# PALOMARES :
# FROM THE ACCIDENT TO THE REHABILITATION PLAN


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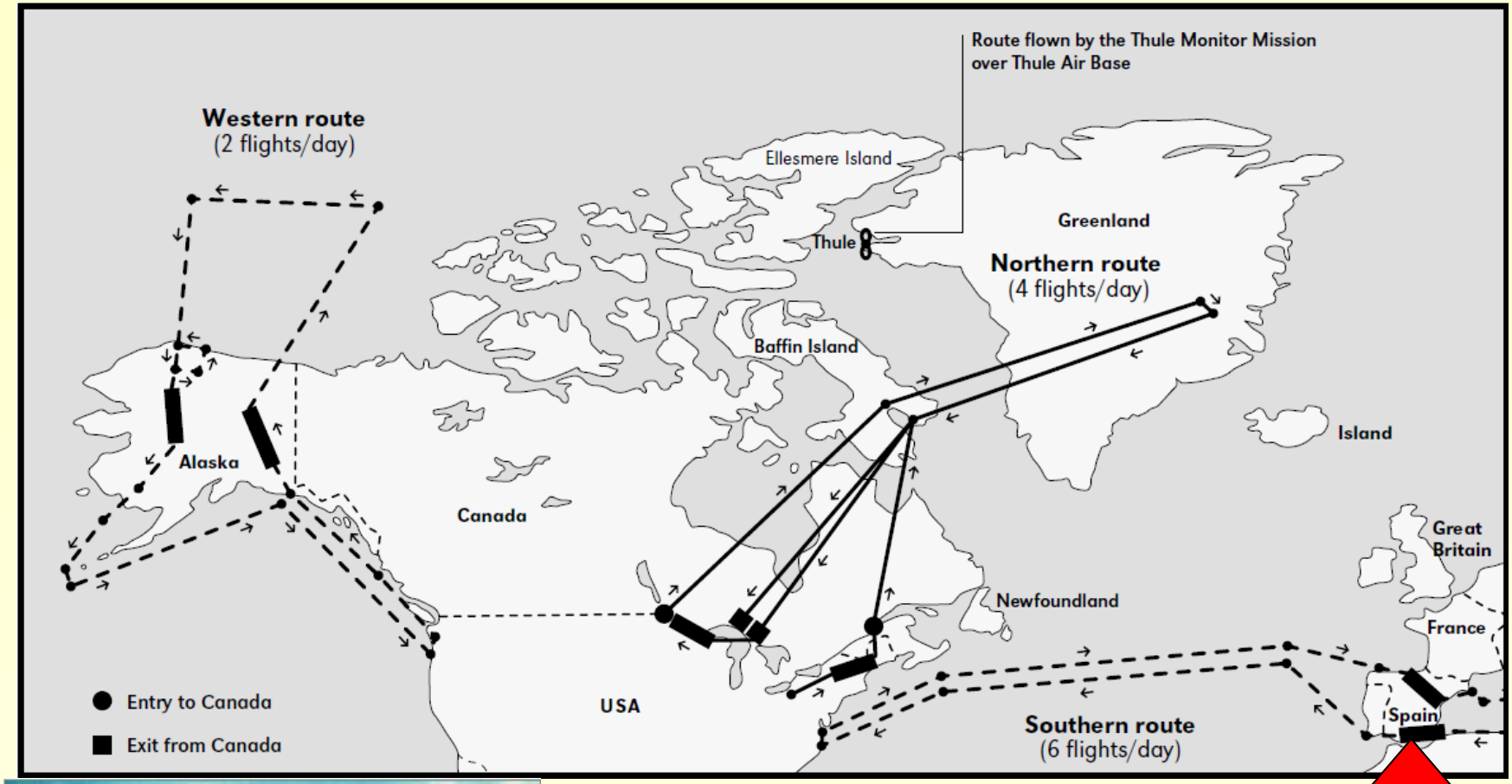
**Environmental Restoration of Radioactive Soils**

**Ministry of Science and Innovation**


**INTERNATIONAL SYMPOSIUM ON DECONTAMINATION**
**– TOWARDS THE RECOVERY OF THE ENVIRONMENT –**
**16 – 17 OCTOBER 2011**
**FUKUSHIMA, JAPAN**

# THE PALOMARES ACCIDENT




**REFUELING OVER SPAIN HAD BEEN A STANDARD DAILY PROCEDURE IN THE "CHROME DOME FLIGHTS" SINCE 1961, FRAMED IN MILITARY AGREEMENTS SIGNED BY US AND SPAIN IN 1953.**

# THE PALOMARES ACCIDENT

- US MILITARY AIRCRAFT ACCIDENT OVER PALOMARES ON JANUARY 1966: COLLISION OF A KC-135 FUEL TANKER AND A B-52 BOMBER CARRYING FOUR NUCLEAR WEAPONS DURING IN-FLIGHT REFUELING.

- THREE BOMBS WERE FOUND ON LAND ON THE NEXT DAY AFTER THE ACCIDENT. BOMB nº 1 WAS FOUND INTACT BUT BOMBS nº 2 AND nº 3 WERE SERIOUSLY DAMAGED DUE TO THE DETONATION OF THE NON-NUCLEAR EXPLOSIVE UPON IMPACTING THE GROUND.

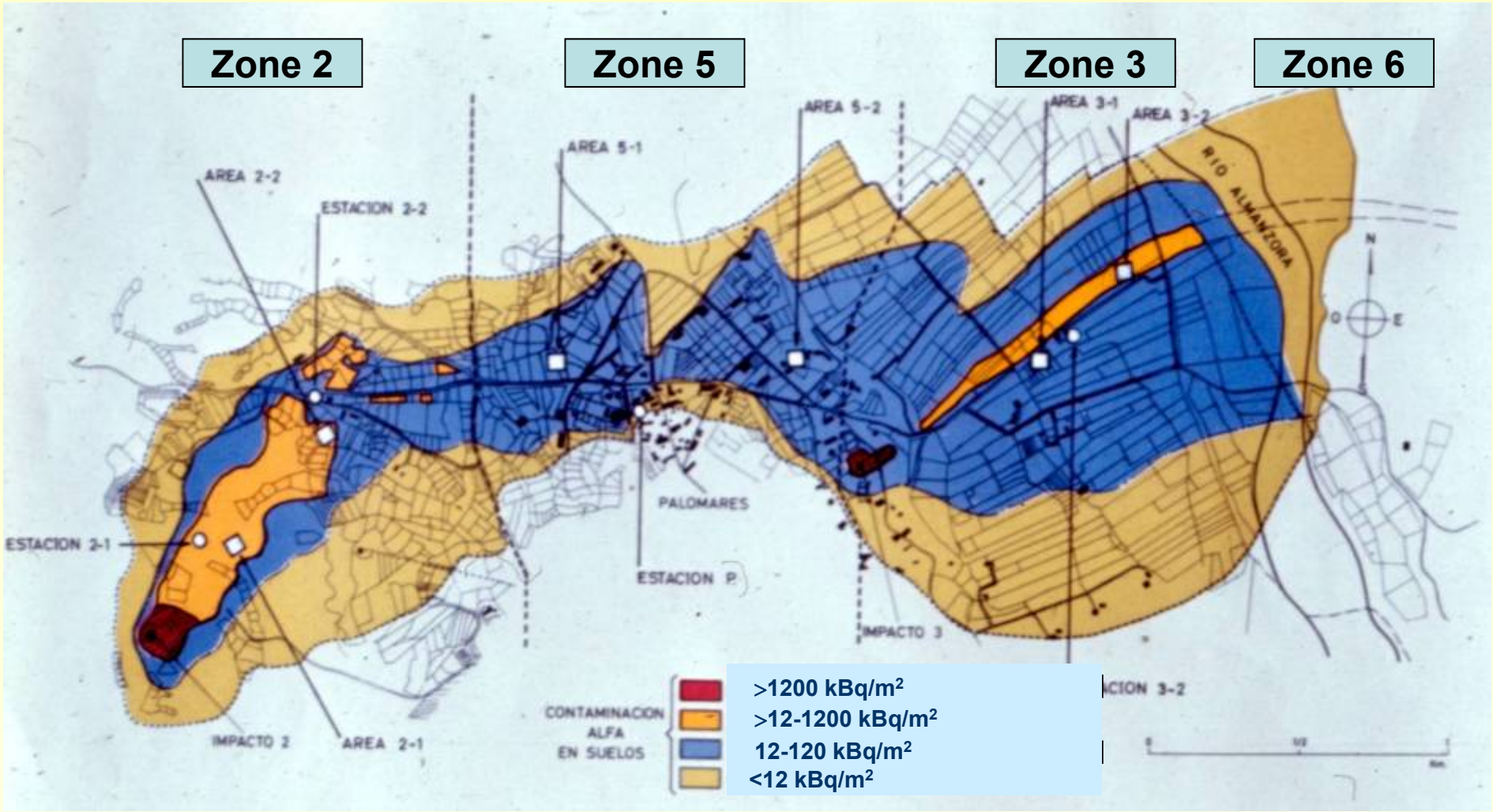
- BOMB nº 4 FELL INTO THE MEDITERRANEAN SEA AND WAS RECOVERED INTACT FROM THE MEDITERRANEAN SEA ABOUT 9 Km OFFSHORE 80 DAYS AFTER THE ACCIDENT.

- EMERGENCY ACTIONS WERE TAKEN BY USA AND SPANISH AUTHORITIES TO RECOVER THE DAMAGED WEAPONS AND CLEAN THE CONTAMINATED AREA.

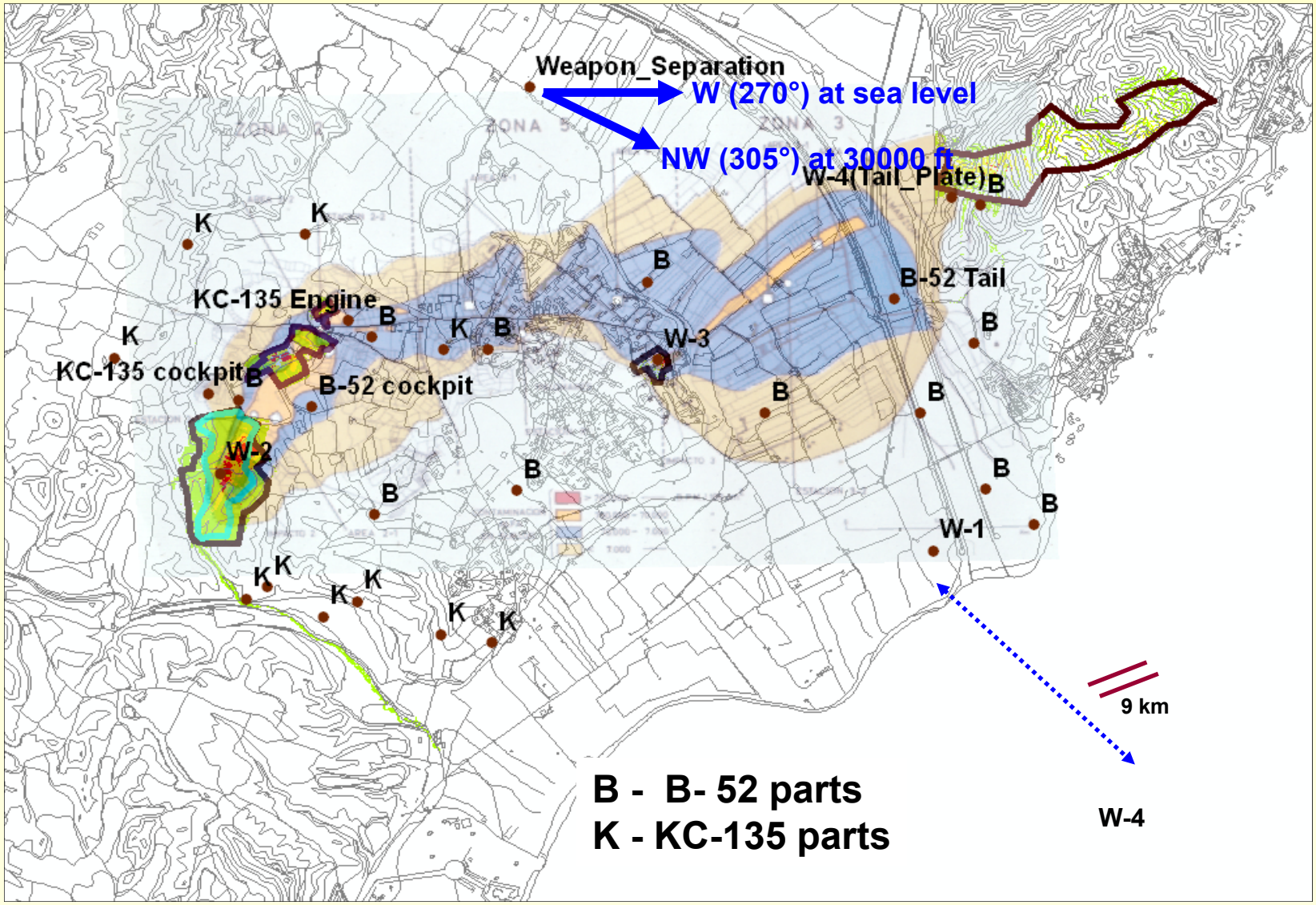
- RADIOACTIVE CONTAMINATIONS DEPOSITED IN SOILS (MAP).

- SUBSEQUENTLY, RADIOLOGICAL MONITORING PROGRAM OF THE POPULATION AND THE ENVIRONMENT IMPLEMENTED BY THE CIEMAT.

# 'ZERO LINE' ESTABLISHED BY US-AF IN FEB 11th, 1966 (263 ha)



# COMPARISON OF INITIAL ZERO LINE AND THE CURRENT AREAS THAT REMAINS AFFECTED AT PRESENT



# REMEDIATION 1966: USA AND SPANISH AUTHORITIES COMPROMISES

## CROPS & VEGETATION

- **ALL CROPS WOULD BE REMOVED FROM AREAS WITH Pu LEVELS OVER 700 cpm* (1 Bq.g$^{-1}$**) AND VEGETATION WITH LESS THAN 400 cpm (0.6 Bq.g$^{-1}$) WAS TO BE BURNED.**
- **VEGETATION WITH Pu LEVELS OVER 400 cpm (0.6 Bq.g$^{-1}$) WOULD BE REMOVED TO THE USA.**

## SOIL

- **WITH Pu LEVELS GREATER THAN 60,000 cpm (88 Bq.g$^{-1}$) WOULD BE REMOVED TO THE USA.**
- **WITH Pu LEVELS BETWEEN 700→ 60,000 cpm (1→ 88 Bq.g$^{-1}$) WOULD BE WATERED AND PLOWED TO DILUTE THE SURFACE CONCENTRATION.**
- **NO REMEDIATION OTHER THAN WATERING WAS REQUIRED FOR AREAS WITH Pu LEVELS LOWER THAN 700 cpm (1 Bq.g$^{-1}$).**
- **WITH Pu LEVELS BELOW 10,000 cpm (14.7 Bq.g$^{-1}$) WOULD REMAIN WHERE OTHER REMEDIATION MEASURES COULD NOT BE APPLIED.**

**VOLUME REMOVED OF SOIL: 832 m$^3$ (from 2.2 ha in Area 2)**
**VOLUME REMOVED OF VEGETATION (MULCHED AND STORED): 306 m$^3$**
**SOIL WATERED AND PLOWED: 115 ha**

**AGREEMENT OTERO – HALL, 1966/02/25 – ATOMIC ENERGY COMMISSION USA / JUNTA DE ENERGÍA NUCLEAR, SPAIN; "COLLABORATIONS IN THE FIELDS OF HEALTH AND SAFETY. INVESTIGATIONS ON PHYSIOLOGICAL AND ECOLOGICAL BEHAVIOUR OF PLUTONIUM OXIDE IN A PREVIOUSLY CONTAMINATED RURAL AREA THAT HAS BEEN DECONTAMINATED".**

***(*) cpm (counts per minute) ( PCAC – 1S Detector)***

***130 cpm = 1 µg Pu.m$^{-2}$ ( 0.0613 µCi.m$^{-2}$ = 2.3 kBq.m$^{-2}$)***

***(**) Fresh contamination resided in the first cm of soil and therefore 1 kBq.m$^{-2}$ means about 0.1 Bq.g$^{-1}$***

# FACTORS AFFECTING THE RADIOLOGICAL SITUATION IN PALOMARES

• THE 1966 REMEDIATION WORKS WERE VERY EFFECTIVE IN REMOVING HIGHLY CONTAMINATED SOILS AND VEGETABLES AND REDUCING THE REMAINING SOIL CONTAMINATION BY DILUTING THE SURFACE CONTAMINATION IN DEEPER SOIL.

•THEREFORE, THE ONLY ZONES WITH REMARKABLE LEVELS WERE EXPECTED TO BE NEAR THE IMPACT POINTS #2 AND #3 AND THE AREAS WHERE REMEDIATION COULD NOT BE PERFORMED, SUCH AS SOME HILLS IN ZONE 2 OR SIERRA ALMAGRERA (ZONE 6).

• AT LEAST TWO IMPORTANT WATER FLOODS OCCURRED IN THE AREA SINCE 1966. FOR THIS REASON, MAJOR WORKS TO CHANNEL THE ALMANZORA RIVER WERE CONDUCTED IN THE 1980$^{S}$.

• INTRODUTION OF INTENSIVE FARMING IN 1980$^{S}$ CAUSED IMPORTANT CHANGES IN LAND USE IN AREA 2 WITH LAND FLATTENING WORKS AND THE CONSTRUCTION OF TWO WATER RESERVOIRS NORTH OF THIS AREA.

• ECONOMIC DEVELOPMENT BASED IN THE VALUABLE TOURISTIC ATTRACTIVE IS INCREASING SINCE 1990$^{S}$ AND RURAL AREAS ARE BECOMING IN NEW URBAN ZONES.

# PANORAMIC VIEW OF PALOMARES

# RADIOLOGICAL SURVEILLANCE PROGRAMME BACKGROUND

- **A RADIOLOGICAL EVALUATION OF LAND IN ZONE 2 WAS MADE IN 1996 RESULTING IN A RADIOLOGICAL INVENTORY OVER PREVIOUSLY ESTIMATED.**

- **MOVEMENTS OF LAND, CONSTRUCTION ENHANCEMENT AND EXPANSION OF AREAS DEDICATED TO INTENSIVE FARMING ARE BEING CONSIDERED AS A POSSIBLE OUTCOME OF THIS CHANGE.**

- **IT BECAME APPARENT THE NEED TO ADOPT CONTROL MEASUREMENTS OF LAND USE BASED IN A RADIOLOGICAL CHARACTERIZATION OF THE PALOMARES AREA.**

- **RADIOLOGICAL SURVEILLANCE PROGRAMME : 1986 →2010.CIEMAT BIANNUAL REPORTS TO THE NUCLEAR SAFETY COUNCIL (CSN).**

- **IMPLEMENTING ARRANGEMENT ON COOPERATION IN RESEARCH OF RADIOLOGICAL EVALUATIONS, 1997/09/15 → 2009/09/30. DEPARTMENT OF ENERGY (DOE), USA / MINISTRY OF INDUSTRY AND ENERGY, SPAIN. ANNUAL REPORTS TO THE DOE.**

# ENVIRONMENTAL RESEARCH PLAN IN RADIATION SURVEILLANCE

- **THE ENVIRONMENTAL RESEARCH PLAN IN RADIATION SURVEILLANCE WAS APPROVED BY THE CSN 12/11/2003 AND BY THE COUNCIL OF MINISTERS ON 12/17/ 2004, WICH INCLUDED TOTAL AND PARTIAL LAND USE RESTRICTIONS.**

- **THE 3-D RADIOLOGICAL CHARACTERIZATION WAS CARRIED OUT IN THE PERIOD 2006 →2008. THE BASIC PURPOSE WAS:**

  **i) TO EVALUATE THE RESIDUAL SOURCE TERM IN THE ZONES AFFECTED SO THE CURRENT RADIATION INVENTORY COULD BE FOUND AND REPRESENTED IN 3-D.**

  **ii) TO IDENTIFY AND VERIFY THAT THE RELATIONSHIP BETWEEN THE $^{239+240}$Pu AND $^{241}$Am WAS CONSTANT AT AROUND 4.**

  **iii) TO DEVELOP A 3-D MODEL OF $^{241}$Am ACTIVITY CONCENTRATION THAT ALLOWED VISUALIZATION OF THE DEPTH DISTRIBUTION OF CONTAMINATION.**

**SINGULAR STUDIES:**

- **RADIOLOGICAL EXTENSIVE CHARACTERIZATION: 660 ha.**
- **INTENSIVE RADIOLOGICAL CHARACTERIZATION: 41 ha.**
- **GEORADAR INSPECTIONS FOR PITS LOCATION.**

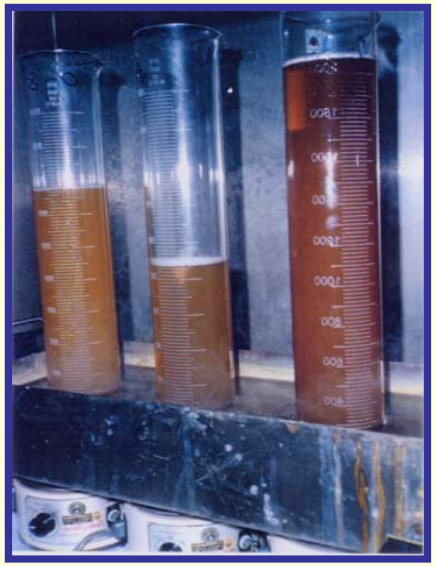
# ENVIRONMENTAL RADIOLOGICAL PROGRAM (1966 → PRESENT)

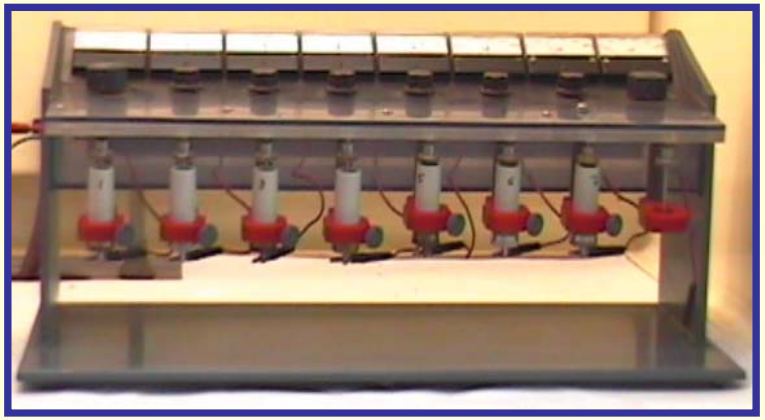
| SAMPLES TYPES | | NUMBER OF STATIONS | FRECUENCY OF SAMPLING | ANALYSED RADIONUCLIDES |
|---|---|---|---|---|
| VEGETATION | WILD (BIOINDICATORS) | 2 | EVERY 6 MONTHS | $^{239+240}$Pu (α spec)<br>$^{241}$Am (γ spec) |
| | CULTIVATED (GREENHOUSE/OPEN FIELDS) | 10 | EVERY 6 MONTHS | |
| AIR | TOTAL SUSPENDED PARTICULATES | 3 | CONTINUOUS (≅150 samples .y$^{-1}$) | $^{239+240}$Pu (α spec) |
| OTHERS | ANIMAL PRODUCTS (HONEY, MILK, SNAILS, FISH) | 4 | ANNUAL (5 samples.y$^{-1}$) | $^{239+240}$Pu (α spec)<br>$^{241}$Am (γ spec) |
| | WATER (FRESH, SEA, TAP) | 4 | ANNUAL (4 samples.y$^{-1}$) | $^{239+240}$Pu (α spec) |
| | SEDIMENTS (RIVER, BEACH) | 3 | ANNUAL (3 samples.y$^{-1}$) | $^{239+240}$Pu (α spec)<br>$^{241}$Am (γ spec) |

# PERSONAL RADIOLOGICAL SURVEILLANCE PROGRAM (1966 → 2010)

## BIOASSAY CONTROLS

- **VOLUNTARY.**
- **24 hrs URINE SAMPLES ARE COLLECTED OUTSIDE OF THE CONTAMINATED AREA OF PALOMARES.**
- **Pu AND Am ANALYSES ARE PERFORMED USING:**
  - **CO-PRECIPITATION OF ACTINIDES AS PHOSPHATES.**
  - **PURIFICATION WITH IONIC- EXCHANGE RESINS.**
  - **PREPARATION OF THE α-COUNTING SOURCE.**
  - **MEASUREMENT BY α -SPECTROMETRY, ICP-MS,AMS.**





# PERSONAL RADIOLOGICAL SURVEILLANCE PROGRAM (1966 → 2010)

| | |
|---|---|
| **POPULATION WITH BIOASSAY CONTROLS (BC)** | 1,073 |
| **NUMBER OF BC PERFORMED IN THE LABORATORY** | 5,004 |
| **NUMBER OF BC WITH A POSITIVE RESULT (α SPEC)** | 154 (3%) |
| **NUMBER OF BC WITH A NEGATIVE RESULT (α SPEC)** | 4,850 (97%) |
| **PEOPLE WITH ANY POSITIVE RESULT** | 119 |

| | | | | |
|---|---|---|---|---|
| **Nº OF POSITIVE RESULTS** | 1 | 2 | 3 | 4 |
| **Nº OF PEOPLE** | 91 | 22 | 5 | 1 |

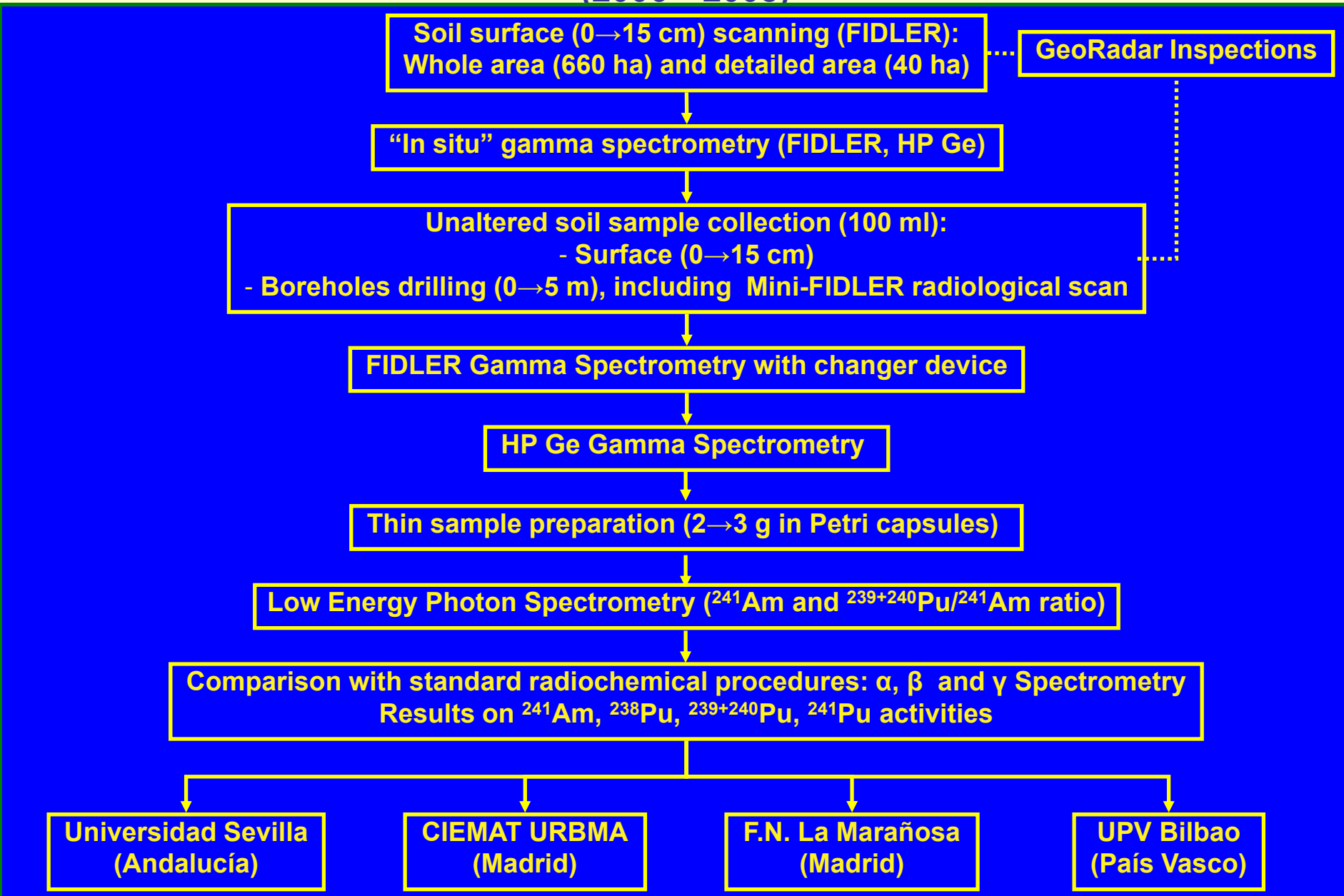
# CRITERIA FOR LAND USE RESTRICTIONS

**RADIOLOGICAL DATA FROM THE DIFFERENT SURVEYS ARE PRESENTED IN GRAPHS AND MAPS USING A COLOR CODE THAT IS BASED ON THE CRITERIA FOR THE USE OF TERRAINS OF PALOMARES ESTABLISHED BY THE NUCLEAR SAFETY COUNCIL (CSN) IN 2003, AND THAT WERE CONFIRMED IN 2007:**

| | |
|---|---|
| | **NO USE RESTRICTIONS: DOSES DUE TO THE EXISTING SOURCE TERM IN SOIL(*) ARE LOWER THAN 1 $mSv.y^{-1}$.** |
| | **PARTIAL USE RESTRICTIONS AND FURTHER STUDIES ARE NEEDED WHEN THE DOSES DUE TO THE EXISTING SOURCE TERM IN SOIL CAN REACH 1 $mSv.y^{-1}$. THE DOSE GUIDANCE CONCENTRATION LEVELS (DGCL) FOR THIS DOSE VALUE IS 5 $Bq.g^{-1}$ FOR $^{239+240}Pu$ OR 1 $Bq.g^{-1}$ FOR $^{241}Am$ (**).** |
| | **TOTAL RESTRICTION FOR ANY USE: THE DOSES DUE TO THE EXISTING SOURCE TERM IN SOIL ARE GREATER THAN 5 $mSv.y^{-1}$. THE DGCL FOR THIS DOSE VALUE IS 25 $Bq.g^{-1}$ FOR $^{239+240}Pu$ OR 5 $Bq.g^{-1}$ FOR $^{241}Am$.** |

**(*) Soil is defined as the first 15 cm of material from the terrain surface.**
**(**) It is assumed a surrogate ratio $^{239+240}Pu/^{241}Am=4$.**

# PALOMARES 3-D RADIOLOGICAL CHARACTERIZATION (2006→2008)



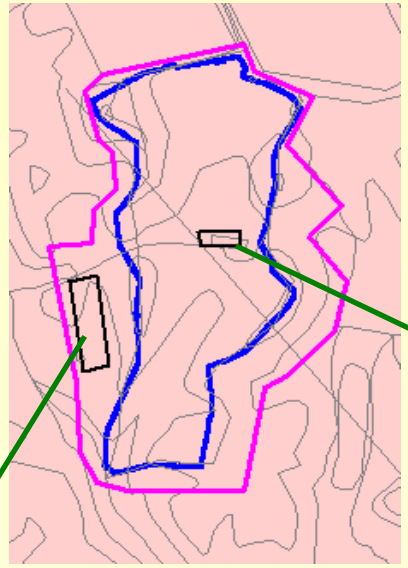
# METHODS TO ESTIMATE THE $^{241}$Am CONCENTRATION IN SURFACE SOIL

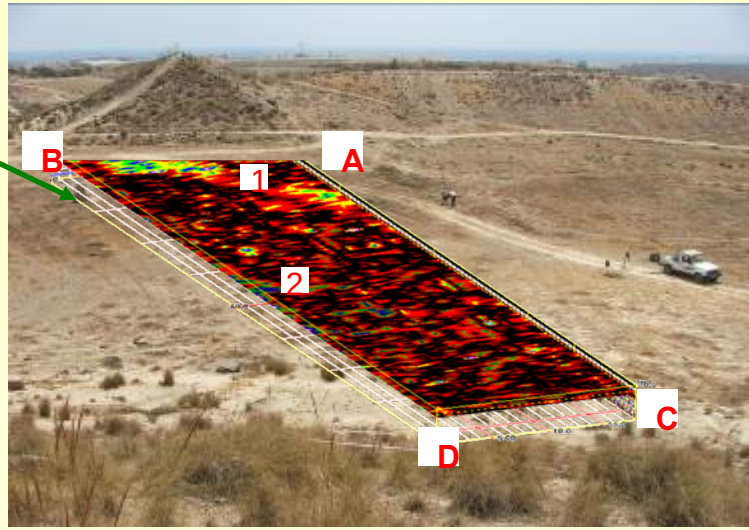
## SURFACE SCANNING

## "IN SITU" FIDLER & Ge SPECTROMETRY

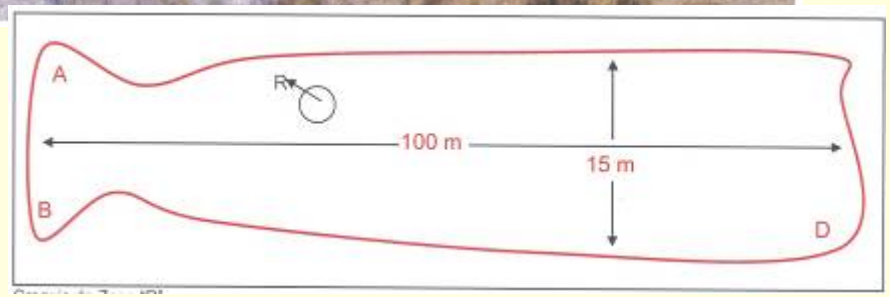
## UNALTERED SOIL SAMPLE COLLECTION AND γ-SPEC IN LABORATORY

# GEORADAR INSPECTIONS AT ZONE 2





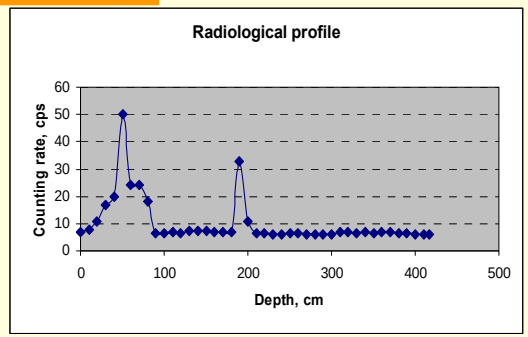

**PIT B**
**100 m x 1 m AND 3.0 m DEEP**
**VOLUME ≈ 3,000 m³**



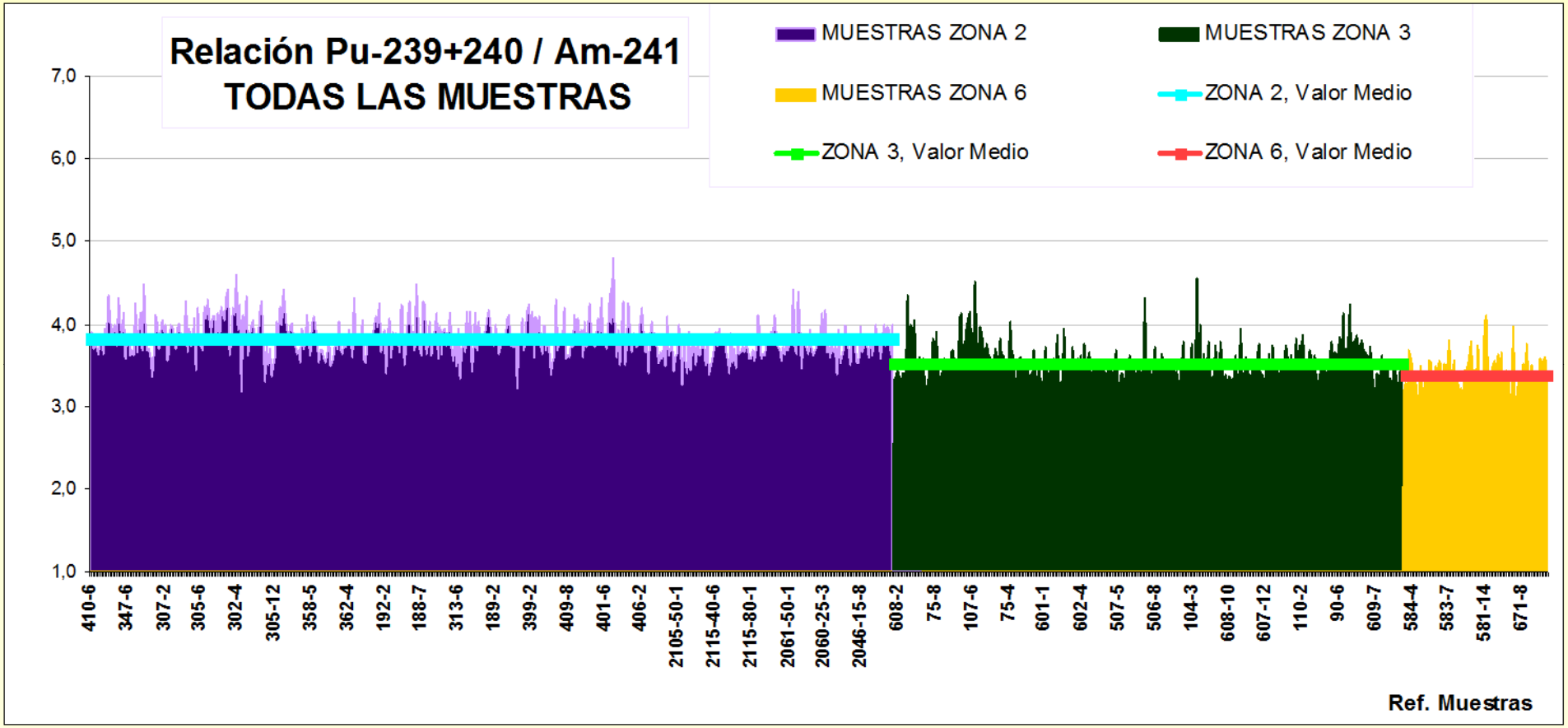

**PIT A**
**40 m x 10 m AND 2.5→3.0 m DEEP**
**VOLUME ≈ 1,000 m³**

# COLLECTION OF UNALTERED SOIL FROM DRILLING


- **734 UNDISTURBED SAMPLES FROM 321 DRILLS UP TO 5 m DEPTH.**
- **RADIOLOGICAL SCAN WERE PERFORMED IN EACH TUBE AND THEN SELECTED PORTIONS WERE CUT FROM THE FILLED PIPE TO PROVIDE 100 ml BEAKERS.**
- **THE SAMPLES WERE TRANSPORTED TO CIEMAT MADRID WHERE THEY WERE MEASURED BY γ-SPECTROMETRY WITH EXTENDED LOW ENERGY RANGE HP-Ge DETECTORS.**

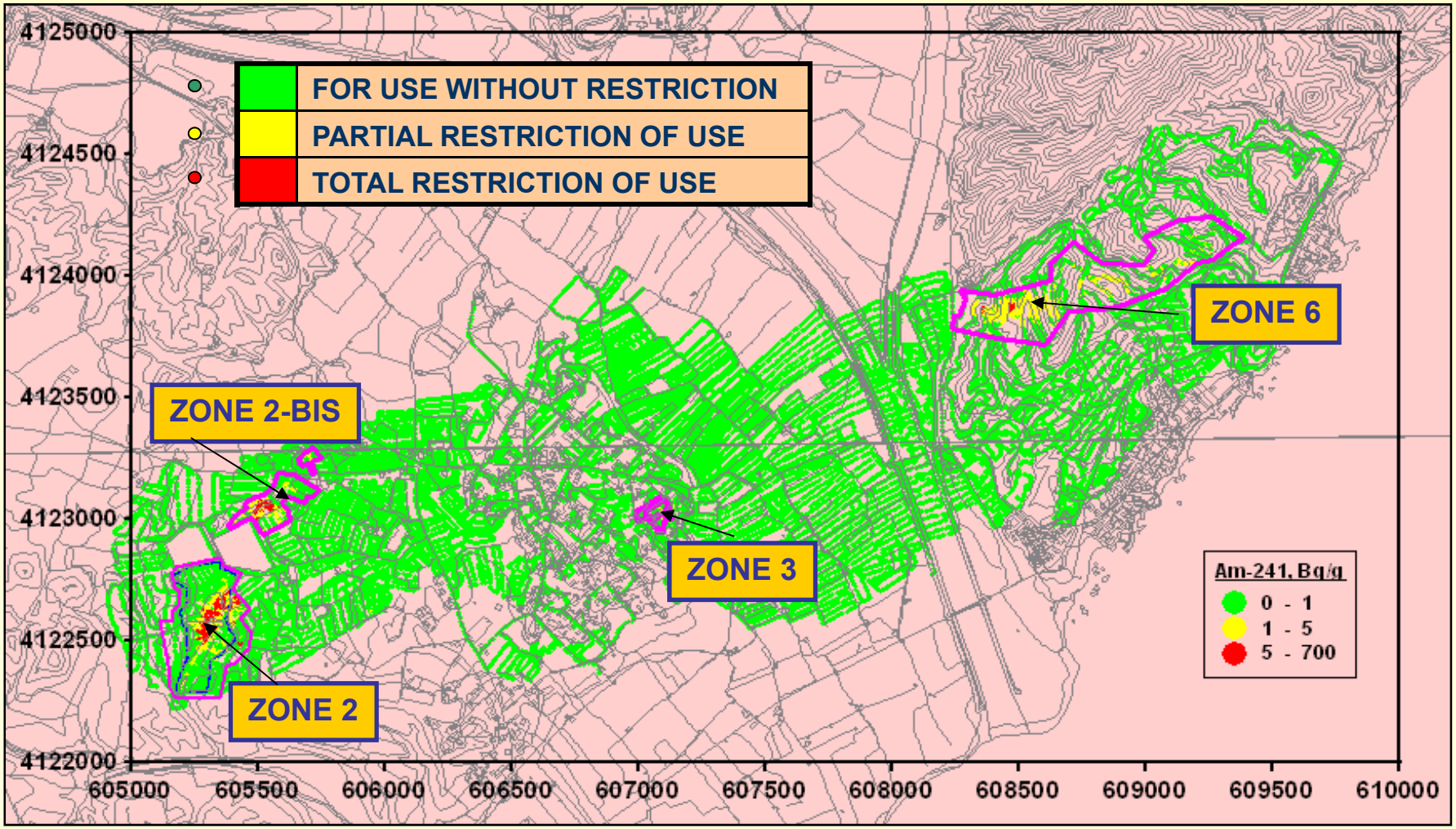


# LEPS MEASUREMENT OF THE $^{239+240}Pu/^{241}Am$

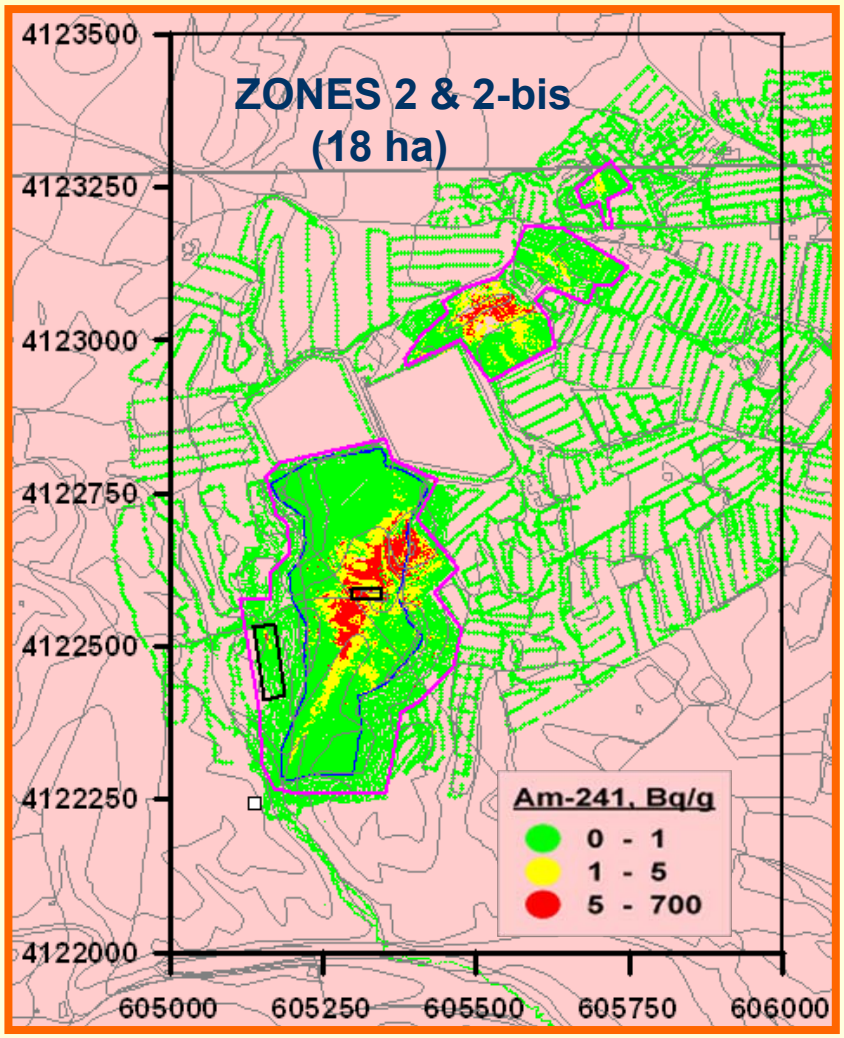


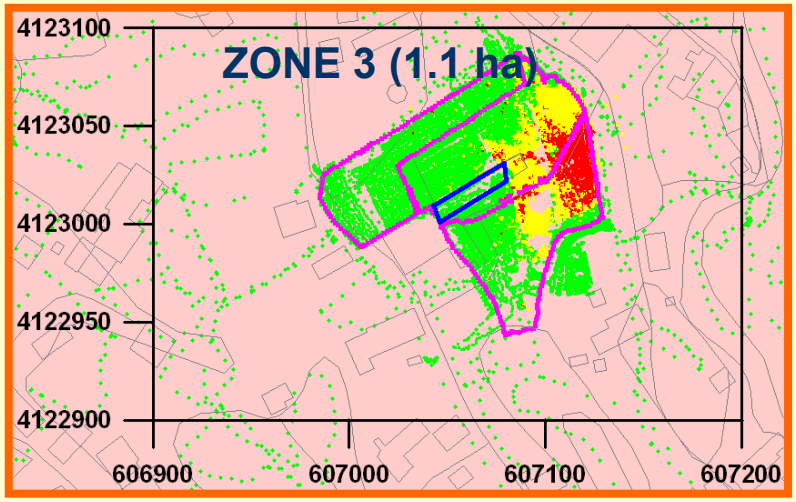

**IT IS CONFIRMED ( successfully validated with radiochemical methods and α spectrometry ) THAT THE APPROACH $^{239+240}Pu$ / $^{241}Am \cong 4$ IS A REASONABLY CONSERVATIVE VALUE FOR THE RATIO AND THEREFORE IT CAN BE EMPLOYED TO ESTIMATE $^{239+240}Pu$ INVENTORY FROM $^{241}Am$ MEASUREMENTS.**

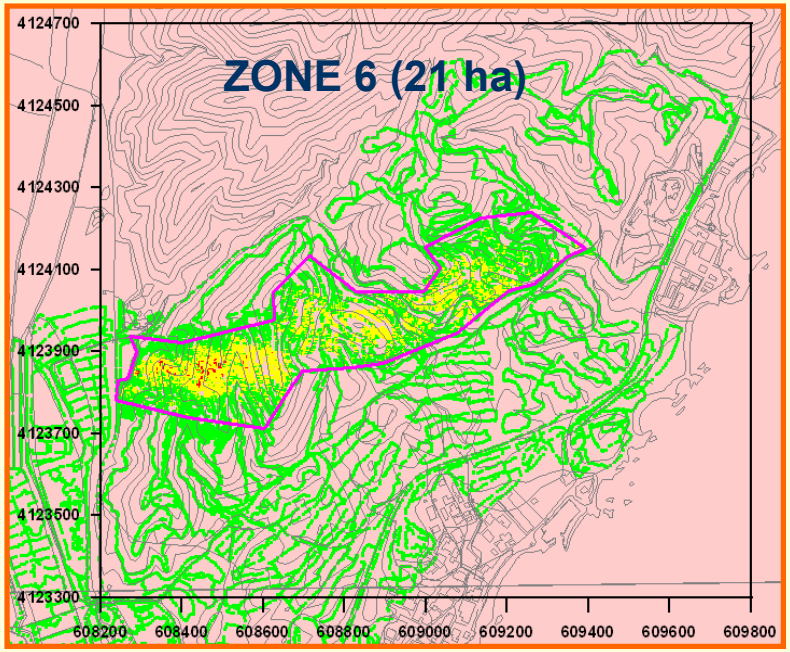
# SUMMARY OF 3D RADIOLOGICAL SOIL SURVEY (660 ha)



# SUMMARY OF 3D RADIOLOGICAL SOIL SURVEY

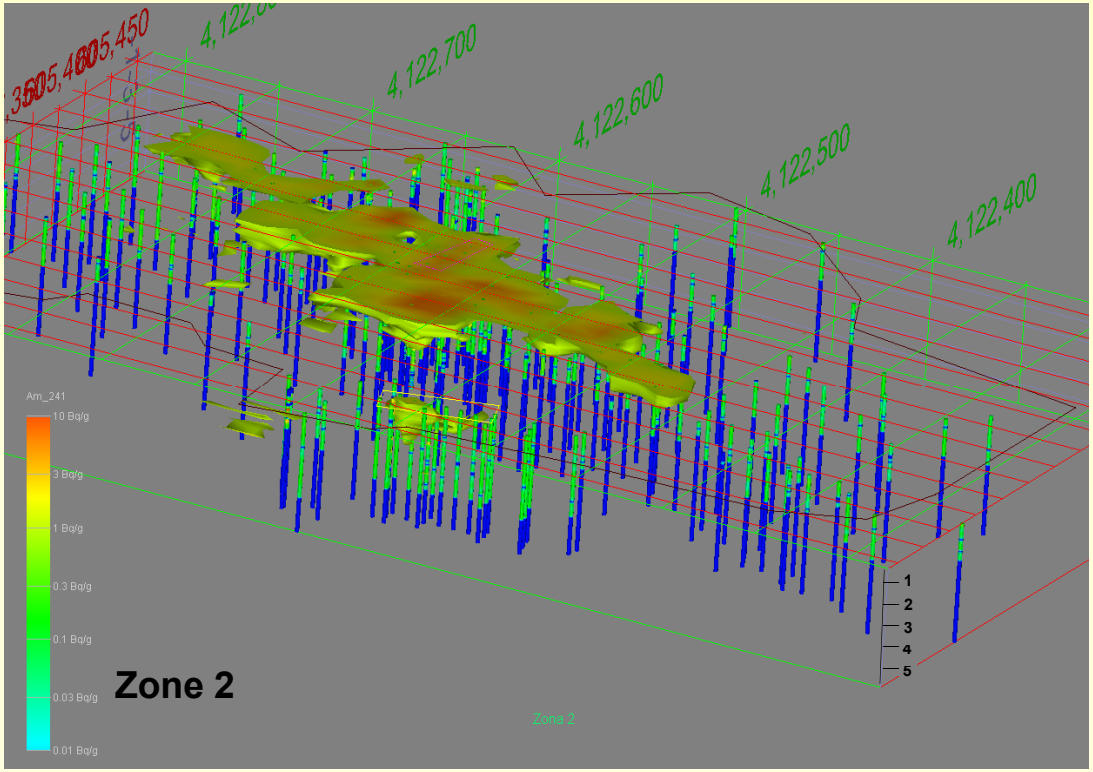


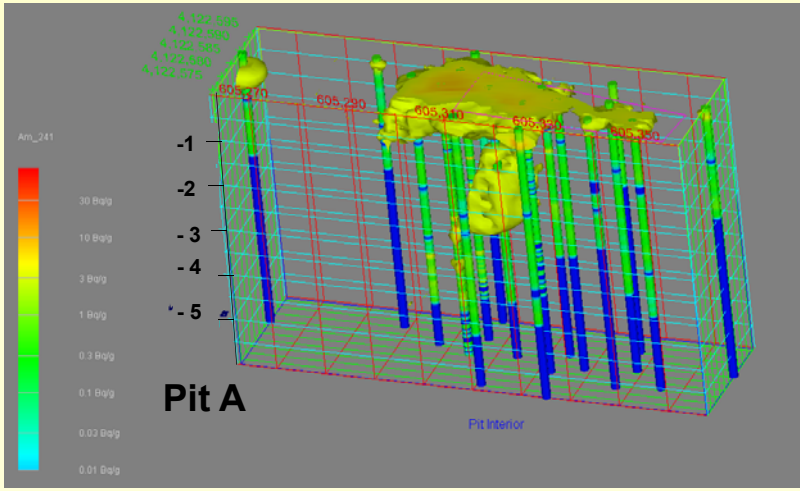



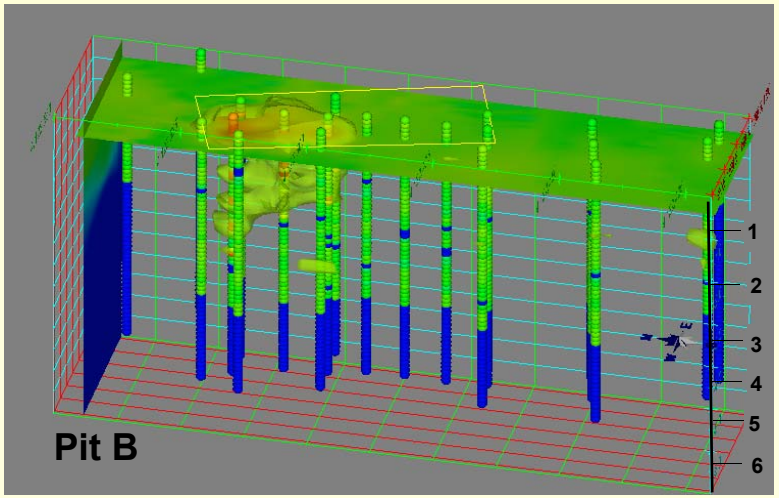



# 3D MODEL OF SUBSOIL CONTAMINATION (0.15→5 m). ZONE 2

**IT ALLOWS THE ESTIMATION OF THE SUBSOIL VOLUME AFFECTED BY CONTAMINATION OVER THE LAND USE RESTRICTION LEVELS ESTABLISHED BY THE NUCLEAR SAFETY COUNCIL (CSN).**

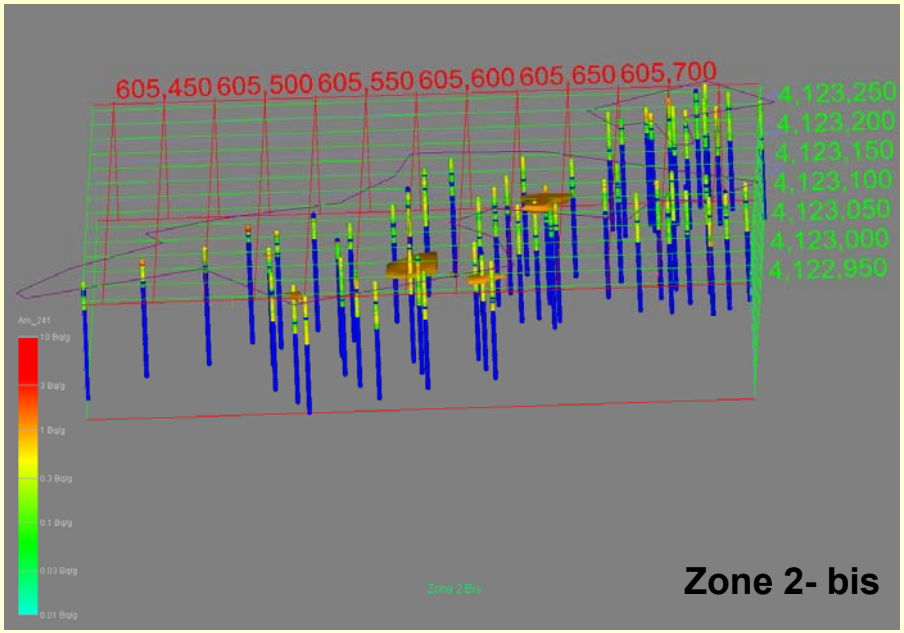


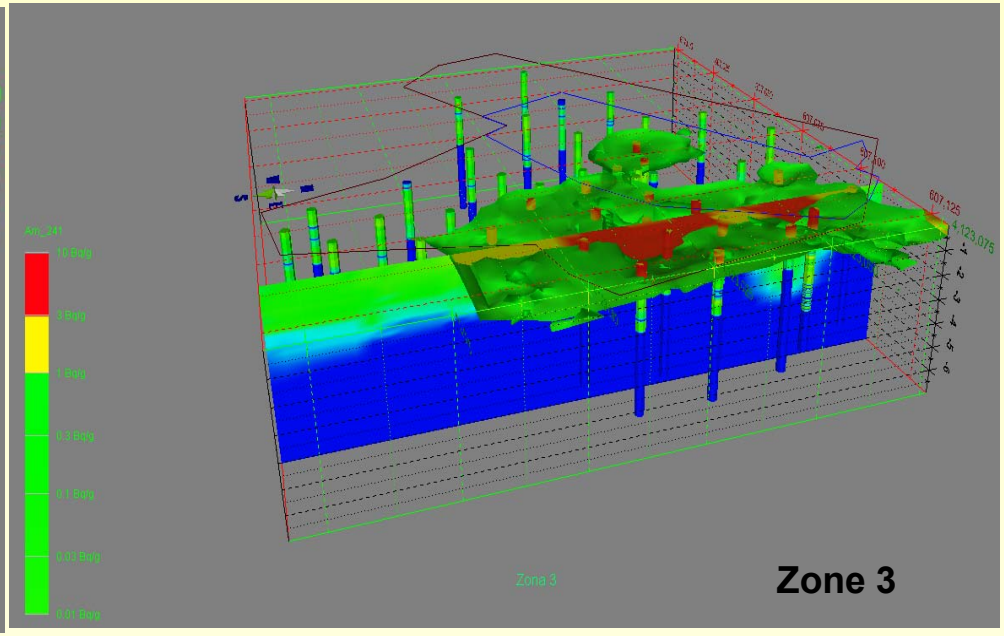



# 3D MODEL OF SUBSOIL CONTAMINATION (0.15→5 m).ZONES:2-BIS, 3

**IT ALLOWS TO ESTIMATE THE SUBSOIL VOLUME THAT IS AFFECTED WITH CONTAMINATION OVER THE LAND USE RESTRICTION LEVELS ESTABLISHED BY THE NUCLEAR SAFETY COUNCIL (CSN).**



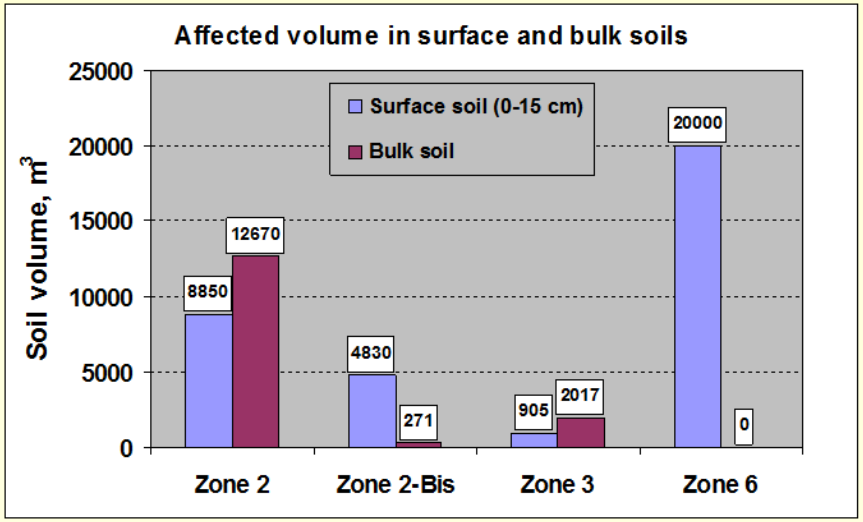



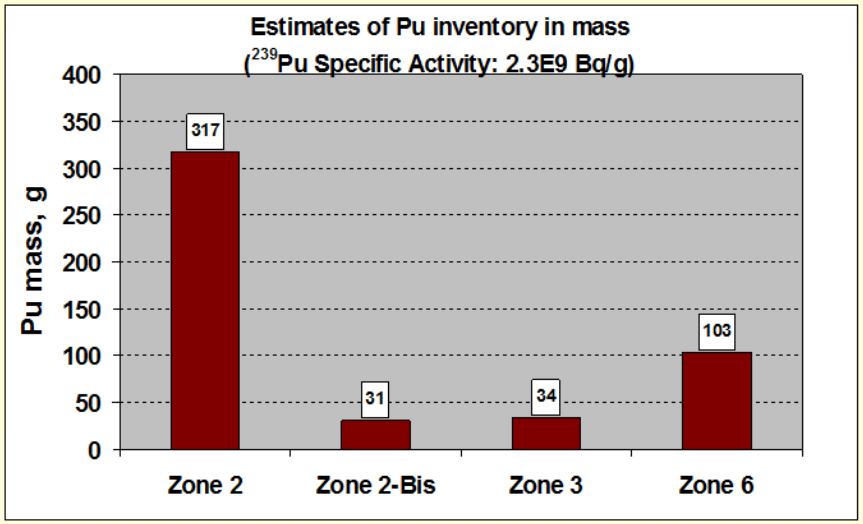

**ZONE 6: IT IS ONLY AFFECTED IN THE TOPSOIL AND THEREFORE THERE IS NO MODEL FOR THE SUBSOIL.**

# SUMMARY OF RESULTS ON AFFECTED LANDS

| | Zone 2 | Zone 2-Bis | Zone 3 | Zone 6 | Total |
|---|---|---|---|---|---|
| Surface of affected topsoil (0-15 cm), $m^2$ | 59,000 | 32,200 | 6,035 | 100,000 | 197,235 |
| Volume of affected topsoil (0-15 cm), $m^3$ | 8,850 | 4,830 | 905 | 20,000 | 34,585 |
| Volume of affected subsoil (0.15cm-5 m), $m^3$ | 12,670 | 271 | 2,245 | 0 | 15,186 |
| Total affected soil, $m^3$ | 21,520* | 5,101 | 3,150 | 20,000 | 49,771 |

(*) Pit A =2,270 $m^3$ Pit B= 669 $m^3$



# IAEA PEER- REVIEW CONCLUSIONS (Feb- Dec 2009) (1/2)

- **THE RADIOLOGICAL CHARACTERISATION OF SOIL IN THE PALOMARES AREA HAS BEEN PRODUCED IN LINE WITH INTERNATIONAL SAFETY STANDARDS. ALSO, THE ANALYTICAL MEASUREMENTS WERE CARRIED OUT UNDER FORMAL ACCREDITATION BY THE SPANISH AUTHORITIES.**

- **THE IAEA REVIEW TEAM WAS IMPRESSED WITH THE COMPREHENSIVE NATURE OF THE SAMPLING AND MEASUREMENTS CARRIED OUT IN THE PALOMARES REGION BY CIEMAT. IT WAS FELT THAT THESE WERE ADEQUATE FOR CHARACTERISING THE CONTAMINATION OF THE SOIL WITH RADIOACTIVE MATERIAL IN RELATION TO THE PREDEFINED REFERENCE LEVELS.**

- **THE CIEMAT STUDY USED A RANGE OF "STATE OF THE ART" TECHNIQUES IN AN INNOVATIVE WAY IN ORDER TO CHARACTERIZE THE SOIL CONTAMINATION, INCLUDING THE USE OF $^{241}$Am AS A RELIABLE MARKER FOR $^{239+240}$Pu.**

- **THE SAMPLE LOCATIONS AND MEASUREMENTS POINTS USED ARE THOUGHT TO BE REPRESENTATIVE OF THE REGION AND SUITABLE FOR CHARACTERIZING FOR LEVEL OF CONTAMINATION IN THE SOIL.**

# IAEA PEER- REVIEW CONCLUSIONS (Feb- Dec 2009) (2/2)

•THE TOOLS USED TO ORGANIZE AND MAP THE DATA ARE CONSIDERED TO BE SUITABLE FOR THE PURPOSE AND REPRESENT AN INTERNATIONALLY RECOGNISED APPROACH. THE RESULTING MAPS PROVIDED A GOOD OVERVIEW OF THE RADIOLOGICAL SITUATION OF PALOMARES.

•THE THREE-DIMENSIONAL SOIL CHARACTERIZATION IS A VERY USEFUL INPUT INTO THE PREPARATION OF A REMEDIATION STRATEGY. HOWEVER, FURTHER WORK IS LIKELY TO BE REQUIRED TO EXAMINE DIFFERENT OPTIONS AND TO ESTIMATE POSSIBLE FURTHER EXPOSURES.

•THE REVIEW TEAM WAS IMPRESSED WITH THE GOOD, POSITIVE RELATIONSHIPS THAT HAVE BEEN ESTABLISHED WITH THE LOCAL PEOPLE AUTHORITIES. IT WAS CLEAR THAT THERE WAS CONFIDENCE IN THE WORK CARRIED OUT BY CIEMAT. IT WAS ALSO NOTED THE LOCAL PEOPLE ARE EXPECTING THE WORK TO LEAD TO A FINAL SOLUTION FOR THE PROBLEM OF THE RADIOACTIVE MATERIAL IN THE REGION. IT WILL BE IMPORTANT TO INVOLVE THEM IN DISCUSSIONS OF REMEDIATION OPTIONS SO THAT THEY ACCEPT THAT THE CHOSEN OPTIONS ARE OPTIMUM.

# VERIFICATION MISSION ART- 35 EURATOM (April 2010)

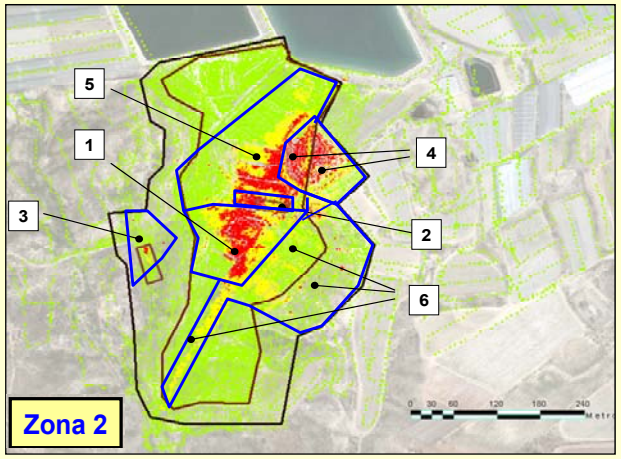
- **IN APRIL 20th TO 21th 2010, AN EUROPEAN COMMISSION TEAM EXPERTS FROM THE DG-ENERGY, HAS UNDERTAKEN A VERIFICATION MISSION UNDER ARTICLE 35 OF THE EURATOM TREATY, IN HIS VISIT TO REVIEW THE CIEMAT RADIOLOGICAL SURVEILLANCE WORKS IN THE SURROUNDINGS OF PALOMARES (ALMERIA).**

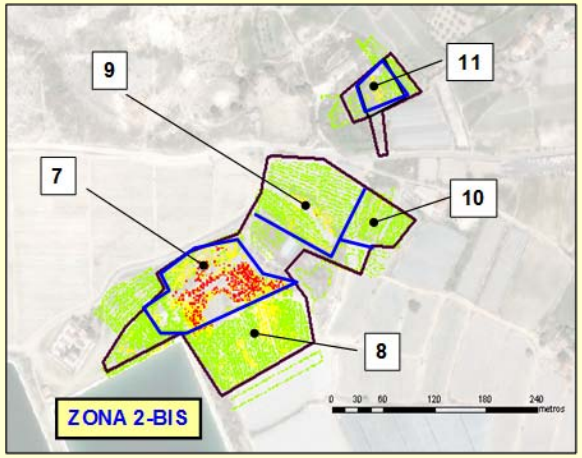
- **AT THE CLOSING MEETING, THE EXPERTS OF EUROPEAN COMMISSION PRESENTED THE PRELIMINARY FINDINGS OF THEIR VERIFICATION THAT WILL BE INCLUDED IN THEIR FINAL REPORT TO BE PUBLISHED SHORTLY.**

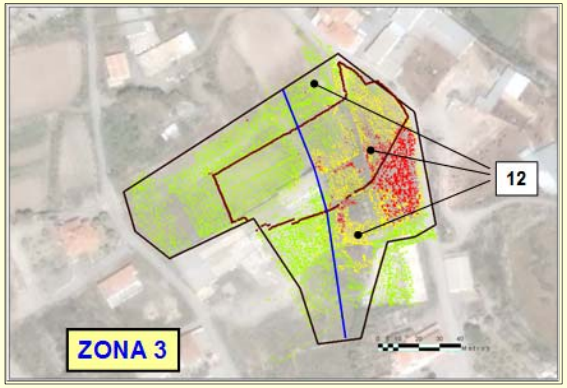
- **THE VERIFICATION TEAM ACKNOWLEDGED THE ONGOING IMPORTANT SCIENTIFIC DEVELOPMENT WORK CONDUCTED BY CIEMAT WITH THE AIM TO REDUCE THE VOLUME OF THE CONTAMINATED SOIL.**

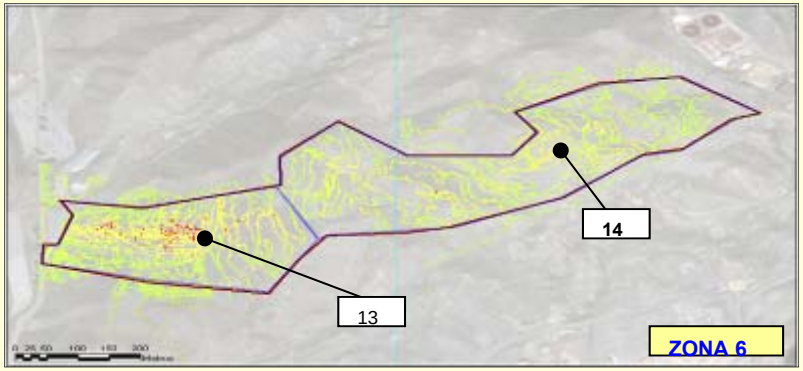
- **THE INSPECTION TEAM HIGHLIGHTED THE COMPREHENSIVENESS AND QUALITY OF THE CHARACTERIZATION PROGRAMME, THE SCIENTIFIC INVESTIGATIONS CONDUCTED AND THE ADEQUACY OF THE MEASURES TAKEN TO PREVENT ACCESS TO THE CONTAMINATED LANDS AND THUS TO PROTECT THE POPULATION.**

# GRANULOMETRY STUDY: MASS AND ACTIVITY DISTRIBUTIONS DEPENDING ON THE GRAIN SIZE (DRY SIEVING)



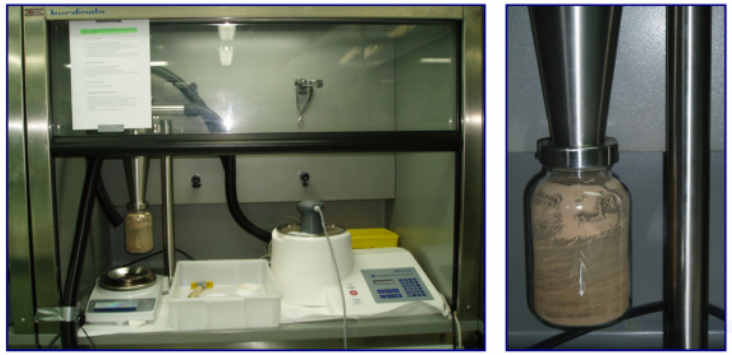




**FOURTEEN PLOTS HAVE BEEN IDENTIFIED BY THE ANALYSIS OF THE RESULTS OF THE 3D RADIOLOGICAL CHARACTERIZATION DIFFERENTIATED BY THEIR GEOGRAPHIC CONTINUITY AND PARTICULAR CONTAMINATION PATTERN.**

# GRANULOMETRY STUDY: MASS AND ACTIVITY DISTRIBUTIONS DEPENDING ON THE GRAIN SIZE (DRY SIEVING)

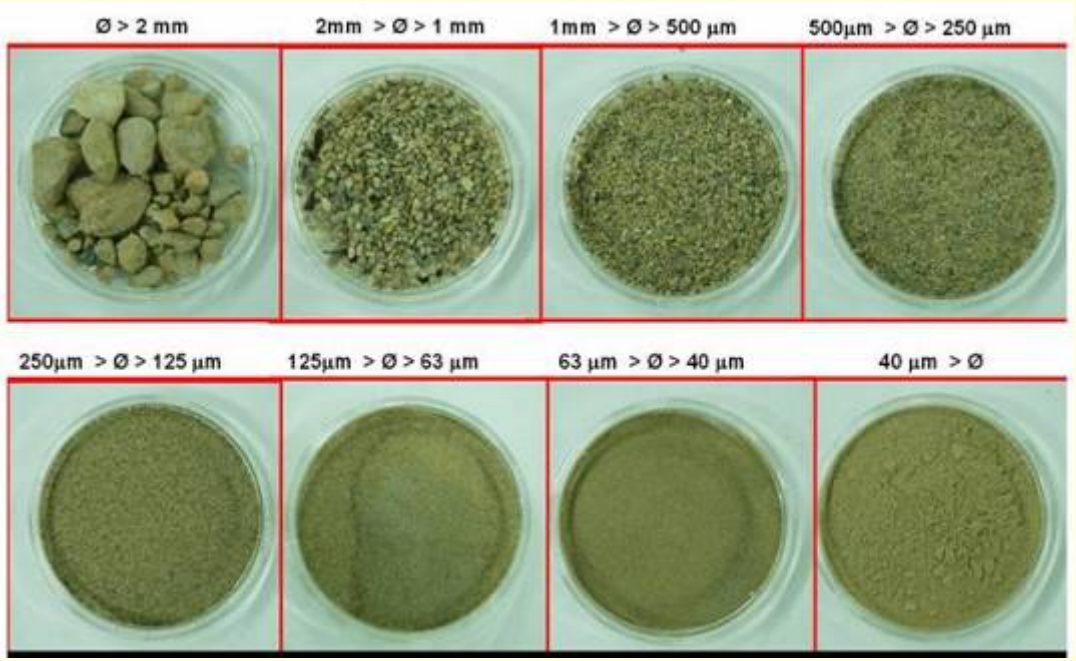
Secado de las muestras bajo epirradiador

Tamizadora en funcionamiento con detalle del ciclón



**STANDARD AIR JET TECHNIQUE WAS EMPLOYED FOR DRY SIZE SEPARATION.**

**MORE THAN 900 SUBSAMPLES WERE PREPARED AND MEASURED BY GAMMA SPECTROMETRY.**



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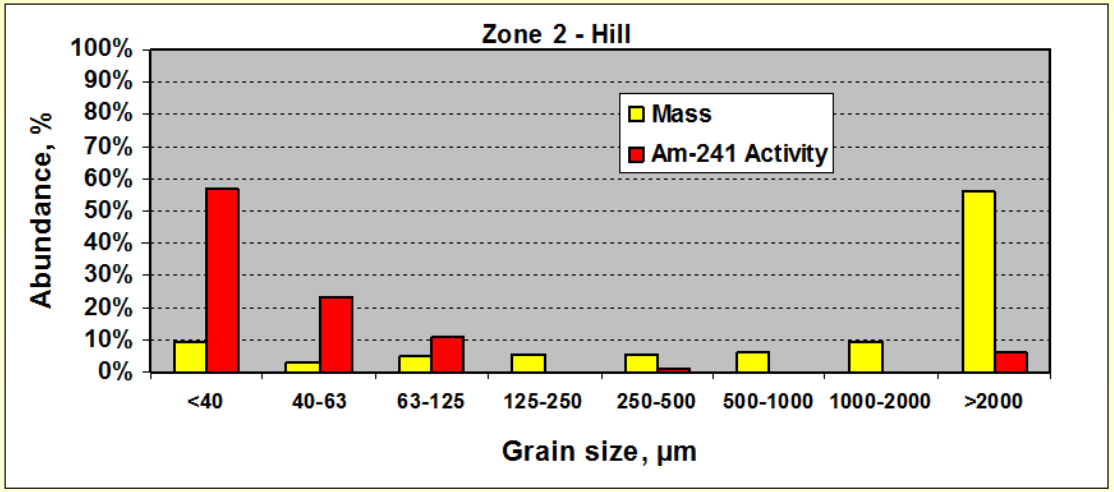
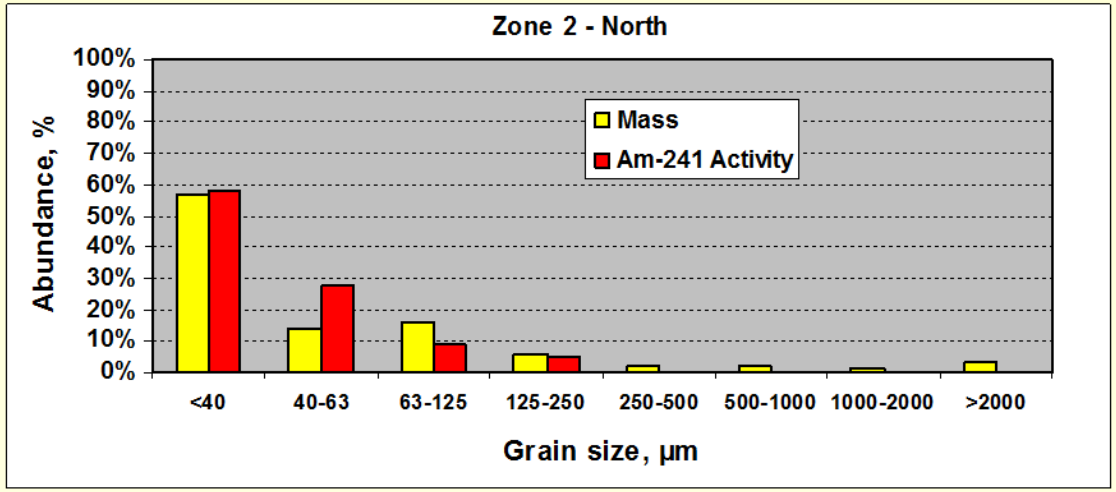
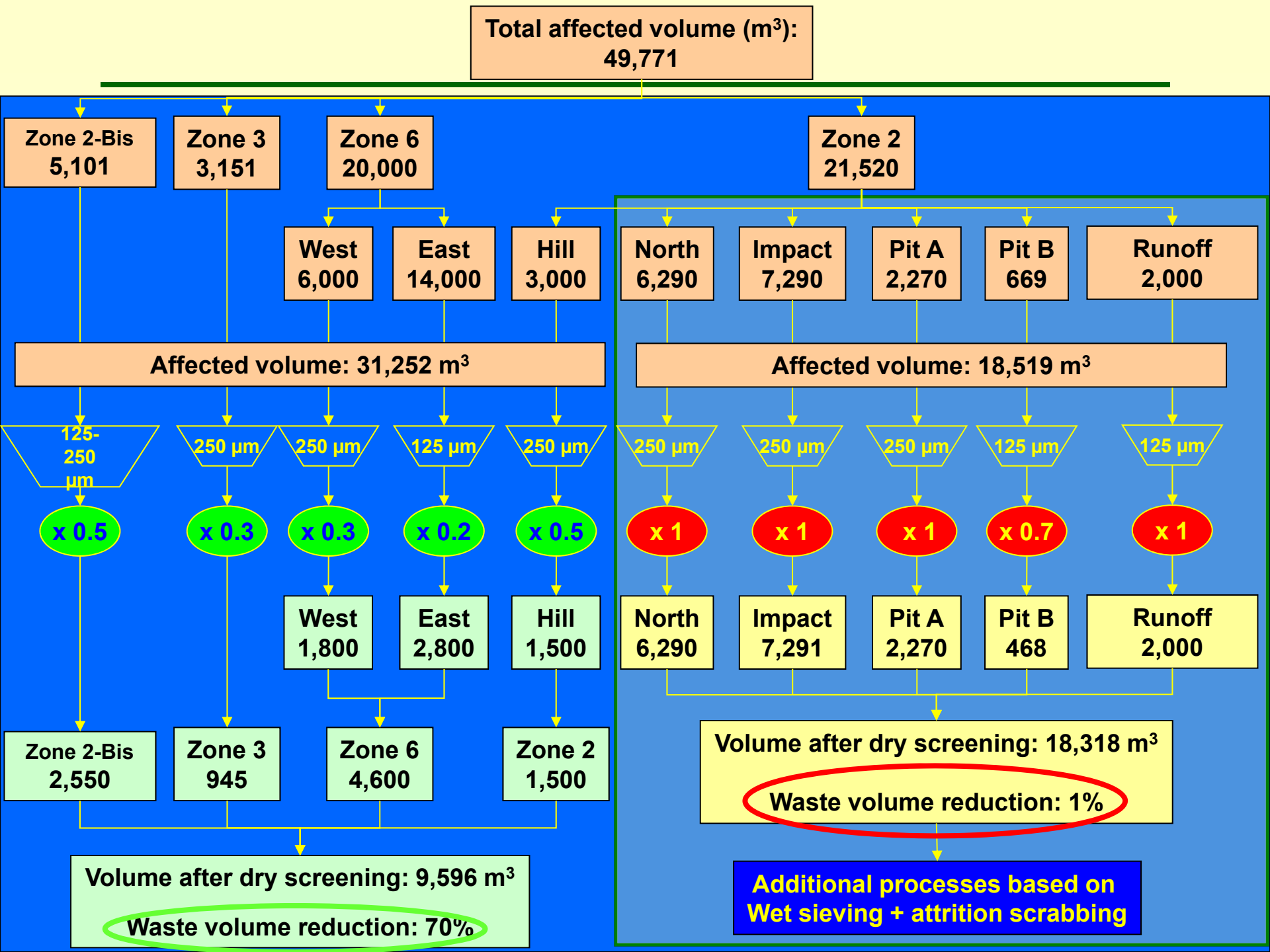



**MOST OF THE ACTIVITY IS LOCATED IN SMALL SIZED GRAINS, WHICH JUST REPRESENTS ABOUT 10% OF THE ORIGINAL MASS: DRY SIEVING TECHNIQUES WILL BE ADEQUATE.**

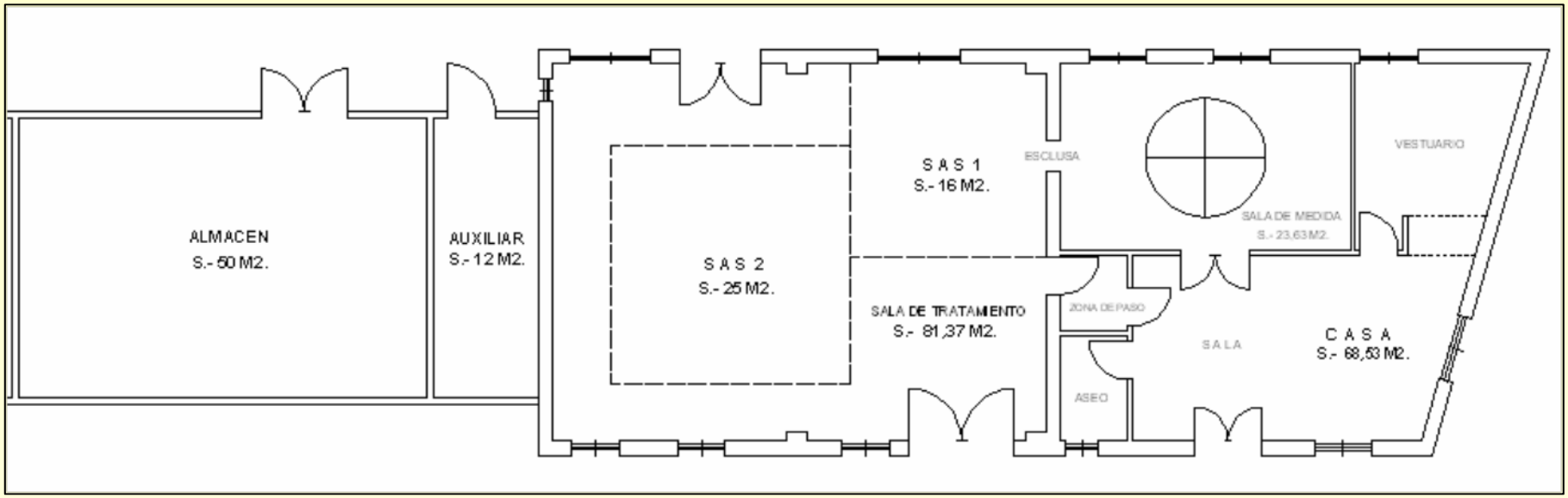


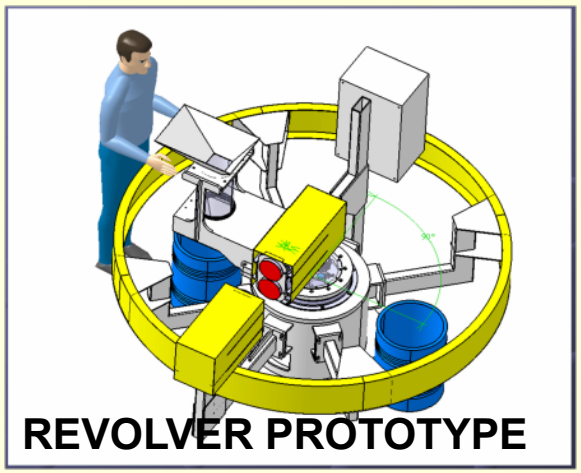

**ACTIVITY AND MASS DISTRIBUTIONS ARE SIMILAR:**
**IN ADDITION TO DRY SIEVING, WET SIEVING TECHNIQUES WILL BE NECESSARY.**

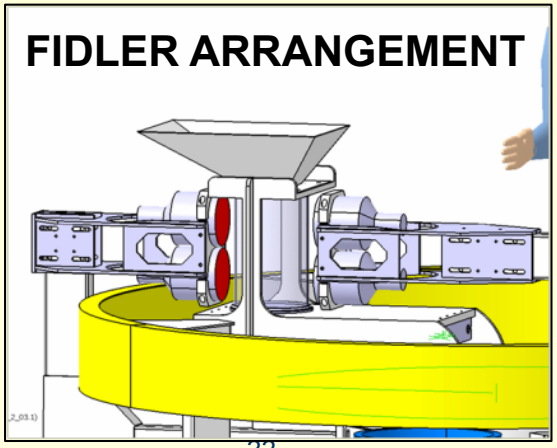

Total affected volume (m3): 49,771
Zone 2-Bis 5,101
Zone 3 3,151
Zone 6 20,000
Zone 2 21,520
West 6,000
East 14,000
Hill 3,000
North 6,290
Impact 7,290
Pit A 2,270
Pit B 669
Runoff 2,000
Affected volume: 31,252 m3
Affected volume: 18,519 m3
125-250 µm
250 µm
250 µm
125 µm
250 µm
250 µm
250 µm
250 µm
125 µm
125 µm
x 0.5
x 0.3
x 0.3
x 0.2
x 0.5
x 1
x 1
x 1
x 0.7
x 1
West 1,800
East 2,800
Hill 1,500
North 6,290
Impact 7,291
Pit A 2,270
Pit B 468
Runoff 2,000
Zone 2-Bis 2,550
Zone 3 945
Zone 6 4,600
Zone 2 1,500
Volume after dry screening: 18,318 m3
Waste volume reduction: 1%
Volume after dry screening: 9,596 m3
Waste volume reduction: 70%
Additional processes based on Wet sieving + attrition scrabbing

# PILOT PLANT FOR MEDIUM-SCALE SOIL STUDIES

**THE BUILDINGS IN ZONE 3 HAVE BEEN CONVERTED INTO A PILOT PLAN FOR SOIL STUDIES (DRY AND WET SIEVING). INVESTIGATIONS WITH LARGE SOIL SAMPLES (150 kg) ARE BEING CONDUCTED TO CHECK THE POSSIBILITIES OF INDUSTRIAL EXISTING TECHNIQUES.**





REVOLVER PROTOTYPE





DRY SIEVER

# PILOT PLANT FOR MEDIUM-SCALE SOIL STUDIES: DRY SIEVING

COLLECTION OF 100 l SOIL SAMPLES

FIDLER “IN SITU” MEASUREMENTS

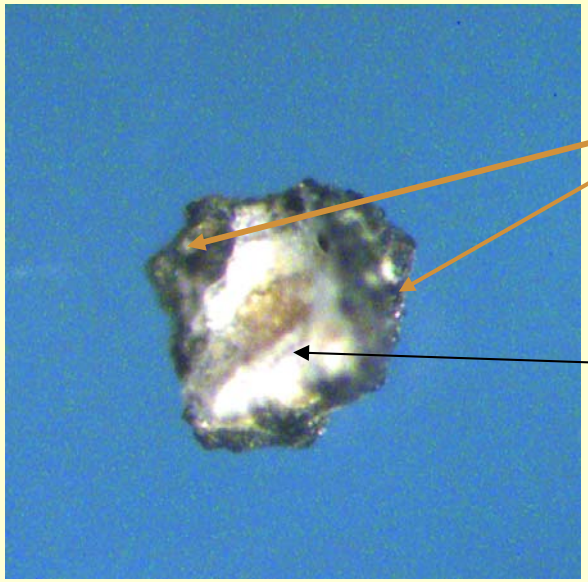
HP Ge 10 l SAMPLE CHARACTERIZATION

SAMPLE DRYING STATION

DRY SIEVER LOADING

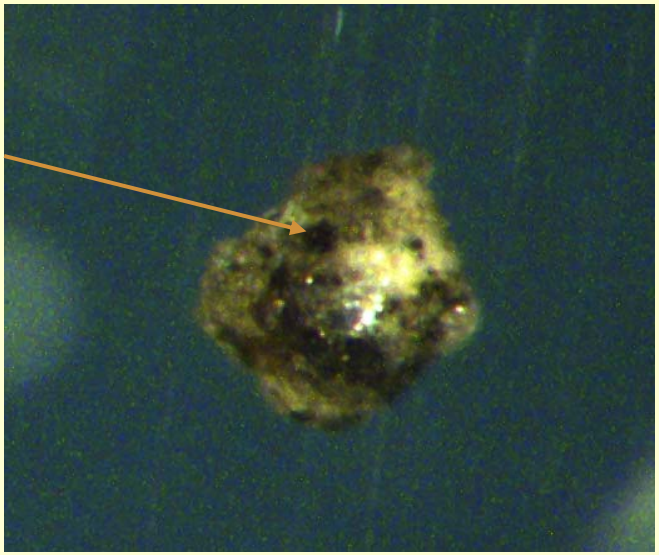
FOUR-FIDLER AUTOMATIC SEGREGATION MACHINE

# LIMITATIONS OF DRY SIEVING TECHNIQUES



NUCLEAR COMBUSTIBLE (black)

$SiO_2$ (white)



**IN SOME CASES DRY SIEVING IS NOT GOOD ENOUGH BECAUSE OF THE AGGREGATES.**

**ADDING WATER IS A SUITABLE SOLUTION (WET SIEVING).**

**THE TRANSURANIC MICROPARTICLES COAT A NATURAL GRAIN, YIELDING AN APPARENT SIZE WHERE THE ACTIVITY IS MUCH SMALLER THAN EXPECTED.**

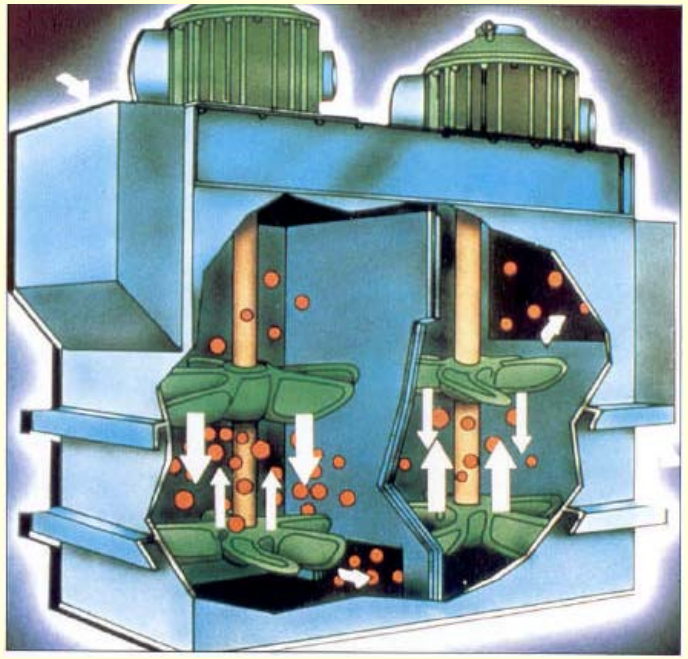
**IN THIS CASE, IT IS NECESSARY TO BREAK MECHANICALLY THE VERY SMALL GRAINS.**

# SCRUBBING ATTRITION

**A TECHNOLOGICAL SOLUTION TO REMOVE THE ATTACHED SMALL TRANSURANIC PARTICLES COULD BE THE SCRUBBING ATTRITION WHICH PRODUCES SURFACE EROSION OF GRAINS.**

**PROBLEM** → **SOLUTION** → **SCRUBBING ATTRITION + WET SIEVING**

**ATTRITION SCRUBBING PRODUCES AN HIGH ENERGY CONTACTING OF PARTICLES IN A LIQUID MEDIUM. PARTICLES ARE IMPACTED VIA THE VELOCITY GRADIENTS CREATED BY IMPELLERS.**



# TREATMENT TECHNIQUES FOR SOILS

**THE MOST EFFECTIVE METHODS TO REDUCE THE VOLUME OF TRANSURANIC CONTAMINATED SOILS ARE BASED ON SIZE PARTICLES SEPARATION (NEVADA TEST SITE - DOE).**

## 1.- DRY SIEVING

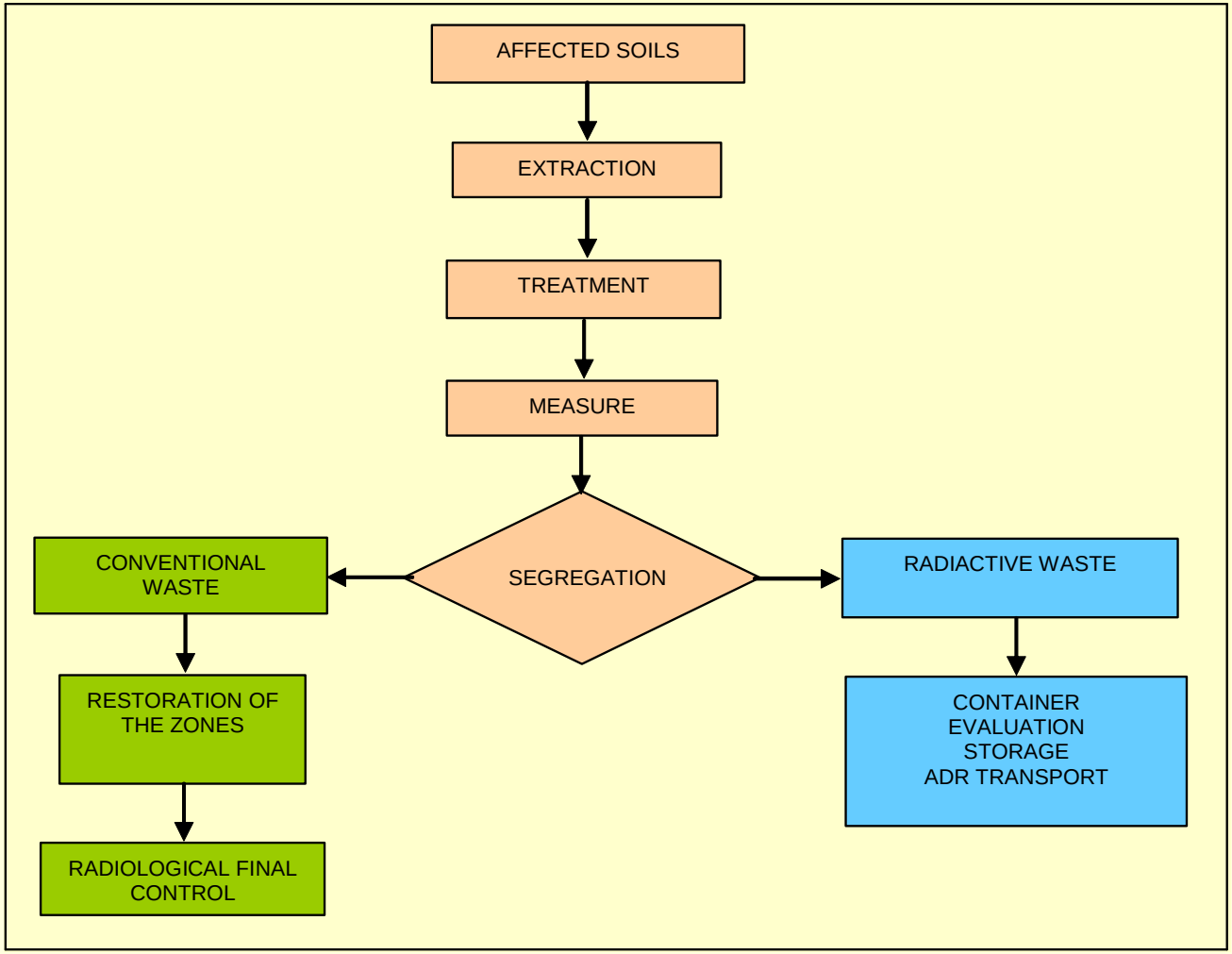
**SOIL PARTICLES ARE SEPARATED BY SIZE USING SIMPLE SIEVES. A LARGE FRACTION IN WEIGHT WITH LOW ACTIVITY AND A SECOND FRACTION WITH HIGH ACTIVITY IN A SMALL FRACTION ARE OBTAINED.**

## 2.- WET SIEVING

**BASED ON THE USE OF SCRUBBING ATTRITION, WASHER CYLINDER AND HYDROCYCLONS, THE LARGE AND MIDDLE SIZE AGGREGATES ARE BROKEN UP AND SEGREGATED BOTH BY SIZE AND SPECIFIC WEIGHT.**

THE COMBINATION OF BOTH TECHNIQUES IS REQUIRED TO MINIMIZE THE RADIOACTIVE WASTE GENERATION

# PRP GENERAL OPERATION DIAGRAM




## OPERATION DIAGRAM

# PALOMARES REHABILITATION PLAN .CONCLUSIONS

- **THE CIEMAT THROUGHOUT THE YEAR 2009 HAS WORKED AT THE PALOMARES REHABILITATION PLAN (PRP), WHICH PRELIMINARY VERSION HAS BEEN CONSIDERED AS ACEPTABLE FOR THE CSN.**
- **THE FIRST PROBLEM WAS TO DECREASE THE VOLUME OF CONTAMINATED LAND, AN ISSUE THAT HAS BEEN RESOLVED AFTER APPLYING GRANULOMETRIC TECHNOLOGIES (DRY AND WET SIEVINGS). AT PRESENT WITH THESE TECHNOLOGIES: 50,000 $m^3$ OF CONTAMINATED LAND MAY BE REDUCED TO ABOUT 6,000 $m^3$.**
- **THE WORK IS PLANNED TO LAST THREE YEARS, THE FIRST FOR CONSTRUCTION OF FACILITIES AND INFRAESTRUCTURES AND PERFECTING THE PROJECT, THE SECOND FOR EXECUTION OF THE PRP ITSELF, AND THE LAST FOR FINAL RADIOLOGICAL VERIFICATION, EVALUATION OF THE SCENARIO AND FINALLY, DOCUMENTING THE ENTIRE PROCESS.**
- **THE PRP ESTIMATED BUDGET IS 31 M € EXCLUDING FINAL MANAGAMENT OF RADIOACTIVE WASTE GENERATED.**

# THANK YOU VERY MUCH FOR YOUR ATTENTION !

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