

# **A CASE STUDY OF REMEDIATION IN A MINING / INDUSTRIAL AREA: ALMADÉN MINE RESTORATION**

**WORKSHOP ON MERCURY MANAGEMENT AND DECONTAMINATION IN THE  
FRAMEWORK OF THE MEDITERRANEAN REGIONAL PLAN ON MERCURY**

**ALMADÉN, SPAIN**

**DECEMBER 12-13 2012**

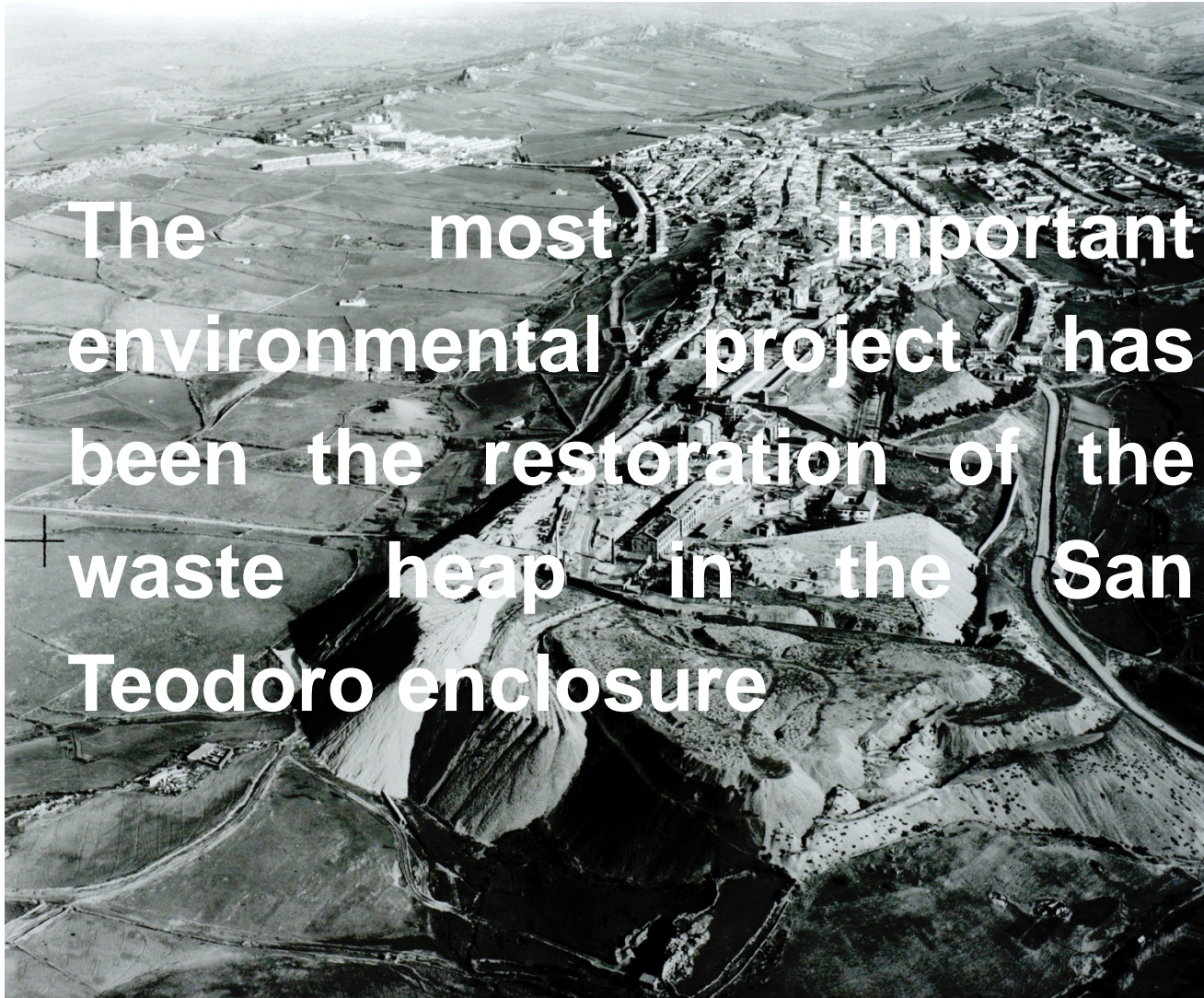


The Almadén mine has been worked for more than 2000 years to the exploitation and production of mercury, it is well-known that it is one of the oldest mines in the world

The mercury production activity ended in July 2003











***DUMP ALMADÉN MINE  
YEAR 1961***





***DUMP  
YEAR 1967***





***DUMP  
YEAR 1973***





***DUMP  
YEAR 1982***



## DUMP MINE ALMADEN RESTORATION

This waste heap contains deposits of waste from the mining operations as well as slag from the metallurgical processes accumulated through the centuries.

The volume of the waste heap is at present close to 3,5 million tons, covering 10 hectares







# ENVIRONMENTAL IMPACT ASSESSMENT

- **HYDROGEOLOGIC CONTAMINATION**
- **ATMOSPHERIC CONTAMINATION**
- **GROUND OCCUPATION**
- **GEOPHYSICAL PROCESSES**
- **GEOTECHNICAL RISKS**
- **MORPHOLOGY AND LANDSCAPE**





# ALTERNATIVE ACTIONS

- **MOVEMENT AND CONSTRUCTION OF A NEW SAFETY DUMP**
  - High environmental and economic impact
- **DUMP FORMING AND WATERPROOFING**
  - Good hydrogeological conditions of the dump



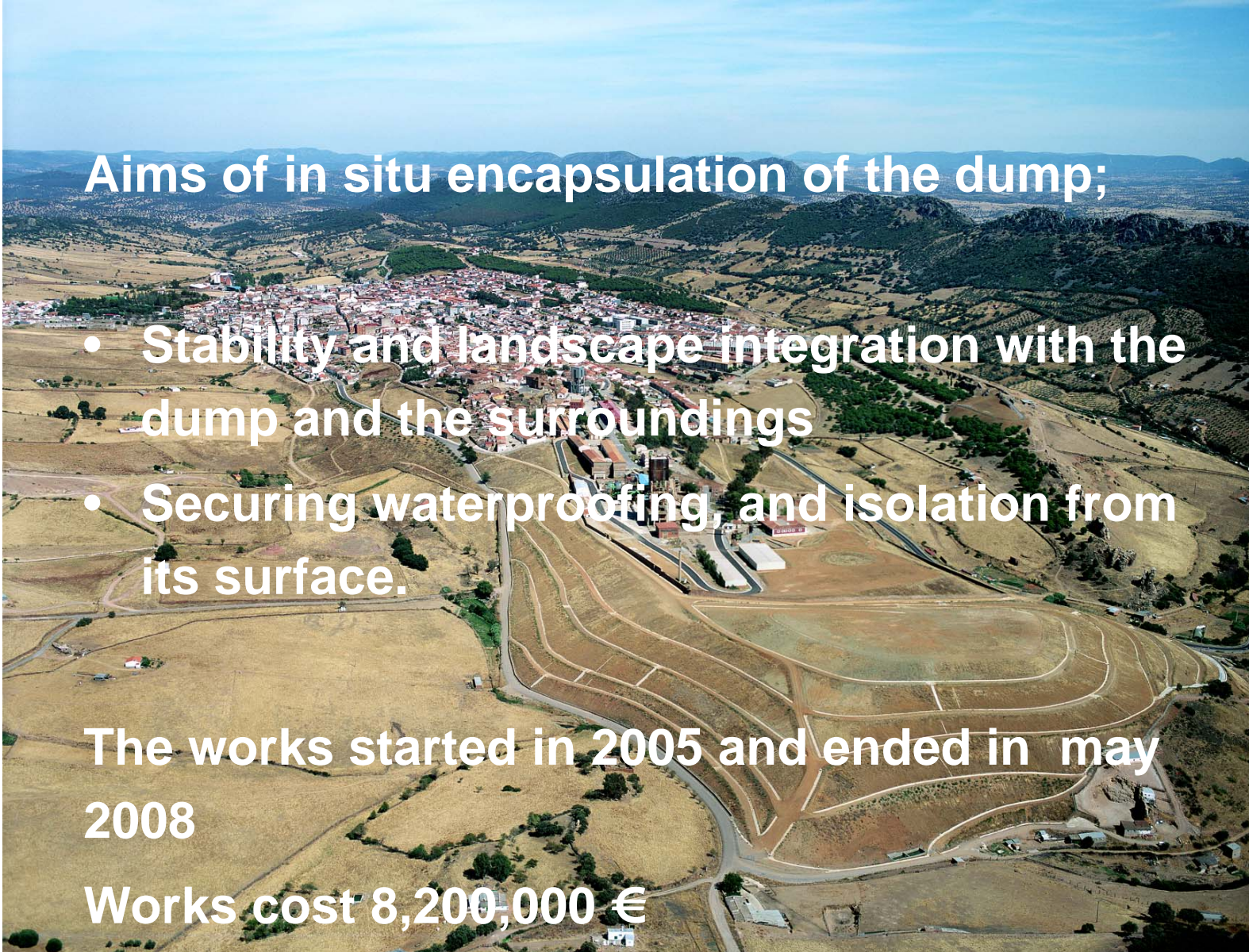


## Aims of in situ encapsulation of the dump;

- Stability and landscape integration with the dump and the surroundings
- Securing waterproofing, and isolation from its surface.

The works started in 2005 and ended in may 2008

Works cost 8,200,000 €







AUGUST 2008



## PHASES

### 1. DUMP FORMING

#### Aims:

- Remodel the slopes and the capping plate of the dump
- Stabilizing their conditions

Earth filling of 493,582 m<sup>3</sup> of material













## 2. DUMP SEALING:

### Functions:

- To prevent the entrance of water in the dump, avoiding the generation of leachate and the material dispersion.
- Insulation, avoiding mercury evaporation in the dump surface



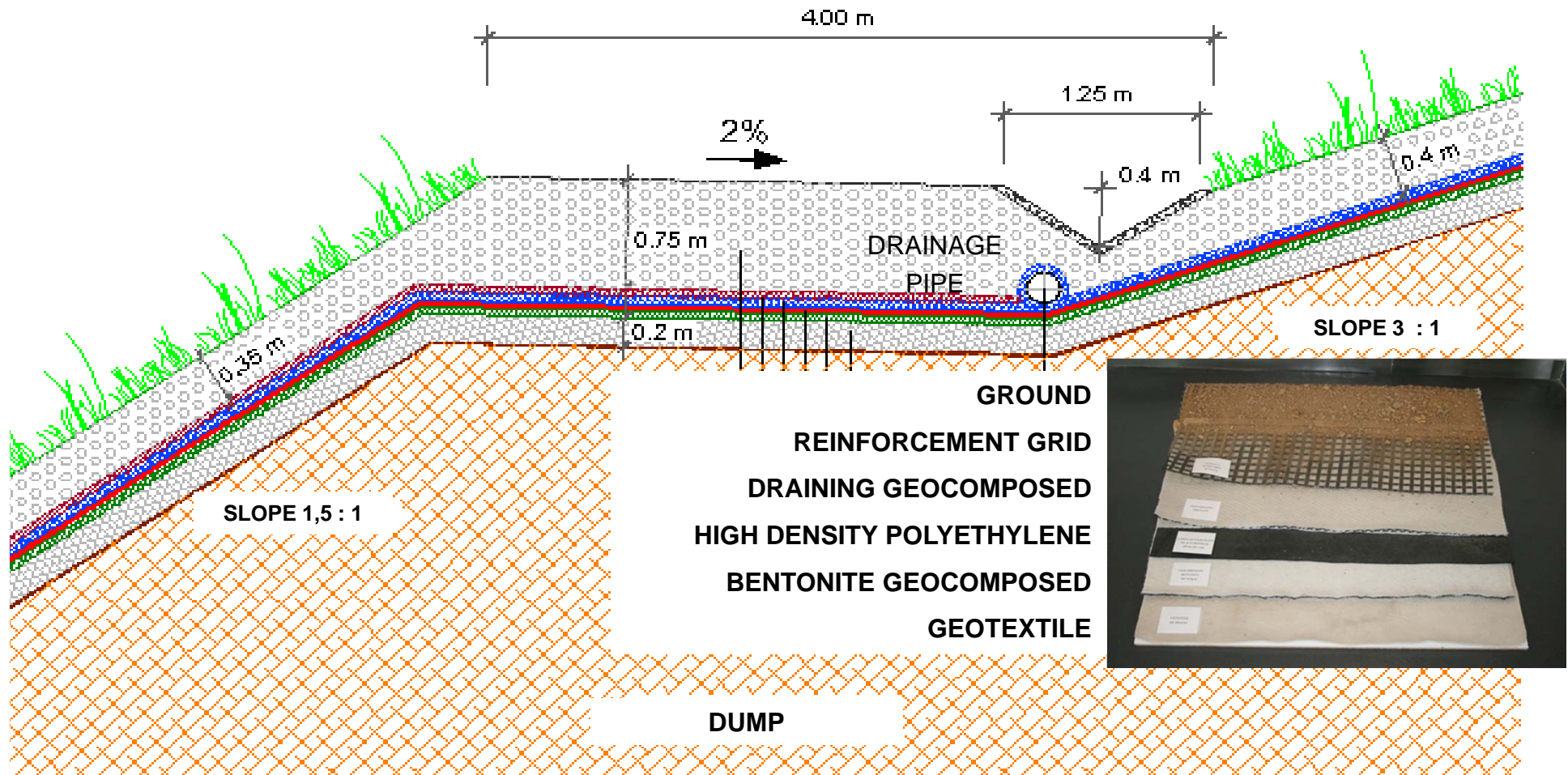








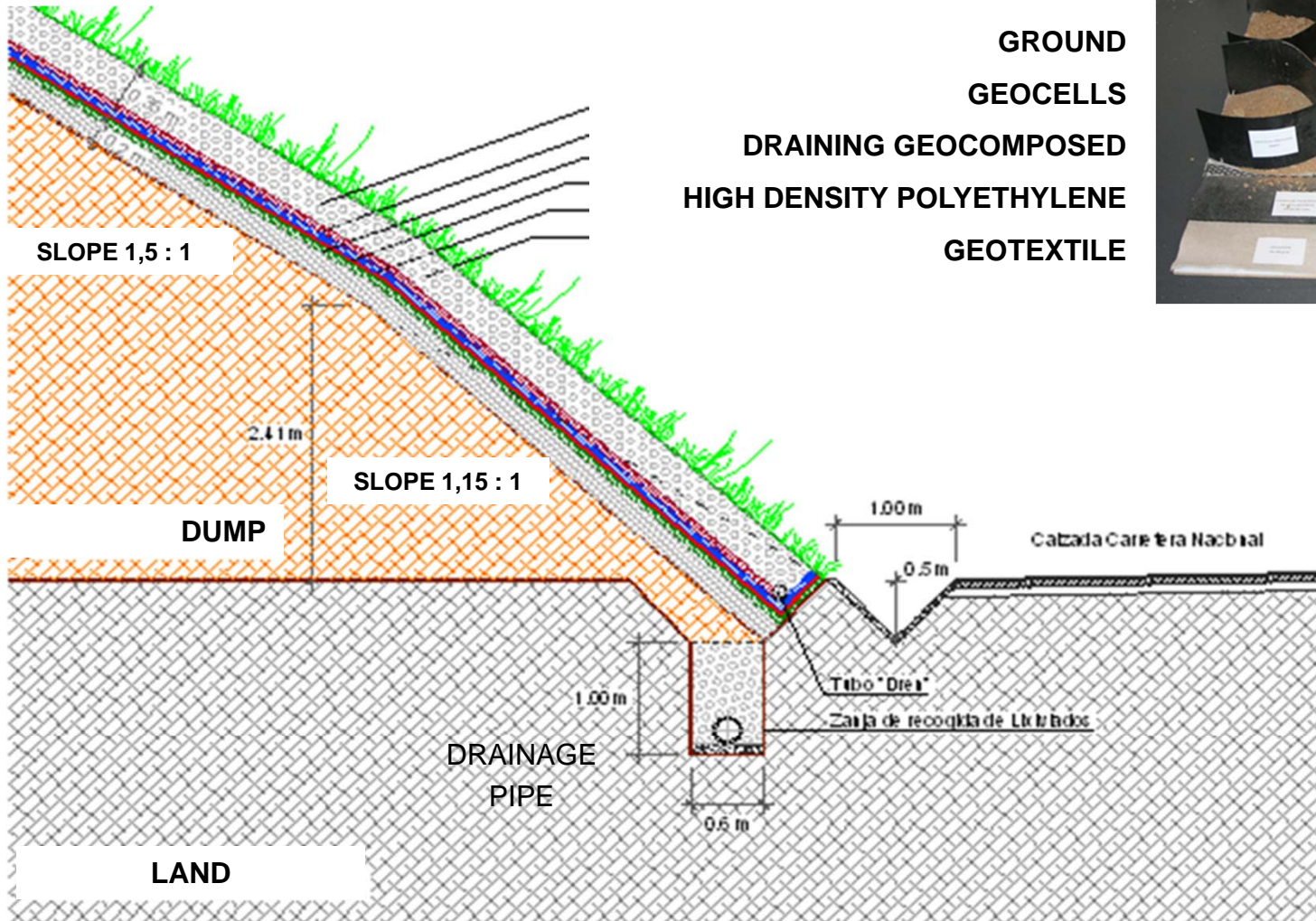




## SEALING SURFACE SCHEME

LOW INCLINATION SLOPE





**GROUND  
GEOCELLS  
DRAINING GEOCOMPOSED  
HIGH DENSITY POLYETHYLENE  
GEOTEXTILE**



## **SEALING SURFACE SCHEME**

**HIGH INCLINATION SLOPE**







## **SEALED SURFACE IS ABOUT 20 SOCCER FIELDS**



**GEOCELLS SOUTH SLOPE**





The sealing package is composed of:

- 175,250 m<sup>2</sup> of geotextil
- 139,932 m<sup>2</sup> m2m2 of bentonite geocomposed
- 202,566 m<sup>2</sup> of high density polyethylene
- 202,116 m<sup>2</sup> of draining geocomposed
- 100,346 m<sup>2</sup> of reinforcement grid
- 50,000 m<sup>2</sup> of geocells





**Works of soil cover**





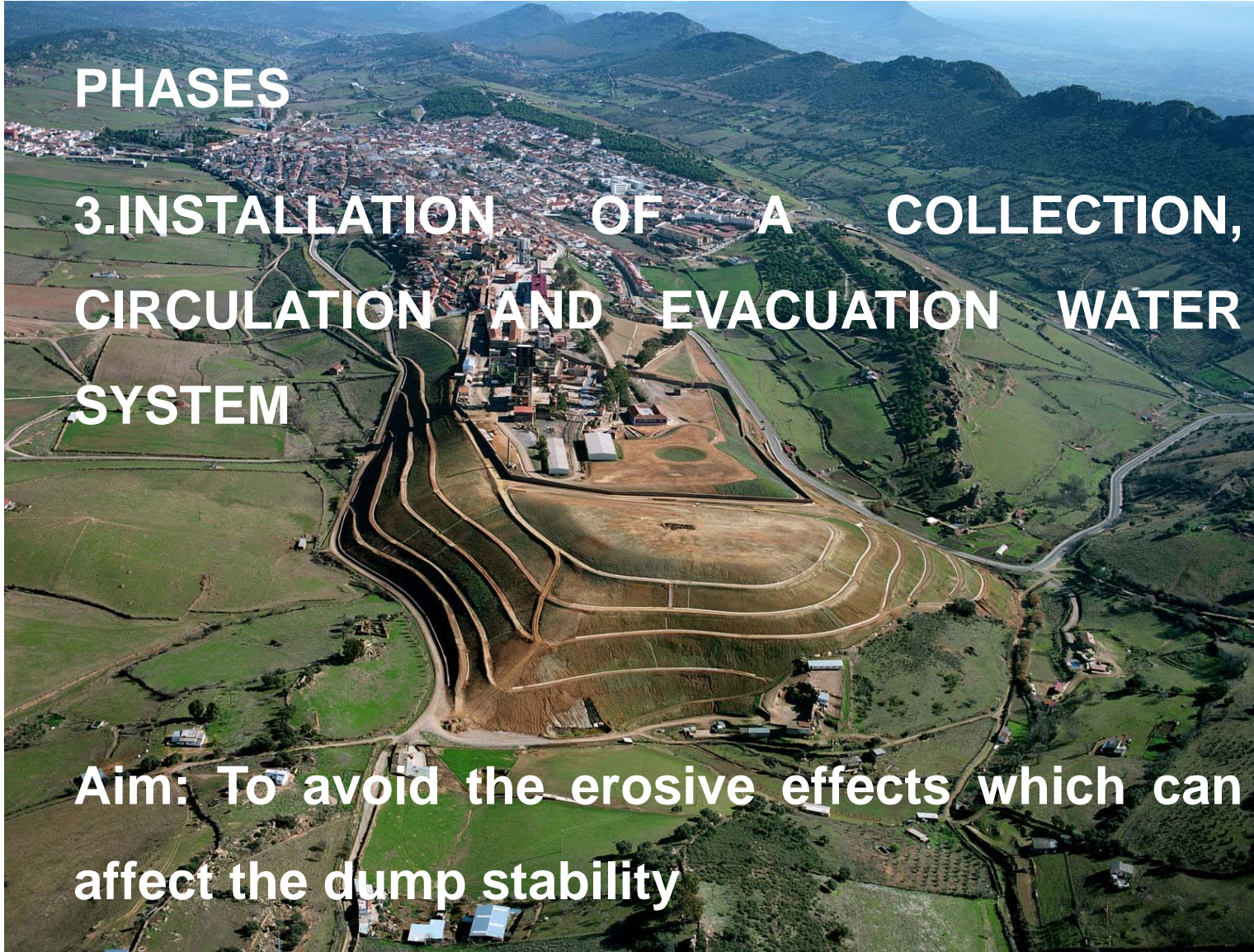
**Geocells installation**



## PHASES

### 3. INSTALLATION OF A COLLECTION, CIRCULATION AND EVACUATION WATER SYSTEM

**Aim: To avoid the erosive effects which can  
affect the dump stability**









## PHASES

### 4. RESTORATION OF THE VEGETAL LAYER.

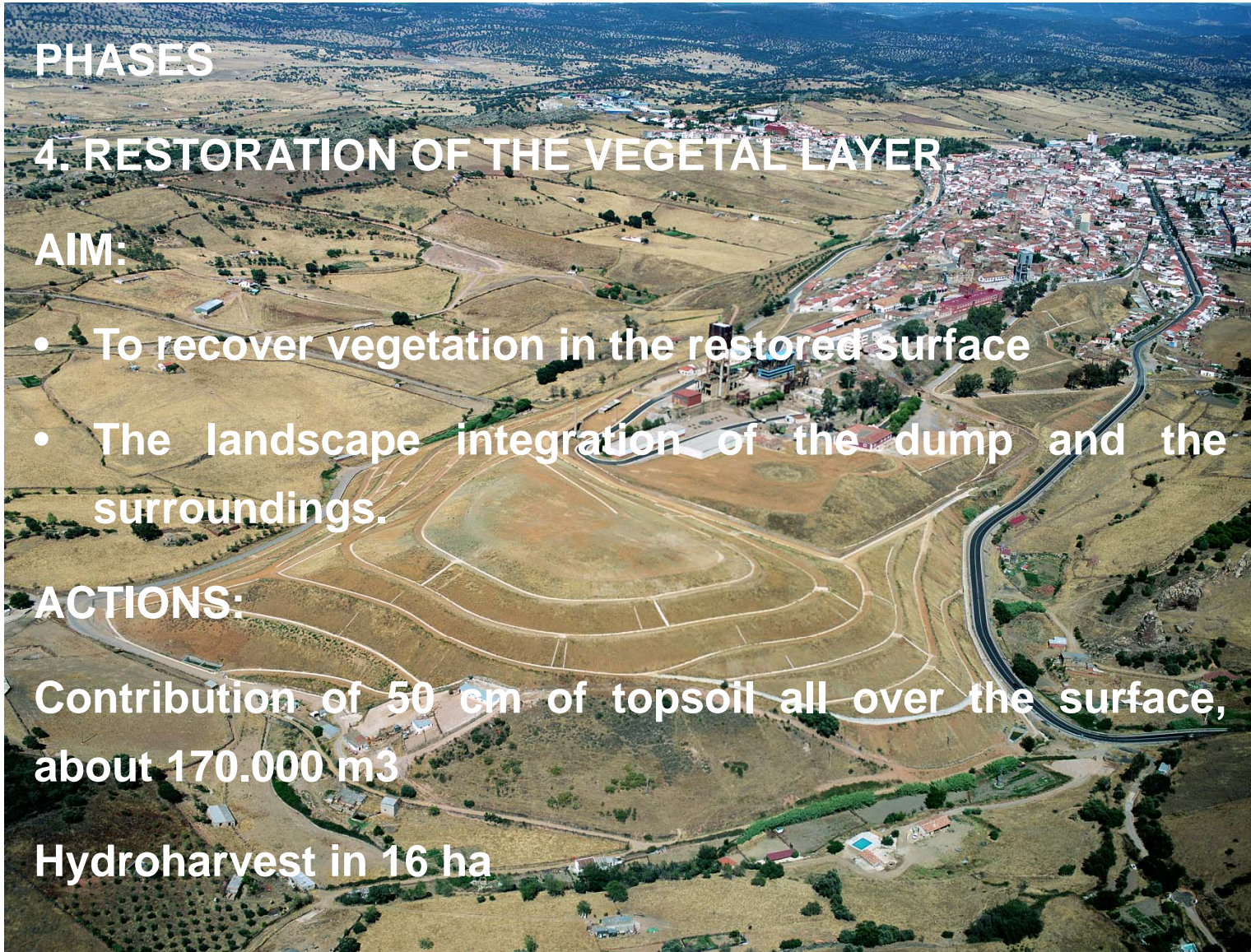
#### AIM:

- To recover vegetation in the restored surface
- The landscape integration of the dump and the surroundings.

#### ACTIONS:

Contribution of 50 cm of topsoil all over the surface,  
about 170.000 m<sup>3</sup>

Hydroharvest in 16 ha







AUGUST 2008





**Final state**





**Before and after works**



## ENVIRONMENTAL MONITORING

### PROGRAMME OF ALMADEN MINE DUMP

Chemical test of different parameters in groundwater, surface water, soil and air.

The expected duration is 50 years

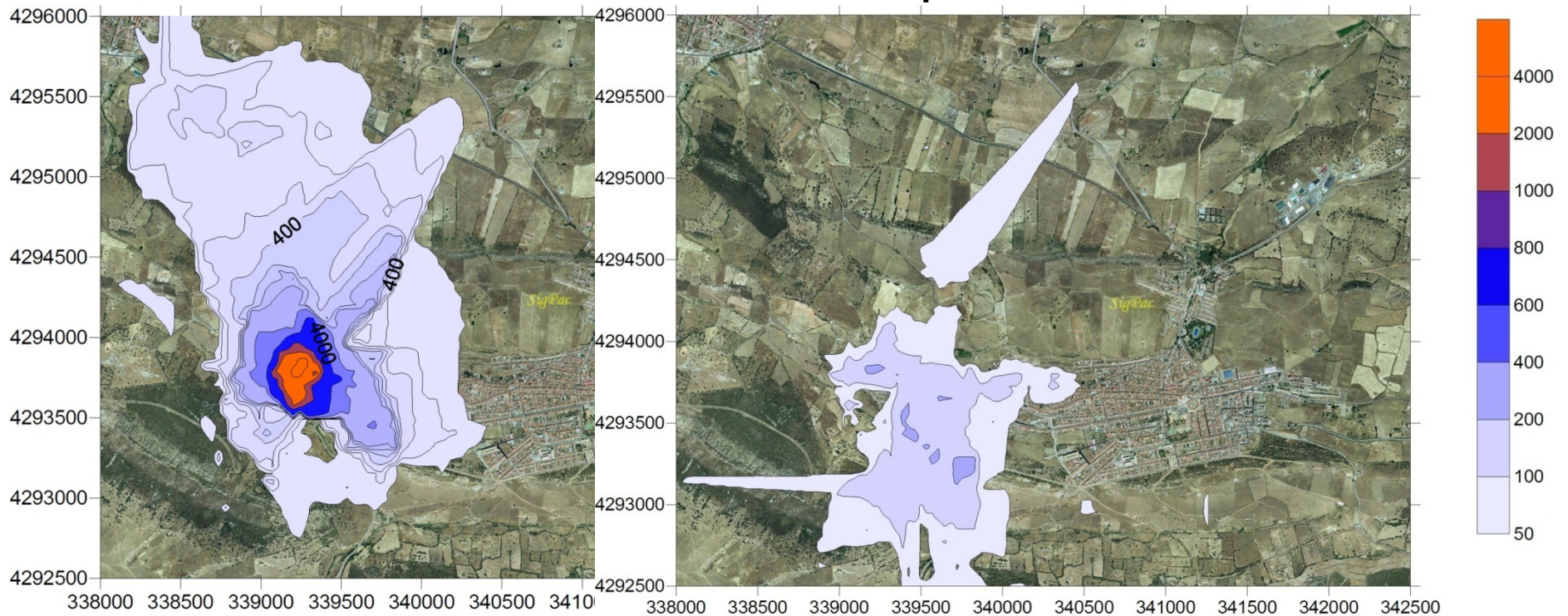




## RESTORATION OF THE WASTE HEAP IN THE SAN TEODORO ENCLOSURE

The first results:

### Emission to the atmosphere



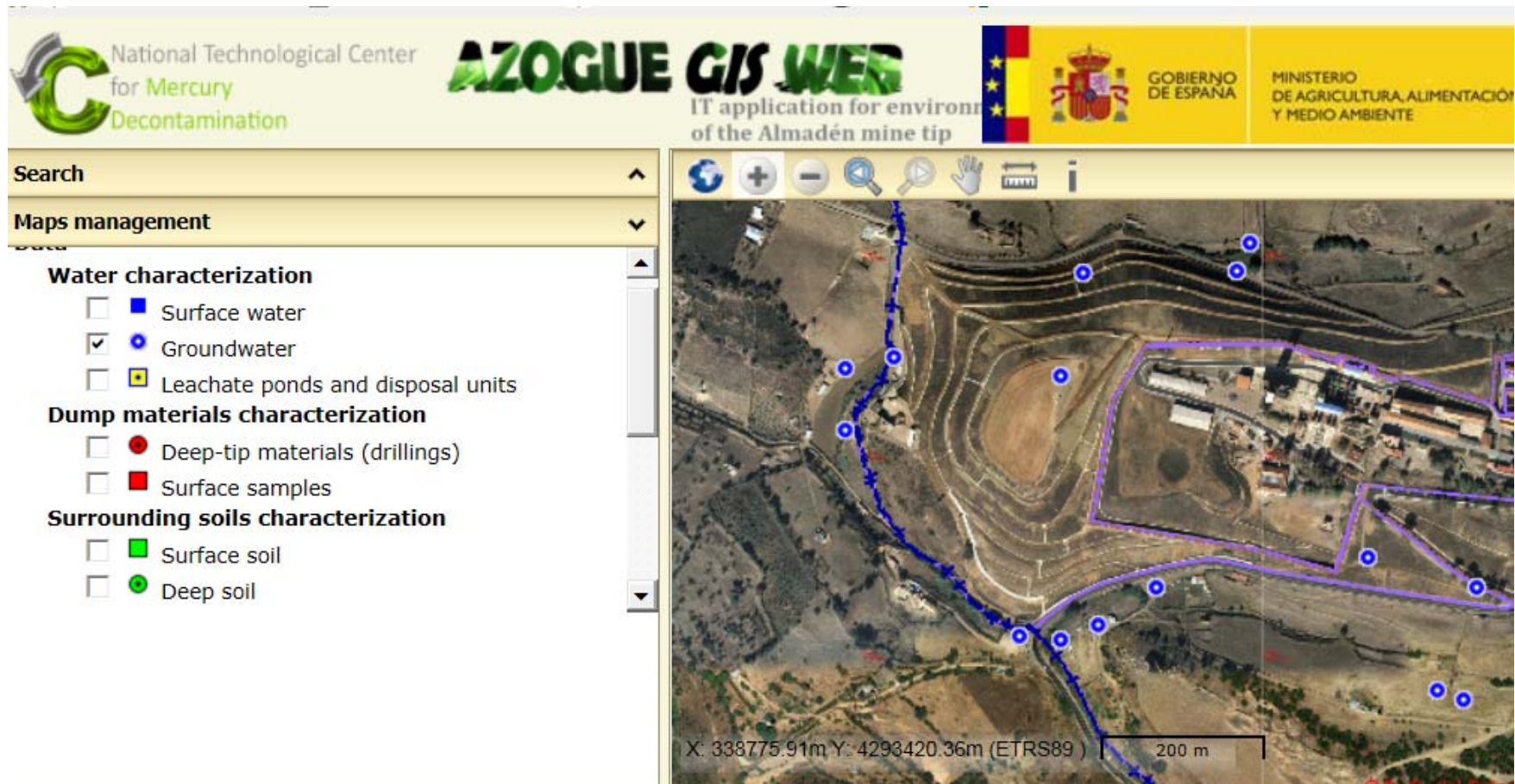
**Test in the air  
during the works  
(ng/m<sup>3</sup>)**

**Test in the air  
after the works  
(ng/m<sup>3</sup>)**



# DUMP ALMADEN MINE WATER MONITORING

## POINTS GROUNDWATER MONITORING AROUND DUMP



The screenshot displays the AZOGUE GIS WEB application interface. The top header includes the logo of the National Technological Center for Mercury Decontamination, the application name "AZOGUE GIS WEB", and the text "IT application for environmental monitoring of the Almadén mine tip". It also features the Spanish national flag and logos for the "GOBIERNO DE ESPAÑA" and "MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE".

The left sidebar contains a "Search" field and a "Maps management" section. Under "Maps management", there are three categories of monitoring points:

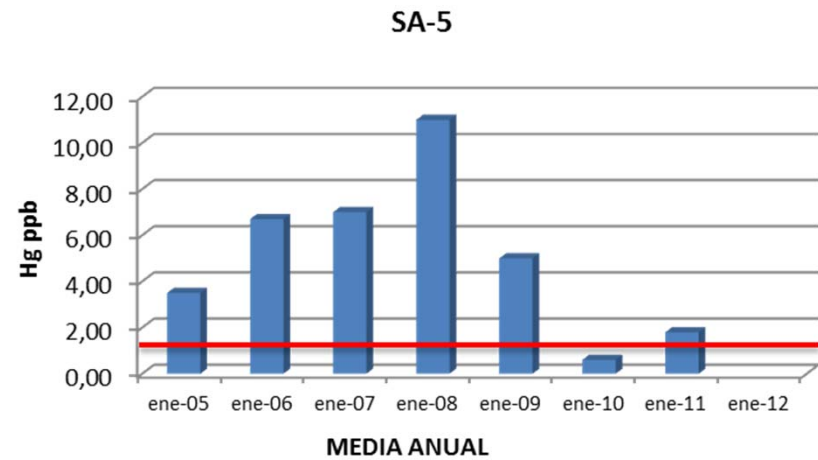
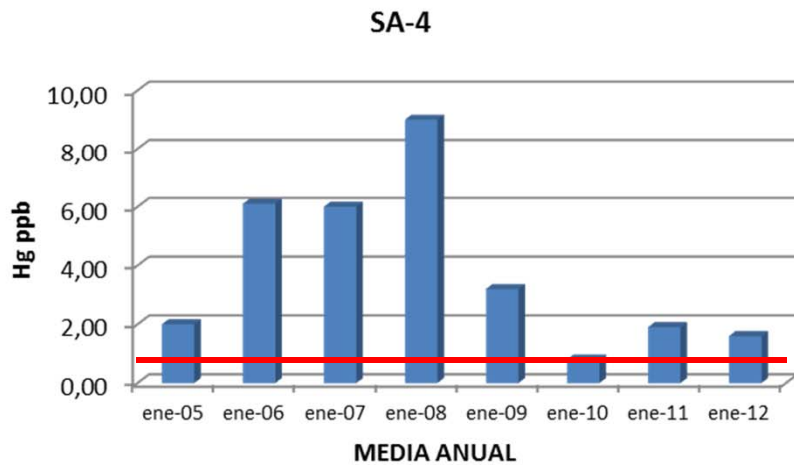
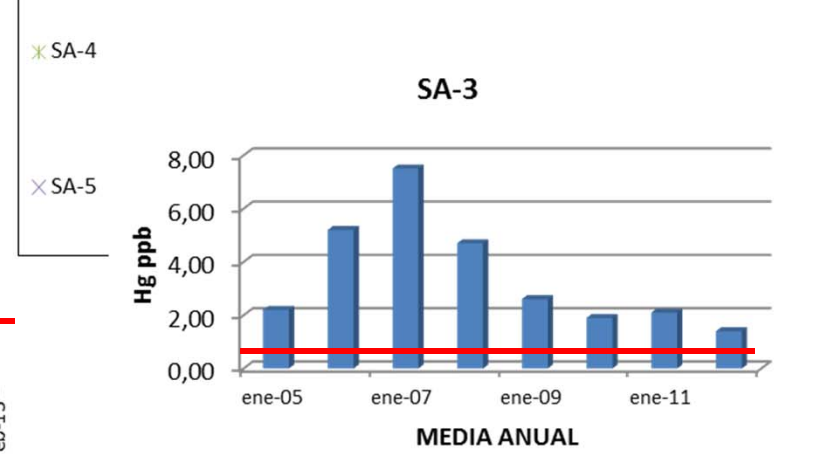
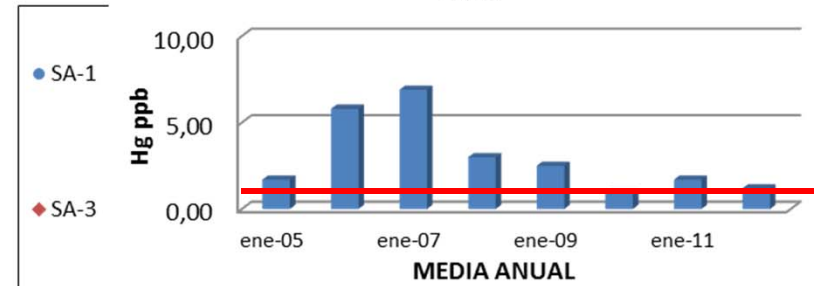
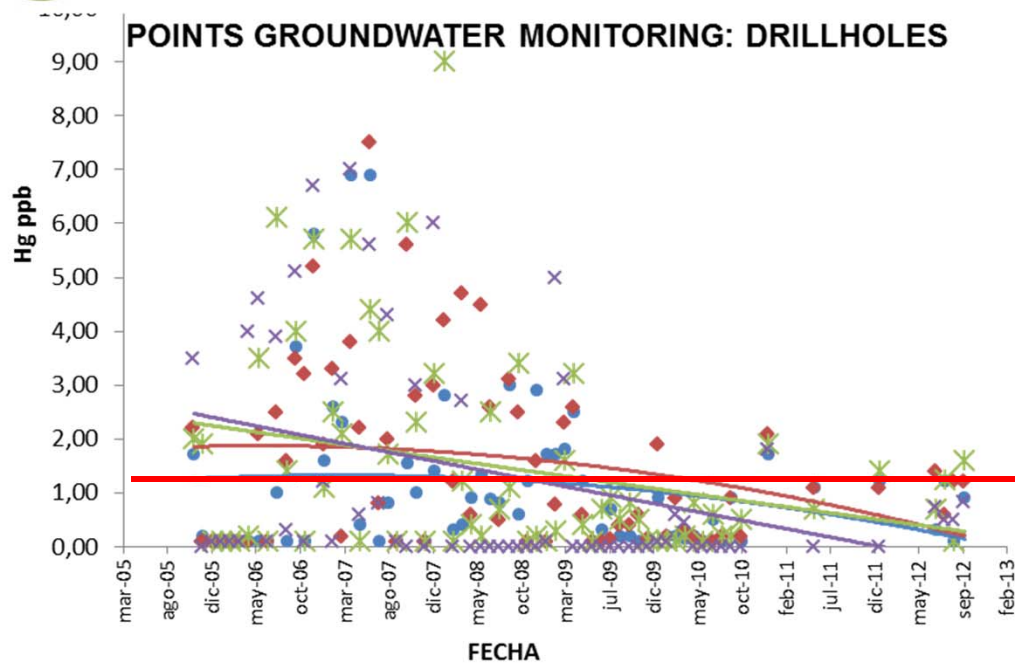
- Water characterization:**
  - Surface water
  - Groundwater
  - Leachate ponds and disposal units
- Dump materials characterization:**
  - Deep-tip materials (drillings)
  - Surface samples
- Surrounding soils characterization:**
  - Surface soil
  - Deep soil

The main map area shows an aerial view of the mine dump with several blue circular markers representing groundwater monitoring points. A blue line indicates a water flow path or boundary. A scale bar at the bottom of the map shows "200 m" and coordinates "X: 338775.91m Y: 4293420.36m (ETRS89)".



# DUMP ALMADEN MINE WATER MONITORING

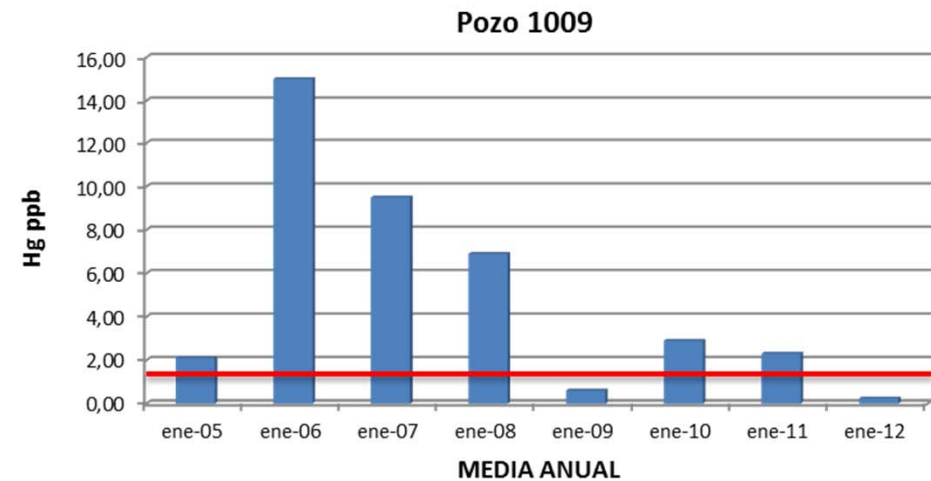
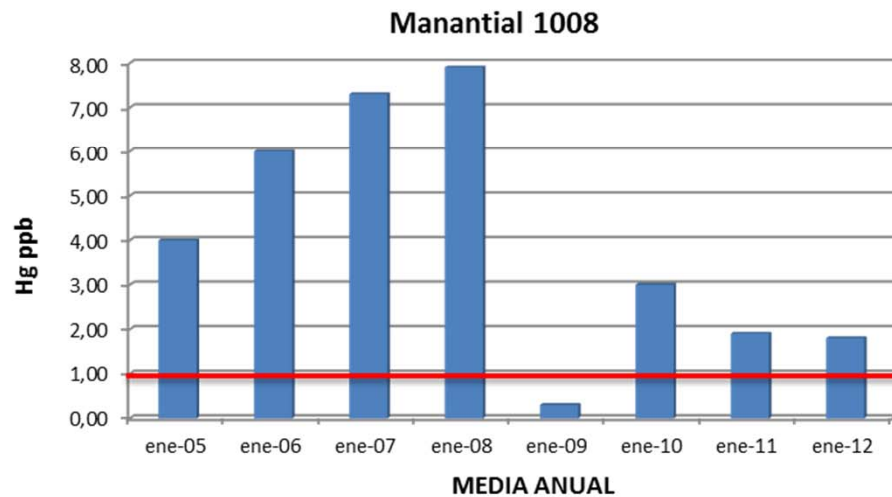
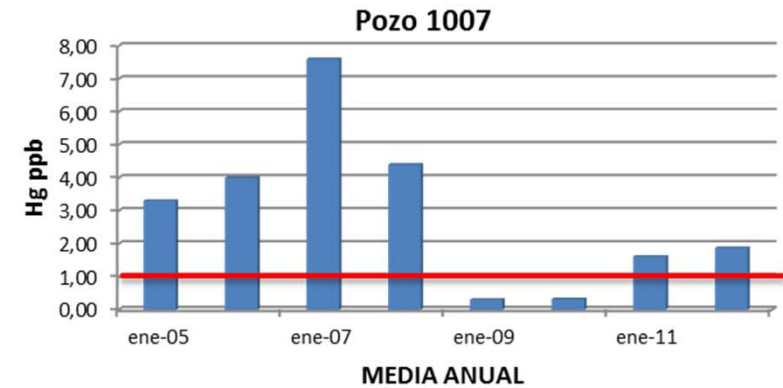
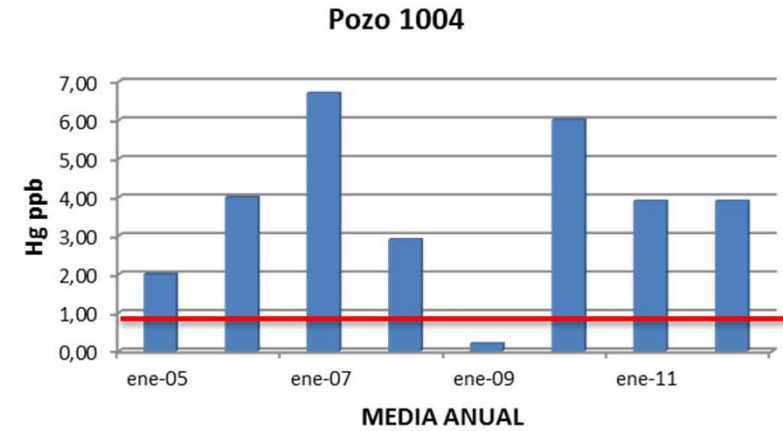
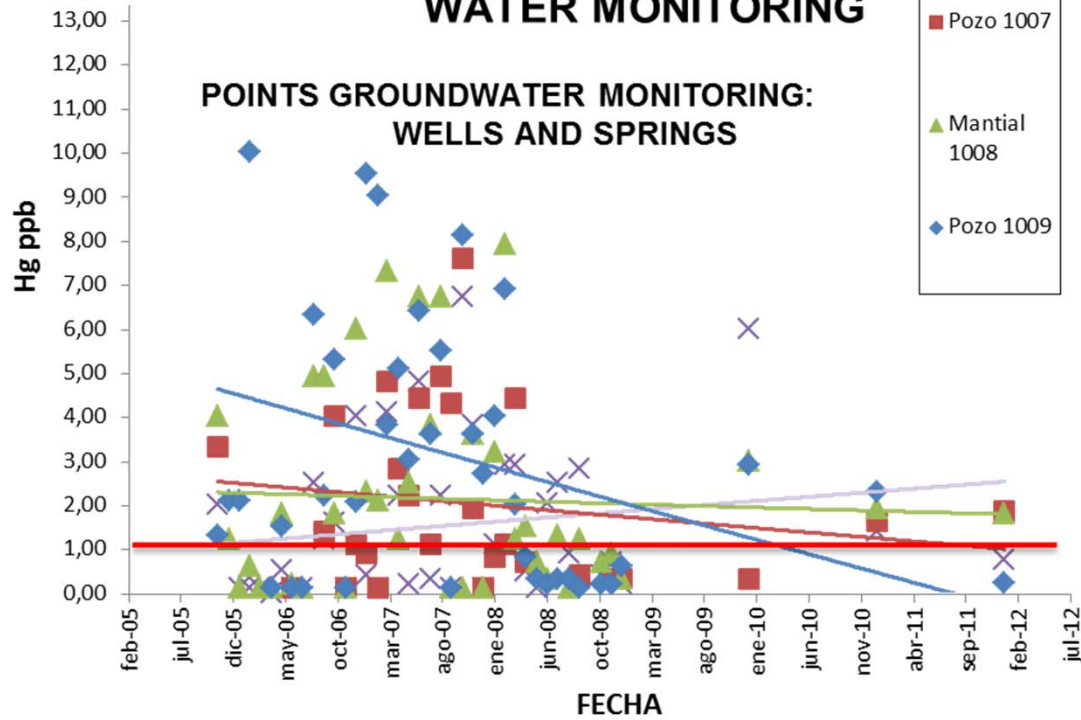
## POINTS GROUNDWATER MONITORING: DRILLHOLES





# DUMP ALMADEN MINE WATER MONITORING

## POINTS GROUNDWATER MONITORING: WELLS AND SPRINGS





# DUMP ALMADEN MINE WATER MONITORING

## POINTS SURFACE WATER MONITORING: STREAMS

### STREAMS FUENTE VIEJA Y AZOGADO

The screenshot displays the AZOGUE GIS WEB application interface. The top header includes the National Technological Center for Mercury Decontamination logo, the application name 'AZOGUE GIS WEB', and the text 'IT application for environmental surveillance of the Almadén mine tip'. On the right, there are logos for the Spanish Government (GOBIERNO DE ESPAÑA) and the Ministry of Agriculture, Food and Environment (MINISTERIO DE AGRICULTURA, ALIMENTACION Y MEDIO AMBIENTE).

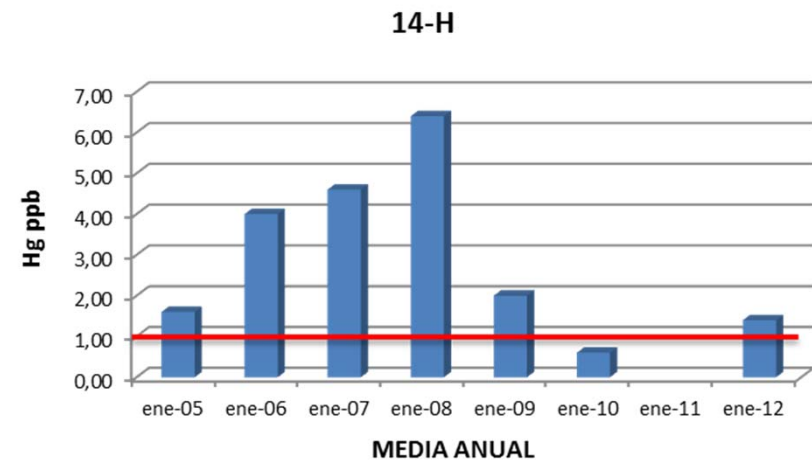
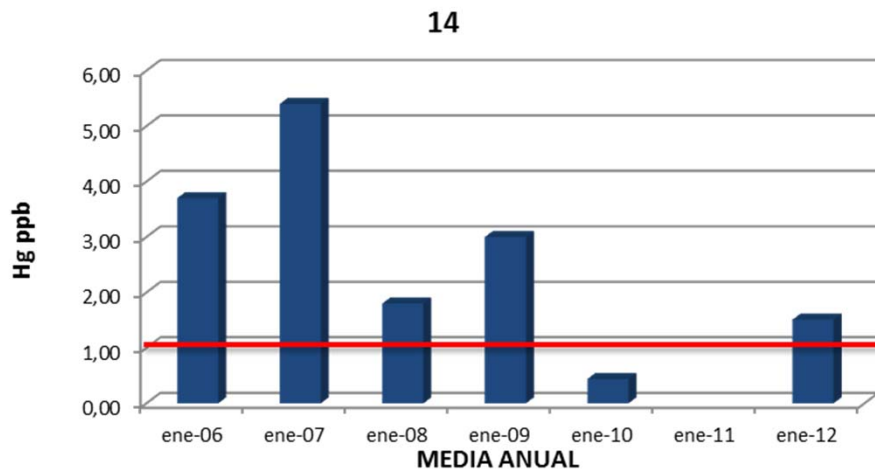
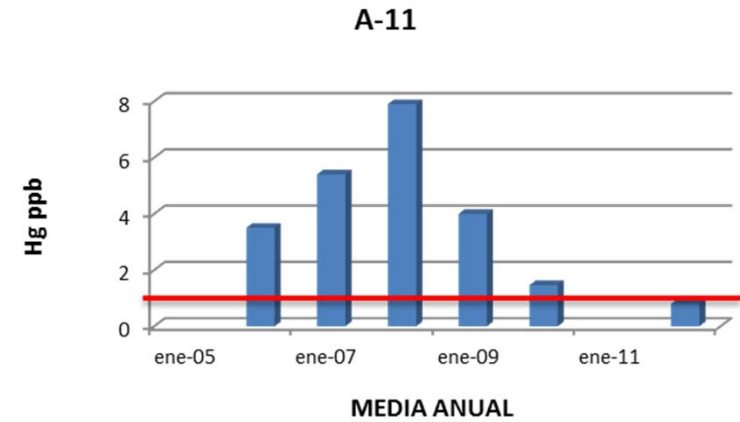
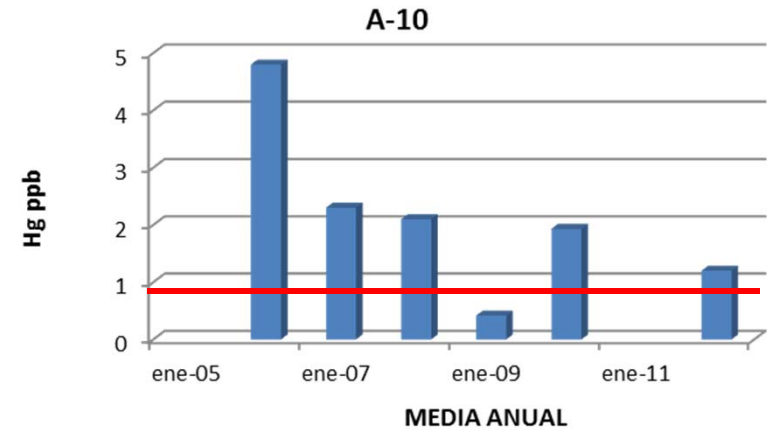
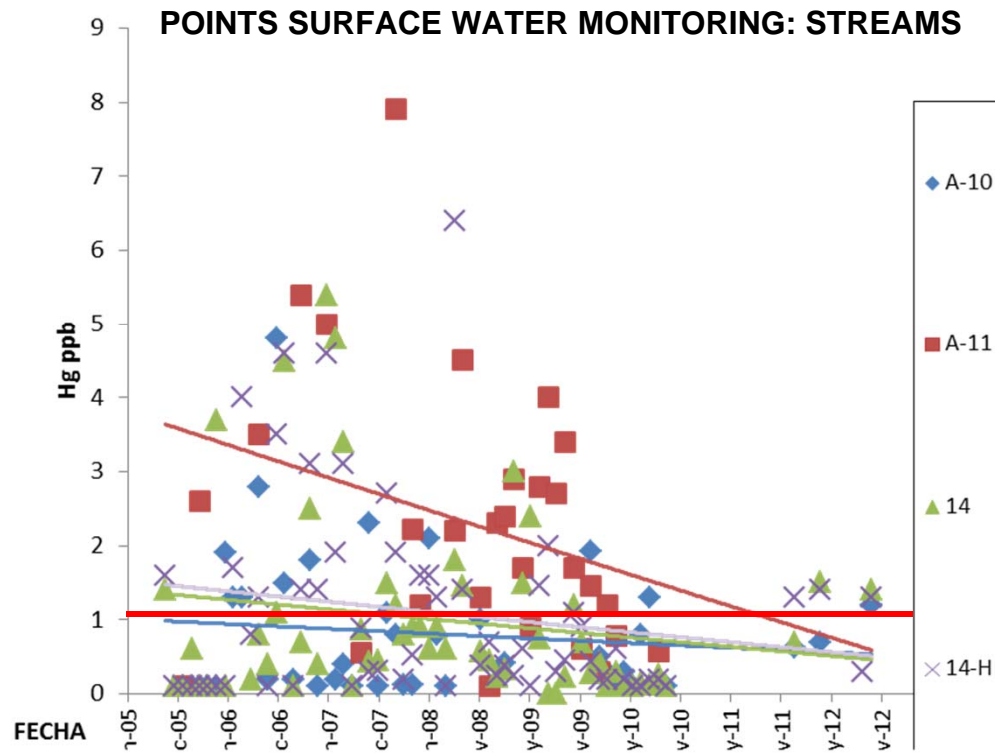
The interface features a search bar, a maps management section, and a data layer selection panel. The data panel is expanded to show the following options:

- Water characterization**
  - Surface water
  - Groundwater
  - Leachate ponds and disposal units
- Dump materials characterization**
  - Deep-tip materials (drillings)
  - Surface samples
- Surrounding soils characterization**
  - Surface soil
  - Deep soil

The main map area shows an aerial view of the mine site with a blue line representing a stream and several blue square markers indicating monitoring points. A purple outline delineates the mine dump area. The bottom right corner of the map area contains the text '© 2012 del Catastro'.



# DUMP ALMADEN MINE WATER MONITORING

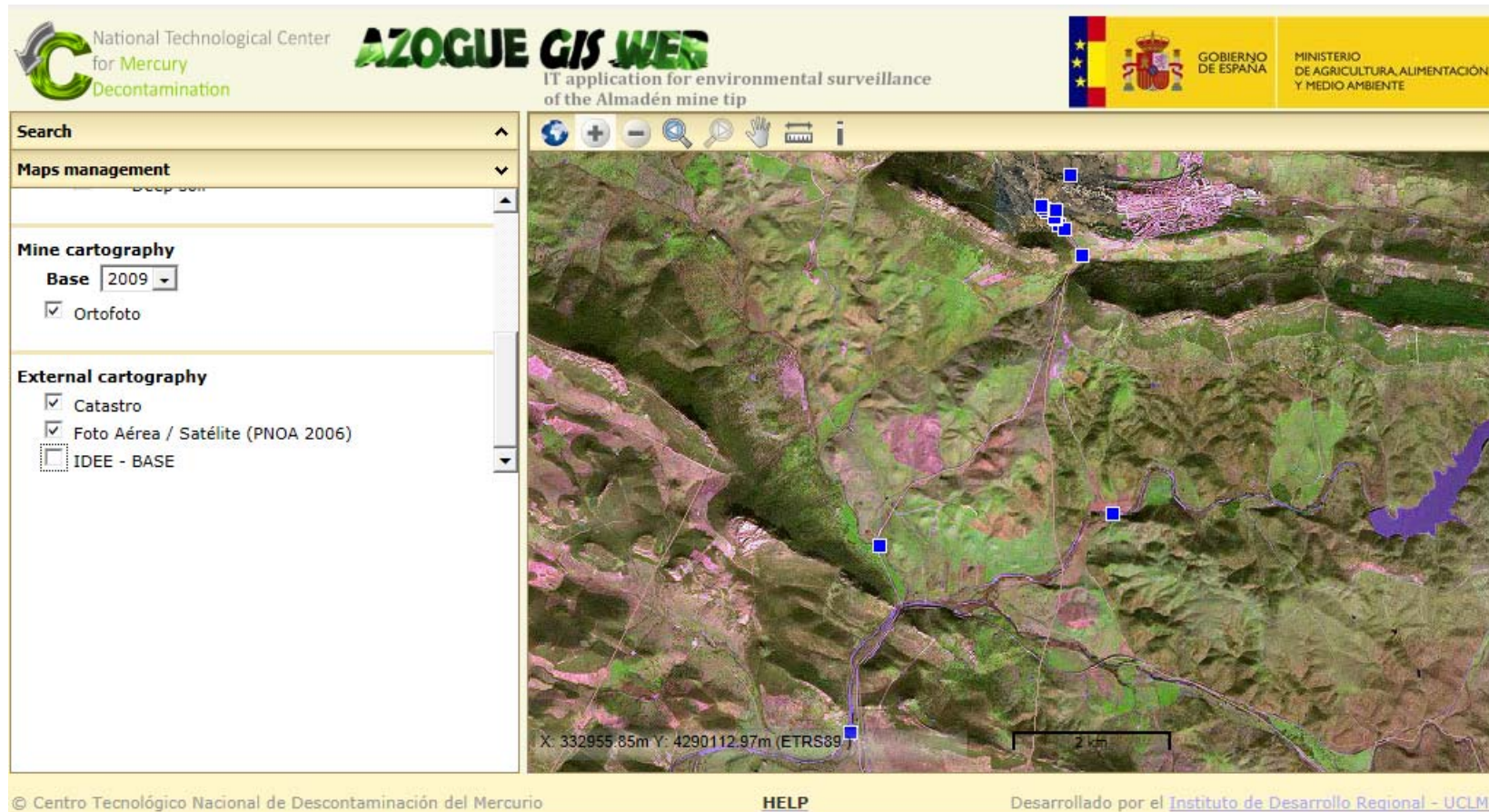




# DUMP ALMADEN MINE WATER MONITORING

## POINTS SURFACE WATER MONITORING: RIVER

- 9,10 Valdezogues river
- 15 Azogado stream



The screenshot displays the 'AZOGUE GIS WEB' application interface. The top header includes the National Technological Center for Mercury Decontamination logo, the application title 'AZOGUE GIS WEB', and the subtitle 'IT application for environmental surveillance of the Almadén mine tip'. On the right, there are logos for the Spanish Government (GOBIERNO DE ESPAÑA) and the Ministry of Agriculture, Food and Environment (MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE).

The main interface is divided into a left sidebar and a central map area. The sidebar contains the following sections:

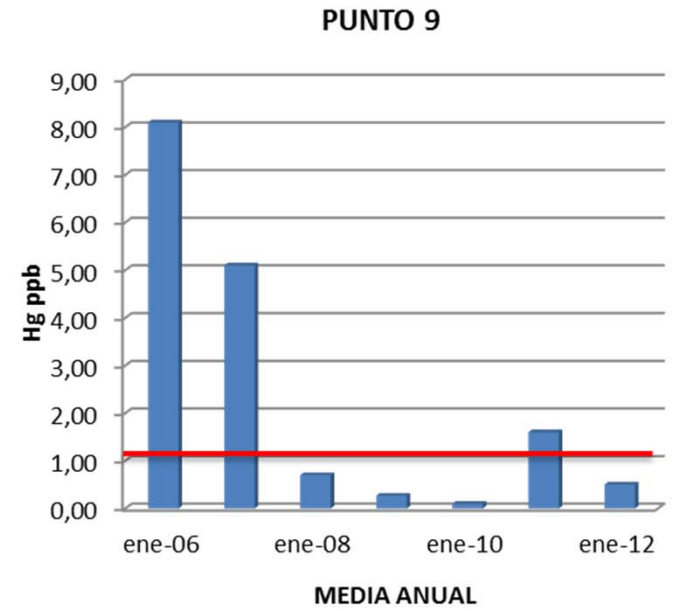
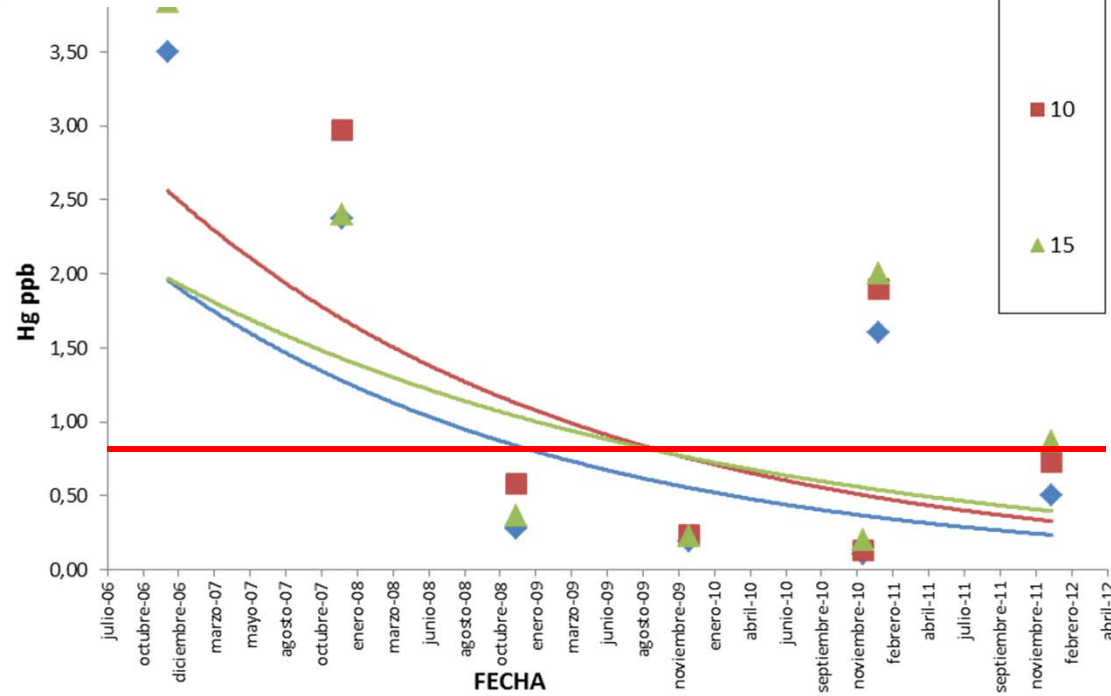
- Search**: A search bar with a magnifying glass icon.
- Maps management**: A section with a dropdown menu.
- Mine cartography**: Includes a 'Base' dropdown menu set to '2009' and a checked checkbox for 'Ortofoto'.
- External cartography**: Includes checked checkboxes for 'Catastro' and 'Foto Aérea / Satélite (PNOA 2006)', and an unchecked checkbox for 'IDEE - BASE'.

The central map area shows a topographic map of the Almadén mine tip. Several blue square markers are placed along the river network, indicating monitoring points. A scale bar at the bottom of the map indicates 2 km. The coordinates 'X: 332955.85m Y: 4290112.97m (ETRS89)' are displayed at the bottom left of the map.

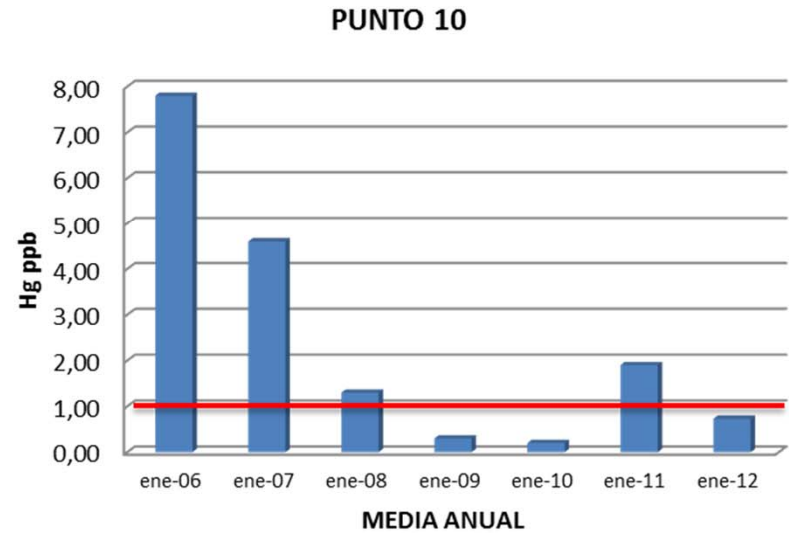
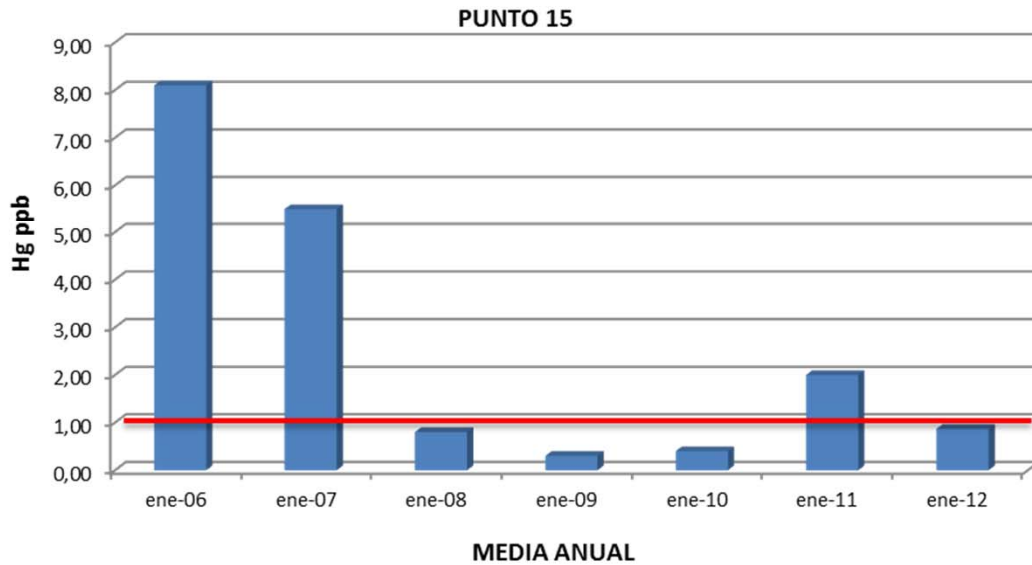
At the bottom of the application, there is a footer with the following text: '© Centro Tecnológico Nacional de Descontaminación del Mercurio', a 'HELP' button, and 'Desarrollado por el Instituto de Desarrollo Regional - UCLM.'.



# DUMP ALMADEN MINE WATER MONITORING



**VALDEAZOGUES RIVER BEFORE ITS CONFLUENCE WITH AZOGADO STREAM (POINT 9), AND AFTER THIS (POINT 10)**



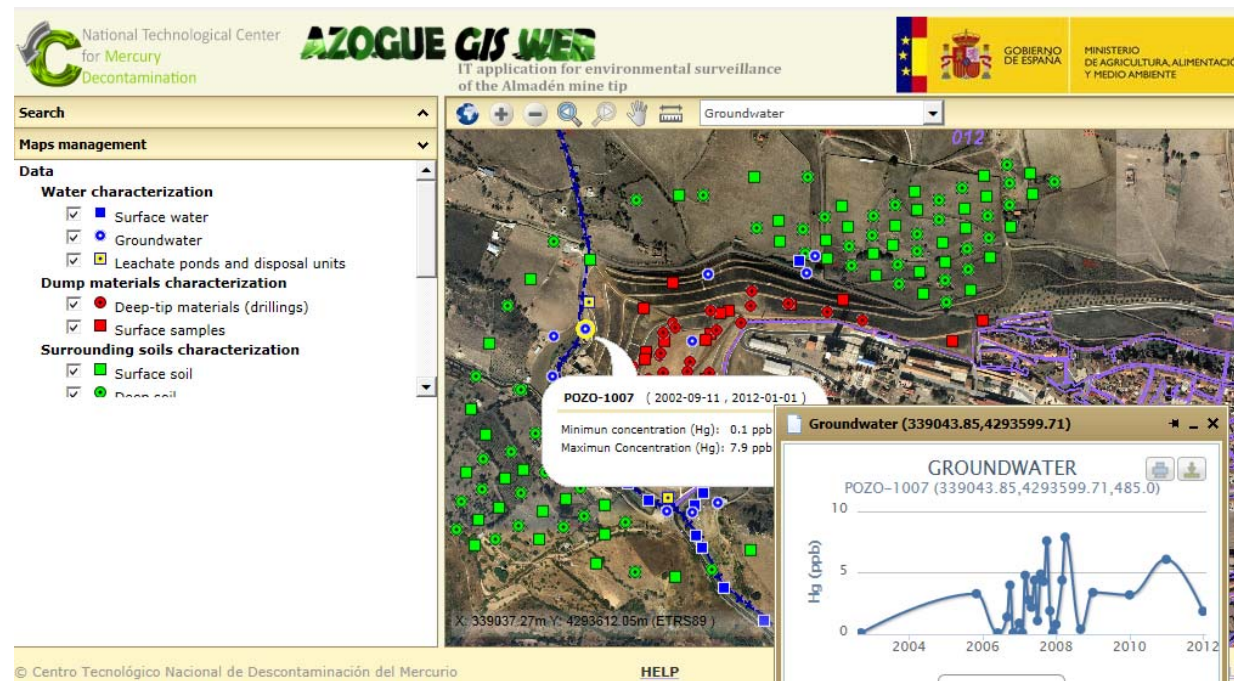


## The restoration works are reducing:

- The material dispersion and mercury evaporation
- The lixivate production which had as final destination the surrounding streams
- The underground flow below the dump

To follow the monitoring visit the website:

[www.ctndm.es/proyectos/1-in.php](http://www.ctndm.es/proyectos/1-in.php)







THANK YOU  
FOR YOUR ATTENTION

Javier Carrasco Milara: [jcarrasco@ctndm.es](mailto:jcarrasco@ctndm.es)