TECHNISCHE UNIVERSITÄT DRESDEN

Groundwater Quality 2019

10th September 2019. Liège, Belgium

DRESDEN concept

S04 Groundwater quality at interfaces

Potential uses of pumped urban groundwater: A case study in Sant Adrià del Besòs (Barcelona, NE Spain)

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Grupo de Hidrología Subterránea GHS UPC DECA CSIC idaea

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

GQ 19 Groundwater Quality 2019

INTRODUCTION

Urban aquifers might be an alternative freshwater resource

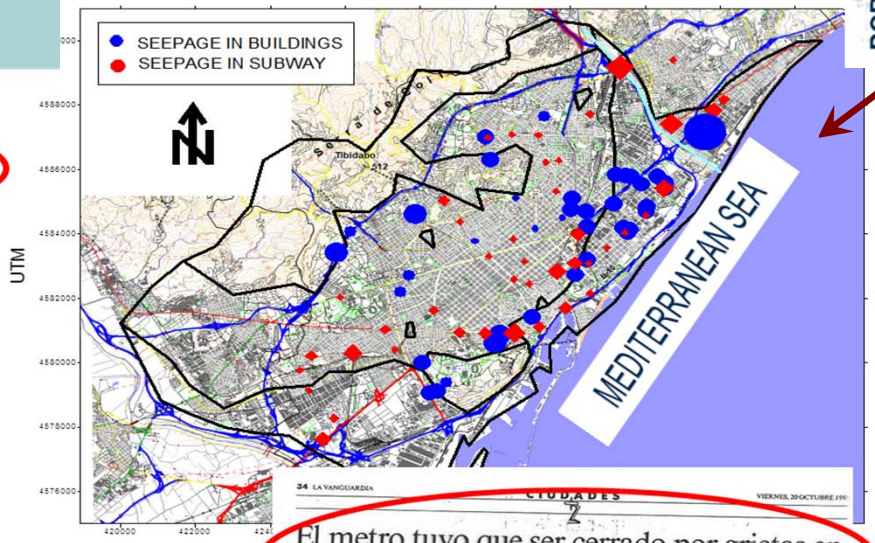
Exemple: BARCELONA

El subsuelo de Barcelona esconde una reserva de agua capaz de llenar cada año un embalse

Prueba piloto en la Vila Olímpica

La subida del nivel freático de las aguas del Besòs inunda varios aparcamientos

Santa Coloma de Gramenet



Geographical situation

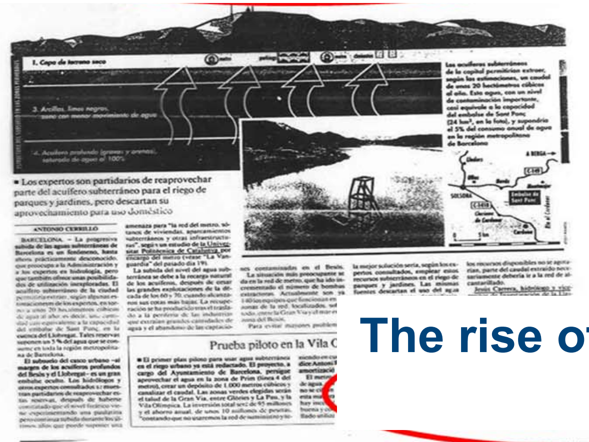
El metro tuvo que ser cerrado por grietas en la zona donde más sube el agua subterránea

INTRODUCTION

Urban aquifers might be an alternative freshwater resource

Exemple: BARCELONA

Barcelona underground hides a water reservoir



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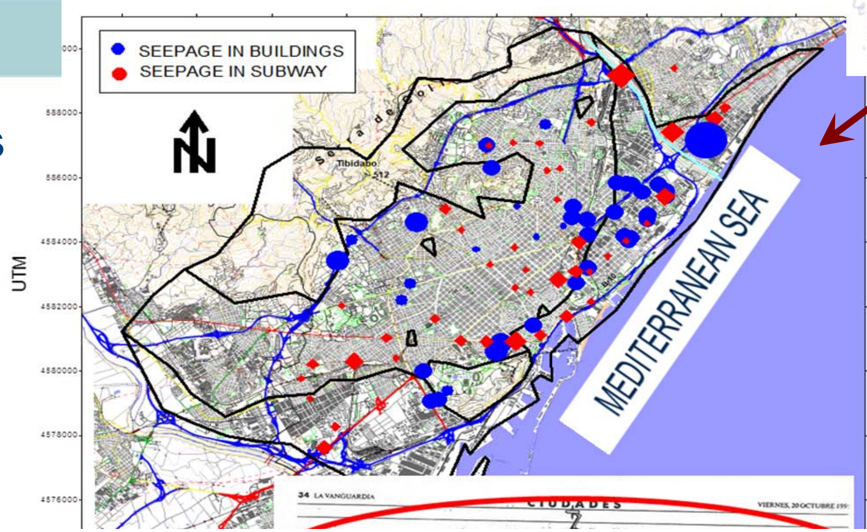
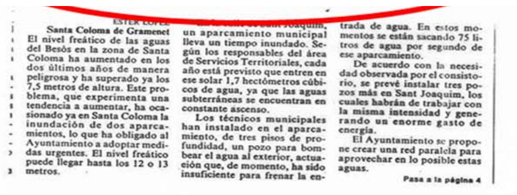


The rise of phreatic levels cause seepage problems in parking lots and in the subway



Santa Coloma de Gramenet

El nivel freático de las aguas del Besòs en la zona de Santa Coloma ha aumentado en los dos últimos años de manera peligrosa y ha superado ya los 7,5 metros de altura. Este problema, que experimenta una tendencia a aumentar, ha ocasionado ya en Santa Coloma la inundación de dos aparcamientos, lo que ha obligado al Ayuntamiento a adoptar medidas urgentes. El nivel freático puede llegar hasta los 12 o 13 metros.

... un aparcamiento municipal lleva un tiempo inundado. Según los responsables del área de Servicios Territoriales, cada año está previsto que entren en ese solar 1,7 hectómetros cúbicos de agua, ya que las aguas subterráneas se encuentran en constante ascenso.

Los técnicos municipales han instalado en el aparcamiento, de tres pisos de profundidad, un pozo para bombear el agua al exterior, actuación que, de momento, ha sido insuficiente para frenar la entrada de agua. En estos momentos se están sacando 75 litros de agua por segundo de ese aparcamiento.

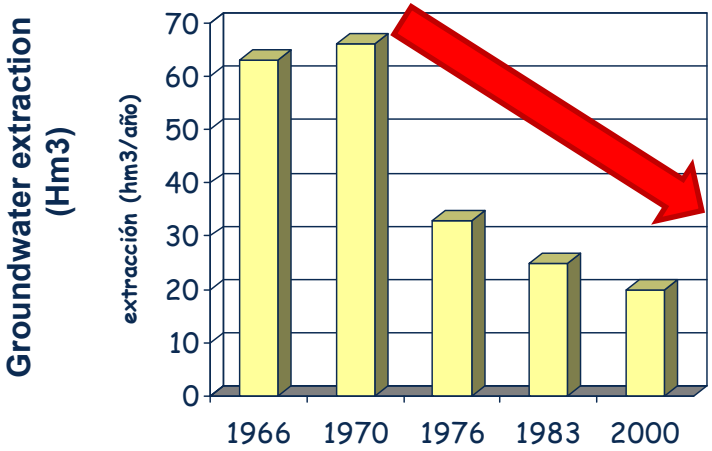
De acuerdo con la necesidad observada por el consistorio, se prevé instalar tres pozos más en Sant Joaquim, los cuales habrán de trabajar con la misma intensidad y generando un enorme gasto de energía.

El Ayuntamiento se propone crear una red paralela para aprovechar en lo posible estas aguas.

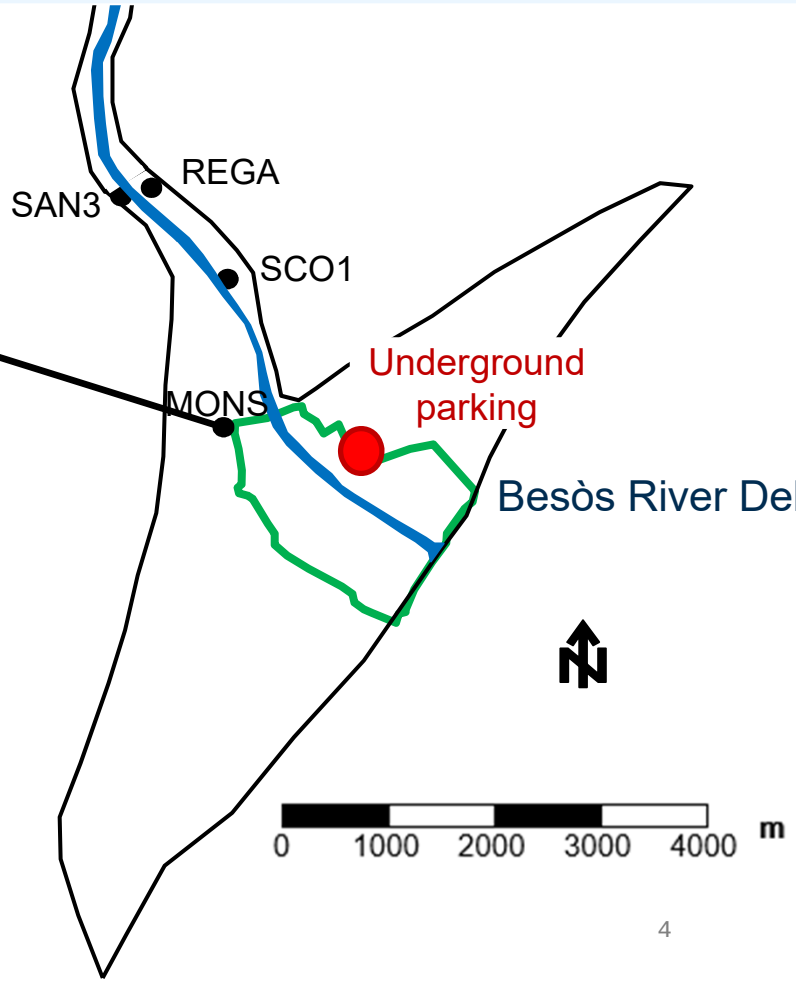
Pasa a la página 4

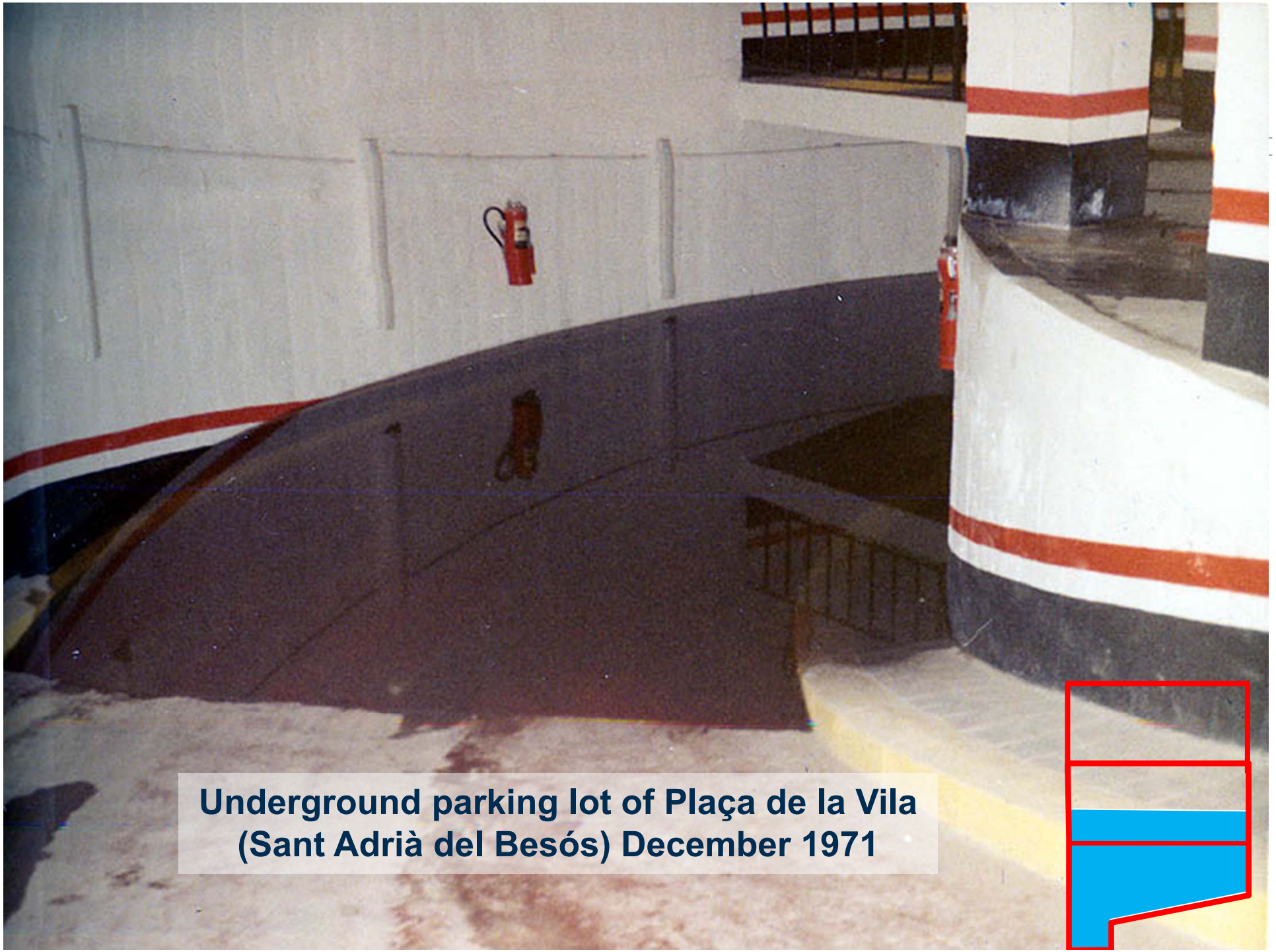
INTRODUCTION

Groundwater extraction



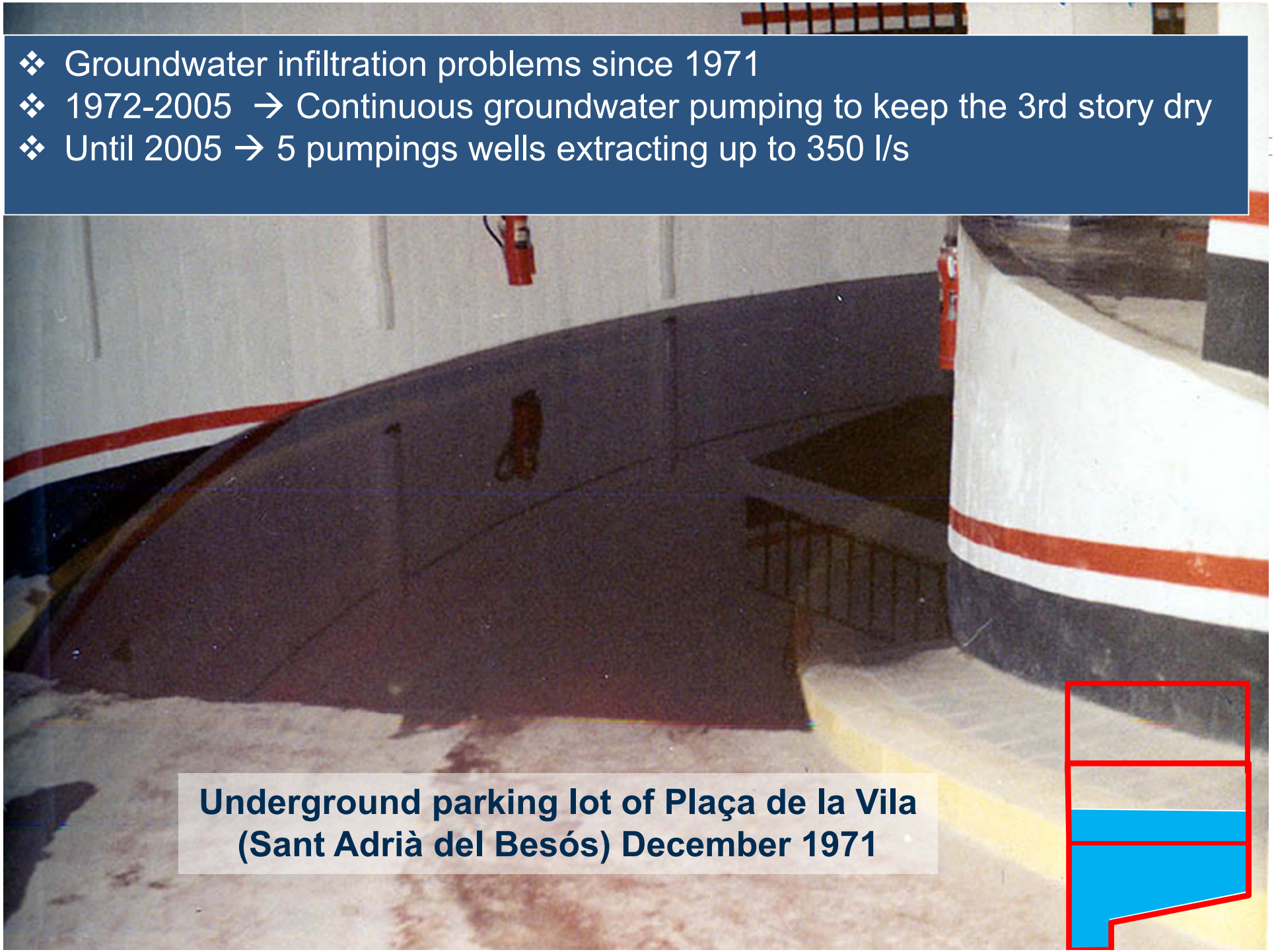
- Besòs River Delta (NE Barcelona, Spain)
- Underground parking lot located 200m from the river Besòs





Underground parking lot of Plaça de la Vila (Sant Adrià del Besós) December 1971

- Groundwater infiltration problems since 1971
- 1972-2005 → Continuous groundwater pumping to keep the 3rd story dry
- Until 2005 → 5 pumpings wells extracting up to 350 l/s



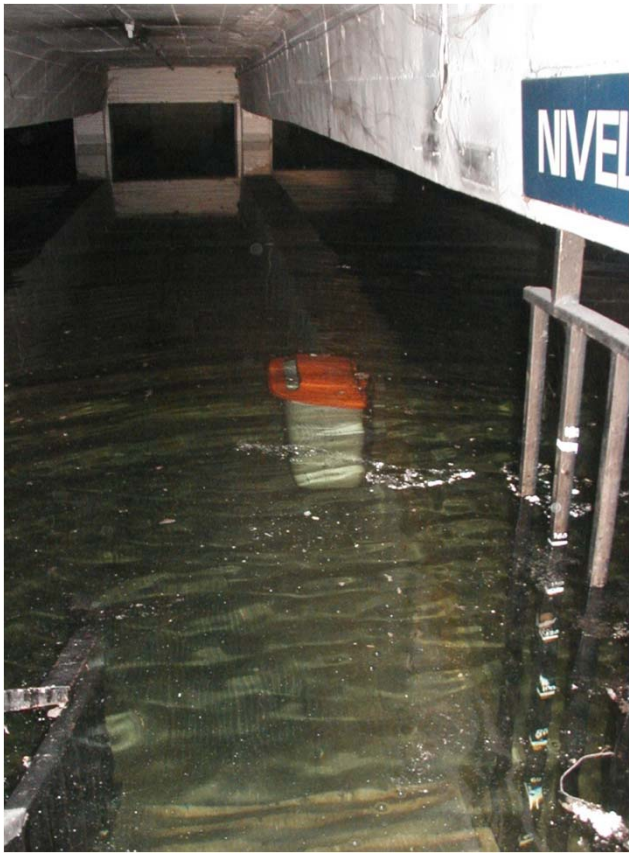
Underground parking lot of Plaça de la Vila (Sant Adrià del Besós) December 1971

INTRODUCTION

Shutdown of the pumping wells

10 min

2 hours



4 hours

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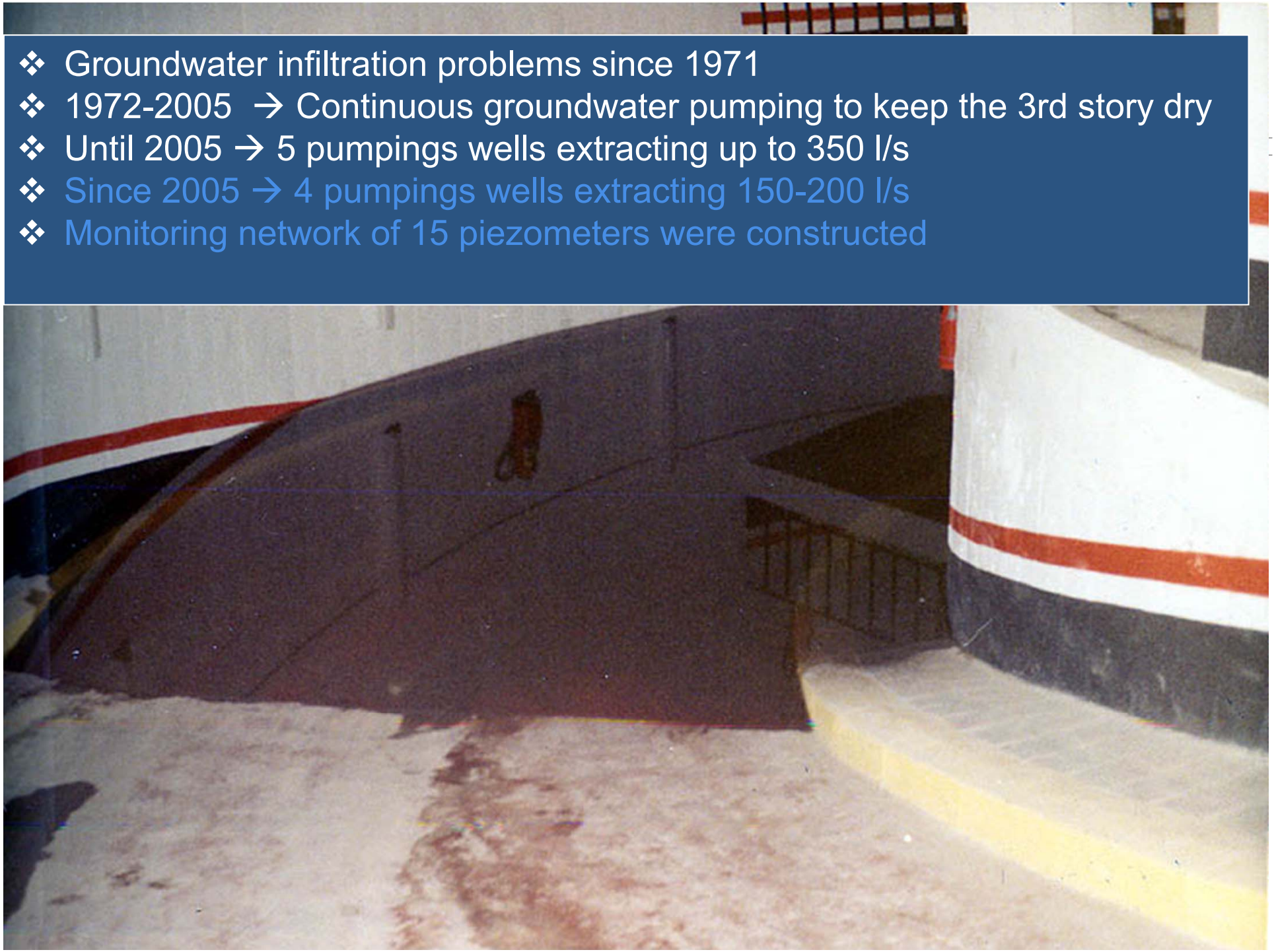
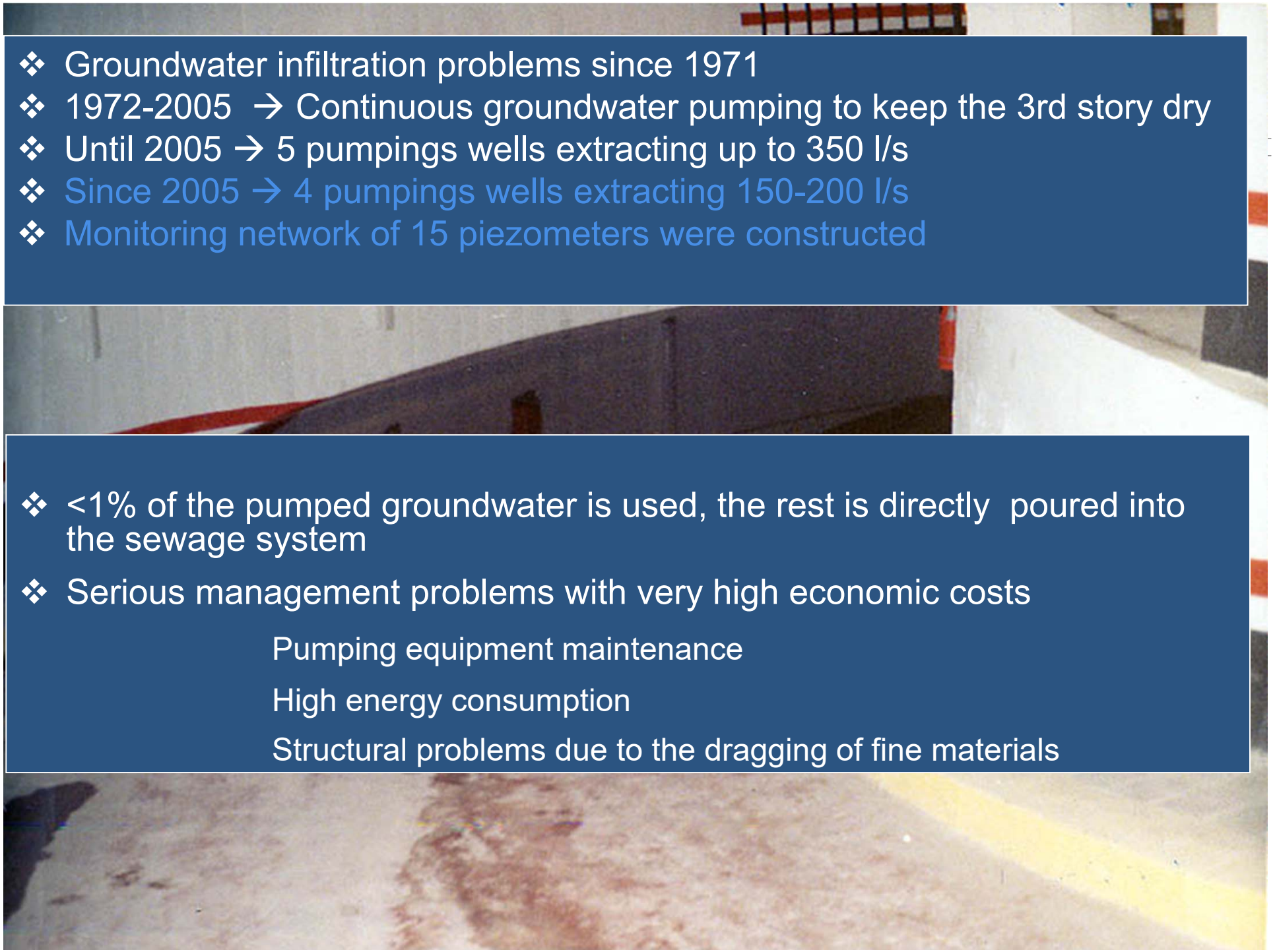
- Since 2005 → 4 pumpings wells extracting 150-200 l/s
- Monitoring network of 15 piezometers were constructed





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- <1% of the pumped groundwater is used, the rest is directly poured into the sewage system
- Serious management problems with very high economic costs

  Pumping equipment maintenance

  High energy consumption

  Structural problems due to the dragging of fine materials

INTRODUCTION

Can this pumped urban groundwater (UGW) be used for other purposes (e.g., drinking water) instead of wasting this valuable resource?

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Can this pumped urban groundwater (UGW) be used for other purposes (e.g., drinking water) instead of wasting this valuable resource?

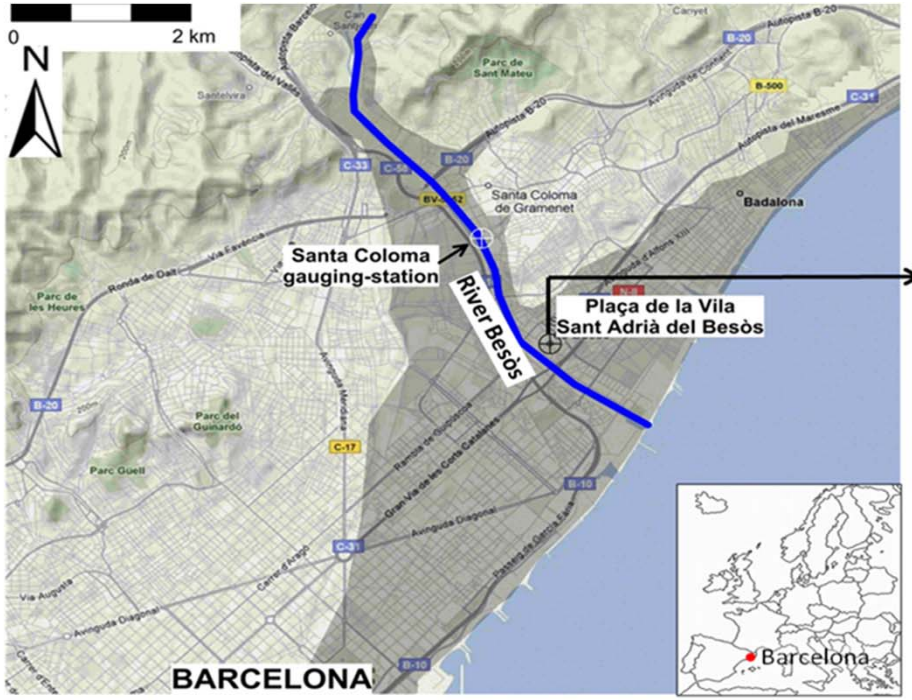
1. To quantify the groundwater recharge

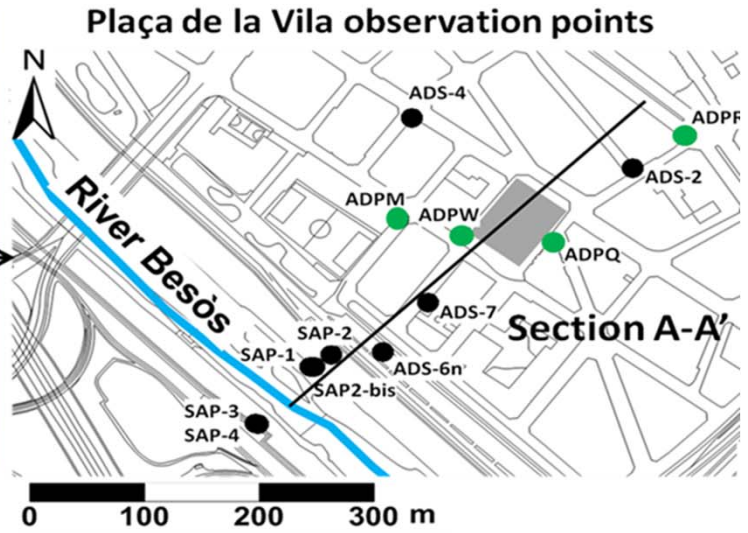
2. To characterize the pollution sources

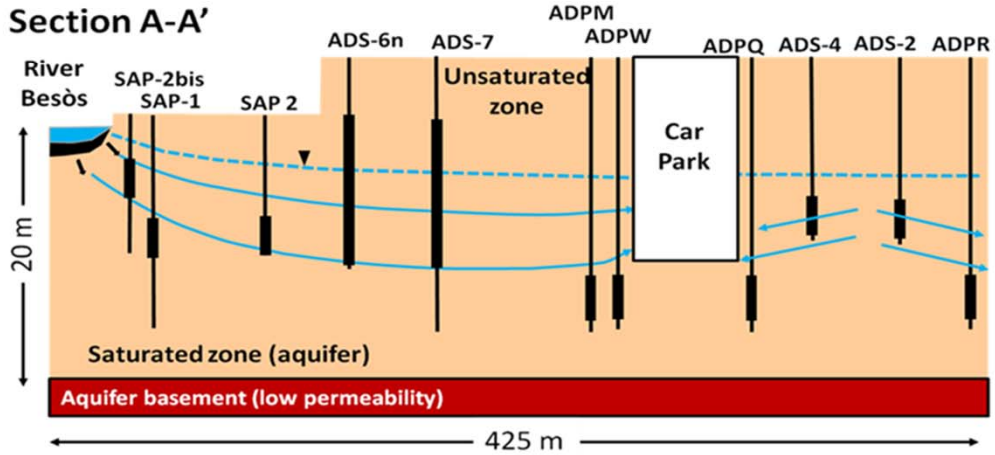
3. To investigate the evolution of UGW quality in relation to the sources

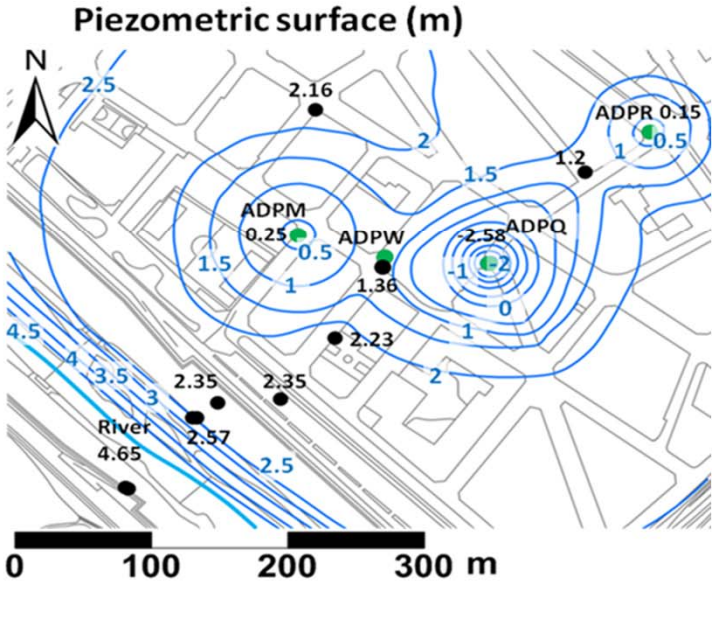
4. To assess the potential uses of UGW

STUDY AREA

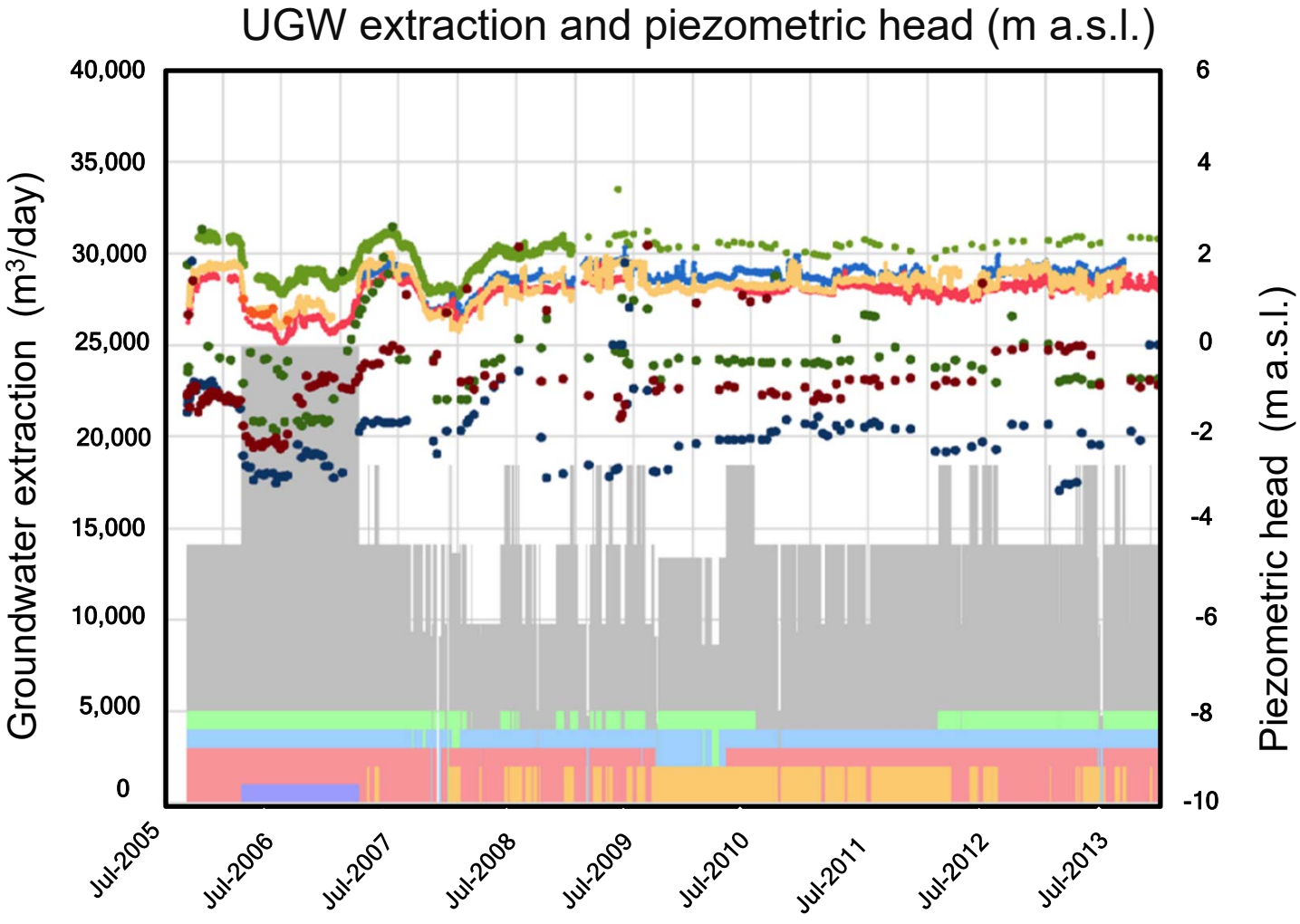

0
2 km
N
Santa Coloma gauging-station
River Besòs
Plaça de la Vila
Sant Adrià del Besòs
Santa Coloma de Gramenet
Badalona
BARCELONA
Barcelona


Plaça de la Vila observation points
N
River Besòs
ADS-4
ADPR
ADS-2
ADPM
ADPW
ADPQ
ADS-7
Section A-A'
SAP-2
SAP-1
ADS-6n
SAP2-bis
SAP-3
SAP-4
0
100
200
300 m

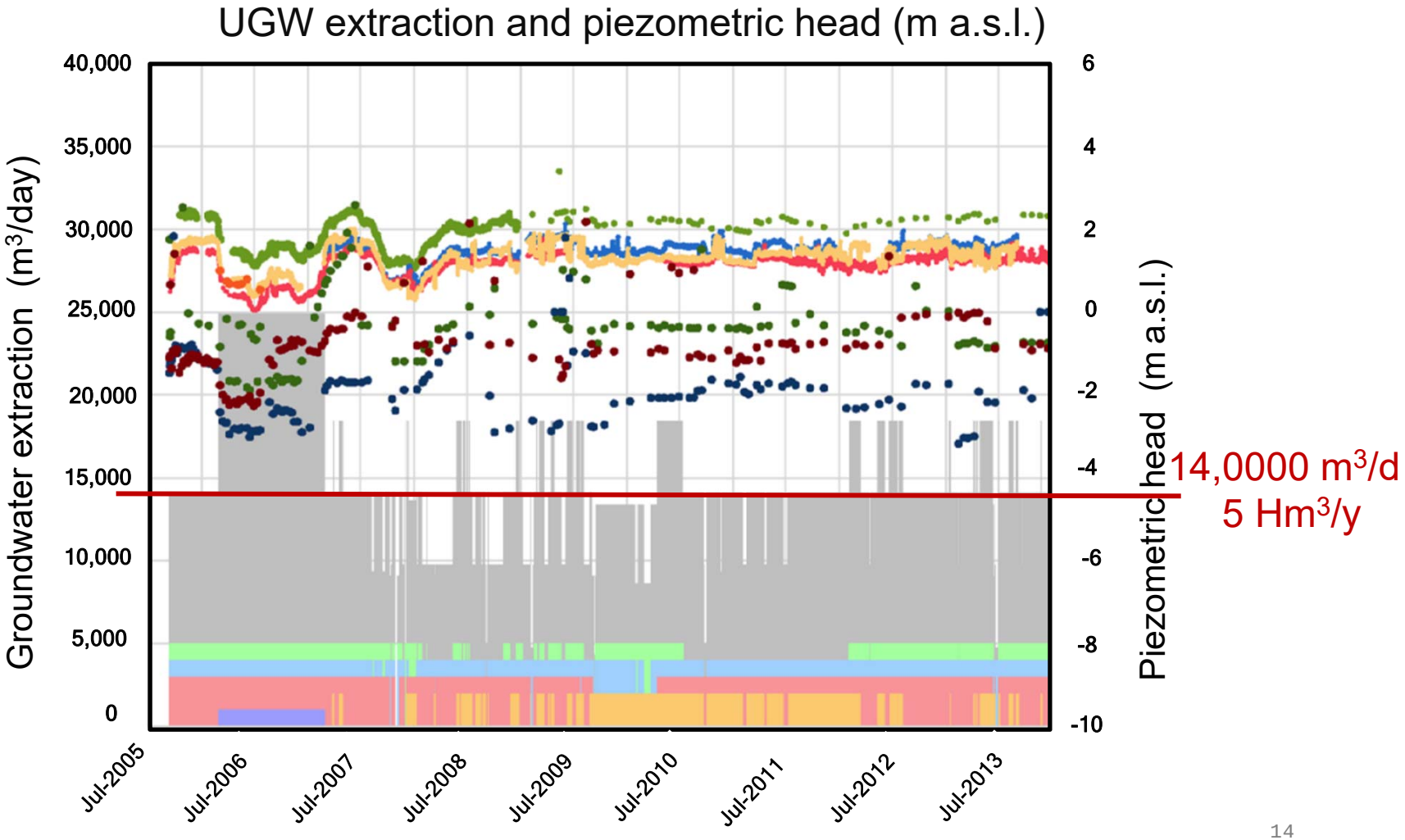

Section A-A'
River Besòs
SAP-2bis
SAP-1
SAP 2
ADS-6n
ADS-7
ADPM
ADPW
ADPQ
ADS-4
ADS-2
ADPR
Unsaturated zone
Car Park
20 m
Saturated zone (aquifer)
Aquifer basement (low permeability)
425 m


Piezometric surface (m)
N
2.5
2.16
2
1.5
ADPR 0.15
1
0.5
1.2
ADPM
0.25
0.5
1.5
ADPW
1.36
2.58
ADPQ
-1
-2
0
1
4.5
4
3.5
3
2.23
2
2.35
2.35
River
4.65
2.57
2.5
0
100
200
300 m

Groundwater recharge quantification

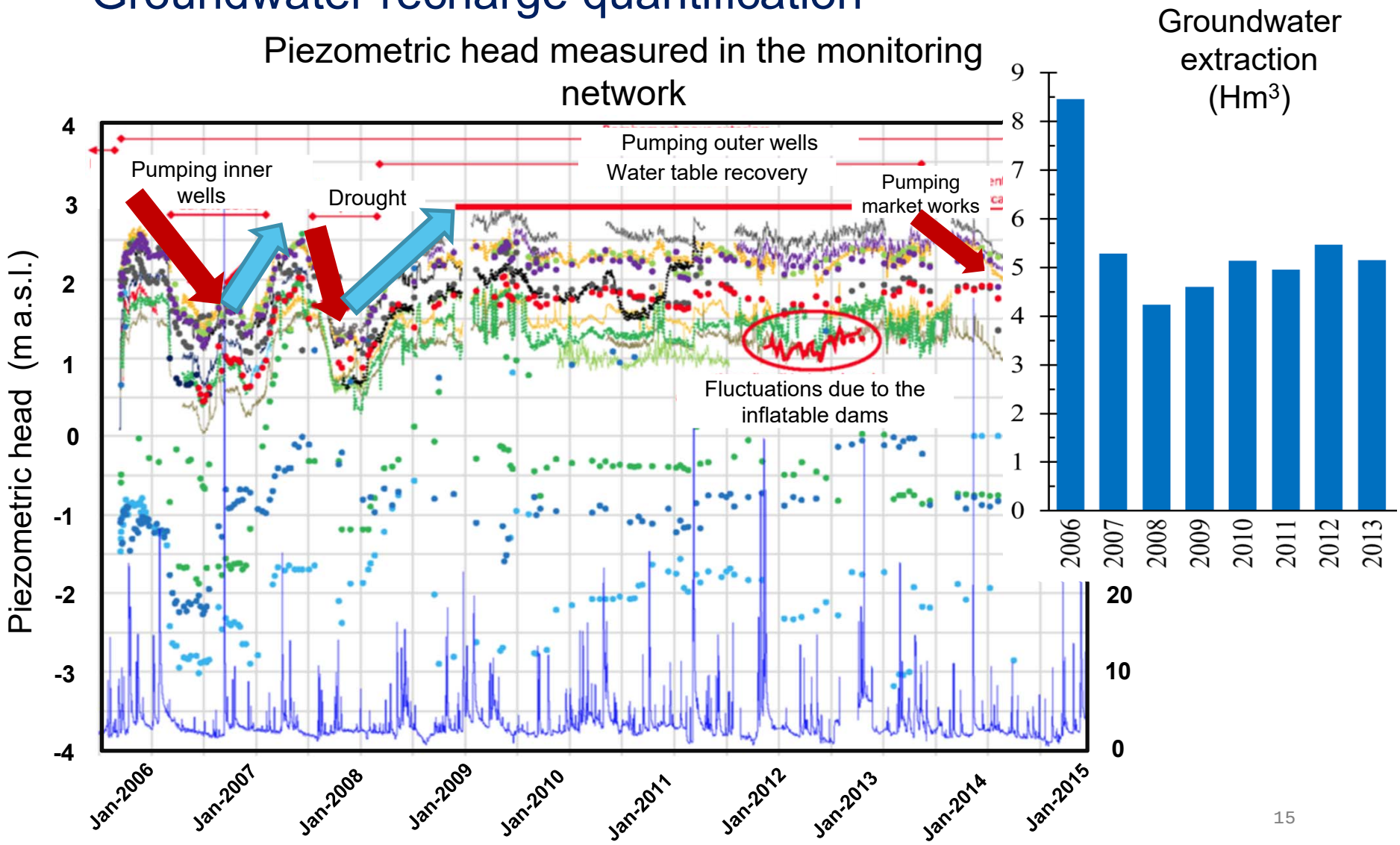


Groundwater recharge quantification



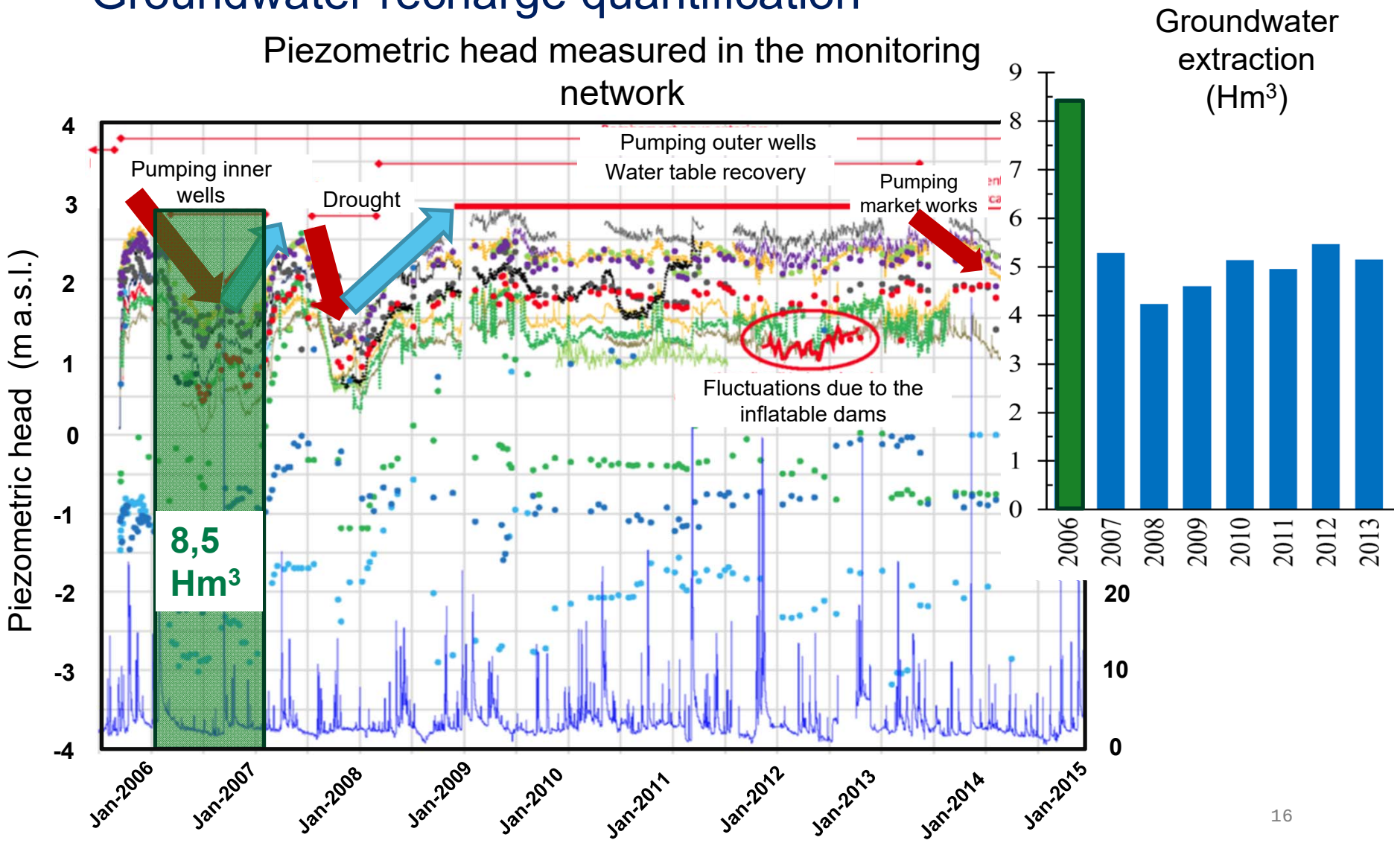
RESULTS&DISCUSSION

Groundwater recharge quantification



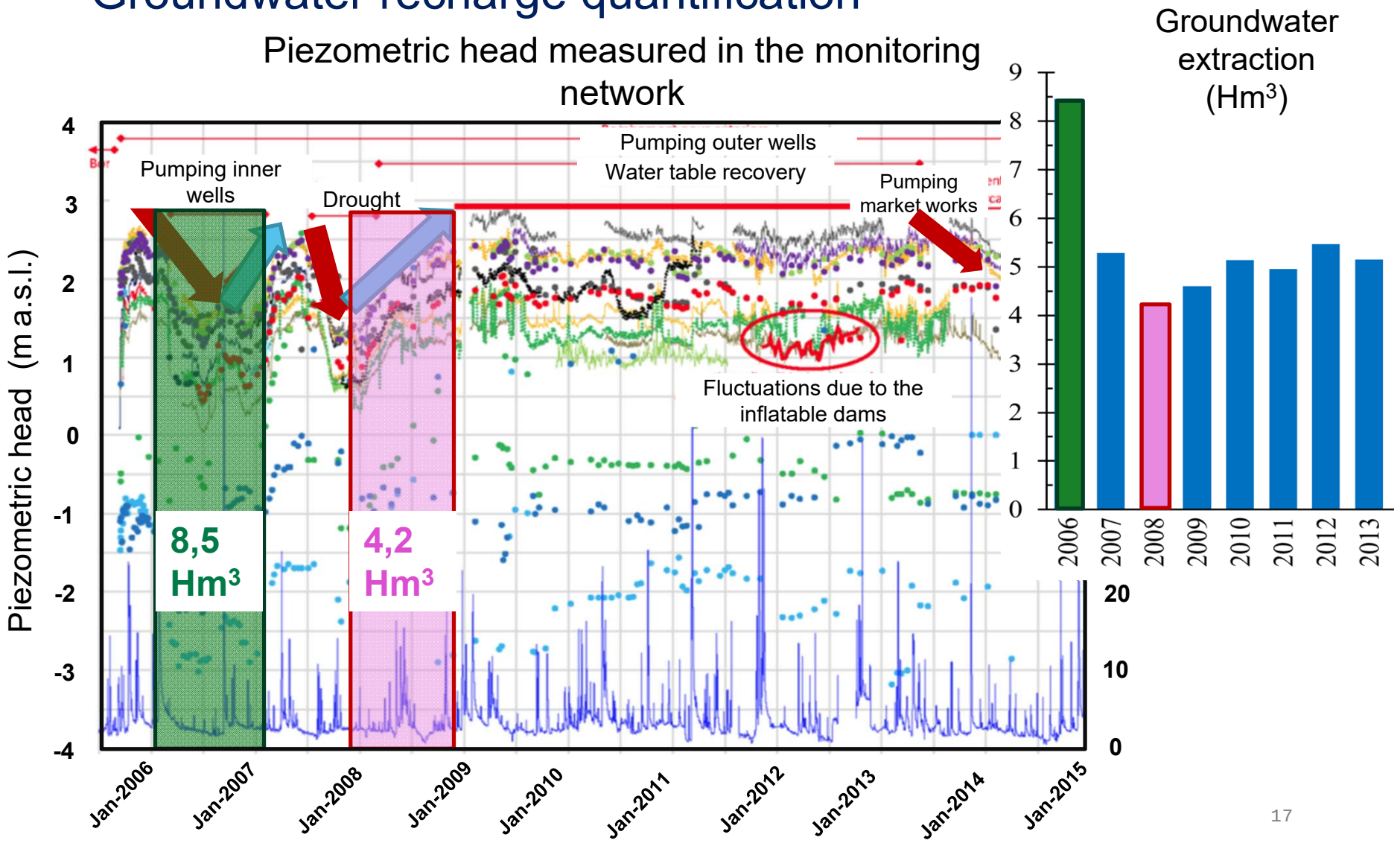
RESULTS&DISCUSSION

Groundwater recharge quantification



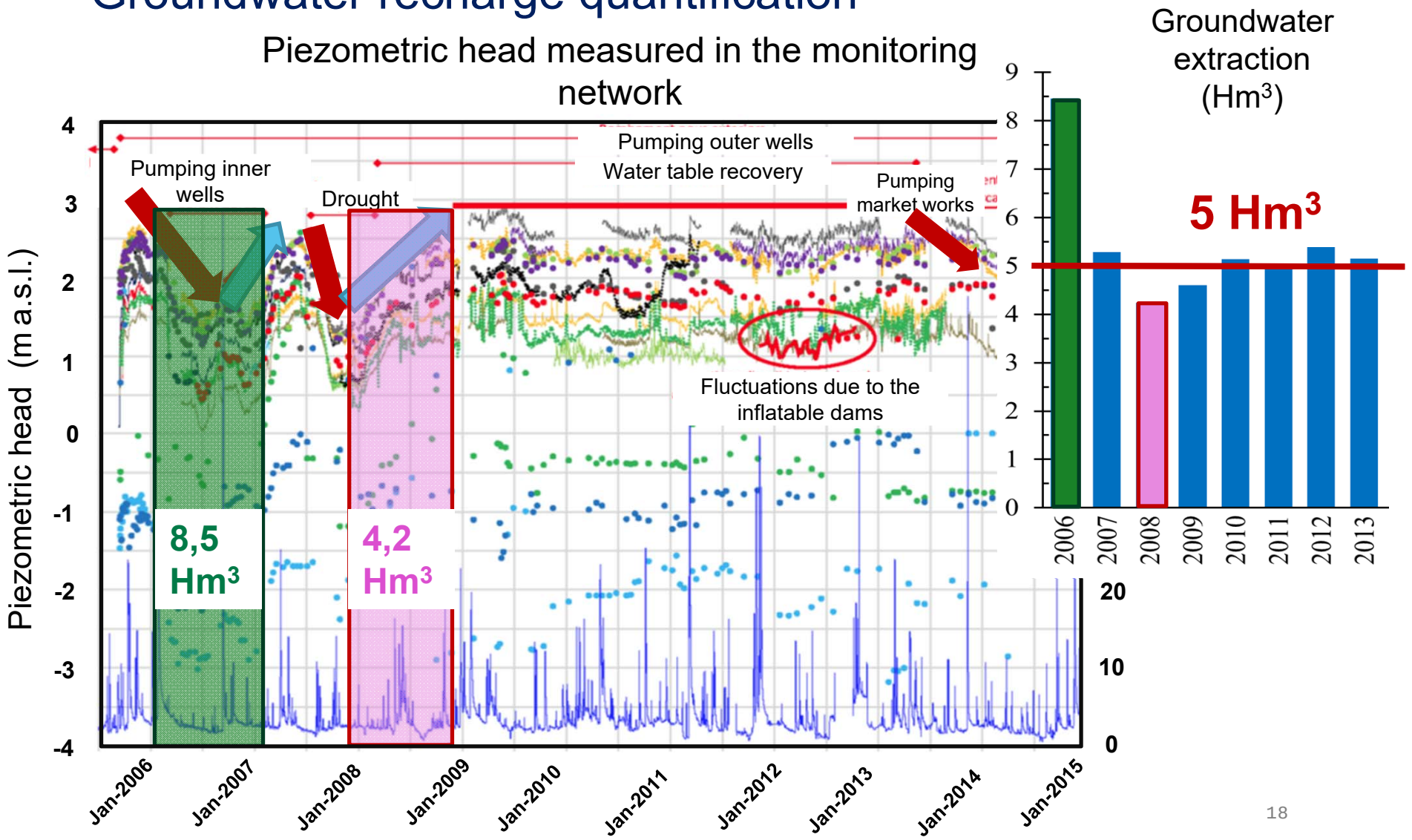
RESULTS&DISCUSSION

Groundwater recharge quantification

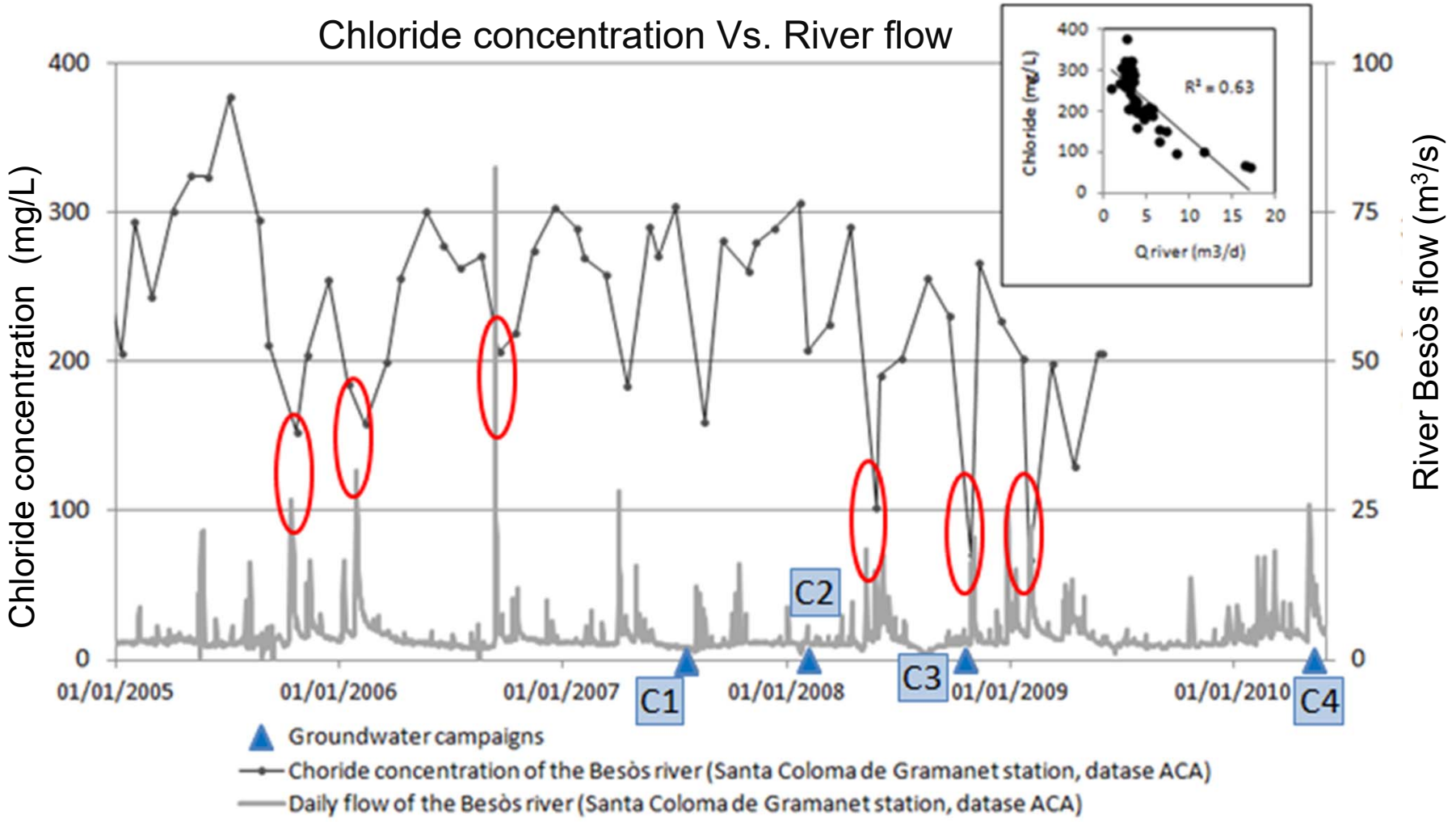


RESULTS&DISCUSSION

Groundwater recharge quantification



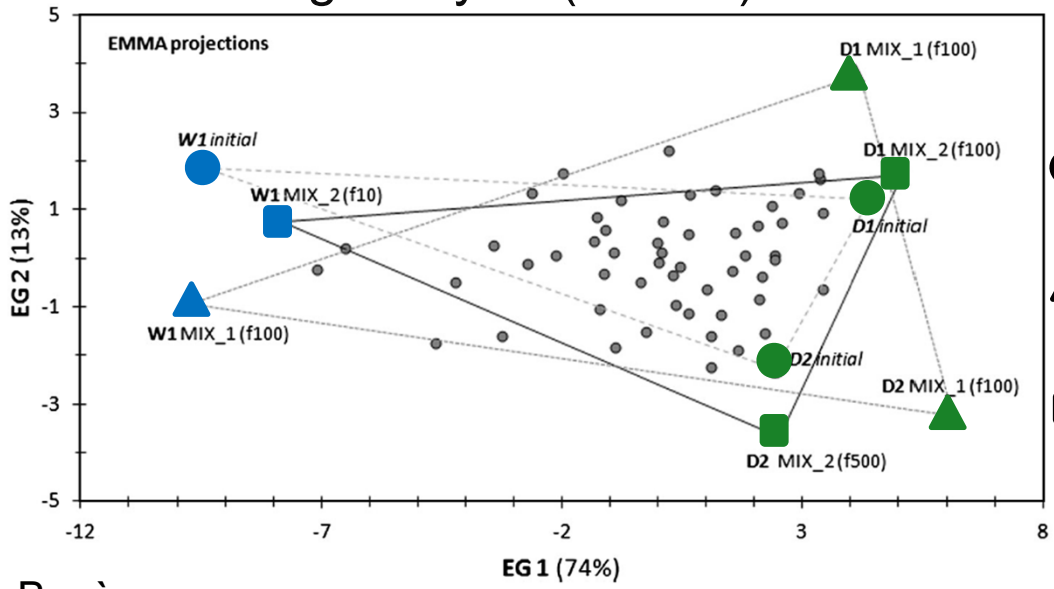
Characterization of the pollution sources



RESULTS&DISCUSSION

Characterization of the pollution sources

End-member mixing analysis (EMMA)



- River Besòs samples (CL,EC,NA,SO4,HCO3, CA,MG,K,NTOT,NH4)
- Initial End-members
- End-member results Analysis MIX_1
- End-member results Analysis MIX_2

Tubau et al. (2014)

3 River Besòs end-members (mg/L)

		Cl^-	SO_4^{2-}	HCO_3^-	Ca^{2+}	EC	NO_3^-	NH_4^+	Mg^{2+}	TOC	O_2	Na^+	K^+
Wet river end-member	(W1)	43.7	52.8	222.7	62.2	586	13.4	4.1	13.3	6.3	8.7	29.0	7.2
Dry river end-member 1	(D1)	356.2	205.9	500.5	139.9	1977	7.4	31.5	24.2	12.4	8.3	280.9	51.1
Dry river end-member 2	(D2)	315.8	198.6	470.3	151.3	1891	13.2	3.6	30.1	8.7	10.6	246.6	36.4

RESULTS&DISCUSSION

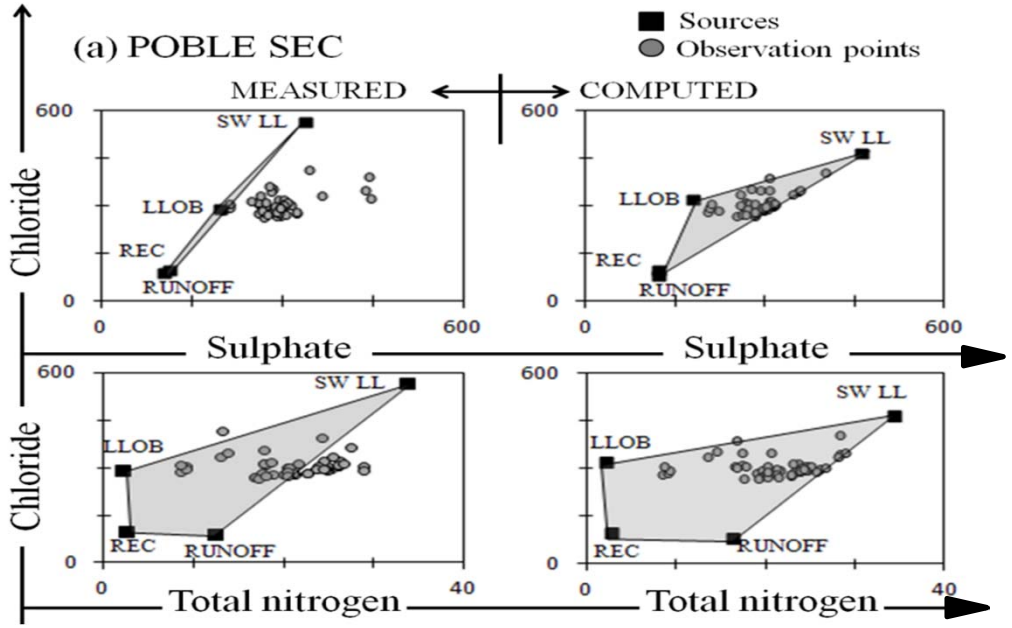
Assessment of the urban groundwater quality

MIX CODE (Carrera et al., 2004)

- Quantifies mixing ratios in the case of uncertain end-members
- Use the concentration of samples (mixtures)

$$\hat{X}_{ij} = \sum_{e} \lambda_{ej} \hat{Y}_{ie}$$

- Uncertainty is quantified in terms of standard deviations



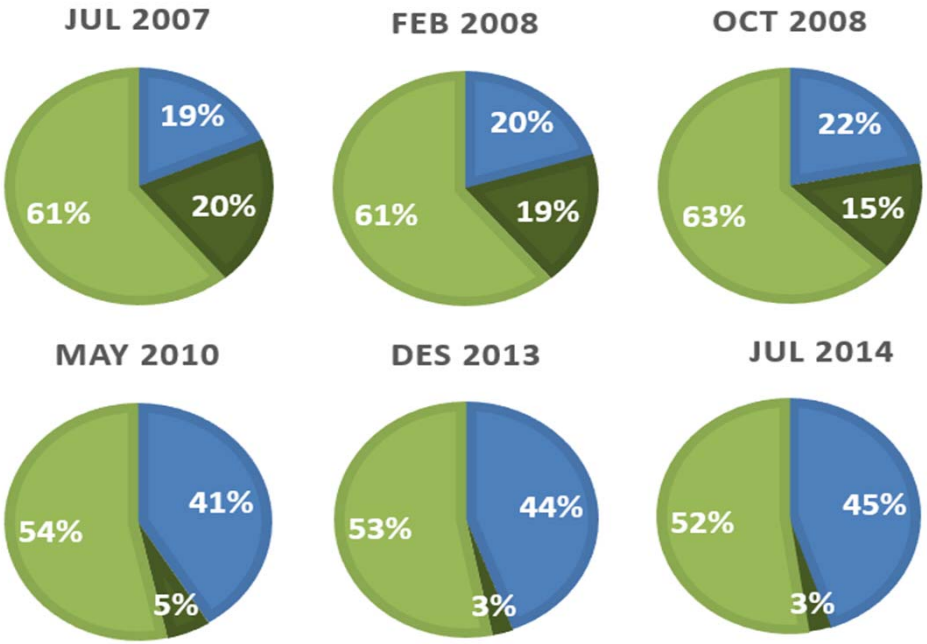
Jurado et al. (2013)

RESULTS&DISCUSSION

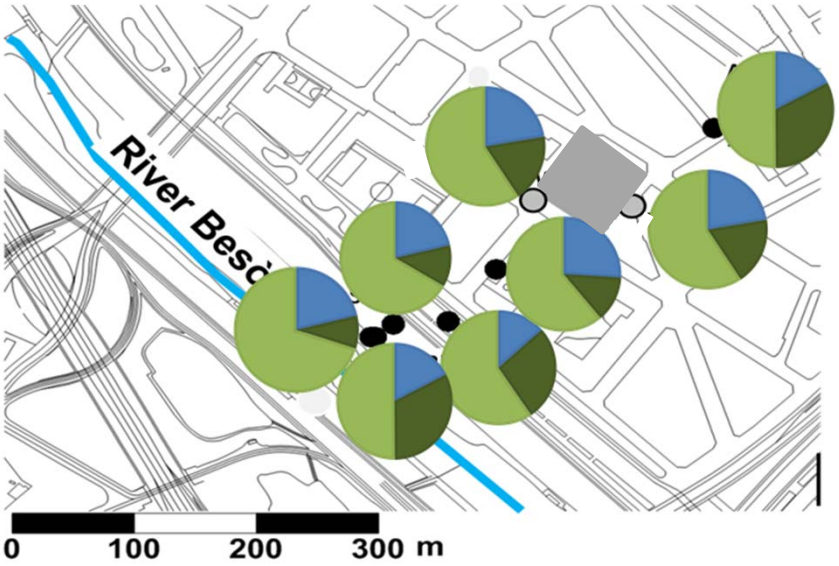
Assessment of the urban groundwater quality

Quantify the proportions in which the River Besòs end-members contribute to the resident water of the aquifer

Average mixing ratios



Spatial distribution of the mixing ratios February 2008 (Sampling campaign 2)



End-members

D2 **D1** **W1**

(Jurado et al., 2017)

Variation of the urban groundwater quality over time

Major and minor ions Vs. RD 140/2003 (sanitary criteria for the quality of water for human consumption)

Compound	Concentrations (mg/L)							
	C1	C2	C3	C4	C5	C6	Cm	RD 140/2003
Chloride	241.5-308.3 (268.1)	242.3-297.6 (268.8)	249.7-278 (259.7)	181.7-211.8 (199.5)	171.9-221 (191.8)	178.9-213.4 (192.9)	229	250
Sulphate	151.7-172 (164.4)	177.3-181.4 (179.3)	155.3-166.5 (160.7)	139.1-165.1 (150.3)	135.2-158.8 (146.8)	122.7-142.1 (135)	155.8	250
Bicarbonate	401-455.9 (428.1)	425.4-470.5 (449)	403.5-442.5 (426.6)	391.3-433.9 (412)	397.8-418.1 (406)	367-410 (399.6)	419.1	-
Calcium	131.4-146.8 (138.6)	137.5-149 (142.7)	129.4-147.9 (138.7)	117.3-135.4 (128.2)	106.4-120.7 (114.6)	92.3-120.9 (111.4)	128.7	-
Magnesium	28.2-29.6 (28.8)	23.6-33 (29.4)	28.1-31.9 (29.6)	25.2-28.7 (27.3)	21.2-25.3 (23.5)	19.8-25.4 (23.1)	26.9	-
Sodium	204-257.3 (225.6)	188.2-211.4 (200)	197.4-224 (209.1)	146.3-165.4 (146.3)	119.5-153.4 (137.3)	120.5-157 (133.8)	175.6	200
Potassium	16.3-28.1 (21.6)	18.2-21.2 (20.1)	16.4-24 (20.8)	14.9-21.3 (17.6)	10.5-15.7 (13.4)	11-21.2 (14.5)	17.9	-
Nitrate	0-14.3 (2.9)	0-24.7 (4.3)	0.47-10.1 (2.3)	0-3.7 (0.8)	0-12.4 (5.9)	0-13.2 (7.3)	3.9	50
Ammonium	2-15.2 (8)	4.7-11.8 (7.7)	4-9 (6.5)	2.1-6.3 (4)	1.2-5.8 (2.7)	0.6-6.6 (2.2)	5.1	0.5
Electrical conductivity	1501-1780 (1631.2)	1581-1757 (1654.8)	1552-1646 (1595.8)	1277-1438 (1375.5)	1293-1460 (1360.2)	1389-1574 (1444.3)	1506.9	2500

RESULTS&DISCUSSION

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Sodium	204-257.3 (225.6)	188.2-211.4 (200)	197.4-224 (209.1)	146.3-165.4 (146.3)	119.5-153.4 (137.3)	120.5-157 (133.8)	175.6	200
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Nitrate	0-14.3 (2.9)	0-24.7 (4.3)	0.47-10.1 (2.3)	0-3.7 (0.8)	0-12.4 (5.9)	0-13.2 (7.3)	3.9	50
Ammonium	2-15.2 (8)	4.7-11.8 (7.7)	4-9 (6.5)	2.1-6.3 (4)	1.2-5.8 (2.7)	0.6-6.6 (2.2)	5.1	0.5
Electrical conductivity	1501-1780 (1631.2)	1581-1757 (1654.8)	1552-1646 (1595.8)	1277-1438 (1375.5)	1293-1460 (1360.2)	1389-1574 (1444.3)	1506.9	2500

Variation of the urban groundwater quality over time

Metals Vs. RD 140/2003 (sanitary criteria for the quality of water for human consumption)

Metals	Concentrations (µg/L)							
	C1	C2	C3	C4	C5	C6	Cm	RD 140/2003
Aluminium	7.1-287.6 (93)	0.9-601.3 (161.6)	0-59.26 (17.6)	0-<LOQ	5.5-23.5 (13.8)	9.5-67.1 (38.4)	53	200
Arsenic	2.4-31.1 (14.8)	4-27.5 (17.1)	3.6-32.2 (16.6)	2.1-17.3 (10.8)	1.6-9.1 (5)	1.5-14.5 (6.4)	11.7	10
Boron	260.7-283.3 (270.2)	229.22-298.9 (266.8)	199.3-264.9 (231.4)	138.2-201.7 (177.6)	163.4-244.3 (207.9)	171.6-223.5 (202.4)	224.8	1000
Cadmium	<LOQ	<LOQ	0 (0)	0 (0)	<LOQ	<LOQ	0.4	5
Chrome	7.2-12.8 (9.6)	10.3-17.4 (14.3)	9.9-13.2 (11.2)	1.7-18.5 (12.8)	<LOQ-2.9 (2.3)	<LOQ-2 (1.5)	8.6	50
Copper	1.7-5.4 (3.6)	1.6-12.7 (6.3)	1.3-6.4 (3.4)	1.4-13.7 (5.8)	1-2.8 (2.1)	<LOQ-2.5 (2)	3.9	2000
Iron	128.2-1563.5 (589.7)	59.9-3595.3 (891.2)	65.4-1610.5 (509)	19.6-554.7 (203.6)	12-536 (185.5)	19.9-414.7 (187.2)	423.1	200
Manganese	175.7-406.6 (285.2)	186.3-588.6 (319.2)	192.5-824.3 (388.4)	64.1-810 (292.6)	2.3-433.2 (133.6)	1.9-382.9 (133.9)	258	50
Nickel	5.2-8.4 (6.5)	6-8.3 (7)	3.4-5 (4.2)	4-6.5 (5.7)	2.2-3 (2.6)	3.8-4.3 (4)	5	20
Lead	<LOQ-1.7 (1.2)	0.81-7.1 (3.4)	<LOQ-1.1 (0.68)	<LOQ-1 (0.32)	<LOQ	<LOQ-1.5 (0.58)	1.1	10

RESULTS&DISCUSSION

Variation of the urban groundwater quality over time

Metals Vs. RD 140/2003 (sanitary criteria for the quality of water for human consumption)

Metals	Concentrations (µg/L)							
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Cadmium	<LOQ	<LOQ	0 (0)	0 (0)	<LOQ	<LOQ	0.4	5
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Nickel	5.2-8.4 (6.5)	6-8.3 (7)	3.4-5 (4.2)	4-6.5 (5.7)	2.2-3 (2.6)	3.8-4.3 (4)	5	20
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RESULTS&DISCUSSION

Variation of the urban groundwater quality over time

Metals Vs. RD 140/2003 (sanitary criteria for the quality of water for human consumption)

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Cadmium	<LOQ	<LOQ	0 (0)	0 (0)	<LOQ	<LOQ	0.4	5
Chrome	7.2-12.8 (9.6)	10.3-17.4 (14.3)	9.9-13.2 (11.2)	1.7-18.5 (12.8)	<LOQ-2.9 (2.3)	<LOQ-2 (1.5)	8.6	50
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Lead	<LOQ-1.7 (1.2)	0.81-7.1 (3.4)	<LOQ-1.1 (0.68)	<LOQ-1 (0.32)	<LOQ	<LOQ-1.5 (0.58)	1.1	10

RESULTS&DISCUSSION

Variation of the urban groundwater quality over time

Organic compounds Vs. RD 140/2003 (sanitary criteria for the quality of water for human consumption)

Compound	Concentrations (µg/L)					
	C1	C2	C3	C4	Cm	RD 140/2003
Atrazine	0.0	0.0-0.037 (0.023)	0.0-0.005 (0.002)	0.0-0.011 (0.0042)	0.008	0.1
Diazinon	0.0	0.0-0.012 (0.006)	0.0-0.03 (0.008)	0.0-.0.004 (0.001)	0.004	0.1
TBA	0.012-0.061 (0.041)	0.047-0.096 (0.071)	0.003-0.042 (0.016)	0.0-0.026 (0.011)	0.034	0.1
Terbutryn	0.0	0.056-0.12 (0.088)	0.0-0.022 (0.0053)	0.0-0.004 (0.007)	0.024	0.1
Total pesticides	0.012-0.061 (0.041)	0.17-0.24 (0.19)	0.003-0.01 (0.033)	0.002-0.041	0.072	0.5
PCE	0.58-1.98 (1.22)	1.06-5.13 (2.43)	1.51-5.25 (2.77)	0.42-44.2 (10.1)	4.13	-
TCE	0-1.25 (0.48)	1.17-4.14 (2.49)	0.59-4.74 (1.96)	0.34-2.1 (1.1)	1.5	-
PCE+TCE	0.58-3.23 (1.7)	2.23-9.2 7 (4.92)	2.14-9.99 (4.73)	0.76-46.3 (11.2)	5.63	10

Variation of the urban groundwater quality over time

Organic compounds Vs. RD 140/2003 (sanitary criteria for the quality of water for human consumption)

Compound	Concentrations (µg/L)					
	C1	C2	C3	C4	Cm	RD 140/2003
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Diazinon	0.0	0.0-0.012 (0.006)	0.0-0.03 (0.008)	0.0-.0.004 (0.001)	0.004	0.1
TBA	0.012-0.061 (0.041)	0.047-0.096 (0.071)	0.003-0.042 (0.016)	0.0-0.026 (0.011)	0.034	0.1
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Total pesticides	0.012-0.061 (0.041)	0.17-0.24 (0.19)	0.003-0.01 (0.033)	0.002-0.041	0.072	0.5
PCE	0.58-1.98 (1.22)	1.06-5.13 (2.43)	1.51-5.25 (2.77)	0.42-44.2 (10.1)	4.13	-
TCE	0-1.25 (0.48)	1.17-4.14 (2.49)	0.59-4.74 (1.96)	0.34-2.1 (1.1)	1.5	-
PCE+TCE	0.58-3.23 (1.7)	2.23-9.2 7 (4.92)	2.14-9.99 (4.73)	0.76-46.3 (11.2)	5.63	10

RESULTS&DISCUSSION

Assessing the potential uses of pumped urban groundwater

Human consumption

Need additional treatment

Ex: Aeration (metals), ion exchange with zeolites, biological filters or chlorination (ammonium)

Managed Aquifer recharge

It Improves the quality of infiltrated water

It allows water storage in the aquifer

Environmental uses

Contribute to the baseflow of the river (summer)

Hydraulic barrier against seawater intrusion

Urban uses

Water public parks

Cleaning of streets / squares

CONCLUSIONS

- There is a huge amount of pumped **UGW** in shallow aquifer of the Besòs River Delta that are not properly managed.

- The quality of the **UGW** depends on the quality of the river Besòs water. In general, the UGW is of **better quality** a**fter periods of rain** when the contribution of the wet end-member is more significant.

- If the UGW would be used as **potable water**, additional **treatment** would be required because some tracers exceed the limit established in RD 140/2003, which establishes the health criteria for the quality of water for human consumption. The main threats are ammonium and metals manganese, iron and arsenic.

- This methodology can be applied to other aquifer settings with similar purposes.

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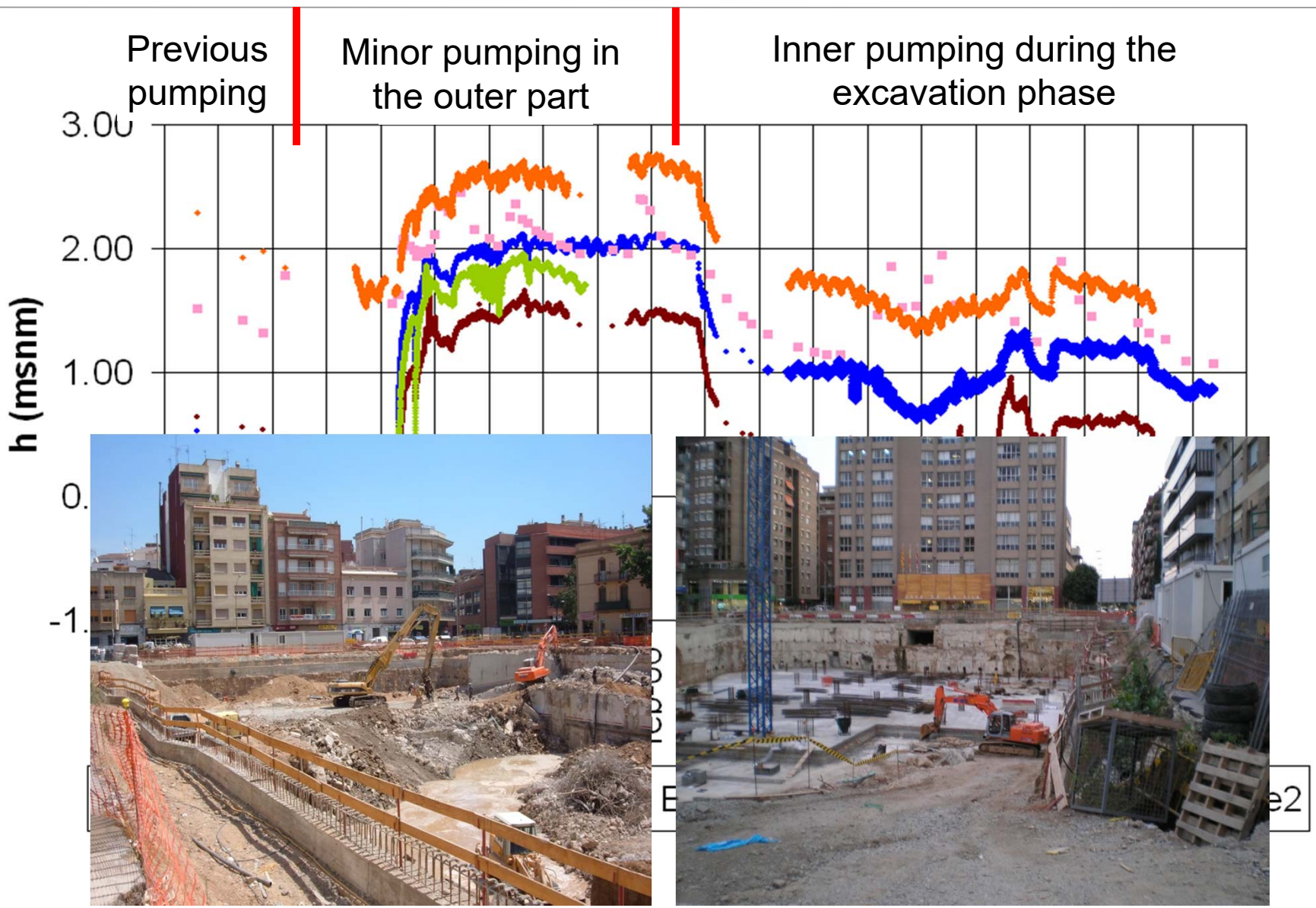
Technische Universität Dresden (Germany)

https://www.ville-sauvian.fr/emplois-saisonniers/

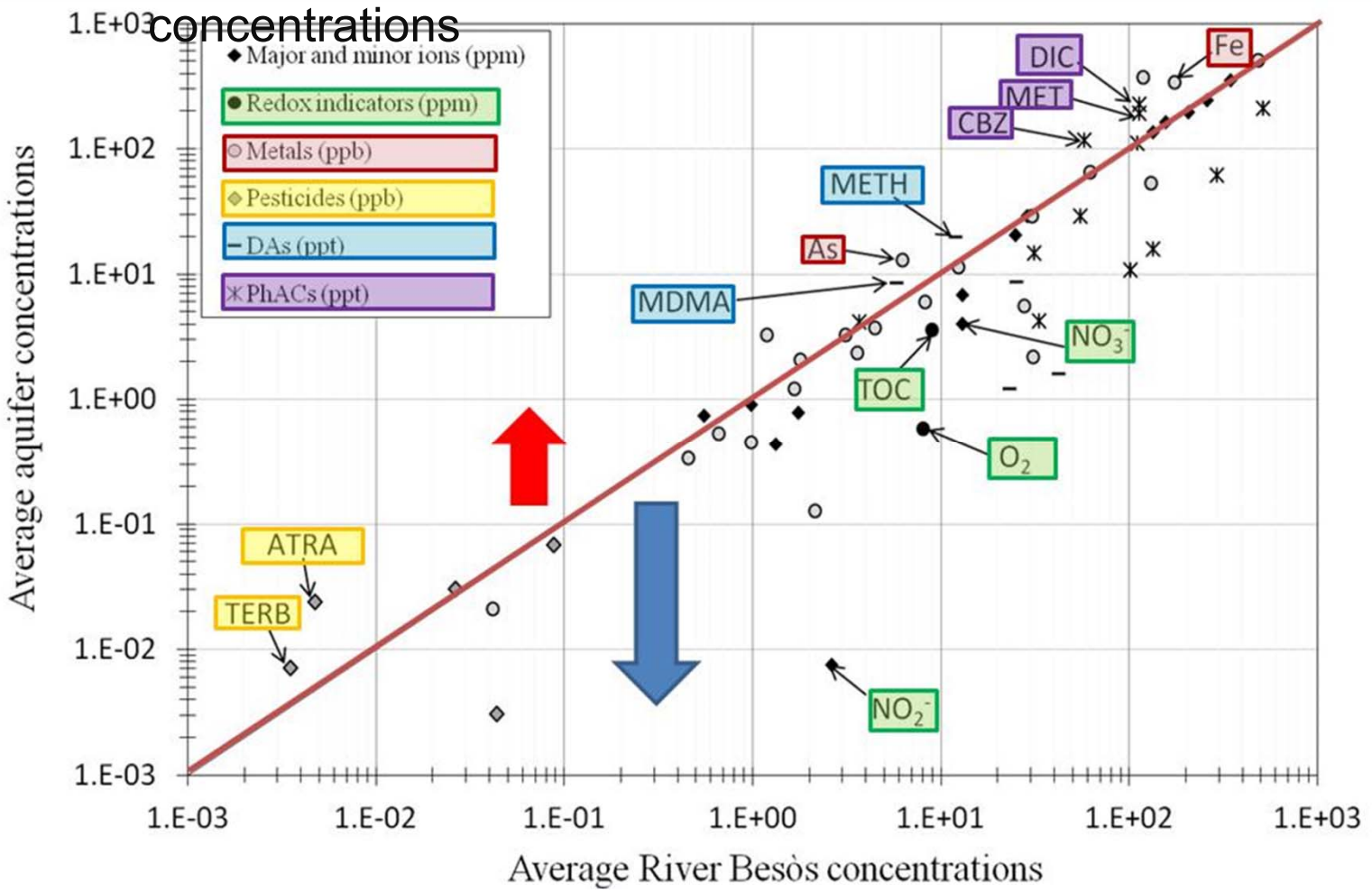
INTRODUCTION



RESULTS&DISCUSSION

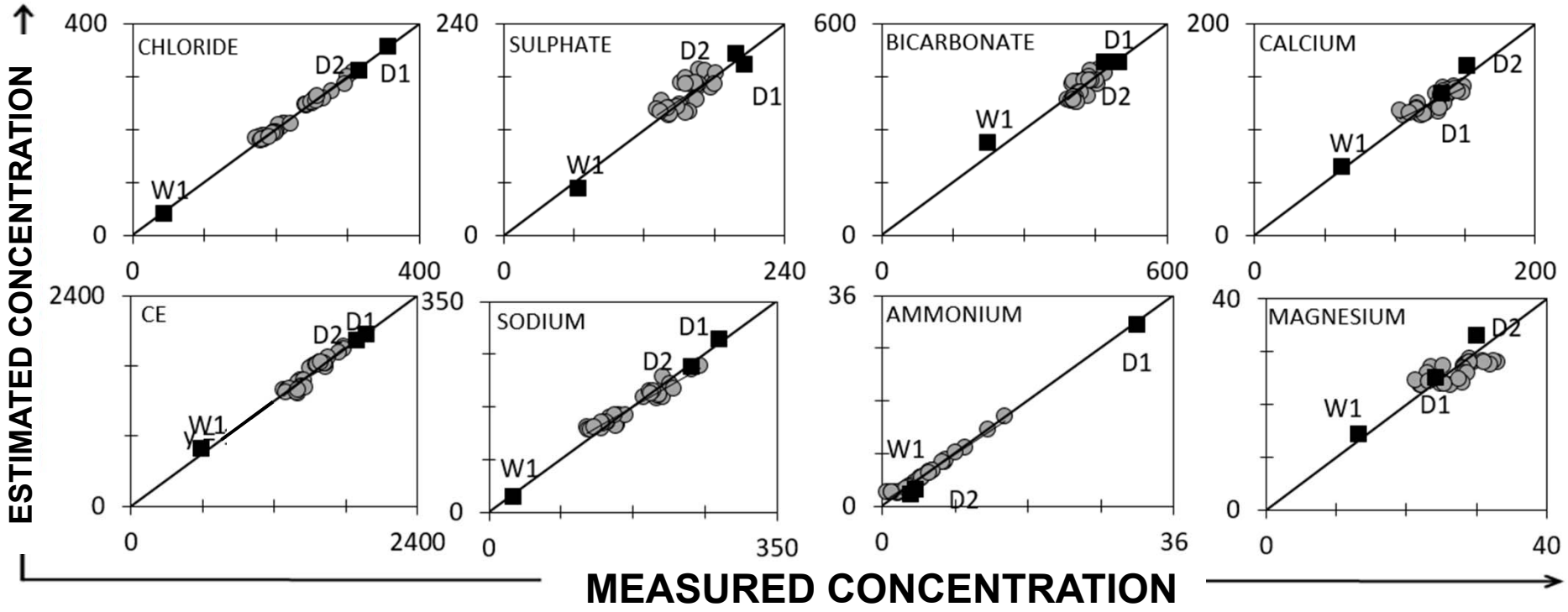
Variation of the urban groundwater quality over time

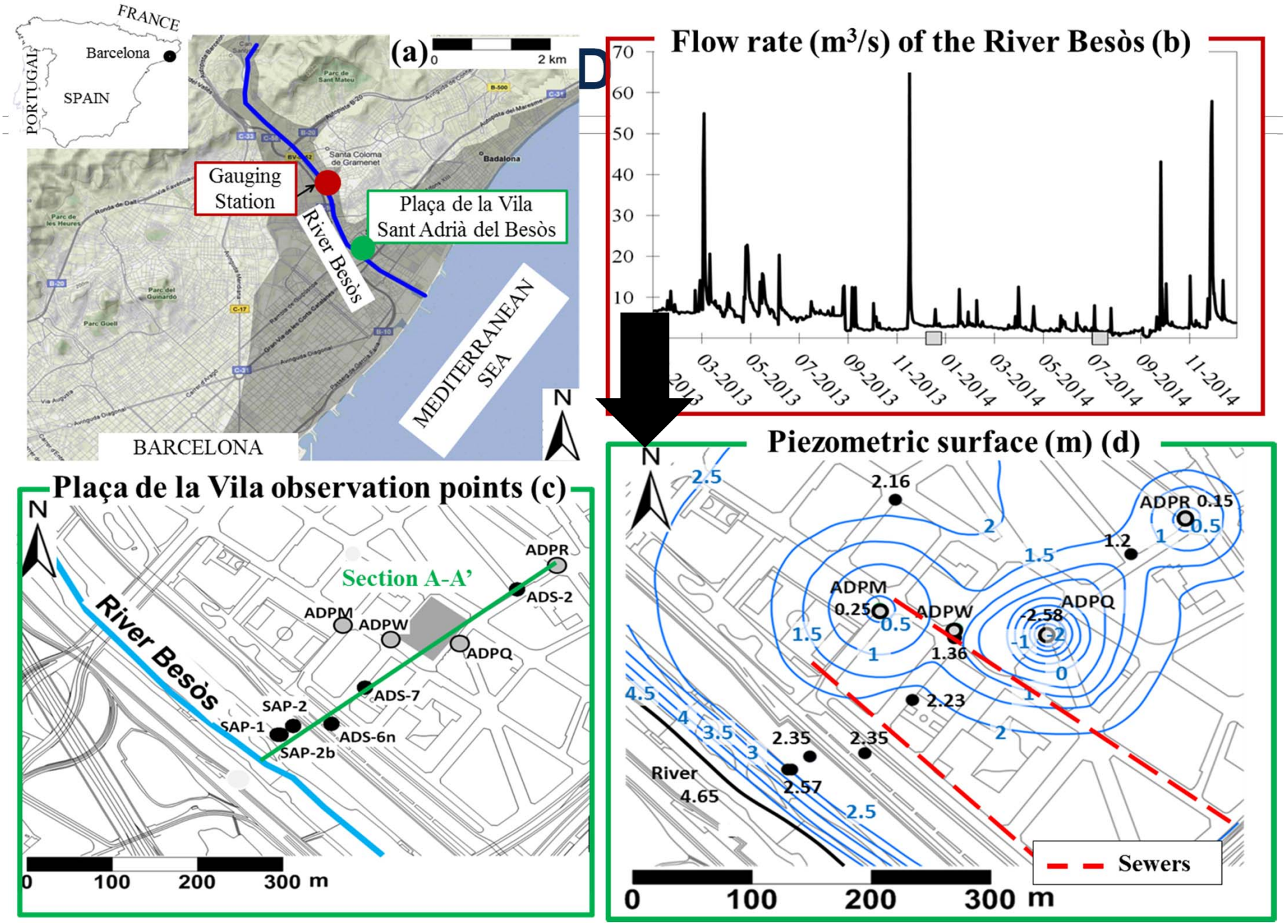
Average river concentrations Vs. Average groundwater concentrations



RESULTS&DISCUSSION

Assessment of the urban groundwater quality




FRANCE
PORTUGAL
Barcelona
SPAIN
(a)
0
2 km
Gauging Station
Plaça de la Vila
Sant Adrià del Besòs
River Besòs
MEDITERRANEAN SEA
BARCELONA
N
Flow rate (m³/s) of the River Besòs (b)
70
60
50
40
30
20
10
03-2013
05-2013
07-2013
09-2013
11-2013
01-2014
03-2014
05-2014
07-2014
09-2014
11-2014
Plaça de la Vila observation points (c)
N
River Besòs
Section A-A'
ADPR
ADS-2
ADPM
ADPW
ADPQ
ADS-7
SAP-2
SAP-1
ADS-6n
SAP-2b
0
100
200
300 m
Piezometric surface (m) (d)
N
2.5
2.16
ADPR 0.15
0.5
1
2
1.2
1.5
ADPM
0.25
ADPW
ADPQ
2.58
0.5
1.5
1
1.36
-1
0
4.5
4
3.5
3
2.23
2.35
2.35
River
4.65
2.57
2.5
Sewers
0
100
200
300 m