REPUBLIC OF ARGENTINA
NATIONAL NUCLEAR ENERGY COMMISSION (*CNEA*)

URANIUM MINING ENVIRONMENTAL RESTORATION PROJECT (*PRAMU*[1])

ENVIRONMENTAL ASSESSMENT

EXECUTIVE SUMMARY

January 2006

[1] *Proyecto de Restitución Ambiental de la Minería del Uranio (PRAMU)*

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ACRONYMS

ALARA	As Low As Reasonably Achievable
APL	Nuclear Regulatory Authority
ARN	Nuclear Regulatory Authority
Bq	Bequerel
CFC	Córdoba Processing Complex
CFM	Malargüe Processing Complex
CFMSR	San Rafael Mineral Processing Complex
CFR	Code of Federal Regulations
CNEA	National Atomic Energy Commission
CRAS	Regional Center of Subsurface Water
DOE	Department of Energy (US)
DIA	Declaration of Impact Assessment
DIPAS	Direción Provincial de Agua y Sanamiento
EA	Environmental Assessment
EIA	Environmental Impact Assessment
GIS	Geographic Information System
IAEA	International Atomic Energy Agency
ICRP	International Commission for Radiological Protection
MCL	Maximum Concentration Level
MOU	Memorandum of Understanding
MSv	MilliSievert
NASA	*Nucleoelectrica Argentina, Ltd.*
NGO	Non Governmental Organization
NP	National Park
NRC	Nuclear Regulatory Agency (US)
PCi	Pico Curie
PIP	Project Implementation Plan
PIU	Project Implementation Unit
PRAMU	Uranium Mining Environmental Restoration Project
Sv	Sievert
SIGA	CNEA Environmental Information and Management System
TOR	Terms of Reference
TWG	Technical Working Group
UEP	Project Implementation Unit
UGA	Environmental Management Unit
UGAP	Provincial Unit for Environmental Management
UGAMU	CNEA Uranium Mining Environmental Management Unit
UMTRA	Uranium Mine Tailings Restoration Act
UMTRCA	Uranium Mine Tailings Restoration Control Act
U$D	U.S. Dollar
US EPA	United States Environmental Protection Agency
WB	The World Bank
WL	Working Level
WLM	Working Level Month

ARGENTINA
URANIUM MINING ENVIRONMENTAL RESTORATION PROJECT
(*PRAMU*[2])
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INTRODUCTION

CONTEXT, OBJECTIVE AND SCOPE OF THIS DOCUMENT

In the 1950s, Argentina established uranium mining and extraction industry to supply nuclear fuel to its nuclear power generating plants and medical and research facilities. In the 1980s and 1990s, when the global market price of uranium dropped below its domestic production costs and some of the ores were exhausted, most of the facilities closed down or were put on hold. As the extraction of uranium from its ores involves a concentration factor of several orders of magnitude, the approximately 2,500 tons of uranium produced left behind a legacy of over 67 million tons of mining and processing residues, 'tailings' in the technical jargon. These tailings pose a potential source of radiation health hazard to the population and the environment. Indeed, two of the defunct facilities are located in the immediate proximity of urban population centers.

The National Commission of Nuclear Energy of Argentina (*CNEA*)[3] is charged with the preparation and implementation of a program for environmental restoration of the sites associated with uranium mining and processing (*PRAMU*)[4]. The objective of the *PRAMU* is to perform the environmental restoration as comprehensively as possible in terms of economic and technical feasibility. To improve *CNEA*'s effectiveness in planning and implementing the *PRAMU* and to address public concerns, the Program involves active public participation in decision-making, as well as institutional strengthening of the implementing agency.

In the absence of adequate national resources for executing the Program, *CNEA* applied for credit from the World Bank (WB). The loan involves a WB credit of 25.0 million U$S, matched by an investment of U$S 3.43 million by the Government of Argentina. The proposed project is a *Sector Investment Loan* that will address the proper closure and remediation of all CNEA closed uranium mining and milling sites as part of an institutional, environmental and social framework approach, with a planned performance period of seven years[5]. Project planning and execution, put on hold in 2002 due to Argentina's fiscal crisis, was resumed in 2005.

For any one of the sites slated for remediation under this Program, a site specific Environmental Assessment (EA) has to be carried out in accordance with both Argentinean (national and provincial) requirements and WB policies. Each of these sites has first to be characterized to identify the types of prevailing contaminants, their extant and potential environmental impacts, and possible contaminant pathways. Based on internationally accepted best practices and standards, effective solutions for the management of the tailings and site restoration would then be developed.

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[2] *Proyecto de Restitución Ambiental de la Minería del Uranio*
[3] *Comision Nacional de Energia Atomica*
[4] See footnote No. 2
[5] Including 10% for physical contingencies and another 5% for annual cost contingencies.

This EA, a component of the *PRAMU*, explores the extant environmental impact in the distinct uranium mining sites across the country and specifically in *Malargüe.* This document is an umbrella EA, comprising the completed and approved *Malargüe* EA, as well as the more limited and preliminary environmental assessments of the other sites slated for remediation and reclamation. The present version of the EA is based on the May 2002 Draft EA and the Supplement for *Malargüe*[6], and incorporates comments received through the public consultation process, revisions recommended by a review panel[7] and WB consultants to a preceding (August 2001) draft, and WB Quality Assurance Team (QAT) review.

While providing a concise summary of the principal document, this Executive Summary does not necessarily mirror the outline of the principal document. To maintain an easy cross reference, the Executive Summary frequently identifies the corresponding section numbers in the original, Spanish language document (e.g., '4.18').

Chapter 1 of the Executive Summary provides an overview of Argentina's nuclear industry and its uranium mining sector, and briefly discusses its legacy. Chapter 2 describes *PRAMU*'s master plan and its components as well as the institutional adjustments of the implementing agency. It also summarizes the legal framework at the national and provincial levels that is pertinent to the environmental management and restoration activities of the sector, and sheds light on the public consultation processes that has been accompanying the EA's preparation. Chapter 3 presents succinctly the current situation at eight of the nine priority sites to be ultimately remediated, describing their potential and actual sources of contamination and, in the absence of adequate environmental impact data, identifying the remaining needs for site characterization. Chapter 4 contains the EA of the *Malargüe* Site. It documents the baseline conditions at the site, assesses its present environmental risks, analyzes several mitigation alternatives and their screening process, and reviews the site-specific public consultation course and the plan for future social participation. Finally, it describes the mitigation measures to be implemented under the selected restoration alternative, their anticipated costs and benefits, and the plans for monitoring during work execution and long-term post-closure monitoring.

1 ARGENTINA'S URANIUM MINING SECTOR: EVOLUTION, CURRENT STATUS, AND ASSOCIATED ENVIRONMENTAL ISSUES AND POLICIES

URANIUM MINING AND NUCLEAR APPLICATIONS

Figure 1 shows Argentina's historical and current sites uranium ore exploration, mining and processing. Uraniferous ores occur along the eastern flank and foothills of the Andean Cordillera in stratiform sandy deposits and in veins in granites. Due to a combination of adverse economic factors (low price on the international market and high domestic production costs), most of the mines and mineral processing facilities were closed during the late 1980s and the 1990s, and some have since been put on standby. Today, there are only two major deposits that, under favorable international market conditions, are capable of producing cost-effectively uranium ore.

[6] Both draft documents were originally posted on *CNEA*'s website: http://www.cnea.gov.ar/Pramu, as would be the present EA.

[7] Frank L. Parker, Miquel Vidal, and Florence Sanchez, Department of Environmental Engineering, Vanderbilt University, Tennessee, USA/ Review of EIA Report for the Argentine – Mining and Decontamination Project *PRAMU*, Report to the World Bank, November 5, 2001.

The *Sierra Pintada* deposit (*San Rafaël*, Province of *Mendoza;* today in stand-by) contains 9,200 tons of mineral reserves at an average grade of 0.15%[8]; and the *Cerro Solo* deposit (Province of *Chubut;* currently subjected to advanced exploration) contains estimated 5,200 tons of uranium reserves with significantly higher uranium grades of 0.3% to 0.5%. Consequently, about 120 tons of uranium concentrates are purchased annually on the international market for processing into nuclear fuel. As a result of recent favorable market price (~USD 30/kg) combined with the devaluation of Argentina's currency, *CNEA* is presently considering the revitalization of the *San Rafaël* mining and uranium dioxide manufacturing facility.

Argentina has two nuclear power generation reactors (*Atucha I* and *Embalse*), and the construction of a third (*Atucha II*) has been put on hold. The reactors use natural uranium as fuel and heavy water as moderator and cooler. With an installed generation capacity of 940 MWe, annual fuel consumption is about 150 tons of uranium[9]. Currently, nuclear power provides about 11.5% of the country's total power.

During the 1980's, the production cycle of nuclear fuel was completed with the construction of uranium dioxide (the raw material for nuclear fuel) manufacturing and heavy water production plants, as well as facilities for the manufacturing of fuel elements for research and nuclear energy reactors. Argentina also has developed, through private- and state-owned facilities, a well-established track record in the production of radioisotopes for medical and industrial uses for both domestic consumption and export.

Overview of the Environmental Problems Associated with Argentina's Uranium Extraction Sector

Up to the early 1990s, Argentina's uranium extraction industry evolved in a lax regulatory environment. This resulted in an environmentally harmful accumulation of solid and liquid wastes associated with uranium mining and processing. Mining took place primarily in hard rock open pits, generating waste piles of sterile overburden and low-grade (marginal) ore. Milling and leaching of the ores required installation of buildings and mechanical equipment and the construction of large leaching pads. These processes generated liquid wastes containing acids, metals and residual uranium compounds, as well as heap-leach residues[10] (for brevity, all referred to in this report as 'tailings'). The primary contaminants associated with the uranium industry -- radionuclides, heavy metals, anions and acid effluents – are further discussed in the following.

- *Radionuclides.* Milling tailings, while relatively low in concentration of long half-life radionuclides, still contain several types of contaminants that pose health risks to the workers and, through dispersion, to the public at large[11]. The most important radioactive components of mine tailings are radium 226, which decays to produce radon 222, and thorium 230[12]. Their exposure pathways include diffusion of radon gas via the air, where it can be inhaled or ingested when blown in particulate form; and mobilization by water through leaching of the tailings and their dispersed dust particles. Both vectors might disperse radioactive and other hazardous materials to surface and/or ground water. Finally, many of the radioactive decay

[8] Currently, this site contains 1,895,000 tons of processing waste, 13,710,000 m^3 of removed overburden, and 376,000 tons of marginal mineral piles.
[9] Once the third nuclear plant becomes operational, the installed generation capacity would increase to 1640 MWe, corresponding to an annual consumption of 300 tons of uranium.
[10] A fine-grained, sand-like material from which the maximum possible quantity of uranium has been extracted by acidic solutions.
[11] E.g., in the U.S.A, all similar material left over from the uranium mining and extraction process falls under the Uranium Mill Tailings Radiation Control Act (UMTRCA) regulations (40CFR 192).
[12] With half-lives as follows: radium 226: 16,000 years; radon 222: 3.82 days; thorium 230: 80,000 years.

products in the tailings emit Gamma radiation, which poses a health hazard to potential recipients in the immediate vicinity.

- *Heavy metals and anions*. The processing releases heavy metals that are associated with the mineralization (e.g., Pb, V, Cu, Cr, Zn), as well as nitrate and sulfate ions, residues of the reactive agents applied towards the leaching of uranium from its ores. Only in the last years of operation have the processing plants started neutralizing the acid effluents with lime. In the meantime, much of the previously formed, untreated effluents dissolved and released heavy metals and radionuclides to the environment.

The combined effect of the unmitigated contamination result in restricted site access and land use, might adversely impact potable water[13], harbors a threat of elevated incidence of lung- and other cancers, and nourishes societal concern about long-term public health and access to natural resources. To counter these adverse effects, *PRAMU* is developing appropriate containment and stabilization measures for each contaminated site, to reduce direct radiation, and to protect the tailings from erosion and atmospheric and/or aqueous dispersion. The measures being adopted are based on risk analysis, availability of resources, and cost-benefit considerations. Their implementation would ensure that (i) the release of contaminants to the environment would become as low as reasonably achievable (ALARA); (ii) Radioactive contaminant doses would be retained at low levels, allowing the ultimate removal of site access restrictions; and (iii) human exposure during site management would be kept to a minimum.

The Structure of Argentina's Nuclear Sector

When established in 1950, *CNEA* was designed as an autonomous Federal entity, charged with developing and managing Argentina's nuclear power generation sector. Under its present charter, *CNEA* is ordained to act both in the public and private domains in all matters pertaining to the scientific, technical, industrial, commercial, administrative, and financial aspects of Argentina's nuclear sector. *CNEA* has been active in fundamental and applied research, uranium ore exploration, mining and production, nuclear energy generation, nuclear medicine- and ionizing radiation-applications, and in the management of radioactive-waste and radiological protection.

Recently, the sector has undergone a major restructuring, including a redefinition of responsibilities. Whereas *CNEA* was left in charge of many of its original functions, a new operating company (*NASA*)[14] and regulatory agency (*ARN*)[15] were established. The *ARN*, an autonomous entity reporting to the Federal Government, is responsible for monitoring the sector's performance and enforcing regulations related to nuclear activities. *NASA*, a Federal corporation slated for privatization, operates Argentina's nuclear power plants.

To fulfill some of its functions (e.g. heavy water and uranium-dioxide production, fuel element manufacturing, nuclear engineering projects, etc.), *CNEA* has also established subsidiary companies that are open to private investment. Presently, *CNEA* has retained its responsibility for the overall management and disposal of all types of radioactive waste and dismantling of nuclear and radioactive facilities, and its mandate is evolving towards research, development, and education in the nuclear field.

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[13] For reference, USA permissible concentrations above natural background are extremely small, i.e., radium 226: $3x10^{-8}$ μ Ci/ml, uranium 238: $4x10^{-5}$ μ Ci/ml.
[14] *Nucleoelectrica Argentina S.A.*.
[15] *Autoridad Regulatoria Nuclear.*

CNEA's Environmental Policies and Objectives

In the implementation of its functions, *CNEA* has to comply with the existing legal framework of environmental protection, and its activities are subjected to the scrutiny of national (*ARN*), provincial (e.g., the Provincial Units for Environmental Management of Mining, or *UGAP*[16], water authorities [*DIPAS*] and others) and municipal authorities. Within the framework of its legal responsibilities, *CNEA* has developed an explicit statement of environmental policy for uranium mining based on the following commitments:

- Improvement of conditions at remediation sites, including the protection of workers, those in adjacent areas and the public at large;
- Implementation and maintenance of an environmental management system that would integrate *CNEA*'s activities, decision making and strategic planning;
- Elaboration of preventive plans and controls for incident, accident and emergency management and development of corresponding standard operating procedures;
- Assessing the environmental impacts of each new project, and specifying measures for maximizing benefits and mitigating or reducing risks;
- Keeping abreast of emerging technologies that are essential for the compliance of *CNEA*'s missions with an improved environmental performance;
- Encouraging *CNEA* personnel to achieve these commitments, by providing training and motivation for environmental protection;
- Verifying, through environmental audits, that the progression of the environmental programs is leading to continuous improvement;
- Setting up environmental criteria for its suppliers and contractors under the guidelines of *CNEA's* environmental policy;
- Providing to the public, on a regular basis, information on environmental monitoring results;
- Assessing periodically the compliance with this policy and revising it as necessary; and
- Sharing these policy tenets with the public[17].

The cited policy is to be reflected by the institution of:

- The management of technology and the environmental realm;
- A program for the management of radioactive waste; and
- The Project for environmental restoration of uranium mining (*PRAMU*).

Public consultation is a key component of the communication policy, setting in motion a decision-making process that is based on the participation of all stakeholders that are interested in contributing to the various aspects of the Program.

Following its original functions in the prospecting, exploration, mining and processing of uranium, *CNEA* has extended its mission to also address pressing environmental issues, including remediation of contaminated sites, evaluation, conservation and rational use of natural resources, study of alternative energy sources and assessment of the impacts of greenhouse gases. The objectives to be attained would be subjected to a cost/benefit analysis that would consider environmental protection and the present as well as the future well being of the community.

[16] *Unidad de Gestion Ambiental Provincial de la Mineria*
[17] *CNEA's* environmental policy regarding uranium mining is posted on the *PRAMU* web site: http://www.cnea.gov.ar

A key short- to mid-term goal is organizational strengthening, to be attained by institutionalizing the team that is presently involved in the Project's implementation. This would ensure that future activities would answer to *CNEA*'s environmental policy, strengthen its environmental program in general, and facilitate the establishment of environmental information and management system for *CNEA*. This step would move *PRAMU* towards compliance with both international and domestic norms at the national, provincial and local levels that are being adopted in the pursuit of sustainable development.

In all the activities related to radiological environmental impact as applied to the *PRAMU*, *CNEA* defers for advice to *ARN*, the national authority mandated with establishing specific standards. The unprecedented nature of this type of project in Argentina, combined with heightened public concern about radiological risks, has induced active public participation as a means for decision-making. In order to ensure future public acceptance, *PRAMU* would deepen the ongoing public communication process to intensify the delivery to the public of the project's goals, their associated methodologies and the risks and benefits associated with its implementation. Finally, past performance would be revisited so as to assess progress towards the achievement of the engineering and public communication goals, to draw lessons learned prior to embarkation upon new projects, and ultimately, to avoid the imposition of unnecessary financial burden on the present as well as future generations.

2 THE PROGRAM OF ENVIRONMENTAL RESTORATION OF URANIUM MINES AND ITS COMPONENT PROJECTS

THE URANIUM MINING ENVIRONMENTAL RESTORATION PROGRAM

The *PRAMU* has a dual purpose: restore, as appropriate, the inactive uranium mining and processing sites, and strengthen the capabilities of *CNEA* to undertake the remediation of uranium production sites through adoption of measures that are transparent, technically sound and acceptable to the public and the regulatory authorities.

The Program comprises three components:

Component 1. Environmental Remediation Works and Studies, specifically including**:**

- Restitution of the *Malargüe* site. The site is located at the northern limit of the *Malargüe* city (about 270 km south of *Mendoza* city). A formal EIA and detailed engineering plans have been prepared and approved by the provincial and national (*ARN*) authorities. The project would fund implementation of remediation and restitution (green area) works, including the relocation of 710,000 tons of tailings and soils, to prevent groundwater contamination and dust and abate radiations and radon emanation, including supervision and monitoring costs.
- Preparation and restitution of other sites. In addition to *Malargüe*, seven sites have been inventoried. The project would fund (a) preparation studies, principally the EIA and engineering design, the set-up of a governance and monitoring scheme and consultation processes and, (b) at three or more of priority sites (*Córdoba*, *Los Gigantes* and *Tonco*), implementation of restitution works and post-remediation monitoring activities.

Component 2. *CNEA* Environmental Institutional Strengthening:
This component includes:

- Strengthening of *CNEA's* Environmental Management Unit (*UGA*) - organization, staffing, financial resources and work methodology; and training;
- Development of an Environmental Management and Information System (including a GIS) (*SIGA*) - implementation, organization, staffing, financial resources and work methodology; works and equipment: upgrade facilities; and training; and,
- Development and implementation of improved and systematized public consultation and information processes, including training.

Component 3. Project Management (*UGA*): project implementation, monitoring and evaluation.

Upon completion of preliminary site studies, a *DIA* and a public consultation process, the subsequent steps towards the implementation of each of the individual sub-projects would entail selection of a mitigation plan, engineering design, authorization by the applicable regulatory agencies and WB approval, contract procurement and execution, and finally, long-term monitoring[18].

Following preliminary site studies, the first step towards authorization of the *Malargüe* Project required the preparation of a *DIA* with the devised remediation plan, assessment of its environmental impact, and demonstration of its compliance with site-specific regulatory standards. Chapter 4 of the original document satisfies this requirement. *CNEA*'s engineering restoration plans for the *Malargüe* site have been approved by *ARN* and by the *Mendoza* Province authorities, and some preliminary restoration work has already been carried out at the site. Similar plans have been under development for the closing of the *Córdoba* manufacturing plant and the *Los Gigantes* mine. Table 1 summarizes the waste quantities at the *PRAMU* sites, their current status, and, to the degree available, the scope of the respective environmental restoration.

Table 1. The *PRAMU* Sites: Waste Quantities, Current Status, and Restoration Plans

SITE, Province	FACILITY TYPE	WASTE QUANTITIES* AND DESIGNATION (in 10^3)	STATUS AND REMEDIATION SCOPE
***MALARGÜE* Mendoza**	Processing	~700-t milling tailings	Relocate within the site, cap, and divert drainage to depress groundwater level. Once restored as green space, relinquish title to provincial authorities.
***SAN RAFAËL*[19] Mendoza**	Processing Mine	1,895-t milling tailings 13,710-m^3 sterile residues* 376-t marginal ore 35-t low-grade ore	Under study to assess choice between scaled-down operation *vs.* closing. Once restored, relinquish title to provincial authorities.

[18] For Project time-line, see the original, Spanish language document.
[19] Options other than restoration are currently under consideration by *CNEA*, e.g., reopening the mine and the uranium dioxide manufacturing facility. If materialized, whatever reclamation is put in place won't be funded under the *PRAMU*.

HUEMUL ***Mendoza***	Mine	19,500-m^3 sterile residues* 2,500-m^3 marginal ore*	After operation ceased in 1974, *CNEA* implemented closure procedures; studies needed.
CÓRDOBA[20] ***Córdoba***	Processing, manufacture of UO_2	57.6-t milling tailings Unspecified amount of manufacturing equipment	Plant to be dismantled and together with tailings, to be relocated outside the densely populated urban area; designated as a green space.
LOS GIGANTES ***Córdoba***	Mine	2,400-t heap-leach tailings 1,000-t sterile residues 600-t marginal ore	While in an unpopulated area, its up-basin location from tourist areas is of particular concern. A possible repository for *Córdoba*'s tailings.
PICHIÑAN ***Chubut***	Processing	145-t milling tailings	Closed since 1980, requires only minor management works. Studies needed.
TONCO ***Salta***	Processing	500-t milling tailings	Remoteness from population centers, arid climate and favorable topography require only a limited restoration scope.
LA ESTELA ***San Luis***	Mine	70-t milling tailings 1,140-t sterile residues	Following cessation of operations in 1990, *ARN* approved the restoration of the mine and tailings by the operator.
LOS COLORADOS ***La Rioja***	Mine	135-t milling tailings 1,000-t sterile residues	Following cessation of operations in 1996, *ARN* approved the restoration of the mine and tailings by the operator.

* To convert volume (m^3) to weight (tons), multiply the volume by an average density of approximately 1.6gm/cm^3. 'Sterile residues' refers to overburden -- non-mineralized rock that has originally surrounded and overlain the uranium-bearing strata.

CNEA's Organizational and Management Changes in Conjunction with PRAMU

To oversee the preparation of the Project, in particular the Project EA and Project Implementation Plan (PIP) as well as manage the program, *CNEA* is in the process of creating a Project Implementation Unit (*UEP*), under the management of a General Coordinator. The *UEP* would be autonomous in terms of staffing, funding, accounting and auditing, fully integrated within *CNEA*'s functional structure, and would report to *CNEA*'s top management.

The *UEP*, charged with project implementation, monitoring and evaluation, would comprise technical and administrative sections. The technical section will consist of a fully dedicated team of mining and environmental experts. The administrative section of the *UEP* will be in charge of coordinating the budgetary and administrative aspects of procurement and disbursements, in accordance with WB standards. In addition to executing its technical and administrative duties, the *UEP* will also be responsible for (i) project monitoring, reporting and evaluation; (ii) establishing communication and/or coordination links between *CNEA* and the different sectors

[20] Additional options are being discussed between *CNEA* and Province/City authorities, e.g., keeping the processing plant operative.

involved in the Project; (iii) ensuring that at each site the local municipal authority formalizes the restrictions on land use, as called for by the adopted remediation solutions applied to that site, and (iv) monitoring the restored site and its sphere of influence.

A Unit for Environmental Management (*UGA*) would be established within the *UEP* at a later stage. Once the *Malargüe* works have been launched, this unit would constitute the Environmental Management Unit (*UGA*) in *CNEA*, charged, among others, with long-term implementation of *CNEA*'s functions within the uranium-mining sector.

The *UEP* would be equipped with an Environmental Information and Management System (*SIGA*). A Geographic Information System (GIS) would facilitate the management, storage, analysis, and distribution of environmental mining information. Typical applications would include e.g., managing a database for the preparation of an EIA, analysis and selection of remediation solutions, and monitoring potential impacts. The information captured by the *SIGA* will be accessible by the public.

THE CONSULTATIVE PROCESS – GENERAL CHARACTERISTICS AND STRATEGIES

Strategies for Involving the Pertinent Communities

It is important to involve the communities that stand to be impacted by the issue of uranium mining waste in reaching an accord on reclamation decisions. Community consensus would guarantee and fortify the sustainability of such reclamation activities. Because the issues of mining legacy and its potential impact on the communities vary from site to site, the general strategy for public consultation would be adjusted to site-specific conditions. Local, participatory workshops to present technical data in a readily understandable form would augment the posting of general information in the local and national media. The workshop process would be documented and analyzed for deducing lessons learned. In addition to consulting with the public at large, consultations at each individual site would also encompass qualified representatives of the legislative as well as province-level and local-governmental authorities.

In setting up the consultative process, *PRAMU* would take into consideration the following points:

- Community participation,
- Sustainability,
- Local availability of human, technical and political resources,
- Teaming between the community and the local authorities, and
- Strengthening communal capacity in project administration.

Benefits and Results

The benefits of the consultation process would include:

- Consensual decisions of the different actors with respect to the selection of reclamation resolutions, future land-use options and monitoring work progress;
- Arousing community interest in participating in project design and implementation;
- Arousing community awareness to resource availability for realizing activities that contribute to its development;
- Strengthening communal capacity to face other initiatives and resolve existing or potential conflicts; and

- Predisposition of the various social and political community participants for articulating issues and possible resolutions in advance.

The results of the projects would include:

- A credible and transparent consultative and information exchange process;
- Involvement of the communities in the management and monitoring of the projects and future uses of the reclaimed sites;
- Improvement of the development and sustainability of the projects through community participation;
- Improved relations among the community's various social and political actors;
- Reaching accords among stakeholders of diverse interests;
- Improvement of the physical setting and the environment in general; and
- Reduction of health risks to stakeholders.

Program Implementation

The *PRAMU* requires the participation and involvement of local social and political stakeholders, as well as that of province-level and national political stakeholders.

- Local authorities are expected to assume the following roles:

- Provide information as necessary,
- Guarantee local legislation to facilitate development activities, and
- Articulate with NGOs and community social stakeholders.

- Province-level authorities (Ministries of Public Works and the Environment) are expected to assume the following roles:

- Set up pertinent province-level standards and articulate with local- and national-authorities on the adopted decisions, and
- Assess and approve the EIA.

- National authorities are expected to assume the following roles:

(i) *CNEA*:

- Supervise and adopt techniques that assist in project implementation;
- Design and propose remediation projects;
- Train facilitators to interact with the community;
- Develop strategies in pursuit of consensus on decisions among stakeholders;
- Articulate with provincial and local authorities for setting forth and developing activities that modify ecologic habitats;
- Facilitate the continued participation and empowerment of the community; and
- Monitor and evaluate the impacts of the project.

(ii) *ARN*:

- Authorize the proposed activities for environmental restoration in all aspects related to radiological and nuclear safety.

- NGOs and civil society at large are expected to assume the following roles:

- Express the interests and needs of the community as well as depict the environmental issues and existing state of health; and
- Retain the right to participate, on either organized or individual basis, by requiring information and expressing opinions.

The Action Plan

The Action Plan would include the following:

- Defining the information that would be communicated to specialized sectors as well as to the public at large concerning *PRAMU*, the advantages and disadvantages to be sustained and the available diverse technical reclamation options;
- Defining the strategies and participatory mechanisms of the different sectors -- social, political, governmental, non-governmental and civil society at large;
- Identifying stakeholders that need to be involved at each of the sites and the most effective means for interacting with them, such as workshops, public hearings and consultations;
- Selecting social actors (e.g., NGOs and universities) involved in environmental affairs to establish a consultative council and a nexus to the community; set up a national level Project Monitoring Committee facilitated by the WB project team and consisting of members from national NGOs, CNEA and representatives of the relevant Federal authorities as well as Committees of the National Congress (Natural Resources and Energy)[21];
- Elaborating the educational campaign;
- Developing a strategy for interaction and feedback with stakeholders;
- Selecting and staging procedures (e.g., mail distribution of fliers and questionnaires, audiovisual material and personal or telephone contacts) for dispensing the information to promote participation;
- Seeking accords and consensus among the different stakeholders;
- Conducting a vigorous publicity campaign via the press and electronic media to broadcast the pending activities and their results.
- Establishment of information centers at each remediation site (the *Malargüe* center will open late in 2005); and
- Development of a publicly accessible website (http://www.cnea.gov.ar), and
- Establish an international Advisory Panel of four members, including acknowledged national and international experts on uranium mining and milling waste management as well as on social and participatory processes, who would review the main project documents and provide policy and technical advice to *CNEA*, as well as to other stakeholder groups. A non-Argentine expert will chair the Panel.

The implementation of these plans is site-dependent. For instance, in the case of *Malargüe*, it has been essential to dispense the information to facilitate progress of the ongoing reclamation work, whereas in *Cordóba* and *Los Gigantes*, where no previous interaction with the community has occurred, it is necessary to solicit initial information exchange.

Key Developments

Consultations within the framework of project preparation have been carried out mainly in relation to the development of this EA, dealing with the objectives and planning of the *PRAMU*.

[21] At present, the Committee consist of representatives of NGOs: Amigos de la Tierra, Greenpeace-Argentina, Fundación Ambiente y Recursos Naturales, Movimiento por la Paz y el Ambiente and Asociación Argentina de Ecología; of Federal authorities: Agencia Regulatoria Nuclear (ARN), Secretariat of Mines (SM); and of advisory bodies: Natural Resources and Energy Commissions from Congress. Representatives from the following entities will be invited: the Secretariat of Environment (SE), the Federal Councils for Environment (COFEMA) and for Mining (COFEMIN).

A first draft of the EA was distributed in November 1998 to stakeholders, including representatives of municipal, provincial and national legislatures and governmental authorities, universities, and NGOs. In general, comments were favorable to project implementation as envisioned and supportive of the role of the consultation and information processes to be developed as part of the project.

The WB set up an informal working and discussion group in May 2001. Its objectives are to provide a forum for information and suggestions, to discuss the design of the participatory mechanisms to be applied during project preparation and implementation and to monitor project activities, particularly with respect to the consultation and decision making processes. The initiative for the establishment of a project-wide "dialogue group" was implemented with the participation of national level NGOs[22], as well as of institutions directly involved in the project, including the *ARN*. The EA was updated and, following an agreement reached with NGOs and other stakeholders in the May 2001 workshop, made available to the public through *CNEA*'s web site (July 2001). Few comments have been submitted so far to the project preparation unit, but the document has been discussed in a second meeting (August 2001) as well as through exchange of electronic messages[23].

In the wake of recent meetings with provincial and *Córdoba* government representatives (April 2005), it was decided to assemble an integrated Technical Working Group (TWG) that would comprise representatives from technical sectors as well as the involved jurisdictions. Another body -- the Social Forum -- would be established based on an MOU and pursuant to local regulations. The Social Forum's mission is to reach a consensus on the resolutions designed by the TWG so as to provide them with political and social stamp of approval or, alternatively, resubmit resolutions that have not passed muster for reconsideration and revision by the TWG. In this context, *CNEA* has entered a compact with the National University of *Córdoba* and the National Technological University to draw into the Forum representative NGOs, with possible inclusion of the WB. In order to develop the strategies for community participation, a TOR was prepared to solicit proposals from NGOs and research institutions for leading the integrated public consultation activities process.

ADHERANCE TO WORLD BANK SAFEGUARD POLICIES

Due to its objective, the *PRAMU* EIA is actually an Environmental Management Plan (EMP). However, considering that the project has a potential for environmental impact, at a minimum the *PRAMU* would trigger the following World Bank safeguard policy: *O.P. 4.01, Environmental Assessment* (for all subprojects) and *OP/BP 4.37,The Safety of Dams* (at *Los Gigantes*). However, considering that, with the exception of *Malargüe*, the exact scope and location of the remediation intervention measures to be implemented at all sites have not yet been identified, an Environment and Social Framework would be prepared by *CNEA*, which would outline principles and procedures that the Project will follow to ensure compliance with relevant Argentine laws and applicable environmental and social safeguard policies of the WB. Additional safeguard policies that might be triggered for specific subprojects include: *O.P. 4.10, Indigenous People; OP 4.12, Involuntary Resettlement;* and *O.P. 4.04, Natural Habitats.*

[22] So far the group includes the following organizations and persons: *Amigos de la Tierra, Asociación Argentina de Ecología, Autoridad Regulatoria Nuclear,* Advisers from the Use of Natural Resources and Energy and Fuels Committees of the Congress, *CNEA, Fundación para la Paz y el Medio Ambiente, Fundación Patagonia Natural, Fundación Ambiente y Recursos Naturales*, Greenpeace, *Unidad de Gestión Ambiental Minera Nacional* and the World Bank. *FUNAM,* an NGO from *Córdoba,* has been contributing as well to the electronic discussion.
[23] See Annexes dealing with Social Communication in the original, Spanish language document.

Safeguard requirements identified at the subproject identification stage will be addressed during the subproject cycle following detailed procedural requirements. The procedural requirements for each safeguard policy triggered at each stage of the subproject cycle will be detailed in the Environment and Resettlement Framework. The Environment and Resettlement Framework complements the Project Implementation Plan and specifies the individual responsibilities of *CNEA* and the WB with respect to individual safeguards.

To ensure that WB Safeguard Policies are properly implemented during the project, disbursement for implementation of any remediation works will be conditioned on the adequate application of the agreed environmental and social framework, and on the review and approval of the respective EIAs and engineering designs by the responsible authorities in Argentina and by the WB. Similar review and approval criteria would apply, when applicable, to Resettlement Action Plans and Indigenous Peoples Planning Frameworks prepared each to address the corresponding safeguard policy prior to subproject implementation.

THE LEGAL AND INSTITUTIONAL FRAMEWORK

The pertinent legislation and regulatory framework applicable to the operation and management of Argentina's nuclear sector is summarized in the following. For details pertaining to specific, Province-level legislation and regulations as well as the organization and responsibilities of the national competent authorities, the reader should consult Section 2.3 of the original document.

Federal vs. Provincial Jurisdictions

- Argentina's environmental legislation started evolving with the introduction of a constitutional reform in 1994. The recent evolution of both Federal and local environmental legislation reflects the growing societal concern with environmental quality.

- The Republic of Argentina is a Federal system, where the national government coexists side by side with autonomous provincial governments. Article 41 of the Federal Constitution (i) guarantees the rights of the citizenry to a healthy environment balanced with the needs for human development; (ii) empowers the federal government to establish the minimum standards for environmental protection, and (iii) gives the provinces powers to complement the national requirements.

- In the nuclear sector, Article 41 is promulgated in the National Nuclear Activity Law (No. 24.804 of 1994) that assigns the federal government the lead role on policy, R&D, regulation, and funding *vis a vis CNEA* and *ARN*. Decree No. 1540/94 practically separates between the implementing agency and the regulatory agency, by creating Argentina's Nuclear Regulatory Authority (*ARN*) and charging it with the authority to "issue regulatory standards with respect to radiological and nuclear safety".

- Law No. 25.018, Plan for Managing Nuclear Waste, specifies *CNEA*'s obligations to (i) manage the waste derived from the mining of uranium, and that resulting from abandoned mineral deposits or decommissioned milling facilities, and (ii) remediate sites impacted by uranium mining. This law also stipulates that *CNEA* has to coordinate its activities with local authorities.

- Argentina's regulatory structure comprises concomitant authorities. According to the Federal Constitution, the environmental protection of a given domain is the responsibility of the jurisdiction that owns the title to that domain. Consequently, the provincial governments are empowered to set up complementary environmental standards, as long as they are no less stringent than the federal standards.

- Relevant environmental legislation is mainly at the provincial level, with the most comprehensive regulations having been established in the Province of *Mendoza*. The responsibility for the environment is at the Ministerial level and the law provides for a process of EIA, resulting in a formal *DIA* (*Decleracion de Impacto Ambiental*) for specific projects. The legislation also provides for public hearings (*Audienca Pública*) as part of the evaluation process. *Córdoba* and all the other Provinces that host uranium production sites have broadly similar legislation under the Federal Mining Code and its provincial complementary standards, with the exception of formal provisions for public hearings.

Regulation of Mining and Mining Legacy

- The mining sector in Argentina is subjected to the authority of the Office of Mining, within the Ministry of Infrastructure and Housing. Decree No. 432/01 defines its responsibilities to include, among others, setting up mining policy and managing the nation's mining activities; promoting the introduction of innovative technologies, and the establishment and management of a central database of geological and mining information.

- Argentina's nuclear regulatory approach, like that of Spain, is performance-based[24], different from the prescriptive regulatory approach developed by the U.S.A.[25]. However, the environmental section of Argentina's Mining Code also incorporates oversight of nuclear activities by a concurring (i.e., provincial) authority, while Spain grants the oversight of nuclear activities exclusively to a single national authority.

- No specific Argentinean standards or guidelines exist for remediation, stabilization and control of inactive uranium mining sites. The radiological impacts of such sites and their mitigation are subject to the basic standard on radiological protection (AR10.1.1)[26]. This law applies to all sources of radiation as well as all phases of the production of nuclear fuels and also to contamination resulting from past practices. Overall, the Argentinean approach is consistent with ICRP[27] recommendations and in line with approaches prevalent in a number of other countries[28].

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[24] Under this approach, the operating arm of a nuclear facility bears the ultimate responsibility for ensuring the safety of the facility at each and every stage. The only role assigned to the regulatory authority is that of critically reviewing the operators' safety specifications.

[25] In the U.S.A., Public Law 95-804, the Uranium Mill Tailing Radiation Control Act (UMTRCA, 1978) (i) mandates the restoration of inactive uranium extraction sites; (ii) regulates the program for the stabilization and proper disposition of mining waste (the Uranium Mill Tailings Remedial Action, UMTRA), and (iii) confers upon the Environmental Protection Agency (USEPA) the responsibility of issuing appropriate remediation standards and guidelines. The applicable cleanup standards, 'Health and Environmental Protection Standards for Uranium and Uranium Mill Tailings' are captured in USEPA's 40 CFR Part 192.

[26] *'Norma basica de seguiridad radiologica'*

[27] International Committee for Radiological Protection

[28] The ICRP distinguishes between two circumstances of exposure to radiation: one, where human activities introduce new sources or modes of exposure (a *practice*), and the other, where these activities reduce the exposure to already existing sources (an *intervention*). Thus, a remediation of an inactive uranium mining

3 PRELIMINARY ENVIRONMENTAL ASSESSMENT OF THE *PRAMU* RESTORATION SITES

The EA for the *Malargüe* site that has been adequately characterized and for which a mitigation engineering design has been completed is the exclusive subject of Chapter 4. The amount of site data available on the environmental contamination and associated health hazards for the other eight sites that are on the restoration target list varies considerably. Among those, the *Córdoba* and *Los Gigantes* sites have been characterized rather extensively, but their mitigation alternatives have not yet been finalized. They are described below in some detail. The salient data on the five remaining sites (*Tonco*, *Huemul*, *Pichiñan*, *La Estela* and *Los Colorados*) - none of which has been studied in detail - are summarized in Tables 2A and 2B. As to the *San Rafaël* Site, the scene of extensive mining and ore concentration activities over several decades, once *CNEA* concludes its review of the prospects for the remaining uranium deposits at this site, it will proceed to decide on its remediation.

THE *CÓRDOBA* SITE

The *Complejo Fabril Córdoba (CFC)* site[29], covering 9.2 ha in the *Alta Córdoba* suburb of the city, was initially established for chromium production during World War II. In 1952 the facility was converted to an experimental uranium leaching plant for the processing of various types of domestic ores. From 1963 to 1976 the plant also processed uranium pre-concentrate for further extraction. At a later stage, uranium purification (in 1976) and uranium dioxide manufacturing (in 1982) were introduced with annual installed capacity of 150 tons, to provide fuel for Argentina's two nuclear reactors and for research applications. The production process entails the dissolution of ammonium di-uranate, purification, evaporation, precipitation as ammonium uranyl carbonate, concentration to uranium dioxide, homogenization, storage in drums, and effluents treatment. Originally outside of the City of *Córdoba*, the site is now surrounded on all sides by middle-class residential neighborhoods[30]. The site's perimeter fence that serves also as the delineator of the backyards of private residences is about 10-15 meters away from the edge of the tailings.

A city of 1.2 million, *Córdoba* is the commercial, industrial, and educational hub of a namesake Province. It is built on a slightly undulating plain and is transversed by the *Rio Suquía* that is regulated by the *San Roque* Reservoir some 25 km upstream. The Reservoir also fulfils an important recreational function for the population of the Province, including sport fishing. The River meanders over fine-grained fluvial sediments (including a 5-10 m thick silty horizon) that overlie, at depths of 15-20 m, sand and gravel deposits, part of the eastern apron of the *Sierras de Córdoba* foothills. The 200 to 600 m thick sedimentary column overlies crystalline rocks. Shallow, low magnitude seismic tremors occur quite frequently, but the area is considered overall of low seismic risk (Seismic Zone 1, and see 2.4.2) as attested by the survival of historic structures built of river pebbles and bricks and roofed with wood and tiles. Climate is mild Mediterranean with annual rainfall of 750mm, and air pollution is moderate. Winds are northeasterly in the spring, summer and fall, and southerly in the winter, with average velocities of 8 km/h. The phreatic aquifer slopes to the SSE, fluctuating between 3 and 50 m below surface.

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and/or processing site is a typical intervention, and consequently, in terms of ICRP terminology, the entire *PRAMU* is a national intervention program.

[29] Based on information derived from INF-UIP-074/98

[30] There are no indigenous communities at the site's vicinity.

Contamination Sources

The site can be divided into two zones: the tailings pile -- the remains of the experimental heap leaching, totaling 36,000 m^3 and occupying about 1.4 ha[31], and the uranium dioxide industrial plant. Sampling was conducted by drilling into (i) tailing piles, down to 1 m below their base, (ii) surrounding land, and (iii) groundwater (see Fig. 2).

Tailings. The uranium tailings were discharged over, and partly admixed with the earlier "chromium" tailings (historical data on chromium production amounts are unavailable). The average concentration/activity of uranium and Ra 226 in the tailings are 337 µg/g and approximately 11 Bq/g, respectively, and their total "radiological content" is about 6.3×10^{11} Bq (i.e., one- to two-orders of magnitude less than in *Malargüe*). The tailings contain also significant amounts of V, Cu, Zn, Cr and Ni, at levels that require proper management[32]. The maximum thickness of the tailings is 5 m, and they form a very mildly sloping mound; an unpaved road that skirts the tailings mound to the E and just several meters away from the backyards of the adjoining residential quarter is located on uncontaminated ground. A stabilized and vegetated soil layer that now covers the tailings limits the dispersion of their components by water and wind to a negligible level. The entrance to the closest administrative buildings on the site is located only about 12 meters away from the tailings' perimeter.

Atmospheric pathways. The radon flux[33] from the tailings is on average 6.6 Bq $m^{-2}s^{-1}$. Radioactivity (Gamma dose) above the tailings varies between an average of 4.94 µSv/h[34] and a maximum of 19.6µSv/h, values that call for tailings' management. The average radium dose in the remaining parts of the *CFC* is 0.15µSv/h[35]. Radioactivity and radon concentration measurements beyond the perimeter of the *CNEA* site (radon: 0.11± 0.01 µSv/h) and in the city of *Córdoba* in general (0.10-0.16 µSv/h) show low risk impact[36].

Aquatic pathways. Seven perforations were drilled in 1999 down to depths of between 40-100 m to locate the ground water table, sample the water for quality analysis and define the specific lithologic sequence underlying the site. The resulting data show that: (i) the local water table is deep (about 49m) and slopes in correspondence to the general topography of the area. Between 2001 and 2004, this level has increased by 1.1 m. (ii) In general, while the quality of the ground water is not affected by the tailings or the site[37], additional studies are needed to determine whether elevated levels of $SO_4^{=}$, Na^+ and $NO_3^{=}$ detected in a couple of wells are caused by the mineral piles; and (iii) the characteristics of the underlying lithology favor ionic exchange and impede the percolation of pollutants that could have originated from the site. These conditions,

[31] Including 4,500 m^3 of contaminated soils
[32] E.g., maximum values are (all data in ppm) 4,325 for V, 2,650 for Cu, 2,385 for Zn, 785 for Cr, and 350 for Ni.
[33] Definition of a radon flux – emission – from the tailings is a statutory requirement of the U.S. EPA (the U.S. standard is 0.74 Bq/m^2s). However, the definition of the radon release rate under field conditions is wrought with difficulties.
[34] This value equals ~35 mSv/year. The Argentinean general standard and internationally accepted standard is 1 mSv per year.
[35] Which for site workers translates roughly to 0.3 mSv/year.
[36] According to measurements performed by *CNEA*, augmented by those of the Provincial Ministry of Health, 4/1994 – 8/1995.
[37] April 2004 samples from wells E2L, S1L, and W3L indicate U concentrations of 16-27 ppb, and Ra 226 of 0.26-0.49 pCi/l.

combined with the depth of the water table, have thus far protected the groundwater from contamination.

Proposed Restoration Measures

Based on the available data, *CNEA* has been charged by the *ARN* with the preparation of an integrated remedial solution for the whole site as well as with its implementation. In the past, an agreement has been reached between *CNEA*, the *Córdoba* Province and the City of *Córdoba* to relocate the existing *Dioxitek* plant and production equipment to another site, and to restore the *CFC* site into a green space. The plant's decontamination[38] and dismantlement will be followed by the removal of the tailings and by site restoration. Lately, however, the City has been reconsidering its position for transferring the production facility on the account of the lost employment engendered.

Considering the low levels of radioactivity monitored at and around the site, the radiological benefits to be gained from removal of the contaminated materials are small. However, the key benefits of the site's restoration would be through availing a brownfields site in the heart of the city for open public space, together with the positive impact on the value of adjoining land and property. Other restoration alternatives worthy of consideration include the removal of the tailings alone to a hazardous waste landfill within several tens of km away from the City; and capping the tailings in situ. This would prevent the difficult-to-control impact of air suspended particulates in the cramped space bordering upon residential neighborhood during the tailings' removal. However, the community adjacent to the plant prefers to see the site vacated and fully reclaimed.

Detailed implementation plans for restoration have not yet been finalized. Once ready, *PRAMU* would initiate public consultation to identify an acceptable set of site restoration measures. The selection of an acceptable site for the disposal of the dismantled plant has so far proven to be the major issue, as the Province of *Córdoba* has passed legislation prohibiting the creation of any new "nuclear sites", including sites for the disposal of the *CFC* tailings. A technically acceptable solution has been explored that involves the incorporation of the tailings and unredeemable debris from the dismantled facilities into the remediation of the *Los Gigantes* mine site (see below).

To relocate the 36,000 m^3 of tailings and the dismantled structures, it is estimated that 27 daily trips for 7-8 months of a sealed, 15-ton capacity truck would be required. However, transportation of the materials would be challenging because of the distance involved (100 km) -- half of it along a single lane, unpaved and multi-use roadway -- and the need to pass through several communities, including the city of *Villa Carlos Paz* and the adjoining *San Roque* Reservoir with its multifunctional role as *Córdoba'*s drinking water storage and recreational lake. To reduce the risks associated with haulage, a bypass would be built to skirt *Tanti*, and the use of the highway as far down as *Villa Bialet Musse* (circumnavigating the Reservoir to the north) is being considered. The plan for managing *CFC*'s waste legacy beyond the tailings dam of *Los Gigantes* was presented to *Córdoba*'s Environmental Agency in July 2003, but so far still not approved.

[38] The decontamination would employ techniques such as pressure washing or mechanical scrubbing, and the operation would be carried out under strict dust control accompanied with monitoring for suspended particulates and levels of radon.

THE *LOS GIGANTES* SITE

The inactive *Los Gigantes* mine is situated 1,700 meters a.s.l in the largely unpopulated rocky and mountainous *Sierra Grande* area (*Córdoba* Province), about 30 km upstream of the city of *Villa Carlos Paz* and 100 km W of the city of *Córdoba*[39] (see Fig. 1). The annual rainfall -- highly seasonal and torrential -- totals about 960 mm, and is only slightly exceeded by evaporation (over 1,000 mm). Predominant wind directions are NNE in the summer and SSE in the winter, with storm conditions of over 20 km/h. The mine is located in the watershed of the *Rio San Antonio* (monthly flow between 1.5 million m^3 in August/September to 35.7 million m^3 in November), the drinking water source of the city of *Córdoba.* A patchy pattern of soil cover prevents agriculture, enabling only sparse cattle- and sheep grazing. The area has some tourism potential, but with the exception of mining activities[40], the land for the most part is inhospitable to permanent inhabitation. There are no settlements close to the mine's area[41], nor any indigenous communities. *CNEA* leases the land on which the mine is located from its legal owner, a religious congregation.

The ore at *Los Gigantes* occurs in fractured granites, pegmatites and associated quartz veins that intrude a metamorphosed basement. At 300 ppm, the ore's grade is very low. The open pit mine (300 x 500m) operated from 1982 to 1989, and was shut down permanently in 1990 (See 2.4.3). The mined ore was heap leached on-site with sulfuric acid and further processed by ionic exchange to produce yellowcake, a semi-pure raw uranium product that was then shipped to *CFC* for the manufacturing of uranium dioxide. Liquid effluents were first neutralized with lime then stored in surface impoundments, and tailings were stored some 800 m away from the streambed of the *Arroyo de la Mina*. The total uranium production from the site (in the form of ammonium di-uranate) was about 207 tons.

Contamination Sources

For the location of the site's key facilities, drainage pattern and sources of contamination, see Fig. 3.

Mining and milling waste. In addition to 1.6 million tones of mining waste and marginal grade mineral, 2.4 million tons of heap-leach residues are deposited at the Mineral Fabrication Site of *Los Gigantes* (*CMFLG*)[42]. The open pit overburden pile as well as the marginal ore and ore piles, with U concentrations between 59-120 ppm, exhibit low levels of Ra226 (0.6-1.2 Bq g^{-1}) and Rn (0.21-0.33 Bq/m^2s) radiation. The leach-processed tailings, with 217 ppm U, have average activity concentration of Ra226 (1.0-1.2 Bq g^{-1}) that does not differ significantly from that of the "ore" (0.9-1.2 Bq g^{-1}) or from the background values of granite (0.8-0.9 Bq g^{-1}). However, as a result of their earlier exposure to acids during the ore leaching process, the tailings contain 25-35% SO_4 and 7-8% P_2O_5 and their pH is as low as 4.85. This hastens their disintegration into sandy material that is being extensively eroded. The tailings are dispersed in the alluvium of the *Rio Cambuche* between the site and the confluence with *Rio Cajón*, about 3 km downstream[43]. The tailings also have rather elevated values of Cu (up to 100 ppm), Cr (150 ppm), V (100-200 ppm) and Zn (300-600 ppm).

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[39] Based on *INF-UIP-053/98*
[40] Quarrying of granite, marble, quartz, feldspar, beryl, and columbite-tantalite.
[41] The closest range farm is located 7 km away from the plant's entrance.
[42] *El Complejo Minero Fabril Los Gigantes.*
[43] Both are tributaries of *Rio San Antonio.*

For comparison, the *Córdoba CFC* processed mineral piles -- ultimately designated for storage at this site -- have significantly higher U (337 ppm), radiation levels (Ra226: 11 Bq g^{-1} and Rn: 6.6 Bq/ m^2s), NO_3 (731 ppm) and heavy metals (Cu, Cr, V and Zn, with 615, 254, 1,032 and 751 ppm, respectively). Their SO_4 content is also high (16%).

Gamma dose values are 0.40 μSv/h over the tailings and 0.19-0.27 μSv/h in their proximity. These doses exceed the background value of 0.22 ± 0.03 μSv/h, measured some 3.8 to 7.2 km north of the waste piles. Still, to attain the permissible dose limit to the general public of 1 mSv/year[44], an individual would have to be exposed to this level of radiation for about 2,400 hours/yr. Likewise, the highest Rn flux levels measured, 134 Bq/m^3, fall below the intervention level[45].

Liquid effluents confined behind dams. Approximately 120,000 m^3 of liquid effluents are confined beyond the main dam -- the lowermost of five dams that jointly occupy an area of 28,000m^2. Chemical analyses of the effluents[46] indicate excessive levels of Ra226 (1.3 Bq l^{-1})[47], NH_4 (164 ppm), SO_4 (2,100 ppm) and Ag (6.8 ppm) and low pH (4.5), as well as elevated values of certain 'secondary' constituents (e.g., Mn, Ca and Mg). To comply with provincial and national drinking water standards, these effluents would have to be treated prior to their discharge into *Rio Cajón.*

Atmospheric pathways. Radon emission from the waste is slightly enhanced due to the increased surface area of the broken-up ore material. Maximum radon flux from the precipitates is about 1.1 Bq/ m^2s, higher than that from other types of waste (0.21-0.33 Bq/ m^2s). Radon concentration in the free air is below detection limit.

Impact on surface water. During the operation of the mine, fish disappeared from the *Rio Cajón* and *Rio Cambuche* downstream from the complex. Presently, fish (implanted trout) is returning to the area. The available monitoring data show background values with respect to the present content of chemical constituents (U, Ra, heavy metals and other ions) 3 km downstream from the confluence of the aforementioned streams and downstream from the tailings. Even though the values of SO_4 and Mn are somewhat elevated, they are still below the drinking water standard at this sampling station. A detailed flora and fauna baseline study[48] of the creeks north of the plant -- that are not affected by dispersion of tailings sediments -- shows species diversity similar to that elsewhere in the region. In a stark contrast, the creeks south of the plant and immediately below the influx point of solid residues from the main tailings dam are practically sterile. However, they show partial recovery several kilometers further downstream, as indicated by the reappearance of algae and invertebrates.

Impact on subsurface water. Sampling in a shallow well (phreatic level at 14.2 m below surface) outside the area affected by the mineral processing provides a baseline of 1.2 ppm/l for U, 0.19 pCi/l for Ra226, 240 ppm for SO_4, and a pH of 6.5. Concentrations of the same parameters in nine shallow wells located within the mineral processing areas indicate contamination levels that run up to 92 ppm/l for U, 8.21 pCi/l for Ra226, 3,200 ppm for SO_4, and pH as low as 3. Impeding

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[44] According to the *ARN* Standard AR 10.1.1
[45] 400 Bq/m^3, according to *ARN* Standard AR 10.1.1, 99; for new housing, the Standard is 200 Bq/m^3.
[46] As of March 2004.
[47] Compared to the USEPA drinking water MCL of 0.18 Bq l^{-1}
[48] *Estudio de plankton, bentos y nekton del gradiente Rio Cajón-Rio San Antonio. Informe téchnico de la situación de la Biota/Manageud Pucheva*, Nov. 2000.

further contamination would require capping of the worst affected areas, in proximity to tailing dams 0, 1, 2 and 3 and to the leach pad piles.

Proposed Remediation Activities

The following remediation activities would be submitted for discussion and approval by the provincial and national regulatory authorities.

Treatment of effluents retained beyond the main dam: treat to reduce chemical load, then discharge to local watercourses. Priority chemicals - NH_4, Ra226 and Mn - would be precipitated by reaction with lime and barium chloride[49]. Biologists from he National University of *Córdoba* would study the impact of the discharged water on the biota of *Rio Cajón*. Province regulators are weary of discharging any treated water to the watershed of *Rio Cajón*, opting instead for storing the treated water in dam #3 for evaporation. However, considering the close balance between precipitation and evaporation at the site, *CNEA* is concerned about the ineffectiveness of this proposed resolution[50].

The main tailings dam: The topographically lowermost dam would be stabilized by reducing its height by 2m, having its slope modified, and its base protected from saturation; this would facilitate expanding its current functions to also include retention of the mineral piles' waste to be relocated from the *CFC*. The susceptibility of the precipitates to seismic liquefaction[51] would be reduced by adding coarser fill from the piles of the waste rock and the marginal ore, capped with a sandy unit and overlain by the relocated *CFC* waste pile material. The topmost caps would consist of low-permeability material removed from the modified dam, topped by sterile rocks to impede erosion.

Córdoba's mineral piles: the precipitates beyond the main dam serve as excellent sealant of the natural substrate, facilitating the relocation of *CFC*'s uranium plant processing residues to a single, impermeable site away from population centers, where effective environmental controls would be established. The project plan was submitted to *Córdoba's* Environmental Agency in July 2003.

The CMFLG mineral piles: are located on granite outcrops along 800 m in parallel to *Arroyo de la Mina*. The height of the piles -- between 20-70 m -- in combination with the rainfall regime, render them highly erodible. Several containment and runoff diversion schemes were considered. They include (i) the construction of sediment containment dams so located as to collect periodic runoff (four dams), and on the riverbed of *Arroyo de la Mina* (one dam); they would allow the fluids from the piles to filter through; (ii) a single, 37m-high dam across the *Arroyo de la Mina*, the water of which would be diverted pass the dam through a 600m-long, 3.5m diameter, galvanized steel pipe positioned on the creek's bed; and (iii) a dam similar to (ii), but with the diversion tunnel of the *Arroyo de la Mina* starting further upstream and excavated on its right flank, topographically above the dam's crown. Options (ii) and (iii) alone would be subjected to

[49] The addition of barium chloride forms a barium sulfate precipitate, where the radium provides isomorphous replacement to form co-precipitation of $Ba(Ra)SO_4$. The concentration of natural radionuclides in the effluents - uranium and thorium – is lowered to discharge standards by adjusting the effluent's pH by addition of lime. The cations, e.g., manganese and magnesium, also form flocculent deposits, thus accelerating the precipitation process. For technical references, see IAEA-TECDOC-1419; INF-UEP 011/02 (*CNEA-PRAMU*) and INF-UEP 029/04 (*CNEA-PRAMU*).
[50] Measures to accelerate evaporation, e.g., by installing a network of heating pipes on the bottom of the impoundment, require a considerable capital investment.
[51] Plant area is located just inside Seismic Zone 2 (Moderate Seismic Risk).

cost-benefit analysis as only they provide adequate space to capture the whole volume (750,000m^3) of the unstable waste piles. In addition, to ensure protection from Gamma radiation, the area of the waste piles should be barred from permanent habitation, including a ban on further mining activity.

Dams 0, 1, 2 and 3: the up to 5m thick precipitates produced by the neutralization of acidic effluents would be capped with a 0.5-2 m-thick layer of overburden and/or mineral waste; to ensure sealing and attenuation of radon emissions, this cap would be covered by material derived from the main dam and overlain with erosion-preventive layer of sterile rocks. Drainage gradient would be retained so as to ensure independent drainage of each of the dams into the *Rio Cajón*.

Open pit: reclamation would involve dismantlement, cutting off of large rocks, cleaning the berms, blasting and reconditioning the watershed of *Arroyo de la Mina*, and leveling and compacting the interior by sweeping loose debris from the pit's open face to facilitate unimpeded drainage.

Marginal ore piles: partially utilized for filling up the impoundment behind the main dam, their volume reduction would enhance their physical stabilization.

Demolition of structures: demolition of the site's masonry structures would generate 3,000m^3 of debris, to be utilized for reinforcing the main dam.

Present Site Situation

The following tasks have been carried out towards the final closure of the site:

- Interim management of the surface impoundments containing precipitates;
- Topographic leveling;
- Sampling of solid and liquid waste;
- Partial dismantlement of the installations;
- Documentation presented to the competent regulatory authorities[52] to address various administrative and regulatory requirements, e.g., applications for authorization of solid and liquid waste management and waste treatment activities, maintenance of impoundments, and mapping borehole location and subsurface water iso-potentials.
- In 2004, following an authorization by *Córdoba*'s Environmental Agency, construction of an impermeable impoundment and starting assembly of the treatment plant.

THE *SAN RAFAËL, TONCO, PICIÑAN, HUEMUL, LA ESTELA* AND *LOS COLORADOS* SITES

Tables 2A and 2B present background information, history of production activity, preliminary information on environmental impacts and associated risk estimates and preliminarily proposed mitigation measures pertaining to the five uranium mining sites that are designated for restoration under the third stage of the *PRAMU*. As stated above, for all these sites environmental baseline studies still needs to be conducted to better define impacts and devise appropriate mitigation measures. In addition, and as indicated earlier, whereas the *San Rafaël* site is a candidate for certain reclamation activities, considering its possible re-activation as a mining and uranium dioxide production site, it won't be funded by the WB's loan.

[52] *ARN, DIPAS (Direccion Provincial de Agua y Saneamiento) and Agencia Córdoba Ambiental*, between August 2002 and December 2003.

Table 2A. Salient features of the *San Rafaël, Tonco* and *Pichiñan* sites, designated for environmental restoration in the third stage of *PRAMU*

SITE, Corresponding Section in Original Document	*SAN RAPHAËL* (2.4.4)	*TONCO* (2.4.5)	*PICHIÑAN* (2.4.6)
LOCATION	*CMFSR* located in namesake county, *Mendoza* Province, 38 km W of the city of *San Rafaël*, 240 km S of the city of *Mendoza*. Located between 65^0 58' to 65^0 48' W and 25^0 18' to 15^0 43' S.	*San Carlos* County, *Salta* Province, 150 km SW from the County's capital. Southern *Los Cardones* National Park now contains S part of *Tonco* Valley.	*Sierra de Pichiñan*, geographic center of *Chubut* Province, 430 km W from *Trelew*.
TYPE FACILITY	- Inactive open pit - Processing plant on hold; area occupied by the complex exceeds 2,000 ha.	- Two mining areas, *Tonco* and *Amblayo* valleys - Processing plant	- Two mining areas: *Cerro Cóndor* & *Los Adobes* - Remains of processing plant (68^0 56' W 43^0 38' S).
PHYSICAL SETTING	Climate: Continental semi-arid, average annual temperature 15 ^{0}C, annual precipitation 343 mm. Winds low and infrequent, relative humidity is 55% on average. Water: In the watershed of *Arroyo El Tigre* (high-stage capacity ~ 500 times that of normal flow), discharges into *Rio Diamante* 5km down-flow from the *CMFSR*, where water is stored for human consumption by the City's population and irrigation of over 65,000 ha.	Elevations: 2,500-3,200m a.s.l Climate: Arid, average rainfall 200mm, primarily in summer; northerly winds. Hail and snow at high elevations. Average temp. 17-20 ^{0}C in summer, 7-9 ^{0}C in winter. Geomorphology: faulted, N-S synclines occupied by the *Tonco* and *Amblayo* River valleys. Soils: skeletal, stony, and unsuitable for cultivation. Flora: dry steppes, xerofilic & halophytic scrub, graminacea, cacti and mesquite. Water: only *Amblayo* River perennial, all others - seasonal Seismic risk: moderate (Seismic Zone 2, 15-	Open, flat to rolling spaces, typical of *Patagonia*. Water: *Rio Chubut* – the only perennial river. Phreatic aquifer 20-50 m below surface, recharged in winter from *Sierra Pichiñan*. Climate: temperate-arid, winter rain & snow; Soils: poor, mostly dry and unsuitable for cultivation; Seismic risk: very low (Seismic Zone 0).

POPULATION, SOCIO-ECONOMICS	Closest town, *Villa 25 de Mayo* (pop. 2,100), is located 11 km NE of site. City of *San Rafaël* (pop. 126,000) is a county seat, industrial center and market town, with strong tourist service industry. Crops include vineyards, fruits and olives. No indigenous communities at the site's vicinity. Economic activities close to site – cattle-, sheep-, and horse raising; practically no agriculture.	20 km away from the boundary of Zone 3). Only 25 people reside in the *Tonco* Valley in several isolated outposts. Closest settlement is *Santa Rosa*, ~20 km downstream from the main complex. Mining, limited cattle- and sheep-raising, small cottage industries, cultivation of vegetables and legumes for local consumption, evolving tourism. - No indigenous communities at the site's vicinity.	*Paso de Indios* (pop. 872) inhabitants, located 70 km to SW, County seat. County is sparsely populated (pop. 1883). Sheep- and cattle raising on scarce pastures. - No indigenous communities at the site's vicinity.
HISTORY OF U PRODUCTION ACTIVITY	Production: 1975-95: 2,460,000 ton extractable ore shipped to *CFM* and *CMFSR*; 1979-97: 1,071 ton U-concentrate from a 0.15% ore grade. In 1987, annual capacity enlarged from 50 ton to 120 ton U. Extraction comprised open pit mining, hydro-metallurgic treatment, acid-pad leaching, and extraction with ion-exchange resins. Global drop in U prices first compelled transition to minimum production (1994), then mine ceased operating in 1995. Return to full operation being assessed in light of the need for infrastructure investments and considering rising U market prices.	Exploration: 1959-1960 Operation: 1963-1980, the *Don Otto* subsurface mine (depth – up to 80m, 18+ km tunnels, shafts); 479,000 ton extracted, 0.084% U, 401-ton uranium. Also, several other minor mines. Defunct plant, auxiliary installations (to be demolished) occupy over 25 ha.	Exploration: from 1956. Operation: open-pit mines, 1977-81. *Los Adobes*: 90,000 ton extracted, 0.12% U, 108-ton metal. *Cerro Cóndor*: 57,000 ton extracted, 0.078% U, 45-ton metal, pit refilled in 1998. Plant (7.4 ha) dismantled, fenced-in.
PRESENT SITUATION		- Subsurface mine access closed and processing plant under controlled access, but recent report points to insufficient signage and fencing. - Analyses collected by *CNEA* in a sampling campaign are being lab-processed. - Recently, *Salta*'s mining authority has solicited preparation of EAs for the	

		individual deposits.	
SOURCES OF CONATMINATION	Associated with operations: - Dust and radioactive gases formed during mining; - Formation of ammonium di-uranate aerosols; - Ammonia and sulfuric acid, stored and used for heap leaching; - Possible infiltration of contaminated effluents in area of heap leaching. Associated with residues and effluents: - Overburden rock piles: 13,700,000 ton (0.003% U); - Pre-processed mineral piles: 1,800,000 ton; - Low grade piles: 35,000 ton (<0.017% U); - Marginal ore piles (prospective reserve): 376,000 ton (0.017- 0.034% U); - Mill tailings: solid precipitates have Ra226: 5.5 Bq/g, Rn: 260 Bq/m^3; very fine, wet 'mud' formed following neutralization of effluents: 265,000 ton, Ra226: 0.207 Bq/g; - 5,223 drums of solid residues from *CFC*, buried in trenches excavated into tailing piles (1,067 ton with 1.3% U); - 80,000 m^3 of neutralized liquid residues beyond evaporation dikes: Ra226: 0.037-0.074 Bq/l; - 800,000 m^3 of open pit mine effluents, treated to remove Ra and U, then discharged to *Arroyo El Tigre*.	Spent acidic and radioactive liquids stored in tanks. Most wastes are tailings (310,000 ton), occupying 34,000 m^2 in three mounds (17-23 ppm U); Ra 226: 49 - 21,456 mBq/g. Three leaching pads (130,000 ton) on pervious bottom occupy 17,500 m^2. - *ARN* sampling (1997-2001) indicates that Ra226 and U, as well as heavy metals and soluble ions in *Rio Tonco*'s water and sediments are below MCLs; but contamination was documented in a section of the *Sunchales* tributary, some 600 m downstream below the complex; - Empty underground fuel storage tanks; - Post-mounted sulfuric acid tanks, to be dismantled.	The plant's area (74 ha) contains 85,000-ton heap leach piles, leaching pads with membrane-sealed bottom and embankment for collecting process effluents for evaporation with clay base, 60,000-ton tailings. Both waste types covered by protective, vegetated rubble cap. *Los Adobes*: Rn flux: primarily between 0.001 (background level) and 0.27 Bq/ m^{2}s, but up to 1.68 Bq/m^{2}s; Average Rn: 18.5 Bq/m^3.
ENVIRONMENTAL IMPACT/RISK ESTIMATES	- Occupational exposure, between 1.8 mSv/y-4.2 mSv/y as function of production scale, well within the regulatory limit of 20 mSv/y[53]. There is no risk to non-workers due to controlled access. *Villa 25 de*	- Low risk of mass movements and mud slides; - Sub-recent N-S fault not considered major threat to tailings;	- No mine effluents (phreatic GW table below bottom of open-pits); - Low Rn flux and

[53] MilliSievert/year (mSv/year).

	Mayo unaffected due to distance. - Exposure to Rn222: 262 Bq/m^3, generates between 0.31 WLM/y[54] and 0.72 WLM/y as function of production scale, well below the regulatory limit of 20 WLM/y. There is no risk to non-workers due to controlled access. *Villa 25 de Mayo* unaffected due to air dilution. - Surface water not affected: concentration of U (1.4μg/l) and Ra226 (0.3 pC/l) in *Rio Diamante* below and above the point of discharge of *Rio El Tigre* are similar to background values. - Subsurface water: no reliable data; required monitoring by a network of piezometers yet to be installed; - Soil and flora – need study; - Air - needs study; - Landscape – scarred by excavation and tailing piles.	- Mine tunnels and unsealed shafts pose physical hazard; - No mine effluents detected due to aridity; - Establishment of the *Los Cardones* National Park reduced cattle grazing and population pressure, providing opportunity for recovery of the natural ecosystems.	remoteness pose insignificant radiological risk to the closest population centers; - Aqueous pathway limited by aridity, and subsurface water too deep to be impacted by Rn.
MITIGATION MEASURES	Closure Plan to include: (i) management of liquid effluents and open-pit water, (ii) management of solid-waste drums, (iii) management of piles of unprocessed minerals, marginal ore and solid precipitate, and (iv) management of overburden piles and the open-pit.	- Excluding visual degradation of landscape by mining, impacts considered minimal; however, an environmental audit would be prepared to identify required remediation needs; - With increasing tourism at the *Los Cardones* NP, funds are allocated for managing safety risks associated with mining legacy (e.g., signage, fencing and capping).	Planning an environmental evaluation to assess impact of mining and processing activities.
REFERENCES	INF-UIP-043/98, Plan *PRAMU, Sitio San Raphael*	- INF-UIP-050/98, Plan *PRAMU, Sitio Tonco;* - INF-UEP 021/03, J. C.Meza, *Comision de*	INF-UIP-051/98, Plan *PRAMU, Sitio Pichiñan.*

[54] Working Level Month, a unit of occupational exposure to potential radon Alfa radiation during one month (170 hours)

Servicio al Sitio Tonco-Amblayo, Oct. 2003.

Table 2B. Salient features of the *Huemul, La Estela* and *Los Colorados* sites, designated for environmental restoration in the third stage of *PRAMU*

SITE, Corresponding Section in Original Document	***HUEMUL*** (2.4.7)	***LA ESTELA*** (2.4.8)	*LOS COLORADOS* (2.4.9)
LOCATION	*Malargüe* County, SE *Mendoza* Province, 45 km S from *Malargüe*.	Primarily in *Chacabuco* County, on the border of *San Luis* and *Cordóba* Provinces, 155 km NE from *San Luis*, and on the E flank of *Sierras de los Comechingones*. 64^0 56' W 32^0 35' S.	*Independencia* County, *La Rioja* Province, 100 km (by road) SSW from namesake Provincial capital, 20 km W of *Patquia*. 67^0 04' W 30^0 00' S.
TYPE FACILITY	Open pit mine in 3 sectors (*Huemul, Agua Botada, Arroyo Seco*).	- Open pit mine - Processing facility over 30 ha.	One major and two minor open pit mines.
PHYSICAL SETTING	Elevation: 1,800 a.s.l. Climate: Arid, average annual temperature 11.7 ^{0}C, average minimum: -15^{0}C, average maximum: 35^{0}C. Flora: Dry scrub with grasses. Water: *Arroyo Agua Botada*, (discharging into the *Rio Grande*) is the only semi-perennial flow.	Geological setting: fluorite-U deposits (0.07% U) in granite batholite along transversal fault exposed by the *Rio Seco*; eastern fold of the *Sierras de los Comechingones.* Climate: continental, arid to semi-arid (annual evapo-transpiration up to 1,400 mm), large seasonal temperature amplitude. Torrential summer rains (80-250 mm/day), periodic snowfall. Average wind velocities 6.5 km/h, from all sectors. Aquifers: interconnected, with divides not corresponding to surface watersheds. Seismic risk: Moderate (Seismic Zone 2), some active faulting at E flank of *Sierras de los Comechingones*.	Geological setting: on W flank of the *Los Mogotes Colorados* anticline. Climate: continental semi-arid, large seasonal temperature amplitude, with annual extremes of -2 ^{0}C and 42^{0}C. Annual rainfall 150-250 mm, primarily as summer rainstorms. Summer evaporation 300-mm/ month, relative humidity 40-50%. Winds, primarily SE and N, rarely exceed 15 km/h. Flora: Dry scrub with grasses. Water: some springs on E flanks of *Sierra de Sanogasta;* most riverbeds only have seasonal flow. Shallow groundwater is scarce and brackish (a drillhole close to the deposit encountered non-potable 'mesothermal', heavily mineralized water),

			and water is supplied from deep (200 m) wells and runoff reservoirs. Seismic risk: moderate (Seismic Zone 2).
POPULATION, SOCIO-ECONOMICS	Limited cattle-, goats-, horses- and mule-raising, no agriculture. No indigenous communities at the site's vicinity.	- *San Luis* (pop. 118,000) and *Villa Mercedes* (pop. 88,519), with close to 70% of the Province's population, are ~ 150-180 km away. All other, small urban centers (pop. between ~ 2,200 and 6,100 each) are 41-67 km away. - Low population density (5.6-7.1 persons/km^2) in three hosting/adjacent counties. Significant migratory element among rural population. - In the Province, cattle-, sheep- and horse-raising, poultry farms and developing agro-industrial (dairy-based) activity. Main crops (some irrigated) are potatoes (national eminence, including export), maize, sorghum, sunflowers, wheat and forage. Also herbs and plants for cosmetic extracts. Increasing appeal for summer tourism. - No indigenous communities at the site's vicinity.	- Area is very sparsely populated. Closest village (15 km N) is *Estacion Los Colorados*, ~ 30 inhabitants; countywide, some 18 farms, with grazing-based goat- and cattle growing. - No indigenous communities at the site's vicinity.
HISTORY OF U PRODUCTION ACTIVITY	Exploration: from 1952. Operation: 1954-76; subsurface mine closed once ore was exhausted. 128,000 ton processed in *CFM;* extracted from a 0.73% U ore, 153 ton of U, 850 ton of Cu.	Exploration: from 1952. Operation: 1953-90 by private entities: first (until 1964), 3,400 ton extracted from high-grade ore (0.4% U), then (1980-90), 22-ton produced from 0.07% U ore. Overall, 1,200,000 ton of rock removed. Extraction: crushing, heap leaching with sulfuric acid over sealed bottom pads (120-day cycle, 20 kg acid/ton), concentration of leachate with ionic	Operation: by *CNEA* -- 1974-77, by private entity[55] -- 1992-96, 55 ton U produced from 0.064% ore. ~1 million ton sterile waste in 3-15 m high piles, 136,000 ton tailings. Extraction: crushing, heap-leaching with sulfuric acid (200-day cycle), extraction by ionic-exchange resins, final precipitation as ammonium di-uranate. Installations

[55] *Uranco S.A.*

		exchange resins, precipitation as ammonium di-uranate. Effluents (60-70 m^3/day) neutralized with lime then disposed of by spray-evaporation into a 1.8 ha impoundment.	dismantled after 1996, leaching heaps capped and ground-leveled to prevent water ponding.
PRESENT SITUATION	- Installations and infrastructure, under jurisdiction of *Mendoza* Province, are in ruins or dismantled. - In 2001, installed a fence around one sector.	Operation legally concluded in March 1991.	Originally, there was no maintenance or monitoring after cessation of operations. Later, *La Rioja*'s Mining Directorate invited *CNEA* to visit the site to recommend required maintenance, and recommendations were implemented at the end of 2004. Site acquired by an entrepreneur for developing tourism initiative. Per requirement of *Patquia*'s residents, *CNEA* -- jointly with *Rioja*'s Mining Directorate -- set up a town meeting to discuss the site's situation and the town's water quality.
SOURCES OF CONATMINATION	- 2,404 m^3 of ore-grade concentrate piles (0.73% U); - 43,361 m^3 of overburden and sterile rock piles; - 37 m^3 of low-grade ore piles.	In the absence of a database to assess all sources, only reconnaissance-based information: sterile waste piles being eroded and dispersed into creek bed; running a risk of uncontrolled rupture. Similar waste located close to Provincial Road No.1.	- Due to operation by private company, *CNEA* lacks information on waste-pile characterization and has not performed environmental monitoring. - Potentially, mine tailings and heap-leach residual waste. Average Rn222 flux: 0.96 Bq/m^2 s. - Ra226 monitored by *ARN*: averages are 2.2-5.4 mBq/l in water, 23.3 Bq/kg in sediments, 0.14mBq/l in shallow subsurface water. - Average U levels in natural waters, shallow subsurface water, in *Patquia*'s potable water and in sediments are 0.003, 0.17, 0.015 (all in mg/l) and 1.7ppm, respectively.

ENVIRONMENTAL IMPACT/RISK ESTIMATES	No data on mine effluents, radiation hazards or conventional contaminants. Unsealed mine openings pose physical hazard.	- Unstable mining screes in highly fractured rock at repose angle; - *Rio Seco* carries debris from overburden screes during high flow stages, possibly carries U with subsurface infiltration.	- Safety hazards associated with vertical open pit walls and with ponding rainwater in the main pit; - Potential for contamination of surface- and groundwater by U. Recent shallow GW-measurements in waste pile areas yielded U values of 3.3 to 273,000 µg/l, and for Ra226, 0.12 to 5.82 pCi/l; - Tailings capping susceptible to erosion; - Landscape scoured by quarrying and tailing piles.
MITIGATION MEASURES	To be designed based on an environmental audit yet to be conducted.	To be designed based on an environmental audit yet to be conducted.	To be designed based on an environmental audit yet to be conducted.
REFERENCE	INF-UIP-044/98, Plan *PRAMU, Sitio Huemul*, with updates.	- INF-UIP-047/98, Plan *PRAMU, Sitio La Estela* - *Informe Uranco S.A.*, 1991.	- INF-UIP-048/98, Plan *PRAMU, Sitio Los Colorados.* - INF-UEP 026/04, *Comision de Servicio al Sitio Los Colorades, La Rioja.*

4 ENVIRONMENTAL ASSESSMENT OF THE *MALARGÜE* PROJECT SITE

GENERAL BACKGROUND[56]

Objective and Scope

The mitigation of the *Malargü*e site comprises several tasks. These include relocating the tailings to a higher, and better-drained ground within the site, provision of drainage to divert runoff and impede infiltration into the extremely shallow phreatic aquifer, sealing the substrate designated to accept the relocated tailings, and capping the relocated tailings with natural, low-permeability material. Finally, the site is to be decontaminated, leveled and revegetated, then subjected to institutional control to enforce limited access.

Physical and Socio-Economic Setting

The *CFM* [57] is located 207 km SW of *San Rafaël* and 344 km S of *Mendoz*a, the capital of the *Mendoza* Province (see Fig.1). It is situated at an altitude of 1,400m a.s.l in the foothills of the Andes, and a few hundred meters to the NE of the town of *Malargüe* (15,300 inhabitants). *Malargüe* is the seat of a sparsely populated (0.5 habitants/km^2) namesake county. Economic activities include tourism (over 15,000 visitors during the last high season, 3,600 guest rooms), light industries (food, beverages and clothing), agriculture (potato seeds and vegetables), goat-, cattle-and sheep growing (over 430,000 heads total), mining of non-metallic resources, and (declining) oil production. An energy and cosmic radiation science research center (*Proyecto Pierre Auger*) -- to employ 250 scientists from 15 countries -- is under construction, slated for completion in 2006. The town has no sewage system or a modern landfill. There are no indigenous communities at the site's vicinity.

Malargüe's climate is sub-arid cold, with average annual temperature of 11.7 ^{0}C and relative humidity of 59%. The average annual precipitation drops from 334 mm in the area down to 200 mm further to the east. Rain falls throughout the year, but with higher intensity in the fall. There are two predominant wind directions[58]: mild (10-12 km/hour on average), northern to northeasterly winds, blowing from the site towards the city, and stronger (19-22 km/h on average but up to 174 km/hour) western to southwesterly winds, blowing away from the city. Only the latter winds are capable of causing significant particulate dispersion from the tailings. Higher rainfall and snow melting from the *Cordillera Principal* feed several perennial rivers and recharge groundwater.

The site is underlain to a depth of 23m by a substratum of young alluvial and aeolian deposits consisting of gravel, sand and finer sediments. These highly permeable sediments host the phreatic aquifer. An impermeable, 3m-thick clay layer underlies this aquifer. Another layer of sand and gravel underneath the clay hosts a pressurized, confined aquifer. The groundwater table is shallow and highly variable, at times reaching the surface and causing inundation of lands adjacent to and outside the NE corner of the site. Consequently, soils are saline. The phreatic aquifer flows towards the NE, away from town, and is only occasionally utilized for irrigation. Drinking water is extracted from two sources located up-basin from the *CFM*. The primary

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[56] See: (INF-UIP Nº 052/98), "*Plan de Preparación del Proyecto de Restitución Ambiental de la Minería del Uranio. Sitio: Malargüe*."
[57] *El Complejo Fabril Malargüe*
[58] Values based on a ten-year measurement period: 1981-1990.

source - *Rio Malargüe*, is supplemented by a 160 m-deep well, located about 4 km SW from the site.

Public roads, a couple of adjacent farms and a gypsum processing plant surround the *CFM* on the E and S, and the railroad and right of way of *Buenos Aires Pacifico* confine it to the W. A 9-ha, contaminated land parcel west of the plant is leased from the *San Gabriel* Farm for experimental runs of phytoremediation. Due to their limited agricultural value, the surrounding lands are used primarily as cattle pastures.

The area has a Moderate level of seismic risk (Seismic Zone 2; estimated maximum potential magnitude of 6.5 with recurrence of 20,000 years). Seismic activity is linked to active reverse and lateral faults that are associated with the convergence of the South American and Nazca Plates.

The natural vegetation consists of steppes of scrub (*matorral*) with sparse bushes separated by soil-denuded tracts and underlain by grasses. Mammals include Vizcacha, armadillo, marmot, fox, skunk, wildcat, and guanaco, as well as introduced rabbit and wild boar[59]. Two province-level protected areas reside within the County limits (see Fig. 4). The Faune Reserve *Laguna Llancanelo* (40 km to the ESE) -- a closed water body occupying a topographic depression, has been recently recognized internationally as one of the largest and well-preserved wetlands of the world with important characteristic avifauna. The *Total Reserve El Payén* (about 230 km to the S) contains quite young (Mid-Quaternary), thick volcanic formations[60] with characteristic flora and fauna. Access to both reserves is limited for scientific research only.

In May 1954, the Province of *Mendoza* relinquished (Decree No. 1633) some 39 ha to the *CNEA* for the purpose of installing a chemical plant for processing uranium ore. Ore was supplied from two sources: the nearby (about 50 km away) *Huemul-Agua Botada* mines, with primarily pitchblende from a cupro-uraniferous sandstone; and the *Sierra Pintada* mines (*San Rafaël*, about 180 km away), with primarily uraninite, uranium-titanium oxides and uranium silicate in sandstone. Production entailed crushing the ore, rod milling, leaching in designated vats with sulfuric- or nitric- acid in the presence of manganese dioxide as oxidant, solid-liquid separation, and extraction of uranium concentrate by ionic exchange resins. Production capacity has increased in stages, reaching 250 ton/day (1978-1986). Since start of operations in 1954, the *CFM* produced 759 tons of uranium from ore with U grade of 0.14%, leaving behind a legacy of 716,000 tons of tailings.

BASELINE CONDITIONS

Following plant closing in 1986, the mill installations were de-contaminated, dismantled and removed from the site. In April 1995, The Provincial Office of the Environmental and Public Works (*MAOP*) approved the selected environmental management option and then authorized a *DIA* (Resolution 738/97), committing *CNEA* to implement the closure of the *CFM*. In 1998, storm-water drainage diversion works and drilling of wells for the provision of water were launched by a private contractor, in line with commitments assumed by *CNEA* in the *DIA* and authorized by *MAOP*. The site is surrounded by a 2 m-high mesh fence and is constantly attended by a watchman. (See section 4.5).

[59] For additional floral and faunal details, see the original Spanish language report.
[60] Associated with the presently inactive volcanic edifice of *Payún*.

Tailings

An area of about 4 ha at the extreme SE sector of the site is a temporary repository of some 475,000 m^3 of processing tailings, surrounded by embankments of 'sterile' residues of the chemical neutralization process. The 6 m-high tailings are confined along their N to SW perimeter by a grove of 15-20m high poplar trees. The tailings, predominantly fine-grain size material (over 80% smaller than 420μ), are covered partially by vegetation. Strong bioturbation activity by rabbit colonies is prevalent at the NE area of the tailings.

Composite sampling of the tailings indicates they contain on average between 101-184 ppm U, 6.9 - 19.4 Bq g^{-1} radium 226[61], and between 584 - 5,062 Bq/m^3 of radon 222. The Rn flux varies between 6.5(± 0.7%) - 10.3(± 0.52%) Bq/m^2s. As neutralization of the processing tailings with lime has been exercised only during the last three years of the plant's operation, the residual acidity of the interstitial tailings-material drops from a pH of 7-8 at the top of the piles to about 3 close to the bottom. Integrated samples from ten boreholes that penetrated the tailings show elevated concentrations of selected heavy metals[62]. Measured values of up to 0.85% Mn, 18% SO_4, 0.24% Ti and 0.2% P_2O_5 are also residues of the leach solutions and the ore-gangue components. Composite samples from a 1-m soil interval underlying the tailing piles have even higher values of Cu, Zn, V, Ba, Ti and Co than the tailings, indicating downward mobilization. There are no liquid effluents at the site.

About 70% of the town's population resides within 0.5 to 6 km from the tailings, although there are several closer dwellings. Dust storms are associated with sudden weather changes in the Austral winter, when rather strong winds descending from the Cordillera to the west suspend soil particles from the scarcely vegetated land surface. The coarser dust fraction contains up to 65 ppm of Zn, Cr, and Cu each, and 1-3 ppm of uranium[63].

IMPACTS – ESTIMATES OF THE PRESENT RISKS

In the absence of physical hazards at the site, the two major risk sources to *Malargüe*'s population are the inhalation of radon 222 and its decay products, and direct exposure to Gamma radiation.

Risk of Inhaling Radon 222 and its Decay Products

Radon 222[64] emanates from within the tailings, diffuses to the surface and disperses in the atmosphere. The rate of emission varies greatly with time, as a function of several synoptic and physical parameters. In order to estimate the radon inhalation risk to the population, continuous radon concentration and radon flux measurements were taken between March 1996 and June 1997 at the top of the tailing piles, at their perimeter, and both outdoors and indoors of dwellings in the town of *Malargüe*. From the data it is possible to calculate the equivalent radiation doses[65]

[61] The site's total radiological content can be estimated, therefore, as anywhere between 4.9 x 10^{12} and 1.39 x 10^{13} Bq.
[62] Averages (in ppm) are 85 ± 48 for Cu, 87± 47 for Pb, and 49 ± 26 for Zn. In addition, Cr and Ni range between 50-150 and 15-50, respectively. For further details, see Tables 4.5.2 and 4.5.3 in the original, Spanish language document.
[63] For further details, see Table 4.5.6 in the original document.
[64] The gaseous decay product of Radium 226.
[65] Equivalent Dose is the quantity of absorbed energy as a result from a given type of radiation, averaged across the volume of a recipient tissue or organ. It is measured in joules per kg, or Sievert (Sv).

for a hypothetical critical population group residing permanently (i.e., 7,000 hours annually or about 80% attendance) on the top of the tailing piles[66].

The radon flux, measured at the top of the piles[67], ranges between 6.1-10.1 Bq/m^{2}s, or about an order of magnitude above the USEPA standard of 0.74 Bq/m^{2}s. Radon concentrations, measured 0.5 m above the tailings pile[68], range between 584 and 5,062 Bq/m^3 - but dispersion quickly reduces radiation at the site's perimeter by a factor of 2-18. Yet, a hypothetical member of a critical population group residing permanently at the site's perimeter would be exposed to an annual dose of 5-6 mSv/year[69]. For reference, the maximum permissible dose mandated by *ARN* for the *Malargüe* site (Mandatory Standard RQ-86) is only 0.1 mSv/year; ICRP60 recommends corrective action for dwellings where annual indoor radon exposure levels exceed 3-10 mSv/year; and the intervention level established by *ARN* for dwellings' indoors is 400 Bq/m^3.

Radon concentrations were measured systematically across the town of *Malargüe* in two separate studies. In the first (1993), samples were collected from a sampling grid of sectors of 45^0, each 500m along the radius from the center of the tailings. Because about 70% of the town's population lives in the SW sector relative to the location of the mining residues, measurements were conducted in three sectors that span azimuths between 157.5^0 and 292.5^0. Employing EPA procedures[70], activated carbon detectors were exposed at each sector for 48 hours after having been calibrated against background levels. The data demonstrated that radon is detectable up to 1.5–2.5 km away from the tailings and that the outdoors concentration of radon never exceeds the USEPA standard of 18.5 Bq/m^3. However, several indoor measurements yielded concentrations exceeding the standard (i.e., up to 31.0 Bq/m^3).

The second study (1996-97, with control measurements still ongoing) focused on the proximal area (0.5-1.0 km) of the SW sector, employing passive-measurement detectors with radiation counters that integrated readings for at least three months. The concentrations registered (between 63-296 Bq/m^3) were higher by two orders of magnitude as compared to the data obtained in the earlier study, with the discrepancy attributed primarily to the different monitoring techniques rather than to differences in synoptic conditions. The new study also demonstrated higher radiation levels indoors than outdoors, apparently as a result of emission from the building materials. Both studies indicate, though, that indoor radon values comply with the internationally accepted limits[71].

During the second study, the concentrations of radon radioactive decay products ('daughters') – Po, Bi and Pb, were measured inside 27 dwellings. These isotopes form radioactive aerosols by adhering to tiny dust particles. The registered concentrations, 5 to 212 Bq/m^3, fall below the ICPR and AR 10.1.1 standards (200-600 Bq/m^3 and 400 Bq/m^3, respectively); furthermore, the Alpha

[66] For details, see Tables 4.6.1 to 4.6.3 in the original document. *Critical Population Group* is the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.
[67] Continuous measurement for one week conducted across most of the year (with the exception of winter).
[68] Continuous measurement for three months, conducted in the spring.
[69] In addition, the radon concentration values measured at the tailings' perimeter exceeds by one order of magnitude the maximum permissible US EPA standard of 18.5 Bq/m^3.
[70] Standard Operating Procedure for Rn-222 Measurements: US EPA 520/5-87-005.
[71] ICRP's standard is between 200 - 600 Bq/m^3.

radiation values for the short-lived decay products: 0.001 and 0.009 WL[72], are well below the USEPA standards[73] and therefore pose no risk to the town's population.

Direct Exposure

The tailings emit on average 6.9 – 10.9 Bq g^{-1} of Ra 226 radiation. Assuming that the uranium-radium disintegration series are the only source of radioactivity in the tailings, a person who accesses the tailings would be expose to an equivalent dose of between 3.4 and 9.7 μSv/h. Consequently, the maximum annual allowable dose at the site of 0.1 mSv/yr would be attained by an individual after spending only 10-30-hours at the site.

Projection of the Radiological Risk

Two cases are presented to demonstrate the risk of contracting cancer as a result of radon inhalation and exposure to Gamma radiation. In the first case, a hypothetical resident living permanently (7,000 hrs of annual exposure) and with no shielding on top of the tailings would receive a combined dose of 157 mSv/year through direct exposure and inhalation. According to published models of life expectancy reduction, this would shorten his life expectancy by almost 10 years. In the second case, living on the perimeter of the site would result in a combined dose of 6.8 mSv/year through direct exposure and inhalation, shortening his life expectancy by about ½ year. However, the amount of radiation projected for frequent trespassers at the site or for occasional visitors (e.g., 1,000 hrs of annual exposure) is well within the international standards.

It is concluded that the radioactive residues at the *CFM* would pose a radiological risk only to a hypothetical group that would choose to live at the site's perimeter, but not to occasional visitors. On the other hand, the radiological effect on the town's population is insignificant.

Impact on Groundwater

The composition and concentration of dissolved constituents in the phreatic aquifer (maximum conductivity of close to 6,000 μmho/cm) suggests that leachates infiltrate from the tailings[74]. Beneath the tailings, and in a plume extending some hundreds of meters to the NE from the site, the phreatic aquifer is contaminated by sulfates of Ca and Na, uranium (max. 17ppm), and Ra 226 (peak concentration: 55 pCi $^{-1}$)[75]. Maximum contamination occurs in the first 10 m below the surface, and immediately below the tailings, and the diffusion occurs primarily laterally. In contrast, the confined aquifer underneath the impermeable clay unit exhibits ionic compositions and concentrations that are indistinguishable from those of groundwater elsewhere in the region.

The groundwater in the sphere of the site's influence is not used for human consumption; water for irrigation is abstracted only from sources located outside the contamination halo. Consequently, presently the aquatic pathway of radioisotopes does not represent a significant hazard to humans.

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[72] Working Level (WL): the combination in a volume of air of any of the short-lived daughters of radon, that during their decay into Pb 210 results in the emission of 130,000 MeV of Alfa-radiation.
[73] Limit: 0.02 WL, and is not to exceed 0.03 WL.
[74] See Table 4.6.4 of the original document.
[75] The US EPA standard for tailings sites is average combined ^{226}Ra + ^{228}Ra concentration below 5 pCi l^{-1}.

ANALYSIS OF MITIGATION ALTERNATIVES

The selection of the preferred mitigation option for the *CFM* (Table 3) was guided by the following considerations:

- Ensure that release of contaminants to the environment is kept below regulatory limits and subjected to ALARA;
- Prevent the establishment of permanent human habitation at, and the use of materials for construction and engineering infill from the remediated site;
- Provide a design that would minimize institutional maintenance and control;
- Avoid forming new sites encumbered with the waste;
- Whatever the selected alternative, impose restrictions on the land use of the designated area;
- Establish a verification period to evaluate the performance of the adopted system in comparison to the model.

Table 3. Evaluated alternatives, their anticipated mitigation effects, costs, need for institutional control and impact on public perception

Alternative	Description	Protection of GW	Protection of Air	Protection of Soil	Cost per-ton	Need for Institutional Control	Public Perception
1. No Action	Leave tailings undisturbed in their current condition.	None	None	None	Nil	Very High	Very Bad
2. Manage tailings at their existing location	Stabilize tailings and cap to prevent Rn emissions, infiltration and bioturbation. Divert runoff to depress GW table below tailings; decontaminate and fill other *CMF* areas with natural soil, revegetate and landscape.	Med.	High	Med.	$9.45	High	Bad

Alternative	Description	Protection of GW	Protection of Air	Protection of Soil	Cost per-ton	Need for Institutional Control	Public Perception
3. Manage tailings by relocation within the site	Relocate tailings to higher grounds to isolate it from GW; encapsulate, by providing an impermeable bottom and cap, and place the neutralized and compacted tailings in-between; divert runoff to depress GW below tailings; decontaminate and fill other *CMF* areas with natural soil, revegetate and landscape.	Very High	Very High	Very High	$13.36	Low	Very Good
4. Manage tailings by relocation to the south	Relocate tailings to a basaltic site with lower GW table, some 35 km to the S. Place neutralized waste in natural depressions and cover with a multi-cap; decontaminate and fill other *CMF* areas with natural soil, revegetate and landscape.	High	Very High	High	$17.70	Low	Bad
5. Manage tailings by relocation to *CMFSR*	Transfer waste by rail to *CMF San Rafaël*, some 180 km away. Manage tailings as under Alternative No. 2. Decontaminate and fill other remaining *CMF* areas with natural soil, revegetate and landscape.	Very High	Very High	Very High	$20.24	Low	Very Good for *Malargüe*, but Very Bad for *San Rafaël*

1. No Action -- rejected because it fails to protect human health and the environment; it also disregards potential externalities (e.g., adverse impacts on *Malargüe*'s economy);
2. Manage tailings at their existing location -- rejected because the current location of the mineral piles on permeable substrate is bound to result in further contamination of the phreatic aquifer;
3. Manage tailings by relocation within the site -- adopted, as providing the best mitigation benefits within reasonable cost;

4. Manage tailings by relocation to the south -- rejected due to high transportation costs and associated risks, risk of relocation to a Quaternary volcanic site, and damage to the reputation of an area reputed for its organic potato seeds; and
5. Manage tailings by relocation to *CMFSR* -- rejected due to high transportation costs and associated risks, and very bad perception by *San Rafaël*'s population.

Based on the considerations summarized in Table 3, in 1994 *CNEA* submitted to the Province's authority a recommendation for implementing restoration by relocating the tailings within the *CFM* site (Alternative No. 3). In addition to the described tasks, the plan also included provisions for a 20-year verification period to evaluate the system's performance, and institutional controls to prevent human habitation and other intrusive activities (e.g., drilling).

DESCRIPTION OF THE *MALARGÜE* RESTORATION PROJECT

To facilitate the adoption of engineering solutions that measure up to the best international practices, *CNEA* has been maintaining technical contacts with countries and institutions experienced in the field of uranium mining. These culminated in technical exchange and cooperation pacts with the U.S. Department of Energy (the UMTRA Project, 1996) and the Spanish Corporation of Radioactive Waste (*ENRESA*, 1999), and, with the support of the IAEA, *CNEA* personnel was trained in the U.S., Canada, and Australia. A *PRAMU* team studied management practices at the uranium processing plant of *Andujar*, Spain, and has been engaged in a joint *CNEA*-USDOE research on semi-permeable membranes.

Site reclamation comprises two key activities: (i) relocate the tailings from their current location that is subjected to frequent flooding to the highest location of the site, and (ii) encapsulate the relocated tailings so as to comply with the established radiation standards. To ensure the containment of the mineral waste piles, *CNEA* adopted an engineering solution comprising a system of multiple and redundant barriers for their encapsulation.

Specifically, the Project entails the following tasks:

- Demolish all masonry and concrete installations that cannot be salvaged, dismantle and downsize machinery and metal components, and place debris in the area designated for receiving the relocated tailings waste.
- Install subsurface drainage pipeline to lower the level of phreatic groundwater in order to isolate the bottom of the newly relocated tailings and enable access for remediation to periodically flooded areas.
- Install a storm-water collector system above the subsurface drainage to divert runoff away from the embankment of the relocated tailings, thus improving the site's drainage and reducing the vulnerability to erosion of the relocated tailings.
- Seal with concrete the bottoms of the irrigation ditches that cross the site en-route to adjacent cultivated areas in order to reduce infiltration to the shallow phreatic aquifer.
- Construct a containment cell around the tailings to impede the migration of contaminants through all possible pathways.
- Condition the prospective floor area of the tailings' new designated site to a depth of 0.7 m, then compact it mechanically.
- Construct a multi-cap, engineered bottom barrier consisting of (from bottom to top):

    - 0.4m-thick cap of porous material (to stabilize the foundation),

- 0.15m-thick sandy-clayey soil cap (to prevent intrusion of the superjacent, clayey cap into the subjacent porous cap),
- 0.5m-thick, very low permeability (between 10^{-8}cm/sec and $2.9x10^{-9}$ cm/sec), low-plasticity compacted clay-cap (a dual-purpose barrier against downward infiltration of contaminated water and ascent of phreatic groundwater into the tailings). The clay source selected for this cap has been experimentally proven impermeable to uranium-bearing solutions.

From the outset it was evident that a thorough understanding of the variations in the level of the local phreatic aquifer is essential for appropriate design of the encapsulation to effectively contain the relocated tailings. A hydrological study[76] revealed that the temporal variations of the phreatic aquifer depend on and lag five months behind those of the *Malargüe River*. Analysis of the River's hydrographs indicated that within a 99% confidence level, the probability it would exceed a flow level of 45 m^3/sec is 0.1%, or once in a thousand years event. Under such an extreme flow regime, the highest phreatic level underneath the NW sector of the relocated tailings would not exceed 0.65m below the surface. The study concluded that the subterranean drainage controls would lower the phreatic level to a sufficient degree such that it won't immerse the bottom barrier; it also demonstrated that even under a worst case scenario the compressed clay cap would still remain an effective barrier.

- Following neutralization with lime and compacting, pile the relocated tailings, contaminated soils and demolition debris in layers to a height of 5m on the engineered bottom barrier, placing the least compressible material underneath the lighter and more compressible fractions. A pilot embankment would be constructed to determine the best methodologies for neutralization, drying, and compacting, and to monitor the subsequent emissions of radon and Gamma radiation.
- Construct a multi-layer, engineered top barrier. The design to be implemented is based on studies to gauge the maximum depth of desiccation under variable weather conditions and reduce the long-term emissions of radon. This barrier would consist of (in ascending order):

  - A 0.5m-thick, very low-permeability (between 10^{-8}cm/sec and $2.9x10^{-9}$ cm/sec), low-plasticity compacted clay-cap, where water saturation will be maintained so as to minimize radon emissions,
  - A 0.8m-thick, compacted sandy-clayey soil cap, to maintain water saturation in the subjacent clay cap and protect it from the superjacent riprap cap, and
  - A 0.5-0.7m-thick compacted riprap cap, comprising scoriaceous volcanic rocks with inter-granular voids filled with clayey soil to provide a substrate for stabilizing herbaceous vegetation. This layer is intended to protect the top barrier against erosion, control radon emissions and Gamma radiation, and prevent biointrusion and long-term tampering.

- Excavate all site soils that have been impacted by industrial activity, place them in the new tailings containment area, and refill with uncontaminated soils to ensure compliance with US EPA standards for radium 226 concentrations[77]. Then revegetate, to convert the site into an access-restricted, fenced-in 'green space'.

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[76] Coria Jofre y Associados/*Evaluación del efecto del drenaje subterráneo en el nivel freático*, Oct. 2002.
[77] According to USEPA 40CFR 192, in the top 15 cm, Ra-226 concentration should remain below 5 pCi gr^{-1} above background and in the next 15 cm further down, concentration should not exceed 15 pCi gr^{-1}. Consequently, exposure should not exceed 20µrad h^{-1} above background level.

The new embankment, located in Sectors 1-4 of the Site (see Fig. 5) would assume the shape of an 8m-high truncated pyramid, with rectangular trapezoid bottom and top surfaces and a base area of about 130,000 m^2. It will slope at about 11^0 along its long axis and about $1/3^0$ across. Its final dimensions and slope are designed to satisfy both practical (proper drainage and wind protection) and aesthetic considerations.

Recent and ongoing activities include the construction of a work camp to house cleanup workers and oversight staff and vehicular decontamination ramp, and preliminary cleanup activities in all the sectors designated to receive the relocated tailings, as follows: in Sector 1, the removal of 27,500 m^3 of contaminated substrate in the industrial area; in Sector 2, cleanup and relocation of the contaminants and infill with clean soil; and in Sectors 3 and 4, the cleanup of the subterranean and surface drainage systems.

Once the source of contamination has been relocated and encapsulated to stop further leaching, restoration of the phreatic aquifer would proceed through natural attenuation. Attenuation would be achieved by dilution of the vigorous flow of the phreatic aquifer (about 500 m/yr) and through ionic retention by a natural clayey surface cap. The process would be closely monitored through extensive sampling of soils and ground water.

The final land use of the restored site would be determined by public consent and endorsement of the authorities at all levels, following a period of site monitoring (estimated at 5 years) to verify the success of the mitigation measures. Concurrently, the municipal authorities would be urged to apply site access restrictions to ensure the integrity of the barriers and monitoring posts, as well as to keep at bay permanent dwelling.

EXPECTED IMPROVEMENTS RELATIVE TO THE PRESENT SITUATION

Table 4 summarizes the actual environmental benefits anticipated in the wake of having the tailings relocated and encapsulated by impermeable capping.

Table 4. Summary of the actual environmental benefits expected from the *Malargüe* restoration project.

Factor	Without Project	With Project	Standards
Air	Radon emissions from tailings: 6-10 Bq/m^2s.	Radon emissions from managed tailings: 0.12 Bq/m^2s.	0.74 Bq/m^2s (USEPA 40CFR 192, Appendix A).
Water	Phreatic aquifer is contaminated, primarily beneath the tailings. Tailings underlain by rather permeable (10^{-3} cm/s) substrate. Ra-226 content in aquifer underneath the tailings: 0.684 Bq/l.	Quality of phreatic aquifer waters improved by encapsulating the tailings, decontamination of the area and natural attenuation. Bottom liner of compacted clay has permeability of 10^{-8} cm/s.	Ra-226: 0.185 Bq/l (USEPA)

Soil	Soils at the sites are contaminated by Ra-226, with values of 30 – 100 pCi g^{-1}.	Site decontaminated to achieve Ra-226 soil contents not to exceed 5pCi g^{-1} above background.	Ra-226 in soils of remediated areas: not to exceed 5 pCi g^{-1} above background
Landscape	Landscape adversely affected by the presence of unmanaged tailings and soils impacted by industrial activities.	Landscape restored, by planting autochthonous woody and herbal species following restoration.	–

PROJECT COSTS AND COST/BENEFIT ANALYSIS

The projected costs of works still to be performed to restore the *Malargüe* site are as follows:

TASK	COST, ($ AR)*
Preparation of new substrate for relocated tailings	12,674,000
Relocation of contaminated soils, tailings	5, 628,000
Rehabilitation of the area	1,498,000
TOTAL, including 5% contingency and VAT[78]	**21,000,000**

* With exchange rate of 1 U$D = 3.01635 pesos (December 24, 2005), equal to U$D 6,963,000

The estimated overall cost of restoring the *CFM* site is approximately U$D 9-10 million, subject to details of the design. Its scope, as defined by the technical authorities, the public and in accord with the authorities of the *Mendoza* Province, includes relocating the tailings from their current location that is subjected to frequent flooding to the highest location of the site, and having them encapsulated. These requirements dominate the scope of the restoration and its cost.

Uranium tailings unit remediation costs elsewhere in the world vary significantly (e.g., from U$D 0.12/ton in South Africa[79], up to U$D 112/ton at the Canonsburg, PA, USA site[80]). This range reflects economies of scale achieved in very large clean-up projects as well as diverse, site-specific conditions and the stringency of the local regulatory standards. A meaningful comparison, therefore, requires a close analog to the *Malargüe* site, where tailings must be relocated to avert actual contamination of the aquifer and potential impacts on an adjacent population center. Even though the remediation plan was developed without a formal optimization of costs and benefits, the unit cost of restoring the *Malargüe* site, $US 13.36/ton, compares favorably with restoration costs -- U$D 20-25/ton[81] -- of comparable sites in western U.S.

[78] The difference between this total cost figure and the U$D 12.7 million total cost cited in Sections 4.7 and 4.13 of the principal document is due to the exclusion of already completed work (i.e., peripheral drainage and dismantlement of installations) from the current total cost figure.
[79] Comparison of Decommissioning and Cleanup Costs of Uranium Producing Projects on an International Basis, German Science Ministry, Bonn 1995 (in German, with summaries in English, French, Spanish, and Russian).
[80] U.S. Uranium Production Facilities: Operating History and Remediation Cost Under UMTRA Project as of 2000, Summary Table, Uranium Ore processed, Disposal Cell Material, and Cost for Remediation as of December 31, 1999.
[81] U.S. Uranium Production Facilities, Op. Cit. The Unit cost of $13.36/ton does not include, however, costs of long-term monitoring, work management and post-closure management.

Preliminary estimate of the benefits associated with the project are based on scenarios that relate future land use at the site and the domestic social cost associated with exposure to radiation through ICRP models of risk projection[82]. These models are based, in turn, on experience gained in restoration of uranium mine tailings in East Germany. The actual calculations employ the estimated costs associated with the reduction in life expectancy as a result of exposure to radiation dose.

With access to the site prohibited and insignificant radiation levels registered in dwellings in proximity to the site, the primary concern is about future site access and land-use scenarios. A worst-case scenario assumes the establishment of permanent dwellings at the site by a group of 100 individuals. The annual costs of the reduction in their life expectancy as a result of excessive radiation dose and the associated economic-losses range between 0.2 million pesos and 1.6 million pesos, depending on the specific parameters employed for the calculation. By the same token, the contamination of the phreatic aquifer down gradient from the tailings involves only very limited economic damage that is associated with the current insignificant use of this water. However, one should be also concerned about the future potential loss of the aquifer and the ultimate impact on the ecosystems at its discharge area down gradient. Any effort to estimate the return on investment for the proposed level of restoration work is fraught with difficulty. However, preliminary estimates indicate that the scope of the proposed intervention is justified by merely preventing the projected life- and health-losses that would be incurred by the construction of dwellings at the site.

As a result of its unprecedented nature in the Argentinean context, and in response to a great deal of public concern about the site's radiation hazards, the regulatory authorities imposed strict remediation standards on the site. These stringent requirements entail a risk premium on the remediation that is induced more by public perceptions than by concrete radiation- or other potential risks. For example, *ARN* have approached the site remediation as if it was a new nuclear power plant (a practice, not an intervention)[83], imposing an annual dose ceiling of 0.1 mSv/year. This dose value provides a safety factor an order of magnitude above that recommended by the ICRP, 1 mSv/year.

POTENTIAL ENVIRONMENTAL IMPACTS ASSOCIATED WITH PROJECT IMPLEMENTATION

The major objectives of the project are to mitigate and control the environmental impacts associated with the residues of processing uranium minerals in *Malargüe*. Proper management and restoration of these residues requires their stabilization and physical isolation to prevent the contamination of air, water and soils and to preserve human health.

Subsurface drainage: The objective of this activity is to depress the level of the phreatic aquifer in the areas of future placement of the waste piles, to prevent degradation of the groundwater. (i) The main positive impact is by decreasing the potential contact between the bottom of the encapsulated waste and subsurface water. This impact would be immediate, continuous and long-term. (ii) The provision of the drained water for irrigation of extensive crops outside and down slope from the site. This impact would be immediate, moderate, and permanent. (iii) Decrease in flooding in the site's NE sector as a secondary result of the subsurface drainage. The direct

[82] U$D 10,000 per Sievert-person, based on AR 10.1.1, 53.
[83] See Footnote No. 31.

benefit is linked with the improved state of the vegetation to be planted in that sector. This impact would be notable, immediate and permanent. The discharge of the water drained from the southern drain does not result in significant changes in its chemical composition; however, it increases the flow between three- and five-fold. Flow fluctuations, and to a lesser degree, the ionic contents of the water, correspond closely to the seasonal fluctuations of groundwater recharge (i.e., maxima during the Austral fall and early winter).

Removal of vegetation and site revegetation: Project execution requires removal of some 3.5 ha out of a total of 16 ha of arboreal (poplar) vegetation in the areas designated for encapsulation, structures and access infrastructure. Considering that some of the removed trees are in poor shape, and that the groves had been a product of prior planting initiative, the selective deforestation would have no impact upon endangered floral or faunal species.

Extraction and hauling of acquired materials: The construction of encapsulation requires five types of natural materials: rocks, clay, riprap, sandy-silty soil and silty soil. The source quarries are located within a distance of 3 to 18 km away from *Malargüe*. In conformance with the pertinent national and Province laws[84], the competent authorities authorized each one of these quarries based on Environmental Impact Assessment reports.

- *Rock quarry*: is located in a foothill area some 12 km away from the site, 1-3 km away from residential areas and about 500m away from a canal supplying water for the town. Anticipated impacts and their mitigation measures include a 300 x 600 m large and a 3-m deep depression (at closure, talus slopes would be smoothened out and the open pit refilled); noise, vibrations, suspended dust and rock projectiles due to blasting (minimal effects on inhabited areas due to sufficient distance); dust settling into the water canal (material akin to otherwise wind-suspended dust, with impact to be minimized by distance); and a plan for monitoring suspended dust, noise level and water quality, to be implemented whenever called for by intensified quarrying activities.

- *Clay quarry*: located in an exposed, low mountainous area some 18 km west of the site. A solitary post for growing cattle is located about 150 m from its edge and there is a nearby spring from where water is diverted for human and animal consumption. Anticipated impacts and their mitigation measures include a 300 x 100 m depression (at closure, to be leveled off); noise, suspended dust and emissions by machinery and trucks (minimize dust by wetting and comply with regulations for noise reduction and air emissions from mobile sources); and the obstruction and contamination of the spring and close-by creek (to be averted by mounting permanent control and monitoring during work execution).

- *Riprap quarry*: an existing quarry utilized by the town about 3 km south of the site. Considering the nature of the exploitation activities, no negative impacts are expected. All environmental requirements applicable to an active quarry regarding noise and dust reduction and truck travel precautions in urban areas would be complied with.

- *Silty-sand quarry*: located on the flank of a small creek, 5 km west of the site. Exploiting a sediment sliver that parallels the bank of a ravine that frequently floods *Malargüe*'s downtown would impart a positive impact by enlarging the cross section of the ravine

[84] National Law 24.585, protection of the environment from mining activity, and Provincial Law 6.159, ecology and environmental protection.

and thus lowering flood crests. Precautions similar to those to be undertaken in the context of the clay and riprap quarries would be adopted here as well.

- *Silty-soil quarry*: would be located 5 km NE of the site. The 2-ha exploitation area is located close to the suburbs where there is ample evidence for similar past activities. No watercourses are located nearby, and no negative impacts are anticipated.

Some concerns common to all quarrying activities include the need for implementation of traffic control in suburban areas, minimizing impact on flora and fauna (the impacted biota contains no endangered species and occupies only a tiny fraction of its natural distribution area), licensing and control of explosives and hazardous materials, and the disposal of municipal- and sanitary waste. The various quarries are all located in sparsely populated areas, would be exploited concurrently for 1 to 2 years, and contracts are already in place with the present property owners of the rock, clay and silt quarries.

Impact of relocating the mineral waste piles: The primary impact of this task -- to be carried out through a 19 months period -- is the risk of causing both workers and the public to inhale suspended particles in the course of the removal and the nearby re-placement of the waste piles. To minimize this impact, workers in the controlled work area would be equipped with personal dosimeters for monitoring individual doses; to minimize dust, overgrown vegetation at the piles area would be removed no more than 15 days in advance of the actual relocation work; and the piles would be excavated utilizing a vertical face, to ensure the mixing of the upper dry sliver with the saturated material down below. All activities would be suspended once wind velocities exceed 20 km/h. The fact that the most frequent winds that blow towards town (to the SW) are of low intensity would help facilitate dust control by wetting.

Hazardous waste: The execution of the project would involve the extensive use of machinery and trucks, entailing the generation of hazardous waste such as used oil, filters and pneumatic fluids. Both national and Province laws regulate the management of these materials[85]. Their potential contaminative impact on soils and water would be minimized by adhering to these laws, as well as by constructing properly protected storage areas for temporarily storing the waste, contracting with a company that specializes in its transport and disposal, and briefing all site personnel on the proper management of these materials.

Social and economic impacts: overall, the Project would have positive social and economic impacts. It would provide employment (though temporary) to about 50 workers and to a fleet of trucks and heavy machinery. More permanently, it will boost municipal efforts -- through the Strategic Plan of *Malargüe* -- to promote economic development by increased appeal to environmentally sustainable tourism and by raising the monetary values of county crops and meat products, marketed as ‘organic’. Concerns for the safety and health of the public residing close to the site’s sphere of activities during the restoration work would be addressed through a plan for social communication.

SYSTEM CONTINGENCIES

Earthquakes, windstorms, floods and fires are the primary natural, unanticipated events that might compromise the integrity of the completed Project.

[85] National Law 24.051 and Provincial Law 5917.

- Earthquakes: a worst-case scenario would entail a return to the pre-Project conditions, i.e., waste is fully exposed to the environment. Depending on the magnitude of the damage, restoration would involve reconstruction of the encapsulated waste, with or without its prior neutralization.
- Windstorms, tornadoes and floods: considering the upper protective riprap capping, the probability of having the encapsulated tailings re-exposed is considered very low.
- Fire: considering that the uppermost cap was designed to withstand fire, the site's integrity is not expected to deteriorate.

ENVIRONMENTAL MONITORING

General

Pursuant to a policy of minimizing the levels of contamination -- both radiological and conventional -- and of preserving natural resources during the reclamation work, *PRAMU* has designed three stages of environmental monitoring, the data of which are to be shared with the potentially affected communities:

- Prior to the launching of each restoration sub-project, to establish a baseline to assess the effectiveness of the restoration work;
- During reclamation work, to ensure improvement in key environmental parameters; and
- Post closure, to ensure the stability of the tailings dam, compliance with the pertaining environmental standards, and placating the public that the restored area no longer presents a risk to the current or future generations.

Monitoring Programs

The monitoring programs to be implemented by *UGAMU*, would have the following objectives:

- Determine the degree of completion of reclamation work with respect to the requirements to control the formation and dispersion of particulate matter;
- Evaluate on a continuous basis the effects on the public and the environment;
- Maintain a dynamic database that would permit to assess the effectiveness of control and protection measures;
- Assess and control the individual dose levels for the workers;
- Assess the levels of occupational exposure in the controlled area;
- Evaluate the efficiency of the measurement equipment;
- Detect anomalies during the reclamation work, and
- Fix the anomalous situations.

Monitoring Criteria

The primary concern associated with the management of uranium waste piles is related to the potential dispersion of natural radioactive elements and conventional contaminants and their impact on workers, the public at large and the physical and biological environment. The following describes the baseline data collection, the monitoring measures that would be put in place during reclamation work to control potential emission levels and retain exposure to levels that are as low as reasonably possible (ALARA), and finally, data to be collected as part of the post-closure monitoring.

1. Baseline Data Collection

Monitoring air dispersion: Unless adequately wetted, the relocation of uranium waste piles would generate significant amounts of dust, as well as increase the emissions of radon. To establish a baseline for air quality around the site and the quarries from which components of the encapsulation barriers would be extracted, a baseline study of air particles was conducted. Similar measurements, conducted during the cleanup of the contaminated floor of Sector 1 and the construction of the access to the new encampment, yielded small variations of the various measured parameters[86].

Monitoring dispersion via soil: The integrated, cross-media study to precede the reclamation work would establish the baseline at the quarries' sites and in their sphere of influence; it would define the type of soil sampling for conventional and other elements (e.g., naturally-occurring uranium and Ra-226). Sample management procedures would be put in place to ensure the retention of the samples' chemical properties. This study would facilitate control during the different work stages.

2. Monitoring During Reclamation

Air monitoring: During the execution of the main tasks, continuous measurements would be performed at the site and its vicinity of suspended particulate matter, primarily the respirable fraction, as well as measurements to record hourly variations in the amount of radon 222 daughters that are associated with settled particulate material. Sampling of particulate material would be carried out in accordance with the following criteria:

- Continuous monitoring during the relocation of the mineral waste piles;
- Selecting at least two- or three measurement points above or adjacent to the site's limits, according to the prevailing wind directions;
- Selecting a measurement point above any residence judged as a significant recipient of particulate material; and
- Selecting a measurement point that is remote enough from the site to serve as a background reference point.

The measurements of radon and its daughters would be performed taking into consideration the following principles:

- Measurement points would be located around the source and along trajectories emanating from it, taking into consideration the wind directions;
- Detectors would be located so as to measure radon concentrations at the sources and above the site's perimeter;
- Both active detectors (for hourly records) and passive, integrated detectors (for average concentrations during measurement) would be concurrently employed;
- Radon emissions would be measured at the work's moving face; and
- Measurement of radon daughters would be accomplished with active detectors to determine the concentration of short-lived Alpha radiation.

[86] Tomellini y Ortega, *Informe final de material particulado en el aire en zonas de influencia del ex Complejo Fabril Malargüe*, Oct. 2003. Eight baseline measurements (11-12 March, 2003) yielded between 71 and 220 $\mu g/m^3$ of suspended particulates. Later measurements during site works, performed in 28-29 of April and 2-3 of June, 2003, resulted in either overall lower (the former) or higher (the latter) amounts of suspended air particulates, but almost without exception the measured concentrations were below background values taken within 1 to 4 km away from the site.

The assessment of air quality during reclamation would consider meteorological parameters such as wind direction and velocity, rain and snow regime, barometric pressure, temperature and relative humidity.

Hydrological monitoring: The monitoring of surface- and ground water would be accomplished to determine the quality of the water and control for possible impacts associated with the relocation of materials from the site as well as from the quarries. The most essential water resource to be monitored during restoration work is surface water, including irrigation canal waters around the site and water circulating at the watersheds adjacent to the quarries. Composite irrigation canal water samples would be collected for laboratory analysis of each flow event during the relocation of the mineral waste piles upstream and downstream from canals that border upon the site. Similar procedures would be applied to sampling of subsurface water. Subsurface water would be similarly sampled and compared to baseline data. Parameters to be analyzed in situ include e.g., pH, conductivity and temperature, whereas laboratory analyses would address dissolved oxygen, TDS, TSS, major ions, metals and natural radioactive elements (uranium and Ra-226).

Monitoring in the quarries: Various monitoring activities would be implemented in conjunction with the different natural materials to be extracted for mineral waste encapsulation from the five selected quarries that are located within 18 km from the site.

Monitoring of external exposure: Monitoring for radiation in the work areas would be applied so as to ensure ALARA exposure levels. Workers in controlled areas would be equipped with a personal dosimeter to ensure that they are not exposed to radiation doses above the permissible level.

Quality assurance: would be guaranteed through a variety of measures, including the assignment of monitoring tasks to appropriately qualified personnel, utilization of proper sampling instruments, correct definition of sampling points, and application of appropriate sampling procedures. To ensure the reliability and precision of the results, *UGAMU* would see to it that the methods deployed are adequate, that the precision of the results enables their comparison with values established by the applicable regulations, and that the measurement equipment is calibrated and well maintained.

Corrective measures: were the measurements to indicate deviations from the prevailing regulations, mitigation measures would be put in place; the effectiveness of such response would be subject to *UGA*'s role in their capacity as manager of the investigation of non-conformances.

Communication of results: the results of the measurements, as well as and pre-, syn-, and post reclamation work monitoring would be integrated with the public outreach program.

3. Post-Closure Monitoring

The proposed repository is a standard design utilized for uranium mill tailings in the U.S. and other countries in the last two decades. While considered state-of-the-art, the long-term performance of such repositories has not yet been established. This explains the need for the long-term monitoring plan as proposed under the Project.

During an estimated period of 20-years, the performance of the system and its components will be verified by monitoring fluctuations in the level of the phreatic aquifer, the hydrochemistry of ground water and surface water, and the emission levels of radon gas and Gamma radiation. To

address system-malfunctions, modifications would be introduced, as necessary. In the longer-term, a monitoring plan would be implemented that would address the physical conditions at the site as well as control the water and air at the site's sphere of influence (see Section 4.18 of original study).

The monitoring would be carried out by the *UEP* of *CNEA*, under a five-year budget of $950,000[87]. Simultaneously, the *ARN* as well as provincial authorities would be involved in the verification plan. All field and laboratory measurements would be executed under a Quality Assurance plan. Monitoring targets would include:

- Aquatic pathway: subsurface and surface water would be monitored by point measurements for uranium, radium 226 and conventional solvents by the existing network of piezometers (on a monthly basis), augmented by a network of piezometers proposed by *CRAS*[88](every four month).
- Air: Radon in air would be measured around the site of the relocated tailings twice-a-year during the first two years, employing continuous sampling for a week at a time, and based on the findings in that period – on an as-needed basis in the out years.
- Soils: Radon emissions and exposure to the gas would be measured at the site of the relocated tailings and in the surrounding areas. For exposure, point data would be collected twice a year for the first year, then – annually, and for gas emissions, a continuous, weeklong sampling would be performed four times a year during the first year, and semi-annually in the out years.
- Containment system: relative movements of the capping will be monitored with respect to fixed reference points, semi-annually in the first three years, then annually.
- Subsurface drainage system: Flow and water quality would be monitored, initially -- three-times a year, and once performance has been verified -- semi-annually.

THE *MALARGÜE* SITE PUBLIC CONSULTATION PROCESS

Process Origins and Evolvement

This project scored a valuable achievement by successfully eliciting participation of and communication with the community that stands to gain from the project. Much of the impetus for the public consultation process is attributable to a nationwide TV program broadcast in 1993. In its course, various NGOs brought to the fore the risks associated with nuclear materials, suggesting that *Malargüe*'s population are destined to experience serious health problems. This resulted in a significant drop in tourism and plunge in the sales of potato seeds, two of the region's economic pillars. While short-term, these economic repercussions nevertheless spurred both the local population and the various regional governmental authorities to try and correct the general perception of the area as being irreparably contaminated, by setting up and achievable and reliable remediation goals.

CNEA acquired experience in public consultation during the *Malargüe* site EIA development process (1992-1996) and its concurrence by the authorities of the *Mendoza* Province (1997). During the preparation of the restoration plans, numerous conferences, discussions and workshops with individuals and groups took place. Different options to deal with the tailings were discussed in a public hearing (December 1993).

[87] Post-closure monitoring costs of the remaining 15-year period have not yet been calculated.
[88] *Centro Regional de Aguas Subterraneas*

Following discussions with various organs of the Province of *Mendoza* and the municipality, a draft EIA report was developed. Following review by the competent Province authorities (the Faculty of Applied Sciences and Industry of the National University of *Cuyo*, the Department of Irrigation and *ARN*), this draft was presented to the public in hearing meetings, workshops and conferences. The resultant public involvement permitted attaining a degree of consensus that facilitated launching project implementation.

Details of the Consultation Process and Lessons Learned

Public hearings: As required for EIA approval under the legislation of the *Mendoza* Province[89], two public hearings were held: one, to discuss engineering concepts (July 1994), and the other – to present detailed planning of the engineering works and monitoring (December 1996). Participants included representatives of the Province of *Mendoza* Ministry of the Environment, Mines Directorate, County authorities, the legislative, the Department of Irrigation, *Malargüe*'s Chamber of Commerce, professionals from the National University of *Cuyo*, watershed inspector, medical professionals and teachers, high-school graduates, landlords and small business owners. The participants expressed the population's desire to see the mining residues relocated to *San Rafaël*. *CNEA* reviewed these requests in conjunction with other options prior to opting for managing the wastes in situ. A day workshop, convoked by a Province delegate on July 4, 1996 provided the community with a stage to express its concerns and invite information, helping make the process more transparent.

Consultations with representative individuals: The preliminary EIA draft report was distributed to 16 persons representing a variety of governmental organizations and NGOs, all involved in the project. Twelve responses were received, and in general, while comments were supportive of the environmental solutions outlined in the draft EIA, there were also dispositions critical of certain plans.

Community survey: In December 2001, a survey was launched that addressed 8,751 legal age adults in *Malargüe*. The key responses were as follows. The uranium waste piles were recognized as the most worrisome environmental issue (36.4%), with lack of sewage trailing behind with 29.1%. Some 58.2% expressed peace of mind with respect to the environmental situation, whereas 41.8% expressed concerns about the negative impacts of the uranium waste dumps on the population, crops and tourist industry. As to the degree of openness of the convocation for the public hearings, 27.3% were familiar with the process; 10.9% identified the means of publicizing the events (personal invitations, brochures, radio and TV announcements, with radio identified as the most effective medium); almost one third of the participants have not responded, and 3.6% responded that they were not informed. As to whether encapsulation is the best solution, 61.8% responded that it is, whereas the others preferred other solutions and 7.3% did not respond or did not know. Of the supporters, 58.8% live close to the site while 66.7% live farther away. Furthermore, 52.7% expressed confidence in the proposed encapsulation as an effectual environmental solution and in its success in addressing population health and economic recovery issues; 30.9% were concerned that the current environmental threats won't be adequately addressed in the long-term, and 9.1% expressed doubts about the quality of the work to be executed and in the durability of the resultant solution. Finally, 94.5% said that implementation should start 'immediately', and a large proportion of the responders, 89.1%, proposed that an NGO should assume the communication and information dissemination tasks.

[89] Law No. 5961 and a derived regulation

The public participation activities culminated in Resolution 378/97, *Declaration of Environmental Impact*, issued by the Ministry of Environment and Public Works. Pursuant to this announcement, *CNEA* was cleared to embark on the tasks of facility dismantlement and the preliminary drainage work.

With the participation of legislators and administrators of the *Mendoza* Province and *Malargüe* as well as representatives of the community, the *Malargüe* consultation process was positively reassessed four years after its completion in terms of its transparency and the validity of its results. Details of the consultation process, together with copies of the formal findings of the authorities of *Mendoza* Province are included in the "*Malargüe* Supplement" to the Draft EA[90]. On the basis of this first-of-its-kind-in-country experience, and given that the environmental requirements of *Mendoza* Province were considered a favorable model for the process, *CNEA* has embarked on a strategy of public consultation for the whole *PRAMU* Program, as well as for its prospective sub-projects.

As the work proceeds, it is essential to reestablish interaction with the community to ensure that the environment is not compromised in the course of project implementation and to reaffirm the accords that have been reached with all the stakeholders. It is also important to consider those public elements that oppose the consensus solutions, to develop synergy and to identify obstacles so as to buttress the adopted implementation strategy. An example of dissent is a recently-published book (June 2004) titled *Radioactive Residues at the Malargüe County*. The author, a licensed environmental professional by the name *Alejandro Moyano*, concludes based on analysis of the events related to the closure of the *CFM*, that while significant time has elapsed since the site's closure was authorized by the provincial authorities, *CNEA* still has very little to show for in terms of project implementation.

Contact with the social and political stakeholders should take place at two levels. The first involves interaction and feedback strategy with the involved players by performing a survey-based study that would certify the interaction among the players to ensure the sustainability of the adopted solutions. Such a survey would be launched once the preparation of TORs is completed for selecting an institution that would develop it. In addition, a day workshop would be convened to report on work's progress and achievements; this would propagate the contact among the players that are responsible for the implementation of the decisions. The other level of communication entails massive promotional campaign through the printed press, radio and TV, to broadcast the adopted decisions and accords so as to maintain a consensus by the different stakeholders.

[90] This Supplement is slated to be posted on the *PRAMU* website, along with the Draft EA.

Fig. 1 Location of Uranium Mining and Milling Tailing Sites, Argentina

Fig. 2: The *Cordóba* Site – Location of the Manufacturing Tailings (NE Area), the Abandoned Plant (Center) and the Active Uranium Dioxide Plant (West Area). Note Also the Location of Sampling Wells.

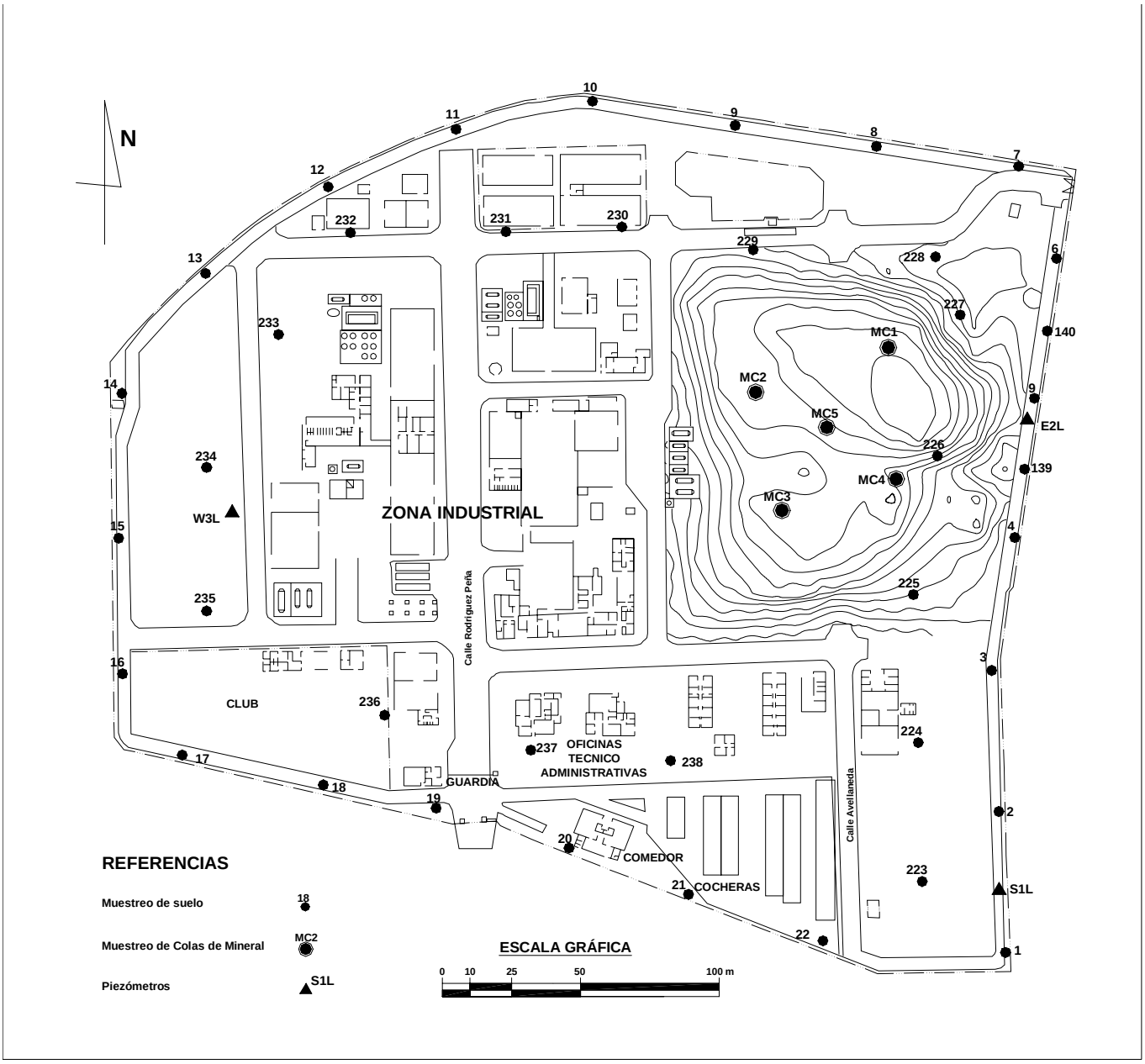

Fig. 3. The *Los Gigantes* Site: Installations, Drainage Pattern and Sources of Contamination

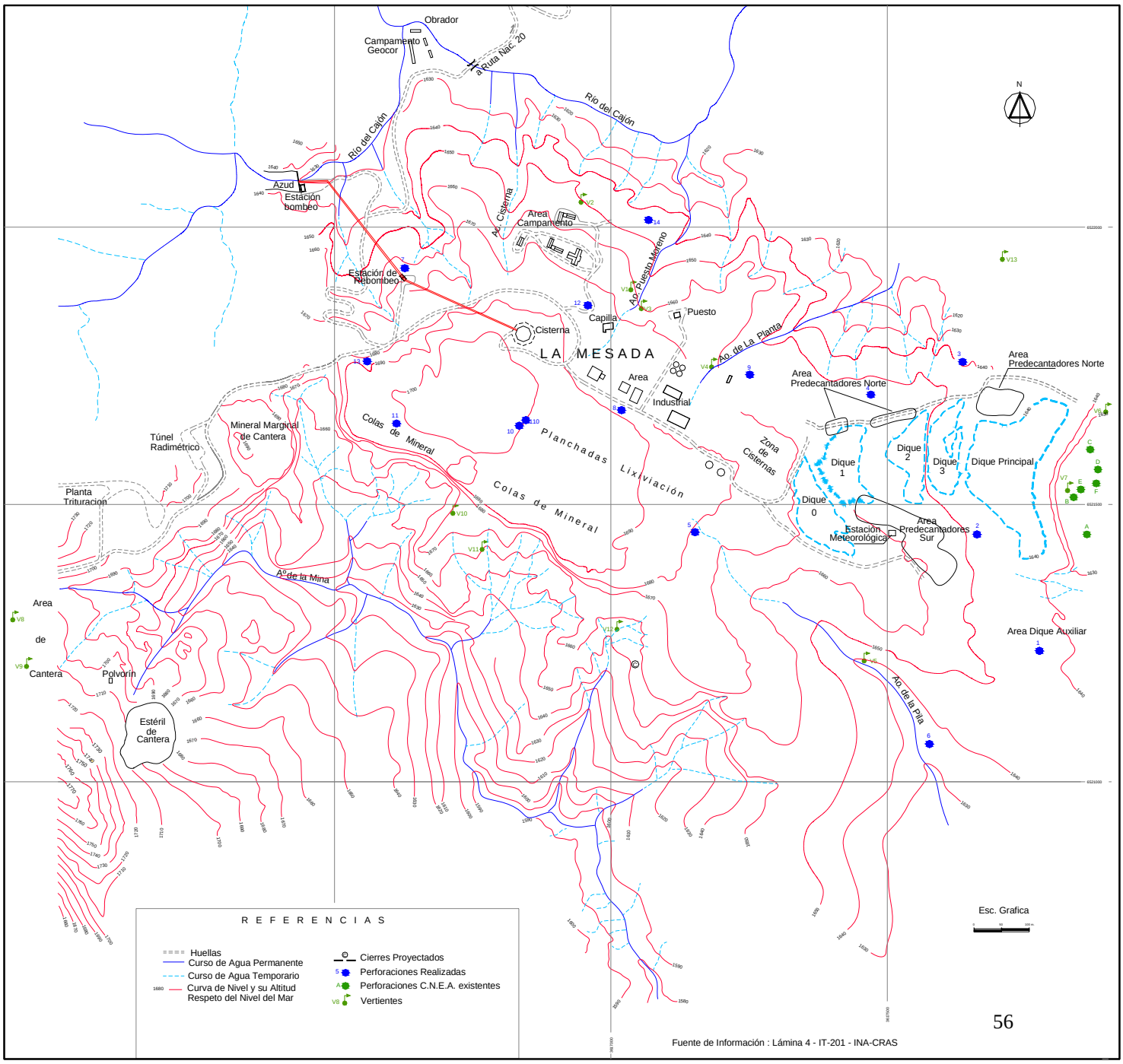

Fig. 4. The *Malargüe* Project Area and its Vicinity

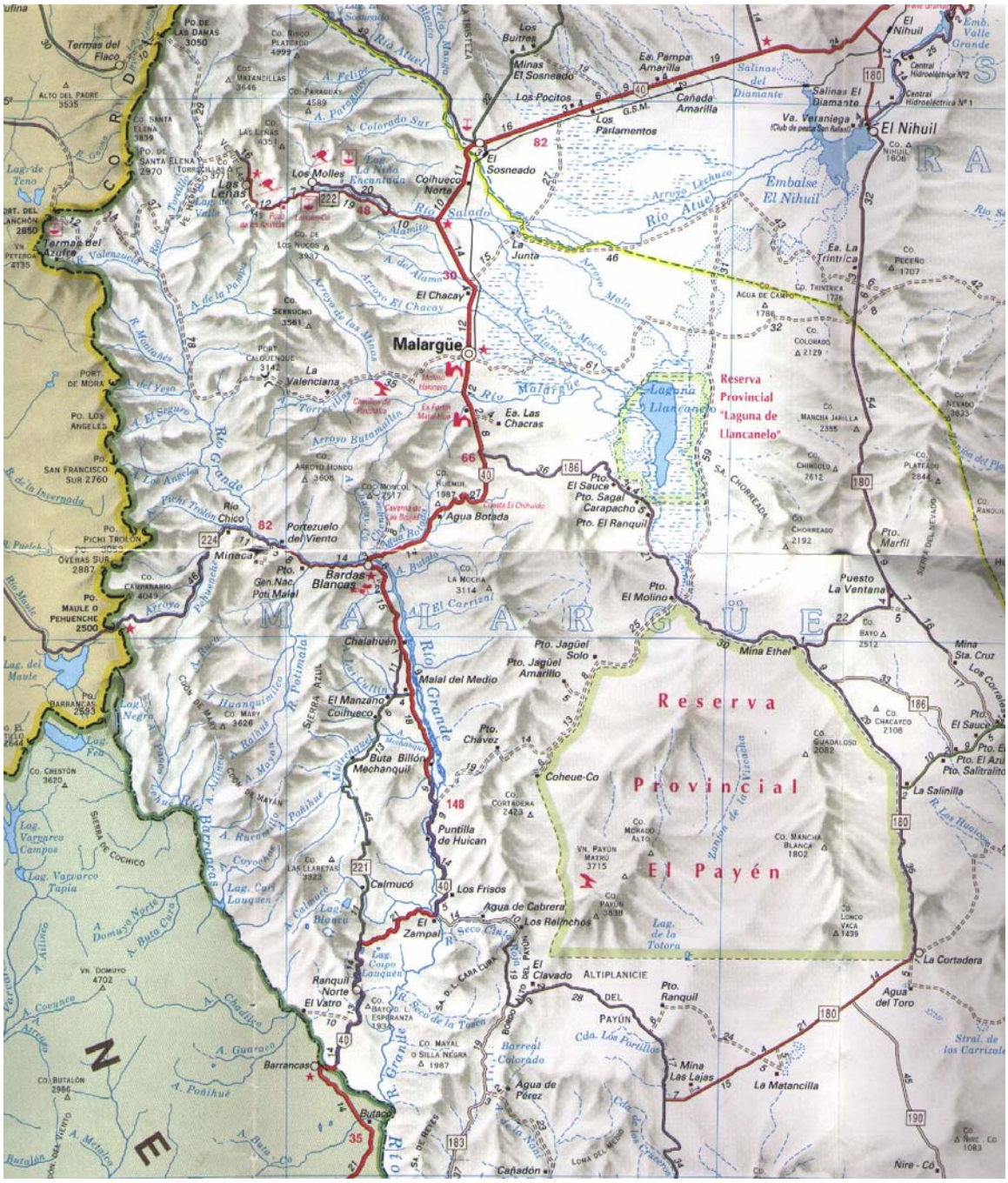

Fig. 5. The *Malargüe* Site: Sectors 1-4 are the Prospective Recipients of the Tailings from Sector 5.