

# La problemática del Mar Menor y las aguas subterráneas



**CSIC**  
CENTRO DE ESTUDIOS DE INVESTIGACIONES CIENTÍFICAS

 Instituto Geológico  
y Minero de España

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FINAL CONFERENCE OF AQUIFER PROJECT IN SPAIN  
SALA D'ACTES FEDERACIÓ OBRERA DE MOLINS DE REI.  
BARCELONA 28/3/2023.

# CAMPO DE CARTAGENA AQUIFER LINKED TO MAR MENOR COASTAL LAGOON (SE SPAIN): A PARADIGMATIC EXAMPLE OF NEGLECTING HYDROGEOLOGY



**2016**  
"Green soup"  
(Eutrophication)



**2019**  
Anoxia



**2019**  
"Floods"



**2022**  
Visit of European  
Commision



**2022**  
Algal bloom

**August 2021**

PLANÈTE - POLLUTIONS Partago

## Espagne : des tonnes de poissons morts en mer Mineure à cause d'une pollution aux nitrates

L'ancien paradis touristique situé au sud-est de l'Espagne se meurt, privé d'oxygène par une pollution aux nitrates agricoles.

**Le Monde**

Le Monde avec AFP ·

Publié le 25 août 2021 à 17h53 · Mis à jour le 26 août 2021 à 04h54 · Lecture 2 min.

## Spain bans fertilisers near saltwater lagoon after dead fish wash up

Officials close eight beaches as residents complain of cloudy, green water that emits a foul smell

Seascope: the state of our oceans is supported by

the David & Lucile Packard FOUNDATION 

About this content  
**Ashifa Kassam**  
 @ashifa\_k  
 Thu 26 Aug 2021 14:39 BST

 **Espagne: asphyxiée par les nitrates, la mer Mineure recrache des milliers de poissons morts**



25 août 2021 à 17:13 · 3 min  
 Par AFP

**Mar Menor**

## Elendes Fischsterben in Dauerschleife

**ZEITUNG ONLINE**

In Europas größter Salzwasserlagune verenden erneut tonnenweise Tiere. Das Mar Menor steht seit Jahren vorm Kollaps durch illegale Abwässer und politisches Versagen.

Eine Analyse von **Barbara Platsch**, Madrid

27. August 2021, 14:49 Uhr / 77 Kommentare / 





## Desastre

### España: el Mar Menor, una laguna que se muere por la falta de oxígeno y la contaminación

Es una de las mayores lagunas litorales del Mediterráneo. La llegada de nitratos de los abonos de la agricultura intensiva la está matando.

DISASTRO AMBIENTALE **CORRIERE DELLA SERA**

## Spagna, strage nel Mar Menor: in pochi giorni 5 milioni di pesci uccisi dai fertilizzanti

di **Peppe Aquaro** | 29 ago 2021

**Los expertos son pesimistas sobre el futuro del Mar Menor**  COMENTARIOS  
**euronews.**

Por **Isidro Murga** con RTVE, EFE · última actualización: 29/08/2021

**Mar Menor: Tonnes of dead fish wash up on Spanish lagoon's shores**

24 August 2021



REUTERS

For days beaches along the Mar Menor in south-eastern Spain have been littered with dead fish

Tonnes of dead fish have washed up on the shores of a large saltwater lagoon in south-east Spain in recent days after a mass die-off that has shocked local residents and environmentalists.

**TV5MONDE Info** @TV5MONDEINFO

En #Espagne, les fertilisants utilisés par l'agriculture intensive provoquent la mort de millions de poissons dans le lagon de la mer Mineure, près de Murcie.  
 #MerMineure #MarMenor



**Espagne : l'agriculture intensive asphyxie la mer Mineure**



**"El Mar Menor no se podrá recuperar si antes no actuamos sobre las aguas subterráneas"**

Luis Alcázar 26/08/2021 12:02

**EL PAÍS**

MAR MENOR >

**ALDI pide explicaciones a sus proveedores de frutas y hortalizas en el mar Menor por la contaminación de la laguna**

La marca advierte de que su política corporativa, responsable con el medio ambiente, les lleva a investigar de forma exhaustiva este caso "para derivar los pasos necesarios"

**October 2021**

**How a Stunning Lagoon in Spain Turned Into 'Green Soup'**

Tons of dead fish have washed ashore in recent years from the Mar Menor, a once-crystalline lagoon on the Mediterranean coast that has become choked with algae. Farm pollution is mostly blamed.



PLANÈTE • POLLUTIONS

**La Mar Menor, une immense lagune salée dont l'écosystème est asphyxié**

Ce lieu dans le sud-est de l'Espagne pourrait être idyllique s'il n'avait été massivement urbanisé, puis contaminé par des tonnes de nitrates. Une initiative citoyenne veut lui donner une personnalité juridique, pour le sauver.

Par Sandrine Morel (Murcie, envoyée spéciale)

Publié le 26 octobre 2021 à 16h12 - Mis à jour le 26 octobre 2021 à 17h22 - Lecture 9 min.



C'est un désastre écologique ! : dans... francetvinfo.fr



Mar Menor. La laguna salada más grande de Europa wikimurcia.com



https://static.eldiario.es/clip/b5592c80-d0c1-4... eldiario.es



Una revista americana tacha al Mar Menor de "destino a evi... laopiniondemurcia.es



Apartamento Juana en Monaco, Apartamentos L... gites.fr



hace 21 horas El mar Menor vuelve a arrojar peces por falta de... nwmovdaly.com



Fact Finding Visit to Mar Menor (Murcia), Spain: 2... europarl.europa.eu



La Comisión Europea califica de "gran desastre" el e... elespanol.com



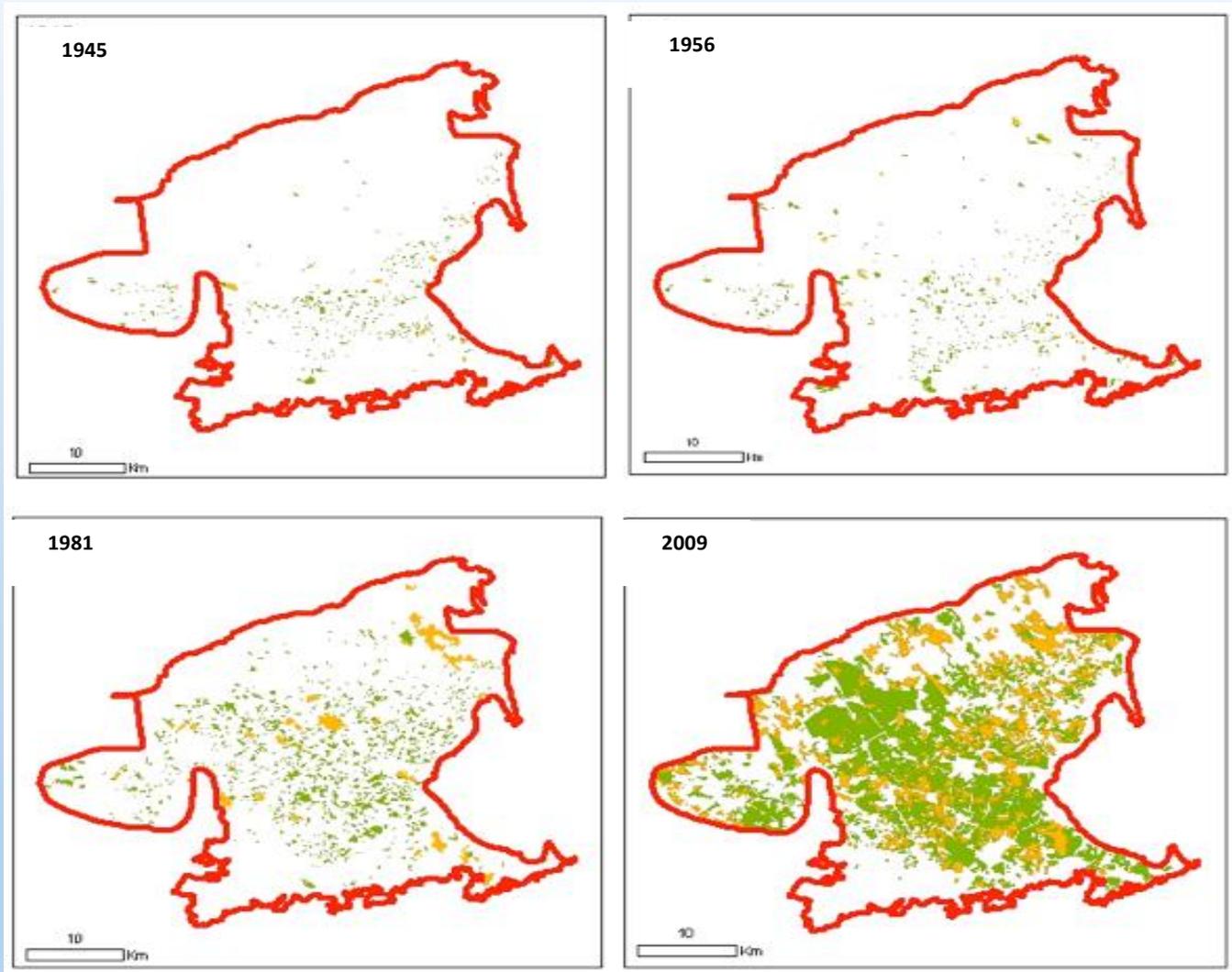
Fotos: La terrible degradación del mar Menor, en imáge... elpais.com



Mar Menor: view from south. Source: Atlas... researchgate.net

## Last century: Blooming the desert

Tentative reconstruction of irrigated area

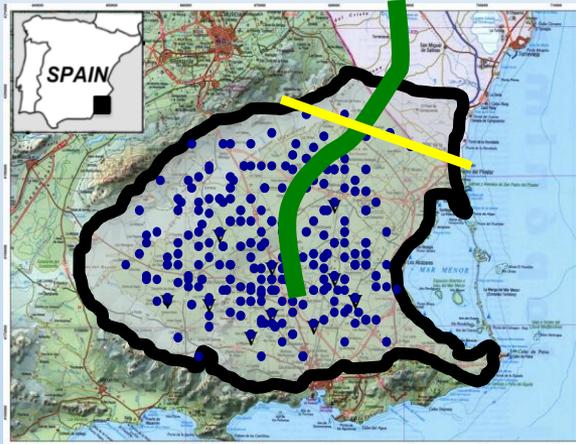


 Hortícolas  
 Cítricos

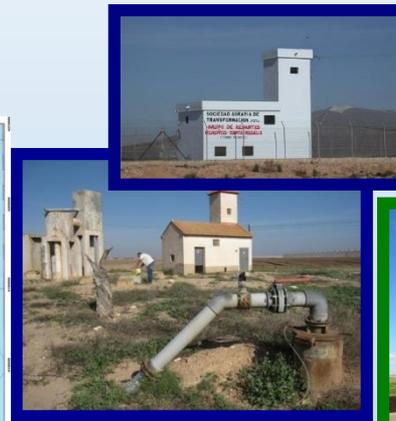
(>50000 ha)

Adaptado de Castel, Gomariz y Guerra (2012)

# Sources to meet growing irrigation water demands



**1200 km<sup>2</sup>**  
 (Aprox. 30% Irrigated)



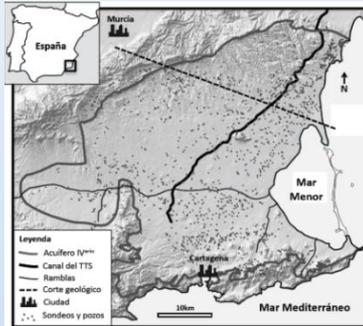
Groundwater to mix and/or desalination of brackish groundwater (Shallow and deep aquifers)



Tajo-Segura Water Transfer Canal

- + Reclaimed water
- + Seawater desalination
- + Regulated Deficit Irrigation

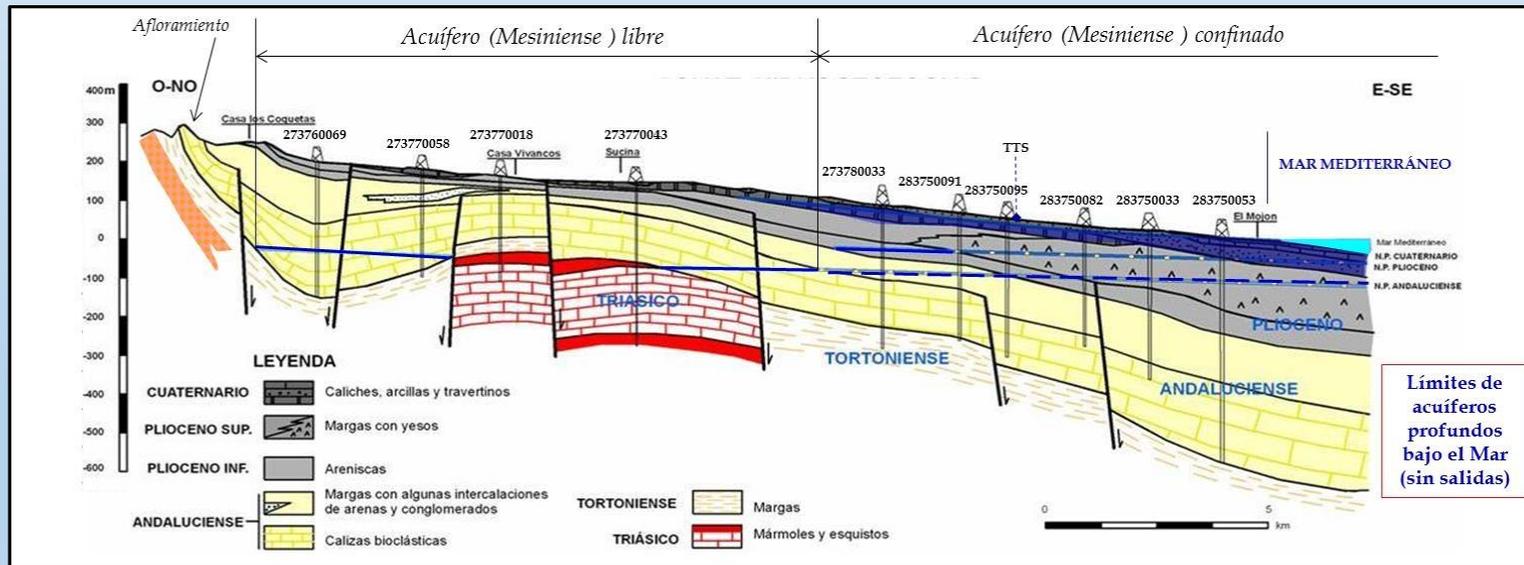
# Campo de Cartagena multilayer aquifer: The shallow aquifer (Quaternary) discharge to the Mar Menor Coastal lagoon



**Sistema multicapa** (aunque no todos los acuíferos están presentes a lo largo de toda la extensión superficial del Campo de Cartagena), **constituido por:**

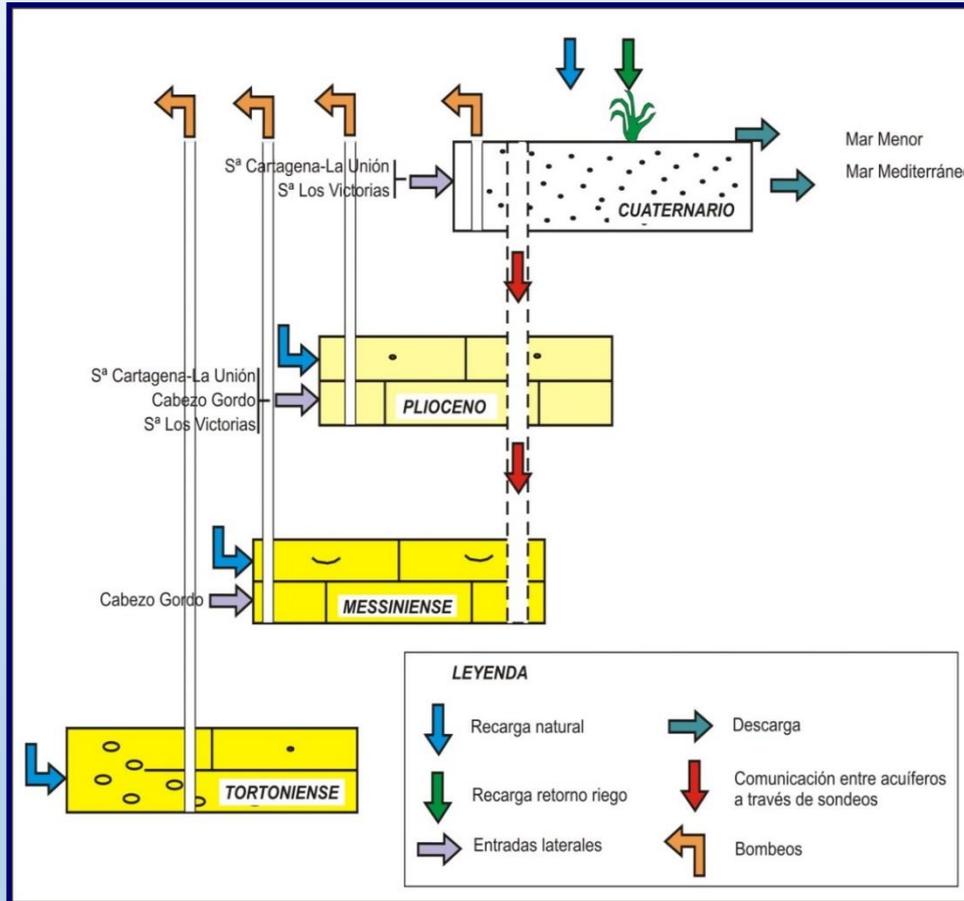
- Acuífero superficial libre de edad Cuaternario
- Tres acuíferos profundos fundamentalmente confinados (de edad Plioceno, Messiniense y Tortoniense).

**Acuífero carbonatado Pérmico-Triásico (aflora en Cabezo Gordo)**



# Campo de Cartagena multilayer aquifer:

## The shallow aquifer (Quaternary) discharge to the Mar Menor Coastal lagoon



Jiménez et al, 2009. Geologica Acta

### BASICAL SCHEME

#### INPUT (groundwater recharge):

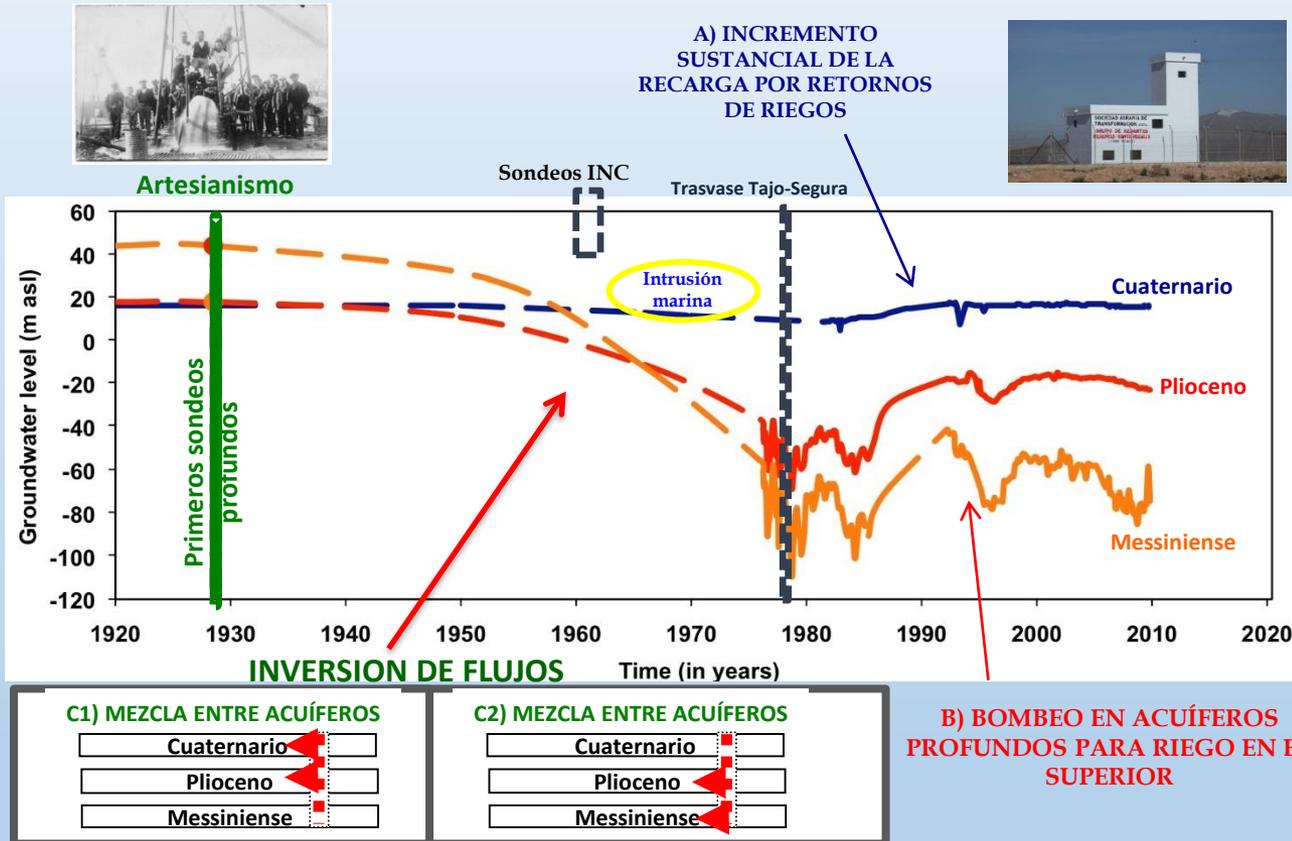
- Infiltration of precipitation and irrigation

#### OUTPUT (descarga):

- Pumping
- Discharge to Mar Menor y Mediterranean Sea
- Discharge to surface network

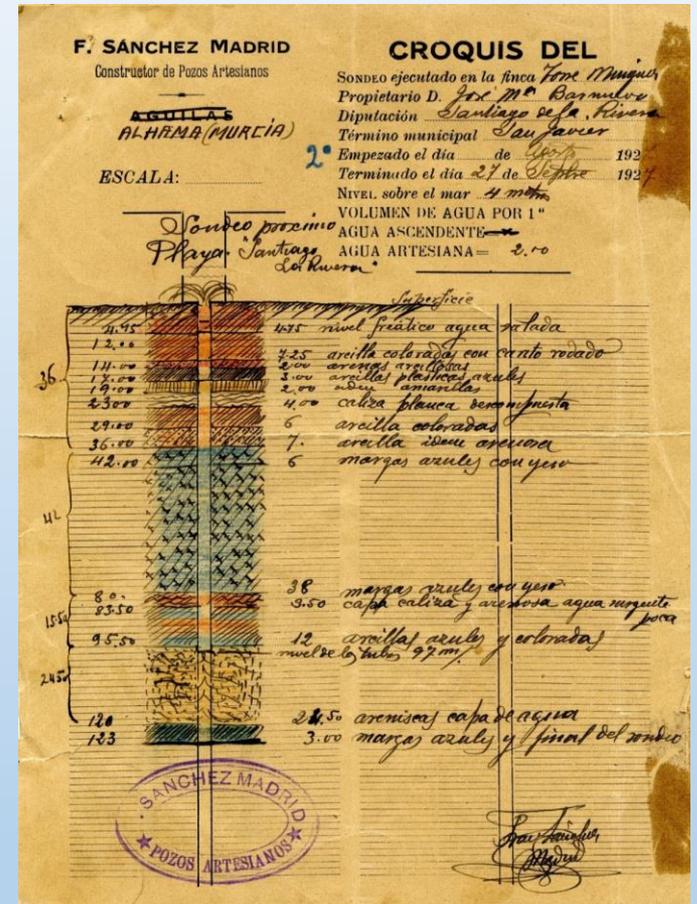
#### Communication between aquifers

# The paradox: Overexploitation in deep aquifers and underexploitation in shallow aquifer (linked to a coastal lagoon)



Adaptado de  
 García-Aróstegui et al (2012)  
 Baudron et al. (2014) *Hydrological Processes*

**HACE UN SIGLO...**  
**INICIO DE LA EXPLOTACIÓN DE LOS ACUÍFEROS PROFUNDOS EN LA ZONA DE SAN JAVIER**



FUENTE: Archivo Municipal de San Javier (<http://archivo.sanjavier.es/>)  
 EXPOSICIÓN: LOS BARNUEVO: 130 AÑOS DE HISTORIA DE LA RIBERA



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REVIEW

## The role of groundwater in highly human-modified hydrosystems: a review of impacts and mitigation options in the Campo de Cartagena-Mar Menor coastal plain (SE Spain)

J. Jiménez-Martínez, J.L. García-Aróstegui, J.E. Hunink, S. Contreras, P. Baudron, and L. Candela

**Abstract:** Hydrological processes and water resources are increasingly modified by anthropogenic actions, leading to multiple pressures on the environment and related ecosystems. A better understanding of the interactions between the anthroposphere and the hydrosphere is necessary to shape more sustainable societies. The pressure of human activities on the environment is especially high along the circum-Mediterranean area because of a combination of biophysical and economic factors. The Campo de Cartagena coastal plain, together with the Mar Menor lagoon, is one of the most exemplary areas in this aspect. This work analyzes this system at the basin level by providing a synthesis of the state of knowledge of each hydrological compartment and the links between them. We pay special attention to the important role that groundwater plays in the overall functioning of the system, both as a promoting and (or) mitigating agent. The principal identified impacts from human actions are water imbalance (28% of consumed water resources are not renewable); aquifer-cross contamination (high areal density, ~1.2 wells/km<sup>2</sup>); acid-mine drainage (mine wastes, accounting for ~175 hm<sup>2</sup> on land and ~25 hm<sup>2</sup> in the sea, accumulated mainly between 1957 and 1992); and lagoon eutrophication (NO<sub>3</sub><sup>-</sup> up to 1 mg/L). A set of mitigation options and complementary management measures that should be implemented following an integrative and holistic approach are presented and discussed, supporting a more sustainable regional economy and the recovery of critical ecosystem services.

# The role of groundwater in scientific papers

Science of the Total Environment 663 (2019) 901–914

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)



## Hydrogeological modelling for the watershed management of the Mar Menor coastal lagoon (Spain)

Andrés Alcolea<sup>a</sup>, Sergio Contreras<sup>b</sup>, Johannes E. Hunink<sup>b</sup>, José Luis García-Aróstegui<sup>c,d</sup>, Joaquín Jiménez-Martínez<sup>e,f,\*</sup>

<sup>a</sup> HydroGeoModels AG, Tösstalstrasse 23, 8400 Winterthur, Switzerland

<sup>b</sup> FutureWater, Calle San Diego 17, 30202 Cartagena, Spain

<sup>c</sup> Geological Survey of Spain, Murcia Office, Avda. Miguel de Cervantes 45, 5A, 30009 Murcia, Spain

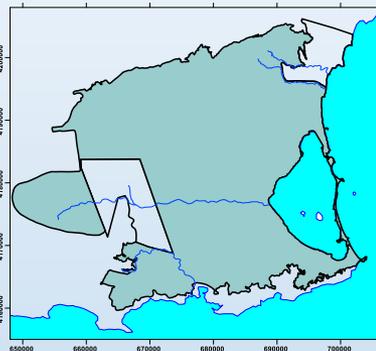
<sup>d</sup> University of Murcia, Institute for Water and Environment, Campus de Espinardo, 30010 Murcia, Spain

<sup>e</sup> Department of Water Resources and Drinking Water, EAWAG, 8600 Dübendorf, Switzerland

<sup>f</sup> Department of Civil, Environmental and Geomatic Engineering, ETH Zürich, 8093 Zürich, Switzerland



# Comparación cifras oficiales de balance hídrico (en hm<sup>3</sup>/año) de la Masa de Agua subterránea 070.052 "Campo de Cartagena" PHCS 15-21 vs Propuesta Proyecto PHCS 22-27



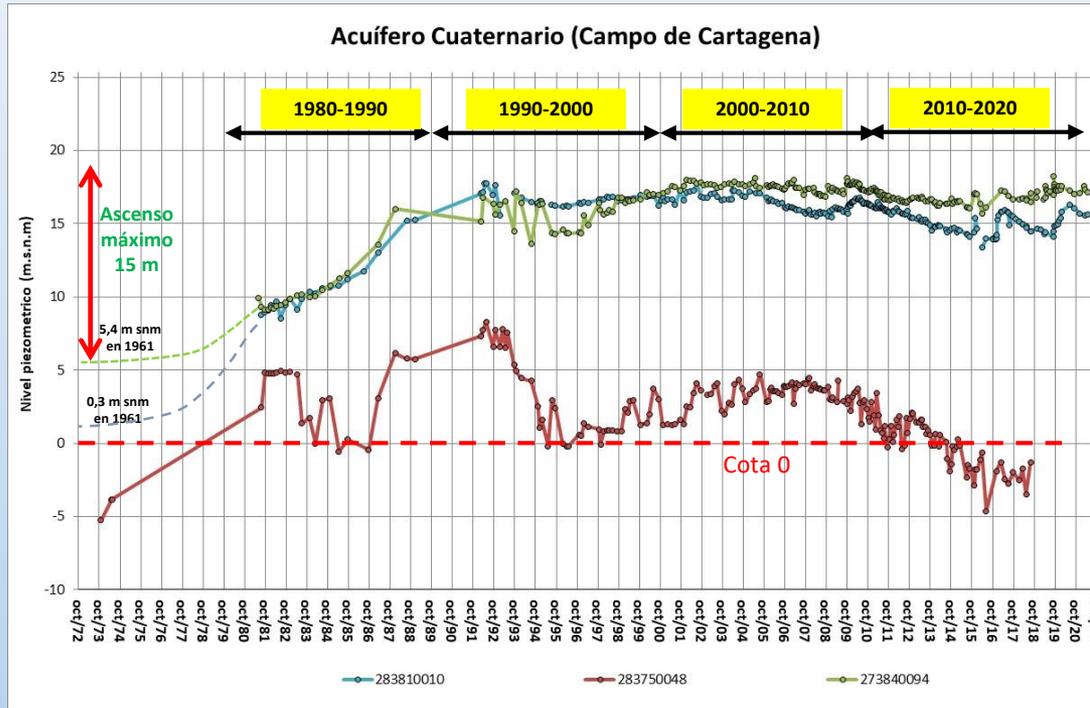
	Entradas		Salidas			BALANCE
	Infiltración por lluvia	Retornos de riego	Bombeos	Al sistema superficial	Salidas al mar	
PHCS 15-21	77.0	18.2	89.0	0.0	6.2	0.0
PP PHCS 22-27	48.8	18.2	58.8	0.0	9.1	-0.9

37%

34%

# Historical rising groundwater level in the shallow aquifer of Campo de Cartagena

Puntos de la red oficial CHS (depurada)



**Problemas de intrusión marina en la década de los 50-70**

**Incremento de la recarga durante los años 70-80.**

**Efecto de las precipitaciones de finales de los 80.**

**Efecto de la sequía de 93-95.**

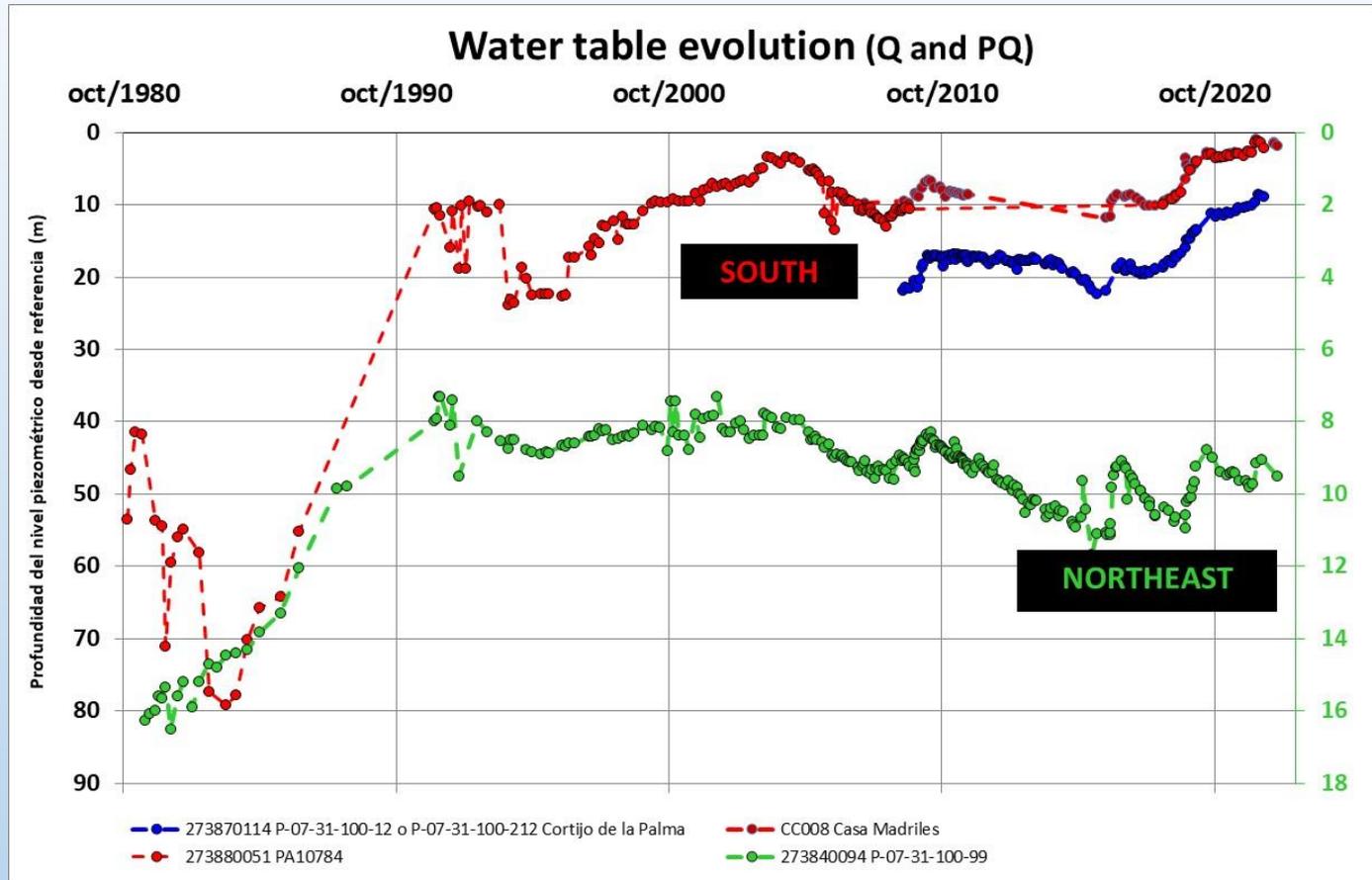
**Tendencias descendentes en el periodo 2005-2015**

**Efectos recientes de los eventos de precipitación de Sep-Oct-2009, 2016 y 2019**



**JL GARCIA ARÓSTEGUI**

## Historical rising groundwater level in the shallow aquifer (Q and PQ-south) of Campo de Cartagena



**Problemas de intrusión marina en la década de los 50-70**

**Incremento de la recarga durante los años 70-80.**

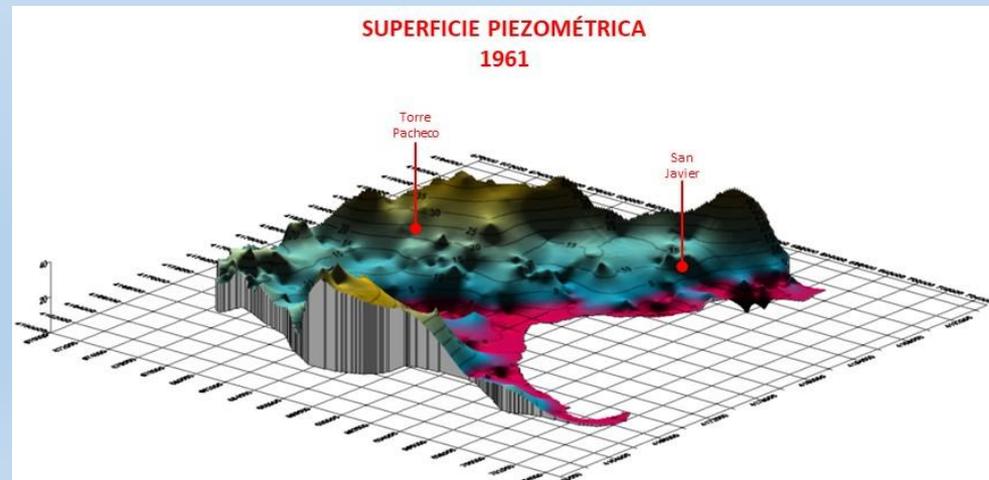
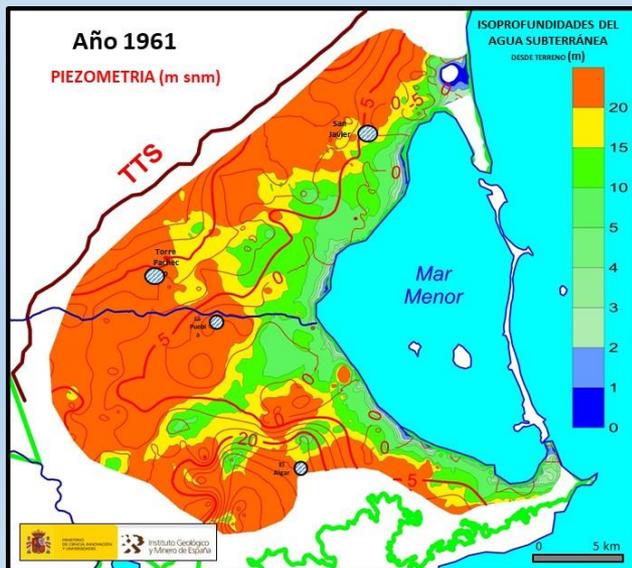
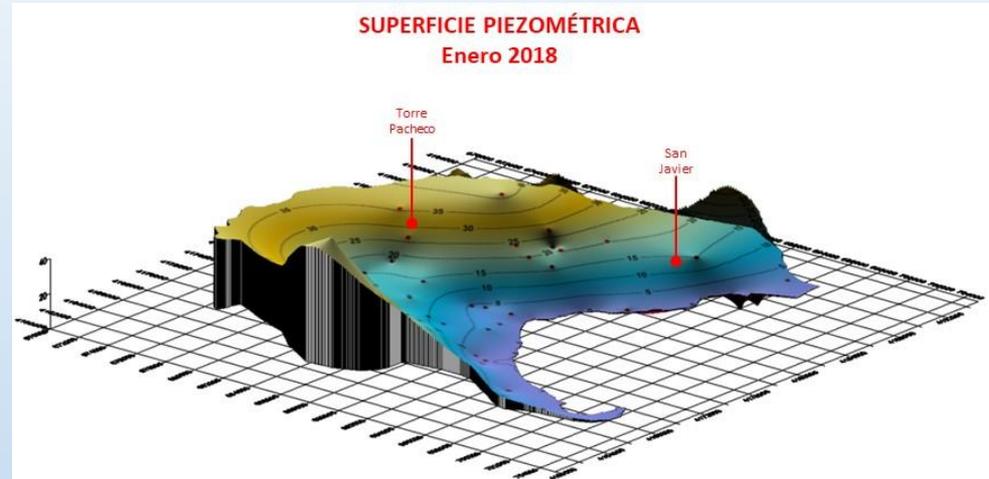
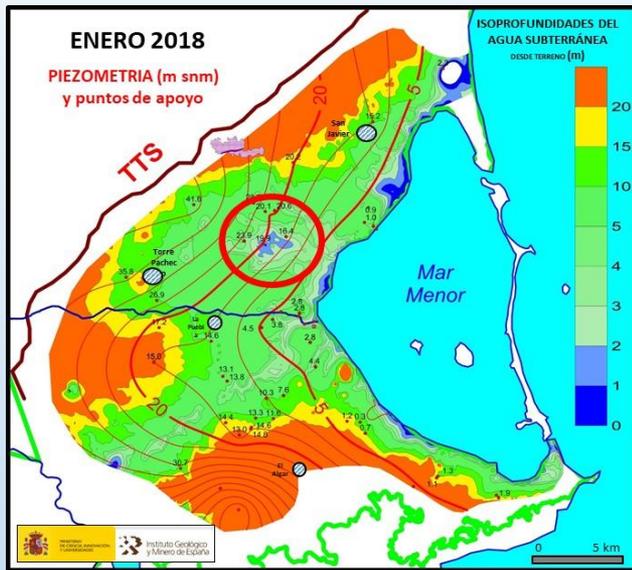
**Efecto de las precipitaciones de finales de los 80.**

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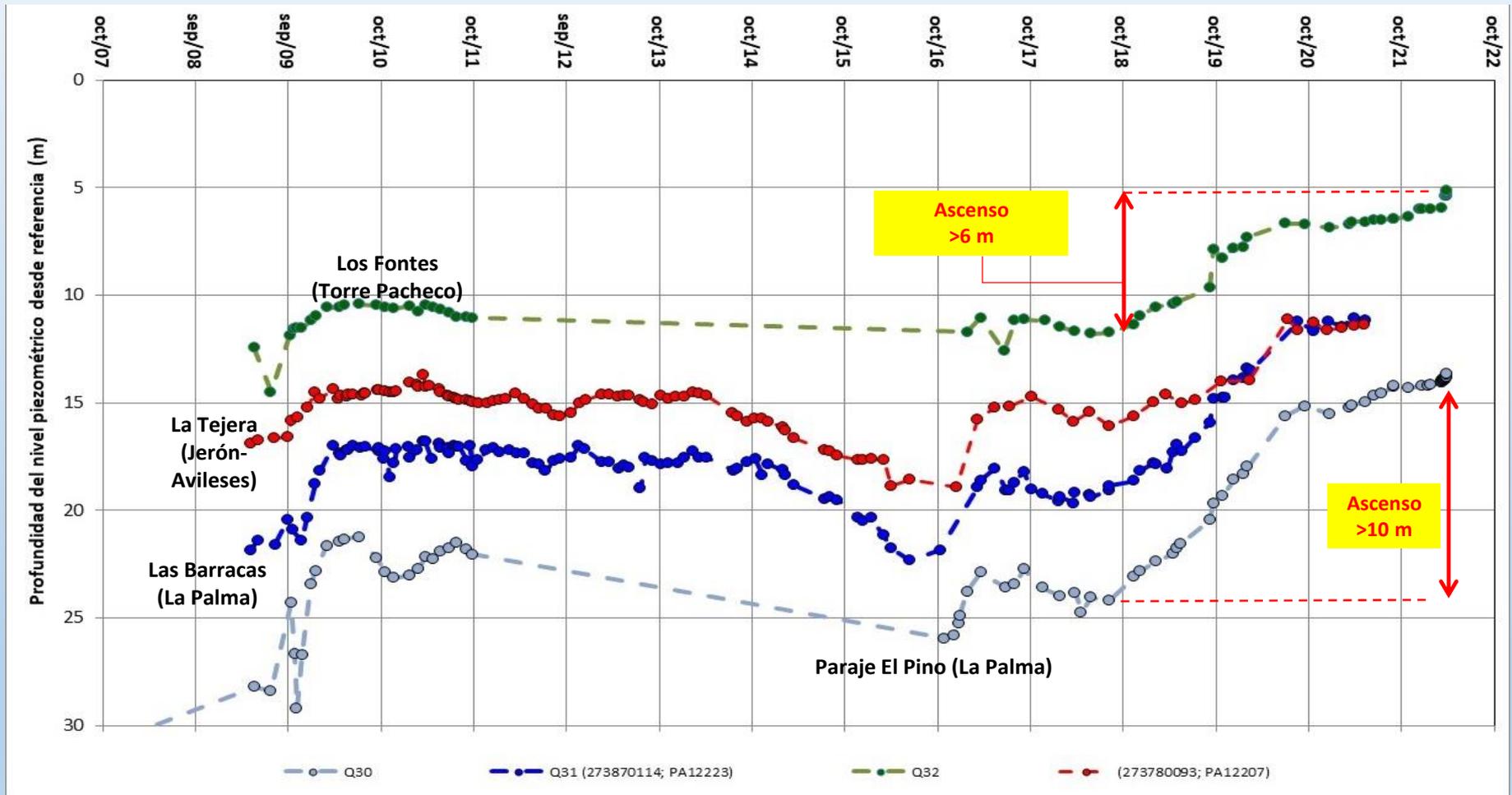
**Tendencias descendentes en el periodo 2005-2015**

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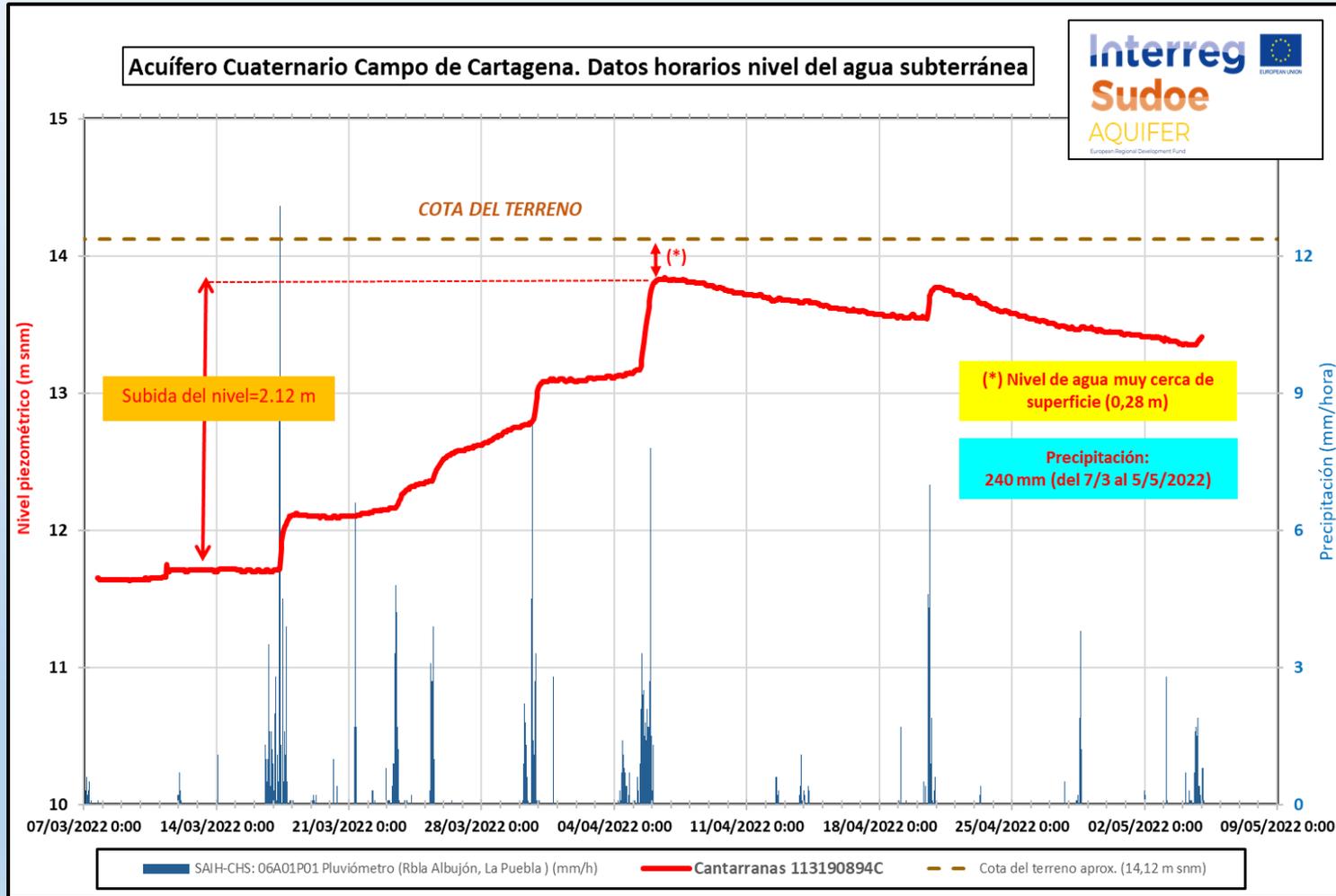
**Sobreelevación histórica del niveles piezométricos en el acuífero Cuaternario del Campo de Cartagena: Comparativa entre 1961 (problemas de intrusión marina) y 2018 (sustancial incremento de la descarga al Mar Menor, con movilización de contaminantes almacenados)**



**Recent groundwater levels rise as a consequence of reducing abstraction and incrementing recharge due to extreme precipitation events**

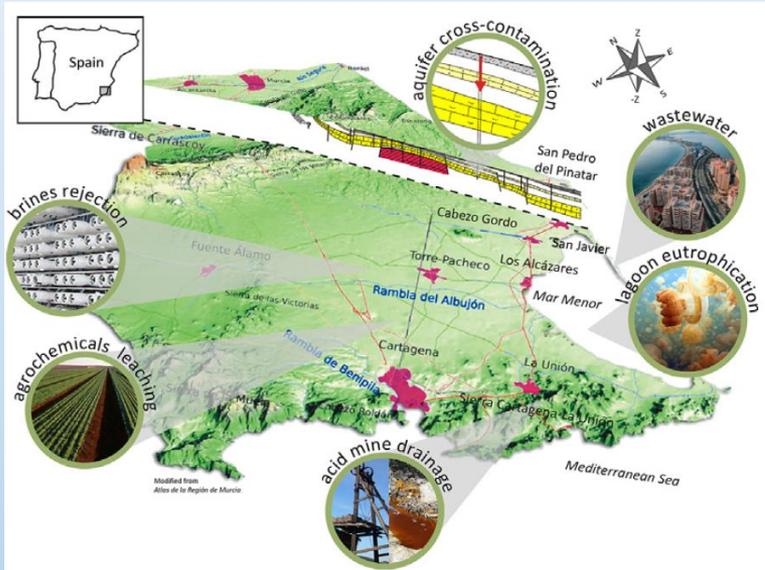


## Evolución temporal horaria del nivel piezométrico y precipitaciones en uno de los puntos de la red AQUIFER-SUDOE del Campo de Cartagena

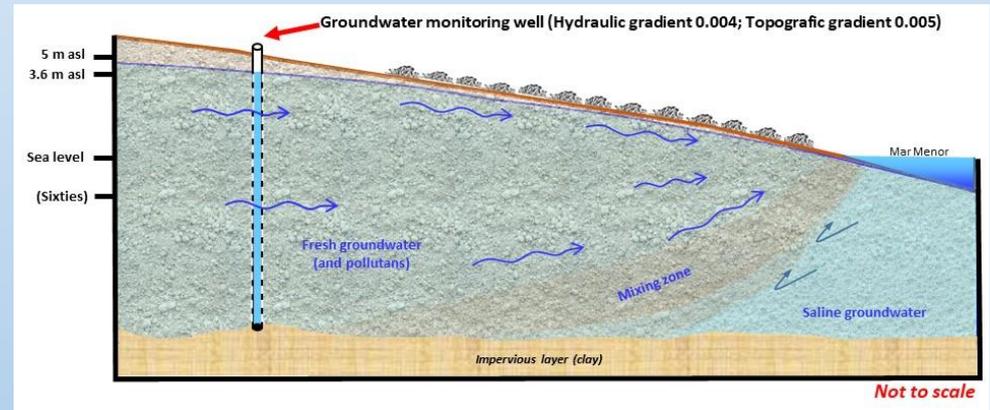


## Groundwater discharge with high contents of nitrates and urban pollutants

### Multiple factors affecting



Alcolea et al., 2019. STOTEN



**Aparición de drenajes, descarga a cauces, mayor salida visible y no visible al Mar Menor, problemas agronómicos, infraestructuras viarias**



16/01/2020



16/09/2020



Rambla de Miranda 17/09/2020



Rambla Albuñón  
02/07/2020



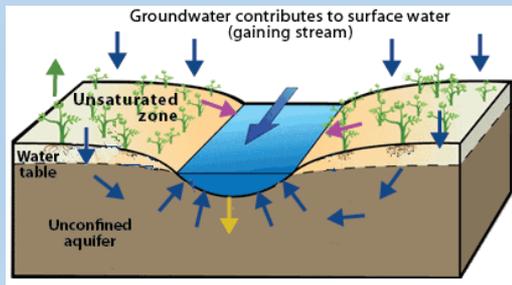
02/07/2020



HGR,  
10/03/2021

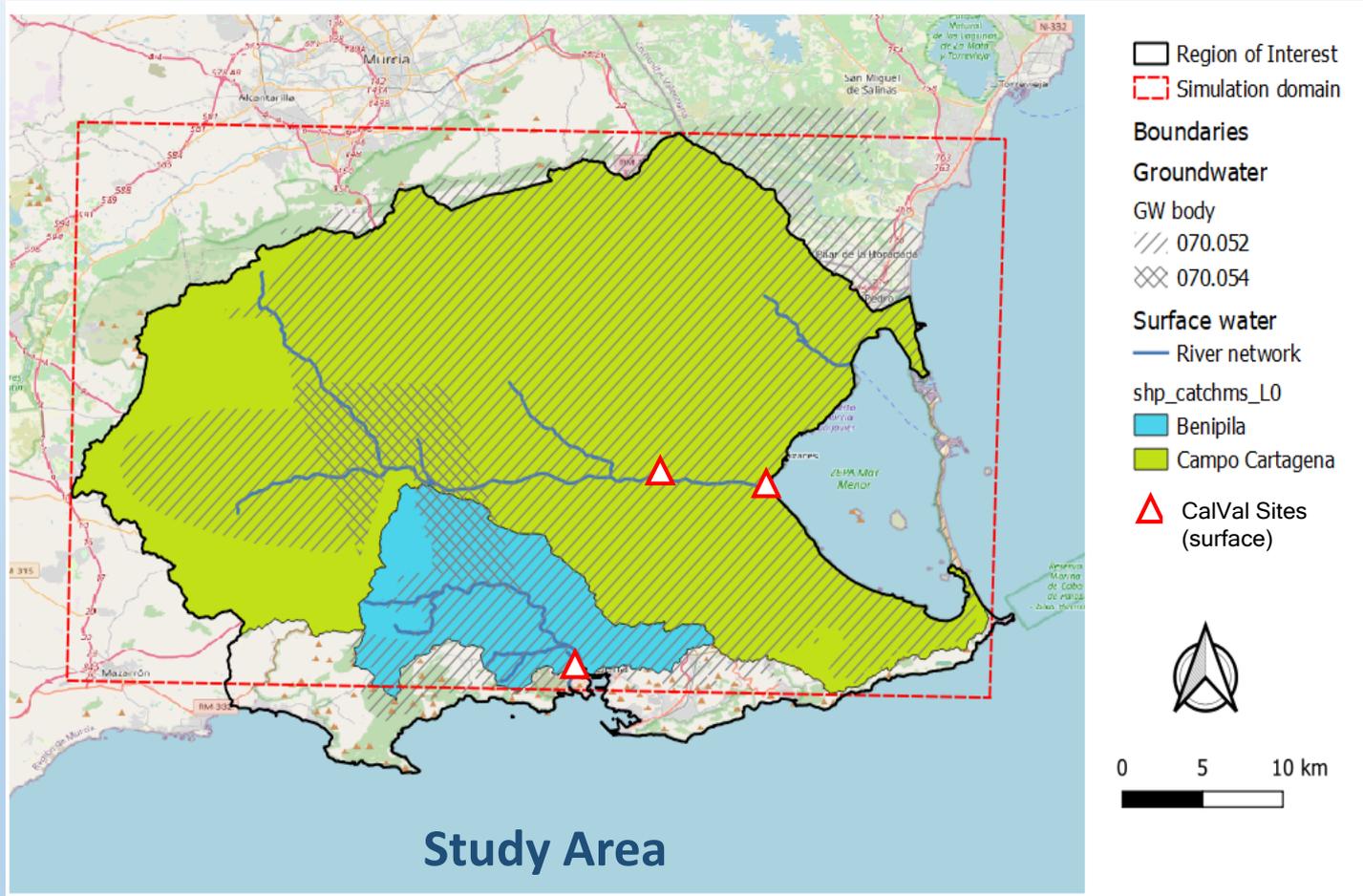


Carmoli 03/02/2020



Lo Poyo  
17/09/2020

# Hydrological modelling and recharge estimation of the Campo de Cartagena aquifer (SE Spain).



# Hydrological modelling and recharge estimation of the Campo de Cartagena aquifer (SE Spain).

## Modelling code

SPHY (Spatial Processes in Hydrology Model <https://www.sphy.nl/code>)  
 Spatially-distributed bucket model (PCRaster)

### SPHY in Region of Study

Updated to version 3.1 (it includes a new irrigation-ET module)

**Simulation period: Jan-1951 ... Dec-2020**

**Spatial resolution: 200 m**

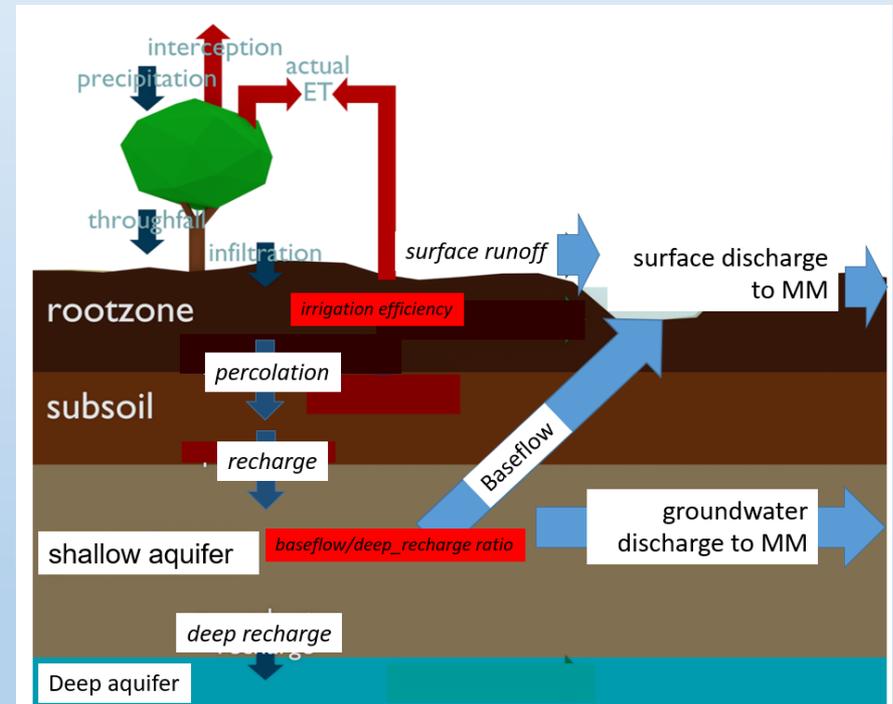
**Temporal resolution: Daily**

### Parameters (maps or fixed values)

- DEM, Slope, Flow direction
- Soil characteristics
  - Root zone depth
  - Sand & Clay fractions, organic matter content
- Surface routing parameter
- Baseflow/deep\_recharge ratio

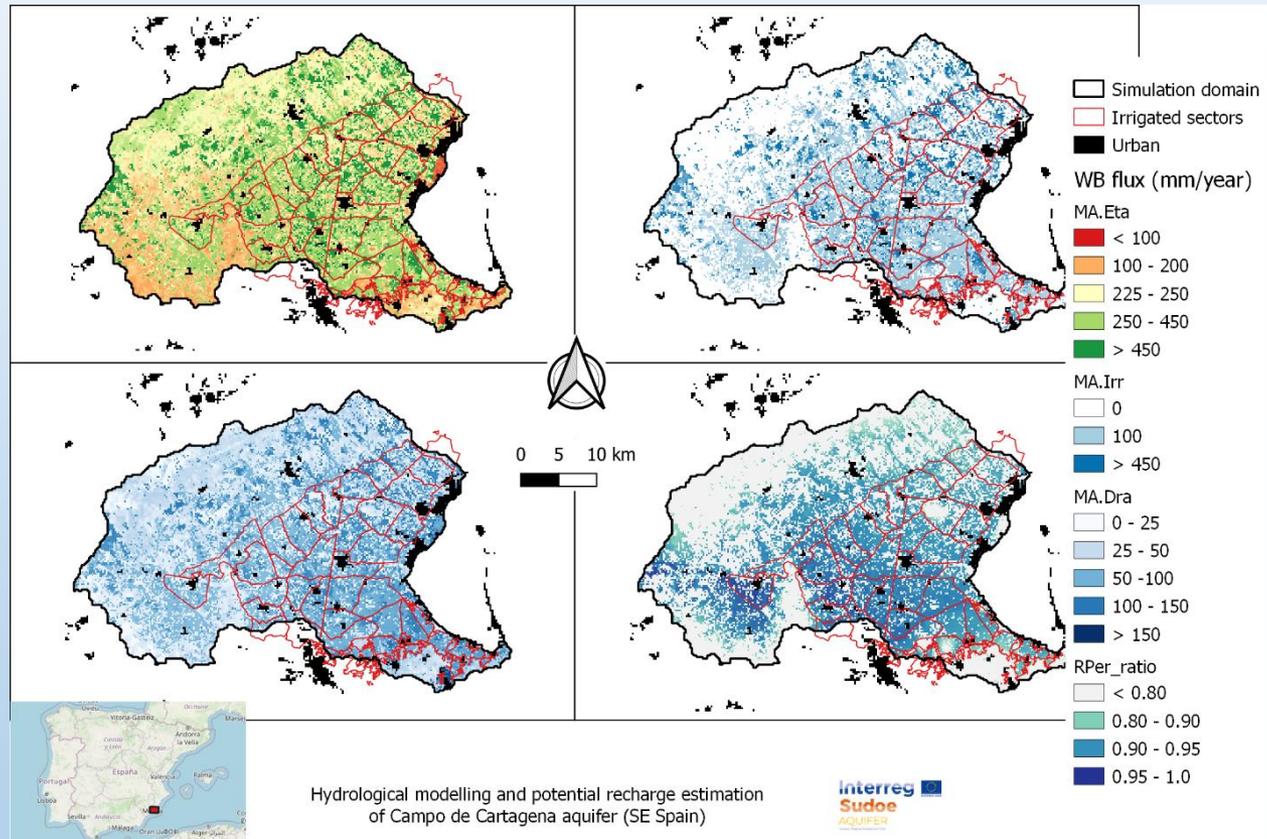
### Variables (dynamic)

- Climate (prcp, tavg, tmin, tmax) (AEMET-CLIMA dataset, 1951-2020)
- Vegetation greenness (NDVI) (NOAA + MODIS)
- Land use-Land Cover (1977, 1988, 2000, 2009, 2020)
- Irrigation efficiency = f(Land Use-Land Cover)



# Hydrological modelling and recharge estimation of the Campo de Cartagena aquifer (SE Spain).

**MEAN ANNUAL VALUES OF THE MAIN WATER BALANCE COMPONENTS (2000-2020). (Provisional)**



**Eta (Actual Evapotranspiration)**

**Irr (estimación de aportes de riego)**

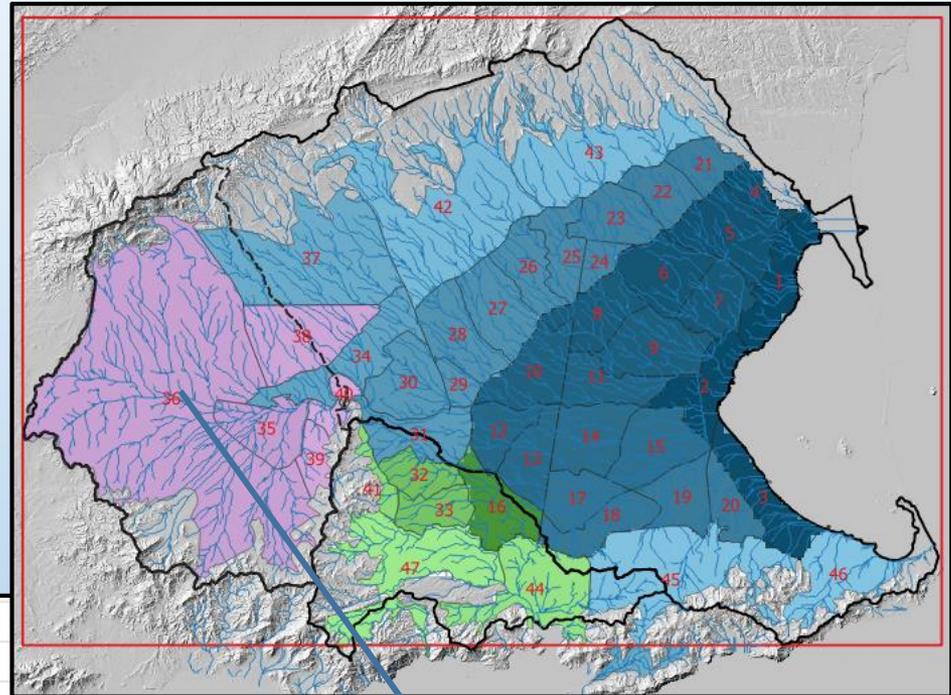
**Dra (drenaje total = percolación radicular RPer + flujo lateral total (escorrentía superficial + flujo subsuperficial))**

**Rper\_ratio (fraction of the root percolation (RPer) over the total drainage that outflows from the root zone (Dra)).**

# Hydrological modelling and recharge estimation of the Campo de Cartagena aquifer (SE Spain).

## “Grandes subregiones de recarga”

(S1 con tonalidad azulados, Campo-Cartagena s.s.);  
 (S2 con tonalidades rosados, área recarga Fuente-Álamo;  
 (S3, con tonalidades verdes, acuífero bajo área Cuenca de Benipila).

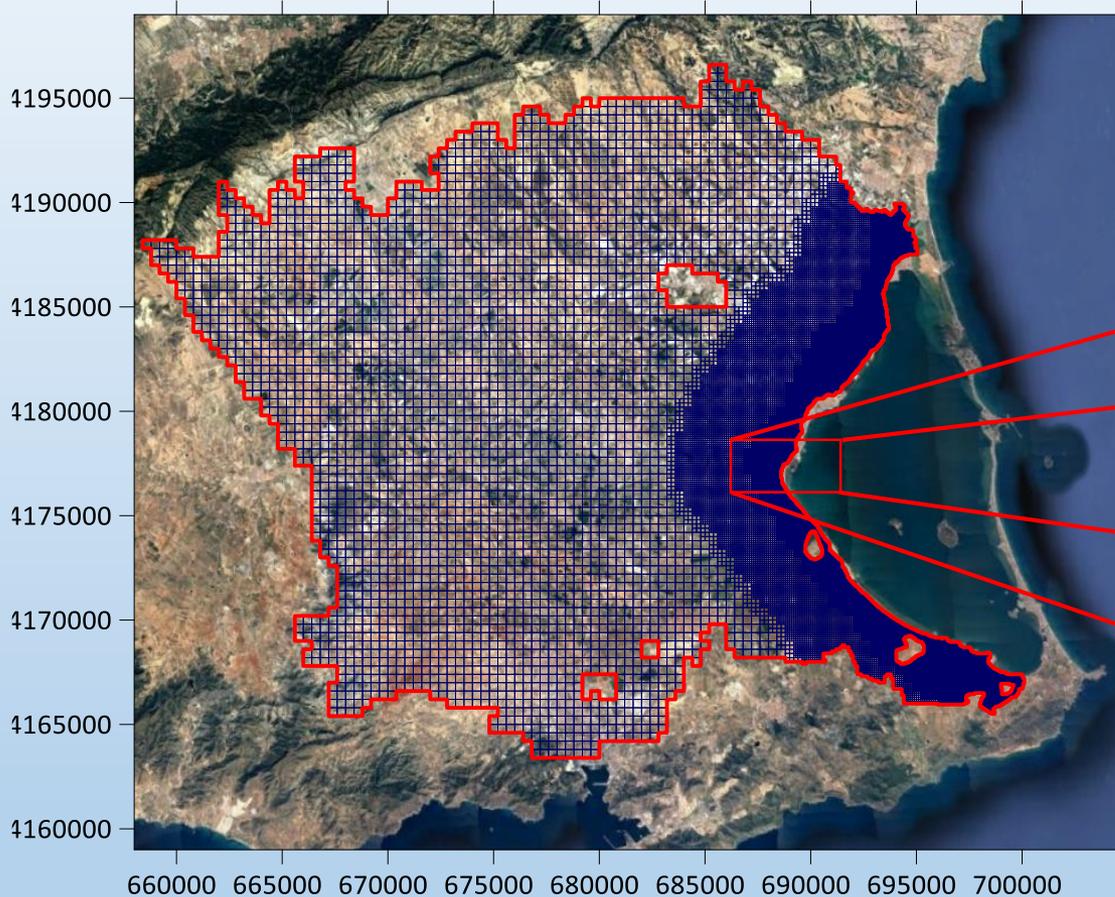


**MEAN ANNUAL VALUES OF THE MAIN WATER BALANCE COMPONENTS (2000-2020). (Provisional)**

v413	S1	S2	S3	TOTAL				
Area (km2)	735	265	113	1113				
	S1_hm3	S2_hm3	S3_hm3	TOTAL_hm3	S1_mm	S2_mm	S3_mm	TOTAL_mm
Pre	223	80	33	336	303	302	292	302
Irr	86	20	11	117	117	75	97	105
Int	35	13	5	53	48	49	44	48
Eta	195	63	21	279	265	238	186	251
RPer	69	21	7	97	94	79	62	87
SRof	11	2	1	14	15	8	9	13

**S2:**  
 Fuera del acuífero (fuera del modelo).  
 Barrera geológica

## Modelización del flujo subterráneo del acuífero cuaternario del Campo de Cartagena, vertiente al Mar Menor



- Área Activa: 745,7 km<sup>2</sup>
- Número de celdas: 67635
- Tamaño de celdas: 400x400 m<sup>2</sup> en el sector oeste y 50x50 m<sup>2</sup> al este y en el contacto de la laguna

**AMPHOS**<sup>21</sup>

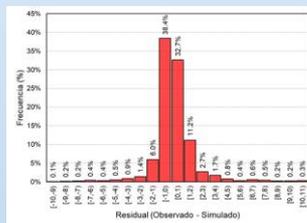
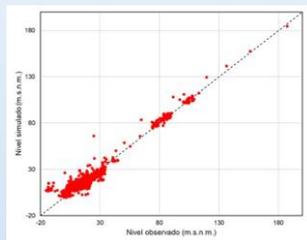


Régimen Estacionario (previo a 1920) con recarga media de toda la serie por zona  
 Régimen Transitorio: 01/01/1920 – 01/01/2021

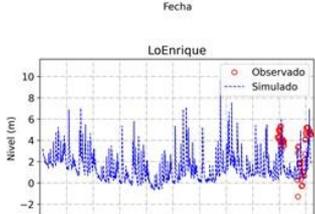
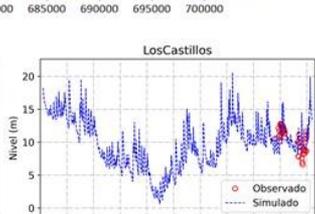
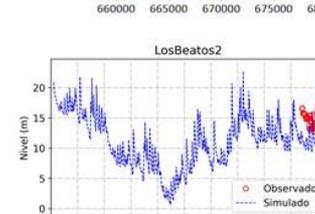
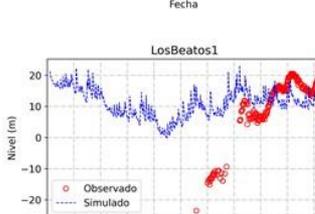
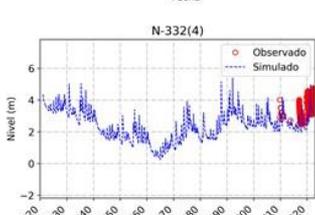
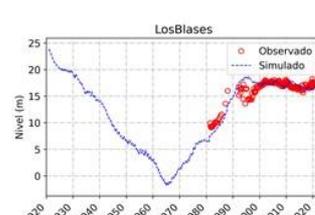
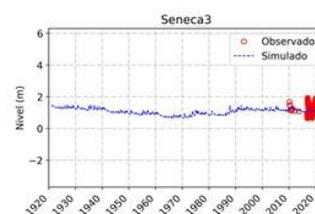
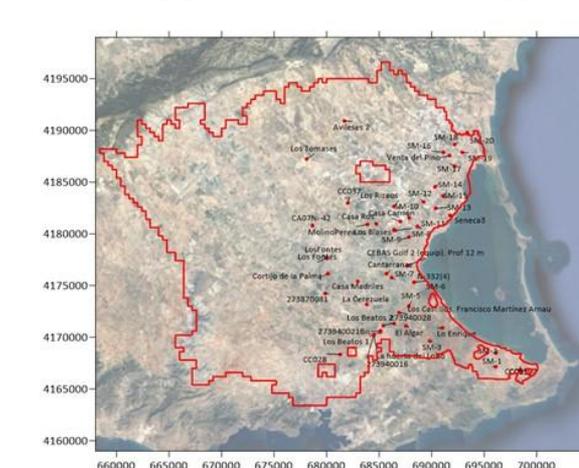
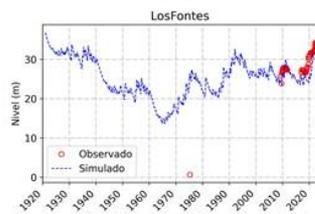
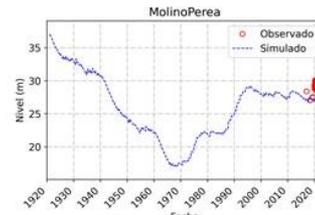
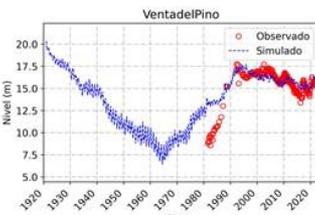
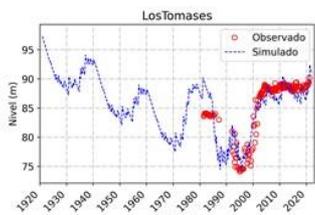
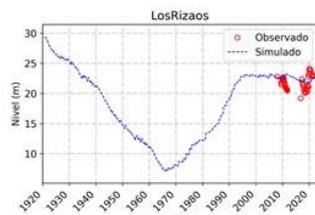


# Modelización del flujo subterráneo del acuífero cuaternario del Campo de Cartagena

## Resultados: Ajustes de Nivel y piezometría

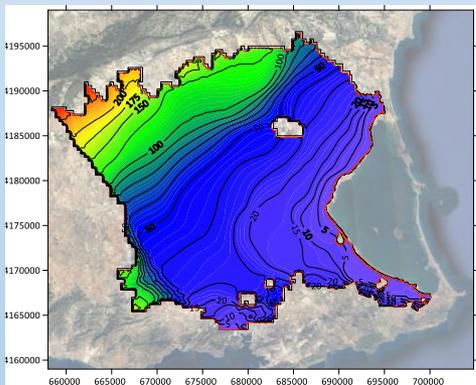
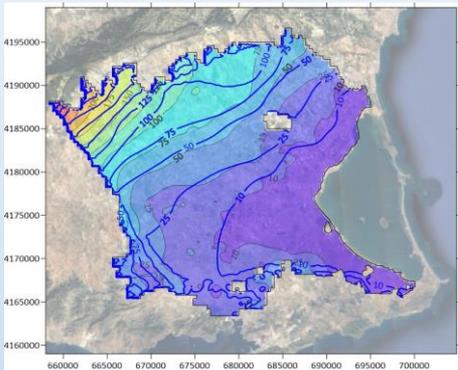
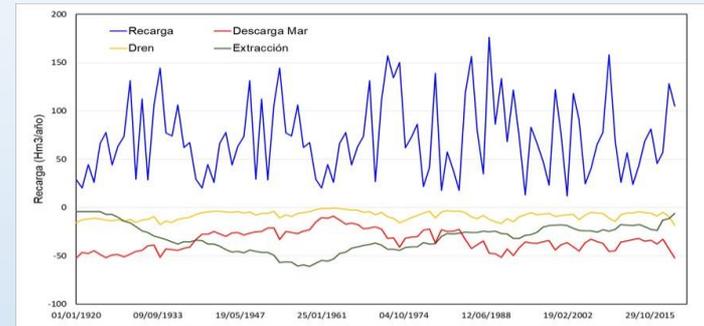


Número de observaciones	26271
Coefficiente de Determinación (R2)	0.971
Error Medio (m)	0.17
Error Absoluto Medio (m)	1.1
Máximo Residual (m)	16.4
Mínimo Residual (m)	-41.0
Desviación Estándar (m)	2.0
RMS (m)	2.1
RMS Normalizado (%)	0.97%
MAE Normalizado (%)	0.53%



# Modelización del flujo subterráneo del acuífero cuaternario del Campo de Cartagena

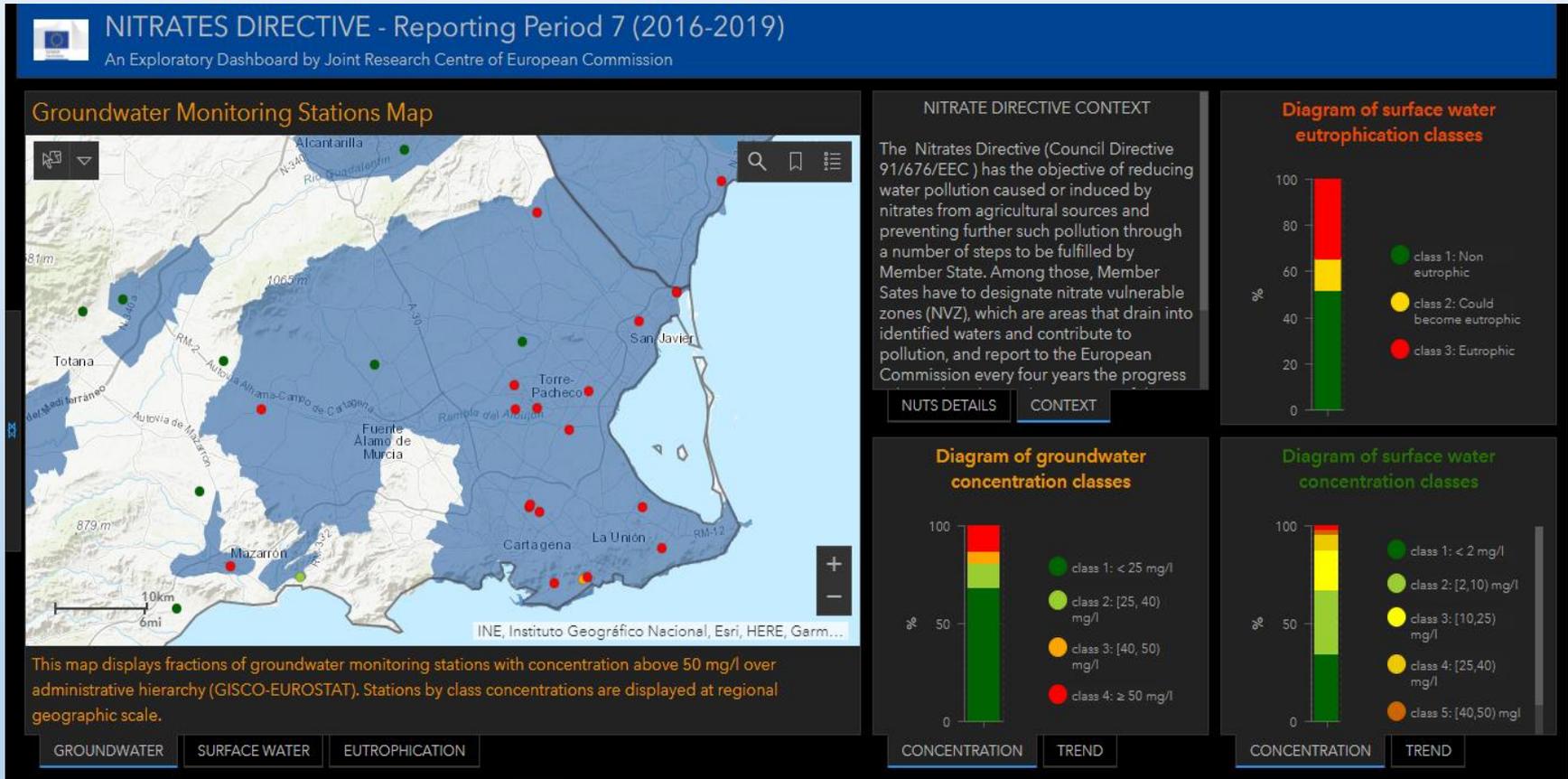
Componente	Promedio 1920-2020 (Hm <sup>3</sup> /año)
<b>Recarga</b>	<b>71.8</b>
<b>Descarga Mar</b>	<b>-33.9</b>
<b>Dren</b>	<b>-8.1</b>
<b>Extracción</b>	<b>-31.2</b>



periodo	Recarga (Hm <sup>3</sup> /año)	Descarga Mar (Hm <sup>3</sup> /año)	Dren (Hm <sup>3</sup> /año)	Extracciones (Hm <sup>3</sup> /año)	Almacenamiento (Hm <sup>3</sup> /año)
1920-1930	57.7	-48.8	-12.8	-7.5	-11.5
1930-1940	80.7	-43.3	-13.0	-30.7	-6.3
1940-1950	57.7	-27.7	-4.8	-40.9	-15.7
1950-1960	80.7	-25.0	-6.7	-53.8	-4.8
1960-1970	57.7	-15.2	-2.2	-47.4	-7.2
1970-1980	86.4	-28.5	-9.0	-40.3	8.6
1980-1990	83.6	-32.8	-7.3	-27.4	16.1
1990-2000	71.6	-41.2	-10.0	-26.4	-6.0
2000-2010	78.6	-39.1	-8.0	-22.1	9.4
2010-2020	64.1	-37.6	-8.1	-17.4	0.9

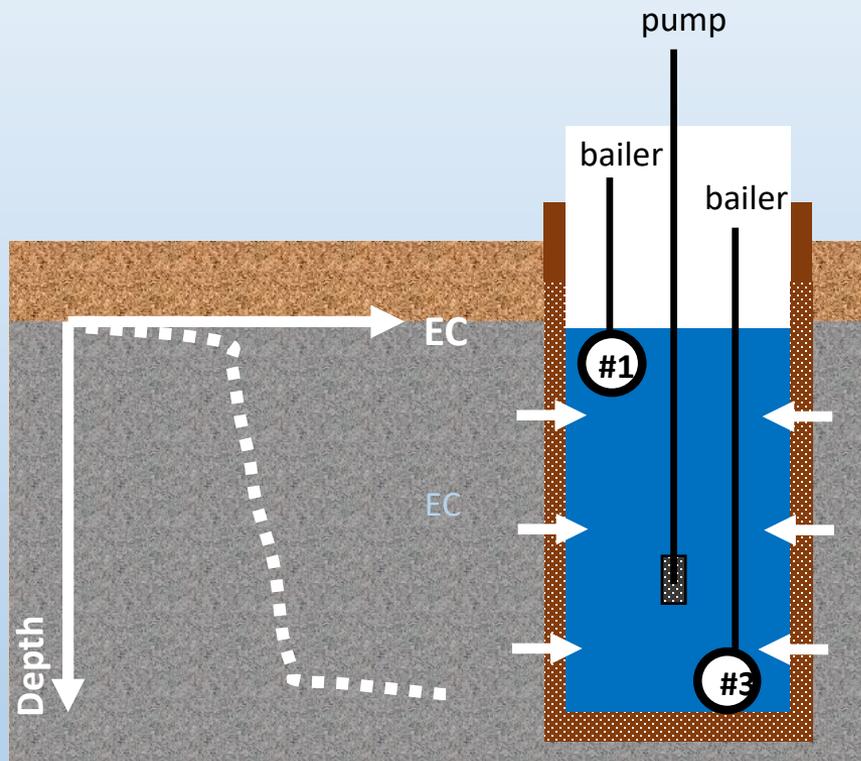
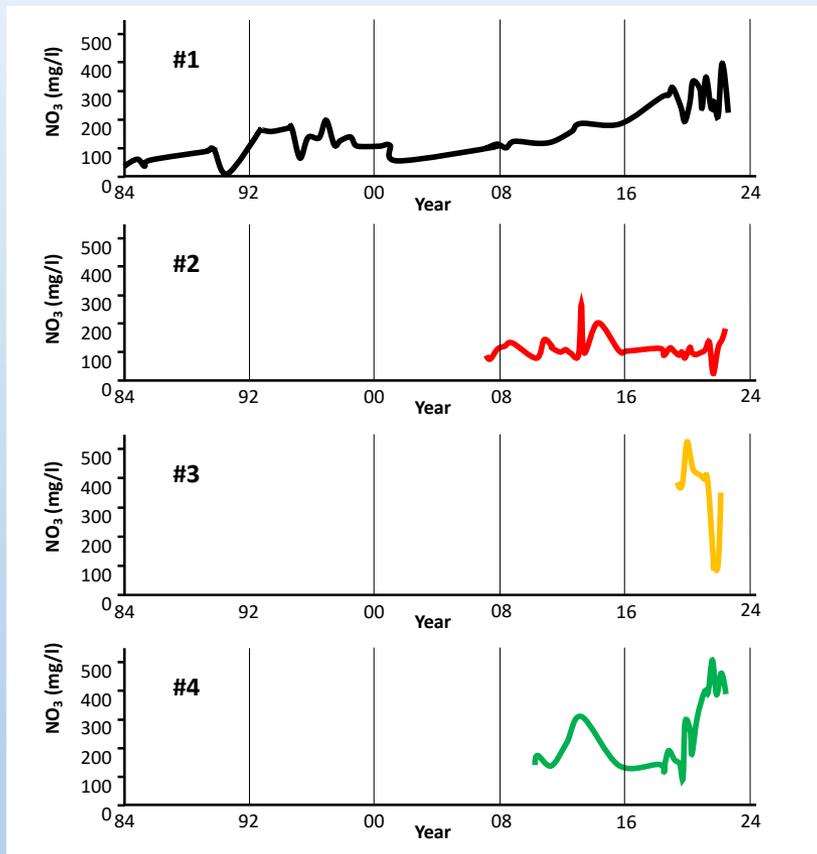
# High contents in nitrates, but groundwater monitoring network have to be improved

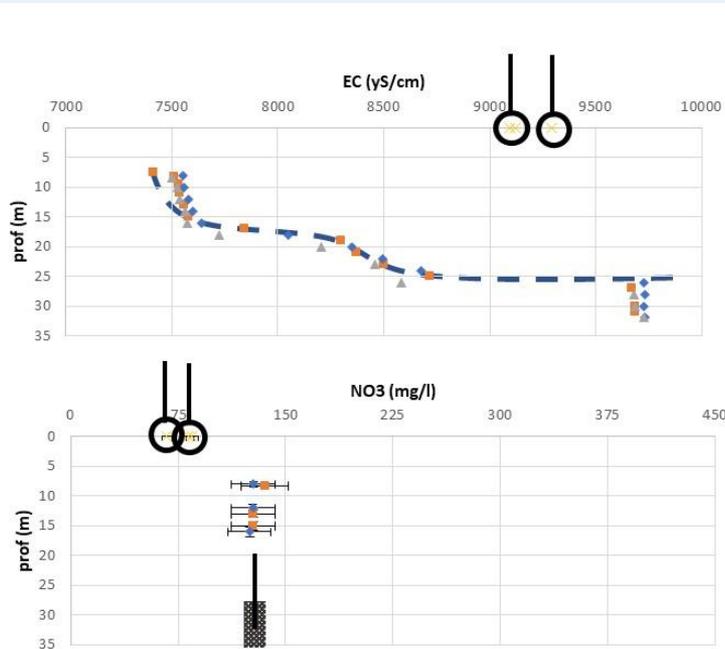
**19 puntos en MASUB Campo de Cartagena (13 con datos en el periodo 2016-2019). (Promedio de 5 campañas en 4 años)**



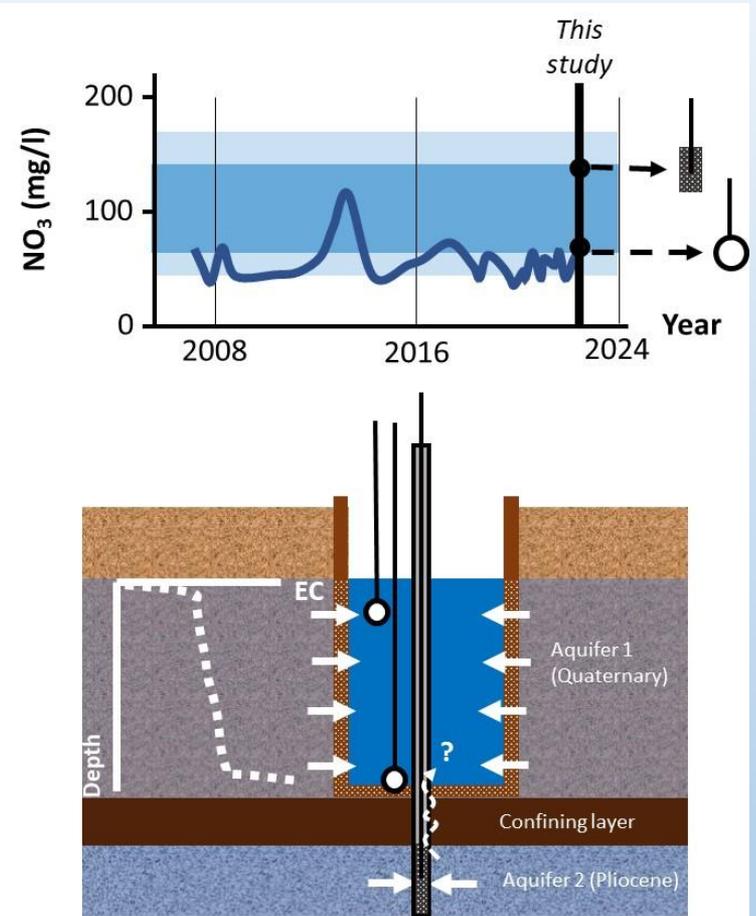
<https://water.jrc.ec.europa.eu/portal/apps/opsdashboard/index.html#/cb6034c2a75e4df282f8a62f90c16caa>

Might sampling protocol explain groundwater nitrate brutal changes?





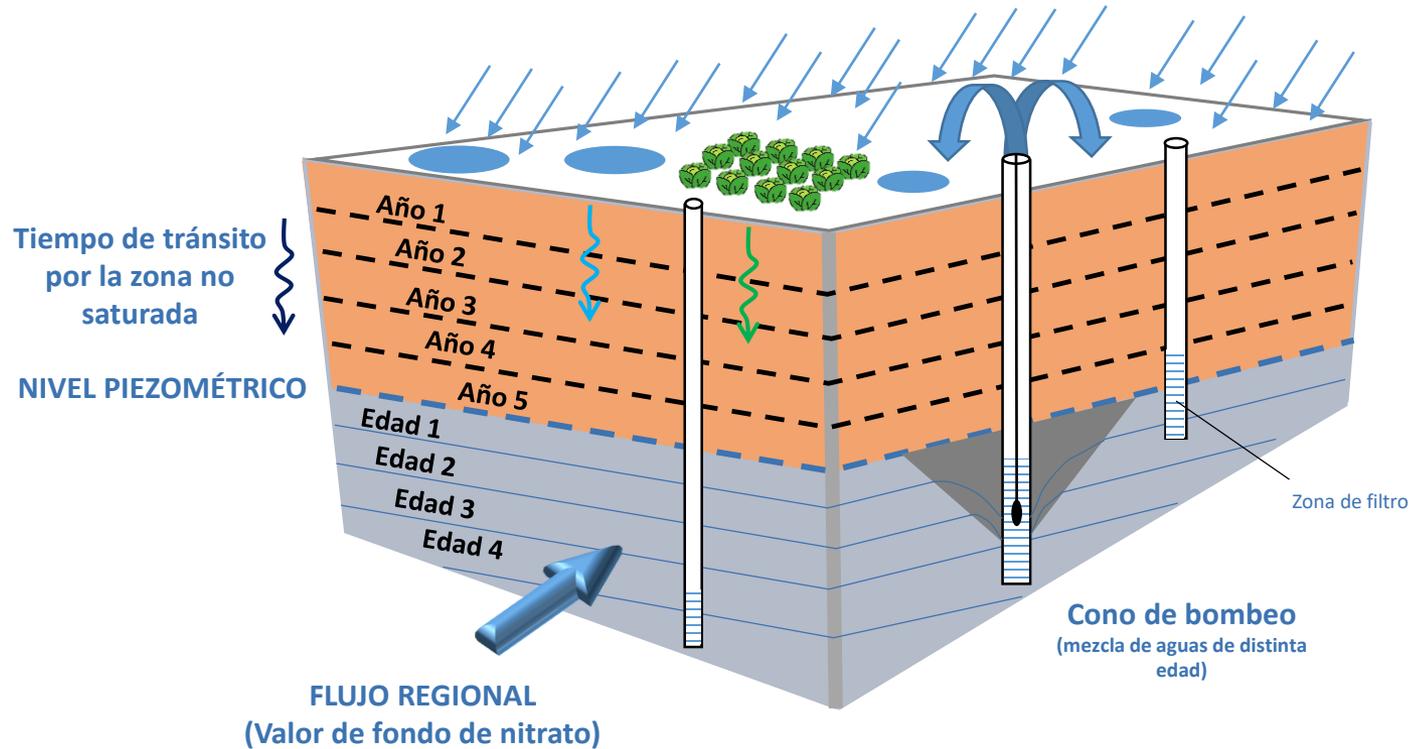
→ From 75 mg/l (bailer)  
to 140 mg/l (pump) for  
ONE SAME WELL (#5)



# REPRESENTATIVIDAD DE LOS PUNTOS DE MUESTREO

Elaborado por García Aróstegui 2022 (Modificado de Sklash and Vakili, 2021 <https://jofnm.com/article-158-Monitoring-groundwater-at-the-field-level.html>)

## Variación espacio-temporal de las precipitaciones y retorno de riego



***Hay que tener cuidado al usar datos de concentración de nitrato de pozos de monitorización individuales para tomar decisiones sobre modificaciones de las prácticas agrarias***

**“Groundwater pollution is a virtually irreversible process”  
 (R. Connor, 30/03/2022).**

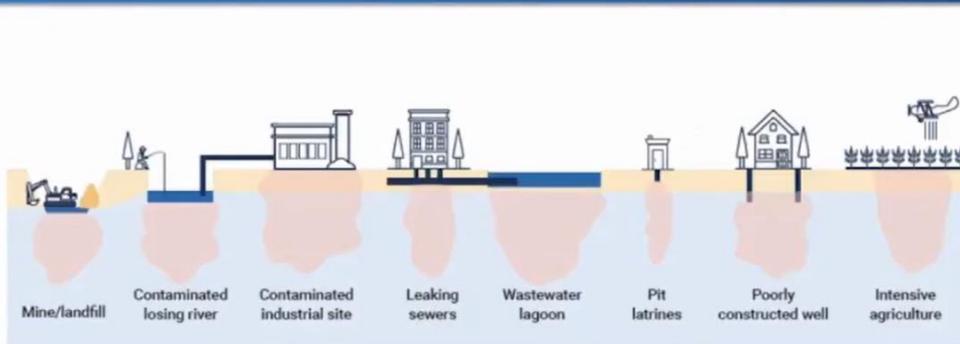
**Is it the case of the Campo de Cartagena aquifer?**

# Webinar on Groundwater: Making the Invisible Visible

Keynote Speaker: **Richard Connor**, Editor-in-Chief of the World Water Development Report 2022

      
 March 30, 2022 | 1pm UTC | 9pm Beijing | 9am New York

## Challenges and Constraints: Groundwater Pollution



**Groundwater pollution is a virtually irreversible process**

UN WATER 

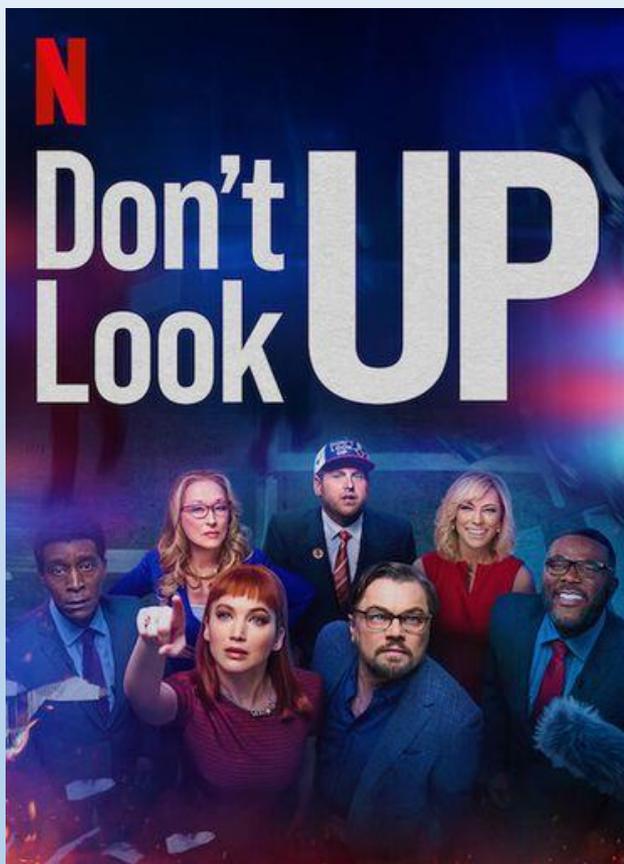
\*Figure 11.1 Pollution sources that threaten groundwater quality



**Richard Connor**

Editor-in-Chief of the United Nations  
 World Water Development Report, UNESCO  
 World Water Assessment Program

## Lesson learnt from the case of the coastal aquifer of Campo de Cartagena Mar Menor, SE Spain



***Look (ALSO) DOWN !!!***

***Role of the hydrogeology:***

***The stored STOCK (legacies), LAG TIME  
and TRAVEL TIME through the aquifer  
must be taken into account***

MUCHAS GRACIAS POR SU ATENCIÓN



Para más información: José Luis García Aróstegui. Coordinador del Proyecto AQUIFER. Email:

[j.arostegui@igme.es](mailto:j.arostegui@igme.es). Telf. 968245012 [www.igme.es](http://www.igme.es)