Final Technical Report for Grant DE-FG01-96EW56093 Nevada Risk Assessment/Management Program (NRAMP)

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1. INTRODUCTION

The Nevada Risk Assessment/Management Program (NRAMP) was part of a national effort by the U.S. Department of Energy (DOE) to develop new sources of information and approaches to risk assessment, risk management, risk communication and public outreach as these objectives relate to the ecological and human health effects of radioactive and hazardous material management and site remediation activities. This final report presents a synopsis of the NRAMP effort that occurred from 1995 to 2000. Included in this report is a brief history of NRAMP including a description of the DOE Notice of Program Interest (NOPI) goals and how the NRAMP objectives tied in with the NOPI goals, a brief description of risk assessment activities related to the Nevada Test Site (NTS), and recommendations for future work.

1.1 Historical Background

DOE's effort to develop new sources of information and approaches to risk-related activities was initiated on November 3, 1993, when then DOE Assistant Secretary Thomas Grumbly requested the National Research Council (NRC) of the National Academy of Sciences (NAS) to:

- Determine if a risk-based approach to evaluating the consequences of alternative actions in DOE's environmental remediation program is feasible and desirable, and
- Consider whether an institution outside the DOE might perform the risk assessments associated with remediation in a more credible manner.

The NRC responded affirmatively to both questions. The NRC response resulted in DOE's development and publication on April 6, 1994, of a Notice of Program Interest in the *Federal Register* (59 FR 16194) seeking to award grants or cooperative agreements to organizations to develop credible processes and methods to support environmental management decision making. The specific assistance sought by the NOPI was to:

- Identify on a site-by-site basis, the risks to human health and the environment,
- Identify data gaps and uncertainties, and then methods for filling or reducing them,
- Recommend the process by which identified risk can be reduced,
- Recommend how public participants should be involved in risk evaluation and how such risks should be communicated to non-technical audiences, and
- Review and define the costs for risk reduction.

More than 25 proposals were received by DOE in response to the NOPI solicitation. The proposals received were handled in accordance with DOE's Merit Review Process described in the May 1991 *Federal Register*. Subsequently, four proposals were competitively awarded cooperative agreements, including a proposal by the Nevada Risk Assessment/Management Program, a joint effort of the Harry Reid Center for Environmental Studies at the University of Nevada, Las Vegas (UNLV) and the firm of E.J. Bentz & Associates, Inc. (EJB&A) of Alexandria, VA.

1.2 NRAMP Objectives

One of the primary NRC (NAS/NRC, 1994) recommendations was that the credibility of an evaluation of site-wide risks would be greatly enhanced if the evaluator were other than the DOE, and the NRC identified six criteria that an institution should satisfy in order to establish credibility:

- It should be perceived as being neutral;
- It should have management capability;
- It should have the ability to conduct scientifically valid and responsible risk assessments;
- Its assessments should be subject to independent, external review by technical experts;
- It should have the ability to plan, organize, manage, and facilitate public participation; and,
- It should have the ability to effectively communicate complicated scientific information on potential risks and uncertainties.

The objective of the NRAMP proposal was to conduct, in cooperation with the public, a risk assessment and risk management evaluation of DOE environmental management activities in Nevada. As noted in DOE's formal announcement of the award, NRAMP proposed to:

- Undertake a research program that will result in a greater understanding of ecological and human effects associated with remediation activities at underground test sites;
- Promote a better understanding of problems associated with radioactively contaminated terrestrial ecosystems; and,
- Develop a robust public outreach and communication program designed to elevate the public's awareness of the ecological and human health effects of radioactive and hazardous wastes.

In pursuing its objectives, NRAMP established both an active stakeholder interaction with the Nevada community and an independent scientific peer review program. Both of these programs have served to assure that NRAMP efforts were relevant, credible, and scientifically defensible.

Upon its completion, NRAMP has distributed 80 reports; produced 44 refereed published papers and articles; gave 42 invited presentations; and, conducted stakeholder working groups, focus groups and continuing education classes and seminars as part of its risk assessment/management program.

1.3 Description of DOE Sites and Activities in Nevada

The DOE Nevada Operations Office (DOE/NV) provides administrative oversight at 10 locations in five states that have been used for development and testing of nuclear devices. NRAMP considered only those sites physically located in Nevada as shown in Figure 1 which include:

1. Nevada Test Site,
2. Nellis Air Force Range (NAFR) Complex,
3. Central Nevada Test Area (CNTA), Project Faultless Site, and
4. Project Shoal Test Area.

1.3.1 Nevada Test Site

The largest DOE/NV location is the multi-functional Nevada Test Site. The NTS encompasses approximately 1350 square miles (3500 km^2) and is surrounded on the east, west, and north by the Nellis Air Force Range Complex that includes the Tonopah Test Range; these properties provide a 15- to 64-mile (24- to 100-km) buffer zone between the test areas and public lands. Radiological contamination exists from (1) 927 nuclear tests and supporting activities at the NTS that were conducted between 1951 and 1992; (2) on-site radioactive waste disposal; and (3) past and on-going subcritical experiments using special nuclear materials.

The NTS is currently a multi-program site. Major programs include DOE Defense Programs, DOE Environmental Management, the Office of Civilian Radioactive Waste Management, and other federal defense agencies. In addition to site remediation, the NTS is one of the primary low-level radioactive waste disposal sites for the DOE defense complex.

1.3.2 Nellis Air Force Range Complex

The Nellis Air Force Range Complex contains both the Nellis Air Force Range and the Tonopah Test Range. The over 4700-square mile (12,000 km5) NAFR buffers the NTS on the west, north, and east boundaries as shown in Figure 1. According to DOE, five safety-shot tests (in the years 1957 and 1963) were conducted on the NAFR Complex wherein nuclear devices were subjected to conventional explosives to determine whether the device could attain criticality under accident conditions (DOE, 1994; DOE/NV, 1995). The yields for the five tests are all reported as zero although plutonium was dispersed into the air and onto the ground in each test. One nuclear test, Small Boy, was conducted in the NAFR just outside the east boundary of the NTS.

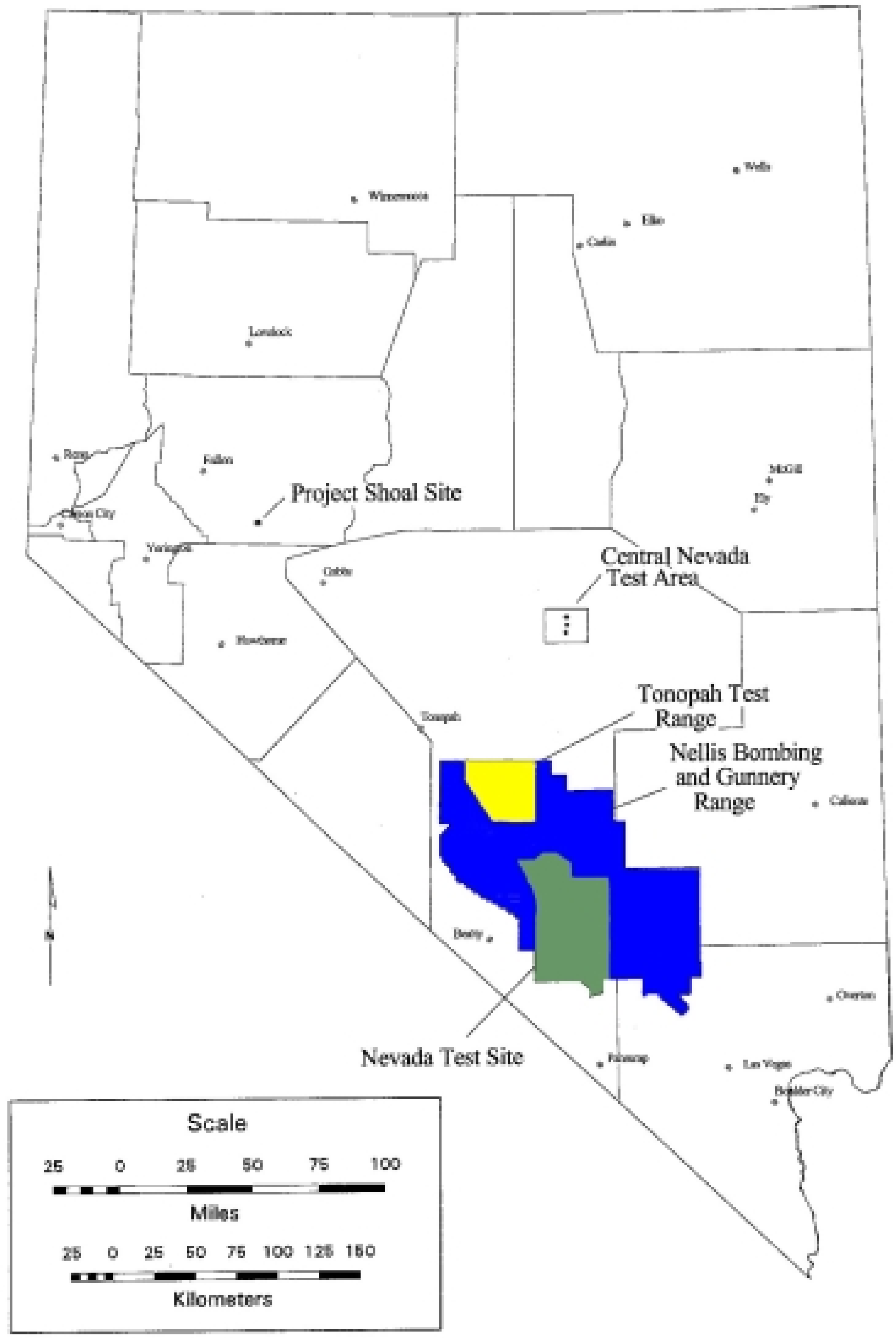

Figure 1. The DOE/NV environmental management sites in Nevada.

1.3.3 Central Nevada Test Area

The Central Nevada Test Area is in remote desert in the south-central Nevada area of Hot Creek Valley. The CNTA is bordered on the southeast by U.S. Highway 6, about 60 miles (100 km) northeast of Tonopah and 110 miles (180 km) southeast of Ely. The CNTA was the site of the Project Faultless underground nuclear event, a 200 to 1000 kiloton detonation 3200 feet (980 m) below land surface on January 19, 1968 (DOE, 1994).

1.3.4 Project Shoal Test Area

The Project Shoal Test Area in west-central Nevada was the site of a 12-kiloton underground nuclear test in 1963. The device was detonated 1200 feet (370 m) below ground surface in granitic rocks of the Sands Springs Range. The hazardous materials resulting from the detonation residue are the radioactive contamination in the aquifers in the area and the chemical contaminants on the surface of the site.

2. NEVADA TEST SITE RISK ASSESSMENT ACTIVITIES

2.1 Synopses of Risk Assessment Projects

2.1.1 On-site Risk Assessments

The U.S. Department of Energy is required by the National Environmental Policy Act (NEPA) to ensure that its actions have minimal effects on human health and the environment, and that risk assessments done to support this goal are open for public scrutiny. A number of such assessments have been performed and are most commonly titled Environmental Assessments or Environmental Impact Statements (EIS). The most recent and comprehensive EIS for DOE sites in Nevada was published in 1996.

Assessment of the impacts that the nuclear weapons program has had at the Nevada Test Site and surrounding land is one of the primary responsibilities of the DOE/NV Office of Environmental Management. A few of their current activities include:

- Evaluation of groundwater contamination and migration resulting from about 260 underground nuclear tests that have likely had a direct impact on groundwater quality below the Nevada Test Site by the DOE/NV Underground Test Area Project;
- Evaluation of the short- and long-term impact of waste disposal at operating radioactive waste management sites located within the Nevada Test Site; and,

- Evaluation and cleanup of surface contamination by the DOE/NV Soils Project and Industrial Sites Project.

2.1.2 Off-site Radiation Health Projects

The Off-site Radiation Safety Program (ORSP) was conducted by Los Alamos National Laboratory and the U.S. Army prior to 1954. From 1954 through 1970, the program was conducted by the U.S. Public Health Service (PHS). Since December 1970, the U.S. Environmental Protection Agency (EPA) has conducted the program under a variety of names. ORSP's three major objectives have been: (1) assuring the health and safety of the people living near the Nevada Test Site, (2) measuring and documenting levels and trends of environmental radiation in the vicinity of nuclear testing areas, and (3) verifying compliance with applicable radiation protection standards, guidelines, and regulations.

In addition to the above monitoring responsibilities, the PHS assembled a nation-wide network of state, county, and city public health officers to exchange radiation experiences and enhance dissemination of radioactive fallout information. The Medical Liaison Officers Network (MLON) was initiated in 1956 and terminated in 1985. Additionally, medical physicians who had experience with radiation were requested to voluntarily participate in the program. Annual meetings were held in Las Vegas where fallout data and reports were presented and discussed. Many of the locations represented by the physicians were provided high-volume air samplers, radiation monitoring instruments, and calibration sources to measure fallout and periodically report to the PHS in Las Vegas. Epidemiological studies were initiated on body burdens of radionuclides and certain disease clusters. The Off-site Human Surveillance Program was part of MLON activities in the late 1960s through the early 1980s. Off-site residents were solicited to volunteer to participate in a human body monitoring program. The volunteers agreed to allow the PHS/EPA in Las Vegas to perform (1) whole body counting for gamma emitters, (2) chest counting for plutonium, and (3) periodic physicals including blood samples. Annual reports were provided to DOE/NV.

U.S. Public Health Service thyroid studies were conducted by Edward Weiss, PHS Headquarters, Rockville, Maryland, from 1963-64. These studies are thought to be in response to citizen and Congressional demand following the 1960-61 Ray Lloyd, University of Utah, and the PHS nurses studies. They had found thyroid nodules and a number of cases of leukemia among the residents of southwestern Utah. Three epidemiological thyroid studies were all done on the same cohort.

The Off-site Radiation Exposure Review Project (ORERP) was conducted by DOE/NV from May 1979 through June 1987 to (1) collect, preserve, and disseminate historical data related to radioactive fallout and health effects from nuclear testing, and (2) reconstruct, insofar as possible, the exposures to the off-site public from nuclear testing at the Nevada Test Site and doses to individuals resulting from these exposures. This included a county-by-county exposure evaluation in all or part of seven western states. The dose assessment effort was divided into six task groups:

- Information Coordination: REECo Coordination and Information Center
- Fallout Verification: EPA's Environmental Monitoring Systems Laboratory and Weather Service Nuclear Support Office
- External Dose: Los Alamos National Laboratory
- Pathway Analysis: Colorado State University
- Internal Organ Dose: Lawrence Livermore National Laboratory
- Soil Concentration: Desert Research Institute

The National Cancer Institute sponsored two studies by the University of Utah of past public exposures to fallout resulting from the atmospheric testing of nuclear weapons at the Nevada Test Site. The studies looked at the incidence of leukemia and thyroid disease in Utah and included a mapping of radioiodine deposition and well-known epidemiological studies.

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3. NRAMP PRELIMINARY RISK ASSESSMENT

The NRAMP approach to risk assessment taken during the 1995-96 effort is summarized in Figure 2 and was designed to assist all involved parties (the NRAMP Stakeholder Working Group and technical team, the DOE Community Advisory Board for Nevada Test Site Programs (CAB), and the general public) to participate in the development of a Preliminary Risk Assessment for DOE sites in Nevada (PRA).

The process of risk assessment for the DOE sites in Nevada is complicated by many contaminant types, potential land uses, exposure pathways, and public interests. In addition, few definitive conclusions can be made about the risks because characterizations are not complete as a result of the size, complexity, and limited funds expended to date.

For the sake of consistency in dealing with the complex and varied technical issues of DOE sites in Nevada, the PRA focus was limited to Maximally Exposed Hypothetical Individual (MEHI) risk from specific land use scenarios and various contaminant source categories. Critical to this approach was the development and use of consistent assumptions and parameters. Therefore, the NRAMP technical team, with the input of the Stakeholder Working Group and the Scientific Peer Review Panel, determined five source categories and five land use scenarios that formed the basis for the NRAMP technical approach to a preliminary risk assessment (see Table 1). This approach is detailed in the PRA Work Plan (HRC, 1996b).

3.1 Place of PRA in Overall NRAMP Process

The NRAMP's primary mission was to increase and apply the scientific knowledge base as it relates to the human health and ecological risks associated with nuclear weapons testing and radioactive and hazardous waste management activities at the Nevada Test Site and other DOE sites in Nevada. The large scope of this work was accomplished through various stages. Preliminary risk assessments were completed regarding public health risks through two letter reports (Johnson et al., 1996a and 1996b) and the PRA Volumes I, II, and III (HRC, 1996a).

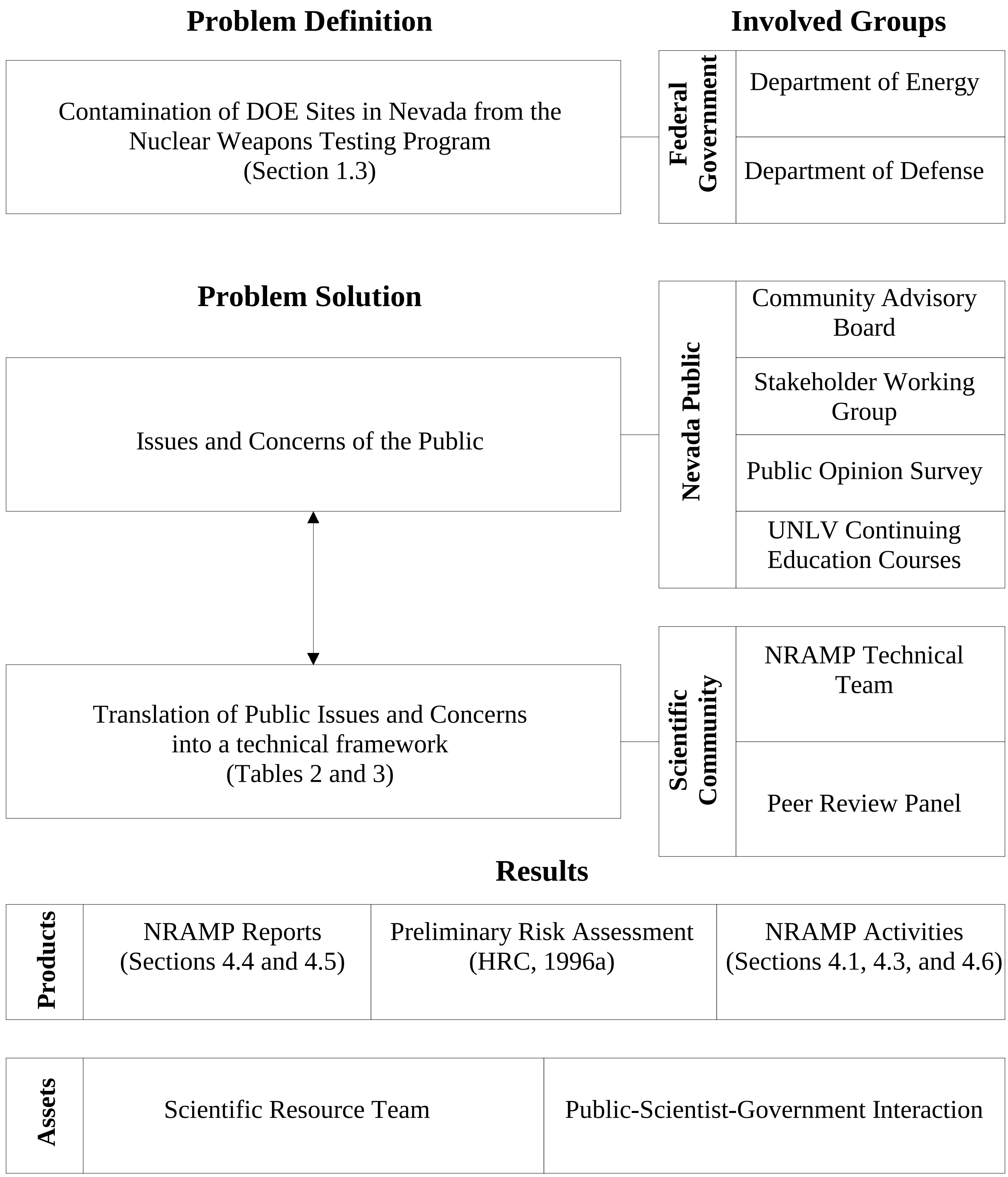

Figure 2. NRAMP approach to public and scientific collaboration in the Preliminary Risk Assessment process.

Table 1. Source categories and public land use scenarios used in the Preliminary Risk Assessment.

Source Categories	**Examples**
Industrial Sites	Chemical hazards at spill sites, waste sites, and landfills
Radioactive Waste Management Sites	Radioactive materials in disposal boreholes and trenches
Surface Soils	Plutonium deposited on soil from atmospheric testing
Transportation-Related Issues	Radioactive material in shipments to the NTS
Underground Test Areas	Residual radioactive material in test cavities
Public Land Use Scenarios	**Examples**
Cultural	Native American ceremonies
Recreational	Hiking
Industrial (Commercial)	Working at Solar Energy Generating Facility
Ranching	Ranches with cattle and home-grown crops
Residential	Isolated housing units

The Preliminary Risk Assessment had the primary objectives of conducting screening-level risk assessments for various source categories, identifying the data gaps for improving future risk assessment activities necessary to understanding the Nevada Test Site, facilitating further discussions with stakeholder groups on acceptable risk levels, and obtaining comments from the Scientific Peer Review Panel on the general approach to risk assessment at the NTS. The PRA forms the initial basis for additional evaluations of planned site remediation activities, the development of additional risk management concepts, and the identification of data and model needs to better understand and manage risks from DOE activities. Site remediation and associated costs were not considered in the PRA screening level effort.

The PRA provides preliminary qualitative and quantitative information about current and future public health risks from the NTS. This information was intended to be applied to the development of refined risk estimates, stakeholder communication on site restoration activities, and prioritization of environmental activities by the DOE. Quantification of risks in the PRA was limited to Maximally Exposed Hypothetical Individual risk scenarios developed in response to stakeholder safety and future land use concerns. Results of risk assessment for these land use scenarios are intended to provide insights on the location, timing, and severity of hazards at the NTS. This MEHI risk approach was initially appropriate at a screening level because of current land use that precludes public access to contaminated areas and the lack of comprehensive information on all contaminants that would be needed to support a more detailed risk assessment. Additional evaluations of the spatial distribution of risks were prepared for specific contaminants where information was available.

Public health risks were investigated in NRAMP through the evolution of two matrices shown in Tables 2 and 3 that were developed through interactions with the Stakeholder Working Group and the Scientific Peer Review Panel. These matrices were used as the basis for categorizing and evaluating risks in the development of the PRA. Contaminants were divided into five source categories given in Table 3 that segmented concerns by location (such as underground and aboveground) and activities (such as industrial, radioactive waste management, and transportation). The components of risk assessment (e.g., source characterization, transport mechanisms, exposure pathways and dose and risk calculations) were then independently studied using the best available knowledge. Consistency between these studies was ensured by defining reference land use scenarios as indicated in Table 3 and identical risk standards and terminology for stochastic and nonstochastic effects. This was accomplished, in part, through the use of the Maximally Exposed Hypothetical Individual approach. This assumes maximum exposure to a Reference Human (ICRP, 1975) at the assumed reference receptor location, through all pathways characteristic of the contaminant under consideration.

Hazardous chemical risks were based on EPA Methodologies and radiological risks on International Commission on Radiological Protection (ICRP) methodologies.

3.2 Data Acquisition and Model Development Process

Significant data sets were obtained for many of the source categories. The Industrial Sites source category used the Nevada Environmental Restoration Project inventory of existing and potential environmental restoration sites at the NTS (DOE/NV, 1994; and DOE, 1995). The Surface Soils source category used data obtained from the Radionuclide Inventory Distribution Program (RIDP). This program used data obtained from three sources: *in situ* spectrometry, aerial surveys, and soil samples. The Surface Soils and Underground Testing Areas both used a DOE document (DOE, 1994) that lists announced nuclear tests from July 1945 through September 1992. This information was supplemented by using computer files supplied by DOE/NV containing depth, longitude, and latitude coordinates for the underground tests, and hard copy files of longitudinal and latitudinal coordinates for atmospheric shots. Source term data at the two radioactive waste management sites (RWMSs) were taken from the Area 5 Performance Assessment (Shott et al., 1995) and the Waste Inventory Report for the Area 3 U3AX/BL Disposal Unit (Elletson and Johnejack, 1995).

Table 2. Matrix translating stakeholder risk issues into a technical framework.

Source Categories	Contaminants	Transport Media	Land Use	Receptors	Time Frame	Exposure Pathways
Industrial Sites	Chemicals	Surface Soil, Atmosphere, Unsaturated Zone	Controlled Access, Surface Access, Drilling Access	Public and Worker Health, Cultural Resources, Ecology	Now, 10, and 100 Years in the Future	Inhalation, Food Chain, Dermal Contact
Surface Soils	Actinides, Fission Products, Activation Products	Surface Soil, Atmosphere, Photon Radiation	Controlled Access, Surface Access	Public and Worker Health, Cultural Resources, Ecology	Now, 10, 100, 1000, and 10000 Years in the Future	Inhalation, Food Chain, Dermal Contact, Radiation Proximity
Underground Test Areas	Actinides, Fission Products, Activation Products	Saturated Zone, Unsaturated Zone	Controlled Access, Drilling Access, Access to Springs	Public and Worker Health, Cultural Resources, Ecology	Now, 10, 100, 1000, and 10000 Years in the Future	Drinking Water, Food Chain, Dermal Contact
Radioactive Waste Management Sites	Transuranic waste, Non-transuranic waste	Surface Soil, Atmosphere, Unsaturated Zone	Controlled Access, Surface Access, Drilling Access	Public and Worker Health, Cultural Resources, Ecology	Now, 10, 100, 1000, and 10000 Years in the Future	Inhalation, Food Chain, Dermal Contact
Transportation-Related Issues	Hazardous Materials and Waste	Atmosphere	Route/Mode Options	Public and Worker Health	Now and Through End of Operations	Radiation Proximity, Mechanical Damage

Table 3. Maximally Exposed Hypothetical Individual risk matrix considered in the Preliminary Risk Assessment.

SOURCE CATEGORIES	PUBLIC LAND-USE SCENARIOS			
	Occasional Use	Continual Use		
	Cultural and Recreational	Industrial (Commercial)	Ranching	Residential
Industrial Sites	Exposure from cultural and recreational activities on sites with chemical contamination.	Exposure to workers at sites with chemical contamination.	Exposure to chemical contamination at agricultural locations at site boundaries and within the sites.	Exposure to chemical contamination at site boundaries and within the sites.
Surface Soils	Exposure from cultural and recreational activities on sites now and after 100 years.[a]	Exposure of workers at sites after 100 years.[a]	Exposure at agricultural locations at site boundaries now and within the sites after 100 years.[a]	Exposure at site boundaries now and within the sites after 100 years.[a]
Underground Test Areas	*NA* [b]	Exposure of workers at sites after 100 years.	Exposure to well water drawn near locations suitable for agricultural activities after 100 years.[a]	Exposure to well water now and at time of peak concentration on site boundaries. Exposure to well water drawn from test cavities after 100 years.[a]
Radioactive Waste Management Sites	Exposure to Radioactive Waste Management Sites at the NTS boundary now and on the sites after 100 years.[a]	Exposure of workers at sites after 100 years.[a]	Exposure to Radioactive Waste Management Sites at the NTS boundary now and on the sites after 100 years.[a]	Exposure to Radioactive Waste Management Sites at the NTS boundary now and on the sites after 100 years.[a]
Transportation-Related Issues	*NA* [b]	*NA* [b]	*NA* [b]	Exposure from proximity to and accidents related to transportation activities.

[a] The date of site release for public access is assumed to be in 100 years.
[b] *Not Applicable*: because it is assumed that there is no significant linkage of contamination source category to land use via an exposure pathway.

A radiologic source term was required for several source categories, but unclassified information on the radiological contaminant composition at the Nevada Test Site was extremely sparse. The Los Alamos National Laboratory report: “Total Radio nuclide Inventory Associated with Underground Nuclear Tests Conducted at the Nevada Test Site, 1955-1992,” (LANL, 1994) is classified but some information from the report has been released. The data that have been released from this report are not detailed enough in terms of site specification to provide a source term for shot-by-shot radiological risk assessment. For the Preliminary Risk Assessment, the NRAMP technical team determined a comprehensive and locale-specific description of the radiological source term that included all scientifically conceivable radionuclides and applied appropriate screening techniques to develop an inventory of significant radionuclides.

Models were used for all the source categories. In many cases, commercially available codes were chosen. The majority of the NRAMP human exposure and dose response modeling used the Multimedia Environmental Pollutant Assessment System (MEPAS; Strenge and Chamberlain, 1995). MEPAS was designed to help screen and rank DOE sites that have potentially hazardous chemical and radioactive releases. It has been peer reviewed and has been extensively used by DOE, national laboratories, universities, state governments and private firms for a variety of environmental problems.

MEPAS uses a physics-based risk computation code that integrates source-term, transport, and exposure models. It computes risk values for chemical and radioactive carcinogens and hazard quotients for non-carcinogens. NRAMP chose to use MEPAS because of its flexibility and ability to generate results that are consistent for each source category considered in the PRA.

Groundwater transport and transportation risk were not modeled using the MEPAS code. Because of natural and anthropogenic heterogeneity in the subsurface environment and dose-response uncertainty, NRAMP risk evaluation was modeled by using a probabilistic framework. A semi-analytical model was used to estimate potential risks to public health at the boundary of the NTS. A time-travel transport approach was adopted. The specific computer code used by NRAMP (referred to as the Solute Flux Method) was provided by the Desert Research Institute, where the code was developed (Daniels et al., 1993; Andricevic et al., 1994; and, Andricevic and Cvetkovic, 1996). The code allowed inclusion of the relevant physics of groundwater contaminant transport and uncertainties in modeling parameters.

Transportation risk was modeled using RISKIND (Yuan et al., 1995). It was selected for use in NRAMP because it considers radiological risk from both normal and accident conditions, is easy to use, and has sufficient flexibility to consider the NRAMP exposure scenarios for low-level radioactive waste.

3.3 Summary of PRA Findings

The results of the Preliminary Risk Assessment (HRC, 1996a) are summarized in Tables 4 and 5 and briefly described below. The focus is on the Nevada Test Site since the NTS represents the most widespread potential risk for Nevada stakeholders. The results are for the public land use scenarios listed in Table 3 for each of the source types. No significant radiological risks to the public were identified at the present time as long as institutional control of the current combined DOE and Nellis Air Force Range complex exclusion area is maintained.

The definition of risk levels (*Negligible*, *Low*, *Medium*, and *High*) is given in Table 6. The subjective terminology is arbitrary because risk numbers do not carry subjective values such as *good*, *bad*, *allowable*, *not acceptable*, *significant*, *low*, *medium*, and *high*, although technical experts may feel these are appropriate. The risk evaluation terms in Table 6 were determined through a process in which stakeholder groups all participated through many written and verbal comments on the draft version of the PRA document. The table took several different forms, as it evolved, in response to suggestions made at invited forums and a weekly university-sponsored evening class. The final version shown in Table 6 appeared to be the most agreeable gradation of risk levels to the diversity of views expressed by stakeholders on the definition of risk.

The intent of presenting MEHI risk results using subjective terminology is to enhance effective communication and understanding of the PRA results. With this intent, many commentators stated that the sequence of negligible, low, medium, and high gave an intuitive gradation that could be understood by all parties involved. In addition, it was suggested by many that the risk values calculated in this study could be better understood if values were compared to risks from other human activities. This aspect of risk communication is more fully presented and discussed in HRC (1996a).

3.3.1 Industrial Sites

Little information was available on the location or composition of contaminants present at the industrial sites on the NTS. Based on analysis of the limited available information, there is currently negligible MEHI risk to the public at the NTS boundary from industrial site contamination. Subjective analysis of risks inside the NTS boundaries indicated there are two categories of industrial sites which present negligible risk (Radiation and Housekeeping), four categories which present low risk (Waste Disposal Sites, PCB’s and Lead, Land Fills, and Oil Related Sites), and one category that presents potentially high MEHI risk (Chemical Storage Sites).

Table 4. Maximally Exposed Hypothetical Individual risk results at the present time at the worst-case locations. Note: these results assume only DOE institutional control up to the Nevada Test Site perimeter.

SOURCE CATEGORIES	LAND USE SCENARIOS		
	Cultural and Recreational	**Industrial (Commercial)**	**Ranching and Residential**
Industrial Sites	**No Result**: Not enough data on contamination.	**No Result**: Not enough data on contamination.	**No Result**: Not enough data on contamination.
Radioactive Waste Management Sites (RWMSs)	**Negligible Risk**: Negligible exposure pathway to NTS border from RWMSs.	**Negligible Risk**: Negligible exposure pathway to NTS border from RWMSs.	**Negligible Risk**: Negligible exposure pathway to NTS border from RWMSs.
Surface Soils	**Low Risk**: from contamination on NTS border at the Schooner test and Frenchman Lake locations.	**Medium Risk**: from contamination on NTS border at the Schooner test and Frenchman Lake locations.	**Medium Risk**: from contamination on NTS border at the Schooner test and Frenchman Lake locations.
Transportation-Related Issues	***NA*** [a]	***NA*** [a]	**Low Risk**: from highest allowable exposure rate under routine operation; and from accident scenario using worst-case shipment contents.
Underground Test Areas	***NA*** [a]	***NA*** [a]	**High Risk**: from using untreated water from a hypothetical well which draws water from near a test cavity located on the NTS border in the Pahute Mesa.

[a] *Not Applicable*: these combinations were not considered applicable in the PRA because it was assumed that there is no significant linkage of the contamination source category to the land use via an exposure pathway.

Table 5. Maximally Exposed Hypothetical Individual risk results 100 years in the future at the worst-case locations. Note: these results assume that institutional control of DOE sites has ended and these sites are open and available for public use.

SOURCE CATEGORIES		LAND USE SCENARIOS		
		Cultural and Recreational	**Industrial (Commercial)**	**Ranching and Residential**
Industrial Sites		**No Result**: Not enough data on contamination.	**No Result**: Not enough data on contamination.	**No Result**: Not enough data on contamination.
Radioactive Waste Management Sites (RWMSs)	***Shallow land burial***	**Negligible Risk**: Risks from the worst-case scenario are below the low risk level.	**Negligible Risk**: Risks from the worst-case scenario are below the low risk level.	**Medium Risk**: from intruding upon (drilling into) Pit 6 in the Area 5 RWMS.
	Greater Confinement Disposal (GCD)	**Low Risk**: from occasional use of the land above an undisturbed GCD Test borehole.	**Low Risk**: from the industrial use of the land above an undisturbed GCD Test borehole.	**High Risk**: from intruding upon (drilling into) several of the GCD sites in the Area 5 RWMS.
Surface Soils		**Low Risk**: from occasional use of land containing surface contamination at several locations within the Nevada Test Site.	**Medium Risk**: from the industrial use of land containing surface contamination at several locations within the Nevada Test Site.	**Medium Risk**: from use of land containing surface contamination at several locations within the Nevada Test Site.
Transportation-Related Issues [a]		***NA*** [a]	***NA*** [a]	***NA*** [a]
Underground Test Areas		***NA*** [b]	**High Risk**: from using untreated water from hypothetical wells at many locations within the NTS and Nellis complex borders.	**High Risk**: from using untreated water from hypothetical wells that tapped into radioactively contaminated plumes.

[a] *Not Applicable*: Transportation-Related Issues were not considered applicable because it was assumed that there are no longer DOE activities occurring within Nevada in 100 years.
[b] *Not Applicable*: this combination was not considered applicable in the PRA because it was assumed that there is no significant linkage of the contamination source category to the land use via an exposure pathway.

Table 6: Definition of terms for the Maximally Exposed Hypothetical Individual risk evaluations used in the Preliminary Risk Assessment.

Term	Lifetime Risk[a] Range	Comment	Hazard Index	Comment
Negligible Risk	Less than 1 in 1,000,000	Negligible risk level by federal regulations	Less than 1	Below threshold for harm
Low Risk	Between 1 in 1,000,000 and 1 in 1000	Below ICRP[b] recommendation to public		
Medium Risk	Between 1 in 1000 and 1 in 10	Above ICRP recommendation to public		
High Risk	Greater than 1 in 10	Above ICRP tolerable level	Greater than 1	Above threshold for harm
No Result	No value	Only subjective assessment is possible	No value	Only subjective assessment is possible

[a] *Risk* is the incremental lifetime probability of the Maximally Exposed Hypothetical Individual contracting a fatal cancer from the exposure and assumes a linear, no-threshold dose response.
[b] International Commission on Radiological Protection (ICRP, 1991)

3.3.2 Surface Soils

At the present time, medium-level MEHI risk could result from radioactively contaminated surface soil sites at the NTS boundary. Risks from radioactive surface contaminants at the Nevada Test Site are medium-level (above recommended limits) on at least eight percent of the Nevada Test Site at the present time. This declines to about three percent in the next 100 years.

3.3.3 Underground Test Areas

Risks from contaminants at DOE sites in Nevada are high-level for the Maximally Exposed Hypothetical Individual in public land use scenarios requiring underground access, such as drilling a well near a nuclear test cavity. High-level MEHI risk could exist near the detonation cavities and near Pahute Mesa through the next 100 years if these areas are released for public land use. Radioactive contamination from an underground test at the border of the NTS has migrated off the NTS in groundwater into the Nellis Air Force Range. The possibility exists that underground contaminants may move beyond the Nellis complex to accessible private and public lands in the future.

3.3.4 Radioactive Waste Site Management

Negligible radiological risk to the public exists from the Radioactive Waste Management Sites at the publicly accessible border of the Nevada Test Site at the present time. Currently there is negligible risk to the off-site public from the two operational radioactive waste management sites on the NTS. Medium-level MEHI risk could exist in the future from shallow radioactive waste burial if the NTS were released to the public. High-level MEHI risk could exist at the Area 5 Greater Confinement Disposal facility if the area were released for public use.

3.3.5 Transportation Related Issues

Transportation-Related Issues associated with radioactive waste suitable for shallow land burial pose low radiological risks. In fact, risk assessment in this area is relatively mature and risk management decisions can immediately impact risks from this ongoing activity. Risks from Low-Level Radioactive Waste transportation and disposal are linked since the dominant existing and projected waste management activity is the disposal of waste imported from other DOE sites. Transportation risks may be dominated by the risk of mechanical harm, not radiation contamination. However, the full range of possible materials that could be shipped to and from the NTS is not currently known and was therefore not included in the Preliminary Risk Assessment.

3.3.6 Project Shoal Site and Central Nevada Test Area

Based on available data, there is negligible risk currently and in the future from surface contamination in these areas. There is negligible risk at the boundaries of Project Shoal from groundwater contamination at the present time. High-level MEHI risk could exist from groundwater contamination within the boundaries of Project Shoal if the site were released to the public in the future. There is high-level MEHI risk from groundwater contamination at the Central Nevada Test Area at the site boundary now and through the next 100 years.

3.4 Implications, Limitations, and Recommendations of PRA Findings

The results of the PRA (HRC, 1996a) have been characterized by the NRAMP Scientific Peer Review Panel and DOE reviewers as "not surprising" and have been presented to several stakeholder audiences. These results are preliminary and risk management conclusions should not be drawn until the quality of the data and the modeling used in this study have been refined. However, the PRA accomplishes two important objectives. First, the PRA identifies gaps in technical knowledge that will be useful to prioritize future risk assessment activities such as gathering additional needed data. Secondly, the procedure has been a valuable experiment in stakeholder involvement in scientific risk assessment. The following sections will discuss some implications from the PRA results and activities and provide some suggestions for future work.

3.4.1 Data Quality and Availability

The worst example of available information for the PRA was the data available for Industrial Sites. Of the 968 chemical Industrial Sites considered in the PRA, 740 sites did not have information about their location. In addition, most sites also lacked information on their chemical constituents. Therefore, the PRA could not evaluate the risk from most of the Industrial Sites. In order to perform a meaningful risk assessment of Industrial Sites, data would be needed on identification of location, identification of waste category, contaminant inventory, and contaminant levels. A prioritization model for identifying, characterizing, cleaning, and closing Industrial Sites would be helpful for risk assessment if it included the following considerations: future land use, public and worker risk, available resources, mortgage reduction, and mission impact.

The other Source Categories also have data deficiencies associated with estimating the amount and distribution of the contamination. In particular, the Surface Soil evaluations relied on the Radionuclide Inventory Distribution Program (RIDP) data even though more recent data exists from the 1994 aerial survey performed by a DOE contractor. This information would help validate the RIDP estimates and provide a better understanding of the spatial distribution of the contamination if it had been made available to NRAMP.

The Underground Test Area evaluations relied on modeling of a radiologic source term derived from publicly available literature. The NRAMP model attempts to estimate a source term that has already been estimated by the DOE. However, the DOE has not released its source term as a matter of national security. The NRAMP technical team feels that the release of certain values, such as the inventory of significant radioisotopes of hydrogen, cesium, and strontium for major testing areas of the NTS, CNTA, and Project Shoal Site, would be an important data refinement that may not jeopardize national security.

Risk evaluation at the Radioactive Waste Management Sites (RWMSs) relied on DOE Performance Assessments. However, these Performance Assessments were not required to include waste buried before 1988 and much of this waste is uncertain because of poor record keeping. The DOE is in the process of completing composite analyses that will include radioactive waste buried before 1988. When this information is available, more complete analyses can be performed for the RWMSs.

Finally, the risk evaluations for Transportation-Related Issues rely on projected shipments to Nevada. Therefore, the risks will depend on the political and regulatory climate at the time of a shipment. The PRA has only assumed that solid low-level radioactive waste suitable for shallow land burial from DOE facilities will be transported to the NTS in amounts projected from current reports.

3.4.2 Limitations and Improvements

Several topics not covered in the PRA were identified by stakeholder groups as important concerns and include the following:

- Uncertainty analysis,
- Ecological risk assessment,
- Mining industry land use scenarios (e.g., intrusion upon waste),
- Cultural resources,
- Archaeological site risk assessments,
- Subsurface contamination not affecting the groundwater,
- Chemical toxicity in all categories, and
- Longer time frames.

The NRAMP technical team noted that risk assessment models (such as the Linear No-Threshold dose response assumption) and risk assessment parameters need refinement in order to increase confidence in risk assessment results. The PRA relied mostly on the Multimedia Environmental Pollutant Assessment System (MEPAS) code that was not developed specifically for NRAMP or Nevada terrain and lifestyles. Therefore, refinement to modeling may include modification of the MEPAS code or cross-utilization with other codes to provide a more appropriate simulation for Nevada. Many default model parameters were used in the PRA because Nevada-specific information is sparse and difficult to find. Refinements also should include incorporation of detailed land use scenario parameters such as indoor/outdoor frequency and age-dependent factors that were not considered in the PRA.

PRA calculations indicate that risks from plutonium inhalation may not be the only significant contribution to MEHI risks from surface contamination. Research programs to supply the missing parameters for both mechanical (such as the resuspension factor) parameters and the radiological (such as slope factors and dose conversion factors) parameters could refine MEHI risk estimates for all the important human-made radioisotopes in the surface soil of the NTS.

Several ways exist to improve risk assessment at the Underground Test Areas, specifically, more site-specific investigation of the hydraulic properties, physical site characteristics, and source term data. Another improvement would be to conduct more complex modeling by inclusion of relevant physical processes affecting the transport, exposure, and dose at the site and by calibrating the existing models. The high-level risk predicted from the Pahute Mesa underground nuclear tests may be unreasonably high because of poorly characterized hydrogeology combined with prudent and conservative assumptions. More characterizations made in the area between Pahute Mesa and the Oasis Valley area would reduce uncertainty.

The groundwater flow directions are not well known. The difficulties of modeling the regional-scale flow include uncertainties in the hydrogeology and the flow parameters. Much of the flow at the NTS appears to be dominated by fracture flow. Characterization and monitoring are both highly complex in regions of fractured flow.

In addition to model and parameter refinements, a rigorous uncertainty analysis and probabilistic risk assessment are required to quantify confidence levels in risk values and consider scenario realism.

The next step after the completion of a refined Preliminary Risk Assessment would be a Baseline Risk Assessment. A Baseline Risk Assessment would be critical to the evaluation of the reduction of risk resulting from planned site remediation activities. After a Baseline Risk Assessment, Risk Management alternatives can proceed.

In addition to these scientific activities, further involvement between the scientific community and stakeholders is important to strive to enhance risk communication between the various involved groups. This can be accomplished through established means such as the university-offered courses, interest group interactions, and involvement with the CAB, or through innovative means such as multimedia or special workshops.

3.4.3 Recommendations Based on PRA Findings

Several actions are suggested by the above data gaps and related implications. They are the following:

- It is imperative that the DOE provide status of characterization and clean up of industrial sites so that risk assessments and risk communication can be performed.

- A prioritization model for identifying, characterizing, cleaning, and closing industrial sites should be completed with stakeholder participation.

- The DOE and its contractors should provide greater access to site data by making declassification of appropriate information (such as non-sensitive components of the radiologic and/or hydrologic source terms) about the site contaminants a higher priority.

- Take precautions to guard against potential future use of high-level risk areas (Underground Test Areas and Greater Confinement Disposal units) through commitment to long-term institutional control.

- Continue to prevent the drilling of wells for drinking water and irrigation around nuclear testing sites in Nevada and expand the restricted area beyond the existing Project Shoal Site and Central Nevada Test Area boundaries.

- Take a long-term multi-program approach to risk assessment of DOE sites that includes involvement by the Office of Civilian Radioactive Waste Management, Defense Programs, and the Nellis Air Force Range staff, as well as the public stakeholders.

- Continue to develop and define land use scenarios that are appropriate to the DOE sites of concern as new information becomes available.

- Allow public opinion to be expressed and recorded, and, if possible, strive for consensus.

4. NRAMP ACTIVITIES

4.1 Stakeholder Interactions

The Nevada Risk Assessment/Management Program has emphasized stakeholder involvement in the risk assessment process for the Nevada Test Site since the program's inception in 1995. The facilitation of public meetings, surveys, continuing education classes, document reviews, and focus groups have been beneficial to all involved. The stakeholder has had the opportunity to gather information and with that information, prioritize their concerns about the environmental conditions and planned activities at the NTS. The NRAMP technical team has based their research efforts on the dialogue with stakeholders to ensure a risk assessment is completed that meets the needs of all concerned.

4.1.1 Stakeholder Working Group and Nevada Survey

The Nevada Risk Assessment/Management Program concept of public involvement was to provide a broad spectrum of people with the opportunity to explore and impact controversial environmental issues. During the 1995-96 NRAMP effort, team members worked with stakeholders to develop credible independent risk assessments, helped stakeholders to evaluate and prioritize future land uses at the NTS, and learned from stakeholders how to communicate risk assessment results in the most effective manner. A Stakeholder Working Group was established to facilitate this communication effort during the design and implementation of the Preliminary Risk Assessment. The list of meetings and topics is given in Table 7.

Because the time constraints of the 1995-96 effort restricted the identification and appointment of a demographically representative stakeholder group, the NRAMP also conducted a stratified random sample of Nevadans' opinions about the NTS in a statewide telephone survey, which was developed through an iterative process with the northern and southern groups, the CAB, and experienced survey researchers. The survey of approximately 400 urban/southern, 400 urban/northern, and 400 rural county stakeholders (1209 total surveys completed) was administered by the Southwestern Social Science Research Center at UNLV under the direction of NRAMP team member Dennis

Soden, and its results were used to validate the representativeness of the Working Groups (Conary and Soden, 1996). In general, the survey showed Nevadans perceived the highest risks from transportation of high-level waste, storage of radioactive waste, and transportation of low-level hazardous waste. Results also indicated the majority of the general public was supportive of continued federal uses of the NTS for new missions but not supportive of weapons testing and waste disposal activities.

4.1.2 UNLV Continuing Education Courses

Stakeholder involvement also developed on a parallel path through a series of UNLV Continuing Education courses and seminars. The courses were held once a week during the fall term 1995 and spring term 1996. Enrollment was low at six and three students, respectively, possibly because of cost and academic rigor. In the fall term 1996 and spring term 1997, a free seminar series entitled "The Legacy of Nuclear Weapons Testing in Nevada" was offered through the UNLV Continuing Education program that resulted in higher attendance. The schedule and information on the seminar series is given in Table 8.

4.1.3 Post-PRA Activities

Following the completion the Preliminary Risk Assessment, NRAMP conducted three focus groups at the university on Groundwater Contamination, Radioactive Waste Management, and Probabilistic Risk Assessment to focus attention on major areas of concern. The Groundwater Focus Group was formed in March 1997, the Radioactive Waste Management Focus Group was formed in October 1997, and the Probabilistic Risk Assessment Focus Group was formed in October 1998. Schedule overlap between focus groups was minimal (or held consecutively) which allowed an individual's participation in all three groups. Also, some duplicate meetings were held usually within the same week to accommodate more participant schedules. Table 9 lists information for the focus groups.

The development of the PRA gave the university experts experience and knowledge of DOE programs that equipped the staff to remain an important third-party reviewer of DOE/NV Environmental Management programs. For example, the university was placed as a core member organization on a radioactive waste management Technical Working Group to conduct detailed reviews of draft DOE documents and also provided continuous technical services to the Town of Pahrump Nuclear Waste Advisory Board. Section 4.4 provides a listing of reports delivered to DOE/NV usually following a DOE/NV program manager's or technical task leader's request. Section 4.6 provides a listing of presentations delivered at the request of various stakeholder organizations.

Table 7. Stakeholder Working Group Meeting Schedule.

Meeting Date	Location	Topic	Attendance
May 25, 1995	Las Vegas	Organizational Meeting	45
June 1, 1995	Reno	Organizational Meeting	10
June 28, 1995	Las Vegas	Nevada Survey	27
June 29, 1995	Reno	Nevada Survey	10
August 23, 1995	Las Vegas/Reno Teleconference	NRAMP Program	31
November 29, 1995	Las Vegas	Working Group Rules and Work Plan	24
December 7, 1995	Reno	Working Group Rules and Work Plan	9
January 24, 1996	Las Vegas/Reno Teleconference	Work Plan and Radiological Risk	25
February 22, 1996	Las Vegas/Reno Teleconference	NTS EIS and Chemical Risk	25
March 27, 1996	Las Vegas/Reno Teleconference	Data Review	24
April 24, 1996	Las Vegas/Reno Teleconference	PRA Interim Results	26
May 29, 1996	Las Vegas/Reno Teleconference	DOE relationship and Groundwater Issues	46
June 26, 1996	Las Vegas/Reno Teleconference	PRA Work Plan	29
July 31, 1996	Las Vegas/Reno Teleconference	Technical Issues	22
August 28, 1996	Las Vegas	PRA Findings	27
September 25, 1996	Las Vegas	PRA Comments	30
October 22, 1996	Las Vegas	Peer Review Panel	40
December 18, 1996	Las Vegas	PRA (Final Working Group Meeting)	32
December 19, 1996	Reno	PRA (Final Working Group Meeting)	6

Table 8. NRAMP-sponsored UNLV Continuing Education Seminar Series Schedule.

Seminar Date	Topic	Attendance
Fall Term 1996		
September 3, 1996	Introduction and Logistics	22
September 10, 1996	History of the Nevada Test Site	33
September 17, 1996	Atomic and Nuclear Physics	25
September 24, 1996	Radiation Biology	19
October 1, 1996	Radiation Standards and Regulations	15
October 8, 1996	Chemical Contamination and Toxicity	10
October 15, 1996	Surface Soil Risk Assessment	18
October 22, 1996	Scientific Peer Review Panel	18
October 29, 1996	Underground Testing Risk Assessment	14
November 5, 1996	Low-Level Radioactive Waste Sites	11
November 12, 1996	High-Level Radioactive Waste Disposal	14
November 19, 1996	Transportation-Related Risk Assessment	11
November 26, 1996	Ecological and Cultural Risks	13
December 3, 1996	Integrated Risk Assessment	13
Spring Term 1997		
January 28, 1997	Introduction and Logistics	9
February 13, 1997	Radioactivity	15
February 20, 1997	Radio-Biological Effects	12
February 27, 1997	Groundwater Contamination	25
March 10, 1997	Pahrump Special Seminar	20
March 13, 1997	Radioactive Waste Management	14
March 20, 1997	Surface Contamination	9
April 3, 1997	Ecological Effects	16
April 10, 1997	Risk Communication	9
April 24, 1997	Land Use at the NTS	10

Table 9. Stakeholder Focus Group Schedules.

Date	Topic	Attendance
Groundwater Focus Group (36 members)		
March 22,1997	Group Formation	16
March 27,1997	Group Formation	16
April 26, 1997	What is Groundwater?	15
May 10, 1997	Groundwater Risk Research and Feasibility Study	16
May 31, 1997	NRAMP research	16
June 14, 1997	NTS Tour: Focus on Groundwater Contamination	18
June 28, 1997	General Radiation Effects	16
July 19, 1997	Review of DOE Groundwater Workshop	13
August 23, 1997	Focus Group Questionnaire	14
September 13, 1997	Groundwater Fingerprinting Project	15
October 18, 1997	FAACO: Clint Case	24
November 22, 1997	Groundwater Primer; Water as a Resource	15
December 13, 1997	Primer Review	14
January 21, 1998	Update (Reno)	9
January 31, 1998	Update (Las Vegas)	17
March 28, 1998	"Where do we go from here?"	12
April 28, 1998	GW Resources, Soils Study, and Fingerprinting Update	12
Radioactive Waste Management Focus Group (48 members)		
October 16, 1997	Group Formation	18
October 18, 1997	Group Formation	18
October 21, 1997	Radioactive Waste Definitions	14
November 22, 1997	Radioactive Waste Definitions	19
December 13, 1997	Radiation Biology	15
January 31, 1998	Transportation Issues Part I	23
February 28, 1998	Transportation Issues Part II	21
March 28, 1998	Current Waste Treatments	15
April 25, 1998	Innovative Technologies	22
May 30, 1998	NTS Tour: Concentration on Radioactive Waste Sites	26
Probabilistic Risk Assessment Focus Group (20 members)		
October 8, 1998	Definition of Risk Assessment	9
October 10, 1998	Definition of Risk Assessment	7
October 22, 1998	Components of Risk Assessment	6
October 24, 1998	Components of Risk Assessment	10
October 27, 1998	Reno Workshop	8
November 7, 1998	Probabilistic Risk Assessment	12
December 8, 1998	Reno Workshop Wrap-up	7
December 12, 1998	Focus Group Wrap-up	9

4.2 NRAMP Scientific Peer Review

As mentioned above, the National Research Council recommended that the credibility of an evaluation of site-wide risks would be greatly enhanced if the evaluator were other than DOE and should be subject to independent, external review by technical experts. Thus, independent peer review was an essential part of the NRAMP process to ensure that all risk assessments are reliable, credible, and clear.

4.2.1 Establishment of the NRAMP Scientific Peer Review Panel

An NRAMP Peer Review Panel Charter and operating procedures were developed by the NRAMP peer review team that were deemed appropriate for the reviews to be undertaken and to be consistent, to the extent practicable, with DOE historic practices. The mission/objective of the Panel as set forth in the Charter (EJB&A, 1995) is "to provide independent, external peer review of NRAMP activities ... in order to provide quality assurance for the risk assessment Work Plan developed in scoping, and in order to insure that the risk assessments are reliable, credible, and clear."

The Charter requires membership of the Peer Review Panel to be fairly balanced in terms of areas of knowledge, technical expertise, and skills relevant to the technical review functions to be performed. Membership of the Panel was therefore required to reflect an appropriate mix and level of knowledge, technical expertise, and skills consistent with the following topical areas that were developed by the peer review team on behalf of the NRAMP:

- Human Health Risk Assessment;
- Ecological Risk Assessment;
- Modeling Environmental and Health Risk Systems;
- Environmental Technology Assessment;
- Risk Management and Economics;
- Risk Communication and Community Consensus Building;
- RCRA and CERCLA Regulatory Compliance;
- Knowledge of the Nevada Test Site; and
- Knowledge of DOE Weapons Complex Sites

The Charter further provides that to more readily maintain a focused approach and to allow for optimum scheduling flexibility, the Panel is to be composed of a small group of six to eight highly qualified, dedicated members.

Potential candidates were developed, solicited, and screened for potential conflicts of interest.

Interested candidates were requested to submit, for the record, a letter of interest providing information regarding the individual's technical qualifications and evidence of independence from the work to be reviewed. Proposed members of the Panel were selected from the identified, qualified pool of candidates submitting letters of interest, with input provided by the NRAMP Stakeholder Working Group through the NRAMP public participation team. Based on the Charter provisions regarding size, composition, and qualifications, the following Panel was selected:

Mr. John S. Applegate, a *magna cum laude* graduate of the Harvard Law School and the current James B. Helmer, Jr. Professor of Law at the University of Cincinnati College of Law, where he teaches environmental law. Mr. Applegate serves as both Chair of the Fernald Citizens Task Force (a DOE Site-Specific Citizen's Advisory Board), and as a member of the DOE's (National) Environmental Management Advisory Board.

Dr. Clinton M. Case, a physicist with the State of Nevada, Division of Environmental Protection (since 1991). Dr. Case holds both an M.S. and a Ph.D. in Physics from the University of Nevada, Reno. Prior to joining the Division of Environmental Protection, Dr. Case served for 11 years as a Research Professor at the Desert Research Institute, University of Nevada, Reno.

Dr. Shih-Yew ("S.Y.") Chen, who serves as Group Leader, Risk Assessment and Safety Evaluation, Environmental Assessment Division, Argonne National Laboratory. Dr. Chen holds an M.S. and a Ph.D. in Nuclear Engineering from the University of Illinois, and is a Certified Health Physicist. His work has focused on radiological human health risk, chemical health risk, transportation risk, and ecological risk, has involved a number of major DOE programs, and has included site restoration and remediation, waste management, environmental risk assessment, and development of state-of-the-art environmental pathway and risk models (e.g., *RESRAD*, *RISKIND*, *RESRAD-ECORISK*).

Dr. Theodore S. Glickman, who serves as Managing Director, Operations Research and Risk Analysis, KPMG Peat Marwick/Resource Planning Consultants (Washington, DC). Dr. Glickman holds a B.S. in Physics (Honors) from the State University of New York, and a Ph.D. in Operations Research and Industrial Engineering (Phi Beta Kappa) from the Johns Hopkins University. Dr. Glickman served as Senior Fellow at the Center for Risk Management, Resources for the Future, Washington, D.C., for seven years.

Mr. Bruce A. Napier, who serves as Staff Scientist, Health Risk Assessment Group, Battelle, Pacific Northwest Laboratories. Mr. Napier holds both a B.S. and an M.S. in Nuclear Engineering from Kansas State University. He designs and directs the maintenance and operation of computer programs to simulate transport and effects of environmental contaminants. Mr. Napier is a member of the Hanford Environmental Dose Overview Panel. He also managed development of the environmental radiation dose code *GENII*.

Dr. Gene Whelan, who serves as Staff Engineer, Environmental Technology Division, Battelle, Pacific Northwest Laboratories. Dr. Whelan holds a Ph.D. in Civil and Environmental Engineering from Utah State University, an M.S. in Mechanics and Hydraulics from the University of Iowa, and a B.S. in Civil Engineering from Penn State University. He has over 18 years experience in all aspects associated with hazardous waste site assessments and evaluations, including the development of several multimedia environmental exposure assessment methodologies (e.g. *MEPAS*), and the application of such methodologies to DOE sites and Federal activities associated with NEPA and CERCLA (e.g. the Modular Risk Analysis applied to the *Hanford Remedial Action EIS*).

Dr. Edward J. Bentz, Jr., who serves as President, E. J. Bentz and Associates, Inc., and as Director, NRAMP Peer Review and National Transferability Tasks. Dr. Bentz serves as Leader of the NRAMP Peer Review Panel. He holds both an M.Phil. and a Ph.D. in Nuclear Physics from Yale University, and has directed and participated in numerous independent peer reviews in energy, environmental, and transportation-related areas.

4.2.2 Implementation of the NRAMP Scientific Peer Review

Peer review of NRAMP activities included review of the following NRAMP products:

- An independent peer review of the NRAMP Draft Work Plan, a document that was to identify the major technical and policy decision points of the NRAMP, and to include a schedule and general plans for involving stakeholders in each of those decisions. This review was to be directed toward insuring the technical integrity, completeness, consistency, and comprehensiveness of the Work Plan, and specifically to include review of the methods proposed; identification of weaknesses and omissions; and review of the plans and protocols, particularly the proposed application of risk assessment science;

- An independent peer review of the NRAMP Draft Preliminary Risk Assessment DOE Sites in Nevada. The purpose of this review was to verify technical content, review assumptions, and assure that appropriate stakeholder issues had been addressed.

4.2.3 Results of the NRAMP Scientific Peer Review

Draft Work Plan: Upon review of the NRAMP Draft Work Plan for the PRA, one of the Panel's key observations was that it was not realistic, with the time and money currently available, for NRAMP to conduct a comprehensive, preliminary baseline risk assessment of the radiological and hazardous materials on the Nevada Test Site. The Panel also made numerous observations about the feasibility and adequacy of the proposed technical approach.

These observations and the Panel's recommendations caused an "open and honest re-evaluation of NRAMP goals, with input from the Working Group" (HRC, 1996b); the Working Group appeared to share the Panel's overall concerns about the comprehensive focus proposed for the PRA. In acknowledgment of the Panel's and of the Working Group's comments, and considering the paucity of the data currently available at the DOE Nevada Operations Office, the NRAMP subsequently refocused its efforts to use the PRA for screening and to identify data and analyses needs in the context of addressing Working Group comments (HRC, 1996b).

Draft Preliminary Risk Assessment: While the Panel felt that "the current approaches used in the PRA help to frame the problems and issues that might require more data and/or detailed analysis" (EJB&A, 1996), the Panel also made many recommendations concerning the need to improve the manner of the technical presentation, to include many technical qualifications and clarifications, to improve the technical clarity and auditability of the assessment, and to clarify major assumptions and their potential ramifications. As a result of the peer review, the PRA was substantially revised to qualify and to clarify the results.

4.3 Groundwater Fingerprinting

The early goal (1995 – 1996) of the NRAMP Groundwater Fingerprinting project was to build a database containing chemical concentrations of groundwaters of the Nevada Test Site and surrounding area. Groundwater samples from over one hundred sites within Southern Nevada and Eastern California have been analyzed for trace elements, major anions, major cations as well as pH, alkalinity, and conductivity. Geochemical and multivariate statistical techniques were applied to these data to help identify the chemical compositional distribution of groundwaters of this region in order to facilitate conceptualization of the groundwater flow regime.

In 1997, the emphasis of this program was placed on the Pahute Mesa – Oasis Valley groundwater flow system. Groundwater samples from 24 springs and wells within the NTS, Nellis Air Force Range, and Oasis Valley were analyzed for trace elements. Multivariate statistics, along with a geographical information system, were applied to these data to search for spatial patterns. Several possible flow paths were identified. In addition, secondary calcite from fracture coating phases of five drill holes on Pahute Mesa (PM-2, PM-3, UE-18t, U-19ar, and U-20as) was analyzed for trace elements. These minerals were used to relate groundwater to their sources and flow paths.

The data set used to evaluate the Pahute Mesa – Oasis Valley flow system was quite limited. A significant number of the wells and springs were within Oasis Valley and only a small number of wells were on Pahute Mesa and the NAFR. No trace element chemistry data were available for wells or springs intermediate between the NTS and Oasis Valley. In collaboration with IT Group, Desert Research Institute, HSI Geotrans, Lawrence Livermore National Laboratories, and the US Geological Survey, a sampling effort has been initiated to increase the data coverage of the Western Pahute Mesa area. Sampling includes eight new Western Pahute Mesa (ER-EC) wells.

Data generated through the above activities have been integrated into the DOE Underground Test Area Project Comprehensive Chemistry Database for Groundwater at the Nevada Test Site (IT, 2000).

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5. SUMMARY AND CONCLUSIONS

NRAMP work activities may be divided into two time periods: 1995 – 1997 and 1997 – 2000. The early work (1995 – 1997) focused on achieving an identification of the scientific and technical problems inherent in performing a health-based risk assessment at the NTS culminating in a screening-level PRA. Work performed during the second part (1997 – 2000) focused on supporting existing DOE/NV programs via university-appropriate research and continuing the original NRAMP mission of stakeholder communication such as focusing and refining components of the preliminary risk assessment.

5.1 Initial Period (1995 – 1997)

Early NRAMP work activities focused on three parallel areas:

- Identification of risk tools and assessments within the DOE Complex that may be of value to the development of a preliminary risk assessment at the NTS. This included reviews of risk assessment tools, processes, and models; reviews of risk communication methods and activities; and case studies of comprehensive health risk assessments at other DOE Complex sites.

- The development of a stakeholder-driven preliminary risk assessment for DOE sites in Nevada. This included establishment of organized stakeholder interactions and the complementary implementation of risk evaluation and calculations.

- The development and implementation of an independent scientific peer review panel to enhance the technical merit of the work.

5.2 Post PRA Period (1997 – 2000)

With the review and issuance of the PRA (December 1996), it became apparent that much of the basic data and information needed to perform a comprehensive risk assessment for the NTS was not yet available (e.g. classified information concerns), or had never been collected. Unlike more mature efforts at other DOE environmental remediation sites – such as Hanford – the NTS had not yet enjoyed the decades of environmental data gathering (and hundreds of millions of dollars spent on data acquisition) necessary for a comprehensive health risk assessment. In addition, the NTS was still an operating site. As such, the PRA was a screening-level analysis, with its greatest value being the identification of missing or incomplete data needs. These early efforts led to the conclusion that additional resources would have to be directed toward further, detailed identification of missing data components, as well as the gathering of missing data itself.

In addition, parallel review of DOE Complex-wide risk assessment and management strategies revealed that many individual DOE sites were developing cleanup strategies dependent on the availability of the NTS for disposal of their LLW. (The central role of the NTS as a LLW has been since confirmed by the February 2000 *Final Waste Management Programmatic Environmental Impacts Statement* Record of Decision on disposal of LLW). This meant that projected DOE off-site LLW disposal volumes – and their characteristics – would dominate future NTS on-site LLW risk assessments – and consequent strategies. Accordingly, it was concluded that additional efforts would also have to be directed toward assessment of these projected LLW disposal volumes from DOE off-site generators. Since many of the NTS-approved DOE off-site LLW generator sites were still in the process of developing LLW characterization data, this effort would require the review of existing LLW volume projections, as well as direct data surveys and analysis of individual waste streams.

To meet these multiple data acquisition, analysis, and development goals – both for existing contamination at the NTS, as well as for projected disposal of off-site-generated LLW contamination – multiple data acquisition and analysis activities were undertaken. In addition, relevant topic-specific technical peer reviews of the data acquisition and analysis were conducted and subsequent risk communication activities with the public were undertaken.

To focus the limited available resources for such a large site (the NTS covers 1375 square miles), priority areas for investigation were identified from the PRA analyses. These priority investigation areas are underground water contamination, contaminated surface soil, and LLW disposal management.

- *Underground Water Investigations*. Numerous field investigations, laboratory analyses, and analytic studies were undertaken to investigate underground water flow (rate and direction), as well as to estimate a hydrogeologic source term. Further, technical reviews were undertaken of the findings and relevant findings were communicated to the public.

- *Contaminated Surface Soils Investigations*. Analytic scoping studies were undertaken, and technical peer reviews were conducted. In addition, at the request of DOE/NV and the State of Nevada, and in participation with the NTS CAB, technical peer reviews were conducted for on-going/planned soil remediation efforts, including those establishing the necessary health-based concentration levels.

- *LLW Disposal Management Area Investigations*. NRAMP staff conducted third-party reviews of Radioactive Waste Management Performance Assessments and Composite Analyses including the Compliance Assessment Document for transuranic waste disposed in NTS Greater Confinement Disposal boreholes. In addition, reviews and comparisons of existing and projected source terms were conducted. As reviews revealed significant omissions in projected data – due in part to the consequences of the WMPEIS process, and in part due to new regulatory requirements – data development efforts were initiated with the endorsement of DOE/NV, and the cooperation of DOE generator sites and DOE/HQ. These efforts have led to the development of NTS-specific, waste stream-specific, LLW volume and characteristic projections.

  Supplementing the development of NTS-specific LLW disposal projections, efforts were also undertaken to identify the specific requirements in applicable LLW disposal regulations, as they would affect data and projection needs. Findings of both the projections and regulatory analyses were provided to the public at both technical and public meetings.

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