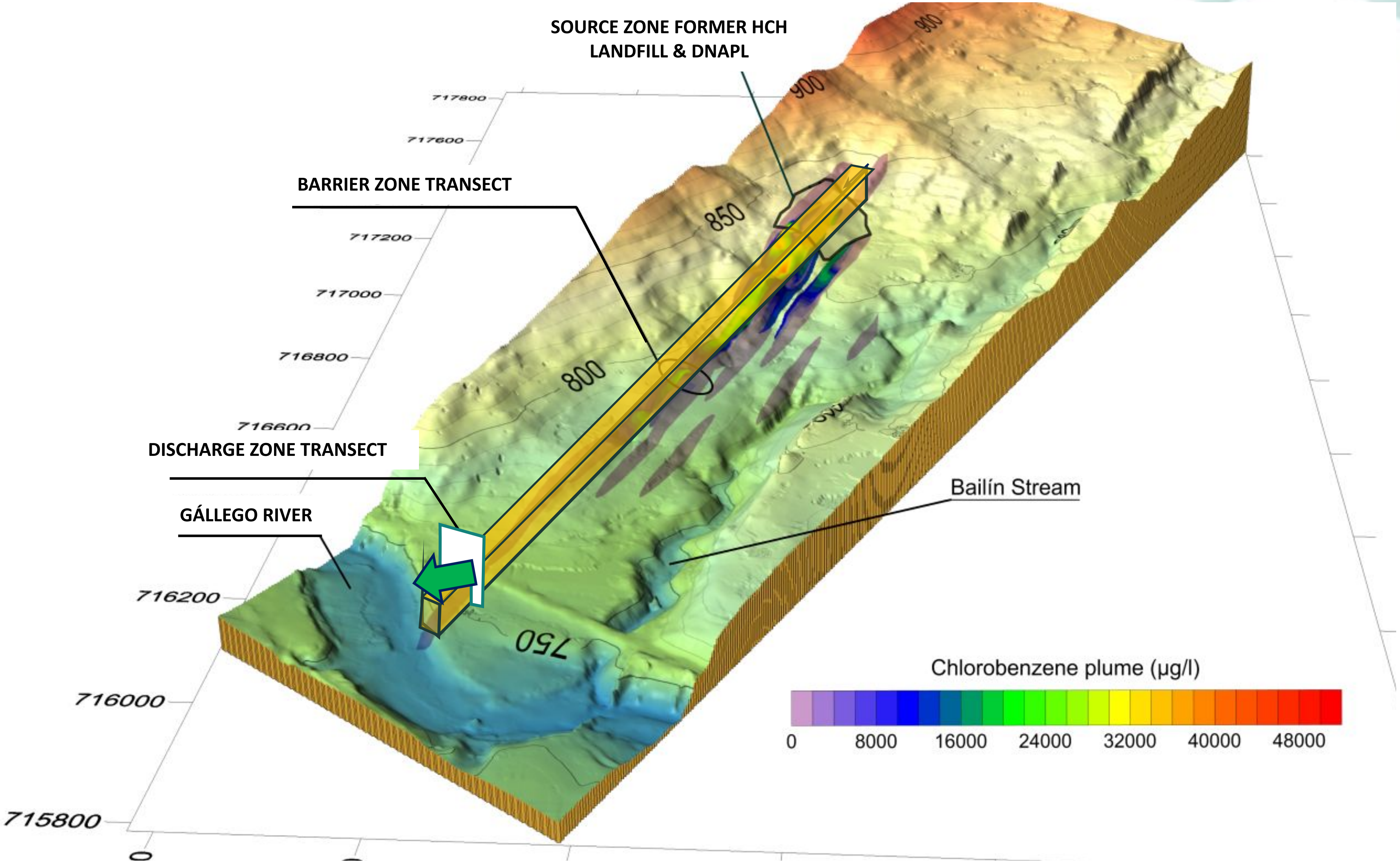


BAILÍN SITE: GROUNDWATER PLUME



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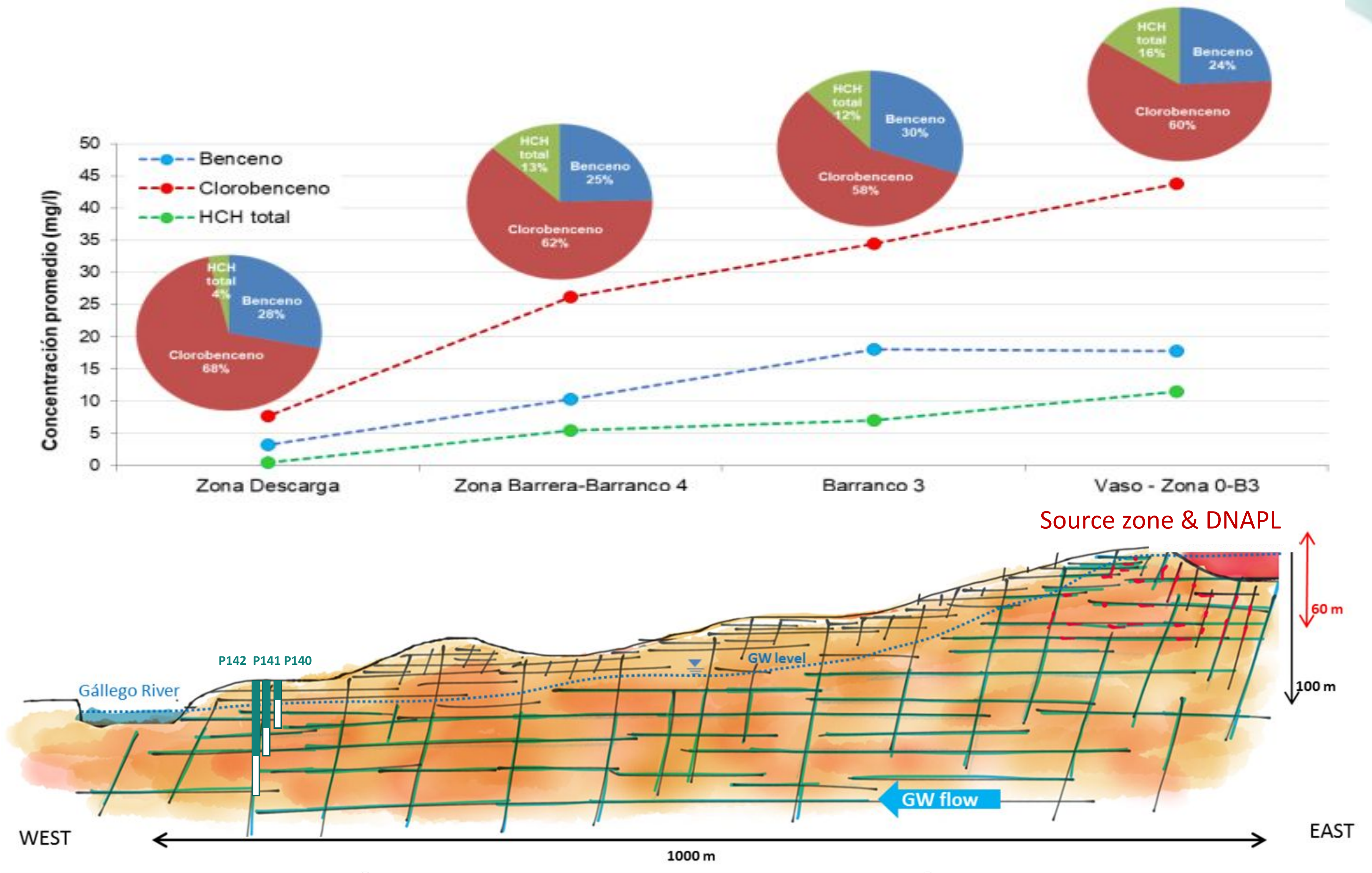


BAILÍN SITE: GROUNDWATER PLUME

Need to couple groundwater flux with concentrations to understand the threat and exposure to the river → **Mass Flux & Mass Discharge studies**

River (regulatory standard values)

Benzene: 8 µg/l
Chlobenzene: 20 µg/l
∑ HCH: 0,02 µg/l

Average annual standard published in the R.D. 817/2015

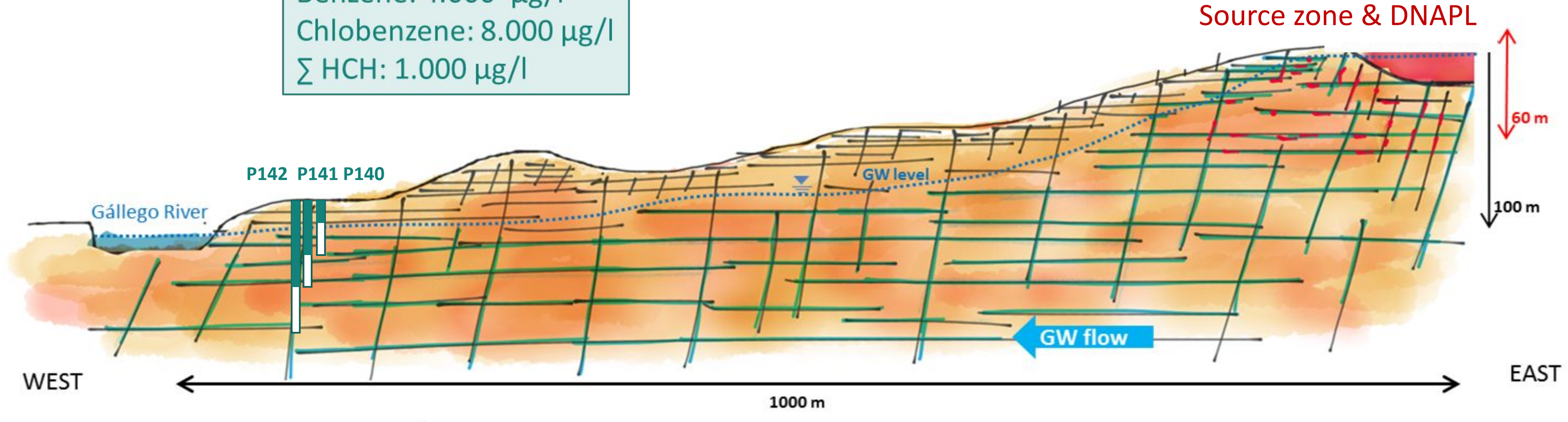
Groundwater MW

Benzene: 4.000 µg/l
Chlobenzene: 8.000 µg/l
∑ HCH: 1.000 µg/l

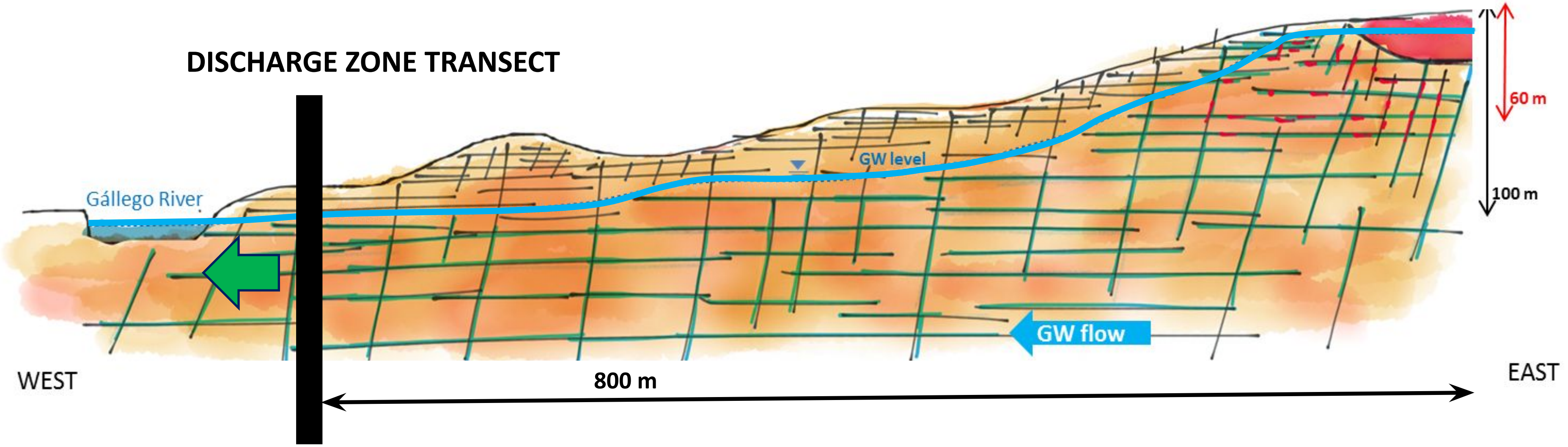
Groundwater (regulatory standard values CHE)

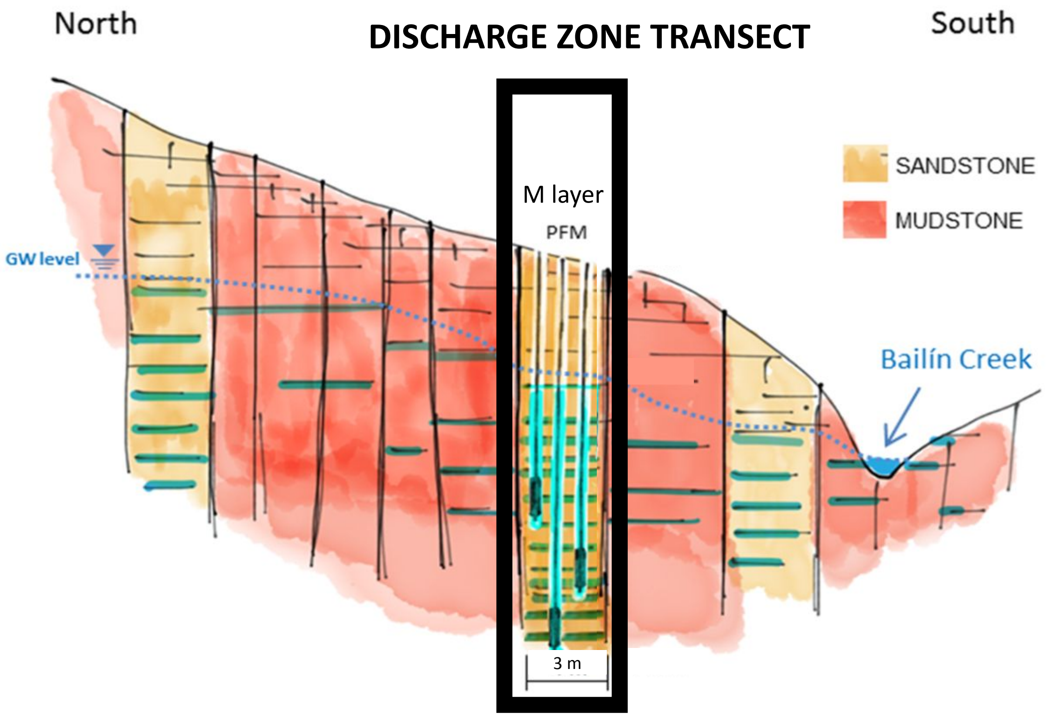
	VGNR (µg/l)	VGI (µg/l)
Benzene:	20	60
Chlobenzene:	85	250
HCH isomers :	0,1 - 2	1 - 6

VGNR: valor genérico de no riesgo
VGI: valor genérico de intervención



MASS DISCHARGE STUDIES





The Goal:

Estimate contaminant mass moving from the groundwater (fractures) to the river.

The main COC:

Benzene
Monochlorobenzene
∑ HCH isomers

MASS DISCHARGE STUDIES

Flujo de masa (*J*): es la masa de un compuesto químico que pasa a través de un plano perpendicular a la dirección de flujo por unidad de tiempo y por unidad de área (g/m^2/día)

$$J = q_0 \cdot C = K \cdot i \cdot C$$

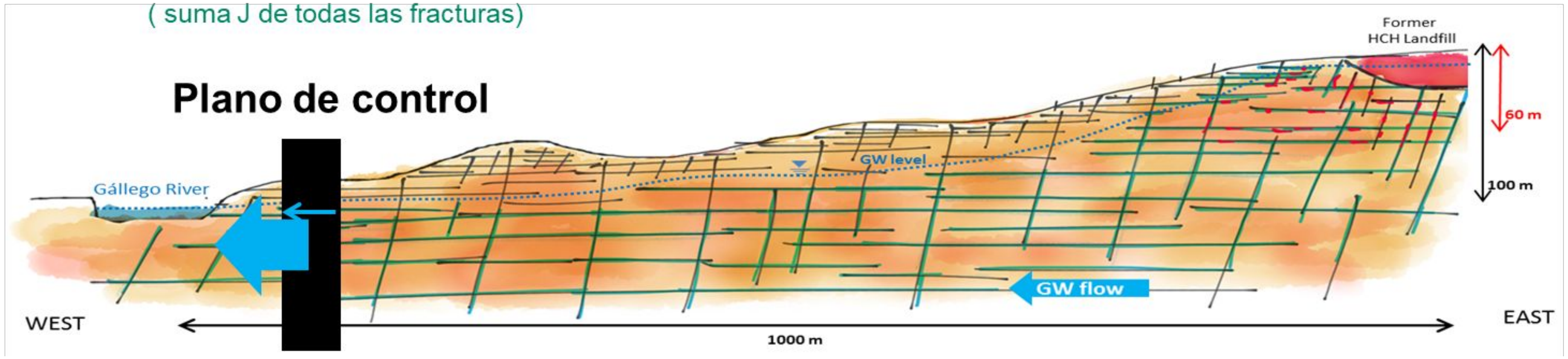
← J: gramos al día de contaminantes que circulan en el agua subterránea por cada fractura

Descarga de masa (*Md*): representa el total de la masa contaminante que circula con el agua subterránea (g/día) a través de un plano de control perpendicular a la dirección de flujo (transecto).

$$Md = \int_A J \, dA$$

Md: total de contaminantes en gramos al día que circulan por el plano de control

(suma J de todas las fracturas)



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RESULTS: AQUIFER MASS DISCHARGE (M LAYER)

Years: 2015 → 2016 →2017 → 2019 → 2021

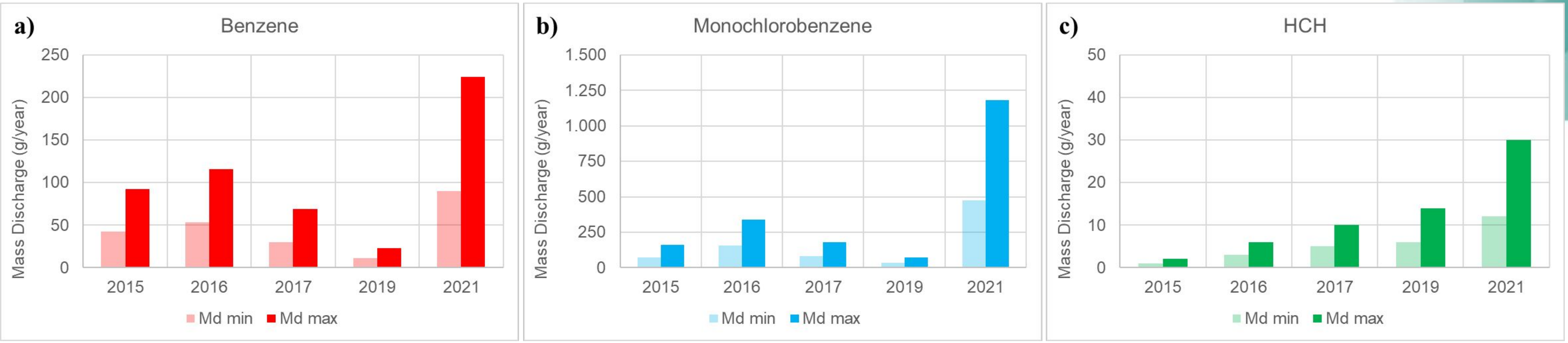


Figure 3. Temporal evolution of the Md (g/year) in the Discharge Zone. Darkest colors in the graphics represent the maximum value of the Md while lighter colors represent the minimun value of the Md. Graph a) shows the evolution of benzene Md; graph b) shows the evolution of monochlorobenzene Md; and graph c) shows the evolution of HCH Md.

Benzene: 20 – 230 (g/year):

Monochlobenzene: 33 – 1.183 (g/year):

∑ HCH: 1 – 30 (g/year):

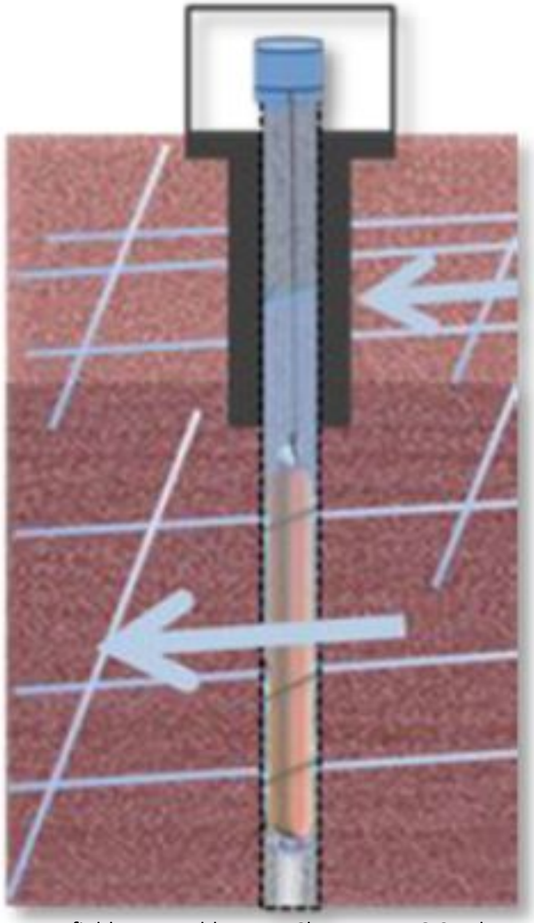
2021 → Higher Md (g/año) for all COC

METHOD SELECTED: PASSIVE FLUX METERS

PFM Samplers can determine Concentration of COC & Groundwater flux at the same time

- Activated carbon retains contaminants → **Concentration, C**
- Several alcohols act as tracers based on their solubility coefficients → **GW flux, q**
- 15 days deployment in the monitoring well

Mass Flux (J) = q x C



Hatfield K., Annable M.D., Cho J., Rao P.S.C., Klammer H. (2004). A direct passive method for measuring water and contaminant fluxes in porous media. Journal of Contaminant Hydrology, 75 (3-4), 155-181.

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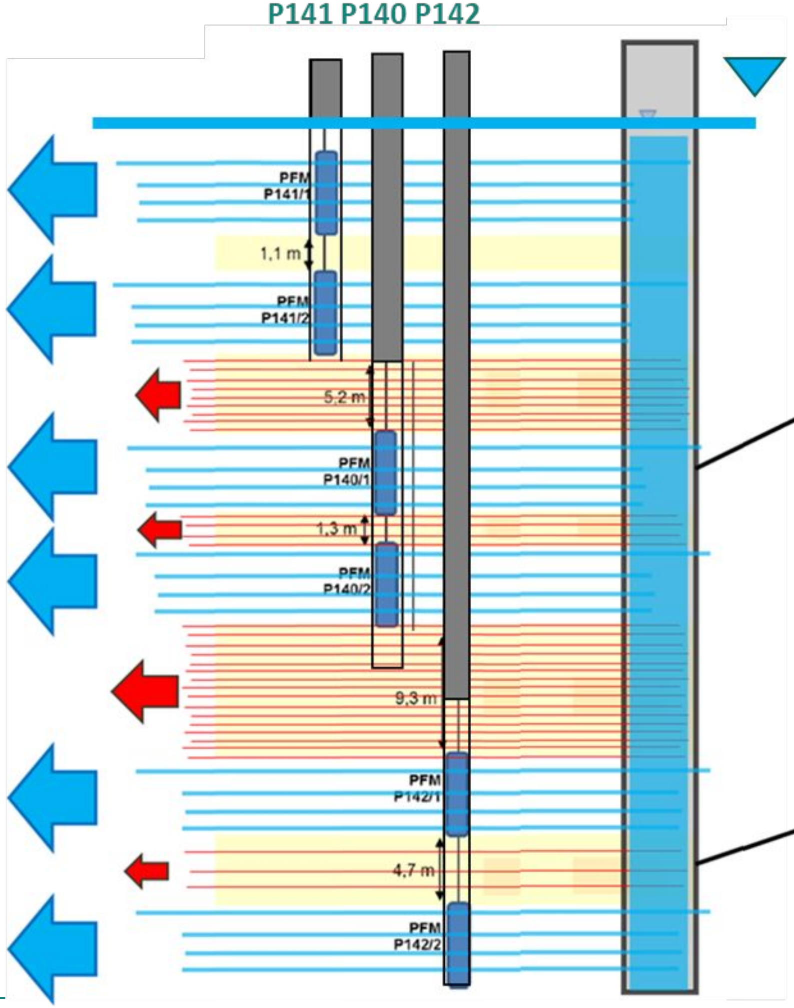
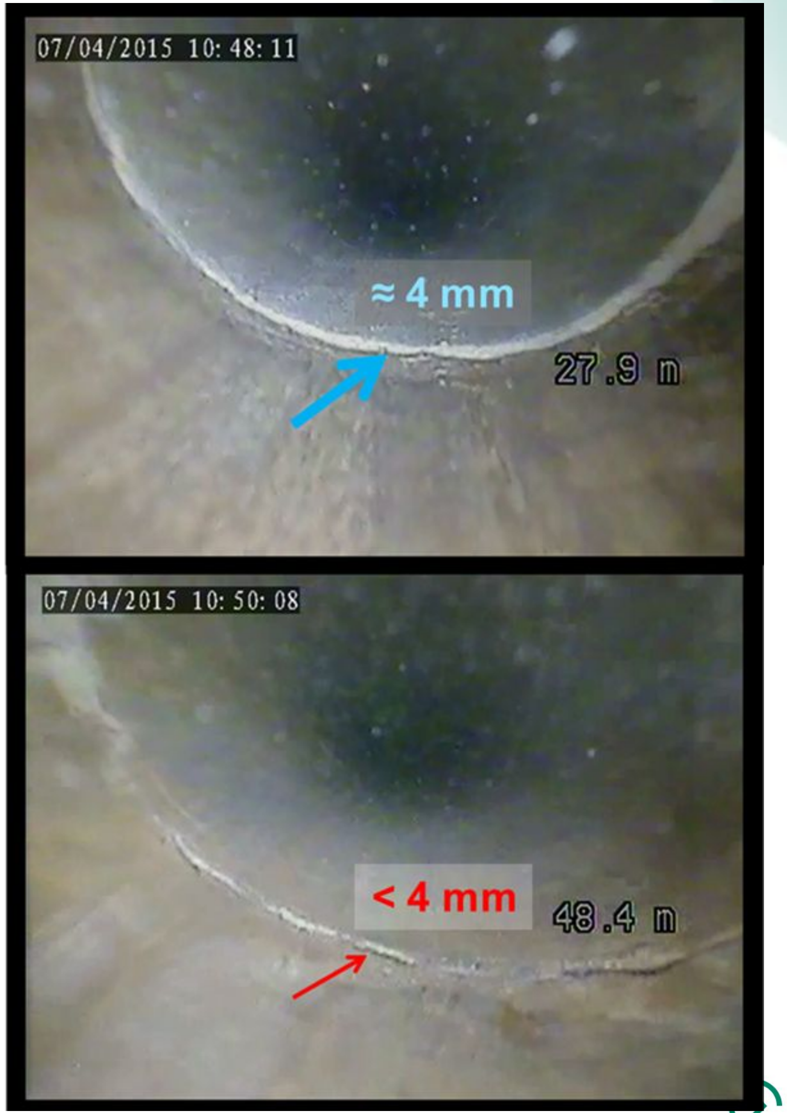




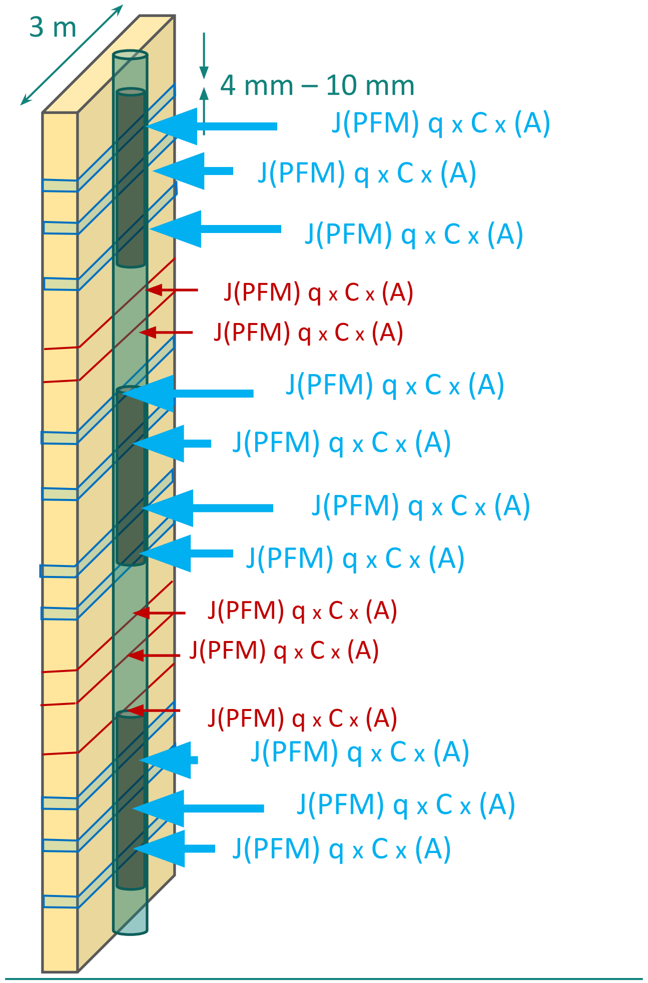
Mass Discharge= ∑ Mass Flux (J)

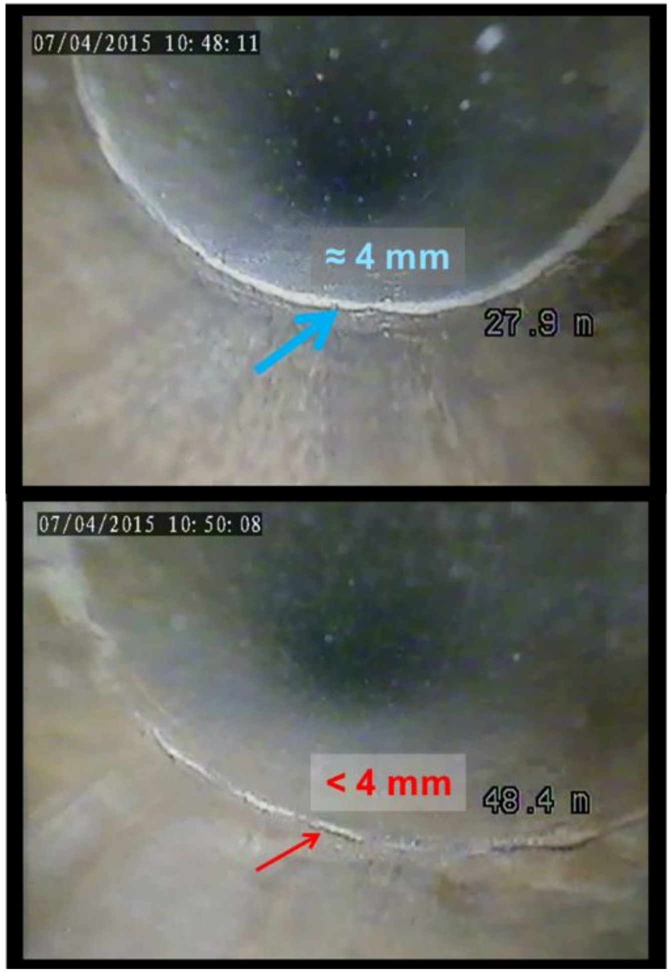
40 -50 fractures logged
45 meters depth

MASS DISCHARGE (RANGE ESTIMATIONS)

PFM ⟶ data of GW flux + Concentration ⟶ Mass Flux (J) = q x C

Each fracture area:
A= M layer width (3 m) x fracture wide (h)





Estimaciones conservadoras

Estimación mínima:

Md= J (PFM) 4 mm + J (promedio entre PFM) 4mm

Estimación máxima:

Md= J (PFM) 1 cm + J (promedio entre PFM) 4mm

40 -50 fractures logged
45 meters depth

Mass Discharge= ∑ Mass Flux (J)

RESULTS: RIVER MASS BALANCE

Mass balance 2021 → Concentration in the river ?

$$C_{river} = Md_{2021\ máx} / Q_{river}$$

	Benzene (µg/l)	Monochlorobenze (µg/l)	∑ HCH (µg/l)
River Flow (average) 1,04 m³/s	0,007	0,04	0,0009
River Flow (min) 0,67 m³/s	0,011	0,06	0,0014
RD 817/2015, de 11 de septiembre	V_{medio}: 8 µg/l $V_{máx}$: 50 µg/l	V_{medio}: 20 µg/l $V_{máx}$: - µg/l	V_{medio}: 0,02 µg/l $V_{máx}$: 0,04 µg/l

River estimated concentrations are below regulatory standards

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CONCLUSIONS

- Mass discharge & mass Balance → no COC concentrations in the river due to M layer mass discharge
- Intensive remedial actions → washing out the fractures → ↑ i → increases GW flux velocities
- Injections → Middle plume vs Source Zone → *"toothpaste model"*

- Mass discharge were estimated in natural GW flux conditions (different seasons)
- It is recommended monitoring the Md annually, if possible, during the pilot test performance

- Mass Discharge scenarios are estimated based on conservative parameter ranges. In order to relate detectable concentrations of HCH in the Gállego river with the Md (M layer) it requires:
    - Increase M layer width >3m
    - Monitoring Md during injections peak stress into the aquifer, (flashing variations)

THANK YOU FOR YOUR ATTENTION

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