

# RESTORATION ACTIVITIES IN URANIUM MINING AND MILLING FACILITIES IN SPAIN



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## Abstract

From the end of the 80's up to now, several tasks have been carried out in Spain on restoration in the field of uranium mining and milling, significant among them being Andújar Uranium Mill (FUA) closure and La Haba closure. Also, a study has been carried out on restoration of inoperative and abandoned uranium mine sites. At present, detailed plans are being worked out for the project on the closure of the Elefante plant. All activities have been developed in the common framework of national standards and regulations which are generally in compliance with the standards, regulations and recommendations of international organizations. This paper describes briefly the standards and the criteria applied to the restoration tasks at various sites of the uranium mining and milling facilities in Spain. The restoration activities have different characteristics: La Haba facility is an isolated and conventional facility to produce uranium concentrate; in the case of old and abandoned uranium mines the intervention criteria is more relevant than the activities to be carried out; the closure (the first phase of licensing) and restoration activities of Elefante plant have to be developed taking into account that it is sited within the area of Quercus plant which is currently in operation.

## 1. INTRODUCTION

From the end of the 80's up to now, Spain has been carried out several works on restoration in the field of uranium mining and milling, such as Andújar Uranium Mill (FUA) closure and La Haba closure. Also, a study has been carried out on restoration of inoperative and abandoned uranium mines. At present, details of the project for closure of the Elefante plant which was built for producing uranium concentrates are being worked out. Also, under development is the closure plan for Quercus plant, which is currently in operation. This closure plan includes a study on the safety and security of the plant.

All these installations (excepting the FUA) belong to the company "Empresa Nacional del Uranio S.A. (ENUSA)", responsible for the preparation of closure plans and facilitate licencing. This company is also responsible for managing the radioactive wastes during the operational phase. Once the operational phase ends the company "Empresa Nacional de Residuos Radiactivos S.A. (ENRESA)" takes responsibility for the management of radioactive waste as per the closure plan. The company "Empresa Nacional de Ingeniería y Tecnología S.A. (INITEC)" provides engineering support to ENUSA and ENRESA in the design and licensing aspects of the closure plans. All activities have been developed in the common framework of national standards and regulations which are in general compatible with the standards, regulations, recommendations and practices followed by international organizations.

The standards and general as well as specific criteria applied to individual sites, and the details of various restoration works developed are described in the following section.

## 2. STANDARD USED

The regulations and standards applicable have been established by the Spanish Nuclear Council (CSN), taking into account the recommendations of international organizations (ICRP, IAEA and OECD/NEA).

The following is the order of priority for the application of Standards and Regulations:

- 1.) Spanish Nuclear Safety Council stipulations described in the document "Radiological criteria for the closure of uranium mining and milling installations", (April 1995, draft)
- 2.) Spanish standards, except in cases where it is obligatory to fulfil the European Union Standards on Security Criteria for specific facility.
- 3.) ICRP, IAEA, OECD standards in this order.

The following table summarizes the applicable Standards classified under two groups. The first is basically related to all aspects of Radiological Protection of workers and the public in general and includes European Union, ICRP, IAEA and OECD Regulations and Standards. The second includes the US legislation with quantitative and qualitative aspects specific for this application.

COUNTRY/ ORGANIZATION	STANDARD	RESPONSIBLE ORGANIZATION	CONTENT SUMMARY
SPAIN	R.I.N.R.	M.I.E.	- Administrative Authorizations Rule - Requirements for the Facility Classification
	R.P.S.R.I.	Presidencia del Gobierno	- Standards for Radiation Protection
	Drinking Water Regulations	Presidencia del Gobierno	- Maximum concentration in drinking water
	Law about ENRESA creation	Presidencia del Gobierno	- ENRESA responsibility
USA	10 CFR 40 Appendix A	NRC	- General Design Criteria to assure stability without maintenance
IAEA	SS-44		- General Criteria for stabilization and surveillance of tailings - Waste Management
	SS-43		- Radiological Safety
	SS-26		- Radiation Protection of workers
ICRP	Nº 24		- Radiological Protection
	Nº 30		- Limits for intakes of radionuclides by workers
	Nº 60		- Radiological Protection

The Radiological Protection aspects are common to Nuclear Industry and are generally well known. On the other hand the requirements for a Stabilization Project concerning protection and long term durability are as follows:

- 1.) The protection will be designed as reasonable and practical, to be effective in any case for 200 years.
- 2.) The project will offer adequate guarantee for Rn-222 emission rate not to exceed 1 Bq/m<sup>2</sup>s averaged over the whole surface of the cover.

- 3.) The concentration of radionuclides more significant from the radiological impact viewpoint in the soils next to the site, will be less than 1 Bq/g over natural background concentration.

### **3. GENERAL DESIGN CRITERIA**

The general criteria which apply in the execution of closure and restoration operations are as follows:

- *Long term stabilization:*  
The final design will be carried out in such a way that guarantees for long term stabilization have to satisfy external intrusive factors.
- *Postclosure impact:*  
The final design will be carried out in such a way that the radiological and environmental impact is kept to the minimum. The radiological impact will be as near as possible to natural background values of the area. With the aim of achieving this, the release of radon and radioactive particulates as well as surface and ground water runoff will be closely controlled.
- *Minimization of visual impact:*  
The final design will have technical features which allow, wherever possible, integration of the affected areas into the environment.
- *Minimization of maintenance:*  
The final design will be carried out in such a way that requirement of extensive maintenance and elaborate control measures are avoided.
- *Minimization of storage:*  
The number and volume of storage requirements will be as low as possible.
- *Minimization of the rainfall collecting area:*  
The size of the rainwater collecting areas will be kept as low as possible to minimize the effect of erosion and inflow.
- *Protection against wind and erosion:*  
The topographic features of the land will be such that the gradients will be small and suitable for protection against wind. The land will be covered with a cover of vegetation.
- *Minimization of the risks:*  
The remediation activities will be carried out in such a way that they do not cause unacceptable risks to the public or the environment.

### **4. CLOSURE OF SPANISH FACILITIES**

Examples of application of Criteria and Standards specified above are:

#### **4.1. Closure of “La Haba” facility**

The experimental plant for uranium ore treatment “Planta Lobo-G” is sited in “La Haba” township (Badajoz).

#### 4.1.1 Facility description

The objective of this facility was to produce uranium concentrate as final product, with a content of approximately 90% of  $U_3O_8$ . The facility had a treatment capacity of 103 000 tons per year of ore capable of producing 32 tons per year of  $U_3O_8$  maximum.

Hydrometallurgical treatment using acid was adopted for producing uranium ore made up of pitchblende, coffinite, phosphouranolate, autunite, sabugalite and copper uranite, the last two being the most plentiful.

The process developed in this facility consisted of the following steps:

- Ore preparation: reception and storage in heap (low-grade) and in ore-yard (ore); grinding (ore); and classification (fine and coarse fraction ore)
- Leaching: “in situ” leaching for low-grade ore; “in situ” leaching for coarse fraction ore; and conventional leaching for fine fraction ore
- Solid-Liquid separation and preconcentration (fine and coarse fraction ore)
- Concentration (coarse and fine fraction of ore and low-grade ore)
- Final product (precipitation, dried and packed)
- Neutralization
- CIX plant: pilot facility to demonstrate the continuous ion change in fluidized bed column, with the object of studying the recovery of uranium contained in low concentration solutions.

In the first years of plant operation, a small dam was built to deposit the exhausted heap or old heap. When this dam was filled, a new dam with higher capacity was built. This dam is 20 metres high, 277 metres long and has a capacity of 101 000 m<sup>3</sup>.

In the mineral extraction and treatment operations the following types of waste have been generated:

- a.) ***Rock wastes (overburden waste piles)***: coming from open-pit operations in the burrows carried out to have access to the ore. These materials were initially stored in overburden waste piles and later transferred to excavated mine holes (transfer mining).

The volume of rock wastes depends on established threshold cut and the mining activities carried out in the open-pit mine. The lens has been worked with a threshold cut of 200 ppm until 1986 and later of 300 ppm, based on which a conservative estimate indicates that the average content of uranium in the heap is 200 ppm.

The specific activity of all radionuclides in the U-238 chain (U-234, Th-230, Ra-226, Rn-222 and Pb-210) in this heap is 2.1 Bq/g in secular equilibrium. Similarly, the specific activity of each radionuclide in the U-235 disintegration chain is only 0.1 Bq/g, and as such its contribution to the overall radioactive inventory can be disregarded.

- b.) ***Leached waste (heap leaching)***, exhausted poor mineral coming from “in situ” leaching operations. The volume depends on the initial ore grade and the treatment capacity of the plant.

The average specific activity of radionuclides in the U-238 chain present in the exhausted ore is: 2.1 Bq/g for U-238 and U-234 each and 4.2 Bq/g for Th-230, Ra-226 and Pb-210 each, assuming a leaching efficiency of 0% for these nuclides.

- c.) **Tailings (tailings piles)**, coming from the dynamic leaching facilities. Stored in dams or buildings in the vicinity of the plant.

The specific activity of the radionuclides in the disintegration chain of U-238 present in these tailings is 2.4 Bq/g for U-238 and U-234 and 12.5 Bq/g for Th-230, Ra-226 and Pb-210, assuming a leaching efficiency for these nuclides of 0%.

The following table summarizes the inventory of leached wastes existing in the facility at the beginning of 1990 and the surface area occupied by the rock wastes:

Heap leaching number	tons (piled ore)	Overburden piles	Surface (m <sup>2</sup> )
3	53 437	Current	139 169
4	39 992	Old	76 402
5	72 261	M <sup>a</sup> Lozano	53 616
6	30 190		
6 (coarse)	26 000		
7	93 477		
8	23 000		

The quantity of tailings is 80 284 tons and are stored in tailings pile.

#### 4.1.2 Specific criteria applied in the closure and restoration

##### 4.1.2.1 Structures, Buildings and Equipments

The criteria for exemption of material generated from uranium mill dismantling are the following:

- Beta and gamma emitters and low toxicity alpha emitters: < 0,4 Bq/cm<sup>2</sup>
- All other alpha emitters: < 0,04 Bq/cm<sup>2</sup>

These values have been obtained from SS n°6 “Regulations for the safe transport of radioactive material”, IAEA Vienna.

#### 4.1.2.2 *Tailings pile*

The stabilization of the tailings pile will be carried out in such a way that the following criteria are fulfilled:

- The stabilization works will reduce the radon flux values to lower than 1 Bq/m<sup>2</sup>s, averaged over the entire dam surface, taking account of the radon flux in the site.
- The stabilization works will be executed according to the closure criteria based on the eventual objective of conservation and maintenance.
- Generation of liquid effluents due to the circulation of runoff water in rainy times is avoided.
- Reuse of exhausted ore that involves an undesirable risk to the public and the environment (e.g. housing construction) is avoided.

#### 4.1.2.3 *Rock waste and mine site*

The criteria applied will be those established in the Royal Decree 2994 about Restoration of Natural Space affected by Mining Activities.

### **4.1.3 Closure programme characteristics and closure operations**

#### 4.1.3.1 *General Aspects of the Programme*

- “In situ” stabilization of tailings pile, consolidating and protecting it against atmospheric attack by construction of a cover which also fulfils the relevant requirements in the basic criteria.
- Site restoration to the conditions as they originally existed before the activities pertaining to the facilities started.
- Decontamination of buildings and equipment to levels specified in the criteria for free or unrestricted use. In case such levels are not reached the items will be incorporated into the tailings pile. Another alternative is reuse in another similar installation.
- Incorporation of the contaminated soils into the tailing conforming to the relevant criteria.

#### 4.1.3.2 *Description of the closure programme*

The closure activities are summarized in the following paragraph:

##### *Structures, Buildings and Equipments*

There are three possibilities (not mutually exclusive):

- 1.) Decontamination of materials, subjecting to storage without protection or transfer to other installations;

- 2.) Moving reusable equipments as “contaminated material” to another similar installation, taking into account the applicable Standard on Transportation of radioactive materials; and
- 3.) Dismantling and demolition of the plant and incorporating the generated wastes into the tailings.

The alternative 1) requires an analysis of the techno-economic viability of decontamination. The alternative (2) is likely to be carried out only with a limited number of equipment. In the case of alternative (3) it would be necessary to determine the volumes which could be incorporated into dam like contaminated waste dumps and the definition of cut-off level of the previous volumes.

### *Tailings pile*

The first tailings pile which contains the process coarse fractions, has been conditioned through levelling of the “in situ” leach heap, closing it and also making suitable natural drainage systems.

In the new dam, water is getting evaporated and is being forced through sprinkler irrigation over the water-collecting area of the dam.

For the attenuation of radon emission caused by Ra-226 disintegration, a layer of clayey material coming from the overburden waste pile will be placed with adequate thickness to reduce the external dose to the level stipulated in the criteria. In the case of tailings pile, besides sterile materials layer, a layer of leaching heap is placed over it. The actions related to the new dam will be carried out when the water which partially fills the dam, gets eliminated.

In order to protect the clayey material of possible demoiaturizing, it will be covered with a sand layer. Finally, the whole pile will be protected with a layer of soil that makes easy the implantation of the roots of vegetation in order to integrate with the environment (Fig. 1).

### *Natural Land*

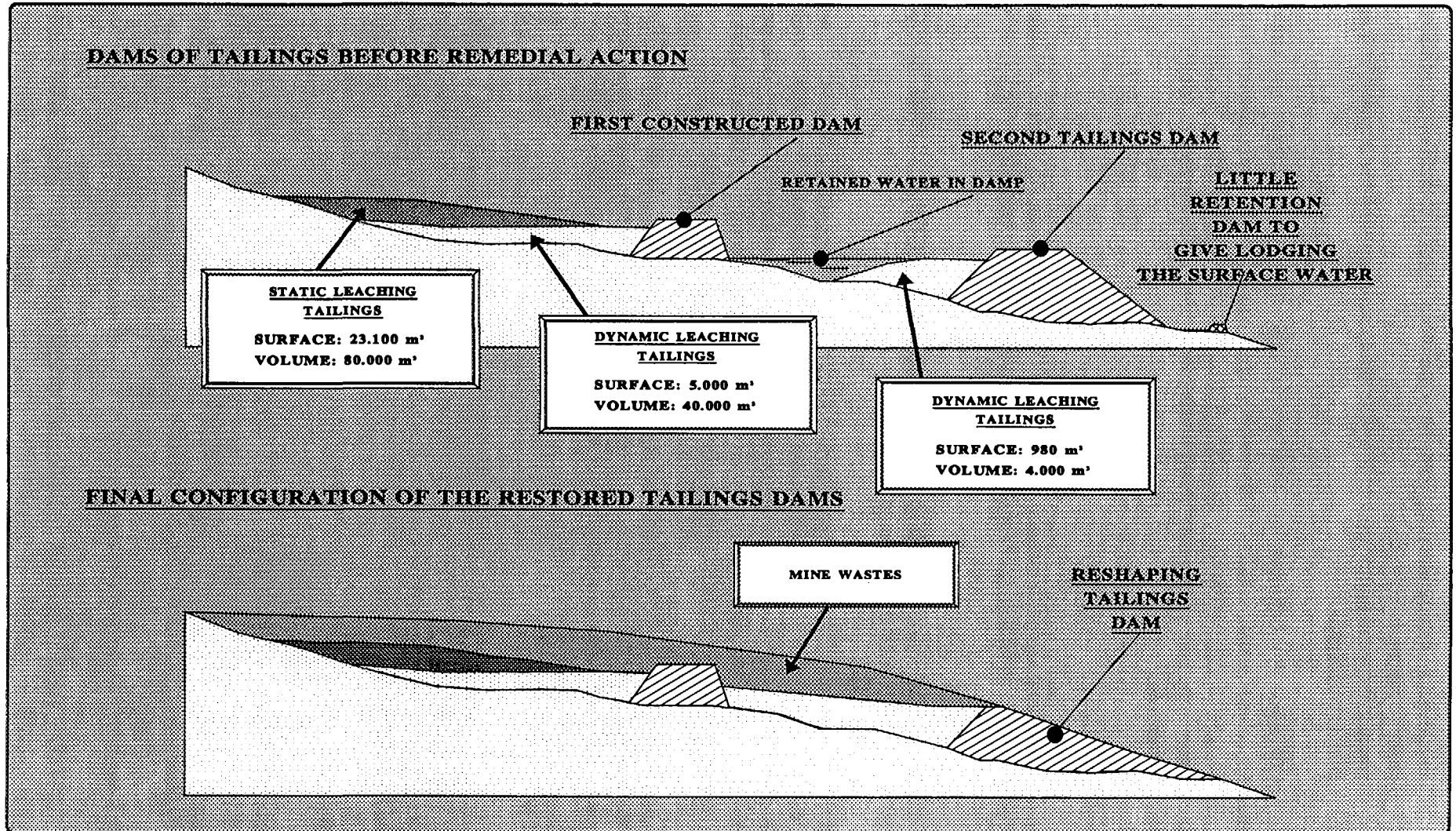
The extent of soil cleaning will depend on the contamination level and the criteria stipulation. First a sampling will be done to determine the Ra-226 concentration and the cleaning need. The contaminated soils will be incorporated into the tailings pile and the excavated area will be filled with fresh soil.

### *Mine Site*

Once the Open-Pit Restoration Plan is implemented the area will be covered with consecutive layers of sterile dense material, coming from the heap M<sup>a</sup> Lozano, until the foreseen level of land restoration is reached. This will act as a barrier against the radon emission with adequate thickness to fulfil the design criteria for shielding.

### *Rock waste (Overburden waste piles)*

Some of them do not require special treatment since from the beginning, cell covers and bench covers have been carried out thereby strengthening their stability and decreasing the effects of erosion.



**FIG.1. LA HABA. DAMS OF TAILINGS, BEFORE AND AFTER RESTORATION WORKS**



#### **4.1.4 Restoration carried out**

To carry out the closure and restoration of a site, the following tasks are involved:

- 1.) Radiometric evaluation of the site:
  - Structures, Buildings and Equipments
  - Natural Land
  - Tailings pile
  - Heap leaching
- 2.) Decontamination and/or dismantling and demolition of treatment plant
- 3.) Decontamination of the natural land
- 4.) Stabilization works of tailings pile
- 5.) Restoration of the open-pit
- 6.) Stabilization of the overburden waste piles
- 7.) Implantation of the autochthonous vegetation species or hydrosowing

These tasks are carried out according to the general design criteria developed based on the above.

#### **4.2. Restoration plan for inactive and abandoned uranium mines**

Environmental Analysis of 26 shut down uranium mine sites, located in the West and South of Spain has been carried out.

##### **4.2.1 Main features of the sites**

The mining activities, carried out from 1950 to 1975 have resulted in the following site conditions having environmental impact:

- 1.) Underground ore extraction structures: unsealed pits and open shafts.
- 2.) Topographical and environmental alterations (Aesthetic impacts): pits, trenches, cavities, gradings, scarfings, loss of vegetation, soil, etc.
- 3.) Land occupied by waste rock piles and mining structures becoming unproductive.
- 4.) Mine and support buildings in bad condition.
- 5.) Radiological impact on the sites in two exposure pathways: air (radon flux, direct radiation and particle emission) and surface water and ground water (natural leaching of waste rock piles, particle releases and ground water flow distribution variations).

The mining sites show wide variation in their condition. For example:

- While in some sites there is hardly any trace of mining works, others have large waste rock piles and surface excavations.
- There are 24 sites where underground operations were carried out and only two are open-pit mines.

- The average radiation levels at contact on the existing waste rock piles range from 50 to 250  $\mu\text{R/h}$  with an average background contact level in nearby sites at 45  $\mu\text{R/h}$ .
- The average Radium concentration in wastes rock piles range from 1 184 Bq/kg to 10 360 Bq/kg.

#### 4.2.2 Assessment criteria

To identify the relative impact due to the mining works, an analysis was performed by comparing the situation which existed previous to mining with the current situation. Prior to mining works, the main features for radiological pathway were:

Land: Undisturbed geology typical of a mineralized area, modifications in radon flux, external radiation

Air: Existence of Rn-222, external radiation, low particles emission

Ground Water and Surface Water: natural contamination (radiological and chemical)

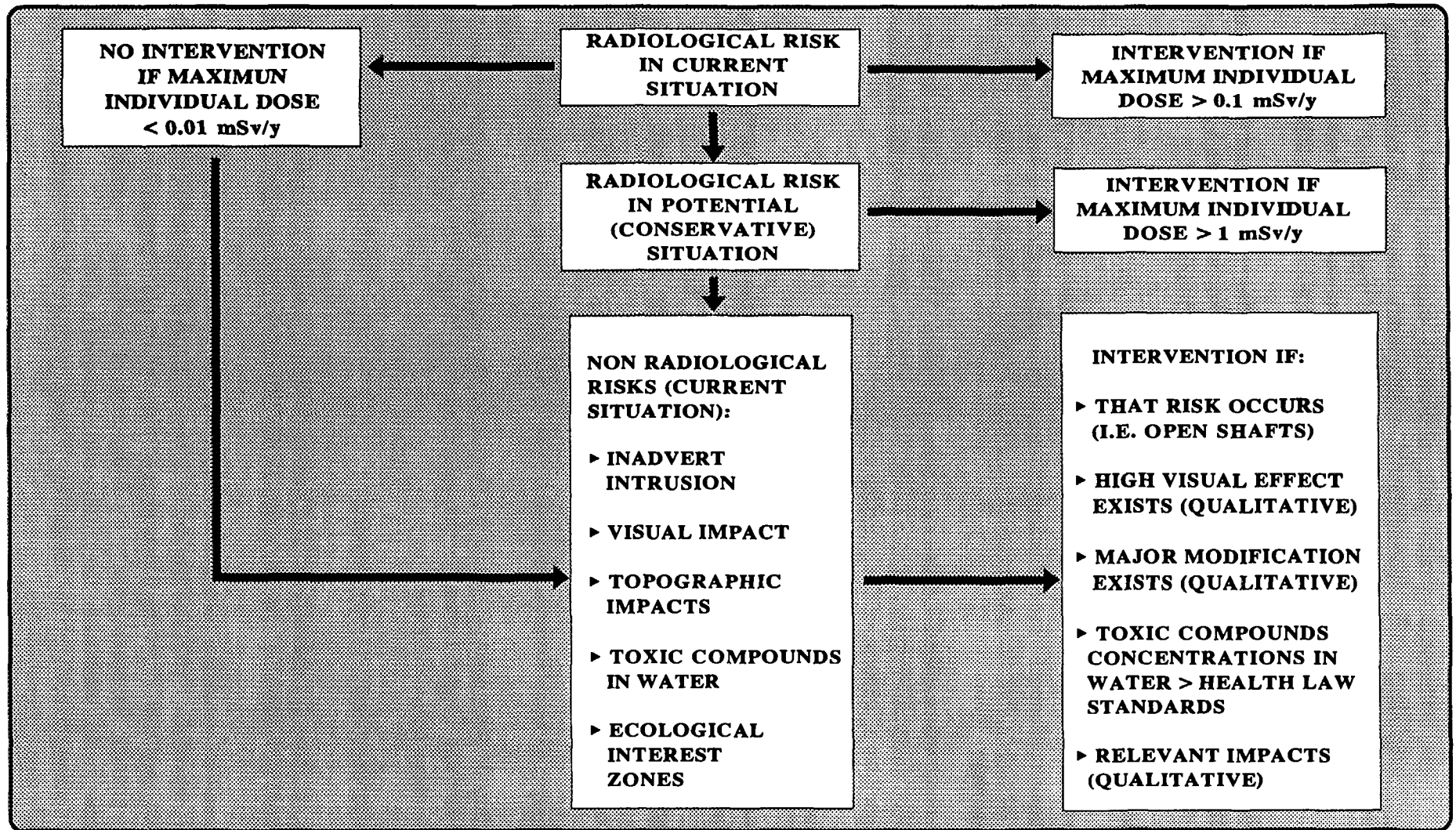
#### 4.2.3 Intervention criteria for the different exposure scenarios

The final results of the detailed radiological and environmental assessment, are analysed according to the following criteria (Fig. 2):

- Nowadays, the intervention is justified when the maximum individual effective dose is greater than 0.1 mSv/y. When the individual effective dose is less than 0.01 mSv/ intervention is not required and it is necessary to evaluate other risks to justify any action.
- When a potential scenario is assessed to result in an effective individual dose greater than 1 mSv/y, the intervention is considered as justified.
- With regard to non-radiological risks, the intervention is justified in the following cases: risk of inadvertent animal and human intrusion, major topographic alterations and major visual and landscape impacts, concentration of toxic compounds in water above regulatory limits and if the area has a special ecological value and relevant impacts to the environment exist.

The doses were calculated for workers and for two classes of critical individual, with the following characteristics:

- *Real Critical Individual*: individual who permanently lives in a real locality near the mining site (8769 h/y) (air pathway) and who consumes off-site near mine water from well (water pathway)
- *Potential Critical Individual*: adult who permanently lives in a hypothetical locality near the mining site (150 metres from a mining pile) (air pathway) and who consumes on-site water from well (water pathway)



**FIG.2. INTERVENTION CRITERIA**

For both cases the following assumptions are made:

- Air: inhalation of radon gas and particles, ingestion of food contaminated by deposited activity and inhalation of radioactive materials air-resuspended;
  - Water: drinking water, ingestion of irrigated vegetables with well water and ingestion of food made up of animal which has consumed of well water;
  - Direct Radiation: on-site occasional exposure with mine-specific factors.
- *Worker (in restoration activities)*: individual who inhales radon gas and particles during restoration works, receiving direct radiation for 170 hours per month by working 80% of the time over the mining pile using machinery of civil works.

#### 4.2.4 Radiological evaluation

The results of the environmental assessment concluded that in 21 of the 26 sites, the effective dose to the most exposed individual by all exposure pathways in the real situation is less than 10  $\mu\text{Sv/y}$ . For this reason in 21 sites there is no justification for intervention due to radiological risks.

The sites where effective doses slightly exceed lightly 0.1 mSv/y are, Cano, Ratones and Gargüera. For the remaining two sites namely, La Virgen and Pedro Negro, the intervention is justified based on a scenario of the potential situation.

#### 4.2.5 Classification

According to the Impact Assessment of the sites and the above criteria, the mines were classified into four groups:

- Group 1 Sites to be restored based on radiological risk in real situation: 3 Mines
- Group 2 Sites to be restored based on radiological risk in potential situation: 2 Mines
- Group 3 Sites to be restored based on non radiological risk in real situation: 14 Mines
- Group 4: Sites not to be restored because of the situation that the negative impact of restoration might outweigh the advantages to the public and improvements in environmental conditions 7 Mines

#### 4.2.6 Objectives and design elements

To remedy the radiological and non radiological impacts and risks, a set of design elements were developed in order to establish the different design approaches for each site:

- 1.) To control the direct radiation and radon flux by providing a protective cover system.
- 2.) To prevent the mining debris and rock wastes dispersion by stabilization of waste rock piles, disposal of mining debris in open pits, and by placement of a cover.
- 3.) To protect the water quality by dewatering of open pits, treatment/evaporation of contaminated waters and backfilling and sealing of shafts.
- 4.) To control the collapse and instability of underground mines by backfilling and sealing shafts and mine openings.
- 5.) To restore the affected sites by grading, reshaping and revegetation of disturbed areas.

### 4.3. “Elefante” plant

The uranium concentrate production plant “Planta Elefante” is sited in Saelices el Chico township (Salamanca) in the same area as “Quercus” plant which at present is still in operation.

During its period of operation the Plant has produced 3 430 tons of  $U_3O_8$  generating 7 150 000 tons of waste from heap leaching and 372 000  $m^3$  of tailings stored in tailings pile: dam 1 (90 000  $m^3$ ), dam 2 (126 000  $m^3$ ) and dam 3 (156 000  $m^3$ ). The dams 2 and 3 are at present closed down.

#### 4.3.1 Facility description

The production process consist of direct acid attack of the uranium ore made up of pitchblende, coffinite, phosphouranolite, autunite, sabugalite and copper uranita, the two last being the most plentiful.

The process developed in this facility consisted of the following steps:

- a.) Ore preparation
- b.) “In situ” leaching
- c.) Extraction-Reextraction
- d.) Precipitation and Filtration
- e.) Drying and packing
- f.) Tailings pond

#### 4.3.2 Current status of facility

The situation with respect to structures, buildings and equipments is as follows:

- Equipment and materials which are operable are incorporated into Quercus Plant
- Short and long term reuse of materials identified
- Materials generated from structures, buildings, equipments and sterile materials are classified and disposed as appropriate.

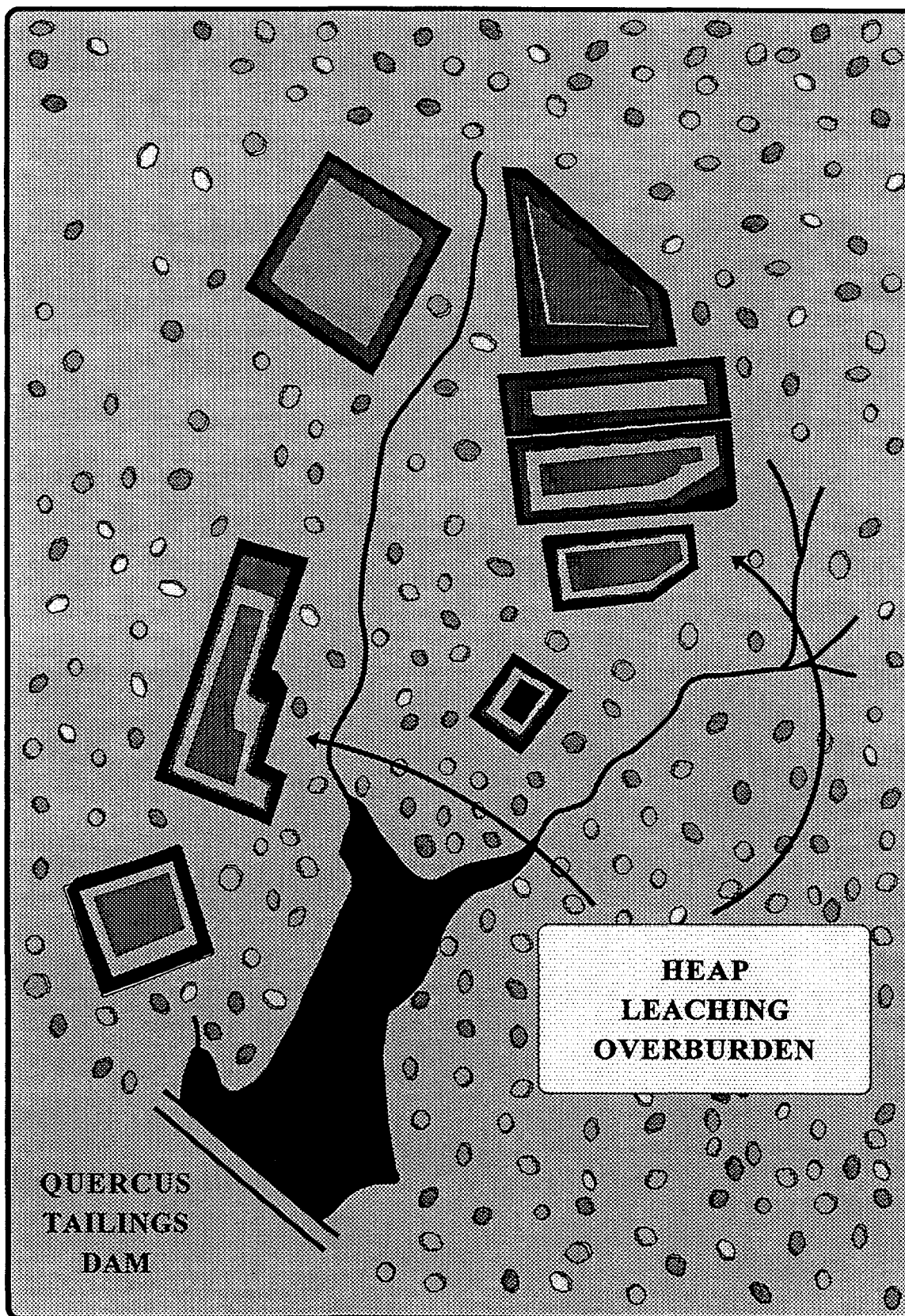
The contaminated materials to be dispersed belonging to structures, buildings and equipments can be grouped under equipments, and dismantled structural debris. The disposal of these wastes will be carried out “in-situ” and they will be covered with the exhausted ore proceeding to the heap leaching (“in situ” leaching). Later according to the selected alternative for the heap leaching closure, a multi layer 3 metre thickness of sterile materials is dumped and clayey vegetation soil covered to restore the site radiological conditions similar to the background.

The two classes of sterile materials generated during the process are: solid (heap leaching wastes), and sludges generated during the neutralisation (tailing ponds). Qualitative and quantitatively the two sterile classes are different and have to be handled, stored and disposed by closure in distinct ways.

#### *Heap leaching:*

All uranium minerals treated in the Elefante Plant have undergone in-situ leaching. The heap leaching wastes were conditioned resulting in truncated pyramidal shape with a height in

the range of 6 to 9 metres (Fig. 3). During the operational phase 2,2 million tons of high-grade ore (initial grade 1225 g  $U_3O_8$ ) and 5 million tons of low-grade ore (initial grade 442 g  $U_3O_8$ ) were treated. The efficiency of recovery after treatment was 80% in high-grade ore and 67% in low-grade ore and as a whole the recovery was 74%.



**FIG.3. ELEFANTE SITE BEFORE REMEDIATION**

The wastes of exhausted mineral in heaps are 7.2 million tons with an average content of 0.18 kg U<sub>3</sub>O<sub>8</sub> per ton. In spite of the uranium content in the exhausted ore being low, about 99.5% of Th-230 and 99% of Ra-226 remain in the exhausted ore due to poor solubility during in-situ leaching. This situation affects the heap closure concerning confinement and long term stability due to dispersion of these nuclides.

#### *Tailings ponds:*

The technical characteristics of the Tailings Pond number 3 (the dams 1 and 2 are already closed down) are: maximum height 12.5 metres, total length 163 metres, maximum capacity 150 000 m<sup>3</sup>. Ra-226 present in the sludges is minimum (specific activity 29.6 Bq/kg), as also the U-238 content (< 1 ppm). Practically the whole of the solid fraction of the sludges is mainly made up of calcium and barium sulphate and chloride. For this reason, the closure of the dams is carried out not only to avoid the dispersion of radionuclides, but also to seal the surface at the top of the pile, improving its stability.

### **4.3.3 Specific design criteria**

The main objective of the dismantling and closure operations of Elefante Plant is that once completed, the radiological condition of the site will be similar to the original background level.

#### *4.3.3.1 Site criteria*

- a.) The closure and stabilization in situ of the heap leaching and tailings pond, favour the criterion of storing all generated wastes in an only site to reduce and make easy the operations of post-closure surveillance. In the same basin will be sited the tailings pile of Quercus Plant, at present operating, whereby in the future, the entire waste will stay integrated in the same structure of waste storage.
- b.) The objective of the closure works is to achieve maximum possible isolation of the wastes to avoid dispersion due to natural phenomenon without need for major maintenance. The tailings pile of Quercus Plant which collects all possible filtrates of the basin, has a waterproofing to isolate the waste site from the ground water circulation.
- c.) The water drainage area is small (4.4 km<sup>2</sup>) and to isolate the waste storage area, a perimetral channel has been built which collects the natural waters of the drainage area and divert them to Agueda river. This channel minimizes the flooding and reduces the potential to erode or move parts of the waste area.
- d.) In the storage area there is no break which could cause a design earthquake intensity of 7 (Richter Scale) to be exceeded.

#### *4.3.3.2 Radiological Protection Criteria*

- a.) With a view to render closed sites suitable for use as forest or unirrigated agricultural land, it is to be ensured that the added residual activity is less than 1 Bq/g for U-238 and its descendants. Additionally, the radiation exposure is kept lower than 0.3 µGy/h, measured at a point 1 metre over the soil surface.

- b.) The annual individual dose to public as a consequence of the closure, will be lower than 0.3  $\mu\text{Gy}/\text{y}$ . To establish this value, the operational limit fixed for Quercus Plant is taken as reference.

#### 4.3.3.3 *Criteria for classification and storage of materials and equipment*

- a.) The dismantling and closure operations of Elefante Plant are carried out within the framework of operations of ENUSA Centre in Saelices el Chico, where the productive operations at Quercus Plant are going on.
- b.) The dismantling and closure operations of Elefante Plant will be carried out in two phases. First, in the short term, developments specific to the plant which will be developed in short term and will include the dismantling of the sections which have not been incorporated into the Quercus Plant, the closure of heap leaching and tailings pond. In the second phase, the equipment and systems that have been reused in Quercus Plant and the sections that have been incorporated in it will be integrated within the general closure programme of Quercus Plant.
- c.) The equipment and systems from Elefante Plant dismantling, such as dust collection systems, radiological survey systems, fire protection systems, etc., as well as other useful process equipments, will be used at Quercus Plant.

#### 4.3.3.4 *Criteria for post-closure survey*

- a.) Once the dismantling and closure operations are completed a survey system of closed areas (heaps and tailings) will be established to check the fulfilment of all conditions.
- b.) The survey programme will have two phases, one specific to the first five years and the other for a longer duration. Finally, the survey programme will stay integrated to the overall Survey Programme of Quercus Plant.

#### 4.3.3.5 *Economic Criteria*

- a.) According to the techno-economical study vide BOE number 51 of 28, February 1987 condition 3.5, during the operational phase, a Restoration Fund was established to cover the Closure Phase.

### 4.3.4 **Closure**

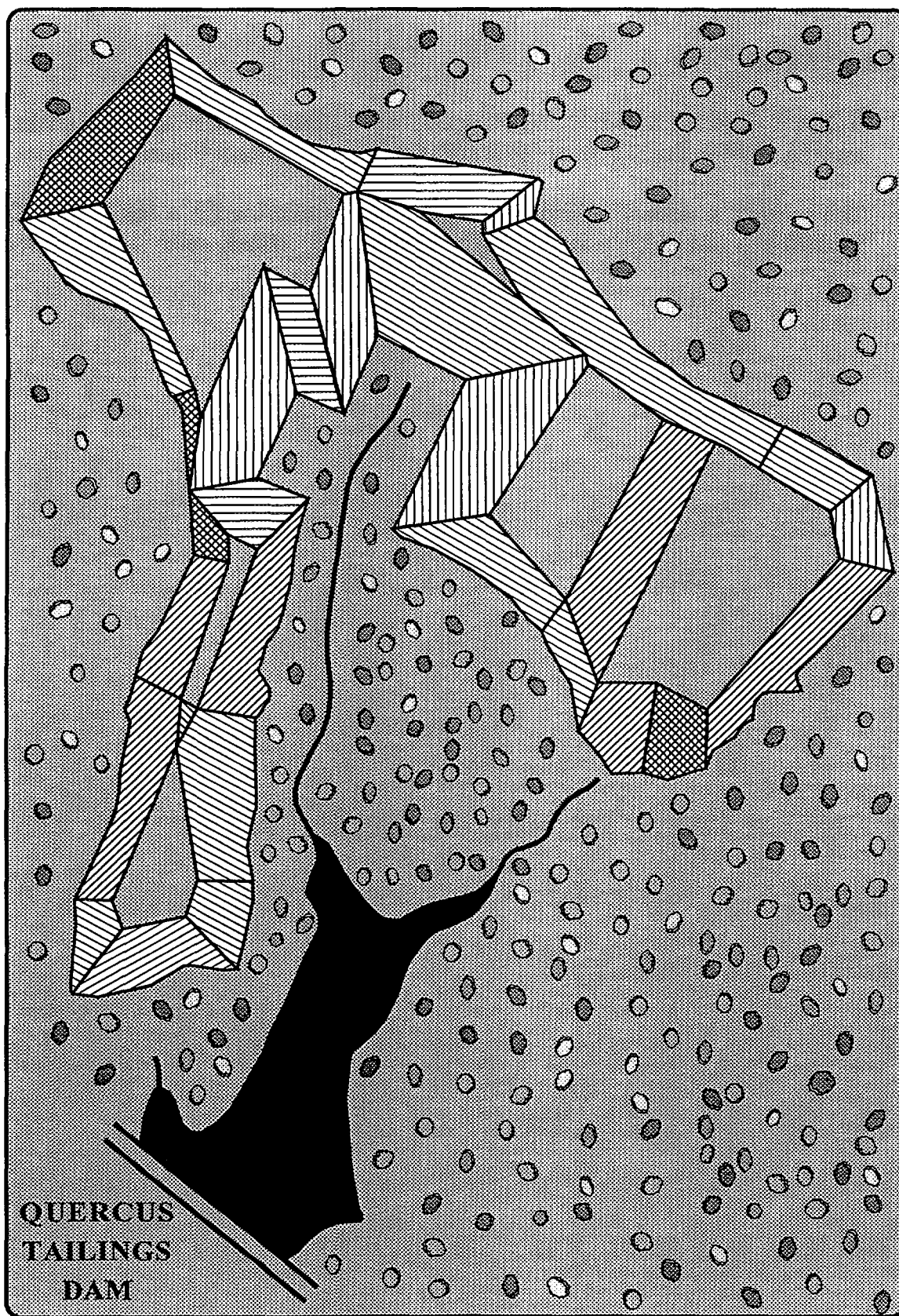
Three possible alternatives of closure have been studied: In-situ closure, closure in the mine hole and closure in a suitable geomorphological structure.

In-Situ Closure is considered a more suitable alternative due to technical (mainly that the closure could be simultaneous, partly, with the production labour of Quercus), economical and safety (mainly the reduction of the post-closure survey due to the integration of heap leaching and tailings pond into a common structure) considerations.

In-situ closure basically consists of spreading the exhausted ore stored in tailings pile on a previously prepared land to get a slope of 5:1 to guarantee their long-term stability. Subsequent waterproofing, if necessary, with clay layer and surface overlap of the new structure made with



arkose, sterile mine and vegetation soil will reduce the radon emanation and protect the pile against wind and water erosion (Fig. 4).



**FIG.4. ELEFANTE SITE AFTER REMEDIATION**

The spread of the tailing pile will also be useful to cover the materials and wastes from closure of Elefante Plant, as well as the dams 2 and 3 will be covered with the exhausted ores. With the aim of minimizing the radon emissions, the highest grade ore will stay in the lower layer, covered with the low-grade ore.

## **5. CONCLUSION**

- 1.) In Spain there are Standards and Regulations to develop site remediation tasks in accordance with the Standards and Regulations of International Organizations.
- 2.) There exists an overall restoration methodology applicable for a whole site. The methodology has adequate flexibility for application to different restoration scenarios.