
REMEDIATION AFTER THE PALOMARES ACCIDENT: SCIENTIFIC AND SOCIAL ASPECTS

CARLOS SANCHO LLERANDI

ENVIRONMENTAL RADIOLOGICAL REHABILITATION PROGRAM

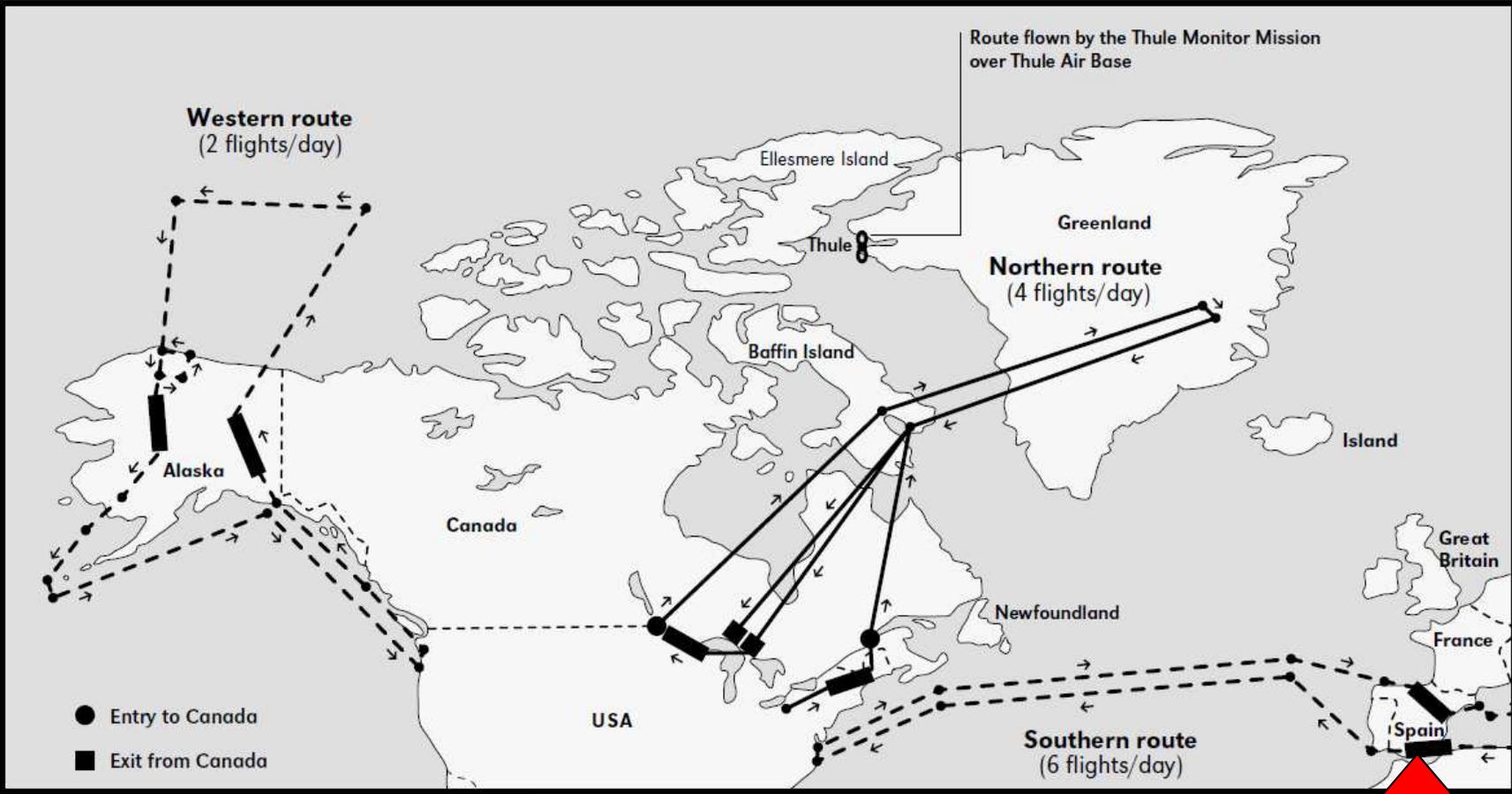
ENVIRONMENTAL DEPARTMENT. CIEMAT

Ministry of Economy and Competitiveness

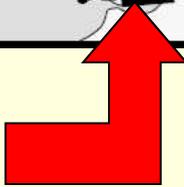


**International Experts' Meeting on Decommissioning and Remediation after a Nuclear Accident
IAEA 28 January – 1 February 2013. Vienna, Austria**

THE CHROME DOME FLIGHTS



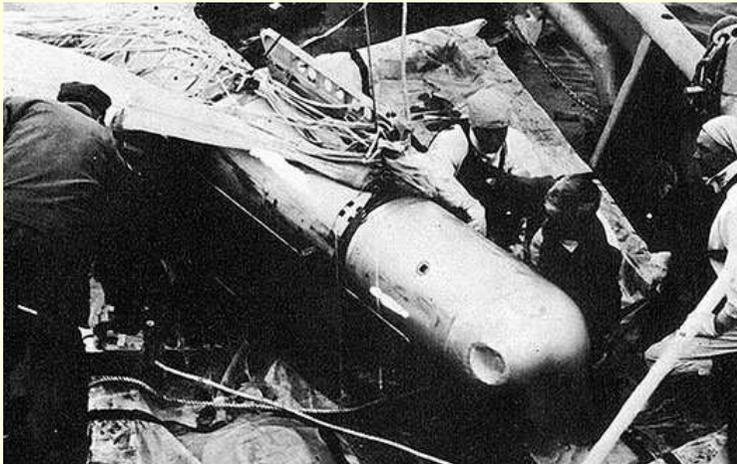
REFUELING OVER SPAIN HAD BEEN A STANDARD DAILY PROCEDURE IN THE "CHROME DOME FLIGHTS" SINCE 1961, FRAMED IN MILITARY AGREEMENTS SIGNED BY US AND SPAIN IN 1953.



THE PALOMARES ACCIDENT

US MILITARY AIRCRAFT ACCIDENT INVOLVING THERMONUCLEAR WEAPONS, 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: # 1 WAS FOUND INTACT
2 AND # 3 WERE SERIOUSLY DAMAGED DUE TO THE DETONATION OF THE NON-NUCLEAR EXPLOSIVE UPON IMPACTING THE GROUND.**
- **# 4 WAS RECOVERED INTACT FROM THE MEDITERRANEAN SEA ABOUT 9 Km OFFSHORE 80 DAYS AFTER THE ACCIDENT.**

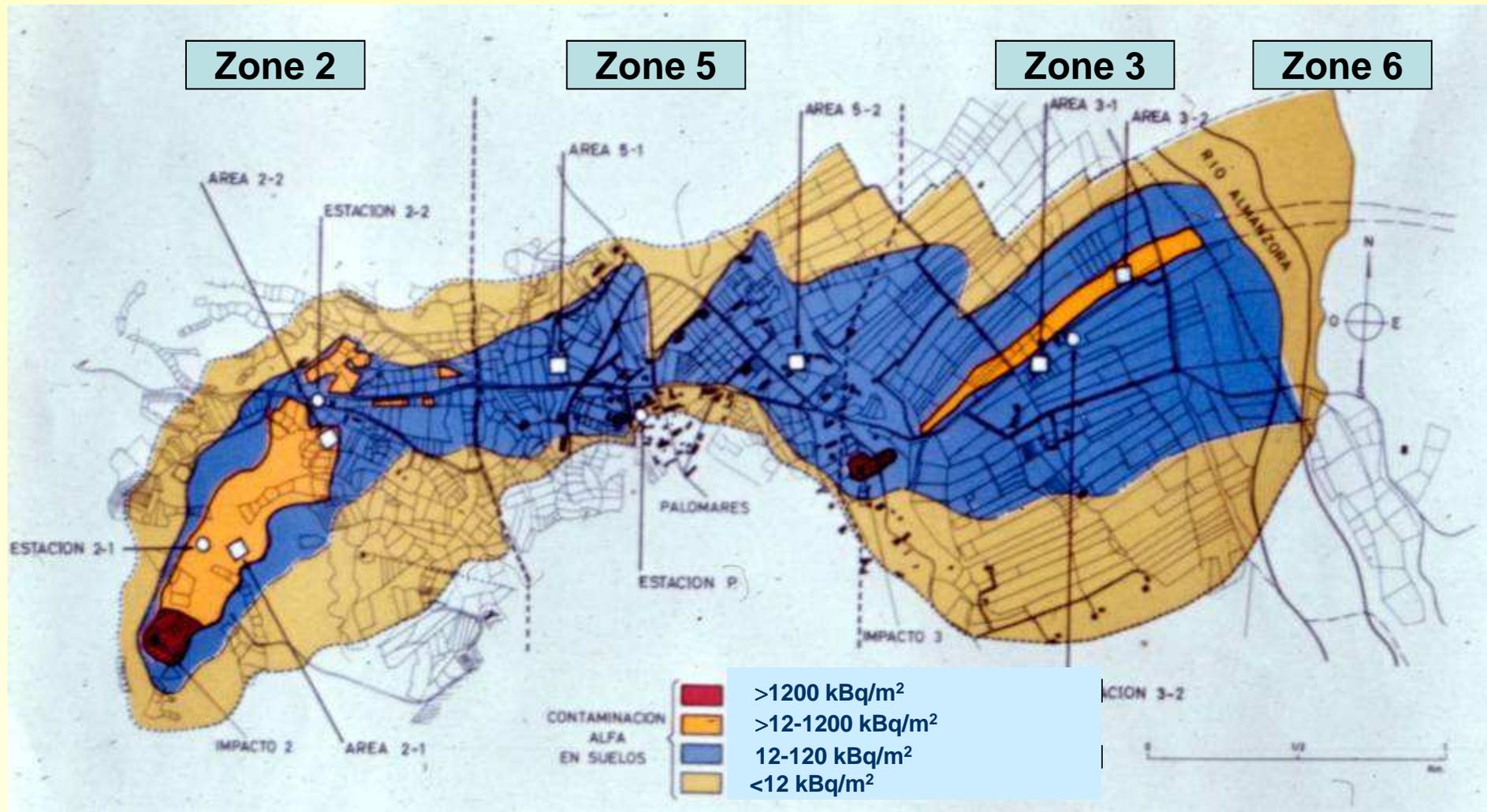


THE PALOMARES ACCIDENT

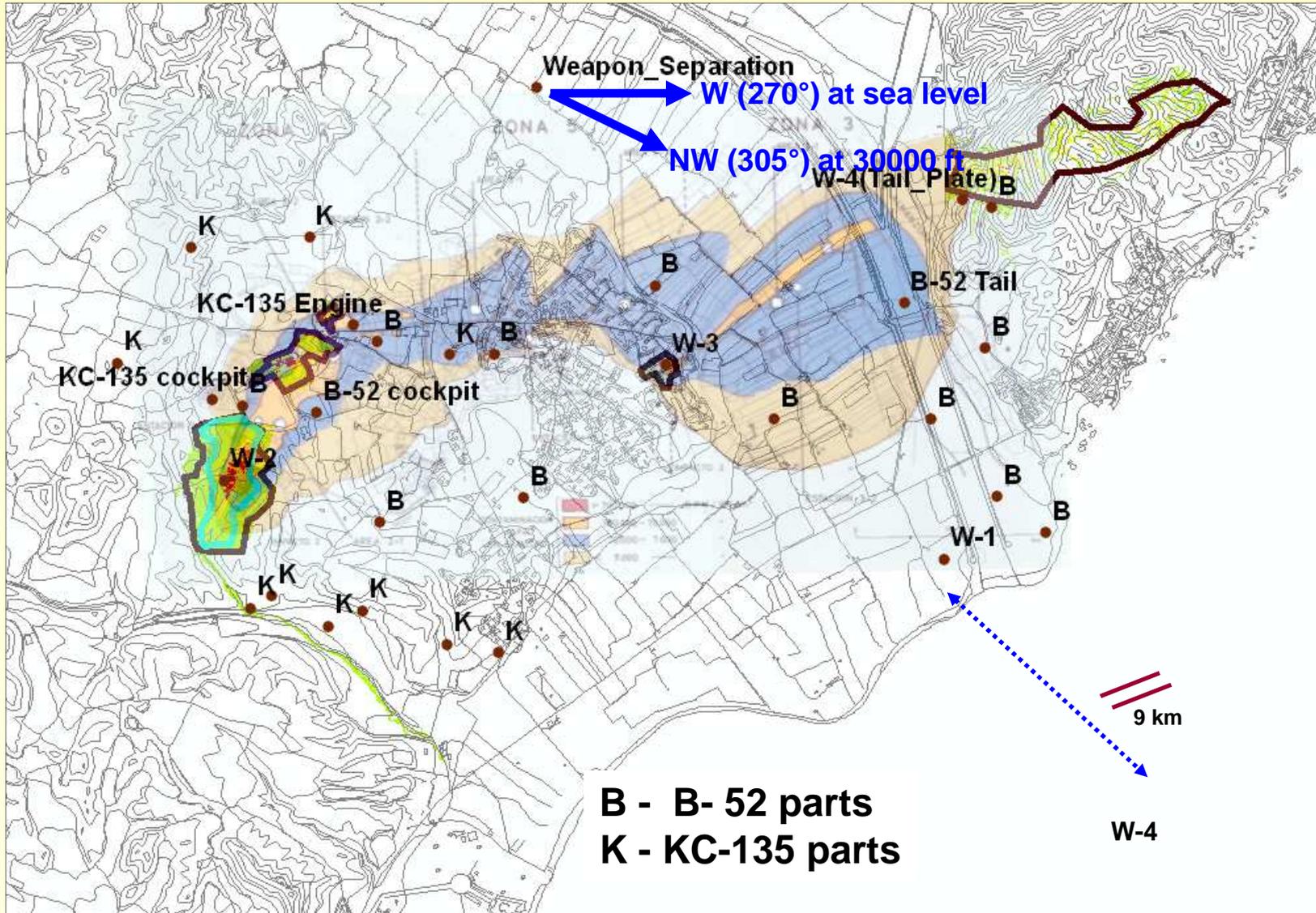
- **EMERGENCY ACTIONS WERE TAKEN BY USA AND SPANISH AUTHORITIES TO RECOVER THE DAMAGED WEAPONS AND CLEAN THE CONTAMINATED AREA.**
- **RADIOACTIVE CONTAMINATIONS DEPOSITED IN SOILS .**
- **SUBSEQUENTLY, RADIOLOGICAL MONITORING PROGRAM OF THE POPULATION AND THE ENVIRONMENT IMPLEMENTED BY THE CIEMAT.**



'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

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

(*) *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*

REMEDATION 1966: USA AND SPANISH AUTHORITIES COMPROMISES

VOLUME REMOVED OF SOIL: 832 m³ (from 2.2 ha in Area 2)

VOLUME REMOVED OF VEGETATION (MULCHED AND STORED): 306 m³

SOIL WATERED AND PLOWED: 115 ha

AGREEMENT OTERO – HALL, 1966/02/25 – ATOMIC ENERGY COMMISSION, UNITED STATES OF AMERICA / 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”.

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.
- INTRODUCTION 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 REPORTS TO THE NUCLEAR SAFETY COMMISSION.
- 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 NUCLEAR SAFETY COMMISSION 12/11/2003 AND BY THE COUNCIL OF MINISTERS ON 12/17/2004, WHICH INCLUDED TOTAL AND PARTIAL LAND USE RESTRICTIONS.
- THE 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.
 - ii) TO IDENTIFY AND VERIFY THAT THE **RELATIONSHIP BETWEEN THE $^{239+240}\text{Pu}$ 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.

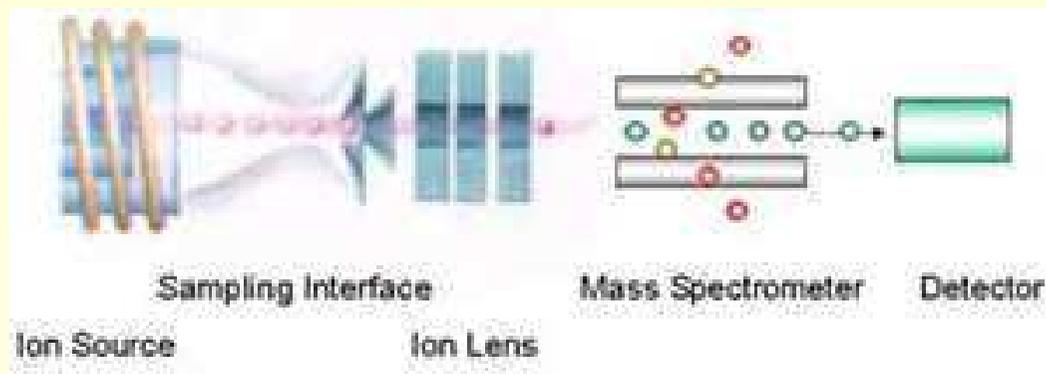
ENVIRONMENTAL RADIOLOGICAL PROGRAM (1966 → PRESENT)

SAMPLES TYPES		NUMBER OF STATIONS	SAMPLING FREQUENCY	ANALYSED RADIONUCLIDES
VEGETATION	WILD (BIOINDICATORS)	2	ANNUAL (4 samples y ⁻¹)	²³⁹⁺²⁴⁰ Pu (α spec) ²⁴¹ Am (γ spec)
	CULTIVATED GREENHOUSE/OPEN FIELDS	15	EVERY 6 MONTHS (28 samples y ⁻¹)	²³⁹⁺²⁴⁰ Pu (α spec) ²⁴¹ Am (γ spec)
AIR	TOTAL SUSPENDED PARTICULATES	3	CONTINUOUS (99 samples y ⁻¹)	²³⁹⁺²⁴⁰ Pu (α spec)
DRY DEPOSIT		3	MONTHLY (36 samples y ⁻¹)	²³⁹⁺²⁴⁰ Pu (α spec)
SOILS		3	EVERY 6 MONTHS (6 samples y ⁻¹)	²⁴¹ Am (γ spec)
OTHERS	ANIMAL PRODUCTS (HONEY, MILK, FISH, SNAILS, GAME)	8	ANNUAL/EVERY 6 MONTHS (9 samples y ⁻¹)	²³⁹⁺²⁴⁰ Pu (α spec) ²⁴¹ Am (γ spec)
	WATER (FRESH, SEA, TAP, RAIN)	6	ANNUAL /EVERY 6 MONTHS (7 samples y ⁻¹)	²³⁹⁺²⁴⁰ Pu (α spec) ²⁴¹ Am (γ spec)
	SEDIMENTS (RIVER, BEACH)	3	ANNUAL (3 samples y ⁻¹)	²³⁹⁺²⁴⁰ Pu (α spec) ²⁴¹ Am (γ spec)

PERSONAL RADIOLOGICAL SURVEILLANCE PROGRAM (1966 → PRESENT)

BIOASSAY CONTROLS

- VOLUNTARY.
- 24 hrs URINE SAMPLES ARE COLLECTED OUTSIDE OF THE CONTAMINATED AREA OF PALOMARES.
- Pu + 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.



VOLUNTEERS PARTICIPATING IN THE HEALTH MONITORING PROGRAM

- TO ESTABLISH THE **STATE OF THE GENERAL HEALTH** OF PEOPLE
- TO IDENTIFY THE PRESENCE OF HEALTH CONDITIONS WHICH COULD CONTRIBUTE TO AN **INCREASED SUSCEPTIBILITY** OF THE INDIVIDUAL TO DEVELOP CERTAIN ILLNESSES
- TO IDENTIFY IN PARTICULAR THE **EXISTENCE OF MORPHOLOGICAL OR FUNCTIONAL CHANGES** TO THOSE ORGANS OR SYSTEMS
- TO PROVIDE **EARLY DETECTION OF THE PRESENCE OF SIGNS** OR SYMPTOMS WHICH COULD BE CORRELATED WITH THE APPEARANCE OF HARMFUL EFFECTS RESULTING FROM EXPOSURE TO RADIATION
- TO ATTEMPT TO **MITIGATE THE CONCERN AND ANXIETY** OF THE POPULATION THROUGH THE PSYCHOLOGICAL EFFECT OF MEDICAL EXAMINATION

VISIT TO THE ENVIRONMENTAL AND PERSONNEL RADIOLOGICAL SURVEILLANCE PROGRAM LABORATORIES

- **GROUP: 10 VISITORS**
- **DURATION: 1h**
- **NUMBER OF PEOPLE INVOLVED: 150 PER YEAR**

OBJECTIVES:

- ✓ **TO MAKE THEM AWARE OF THE **INDIVIDUAL AND COLLECTIVE BENEFITS** ACHIEVED BY PARTICIPATING IN THE HEALTH MONITORING PROGRAM**
- ✓ **TO **OBTAIN 24h URINE SAMPLES** PROPERLY COLLECTED**
- ✓ **TO **INFORM** ABOUT THE ACTIVITIES CARRIED OUT IN THE PALOMARES ENVIRONMENTAL AND PERSONNEL RADIOLOGICAL SURVEILLANCE PROGRAM**
- ✓ **TO **ANSWER** QUESTIONS AND TAKE NOTE OF THE VOLUNTEERS REQUESTS**

CRITERIA FOR LAND USE RESTRICTIONS

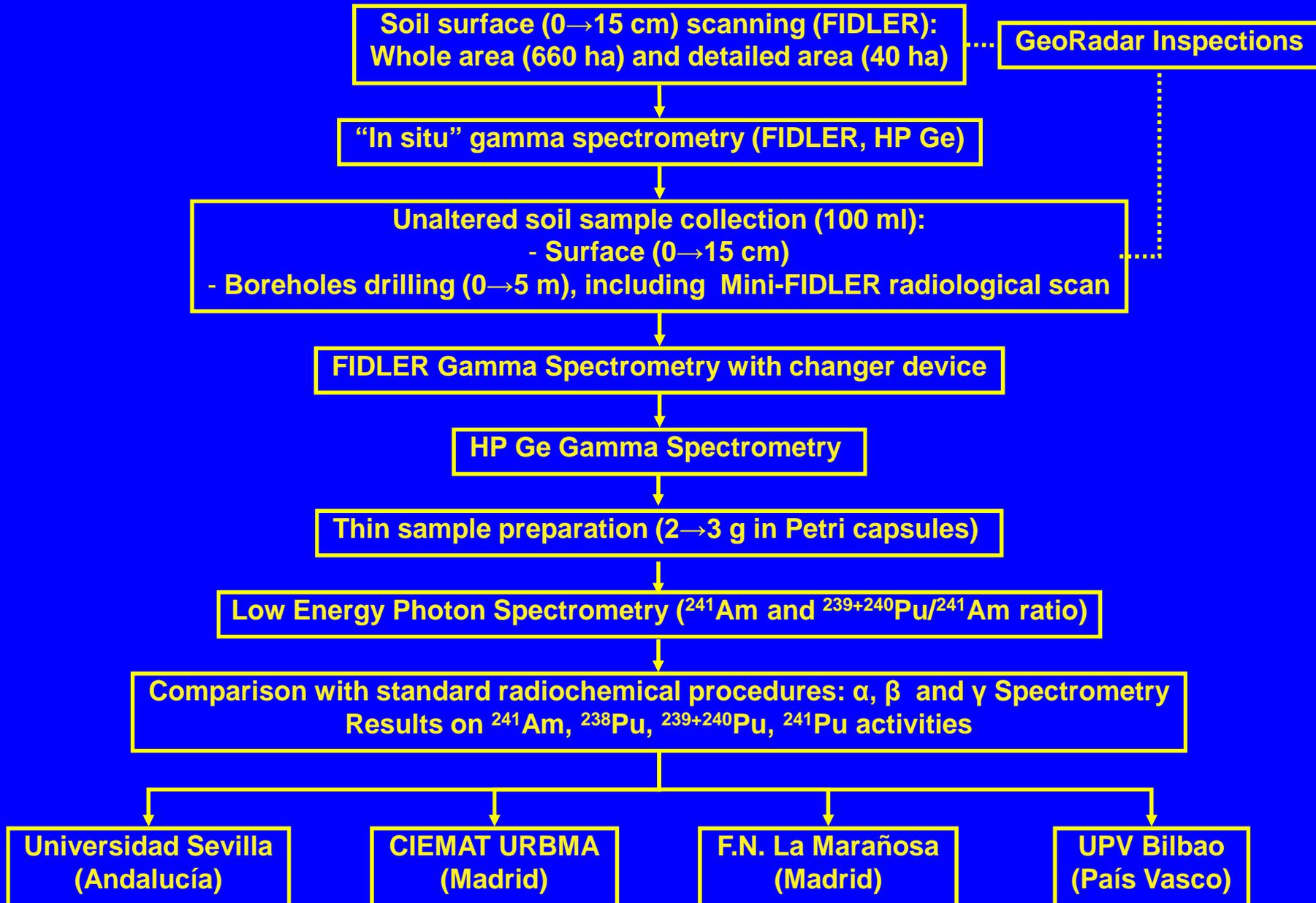
RADIOLOGICAL DATA FROM THE DIFFERENT SURVEYS ARE PRESENTED IN GRAPHS AND MAPS USING A COLOR CODE THAT IS BASED ON THE CRITERIA FOR THE USE OF TERRAINS OF PALOMARES ESTABLISHED BY THE NUCLEAR SAFETY COMMISSION:

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

(*) Soil is defined as the first 15 cm of material from the terrain surface.

(**) It is assumed a surrogate ratio ²³⁹⁺²⁴⁰Pu/²⁴¹Am=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

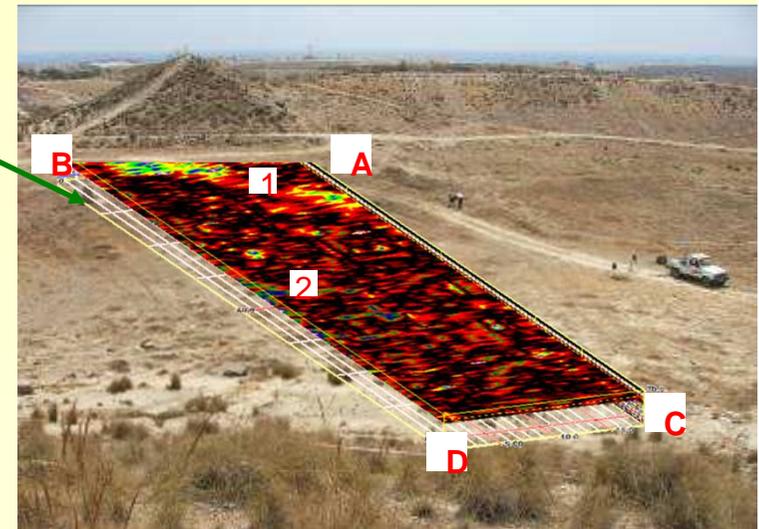
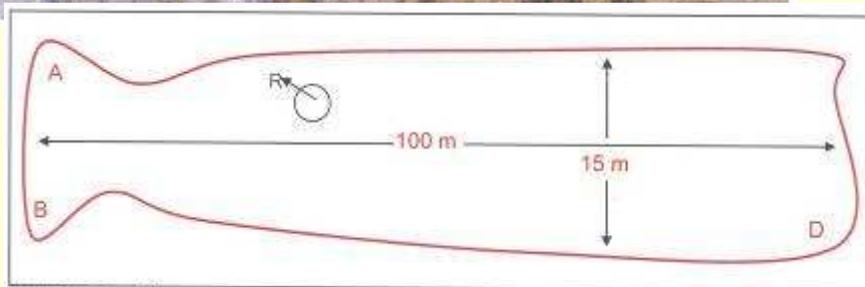
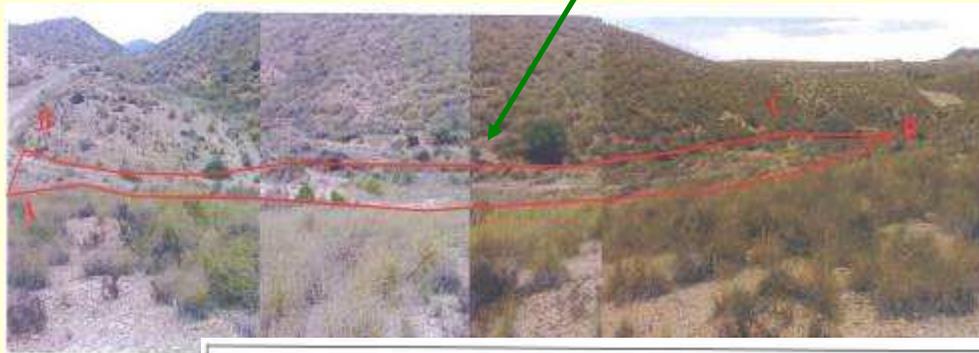
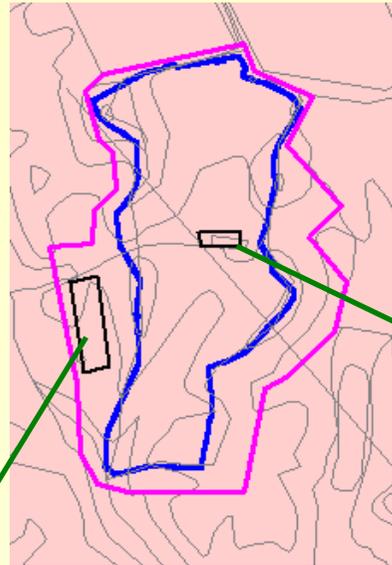


(*) Has a large-area (12.6 cm), very thin (0.16 cm) sodium iodide detector optimized for low energy photons (~10-100 keV). The emitters such as Pu (13.6 keV) and Am-241 (59.5 keV).

GEORADAR INSPECTIONS AT ZONE 2



PIT B
100 m x 1 m AND 3.0 m DEEP
VOLUME $\approx 3,000 \text{ m}^3$

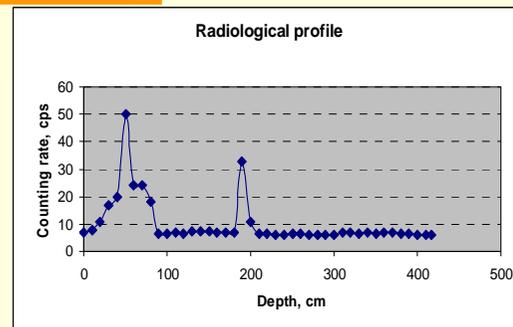


PIT A
40 m x 10 m AND 2.5 → 3.0 m DEEP
VOLUME $\approx 1,000 \text{ m}^3$

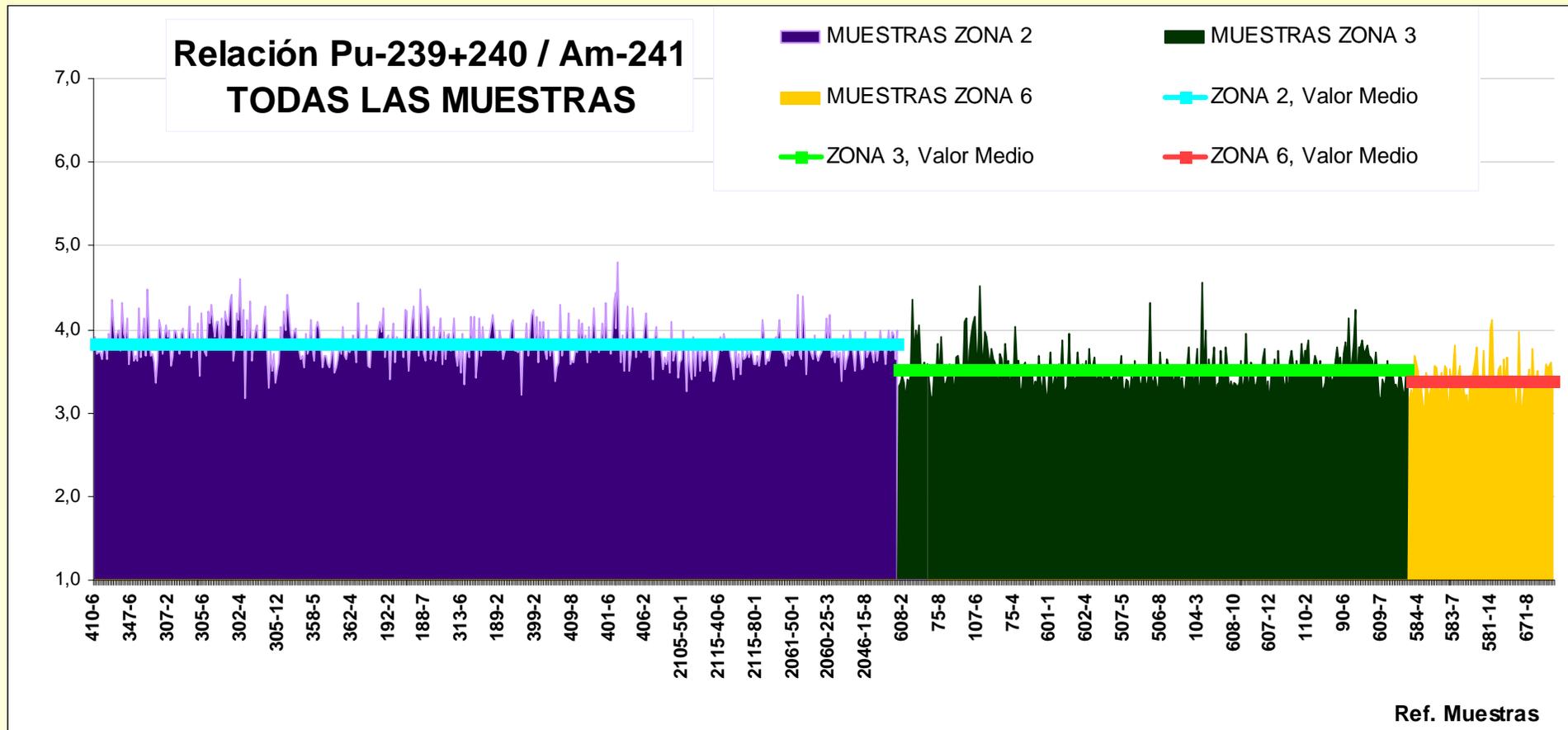
COLLECTION OF UNALTERED SOIL FROM DRILLING



- 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.

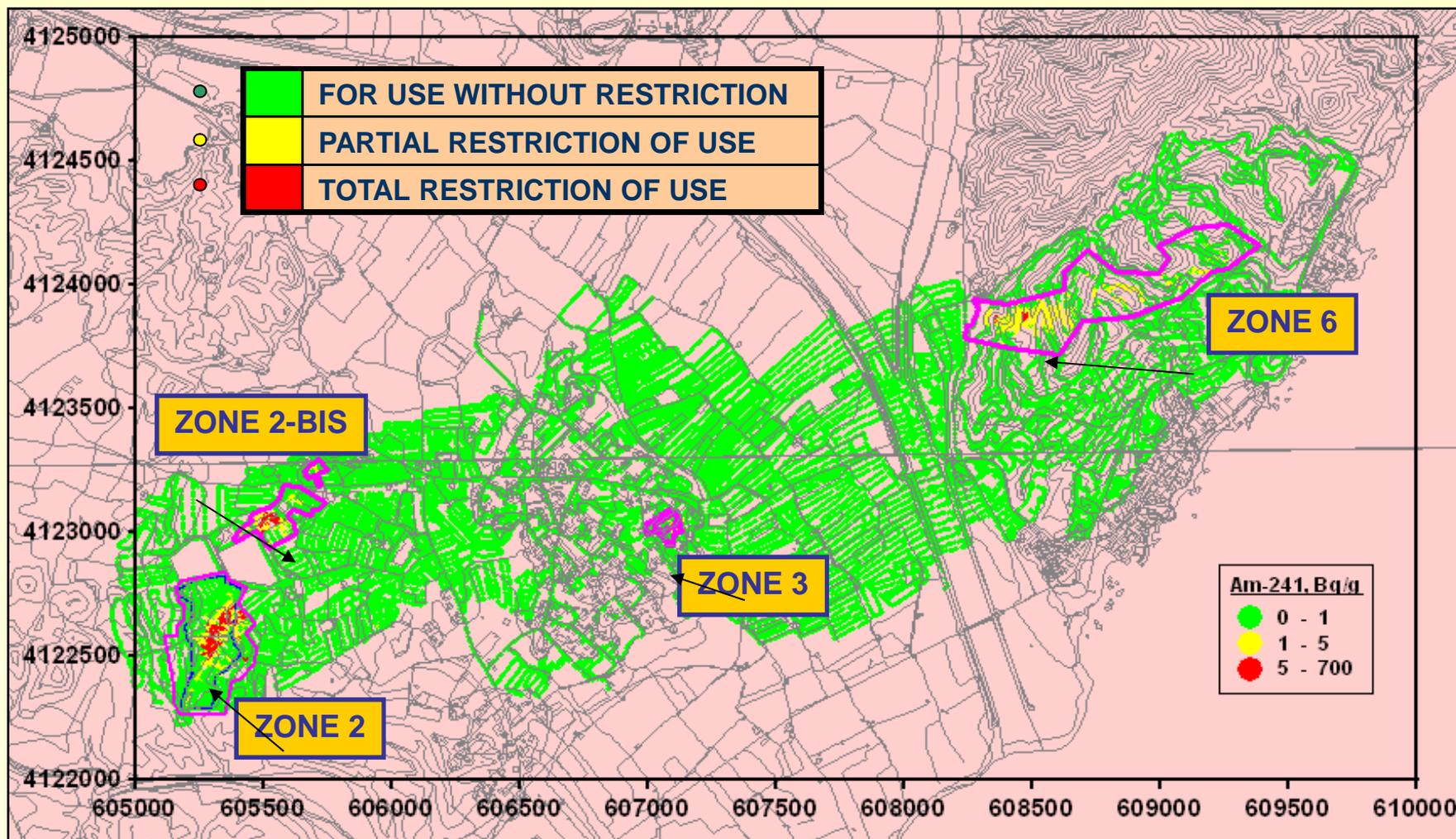


LEPS MEASUREMENT OF THE $^{239+240}\text{Pu}/^{241}\text{Am}$

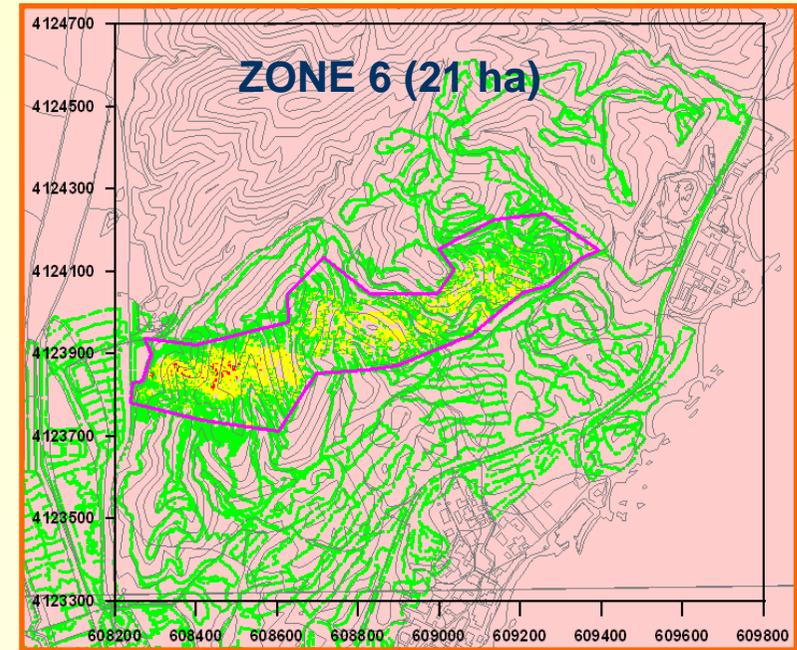
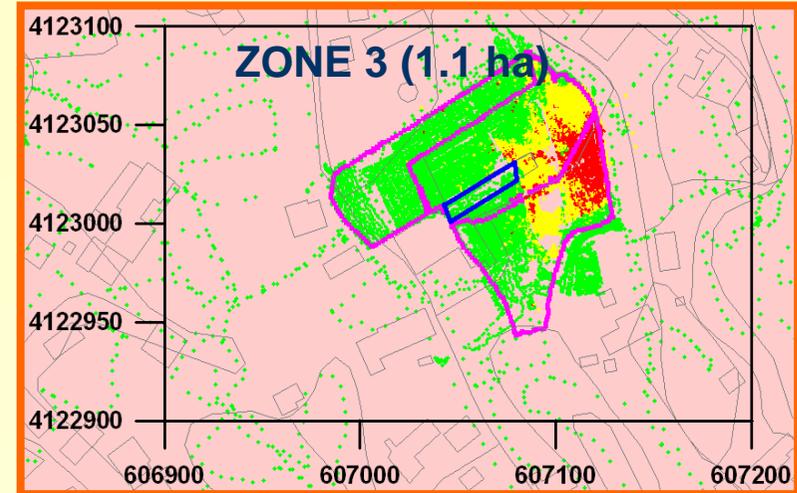
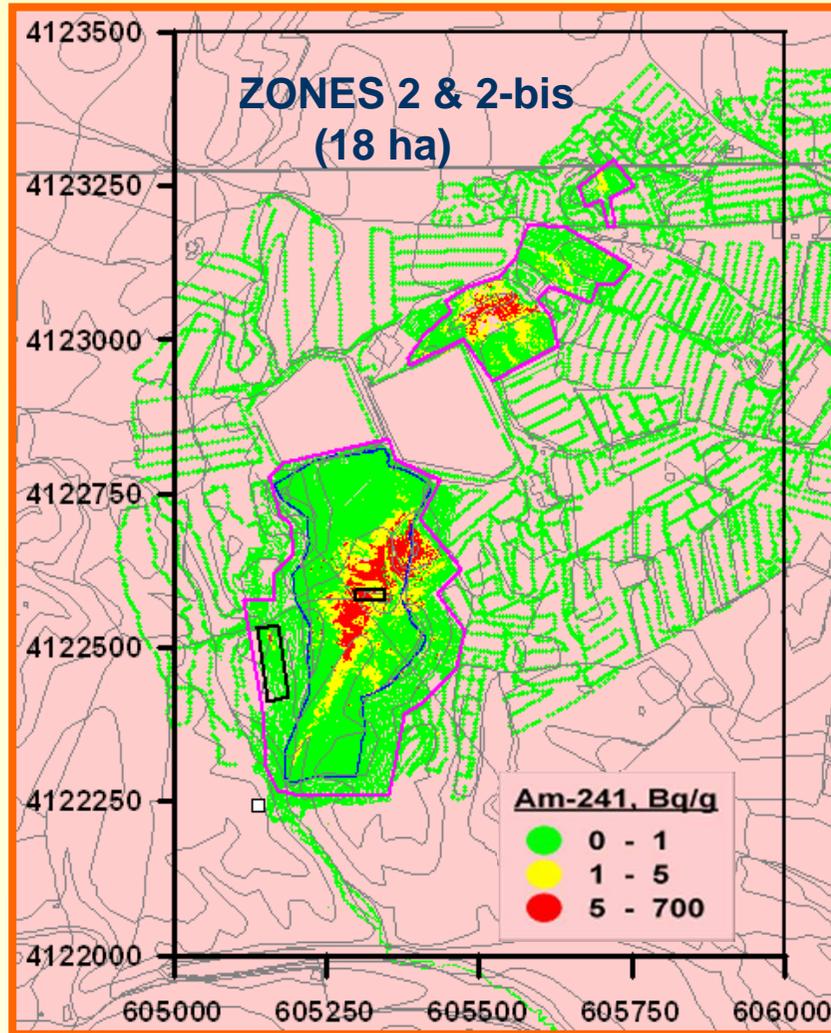


IT IS CONFIRMED (successfully validated with radiochemical methods and α spectrometry) THAT THE APPROACH $^{239+240}\text{Pu} / ^{241}\text{Am} \cong 4$ IS A REASONABLY CONSERVATIVE VALUE FOR THE RATIO AND THEREFORE IT CAN BE EMPLOYED TO ESTIMATE $^{239+240}\text{Pu}$ INVENTORY FROM ^{241}Am MEASUREMENTS.

SUMMARY OF 3D RADIOLOGICAL SURVEY (660 ha)

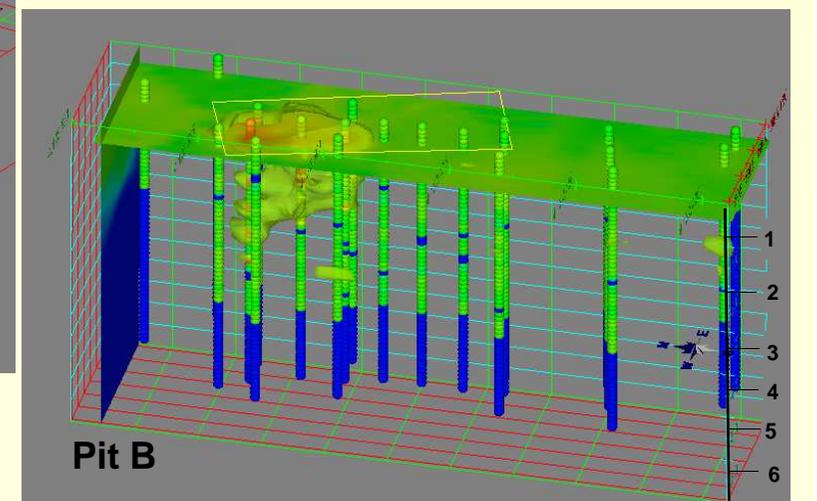
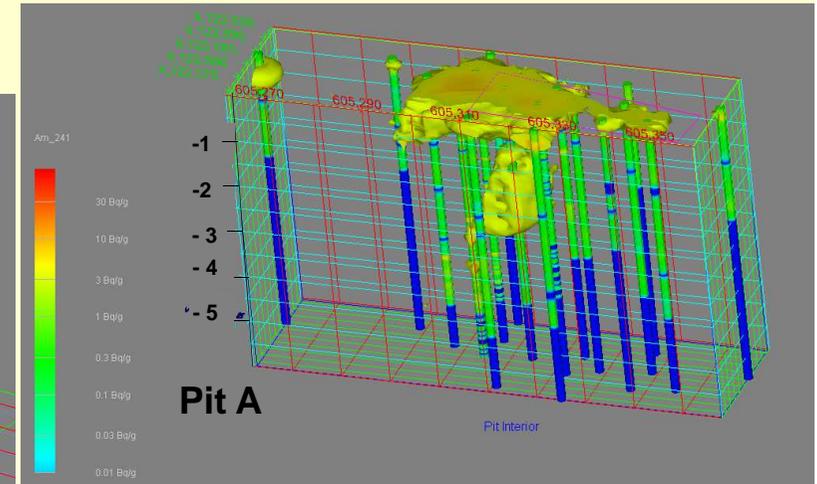
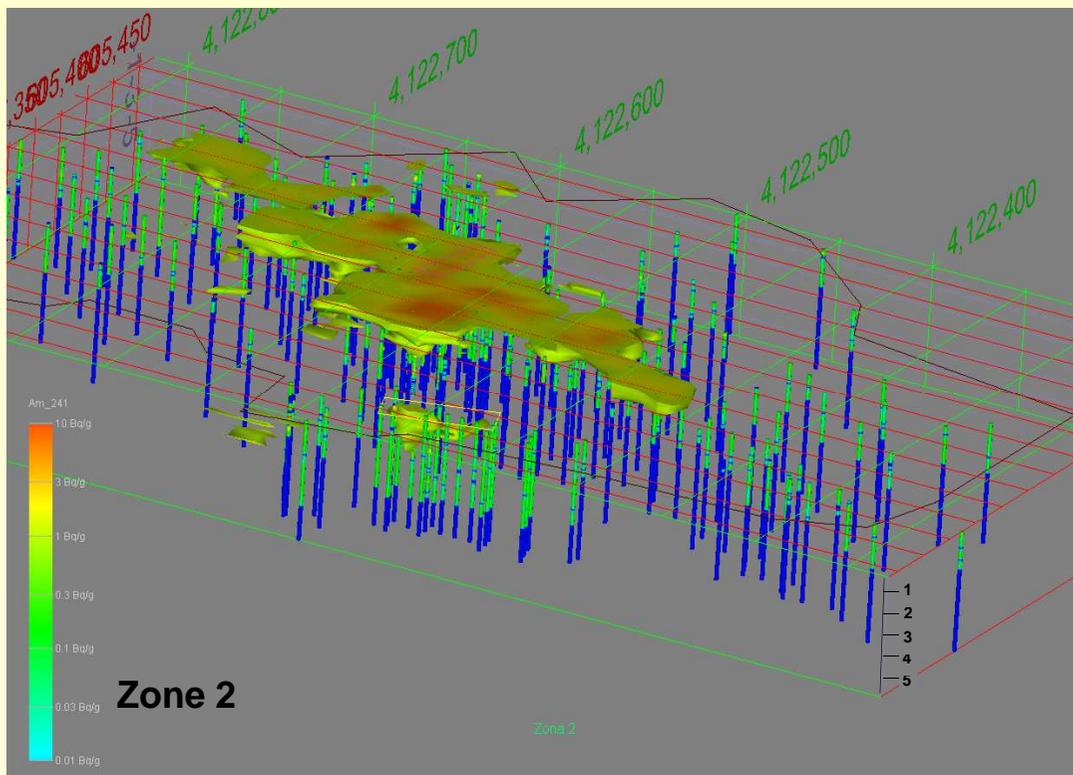


SUMMARY OF 3D RADIOLOGICAL SURVEY



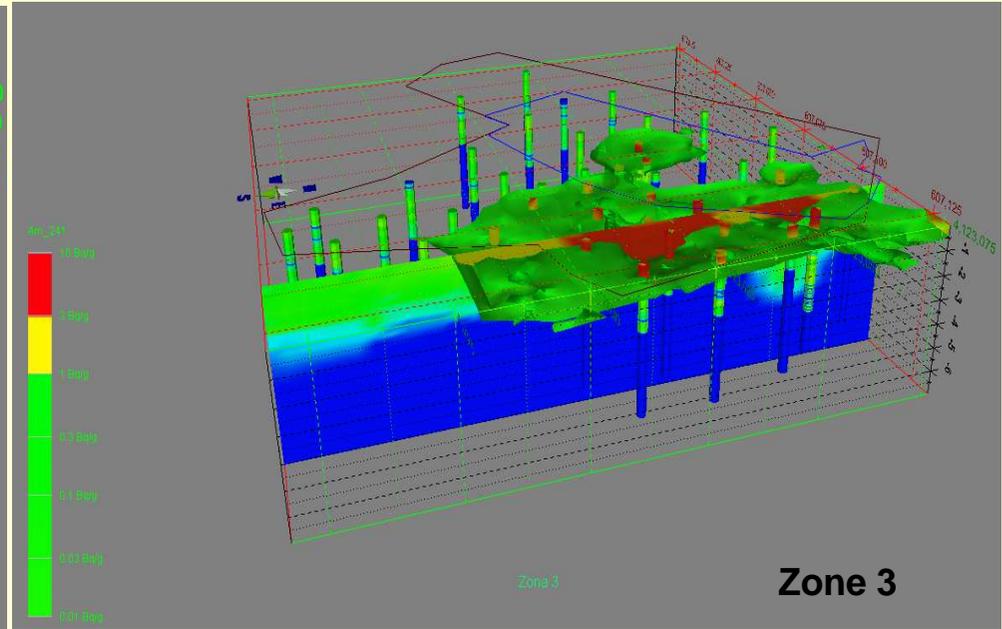
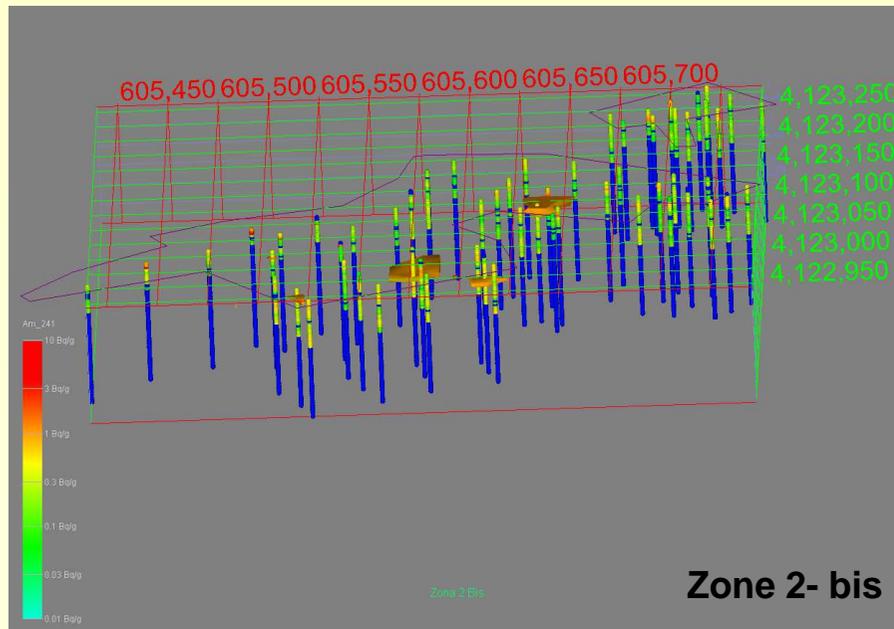
3D MODEL OF SUBSOIL CONTAMINATION (0.15→5 m). ZONE 2

IT ALLOWS THE ESTIMATION OF THE SUBSOIL VOLUME AFFECTED BY CONTAMINATION OVER THE LAND USE RESTRICTION LEVELS.



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.

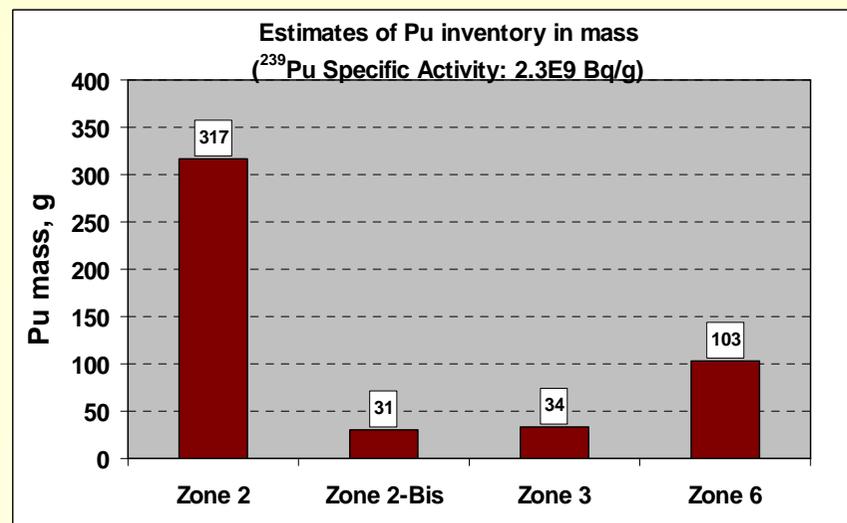
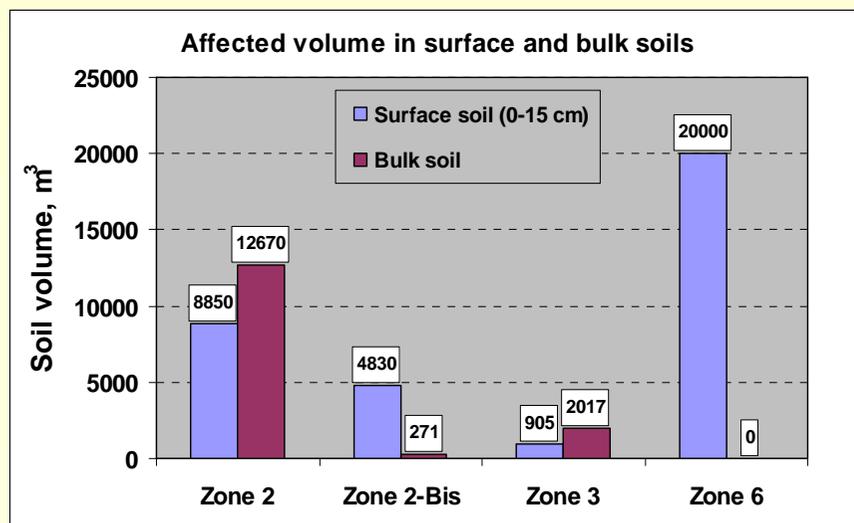


ZONE 6: IT IS ONLY AFFECTED IN THE TOPSOIL AND THEREFORE THERE IS NO MODEL FOR THE SUBSOIL.

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 m³ Pit B = 669 m³



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 $^{239+240}\text{Pu}$.
- 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.

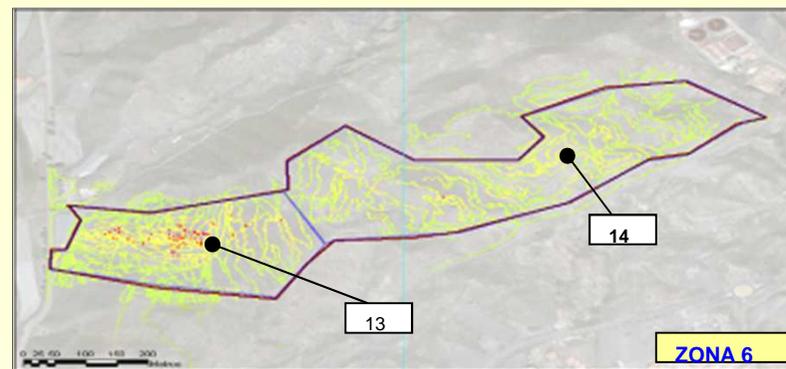
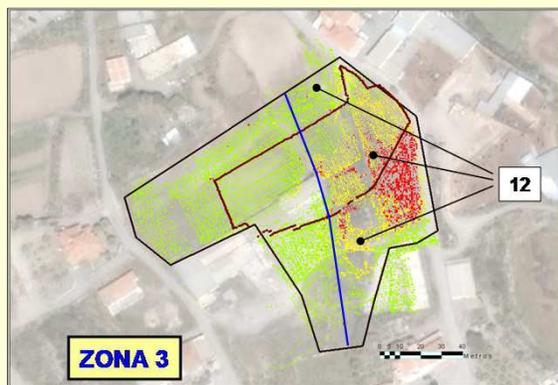
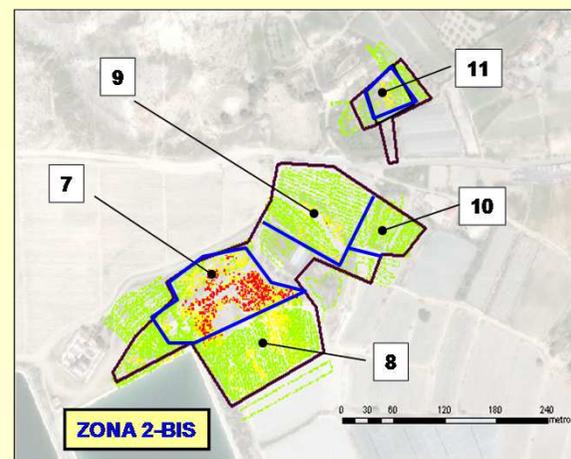
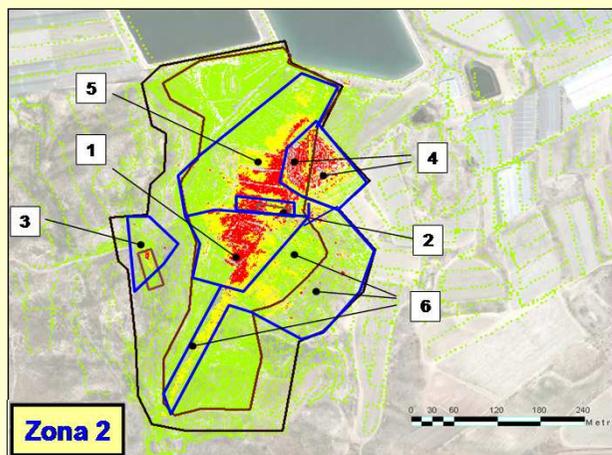
VERIFICATION MISSION ART- 35 EURATOM (April 2010)

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).

CONCLUSIONS:

- 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.

3D RADIOLOGICAL CHARACTERIZATION

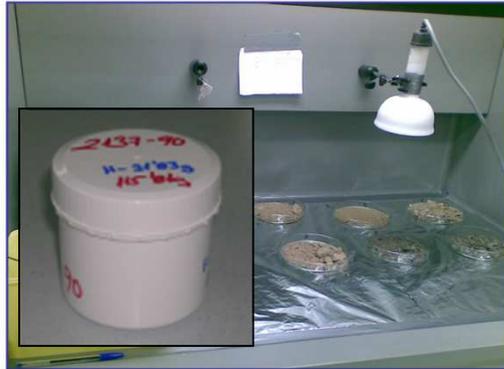


FOURTEEN PLOTS

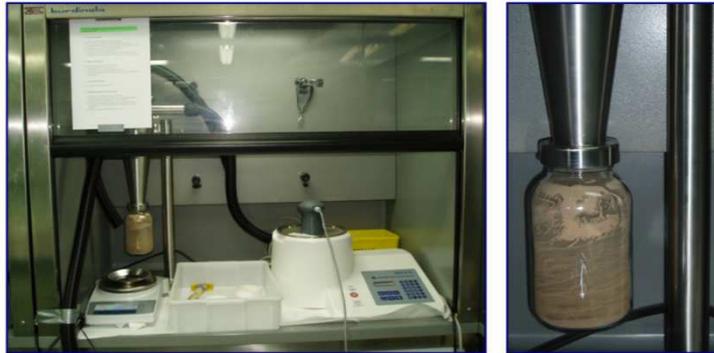
DIFFERENTIATED BY THEIR GEOGRAPHIC CONTINUITY AND PARTICULAR CONTAMINATION PATTERN

GRANULOMETRY STUDY: MASS AND ACTIVITY DISTRIBUTIONS DEPENDING ON THE GRAIN SIZE (DRY SIEVING) (1-2)

Secado de las muestras bajo epirradiador



Tamizadora en funcionamiento con detalle del ciclón

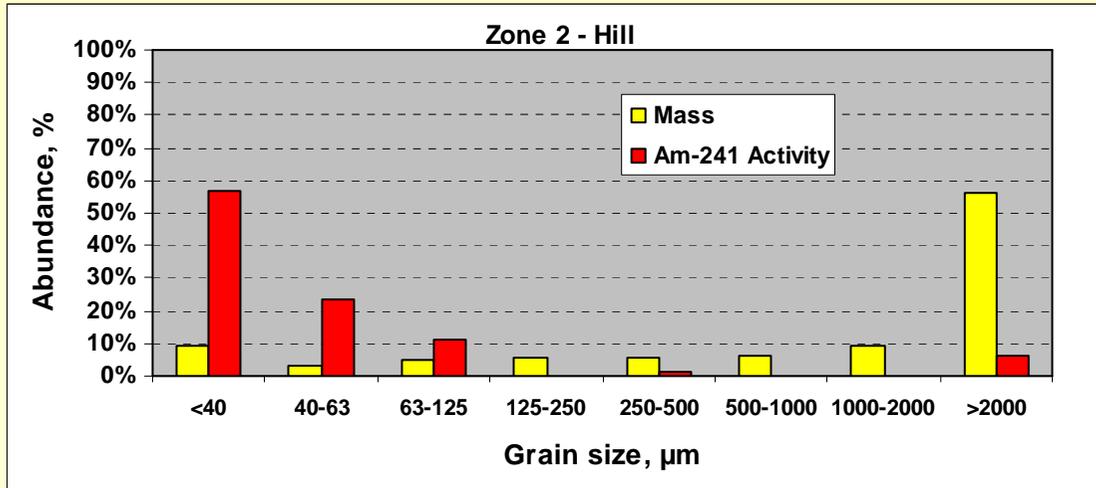


STANDARD AIR JET TECHNIQUE WAS EMPLOYED FOR DRY SIZE SEPARATION.

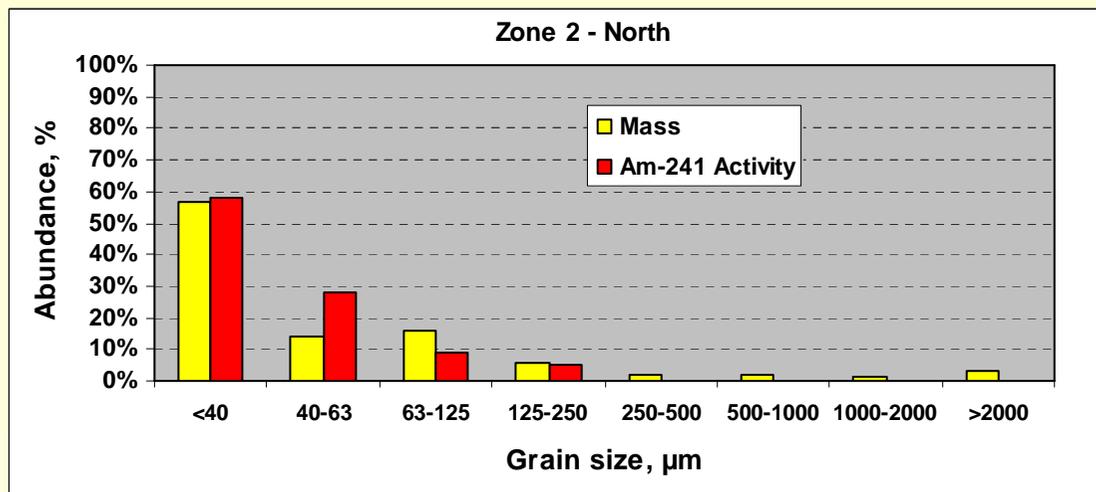
MORE THAN 900 SUBSAMPLES WERE PREPARED AND MEASURED BY GAMMA SPECTROMETRY.



GRANULOMETRY STUDY: MASS AND ACTIVITY DISTRIBUTIONS DEPENDING ON THE GRAIN SIZE (DRY SIEVING) (2-2)

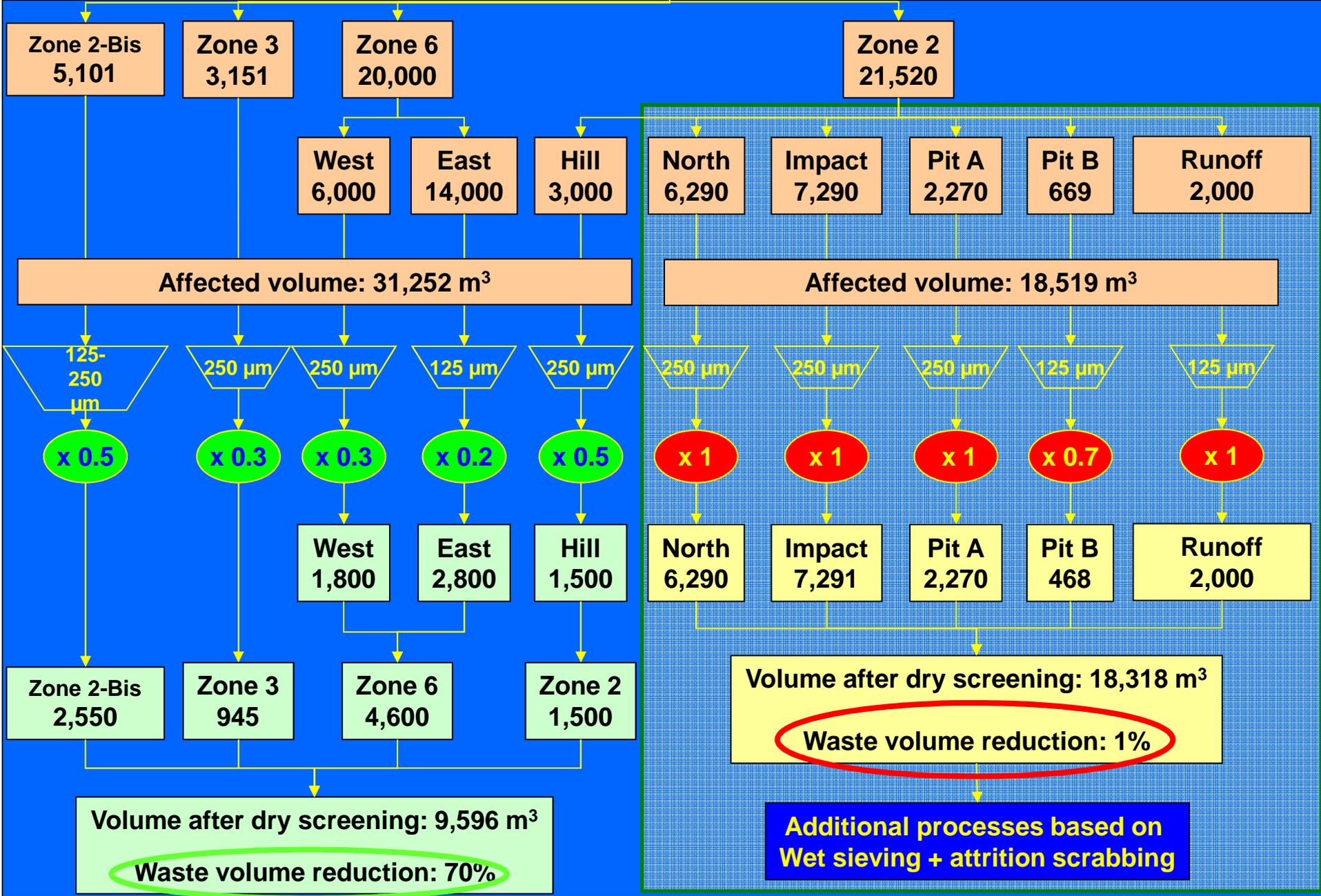


MOST OF THE ACTIVITY IS LOCATED IN SMALL SIZED GRAINS, WHICH JUST REPRESENTS ABOUT 10% OF THE ORIGINAL MASS: DRY SIEVING TECHNIQUES WILL BE ADEQUATE.



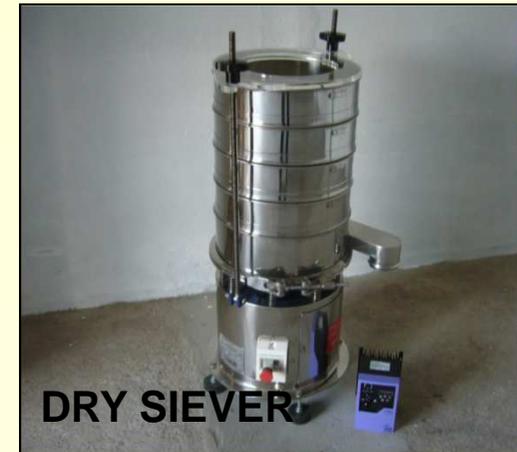
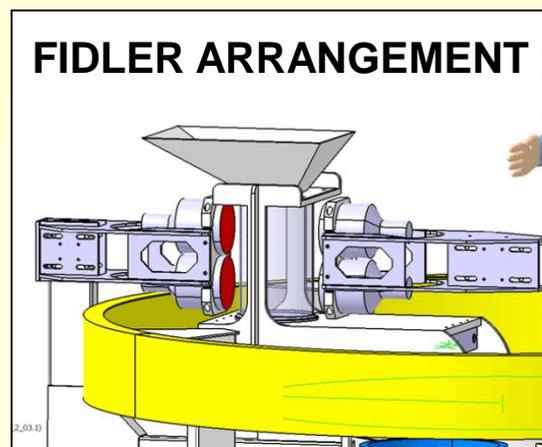
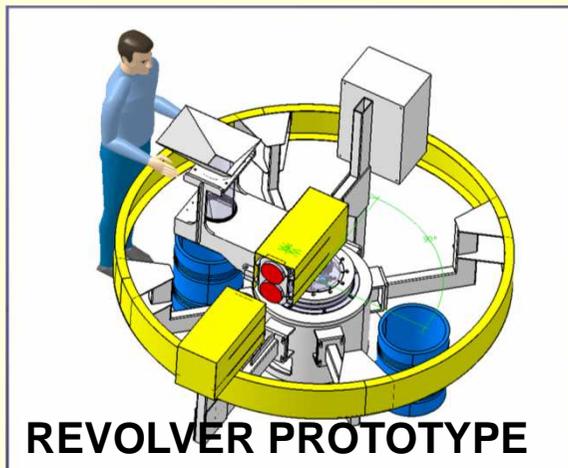
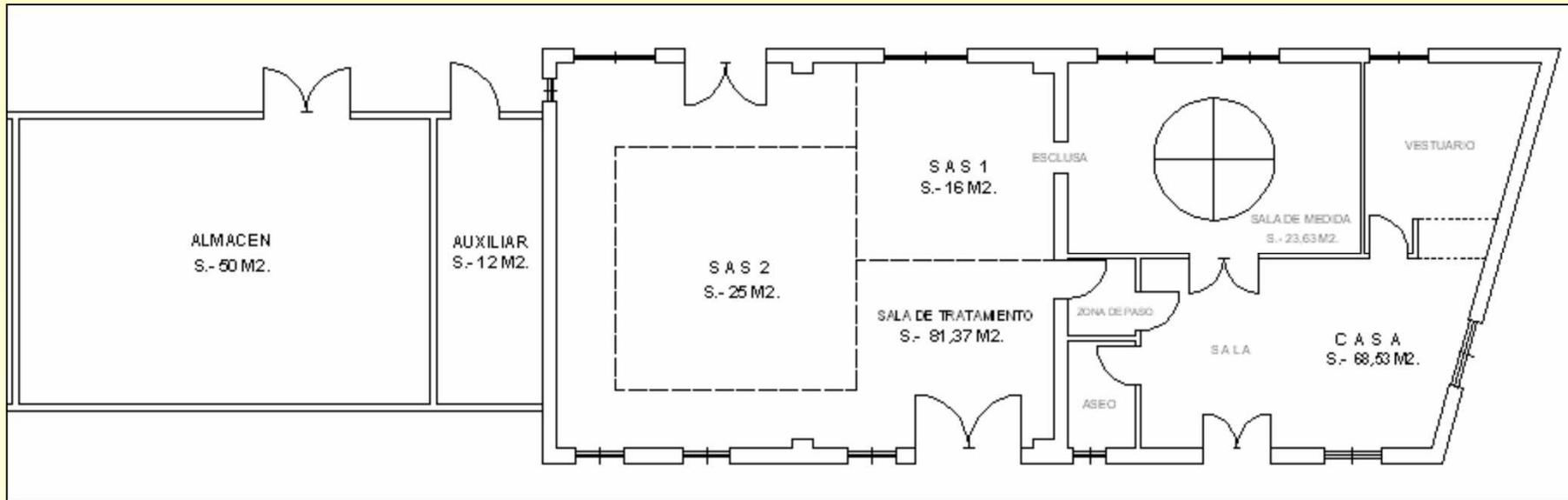
ACTIVITY AND MASS DISTRIBUTIONS ARE SIMILAR: IN ADDITION TO DRY SIEVING, WET SIEVING TECHNIQUES WILL BE NECESSARY.

Total affected volume (m³):
49,771



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.



PILOT PLANT FOR MEDIUM-SCALE SOIL STUDIES: DRY SIEVING



COLLECTION OF 100 l SOIL SAMPLES



FIDLER "IN SITU" MEASUREMENTS



HP Ge 10 I SAMPLE CHARACTERIZATION



SAMPLE DRYING STATION

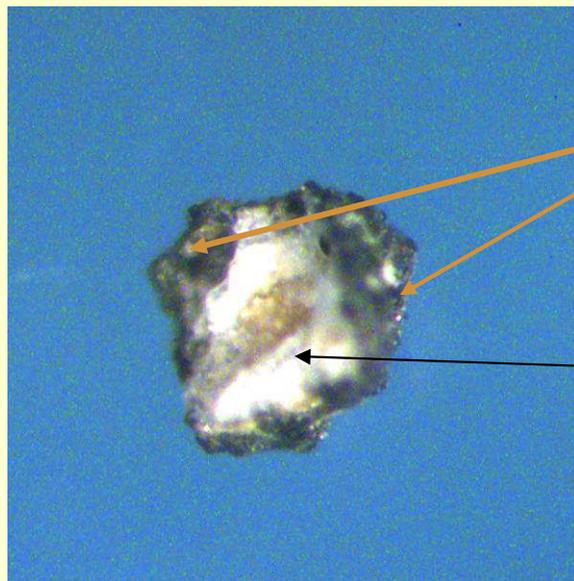


DRY SIEVER LOADING



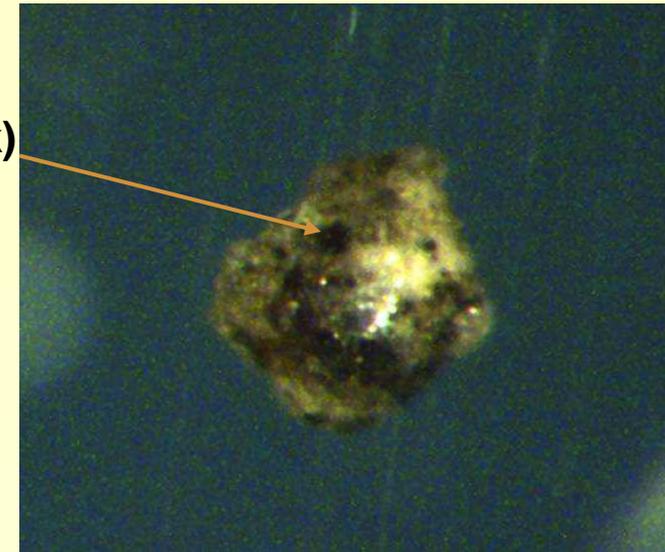
FOUR-FIDLER AUTOMATIC SEGREGATION MACHINE

LIMITATIONS OF DRY SIEVING TECHNIQUES



NUCLEAR
COMBUSTIBLE (black)

SiO₂ (white)

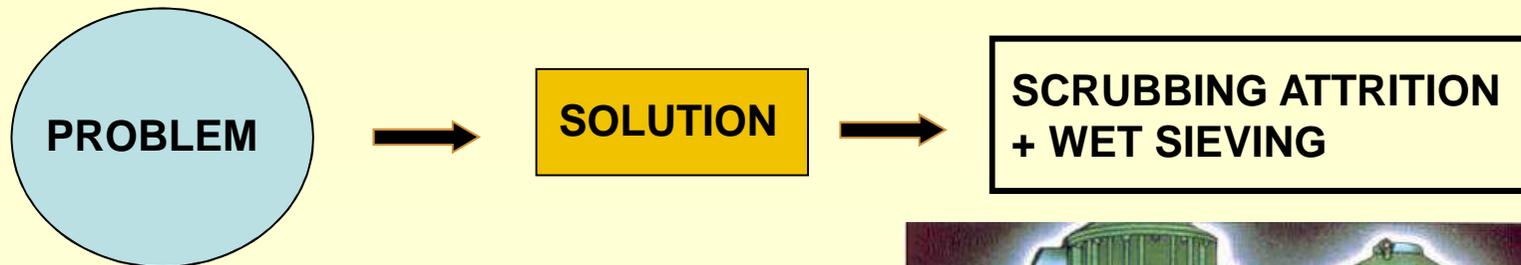


IN SOME CASES DRY SIEVING IS NOT GOOD ENOUGH BECAUSE OF THE **AGGREGATES**.
ADDING WATER IS A SUITABLE SOLUTION (WET SIEVING).

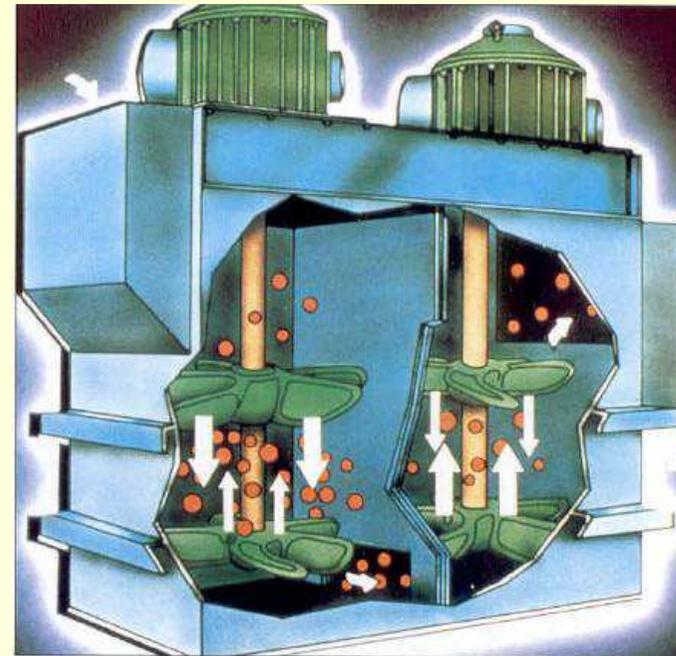
THE TRANSURANIC MICROPARTICLES COAT A NATURAL GRAIN, YIELDING AN
APPARENT SIZE WHERE THE ACTIVITY IS MUCH SMALLER THAN EXPECTED.
IN THIS CASE, IT IS NECESSARY TO **BREAK MECHANICALLY** THE VERY SMALL GRAINS.

SCRUBBING ATTRITION

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



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

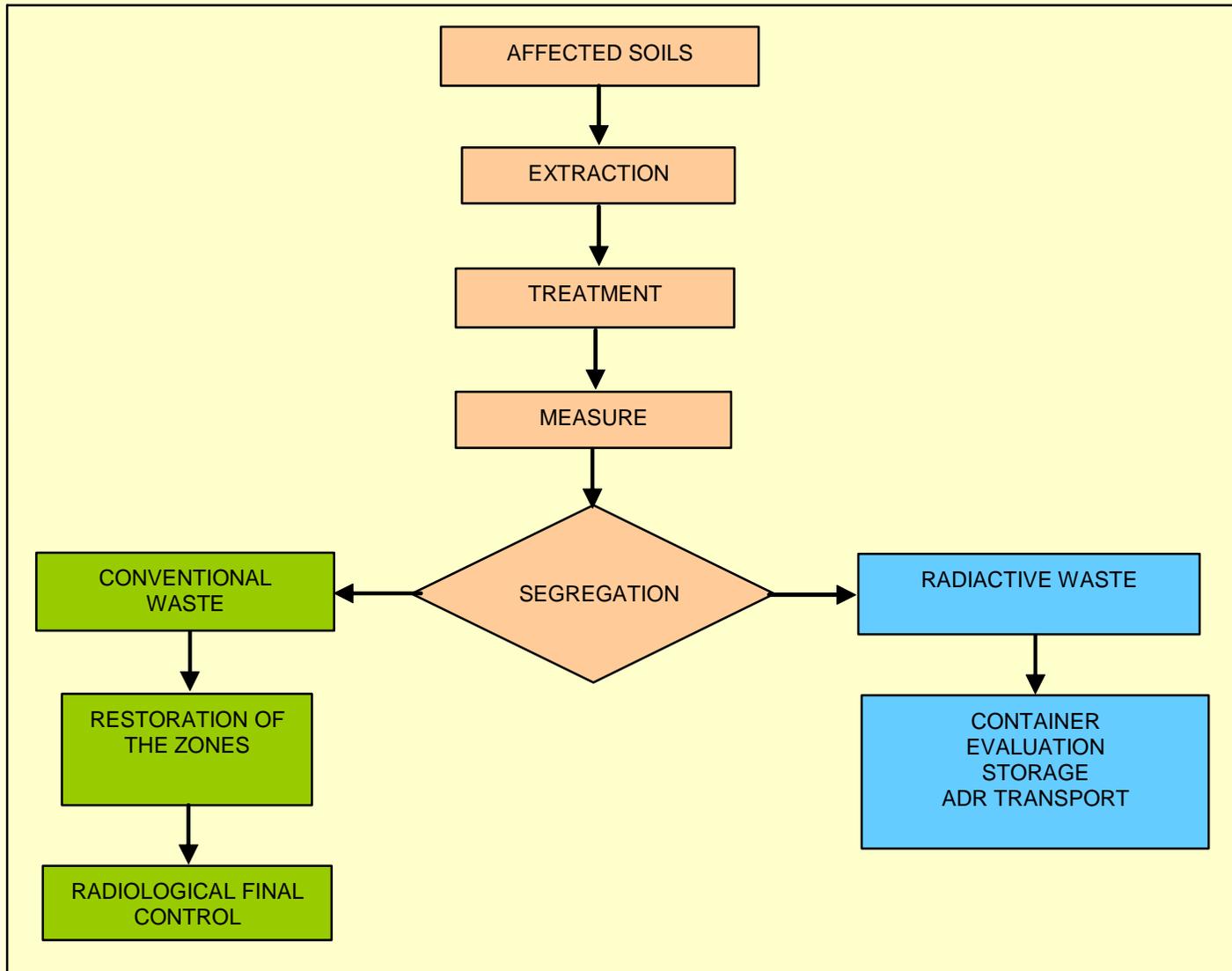
SOIL PARTICLES ARE SEPARATED BY SIZE USING SIMPLE SIEVES. A LARGE FRACTION IN WEIGHT WITH LOW ACTIVITY AND A SECOND FRACTION WITH HIGH ACTIVITY IN A SMALL FRACTION ARE OBTAINED.

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



THE PLANNING FOR STAKEHOLDER INVOLVEMENT (1-2)

IS A TOP PRIORITY. THIS STRATEGY WILL CONTAIN AT LEAST:

- 1.-DETAILED DESCRIPTION OF CLEANING AND REMOVAL THAT EXPLICITLY REFERS TO **TECHNICAL AND SCIENTIFIC GUARANTEES** BACKING THE SAFETY OF THE ENTIRE PROCESS, LEADING TO A PUBLIC DISCOURSE OF CONSENSUS AND DIFFUSION
- 2.-ANALYSIS OF THE SOCIAL, MEDIA, POLITICAL, SCIENTIFIC, TECHNOLOGICAL, INSTITUTIONAL, ENVIRONMENT TO EVALUATE SCENARIOS, DETERMINE POSSIBLE **CRISIS SITUATIONS** AND SELECT TARGETS FOR ACTION
- 3.- PLAN OF ACTION THAT ARTICULATES THE NECESSARY **POLITICAL CONSENSUS**, INSTITUTIONAL AGREEMENTS, SOCIAL DIALOGUE AND WITH COMMUNICATIONS MEDIA, INCLUDING THE NECESSARY TOOLS: PLANS FOR INSTITUTIONAL AND SOCIAL RELATIONS, PUBLIC RELATIONS, PRESENCE OF EXPERTS AND SCIENTIFIC COMMUNITY, INFORMATION, APPROPRIATE SPEAKERS

THE PLANNING FOR STAKEHOLDER INVOLVEMENT (2-2)

4.- THE KEY TO SUCCESS OF A SOCIAL ACCEPTABILITY STRATEGY IS **ANTICIPATION**, AVOIDING THE APPEARANCE OF EARLY POINTS OF CONFLICT THAT COULD POLARIZE POSITIONS, CAREFUL PLANNING OF STAGES, CONSTRUCTION OF A SOLID DISCOURSE AND THE USE OF ALL OF THE TOOLS NECESSARY IN VIEW OF THE AUDIENCES AND RISK SCENARIOS



WORK IN PROGRESS (1-2)

THE FOLLOWING ISSUES COULD IMPROVE THE FINAL REHABILITATION PLAN:

- SHOULD CONSIDER INCLUDING A DISCUSSION OF **IMPORTANT PROJECT UNCERTAINTIES**, SUCH AS THE RANGE OF POTENTIAL SOIL VOLUMES AND THE IMPACT ON COST AND SCHEDULE. THE SOIL EXCAVATION TECHNIQUES MAY CAUSE THE QUANTITY OF EXCAVATED SOIL TO INCREASE DUE TO EQUIPMENT AND OPERATOR LIMITATIONS
- COULD INCLUDE CONSIDERATION AND EVALUATION OF TECHNOLOGY OPTIONS THAT COULD FAVORABLY IMPACT PROJECT COST AND TIMEFRAME. **THE OPTION OF BULK REMOVAL** OF SOIL RATHER THAN TREATMENT AND CONCENTRATION OF CONTAMINATED SOIL SHOULD BE INCLUDED IN ANY DISCUSSION

WORK IN PROGRESS (2-2)

THE FINAL REHABILITATION PLAN SHOULD CONSIDER :

- **PACKAGING EFFICIENCIES** OPTIMIZED THROUGH USE OF LARGER PACKAGES FOR STORAGE AND TRANSPORT OF CONTAMINATED SOIL
- **UNINTENDED CONSEQUENCES** THAT MAY OCCUR IN WASTE PROCESSING CREATING MORE DIFFICULT WASTE STREAMS, SUCH AS CONCENTRATION OF RADIOACTIVITY REQUIRING MORE ROBUST PACKAGING OR DISPOSAL OF CONTAMINATED SOIL
- **UNANTICIPATED SOIL CONTAMINANTS**, SUCH AS PESTICIDES, ORGANIC CONTAMINANTS, AND HEAVY METALS THAT MAY VIOLATE WASTE ACCEPTANCE CRITERIA AT POTENTIAL DISPOSAL SITES (ESPECIALLY IN PITS). CONTAMINANTS SHOULD BE MEASURED POST-SIEVING TO DETERMINE IF METALS INADVERTENTLY HAVE BEEN CONCENTRATED TO EXCEED DISPOSAL SITE WASTE ACCEPTANCE CRITERIA

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 ACCEPTABLE FOR THE NUCLEAR SAFETY COMMISSION
- AFTER APPLYING GRANULOMETRIC TECHNOLOGIES (DRY AND WET SIEVINGS).WITH THESE TECHNOLOGIES: 50,000 m³ OF CONTAMINATED LAND MAY BE REDUCED TO ABOUT 6,000 m³
- THE WORK IS PLANNED TO LAST THREE YEARS
- THE PRP ESTIMATED BUDGET IS 31 M€ (2009) EXCLUDING FINAL MANAGAMENT OF RADIOACTIVE WASTE GENERATED.

FROM THE SIERRA ALMAGRERA TOWARDS THE MEDITERRANEAN SEA

