Radionuclide Inventory and Distribution Program (RIDP): A User Relational Database for Preservation and Analysis of Historic Measurements of Radionuclides in Soil – 11235

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ABSTRACT

The Radionuclide Inventory and Distribution Program (RIDP) was the first comprehensive survey of the distribution of radionuclides created from nuclear testing on the Nevada National Security Site (NNSS) (previously known as the Nevada Test Site {NTS}). Activity of gamma-emitting radionuclides was measured in nanocuries/meter^2. Activity for 13 man-made radionuclides was measured directly. Measurements for three naturally occurring radionuclides were also made: K-40, Th-232, and U-238. Extensive use was made of the RIDP results over time. However, the original data was stored on magnetic tapes which eventually limited its accessibility. Errors were made by users relying on hard copy data in RIDP reports. For example, for short lived radionuclides (e.g., Co-60), activity levels at different locations that were collected at different times were compared without correcting for decay.

A database was developed for the RIDP measurements to be electronically incorporated into tables, spreadsheets and GIS software. The data was first recovered from magnetic tapes and transferred to a flat-file database. This was then converted to a relational-database design and a graphical user interface application was designed using Microsoft® Office Access. The application generates coordinates and maps of where measurements were taken and the activity values of gamma-emitting radionuclides at each location. The Nevada Grid Coordinates are used for result location reference. It also provides consistency to decay corrected results using current standards for the half-life values of the radionuclides for past or future dates. Another capability is the identification of all RIDP points in an area around an NNSS coordinate specified by a user. This feature provides data that could be used to discuss health and safety risks for an activity planned in an area. The application operates as a stand-alone system on a personal desktop and has been distributed to other agencies working on projects for the DOE NNSA.

INTRODUCTION

The Radionuclide Inventory and Distribution Program (RIDP) was conducted between 1981 and 1986 by using ground-based, *in situ* gamma spectrometry and was the first and still is the most comprehensive survey of the distribution of man-made radionuclides from nuclear testing and associated activities on and adjacent to the NNSS (Fig 1.). There was a previous study done by the Nevada Applied Ecology Group (NAEG) that included measurements of soil surface and subsurface contamination from nuclear testing [1]. The RIDP technique for measuring gamma-emitting radionuclides in surface soil using *in situ* gamma spectrometry was developed in the mid-1970's by Lawrence Livermore National Laboratory (LLNL). This technique made it possible for RIDP to conduct surveys of large areas [2]. A two-stage strategy was used for surveying the sites.

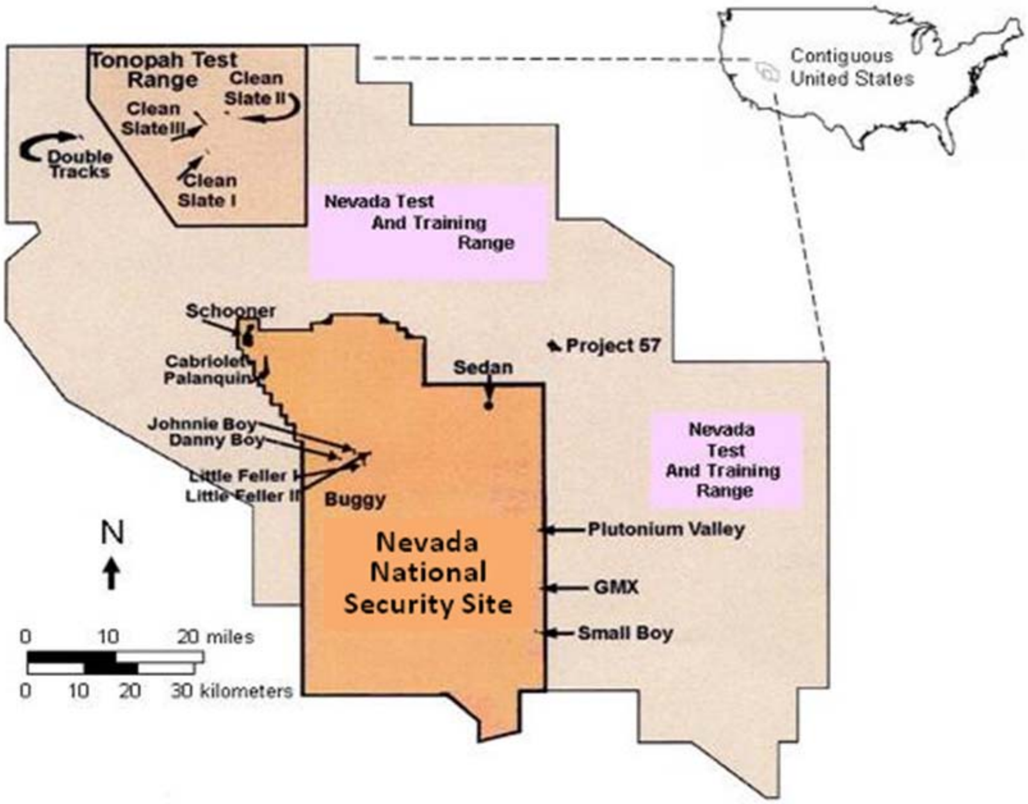


Fig 1. Location of the Nevada National Security Site and major areas of soil contamination. In addition, nuclear testing resulted in areas of soil contamination on the adjacent Nevada Test and Training Range, and the Tonopah Test Range.

First, between 1976 and 1984, results of a series of aerial radiological surveys flown by EG&G, Inc. that included all nuclear test site locations on the NNSS using an array of sodium-iodide scintillation detectors help define precise areas to be surveyed on the ground. Second, *in situ* ground measurements were done under RIDP between 1981 and 1986. By the end of the RIDP program, 16 man-made radionuclides had been found in measureable amounts in soil at one or more locations on the NNSS. At that time Pu-239 and Pu-240 could not be distinguished by gamma spectroscopy and are thus reflected in the RIDP data results as Pu-239,240. Three naturally occurring radionuclides, K-40, Th-232, and U-238, were also measured. The units for all surface measurements were in nanocuries per square meter (nCi/m^2).

DATA COLLECTION DURING RIDP SURVEYS

The majority of RIDP *in situ* ground measurements were made with collimated high-purity germanium detectors suspended 7.4 meters (m) above the ground using a tracked off-road vehicle. (Fig. 2) The location of most *in situ* measurements sites was determined using a microwave ranging system using a receiver and transmitter mounted on the vehicle and two or more transponders positioned on high points in the region. In some areas of more complex terrain that the vehicle could not cross, similar measurements were made from instruments

Fig 2. A tracked vehicle with a mast which was mounted with a high purity germanium detector for the RIDP measurements.

mounted on tripods. The actual area measured on the ground depended on the isotope. For a lower energy isotope such as Am-241, the RIDP "value" was integrated over a circular area of about 10 m in diameter. For higher energy isotopes (e.g., Co-60), the diameter was as high as 21 m. The combination of the aerial surveys to determine the approximate size of the above-background area of radionuclides, kriging, and a "polygons of influence" method using the *in situ* measurements, was used to calculate the size of test areas and inventories for radionuclides [3]. In addition to *in situ* ground measurements at each location, a few surface samples were analyzed radiochemically for Sr-90, Pu-238, Pu-239,240, Cs-137, and Am-241. The ratios of Sr-90 to Cs-137, Pu-238 to Am-241, and Pu-239,240 to Am-241 were used for estimating inventories of Sr-90, Pu-238, and Pu-239,240. Also, a profile of soil samples to a depth of between 15 and 30 cm was collected. Gamma spectrometry performed on these profiles was done to determine radionuclide depth distributions and calculated inverse relaxation lengths.

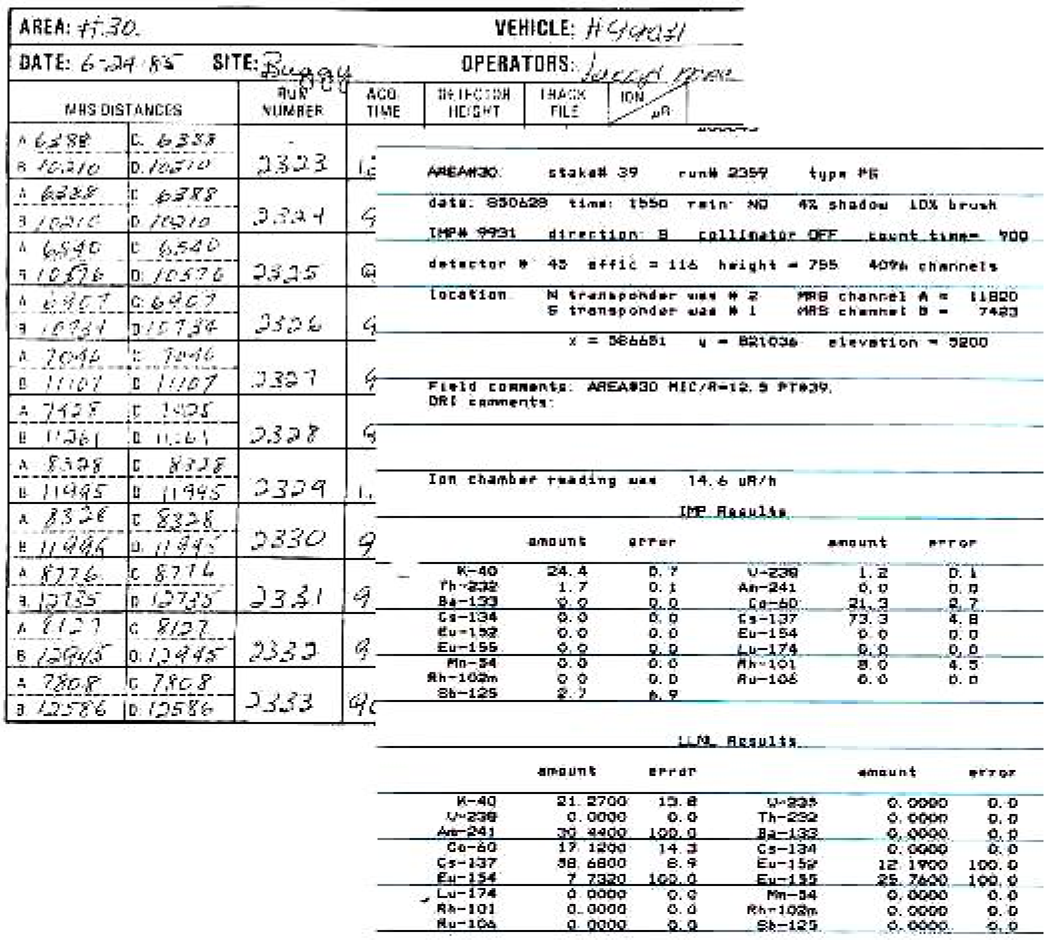
The role of the Desert Research Institute (DRI) of the Nevada System of Higher Education in RIDP was to analyze and report the results of field measurements that were collected and then processed by LLNL. After the initial field measurements were made, the spectra were transferred to magnetic tapes that were forwarded to DRI for preliminary processing. The principal value was the Peak Search, representing the highest gamma value measured in the field for each of the gamma-emitting radionuclides at each test site. The analyzed data plus the original raw spectra data were archived onto nine-track tapes and stored at DRI.

RECOVERY AND PRESERVATION OF THE ARCHIVED RIDP DATA

For a time, it was possible to download and export data off the magnetic tapes for use in other studies and reports. However, as computer technology advanced, the need to preserve the data on another type of media was inevitable and called for a strategy to be able to recover the archived data electronically in the future. During the program the original results processed by LLNL were printed to hardcopy along with the original field log recording forms. For some time, although data was still on magnetic tapes, most use of the RIDP results was from values published in these reports (Fig 3.). A final summary report for RIDP was published in 1991 [4], although other reports were published as various parts of the NNSS were surveyed.

However, analyses using values from RIDP reports resulted in increasing inconsistencies and errors. Particularly for short-lived radionuclides, values for measurements taken for different years were used from reports without any decay correction to make them consistent with one another. For a few radionuclides, half-life values used at the time the data were collected, were no longer those that are standard values used today. These types of issues came to a head between 2003 and 2005 when authors of a series of Document Safety Analyses prepared for contaminated soil sites made extensive use of the RIDP data, but combined values from measurements made in different years and which were not consistently decay corrected to the present.

In 2004 the decision was made to make the data more accessible for use as well as to standardize the data so that analyses using it would be more precise. The age of the tapes made it necessary to find an "Overland Data" table-model drive and a "SUN Sparc Classic" computer to read and download the data from the magnetic tapes, and then saved to a server. It was then reviewed, analyzed, organized, and saved to compact discs for the backup archival media. To ensure the



IMP Results

	amount	error		amount	error
K-40	24.4	0.7	U-238	1.2	0.1
Th-232	1.7	0.1	Am-241	0.0	0.0
Ba-133	0.0	0.0	Co-60	21.3	2.7
Cs-134	0.0	0.0	Cs-137	73.3	4.8
Eu-152	0.0	0.0	Eu-154	0.0	0.0
Eu-155	0.0	0.0	Lu-174	0.0	0.0
Mn-54	0.0	0.0	Rh-101	8.0	4.5
Rh-102m	0.0	0.0	Ru-106	0.0	0.0
Sb-125	2.7	6.9			

LLNL Results

	amount	error		amount	error
K-40	21.2700	15.8	U-235	0.0000	0.0
U-238	0.0000	0.0	Th-232	0.0000	0.0
Am-241	30.4400	100.0	Ba-133	0.0000	0.0
Co-60	17.1200	14.3	Cs-134	0.0000	0.0
Cs-137	58.6800	8.9	Eu-152	12.1900	100.0
Eu-154	7.7320	100.0	Eu-155	25.7600	100.0
Lu-174	0.0000	0.0	Mn-54	0.0000	0.0
Rh-101	0.0000	0.0	Rh-102m	0.0000	0.0
Ru-106	0.0000	0.0	Sb-125	0.0000	0.0

Fig 3. RIDP field log recording form and LLNL results from *in situ* ground measurements data collection.

integrity of the data, a test database was established to query the data and create an export to the Environmental Systems Research Institute (ESRI) ArchMap®. The export files included a location name, E and N Nevada grid coordinates, and the appropriate NNSS area designation. The grid coordinate information was then imported into the ESRI ArchMap® to compare measurement points against plots published in reports to ensure that all the data were found, retrieved, and correctly labeled [4]. A strategy was planned to meet the needs of current and future users to not only access the data but use a software tool that would provide consistency of data queries, analysis, decay correction, and exports. Because a major purpose of developing the RIDP database was to make it available electronically on software that was commonly used in the computer industry, Microsoft® Office Access was selected as the tool to develop the database and an interactive user application.

DEVELOPMENT OF THE RIDP DATABASE

The RIDP database is a relational-design, desktop application that was developed in Microsoft® Office Access 2000 (9.0.2720). The application is interactive in that a user enters specific criteria into fields that may be used to perform calculations and view spatial distribution of where particular radionuclides were detected. The application design allows a user to work through menus that categorize information according to criteria such as type of radionuclide, the name of the test, the administrative area of the NNSS, and simple grid coordinates. Results may be generated as a report, map, or dataset that can be printed to hardcopy or exported to a hypertext markup language (HTML) format. From the HTML format the information can then be saved in formats for use in other software tools such as word processing, spreadsheets, or GIS.

Major Analysis Capabilities of the Database

Since the RIDP application was distributed in June 2006, requests for specific datasets and result analysis have been more frequent in support of DOE projects. The development of the database was funded as part of the Soils Sub-Project of the DOE National Nuclear Security Administration, Nevada Site Office. The RIDP application and data has been one of the first tools used to determine potential risk-based boundaries for sites where a remediation alternative being considered is closure-in-place with administrative control (e.g., fencing and posting). One benefit of the database is that the radionuclide data results can be decay corrected to any point of time, past or future (Table 1). The decay corrected result is calculated using an equation programmed in the application that uses the radionuclide standard half-life values which provides data consistency and integrity. A potential application of this for the Soils Sub-Project, for sites whose risk is dominated by gamma-emitting radionuclides with short half-lives, is to calculate how long a site might need to remain under administrative control before decay reduces this risk below regulatory standards.

The NV grid coordinates and collection location together determine the primary key in the database design that relates all of the data tables. The spectral gamma measurements at individual points for the particular testing events or NNSS administrative area are the main RIDP products whose analysis is presented in the database. Using a relational design has enabled the RIDP application to be developed at a user-friendly and interactive level. With select lists, “click” action buttons, and user-provided parameter fields, a user can create exportable items such as user specified reports, datasets, maps, and historical information about the RIDP program and DOE publications.

Table 1. Radionuclides and their half-life values in the RIDP database.

Radionuclide	Name	Half-life Value (y)1	Units	Decay of Concern
Am-241	Americium-241	432.2	Years	Alpha
Sb-125	Antimony-125	2.7582	Years	Gamma
Ba-133	Barium-133	10.535	Years	Gamma
Cs-134	Cesium-134	2.0648	Years	Gamma
Cs-137	Cesium-137	30.07	Years	Gamma
Co-60	Cobalt-60	5.271	Years	Gamma
Eu-152	Europium-152	13.537	Years	Gamma
Eu-154	Europium-154	8.593	Years	Gamma
Eu-155	Europium-155	4.7611	Years	Beta
Lu-174	Lutetium-174	3.31	Years	Gamma
K-40	Potassium-40	1.28E+09	Years	
Rh-101	Rhodium-101	3.3	Years	Gamma
Rh-102	Rhodium-102	3.742	Years	Gamma
R-106	Ruthenium-106	373.59	Days	
Th-232	Thorium-232	1.41E+10	Years	
U-235	Uranium-235	7.04E+08	Years	
U-238	Uranium-238	4.47E+09	Years	
Source: http://wwwndc.tokai.jaeri.go.jp/CN04/index.html, Nuclear Data Center, Japan Atomic Energy Agency (JAEA), WWW Chart of Nuclides 2004, J. Katakura, Modified 2005/10/20				

Listed below are the major analysis capabilities included in the application [5]:

- RIDP Activity by NNSS Area or by Test or Location Name: lists can be generated of RIDP measurement points and concentration values in nCi/m^2 of man-made radionuclides for particular tests or administrative areas on the NNSS.
- RIDP Radionuclide Decay Correct to User-specified Date: as above, but with the ability to decay correct all measurements to present-day concentration values or other user specified dates (e.g., such as to determine a potential exposure a receptor would have received at a site in the past). One possible application of this menu option is to estimate future concentration values and risk if a strategy of radioactive decay was used to reduce the risk of an area rather than doing so by, for example, excavation of contaminated soils (Fig. 4).
- RIDP Measurement Maps: maps can be viewed of the NNSS showing the location of all RIDP measurement points where each man-made radionuclide was detected (Fig. 4).

- Reports and Information Lists: this gives the pertinent history of the tests evaluated as part of RIDP, and properties of radionuclides measured. Information concerning tests is from DOE (2000) [6].
- Published RIDP Reports: Although the entire documents are not in the database, for the various RIDP reports published, ".pdf" files of the title page, abstract, and table of contents are included. This can help the user identify which reports to review if more detail is needed on particular RIDP procedures and data collection efforts. Complete reports can be viewed at the U.S. Department of Energy Nuclear Testing Archive (755 East Flamingo Road, Las Vegas, Nevada 89119).

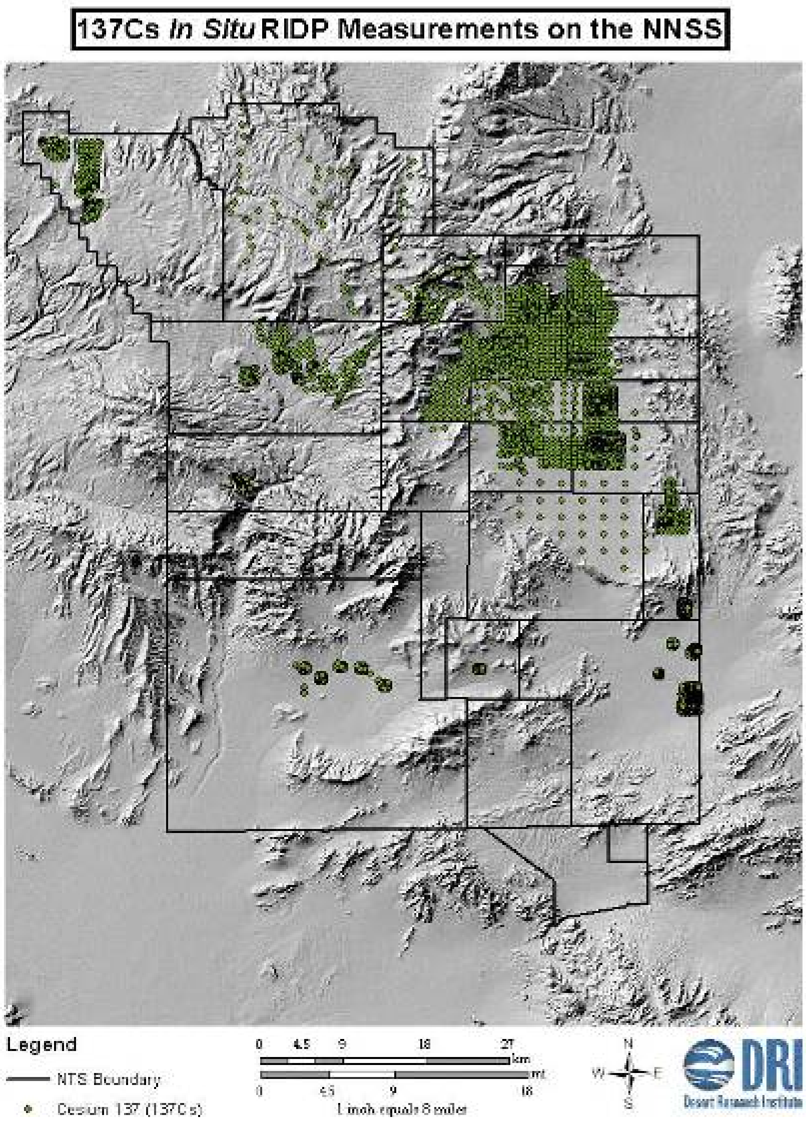


Fig 4. RIDP database export NNSS map showing the locations of RIDP *in situ* gamma spectrometry measurements where the radionuclide Cs-137 was detected.

CONCLUSION

The results of RIDP and, in particular, the *in situ* gamma spectrometry measurements for different test locations and other areas on the NNSS, remain important data for assessing safety, risk, and site characterization for areas of elevated radionuclides. The relational RIDP application provides improved access to the data, and an automated and systematic means of determining radionuclide concentrations for testing areas and NNSS administrative areas. In addition, routines for decay correction will improve the consistency of calculations of modern as well as future projections of radionuclide concentrations. Also, the additional capability to search for RIDP data points in a defined vicinity of any point on the NNSS could significantly aid in using the results of RIDP as a site assessment and planning tool to determine what types of exposure a person might receive from a new activity planned at a specified location.

ACKNOWLEDGMENTS

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