

**« Salsigne » : the restoration of a contaminated site taking sanitary, environmental and economic objectives into account**

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**NATO CCMS Pilot Study 'Mega-Sites'**

# Scope of the presentation

## ● Introduction

- ✚ Presentation of the site and the context
- ✚ Historical background
- ✚ Environmental context
- ✚ Conceptual model

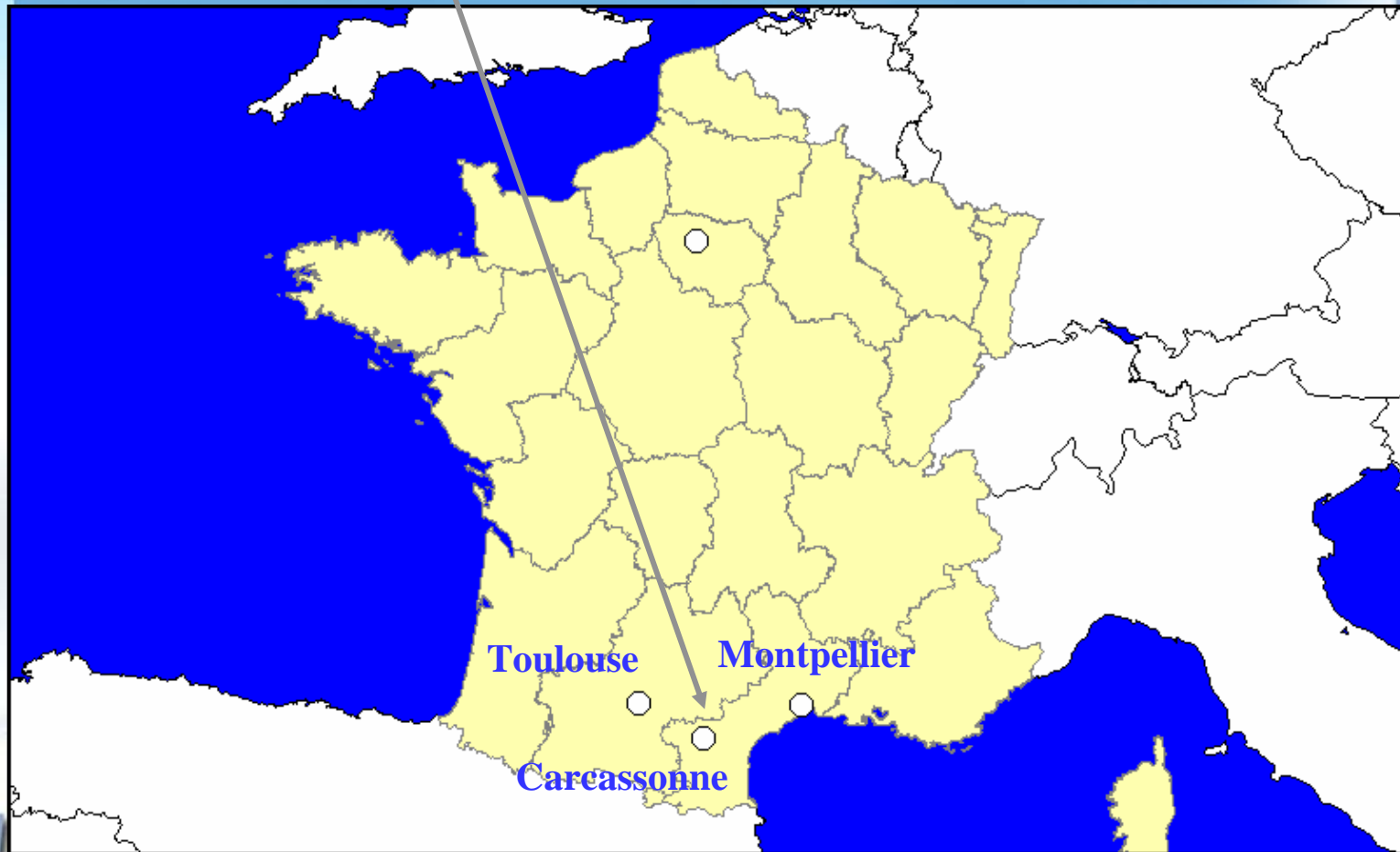
## ● Work done (1999 – 2004)

## ● Remediation project

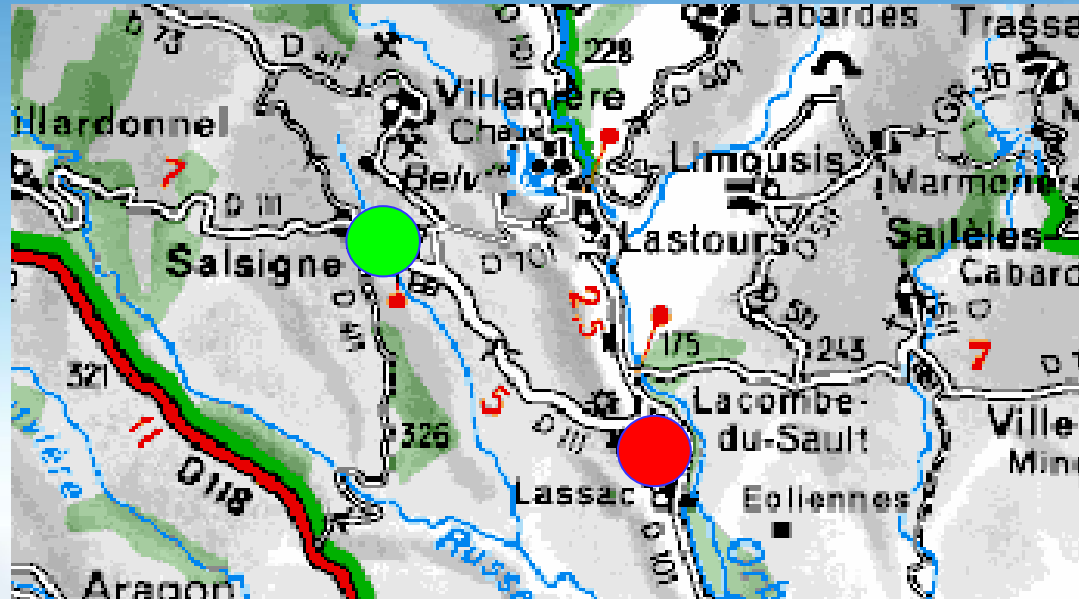
- ✚ Financial stakes ?
- ✚ Why Phytostabilisation and how ?

## ● Conclusion

# Salsigne – La Combe du Saut

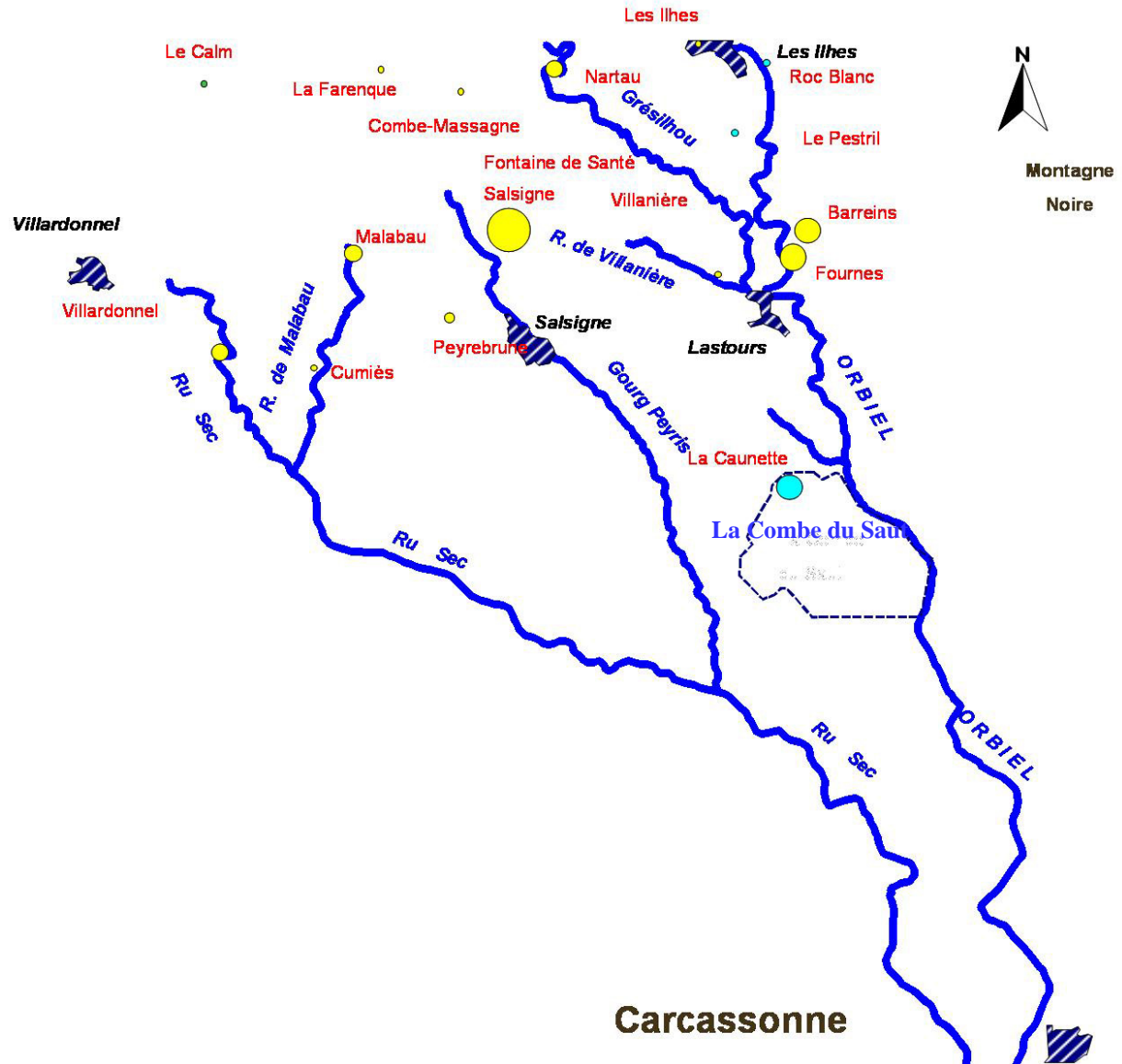


# La montagne Noire



Carcassonne

# Orbiel Valley : former mines



# Geology

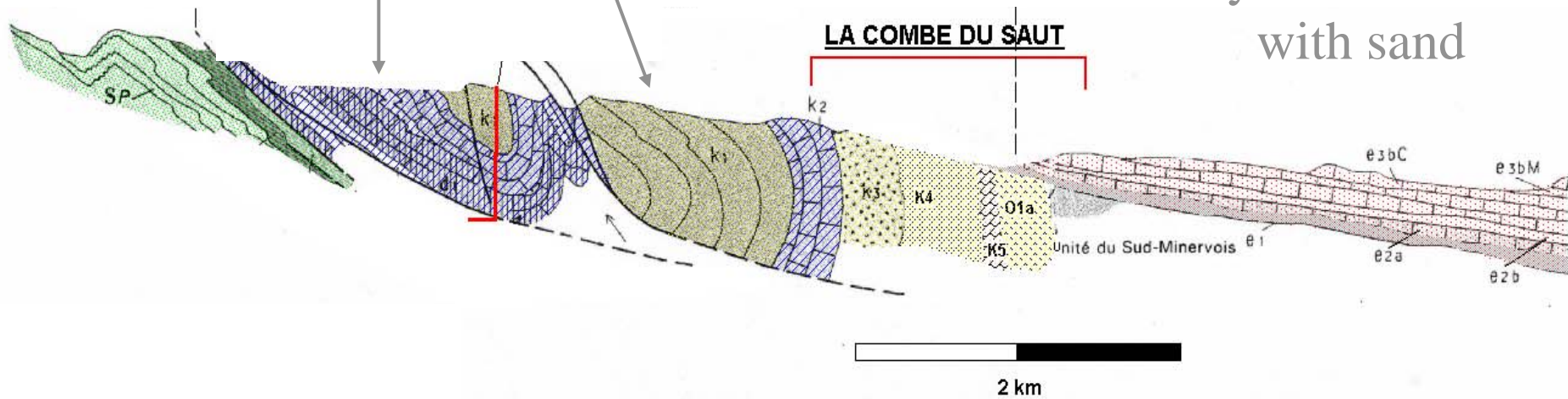
North

South

Limestone

Gres and shists

Clay and limestone  
with sand



# Production during XX<sup>th</sup> Century



- **Pyrometallurgy and cyanuration**
- **15 million tonnes of ore**
- **110 tonnes of gold**



Period	Arsenic trioxyde (tons/year)
From 1924 to 1927	150 to 900
From 1928 to 1938	3000 to 6000
From 1939 to 1954	1000 to 10 000
From 1955 to 1960	6000 to 7000
From 1961 to 1992	10 000 (in 1990)
<b>TOTAL</b>	<b>200 000</b>



# Mission of ADEME

**1998 : 30 million of euros**

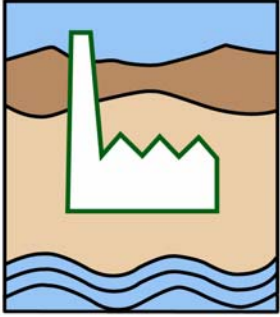
- **June 1999 :**      **Monitoring  
Waste management  
Demolition  
Studies**
  
- **March 2004 :**      **Remediation project  
Monitoring plan**



# Difpolmine demonstration project

- Life Environment 2002
- Water management and phytostabilisation
- [www.ademe.fr/difpolmine](http://www.ademe.fr/difpolmine)

DIFPOLMINE



Diffuse Pollution  
from Mining Activities



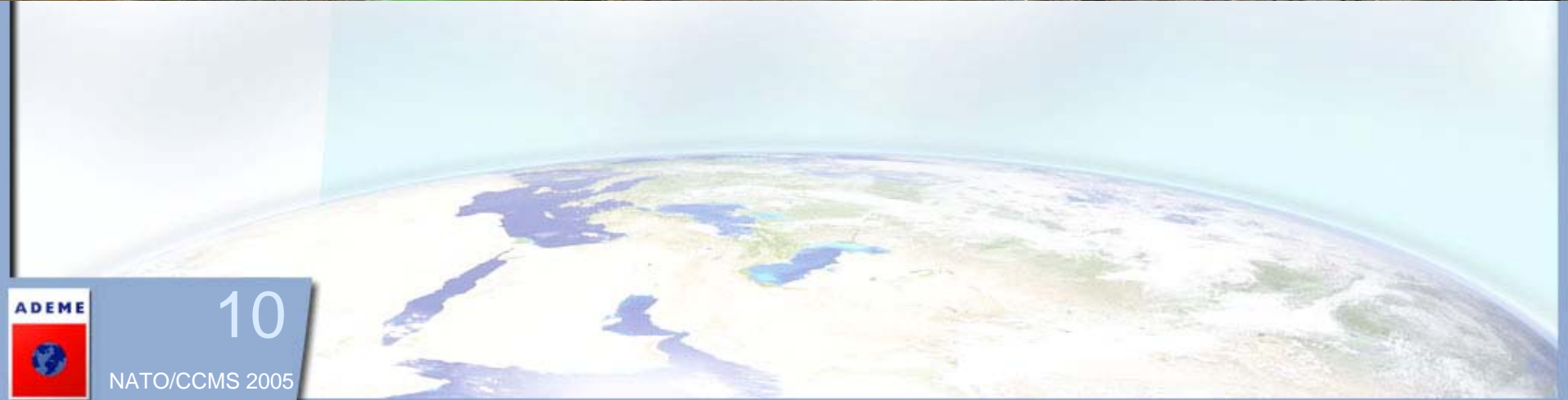
- + IRH Environment
- + Limburg University
- + Budapest University
- + Water Agency RMC



# Salsigne – La Combe du Saut

## 1999

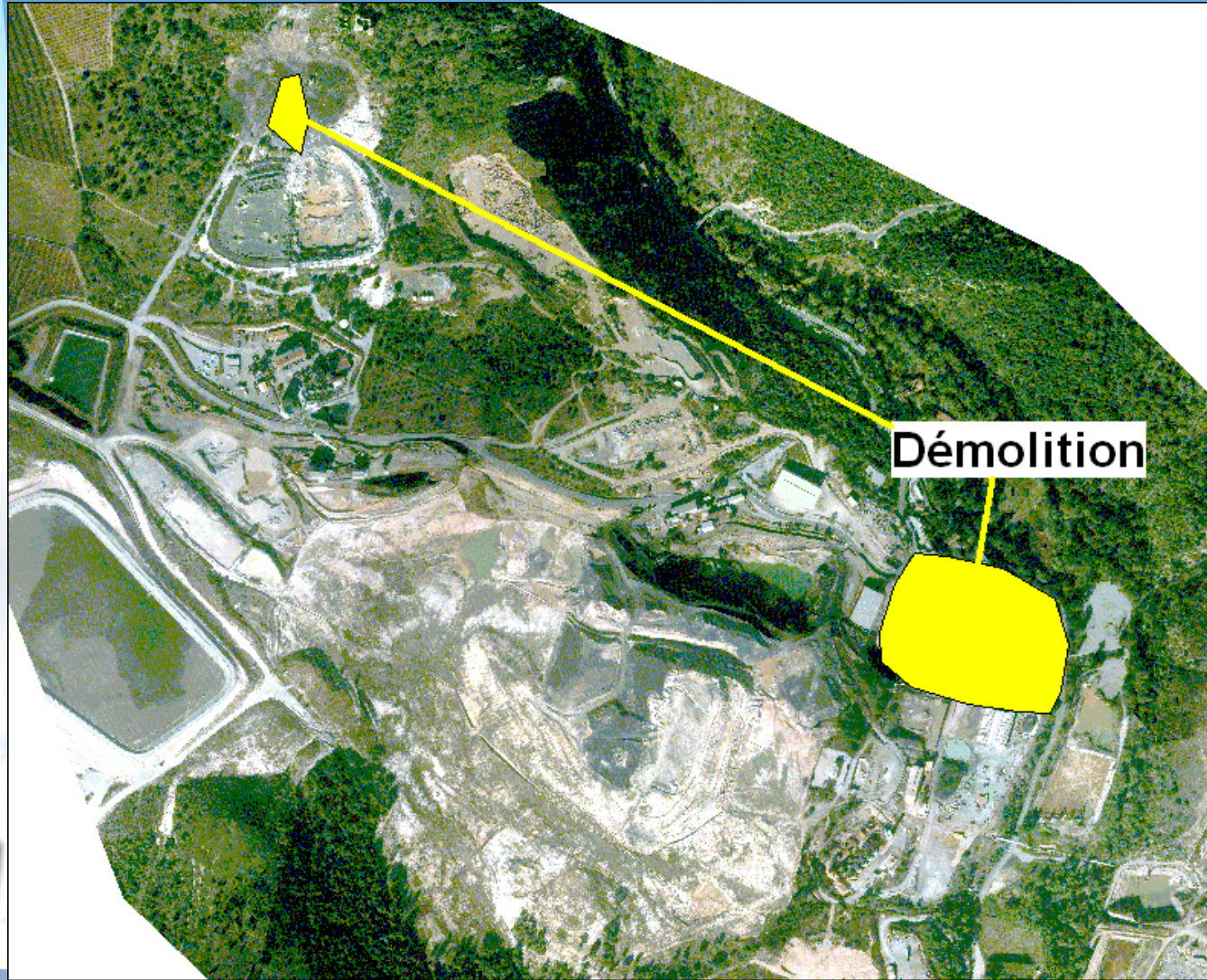
01/09/01



# Waste management



# Demolition



# Demolition



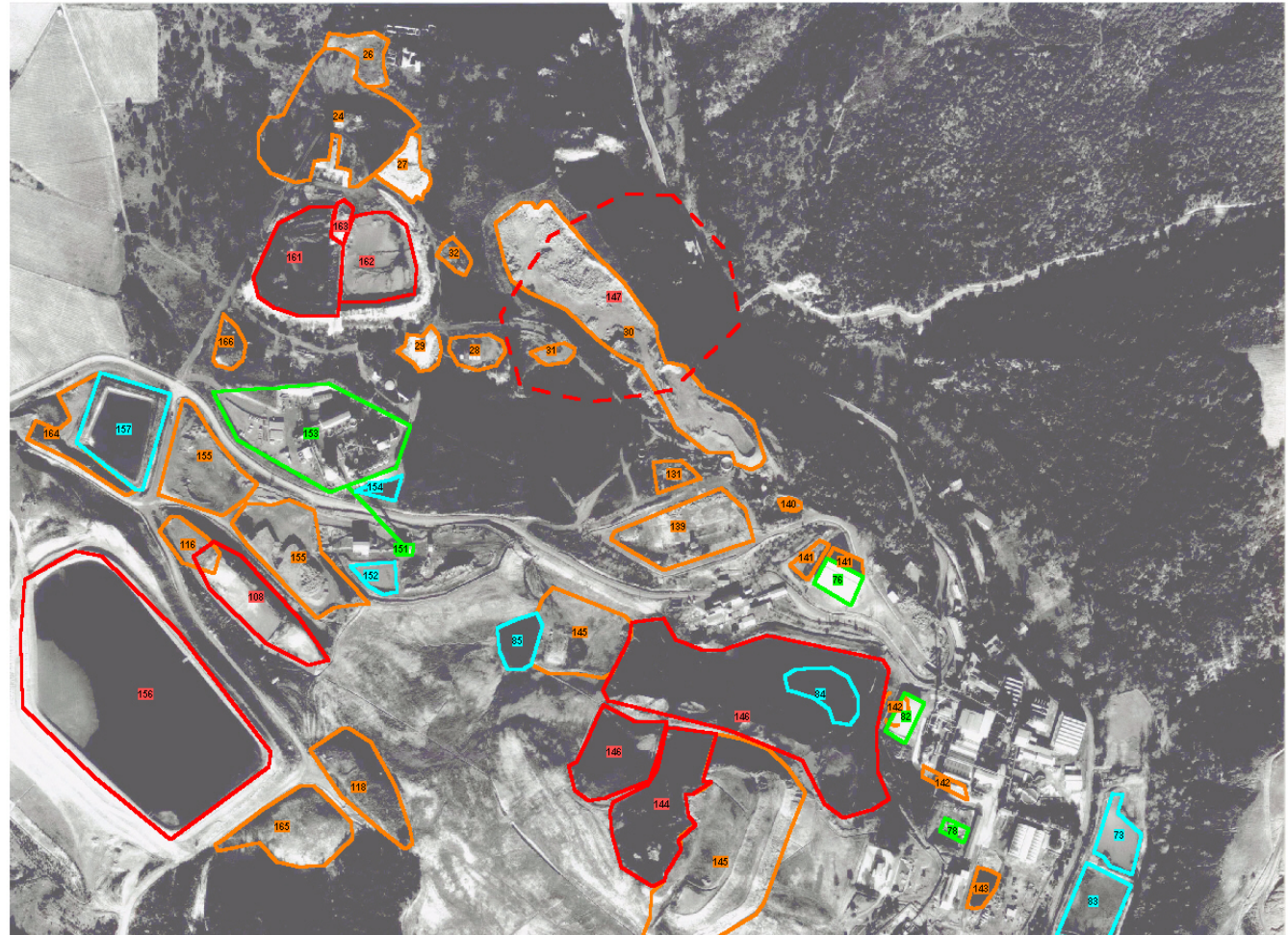
# Watertight area



# Watertight area

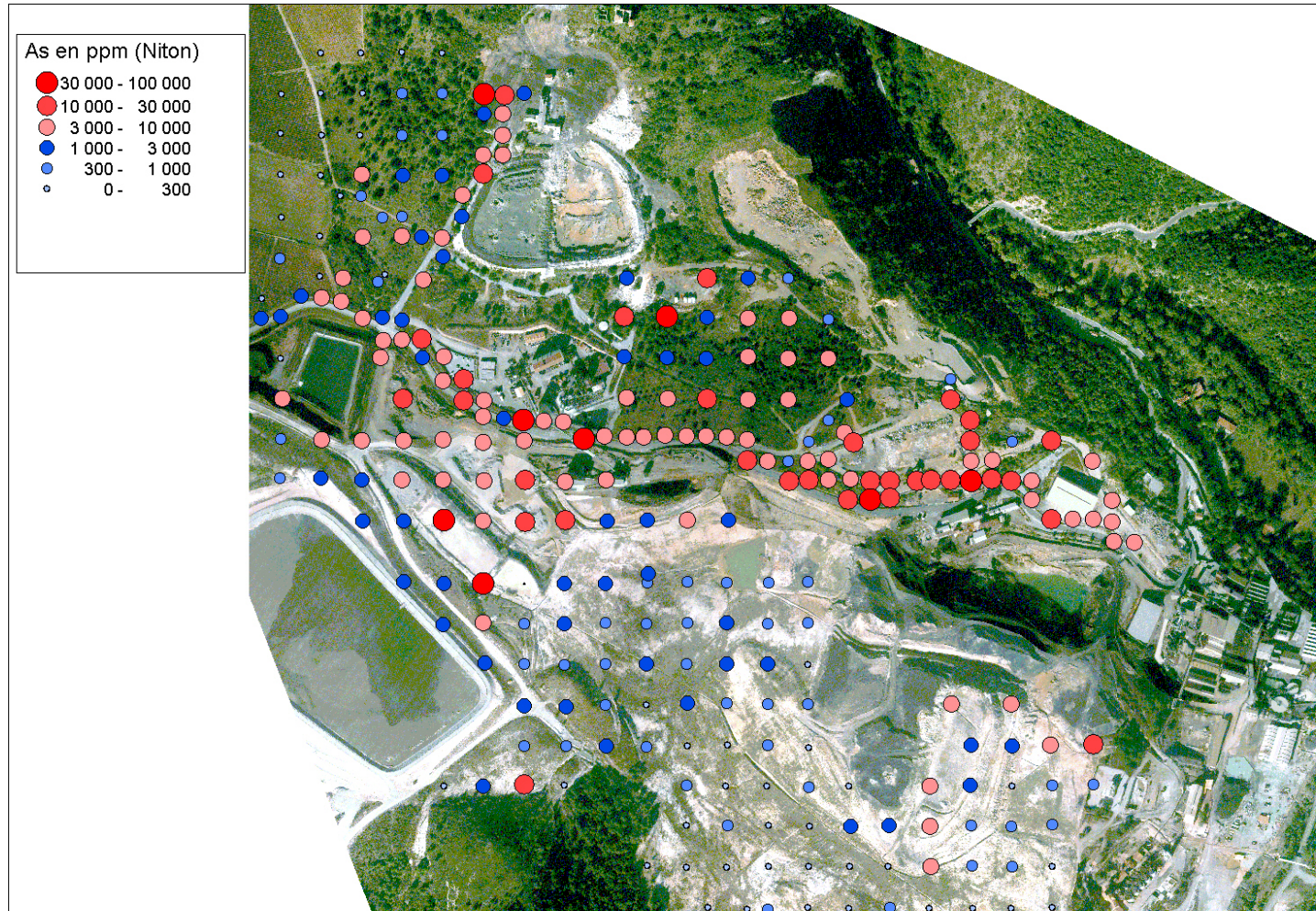


# Source characterisation





# Arsenic soil concentration



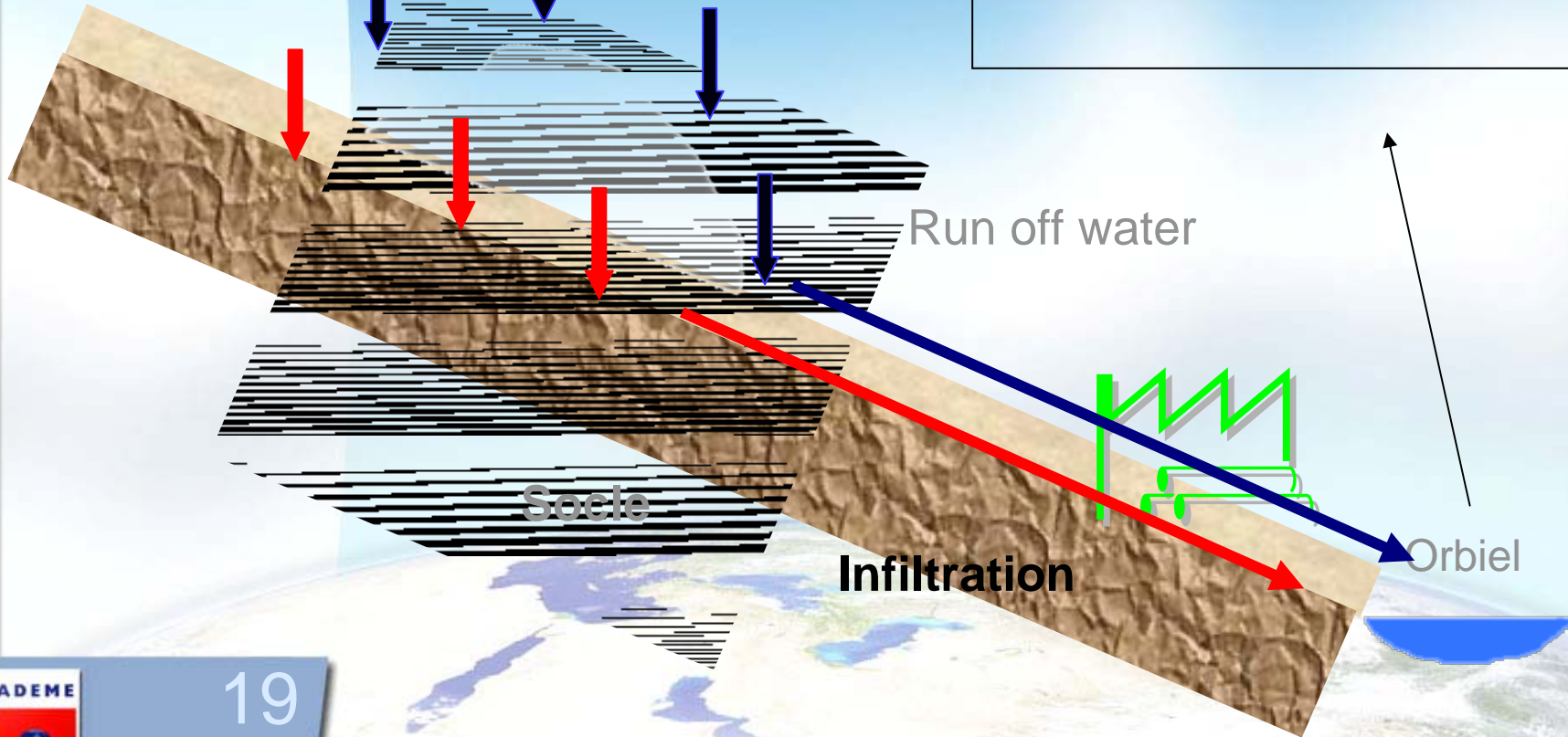
# Sources

- 2,4 million m<sup>3</sup> of waste and polluted soil
- 53 hectares

# Conceptual model



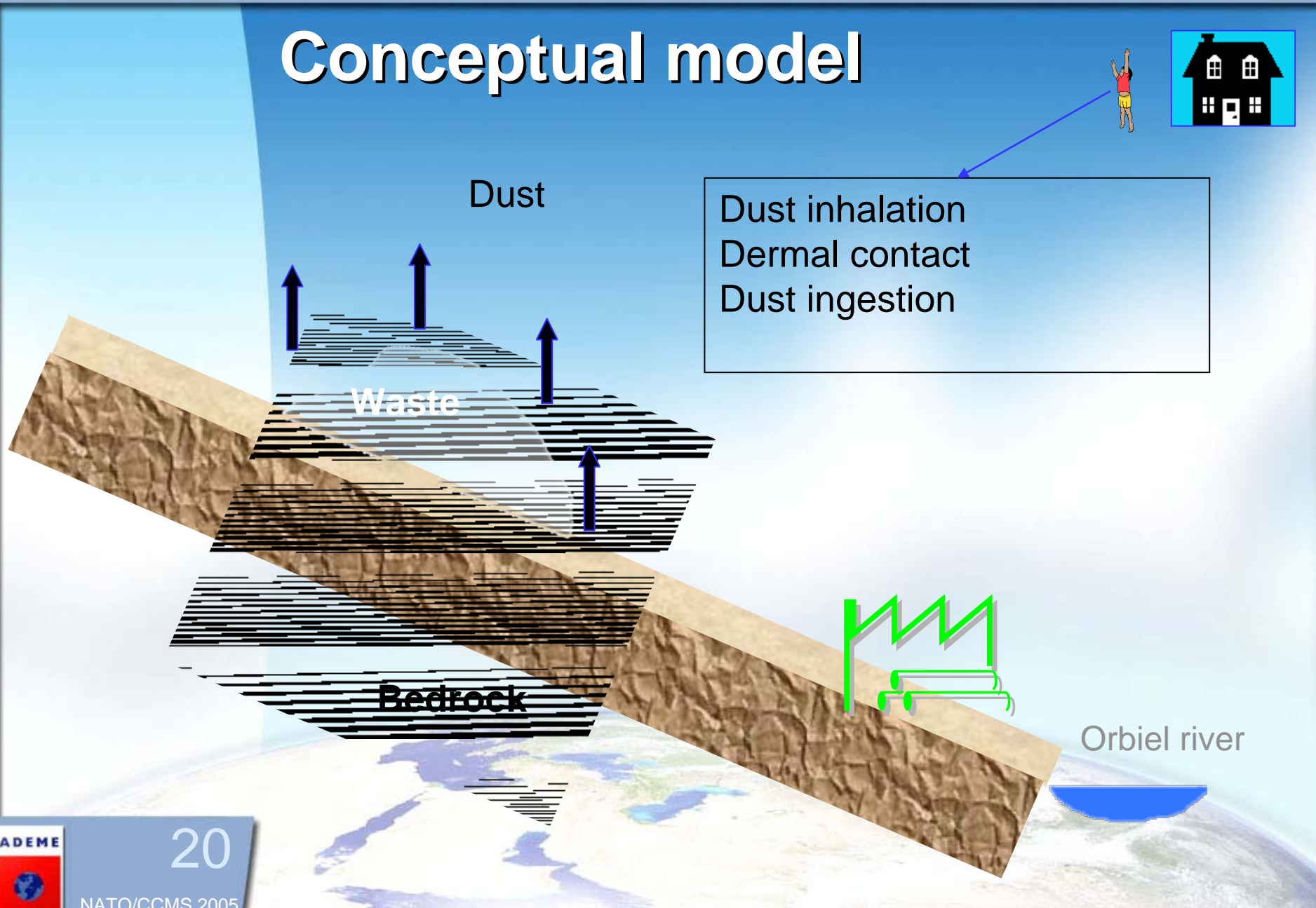
Water ingestion  
Fish ingestion  
Fruit and vegetable ingestion



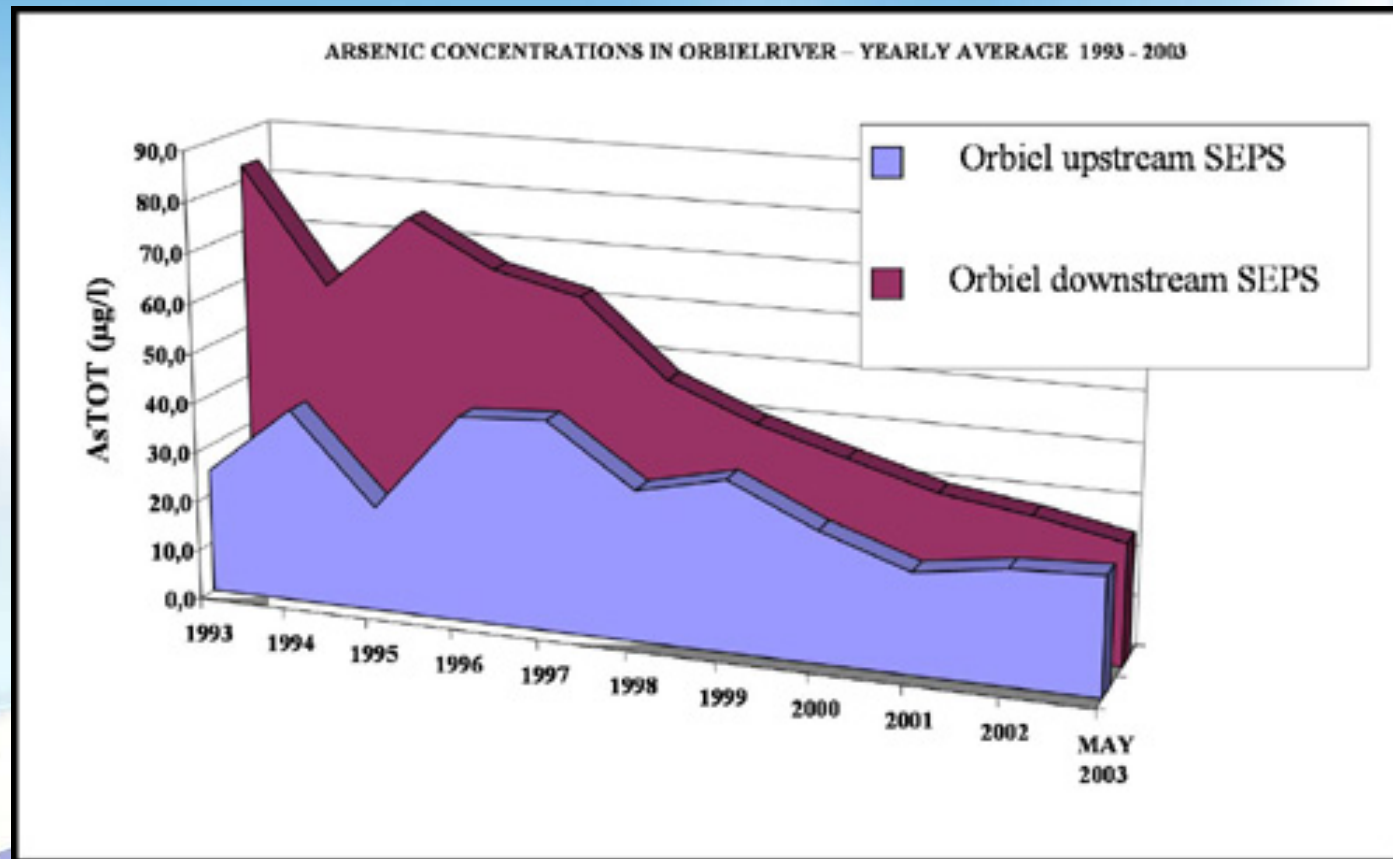
# Conceptual model



Dust inhalation  
Dermal contact  
Dust ingestion



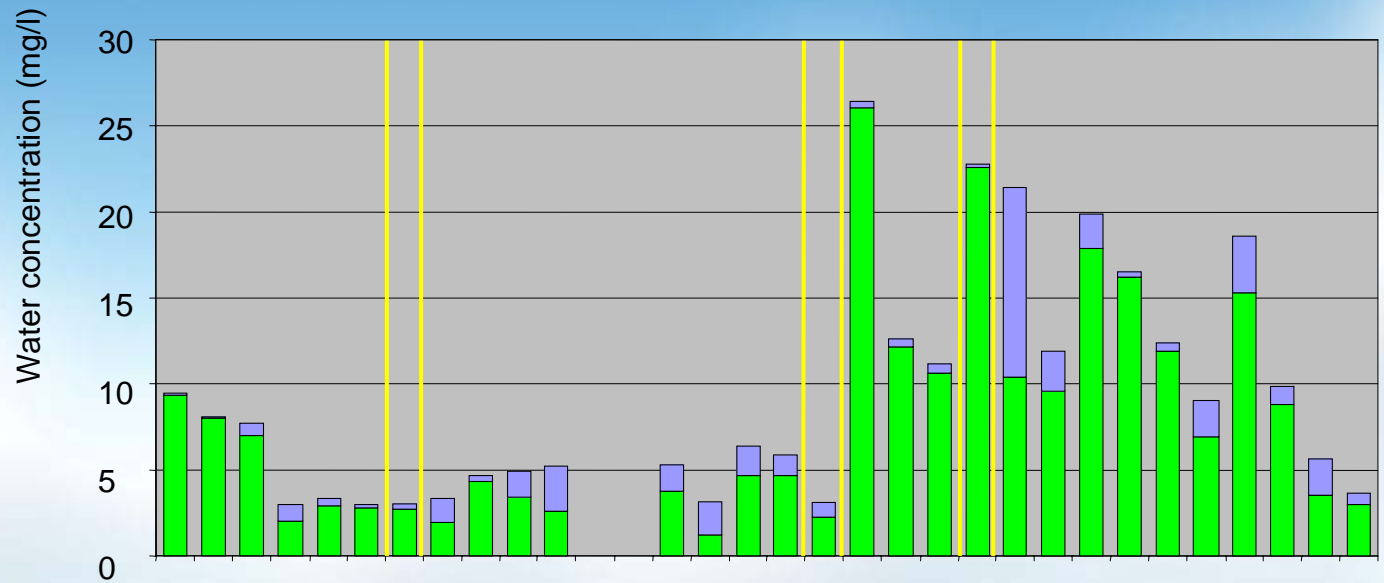
# Yearly average As concentration in the river Orbiel



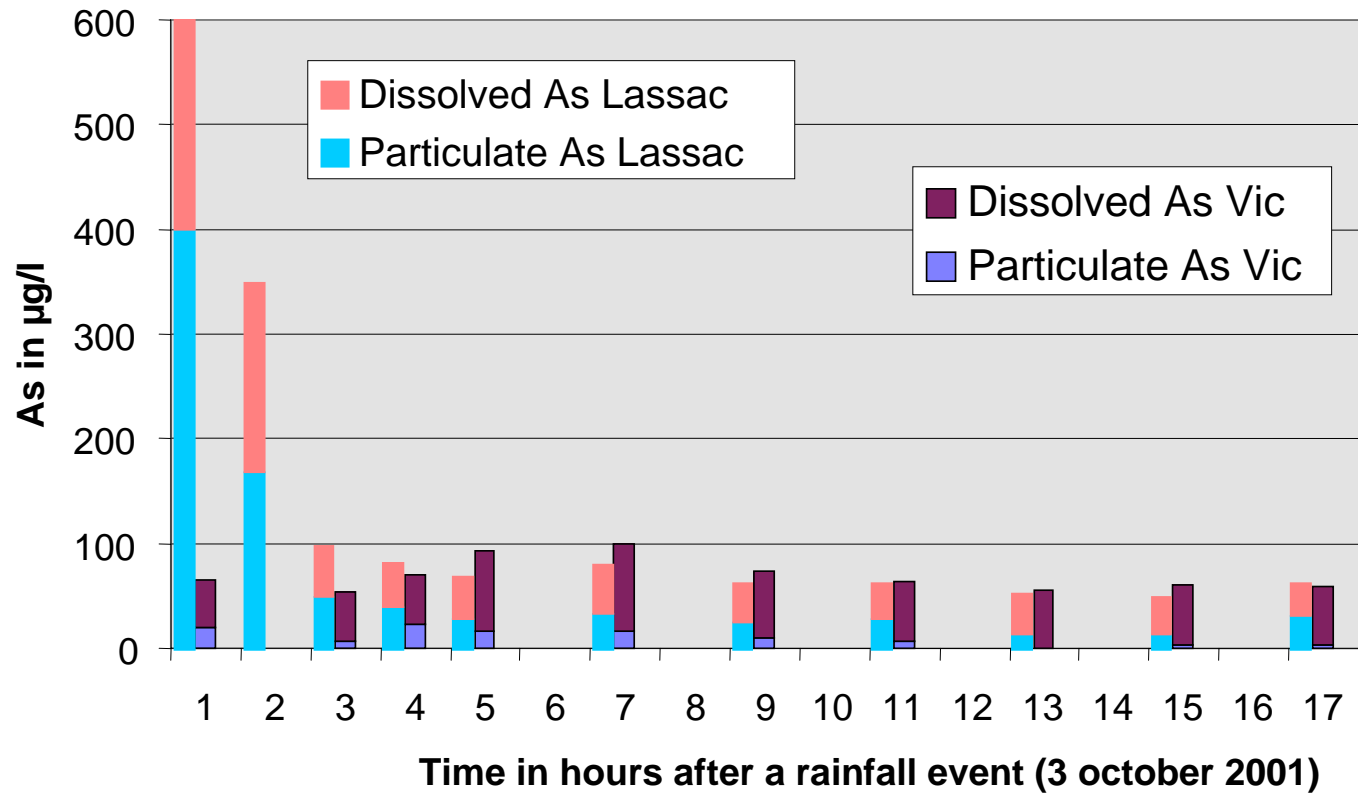
# Run off water

From 03/04/02 to 31/08/02

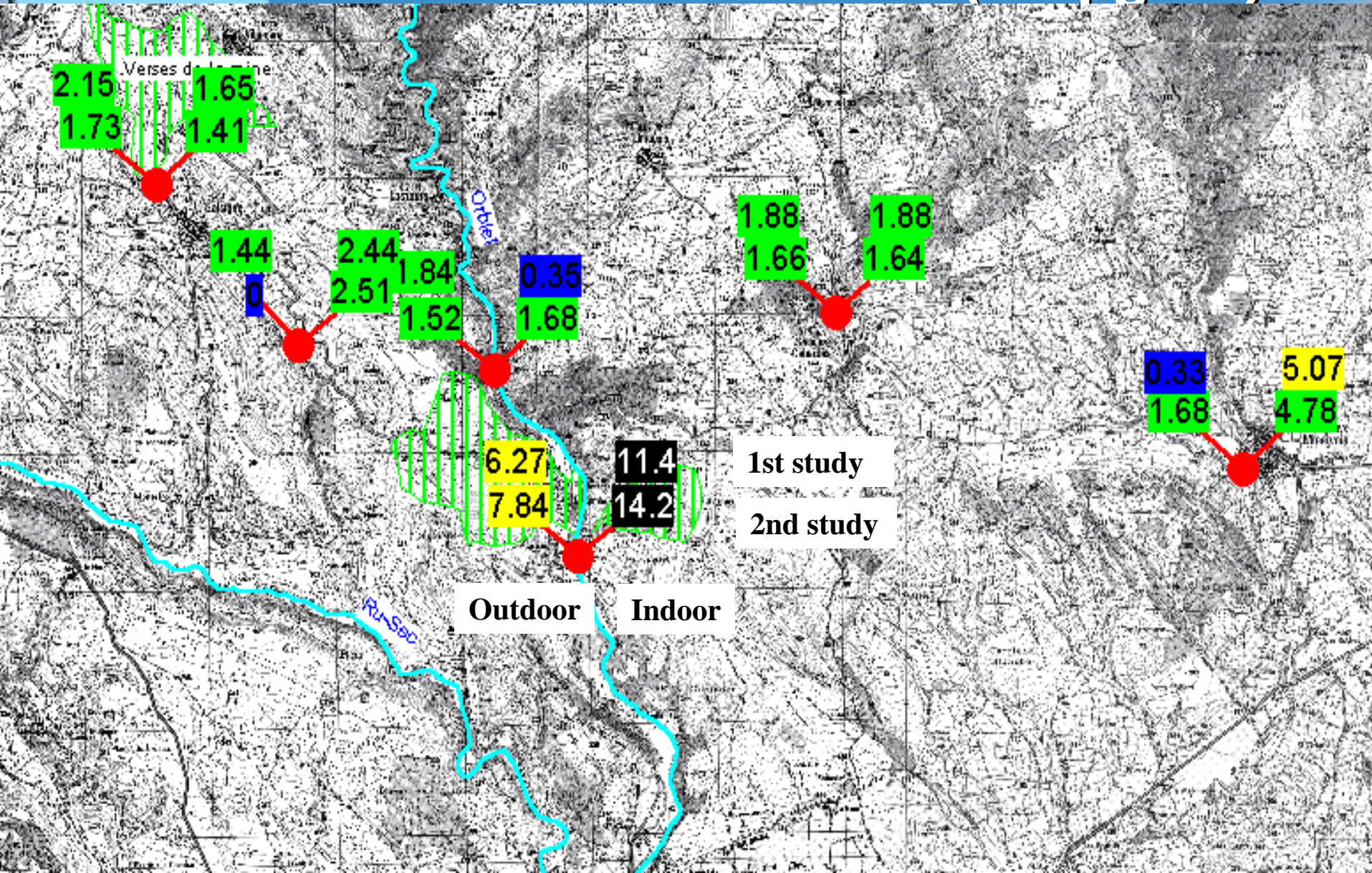
■ As particulate    ■ As dissolved



# Pollution peak in the river



# Dust contamination 2001 (As $\mu\text{g}/\text{m}^3$ )





# Risk assessment

## Carcinogenic effects

	Oral route			Breathing route		
Risk	Resident	Farmer	Fisherman	Resident	Farmer	Fisherman
Adult	1,7.10 <sup>-3</sup>	2,4.10 <sup>-3</sup>	2,1.10 <sup>-3</sup>	2,5.10 <sup>-3</sup>	3,6.10 <sup>-3</sup>	3,3.10 <sup>-3</sup>
Children	3,3.10 <sup>-3</sup>	3,4.10 <sup>-3</sup>	3,6.10 <sup>-3</sup>	1,9.10 <sup>-3</sup>	1,9.10 <sup>-3</sup>	1,9.10 <sup>-3</sup>

## Noncarcinogenic effects

	Breathing route : toxic total			Breathing route : nervous system		
Hazard index	Resident	Farmer	Fisherman	Resident	Farmer	Fisherman
Adult	1,74	2,25	2,14	5,28	6,74	6,42
Children	2,17	2,17	2,17	6,55	6,55	6,55

# Salsigne – La Combe du Saut

**1999 / 2005**

01/09/01



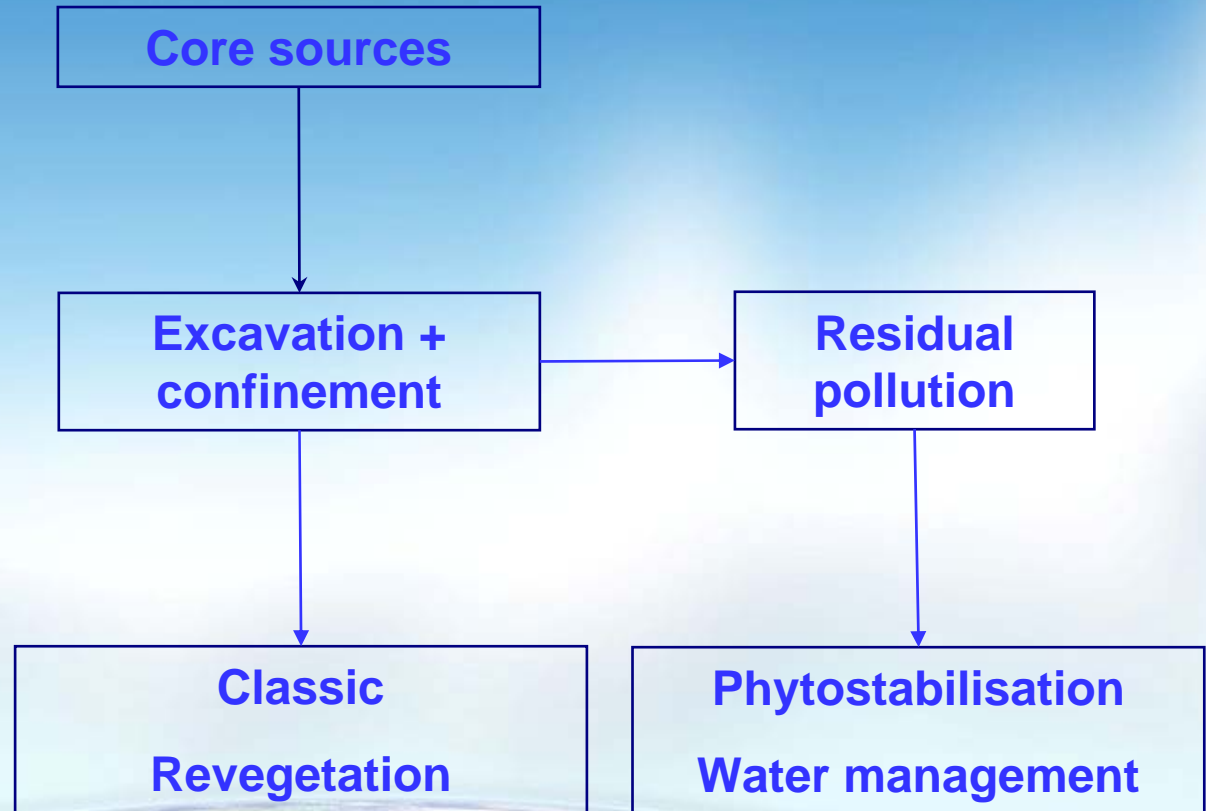
## Total cost : work done between 1999 and 2004 (millions of euros)

<b>Operation</b>	<b>Cost</b>
Monitoring and water treatment :	3.5
Waste management :	3.0
Demolition :	3.5
Watertight area :	1.0
Studies and prime constructor :	1.5
<b>Total Cost :</b>	<b>12.5</b>

## Evaluation of total cost / quantity of polluted soil with conventional techniques (Million of euros)

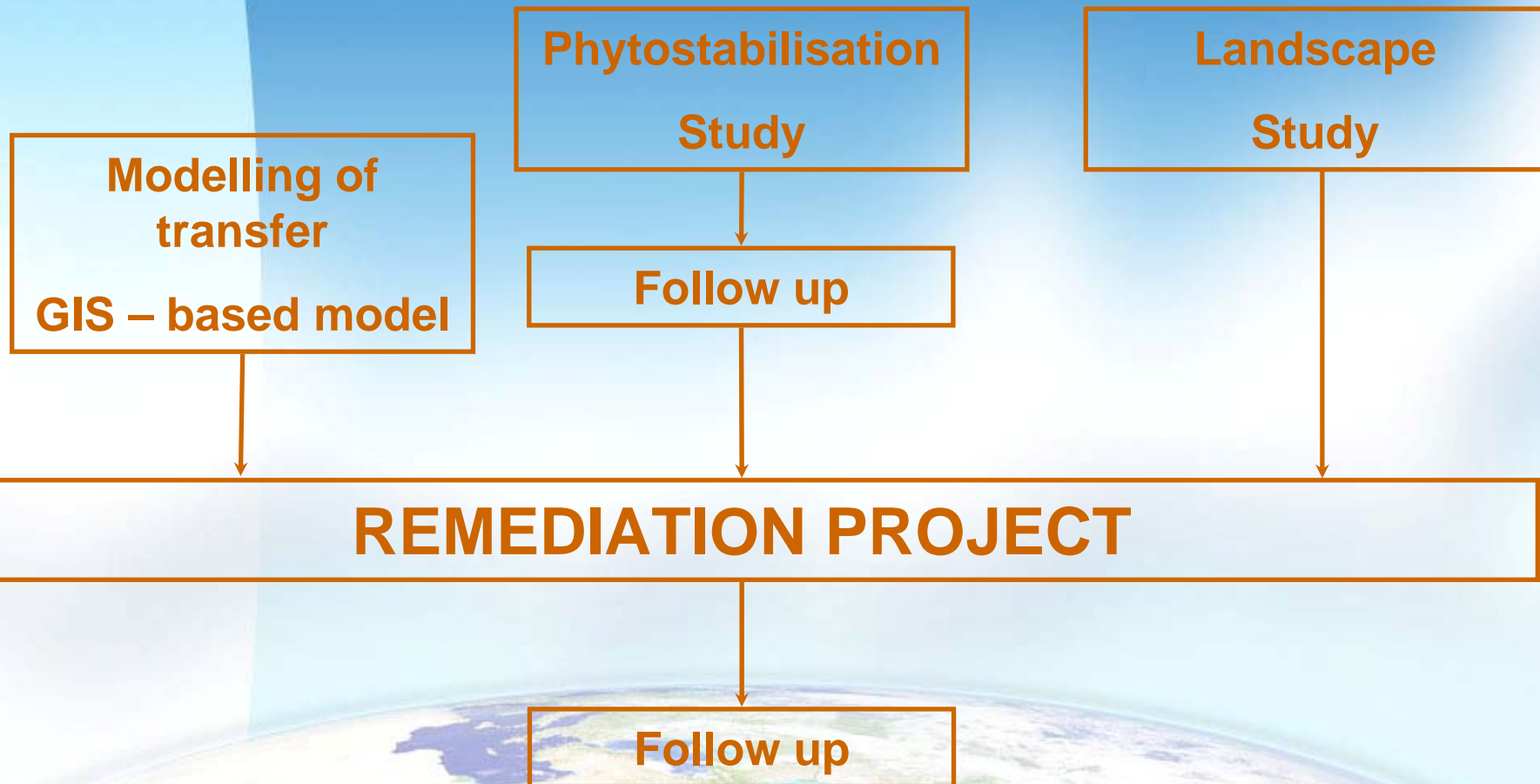
Type of treatment	euro/m <sup>3</sup>	500 000 m <sup>3</sup>
Excavation	3	1,5
Confinement Min	15	7,5
Confinement Max	30	15
Stabilisation	300	150
Landfilling (stabilisation)	500	250

# Remediation project

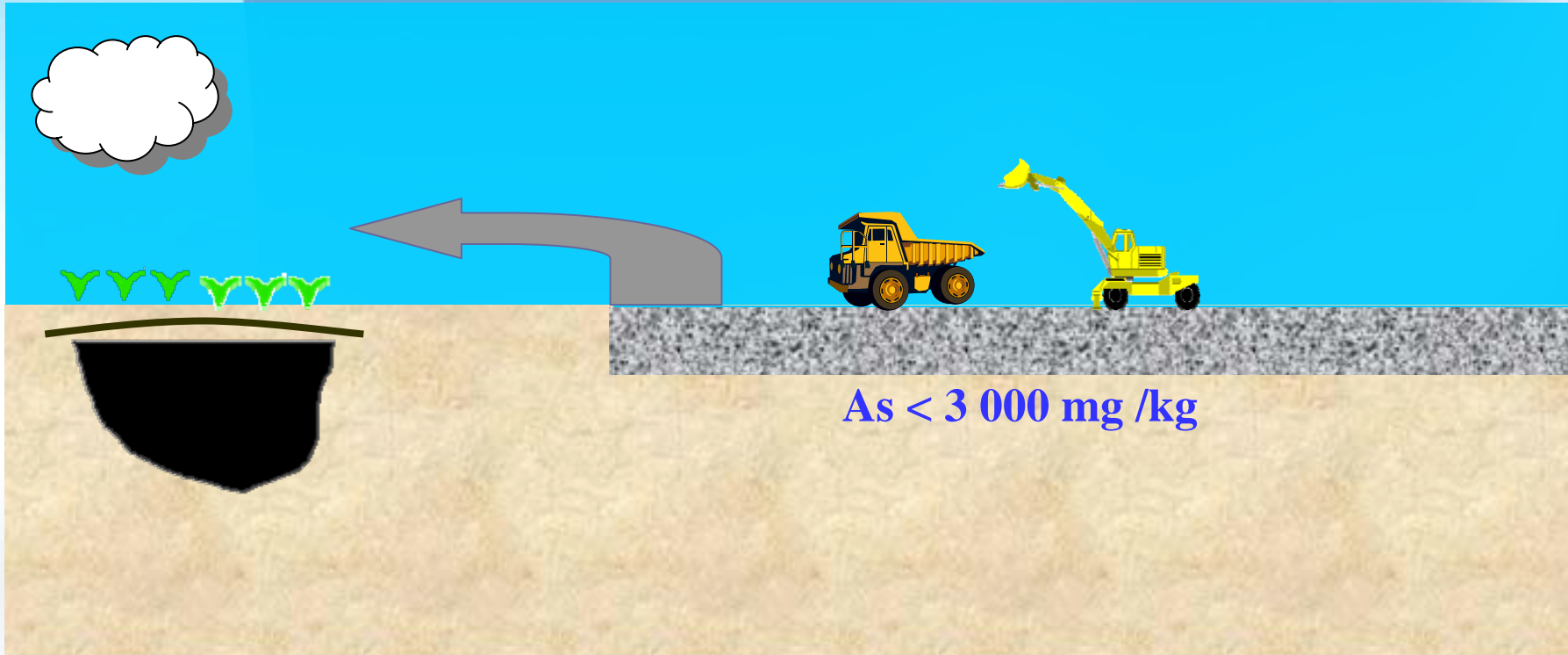


# Comparison between confinement and phytostabilisation

	Confinement		Phytostabilisation	
	Efficiency	Limiting factors	Efficiency	Limiting factors
Contact with the soil	+++	Soil use restriction Long-term monitoring	-	Soil use restriction Long-term monitoring
Dust emission	++		- /+	
Water concentration	++		- /+	
Cost / m <sup>2</sup> / 20 cm depth	- /+ (6 euros)		+++ (2 euros)	



# 1. Excavation





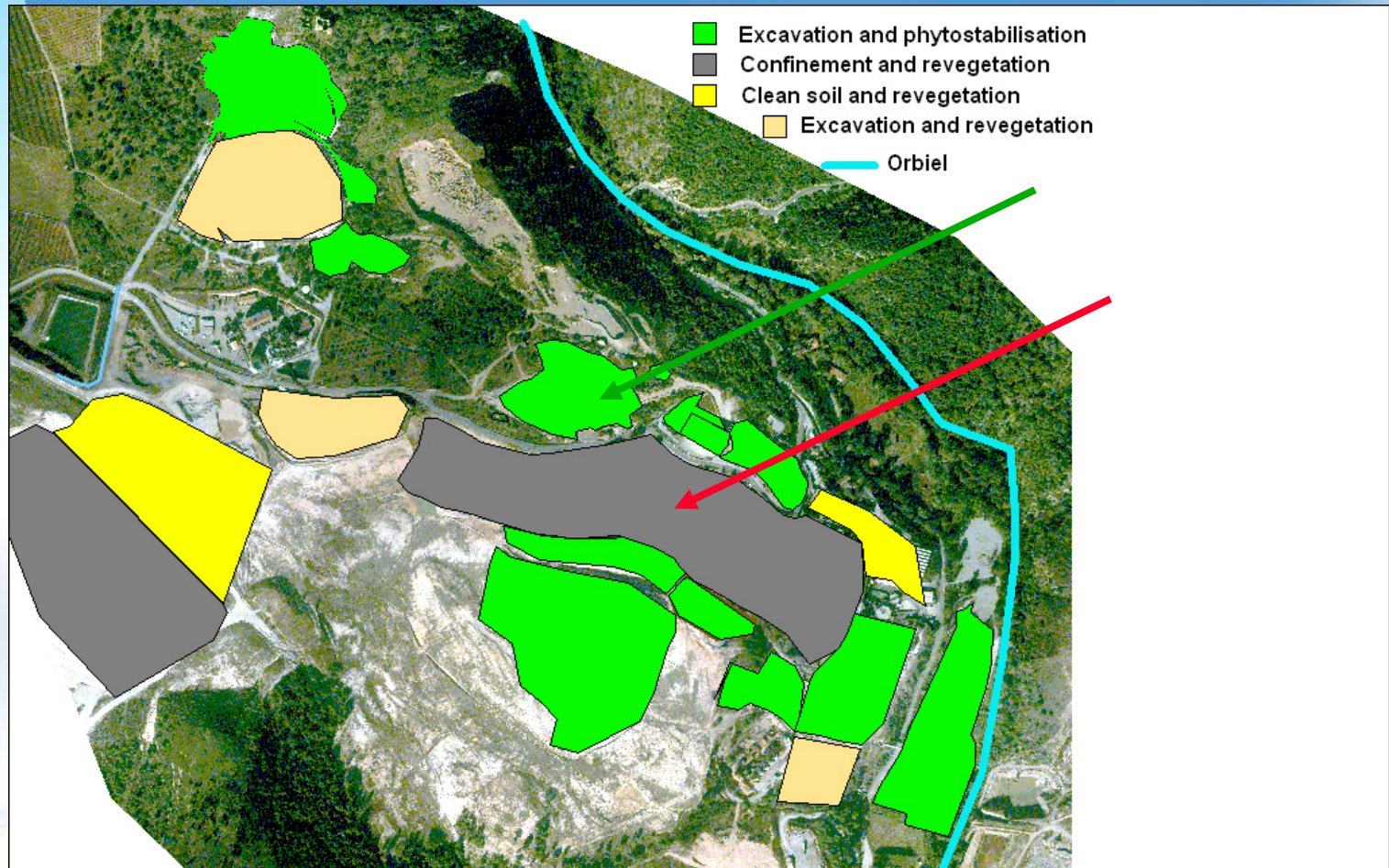
# Confinement area



## 2. Phytostabilisation



# Remediation programme

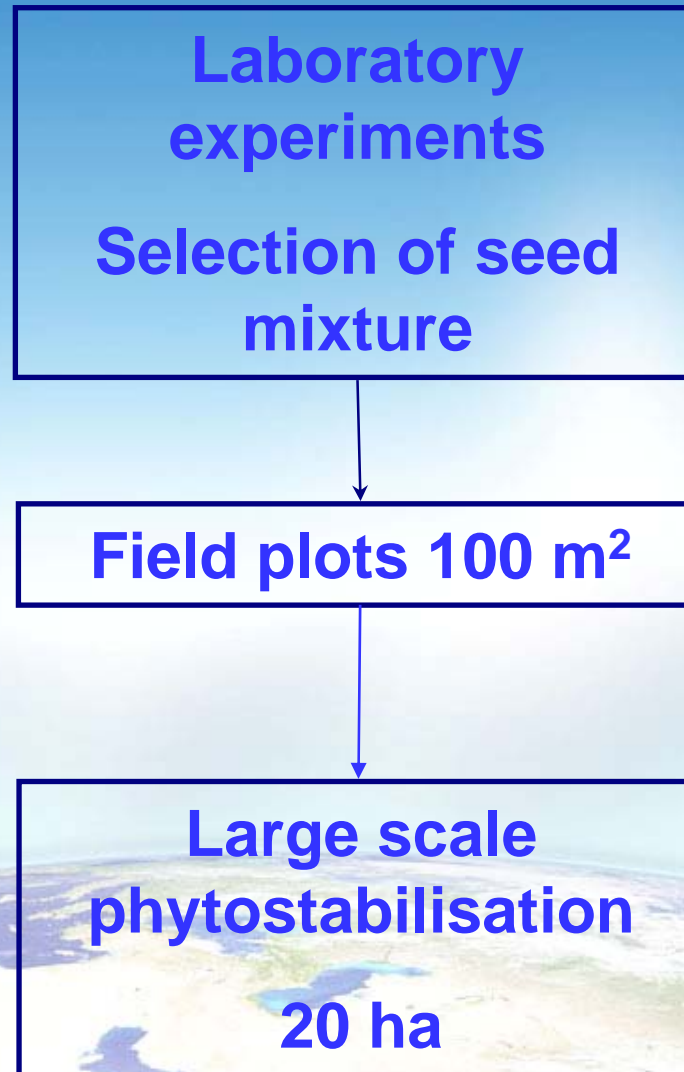


# Remediation programme (million of euros)

<b>Operation</b>	<b>Cost</b>
Excavation and transportation of waste and soil into the confinement area	2,5
Stabilisation of waste	1
Protection with a geomembrane (110 000 m <sup>2</sup> )	4
Water management systems	1,5
Phytostabilisation	0,5
Prime constructor	1
Monitoring and water treatment	1
Other	1
<b>TOTAL</b>	<b>12,5</b>

	2005			2006			
	TR2	TR3	TR4	TR1	TR2	TR3	TR4
Excavation	■	■					
Call for tender (Phase 2)	■	■					
Capping			■	■	■		
Phytostabilisation					■	■	

# Phytostabilisation (Difpolmine)



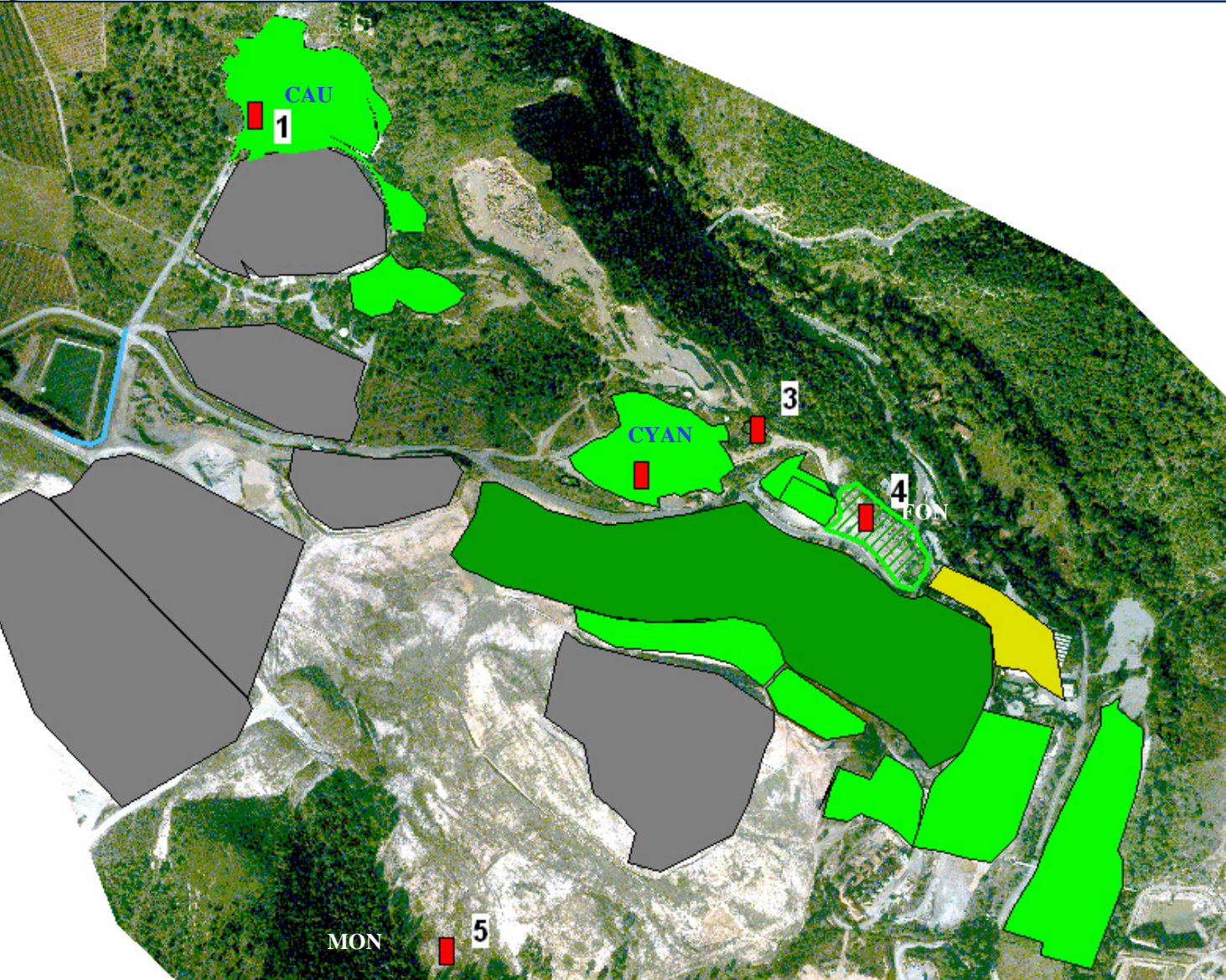
# Laboratory experiments

Location	Steel shots addition	Water soluble As (mg/kg DM)	% reduction
Control		<0.25	
Caunette	no	584 ± 112	
	yes	360 ± 44	39%
Cyanuration	no	1.6 ± 0.1	
	yes	0.29 ± 0.07	82%
Cyanuration2	no	7.1 ± 0.3	
	yes	4.5 ± 0.4	36%
Fonde	no	17.6 ± 0.4	
	yes	3.6 ± 0.6	79%
Monitoring	no	8.3 ± 0.2	
	yes	0.4 ± 0.1	95%

# Laboratory experiments

	Subplot 4.1 (untreated)	Subplot 4.2 (steel shots+seed mixture)
Total As ( <i>aqua regia</i> ) (mg kg DW <sup>-1</sup> )	<b>815</b>	
Water Soluble As (mg kg DW <sup>-1</sup> )	<b>17.6 ± 0.4</b>	<b>3.6 ± 0.6</b>
Biomass aerial parts bean plants (g/plant) (control value=1.18 ±0.24)	<b>0.76 ±0.16</b>	<b>1.13 ±0.35</b>
Root weight bean plants (g/plant) (control value=1.03 ±0.20)	<b>0.3 ±0.1</b>	<b>0.93 ±0.43</b>
GPOD capacity in leaves (mU g FW <sup>-1</sup> ) (control value=708 ±39)	<b>1084 ±334</b>	<b>803 ±244</b>
GPOD capacity in roots (mU g FW <sup>-1</sup> ) (control value=4050 ±728)	<b>8195 ±1714</b>	<b>4644 ±841</b>

# Location of the field plots





# Phytostabilisation field plots



# Water monitoring system

Balancing  
device

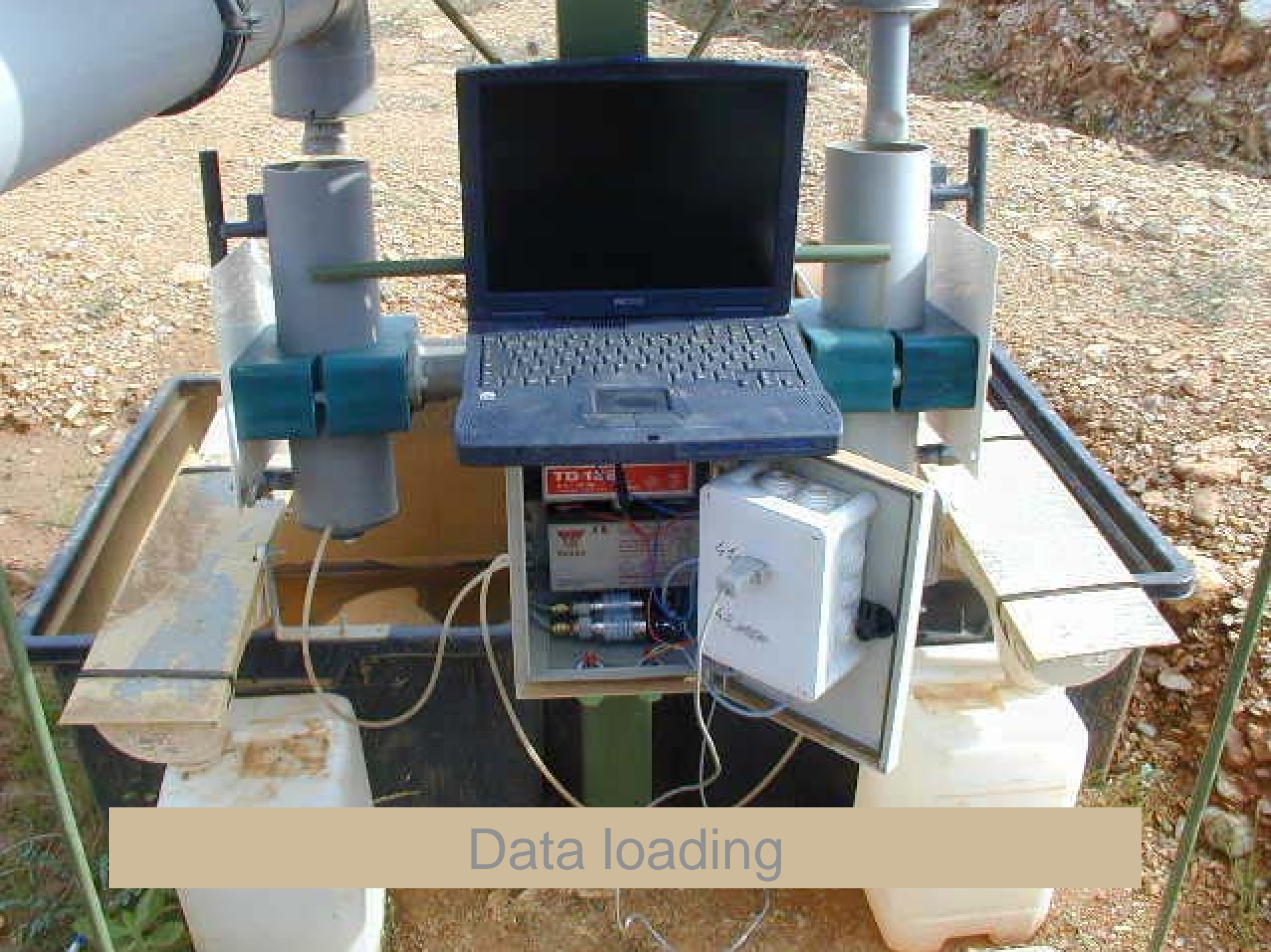
Water arrival

Lateral  
sampling tube

Guidance of  
water to bottle

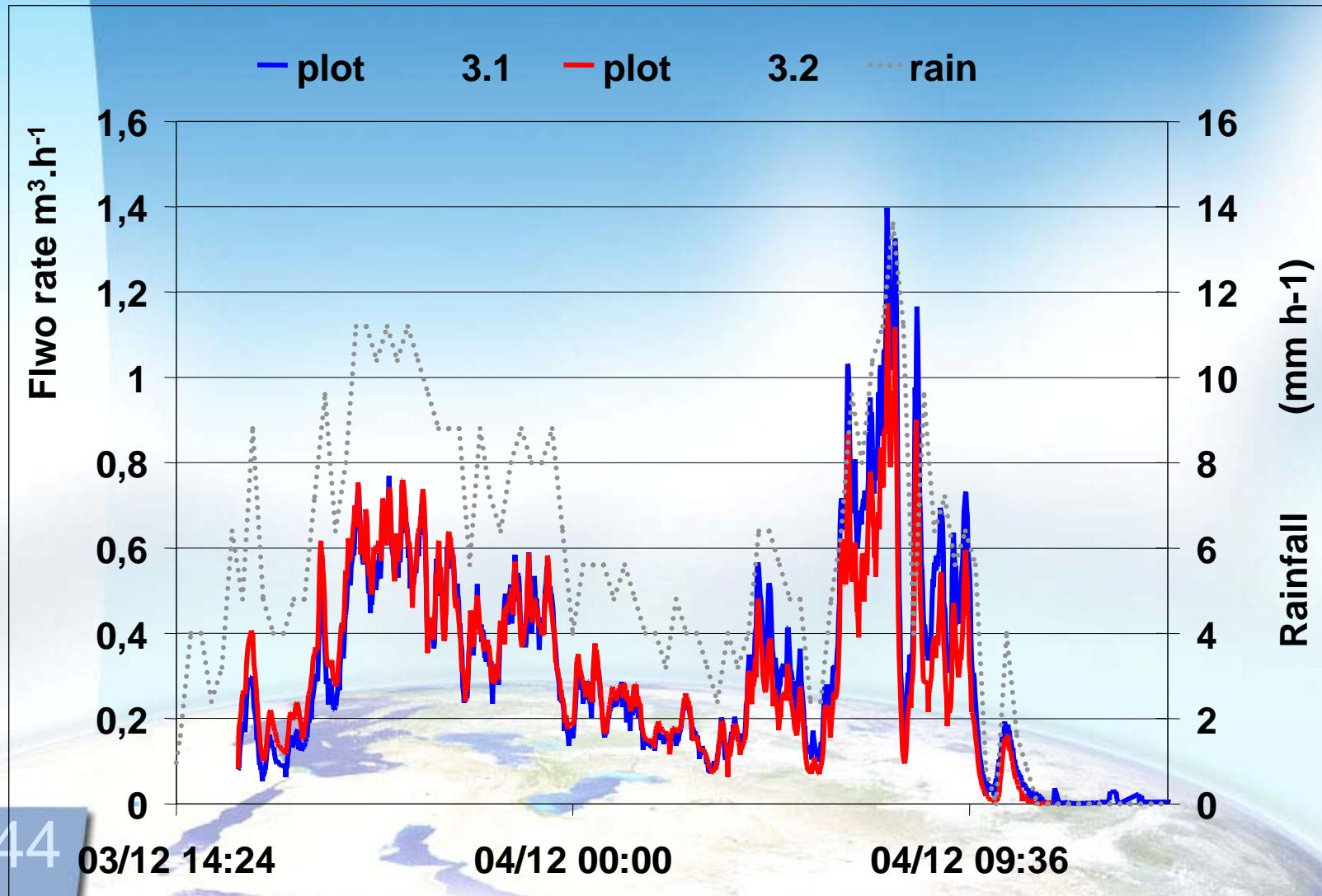
Sediment  
collector



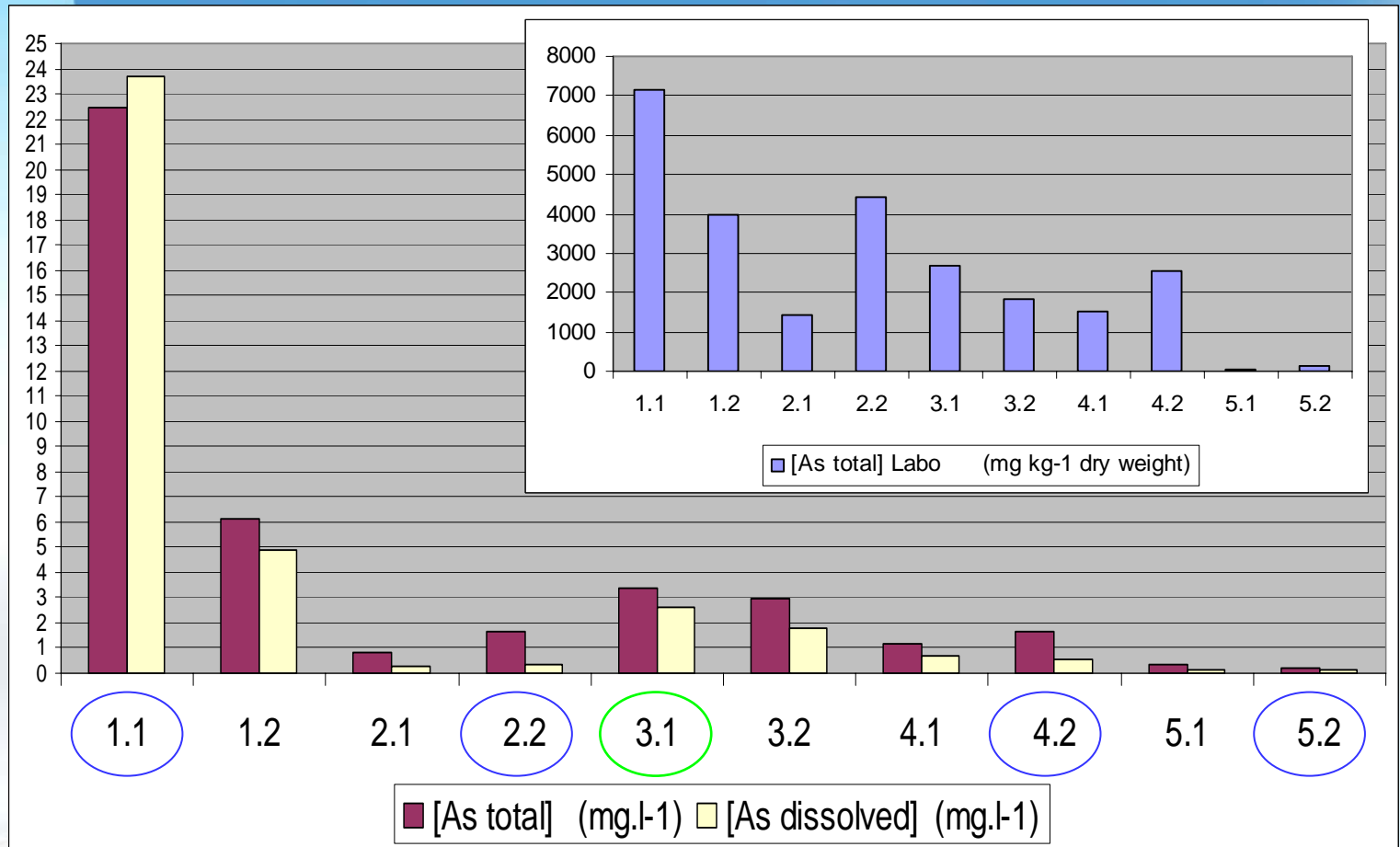


Data loading

# Follow up of the waterflow



# Follow up of As concentration in water



1.1 Steel shots + seed mixture     
 3.1 Seed mixture only

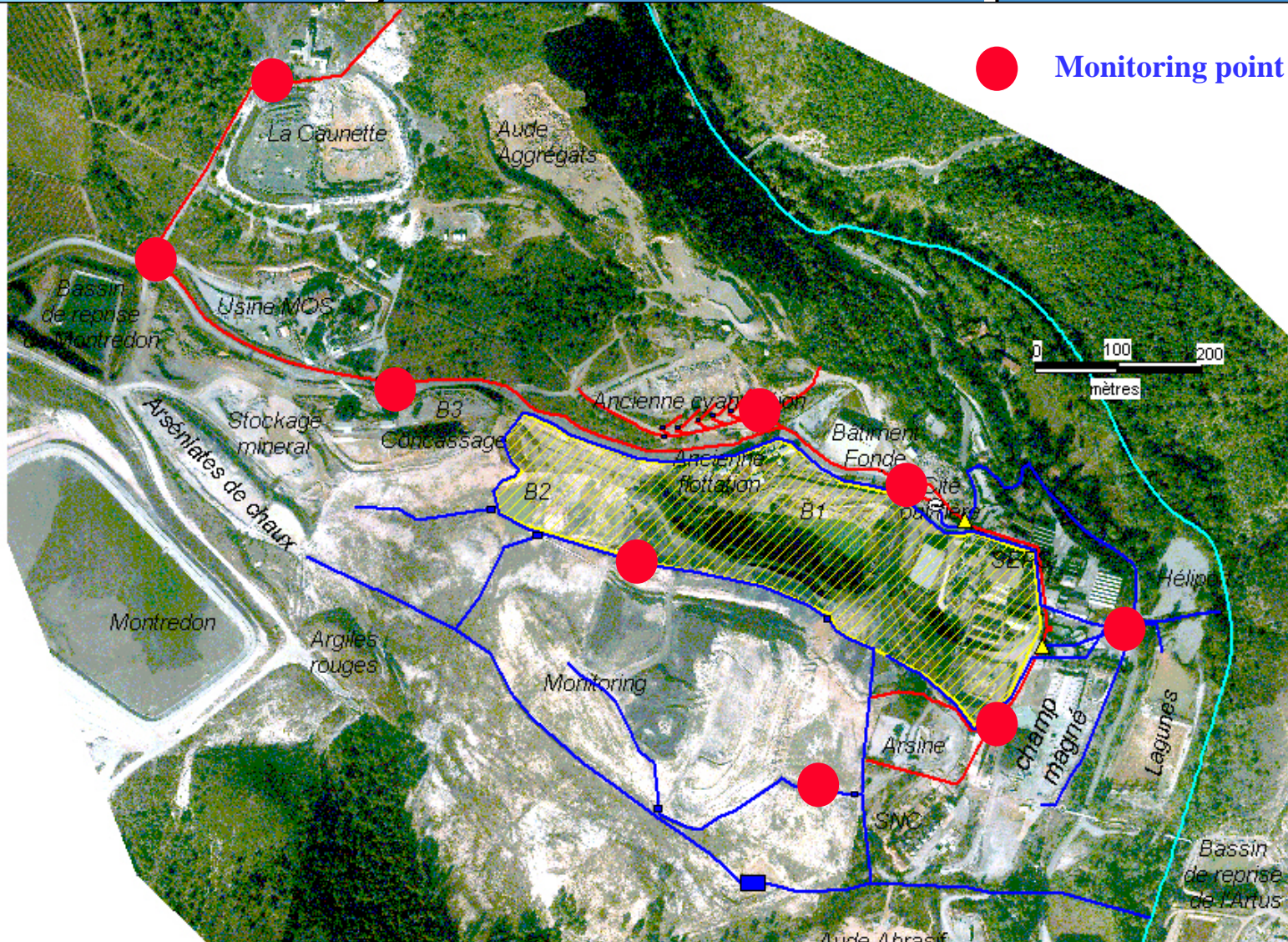
# Field plots 4 in April 2005



# Field plots 1 in April 2005



# Large scale follow up



● Monitoring point





# Conclusion

- **Large metal polluted site remediation is very costly**
- **Cost effective technique like phytostabilisation have to be evaluated**

**La Combe du Saut :**

- **Laboratory experiments : positive results**
- **Field plots : operational water follow up system**
- **Future work : large scale phytostabilisation follow up**

**Thank you for your attention**

## QUEL DEVENIR POUR LES GRANDS SITES POLLUÉS PAR DES MÉTAUX ?

*What will become of large metal-polluted sites ?*

12, 13, décembre 2006  
au Corum de Montpellier

### Conférence Difpolmine

Quelle est la situation internationale ?  
*What is the international situation ?*

Le rôle de l'érosion ?  
*What is the role of erosion ?*

La phytorehabilitation est-elle une solution ?  
*Is phytoremediation a solution ?*

Quelle gestion pour le long terme ?  
*What is the long term post management ?*

Quels sont les risques résiduels ?  
*What are the residual risks ?*

#### Comité scientifique :

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**Appel à communications en septembre 2005**  
*Call for papers in september 2005*