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European water policy: challenges for Hydrogeologists

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Integration of groundwater protection for human consumption in land use planning

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EFG Panel of experts on hydrogeology

Official Spanish Association of Professsional Geologists (ICOG)

2012

Protection of groundwater intended for human consumption: a proposed methodology for defining safeguard zones

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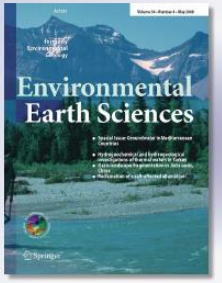

Springer

Jiménez Madrid, A.
Carrasco Cantos, F.
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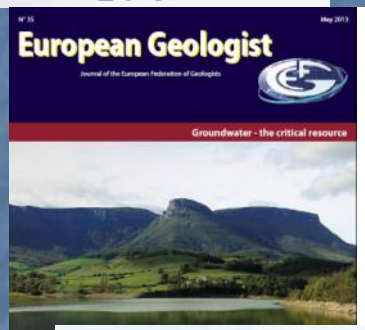
2013



Integration of groundwater protection for human consumption in land use planning

C. Martínez-Navarrete*, A. Jiménez-Madrid, S. Castaño, J.A. Luque and F. Carrasco

PROTECCIÓN DE LAS AGUAS SUBTERRÁNEAS DESTINADAS AL CONSUMO HUMANO. PROPUESTA METODOLÓGICA PARA LA DELIMITACIÓN DE ZONAS DE SALVAGUARDA: MÉTODO GPZ (GROUNDWATER PROTECTION ZONES)

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Palabras clave: Agua Subterránea, Directiva Marco del Agua, Zonas de Salvaguarda, Método GPZ, Riesgo de Contaminación.

RESUMEN

En este artículo se presenta una metodología para la delimitación de zonas de salvaguarda como figura de protección de las masas de agua subterránea utilizadas para consumo humano que permita priorizar en el territorio las medidas de protección a establecer de acuerdo con los requerimientos de la Directiva Marco del Agua (DMA). Para ello, en primer lugar se evalúa el riesgo de contaminación de las aguas subterráneas mediante la combinación de la caracterización de las presiones y la evaluación de la vulnerabilidad intrínseca a la contaminación. En segundo lugar se identifican las captaciones de abastecimiento existentes en la masa de agua subterránea y se delimitan sus zonas de alimentación. Por último, se integran los perímetros de protección existentes y los que se definan en las captaciones significativas.

Los resultados obtenidos en una masa de agua carbonatada del sur de España son coherentes con los datos de calidad existentes y muestran el porcentaje de territorio que debe ser protegido para conservar la calidad de las aguas destinadas al consumo humano facilitando así su futura integración en los instrumentos de planificación para una adecuada ordenación del territorio.

1.- INTRODUCCIÓN

Con la Directiva Marco del Agua, DMA, la protección del agua se ha convertido en uno de los objetivos ambientales prioritarios de las políticas europeas. Por ello, es necesario desarrollar metodologías que mejoran la protección contra la contaminación a fin de alcanzar un buen estado en cuanto a la cantidad y la calidad de las masas de aguas subterráneas utilizadas para el consumo humano que garanticen el cumplimiento de los requerimientos de la DMA (Comisión Europea, 2003; Carrasco *et al.*, 2008).

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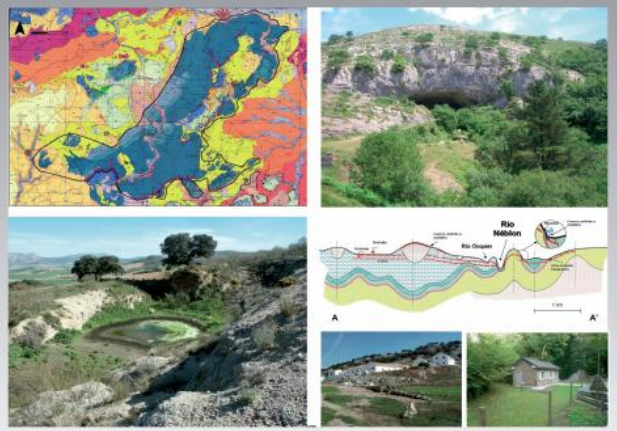
2013

PUBLICACIONES DEL INSTITUTO GEOLÓGICO Y MINERO DE ESPAÑA
Serie: TESIS DOCTORALES N.º 20

Estudio metodológico para el establecimiento de zonas de salvaguarda de masas de agua subterránea en acuíferos carbonatados utilizadas para consumo humano. Aplicación de la Directiva Marco del Agua



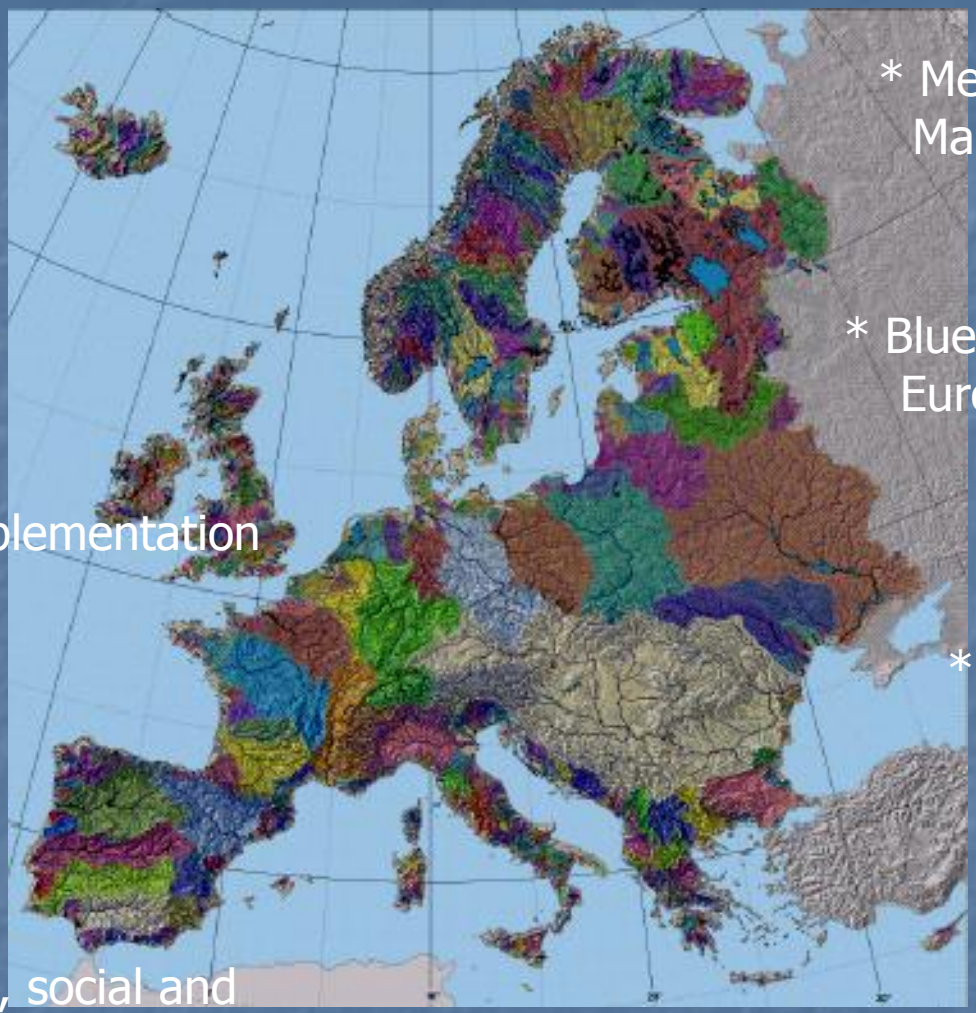
Alberto Jiménez Madrid

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

Instituto Geológico y Minero de España

2012

❖ European water policy



* Member states River Basin Management Plans (RBMP)

* Geology

* Blueprint to safeguard Europe's Water Resources

* CIS for implementation of WFD

* Integration of water policy objectives into other policies

- Land use planning

* Economical, social and environmental systems

* Bussines opportunities

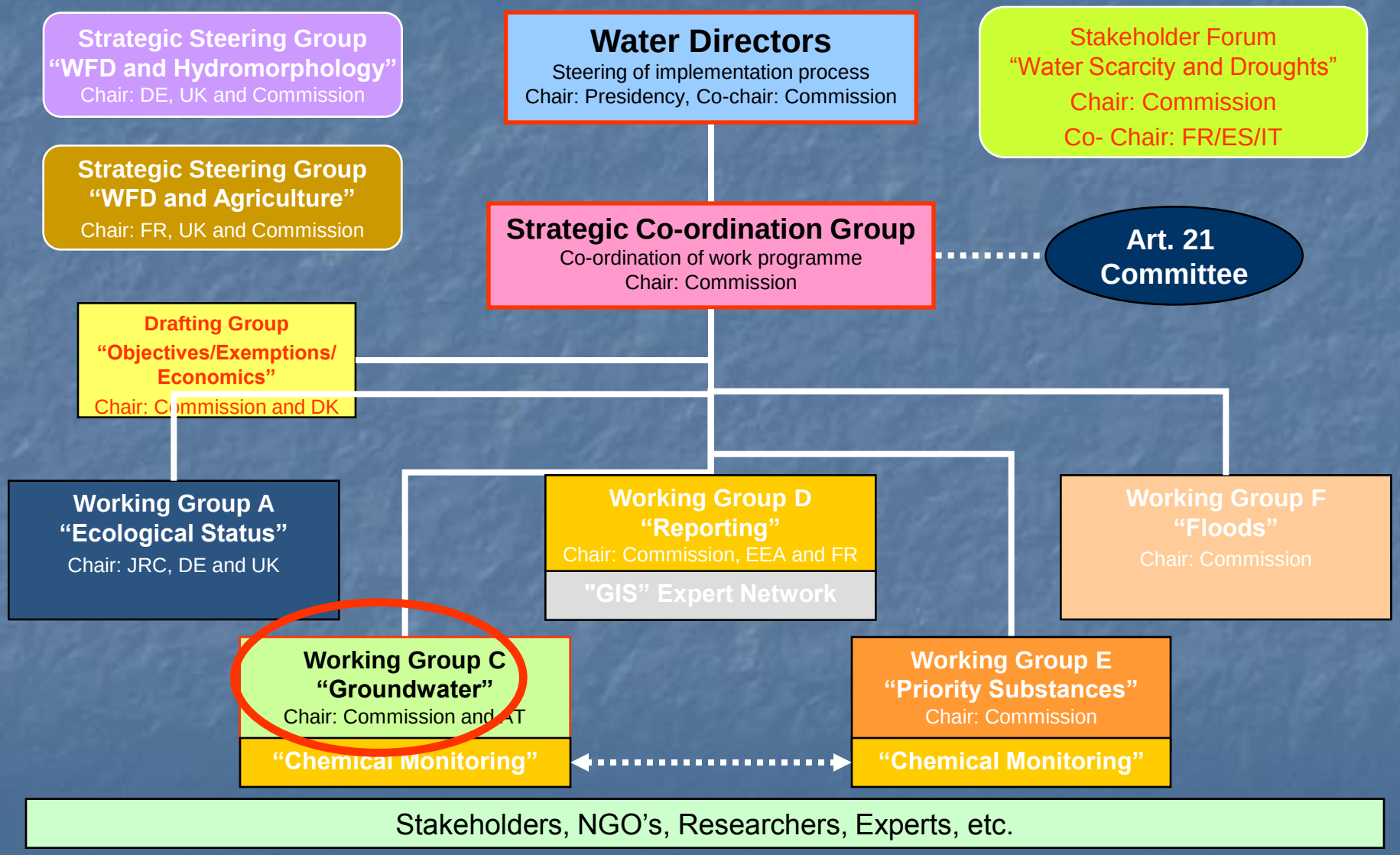
* Hydrogeologists role in the implementation of WFD

- **The protection of water** has become one of the **high-priority environmental objectives** in the European Policies with the entry into force of the Water Framework Directive (**WFD**), and the Directive regarding the protection of groundwater against pollution and deterioration.

- This legislation emphasises among other aspects, the **importance of groundwater as a source of water supply to the population** and the necessity to **protect** this resource in the water bodies used for drinking water abstraction.

- The **need to make the socioeconomic activity compatible with the safeguard of the quality** and quantity of groundwater has been addressed historically through land use planning. To achieve it, the vulnerability cartography has been used, and wellhead protection areas have been established

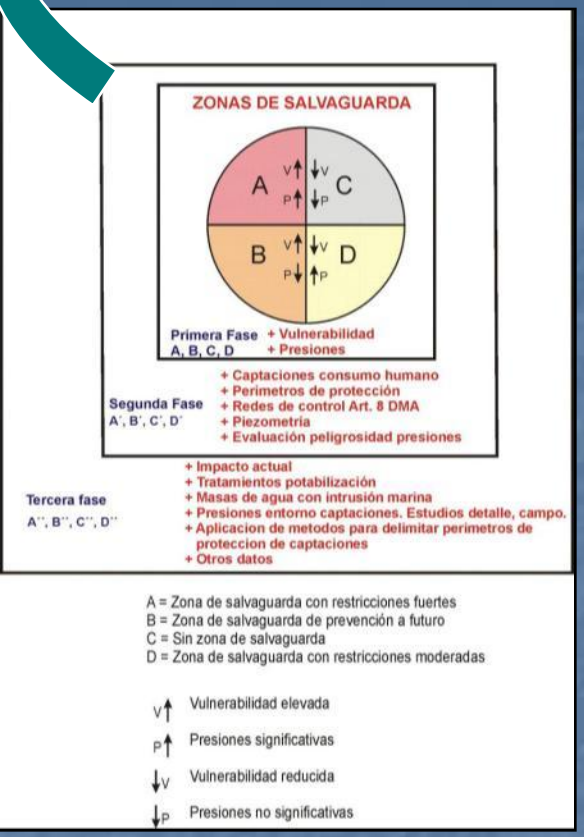
Common Implementation Strategy 2007-2009



European Groundwater Conference, 2010. Madrid, Spain

2011-2013

NECESSITY FOR MODIFYING THE APPLIED METHODOLOGY INCLUDING NEW ITEMS



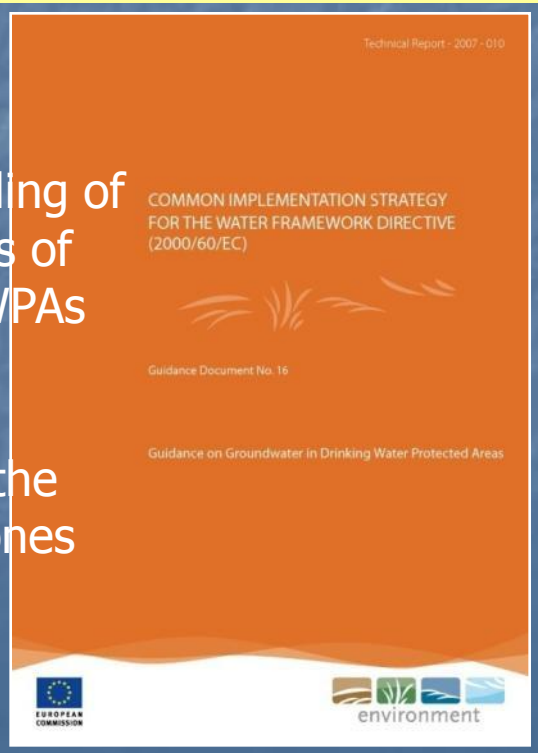
Collaborative project carried out in Spain between the Ministry of Environment and IGME (2007-2010)

Guidance on groundwater in Drinking Water Protected Areas

Groundwater protected areas GW-2 (2005-2007)

* Common understanding of WFD. Clarify issues of groundwater in DWPAs

* A risk based approach to the delineation of safeguard zones is suggested



- **Article 6** of the **WFD** requires to be a **register of protected areas** within each river basin district. These records shall include, among others, the **DWPAs**, which are all groundwater bodies used for the abstraction of drinking water that provide an average of **more than 10 m^3 per day or serve more than 50 people** and those water bodies destinated for such use in the future.

- **DWPAs** correspond to the **total extension of groundwater bodies** used for human consumption (10 m^3 per day or serve more than 50 persons).

- This does not imply that the measures to **reach article 7.2 objectives** must be applied over the entire extension of the DWPAs. These requirements (Directive 98/83/CE, regarding **potable waters**), must be fulfilled at the point where the water is provided to the consumer **after the required purification treatments**.

- **Article 7.3** of the WFD enforces the necessary protection for DWPAs "with the aim of avoiding deterioration in their quality in order to **reduce the level of purification treatment** required in the production of drinking water" **at abstraction points, previous to purification treatments**.

- Restrictive measures to fulfil requirements of **article 7.3** cannot be applied with the same intensity over the whole extension of DWPAs. WFD provides (article 7.3) the **possibility of defining "safeguard zones" in which to focus the restrictions** and control measures to protect groundwater.

PROPOSED METHODOLOGY

1. Characterisation of pressures
2. Vulnerability of groundwater to contamination
3. Risk of groundwater contamination
4. Water abstraction points distribution
5. Zones of contribution of supply abstraction points
6. Wellhead protection areas

GIS tools

SAFEGUARD ZONES

CHARACTERISATION OF PRESSURES

Map of pressures.
Quantitatively assess the pressure risk

COST Action 620

De Keteleare et al., 2004 methodology:

Hazard index (HI):

- Weighting factor (**H Factor**): **10-100**
  Score assigned by a Committee of european experts
- Ranking factor (**Q_n Factor**): **±20% (×0,8-1,2)**
  Depends on the **quantity** of pollutant that could be released into environment
- Reduction factor (**R_f Factor**): **0-1**
  Likelihood of a contamination event to occur

$$HI = H \times Q_n \times R_f$$

NEW INDEX PROPOSED: IP INDEX

H Factor

It corresponds to the H factor of the original method.
New name: IP factor

Q_n Factor

Replaced by a threshold to asses the impact on contamination of each activity → **+40% surpassing the threshold**

Pressures	Intensity of Pressures (IP)	Threshold	Surpassing Threshold (IP)
Urbanised areas with seawage system	35	> 500 inhabitants	49
Urbanised areas without seawage syst	70	> 300 inhabitants	98
Isolated houses without seawage syst	45	> 15 houses	63
Solid urban waste landfill	50	> 10.000 inhabitants	70
Traffic roads	40	> 2.500 vehicles/day	56
Intensive livestock	40	> 500 livestock	42

R_f Factor → Removal of this factor. Difficult to characterize (exist few objective criteria)

IP index (Intensity of pressures)= IP factor or 1, 4 x IP factor (Threshold surpras)

Overlapping pressures are characterized by the sum of their respective IP values

IP INDEX CATEGORIES

Intensity of pressures (IP)	IP Index
0-19 (Very low)	1
20-39 (Low)	2
40-59 (Moderate)	3
60-79 (High)	4
>80 (Very high)	5

VULNERABILITY OF GROUNDWATER TO CONTAMINATION

- It is the susceptibility to contamination due to the impact of human activities

- There are many methods to evaluate the vulnerability:

  - GOD, Foster, 1987
  - DRASTIC, Aller el al., 1987
  - SINTACS, Civita, 1994
  - EPIK, Dörfliger , 1996
  - PI, Goldscheider et al., 2000
  - SLOVENIAN APPROACH Ravbar and Goldscheider, 2007
  - PaPRIKa, Dörfliger and Plagnes, 2009
  - DRISTPI, Jimenez Madrid, 2011
  - … …

VERSATILITY:
Any existing method that evaluate vulnerability **can be integrated** provided that the results of the index are **reclasified into values between 1 and 5**

VULNERABILITY OF GROUNDWATER TO CONTAMINATION

Vulnerability of groundwater to contamination is the susceptibility to contamination due to the impact of human activities

Intrinsic vulnerability

Specific vulnerability (of each pollutant)

Vulnerability of the resource

Vulnerability of the source

COP Method

- **Carbonate aquifers** are particularly vulnerables to pollution due to their special hydrogeological characteristics: natural recharge can be diffuse through ground and concentrated via dolines or sinkholes, epikarst develops where water is stored and flow is concentrated and recharge areas are often extensive and far away from the discharge point. For this reason, a pollutant can reach the aquifer quickly from a wide area affecting groundwater quality.

COP METHOD. Vias et al., 2006

O FACTOR (Overlying layers)

$[O_S]$ Soil

I

Clayey	> 30 % Clay
Silty	> 70 % Silt
Sandy	Sand > 70 % Clay ≤ 15 %
Loam	Rest

II

Thickness	Texture: Clayey	Silty	Loam	Sandy
> 1.0 m	5	4	3	2
0.5 - 1 m	4	3	2	1
< 0.5 m	3	2	1	0*

*: Also 0 when no soil is present

→ $[O_S]$

$[O_L]$ Lithology

III

Lithology and fracturation	Value
Clays	1500
Silts	1200
Marls and non-fissured metapelites and igneous rocks	1000
Marly limestones	500
Fissured metapelites and igneous rocks	400
Cemented or non-fissured conglomerates and breccias	100
Sandstones	60
Scarcely cemented or fissured conglomerates and breccias	40
Sands and gravels	10
Permeable basalts	5
Fissured carbonated rocks	3
Karstic rocks	1

Thickness of each layer

V

Confining conditions (cn)	Value
Confined	2
Semi-confined	1.5
Unconfined	1

(ly) (m) (cn)

Layer index = Σ (ly · m)

IV

Layer index	Value
(0 - 250]	1
(250 - 1000]	2
(1000 - 2500]	3
(2500 - 10000]	4
> 10000	5

Value Layer index · cn = $[O_L]$

O SCORE = $[O_S] + [O_L]$

VI

O SCORE	Protection value
1	Very low
2	Low
(2 - 4]	Moderate
(4 - 8]	High
(8 - 15]	Very High

→ **O MAP**

C FACTOR (Concentration of flow)

SCENARIO 1 — Swallow hole recharge area

Distance to swallow hole (dh)

VII

Distance to swallow hole (m)	Value	Distance to swallow hole (m)	Value
≤ 500	0	(3000 - 3500]	0.6
(500 - 1000]	0.1	(3500 - 4000]	0.7
(1000 - 1500]	0.2	(4000 - 4500]	0.8
(1500 - 2000]	0.3	(4500 - 5000]	0.9
(2000 - 2500]	0.4	> 5000	1.0
(2500 - 3000]	0.5		

Slope and Vegetation (sv)

IX

Slope	Vegetation cover	Value
≤ 8 %	-	1
(8 - 31]	High	0.95
	Low	0.9
(31 - 76]	High	0.85
	Low	0.8
> 76 %	-	0.75

Distance to sinking stream (ds)

VIII

Distance to sinking stream	Value
< 10 m	0
10 - 100 m	0.5
> 100 m	1*

*: Also 1 when no sinking stream is present

C SCORE = dh · ds · sv

SCENARIO 2 — Rest of the area

Surface features (sf)

X

Karstic features	Surface layers: Absence	Permeable	Impermeable
Developed karst	0.25	0.5	0.75
Scarcely developed or dissolution features	0.5	0.75	1
Fissured carbonate	0.75	0.75	1
Non karstic terrains	1	1	1

Slope and Vegetation (sv)

XI

Slope	Vegetation cover	Value
≤ 8 %	-	0.75
(8 - 31]	High	0.8
	Low	0.85
(31 - 76]	High	0.9
	Low	0.95
> 76 %	-	1

C SCORE = (sf) · (sv)

XII

C SCORE	Reduction of protection
[0 - 0.2]	Very High
(0.2 - 0.4]	High
(0.4 - 0.6]	Moderate
(0.6 - 0.8]	Low
(0.8 - 1.0]	Very Low

→ **C MAP**

P FACTOR (Precipitation)

$[P_Q]$ Quantity

XIII

Rainfall * (mm/year)	Value
> 1600	0.4
(1200 - 1600]	0.3
(800 - 1200]	0.2
(400 - 800]	0.3
< 400	0.4

*: Average rainfall for wet years. Wet year ≥ (0.15 · $\bar{x}$) + $\bar{x}$

$[P_I]$ Temporal distribution

Temporal distribution = P (mm/year) / Nº rainy days

XIV

Temporal distribution (mm/day)	Value
< 10	0.6
(10 - 20]	0.4
> 20	0.2

P SCORE = $[P_Q] + [P_I]$

XV

P SCORE	Reduction of protection
0.4 - 0.5	Very High
0.6	High
0.7	Moderate
0.8	Low
0.9 - 1	Very Low

→ **P MAP**

COP Index = C SCORE · O SCORE · P SCORE →

XVI

COP Index	Vulnerability classes
[0 - 0.5]	Very High
(0.5 - 1]	High
(1 - 2]	Moderate
(2 - 4]	Low
(4 - 15]	Very Low

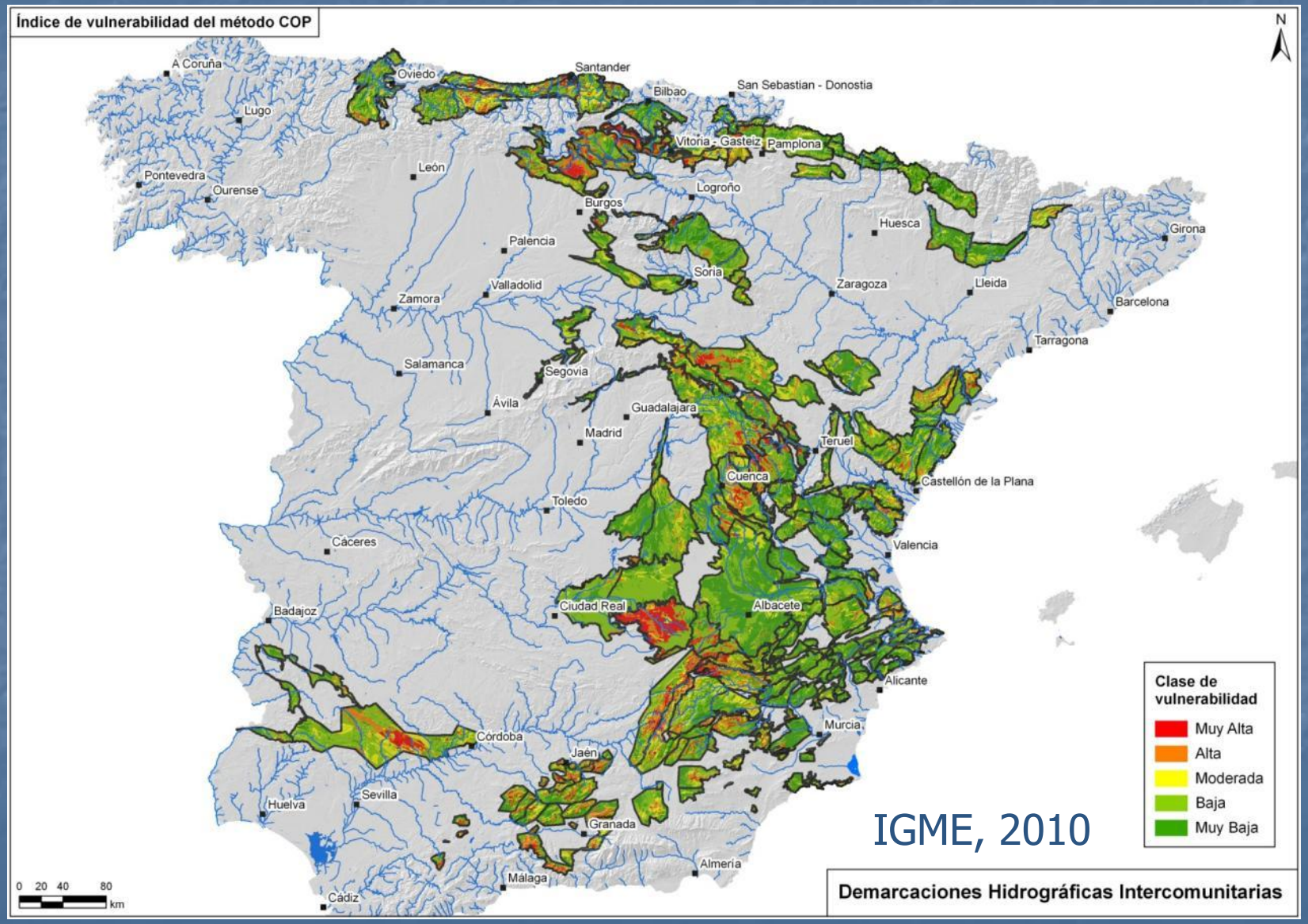
→ **COP Map**

Index of intrinsic vulnerability COP method

Index of intrinsic vulnerability of COP method is calculated as the multiplication of the three previous factors:
COP= C · O · **P**

COP index	Vulnerability classes
0 – 0,5 (Very high)	5
0,5 - 1 (High)	4
1 - 2 (Moderate)	3
2 - 4 (Low)	2
4 - 15 (Very low)	1

Intercommunity river basins. Vulnerability of groundwater bodies. COP method.



IGME, 2010

RISK OF GROUNDWATER CONTAMINATION

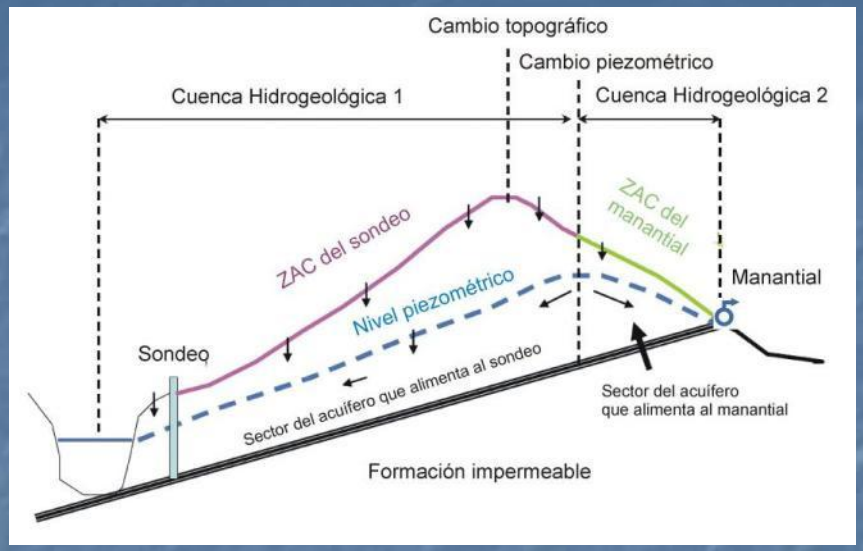
RISK = PRESSURES x VULNERABILITY

Risk index **(RI)** = Intensity of pressures (**IP** index**)** x Vulnerability index (**COP)**

RISK INDEX (RI)		VULNERABILITY					RISK INDEX CATEGORIES (RI)
		1	2	3	4	5	
PRESSURES	1	1	2	3	4	5	Very low (1 - 2)
	2	2	4	6	8	10	Low (3 – 4)
	3	3	6	9	12	15	Moderate (5 – 9)
	4	4	8	12	16	20	High (10 – 16)
	5	5	10	15	20	25	Very high (17 – 25)

VERSATILITY: **Any existing method** that evaluate pressures and vulnerability can be integrated provided that their results are reclasified (1-5)

ZONES OF CONTRIBUTION (ZOC) OF SUPPLY ABSTRACTION POINTS



ZOC is the area that contributes to the abstraction points recharge by water infiltration.
Its delimitation require to analyze:

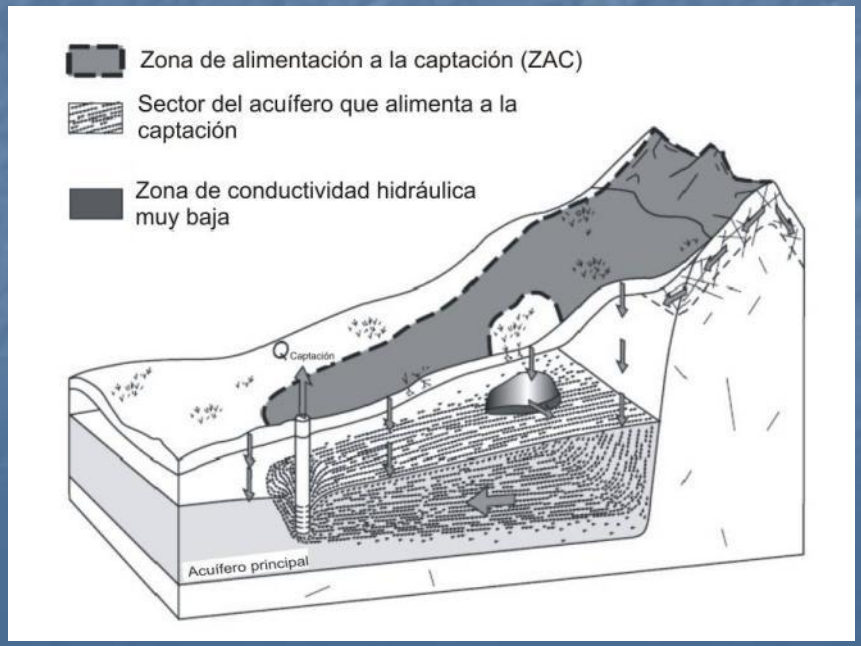
Geological structure

Hydrodynamic methods

Analytical methods

Numerical models

Other methods:
Hydrochemistry
Isotopes
Tracer test
Geophysic methods

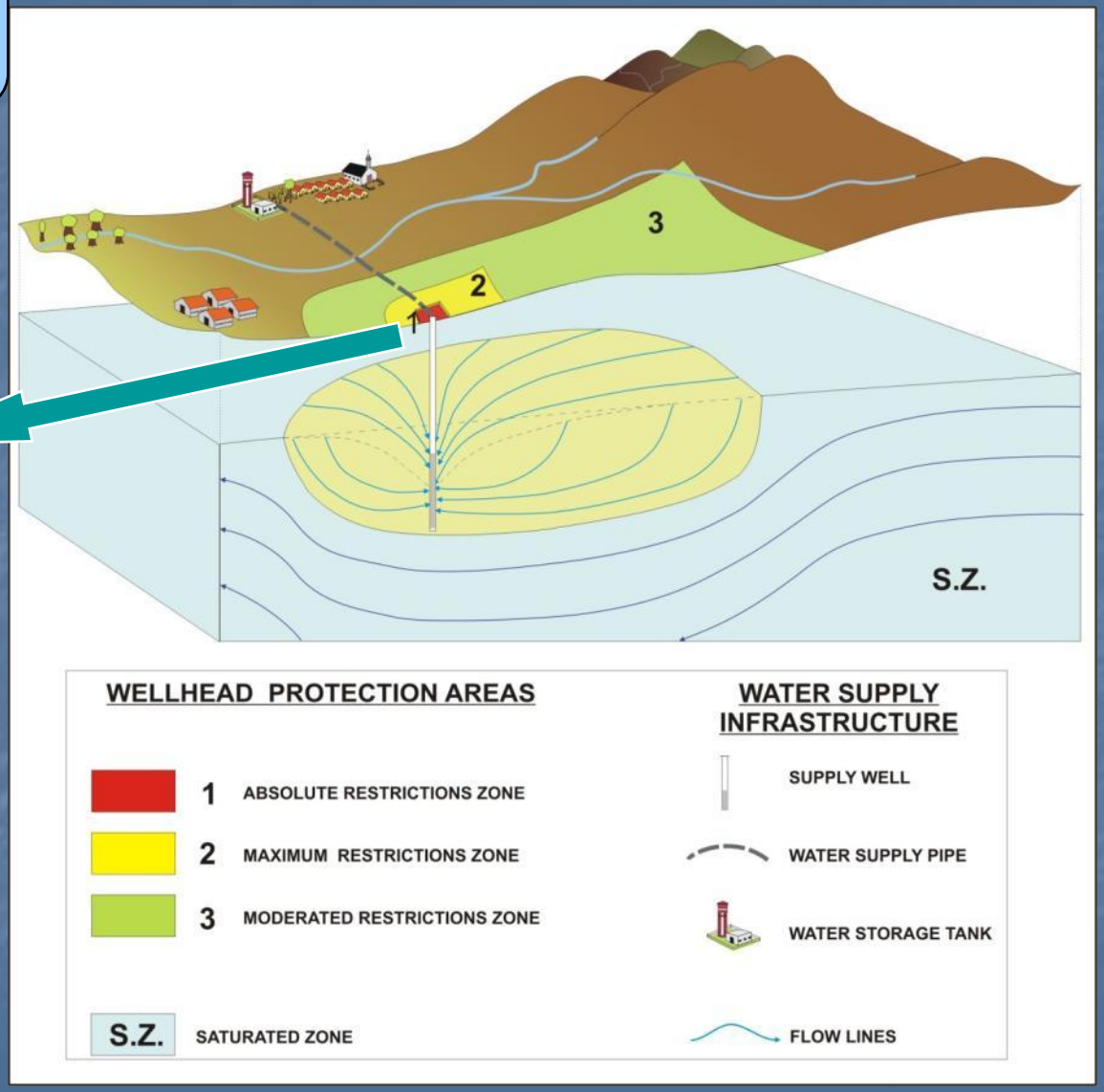


Vernoux et al., 2007. BRGM guideline

Register of protected areas (WFD, art. 6)

Wellhead protection areas

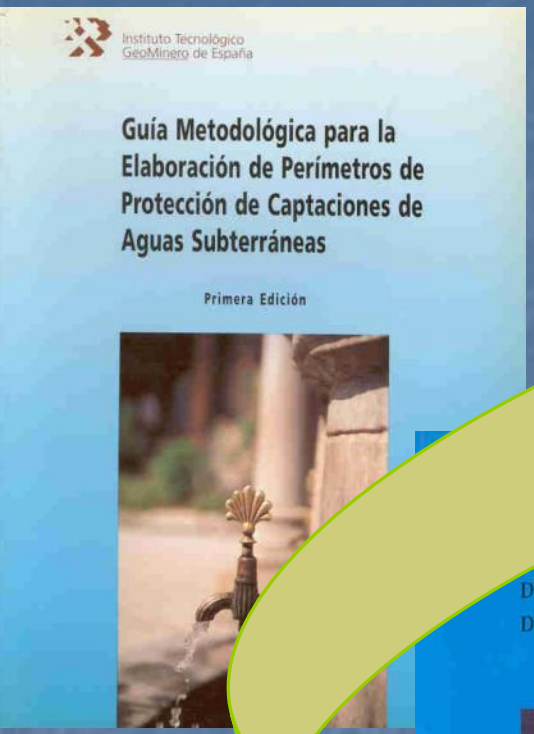
Areas surrounding abstraction points in which in a progressive way activities or facilities that may pollute groundwater are restricted or prohibited



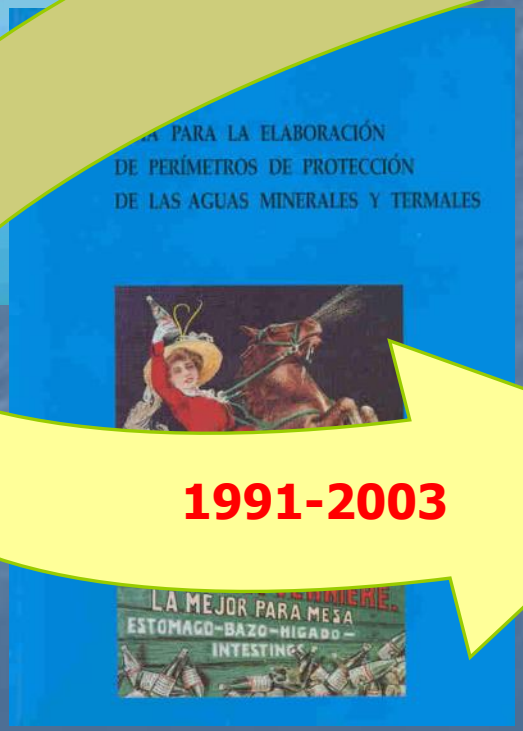
Martínez Navarrete and García García, 2003. IGME.

The Spanish experiences in methodological guidelines

Many methods are used fot the wellhead protection areas delineation

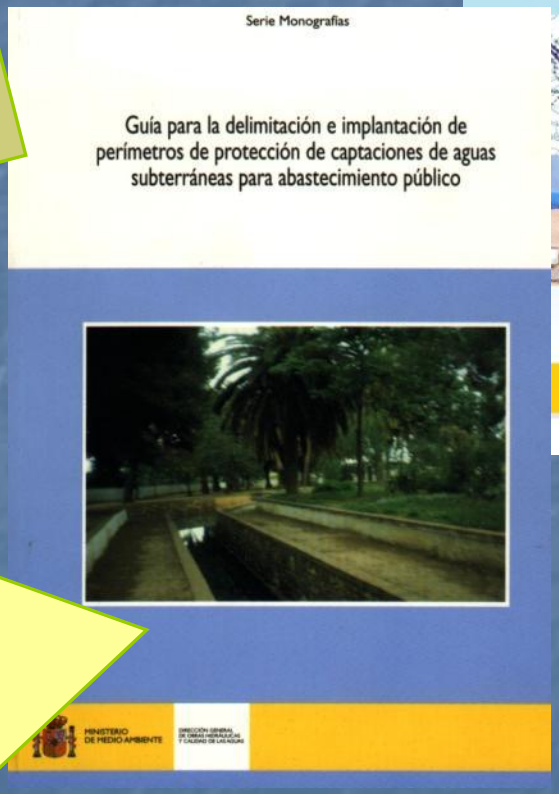


1991

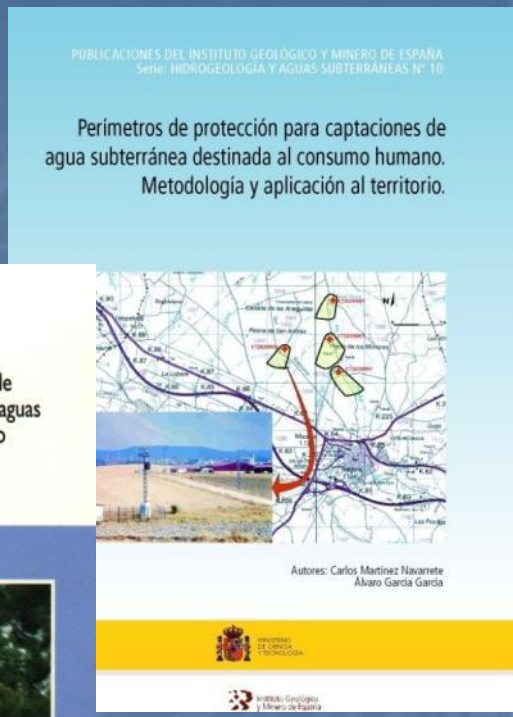


1996

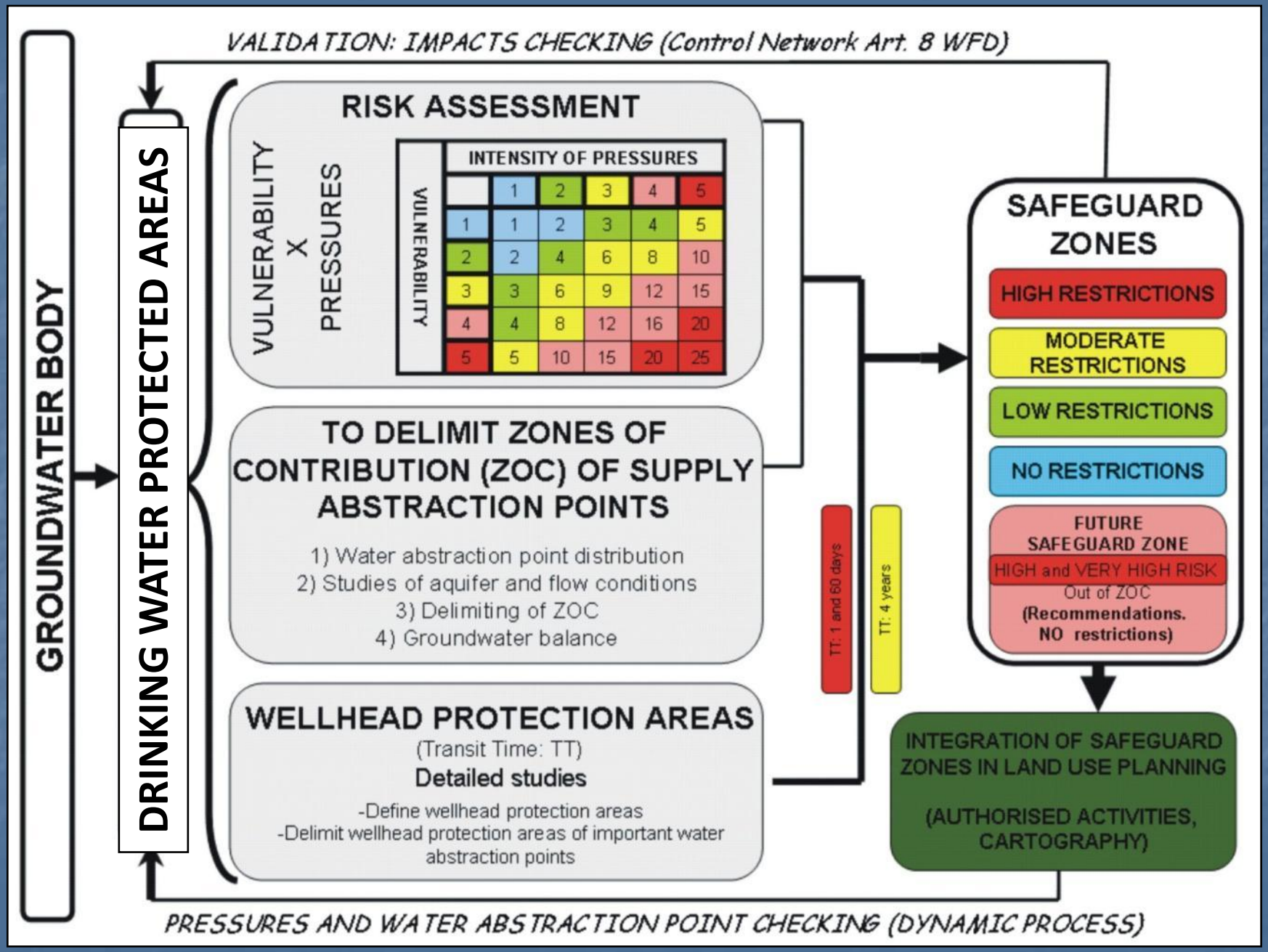
1991-2003



2002



2003



RI:

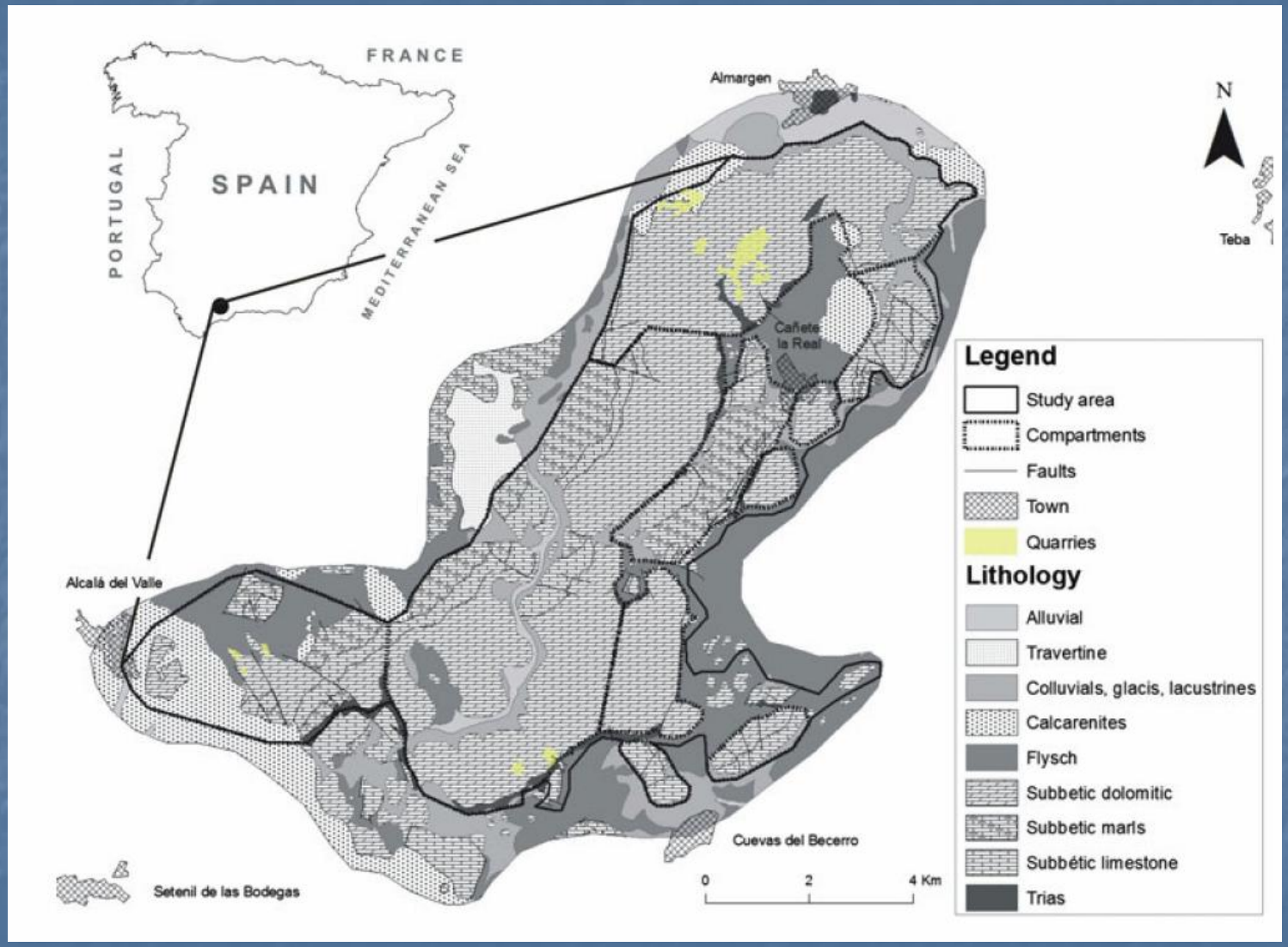
17-25

5-9; 10-16

3 - 4

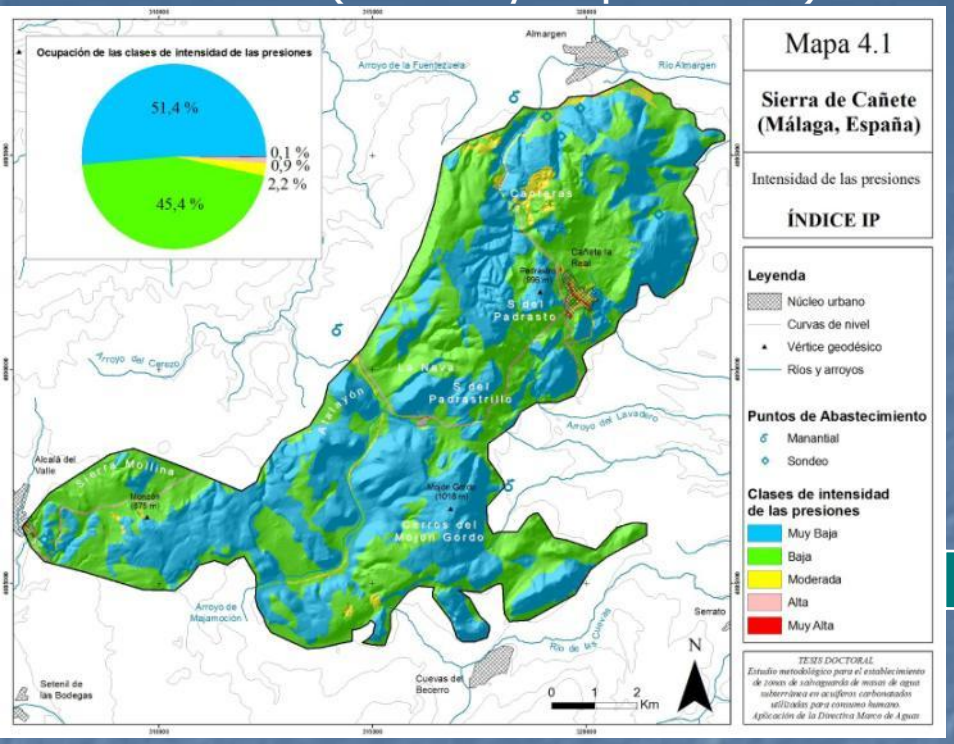
1 - 2

GEOGRAPHICAL AND HYDROGEOLOGICAL SETTING OF SIERRA DE CAÑETE

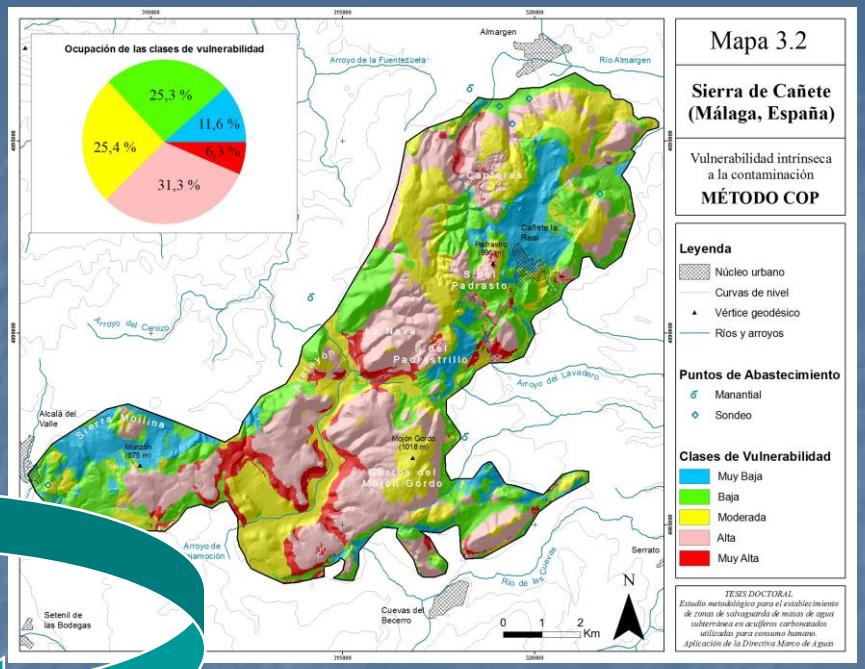


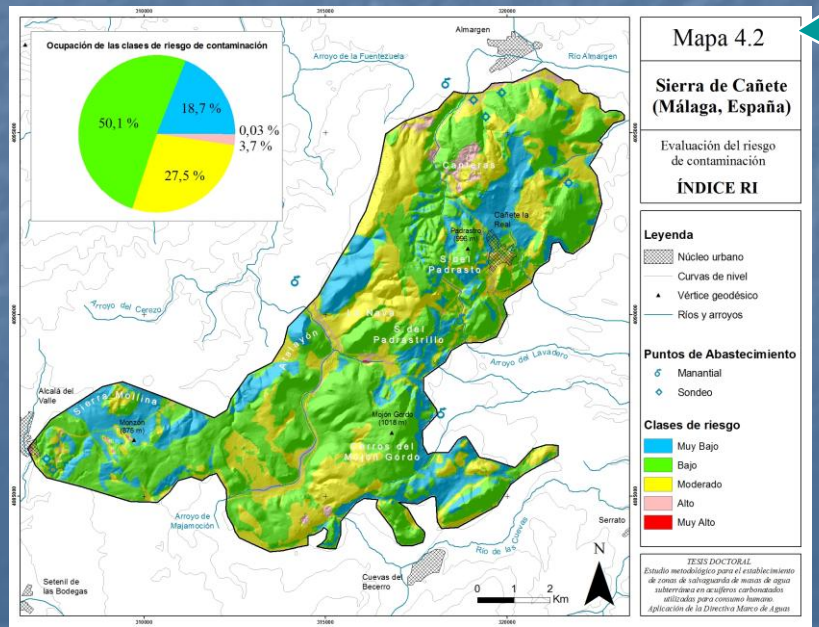
Jurassic limestones and dolomites

IP Index (Intensity of pressures)IP



COP index (vulnerability index)





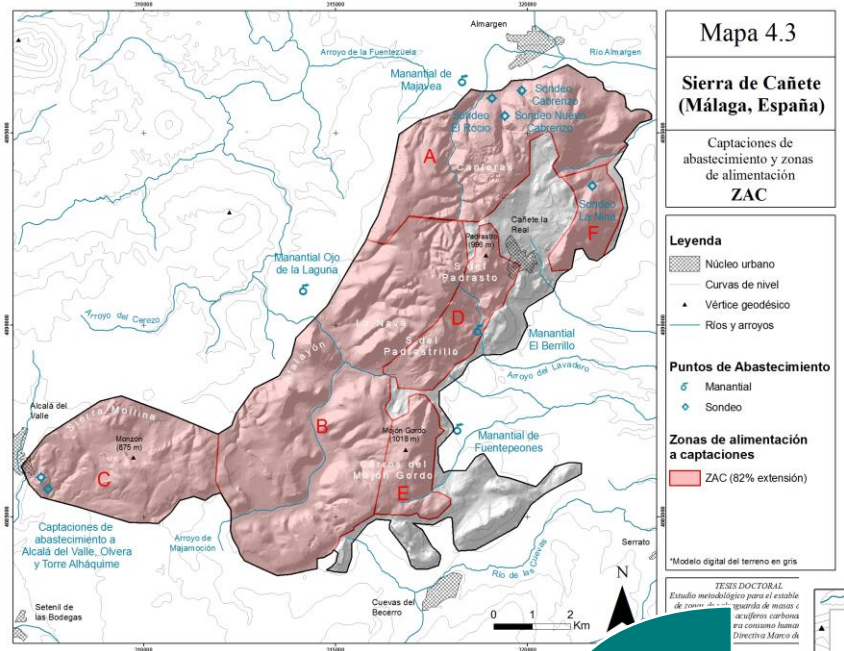
Sierra de Cañete

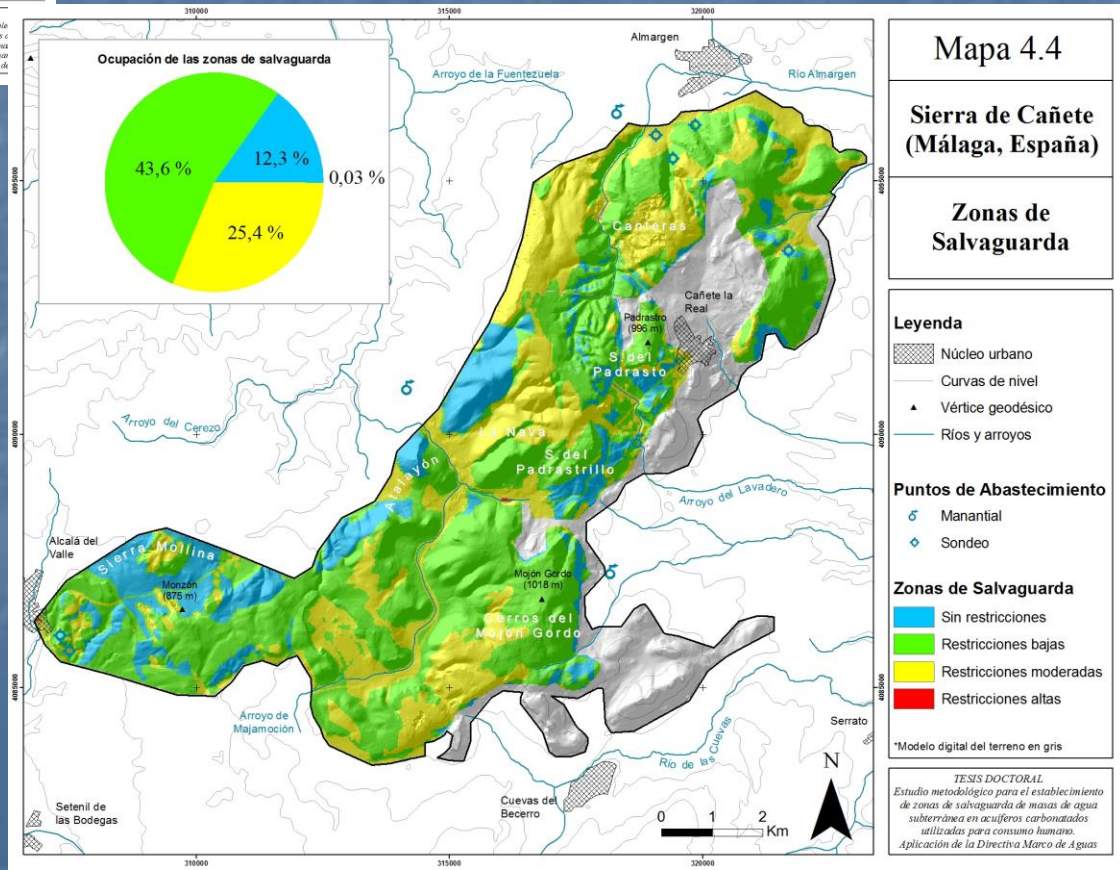
RI Index (Risk of groundwater contamination)

Categories:

- -Very low
- - Low
- - Moderate
- - High
- - Very high

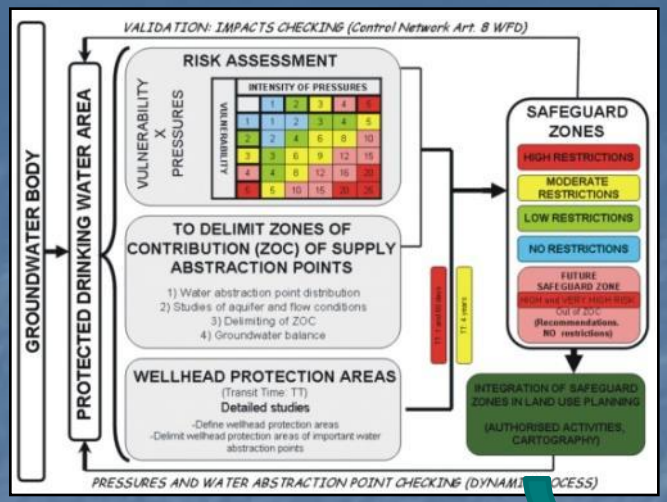
Zones of contribution (ZOC) of supply abstraction points





SAFEGUARD ZONES

- **HIGH RESTRICTIONS** (RI: 17-25)
- **MODERATE RESTRICTIONS** (RI: 5-16)
- **LOW RESTRICTIONS** (RI: 3-4)
- **NO RESTRICTIONS (RI: 1-2)**



AUTHORISED ACTIVITIES CARTOGRAPHY

so that existing activities added to the new authorised activities don´t exceed a risk value (RI) of 12

VULNERABILITY \ INTENSITY OF PRESSURES	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Risk Index: 1 - 25

AUTHORISED ACTIVITIES CARTOGRAPHY

Step 1:

RISK (RI) = PRESSURES (IP) x VULNERABILITY (COP)
Maximum allowable risk = IP maximum x Vulnerability (COP)
If Maximum allowable risk = 12
IP maximum = 12 / COP

Step 2:

Reclasification of IP maximum (step 1) to values 1-5
(Values >5 are reclasified as 5)

Step 3:

Authorised activities = IP maximum (step 2) – IP present activ
There are 6 classes of autorised activities

Authorised activities	Description
Class 0	0 and negative values. No more activities are allowed
Class 1	Permitted activities whose accumulated IP <19
Class 2	Permitted activities whose accumulated IP <39
Class 3	Permitted activities whose accumulated IP <59
Class 4	Permitted activities whose accumulated IP <79
Class 5	Permitted activities whose accumulated IP <100

AUTHORISED ACTIVITIES CARTOGRAPHY

STEP 1

IP Present activities

1	3	2
1	5	2
2	3	4

x

Vulnerability index (COP)

2	3	3
4	1	2
4	4	5

=

Risk index (RI)

2	9	6
4	5	4
8	12	20

Tamaño de celda 10 x10

Maximum allowable risk

12

/

COP

2	3	3
4	1	2
4	4	5

=

IP maximum

6	4	4
3	12	6
3	3	2,4

STEP 2

Reclasification

5	4	4
3	5	5
3	3	2

STEP 3

IP maximum

5	4	4
3	5	5
3	3	2

-

IP present activ

1	3	2
1	5	2
2	3	4

=

Authorised activities

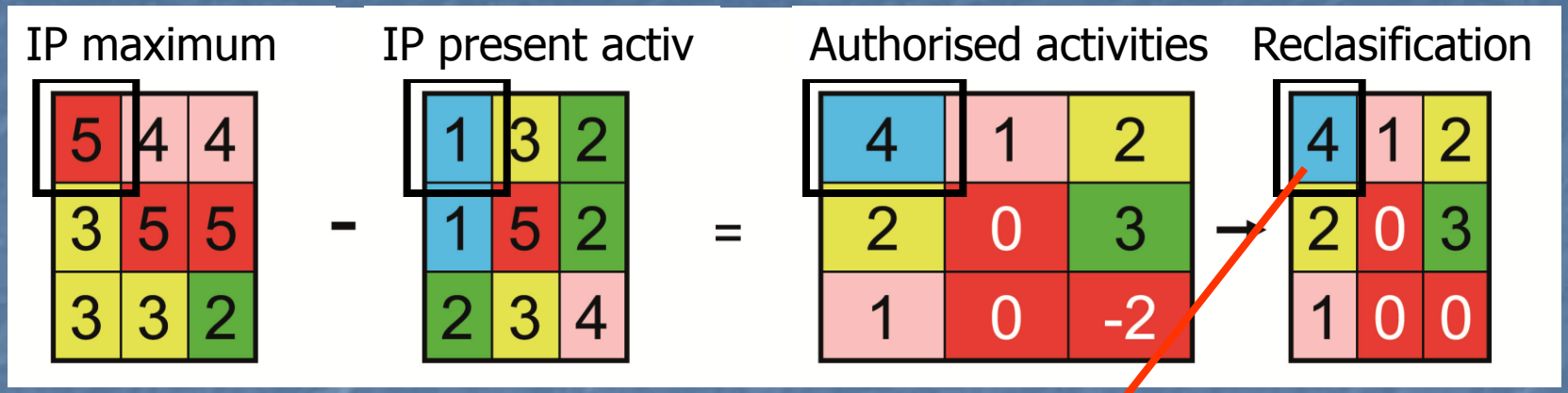
4	1	2
2	0	3
1	0	-2

Reclasification

4	1	2
2	0	3
1	0	0

AUTHORISED ACTIVITIES CARTOGRAPHY

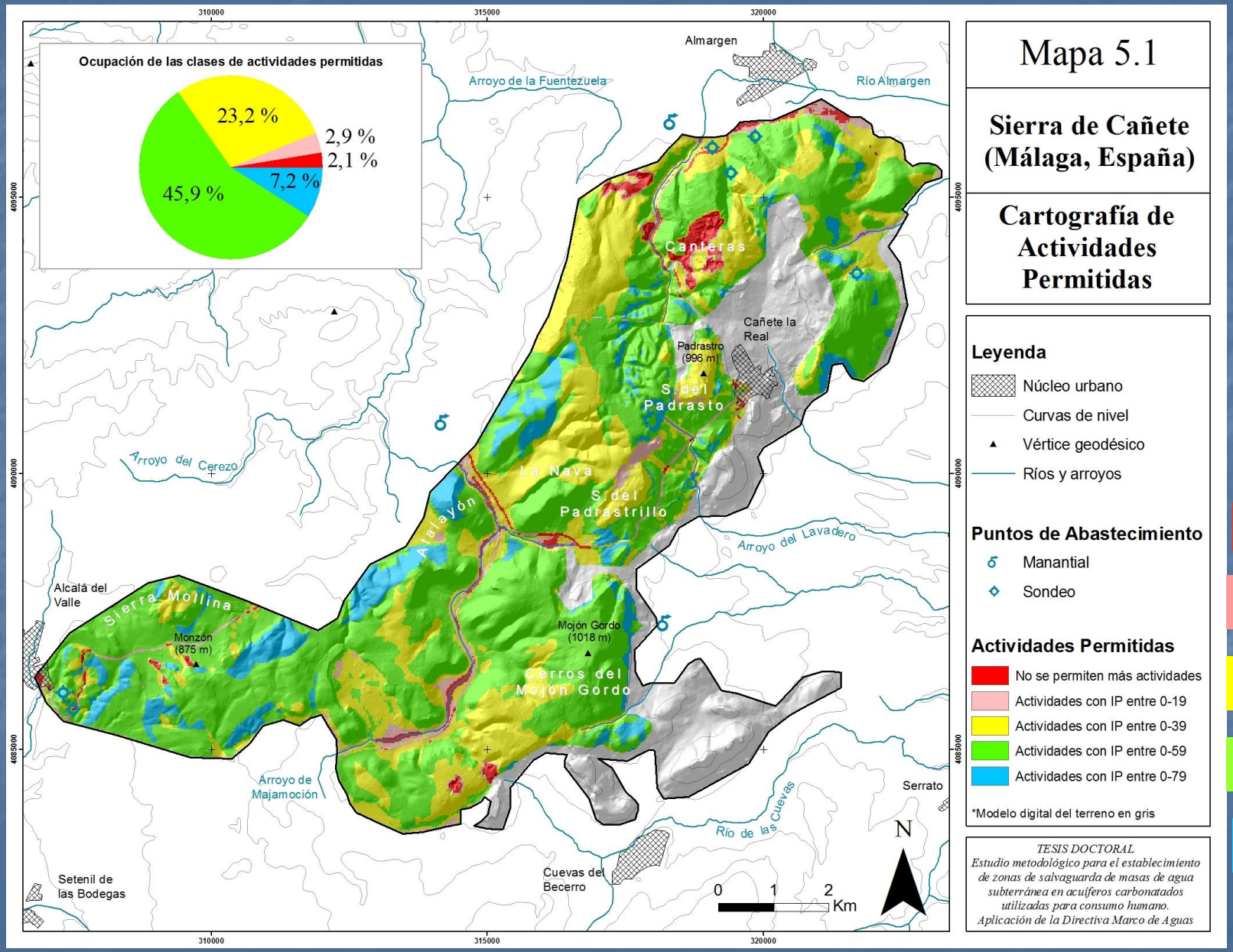
STEP 3



NEW permitted activities whose accumulated IP < 79 (CLASS 4)
Example: 70; OR 35 + 40

Pressures	Intensity of Pressures (IP)	Threshold	Surpassing Threshold (IP)
Urbanised areas with seawage system	35	> 500 inhabitants	49
Urbanised areas without seawage syst	70	> 300 inhabitants	98
Isolated houses without seawage syst	45	> 15 houses	63
Solid urban waste landfill	50	> 10.000 inhabitants	70
Traffic roads	40	> 2.500 vehicles/day	56
Intensive livestock	40	> 500 livestock	42

AUTHORISED ACTIVITIES CARTOGRAPHY



No activ

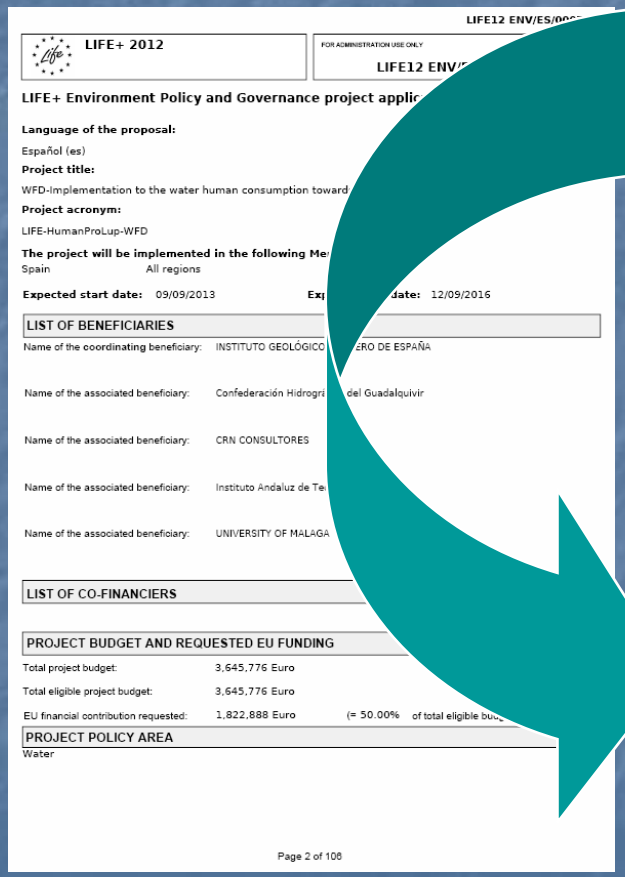
IP < 19

IP < 39

IP < 59

IP < 79

It is necessary to validate – in various media, with different pressures and socioeconomic cicumstances- this methodology that integrates the protection of groundwater in the planning process **considering the economic assessment of different management scenarios**



LIFE12 ENV/ES/00

LIFE+ 2012

FOR ADMINISTRATION USE ONLY

LIFE12 ENV/

LIFE+ Environment Policy and Governance project applic

Language of the proposal:

Español (es)

Project title:

WFD-Implementation to the water human consumption toward

Project acronym:

LIFE-HumanProLup-WFD

The project will be implemented in the following Me

Spain All regions

Expected start date: 09/09/2013 **Exp date:** 12/09/2016

LIST OF BENEFICIARIES

Name of the coordinating beneficiary: INSTITUTO GEOLÓGICO ERO DE ESPAÑA

Name of the associated beneficiary: Confederación Hidrogra del Guadalquivir

Name of the associated beneficiary: CRN CONSULTORES

Name of the associated beneficiary: Instituto Andaluz de Te

Name of the associated beneficiary: UNIVERSITY OF MALAGA

LIST OF CO-FINANCIERS

PROJECT BUDGET AND REQUESTED EU FUNDING

Total project budget: 3,645,776 Euro

Total eligible project budget: 3,645,776 Euro

EU financial contribution requested: 1,822,888 Euro (= 50.00% of total eligible bu

PROJECT POLICY AREA

Water

Page 2 of 106

28-09-2012 proposal

-**SELECTION CRITERIA**: Technical selection, AWARD, Admissibility, exclusion and eligible phase, and financial selection phase

-

PASSED

-**REVISION PHASE**: Questions for further clarifications (04-2013)

-

FAILED

Other proposals…

Thanks for your attention!

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