

**SOURCE AND PATHWAY DETERMINATION  
FOR BERYLLIUM FOUND IN  
BECHTEL NEVADA NORTH LAS VEGAS FACILITIES**

**July 2004**

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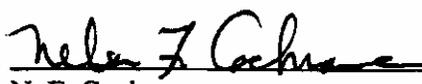
# **Bechtel Nevada**

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**July 2004**

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## EXECUTIVE SUMMARY

In response to the report “Investigation of Beryllium Exposure Cases Discovered at the North Las Vegas Facility of the National Nuclear Security Administration,” published by the U.S. Department of Energy (DOE), National Nuclear Security Administration (NNSA) in August 2003, Bechtel Nevada (BN) President and General Manager Dr. F. A. Tarantino appointed the Beryllium Investigation & Assessment Team (BIAT) to identify both the source and pathway for the beryllium found in the North Las Vegas (NLV) B-Complex. From September 8 to December 18, 2003, the BIAT investigated the pathway for beryllium and determined that a number of locations existed at the Nevada Test Site (NTS) which could have contained sufficient quantities of beryllium to result in contamination if transported. Operations performed in the B-1 Building as a result of characterization activities at the Engine Maintenance, Assembly, and Disassembly (EMAD); Reactor Maintenance, Assembly, and Disassembly (RMAD); Test Cells A and C; and the Central Support Facility in Area 25 had the greatest opportunity for transport of beryllium. Investigative monitoring and sampling was performed at these sites with subsequent transport of sample materials, equipment, and personnel from the NTS to the B-1 Building. The timeline established by the BIAT for potential transport of the beryllium contamination into the B-1 Building was from September 1997 through November 2002.

Based on results of recently completed swipe sampling, no evidence of transport of beryllium from test areas has been confirmed. Results less than the DOE beryllium action level of  $0.2 \mu\text{g}/100 \text{ cm}^2$  were noted for work support facilities located in Area 25.

All of the identified sites in Area 25 worked within the B-1 tenant’s residency timeline have been remediated. Legacy contaminants have either been disposed of or capped with clean borrow material. As such, no current opportunity exists for release or spread of beryllium contamination.

Historical records indicate that there are locations at the NTS which contain hazardous quantities of beryllium; however, because beryllium was not always considered a contaminant of concern, complete characterization was not performed prior to remediation efforts. Today, it is not practical to characterize Area 25 for beryllium due to the successful remediation.

Analysis of sample data collected in B-1 for the BIAT was performed for the purpose of confirming past results and identifying a source of beryllium through the use of markers. The results confirmed the presence of man-made beryllium contamination in the B-1 High Bay at levels consistent with the NNSA Report. No source markers were found that would be associated with NTS historical nuclear rocket or weapons-related operations. Beryllium contamination was identified in the southwest area of the B-1 High Bay in characteristic association with materials handled during historic metal-working operations.

Use of source marker analysis suggests a contributor of beryllium found in carpeted areas of the B-Complex may be naturally occurring. Naturally occurring beryllium is not regulated by Title 10 Code of Federal Regulations Part 850 (10 CFR 850) (see Appendix A).

No current uncontrolled beryllium source or transport pathways have been identified as available for spread of contamination to uncontrolled areas from the NTS.

## 1.0 Overview

BN President and General Manager Dr. F. A. Tarantino appointed the BIAT on September 8, 2003. The team consisted of representatives from BN, Tenant Organizations, and the National Laboratories. NNSA Report “Investigation of Beryllium Exposure Cases Discovered at the North Las Vegas Facility of the National Nuclear Security Administration,” [NNSA03] published in August 2003, concluded that the most probable source of beryllium contamination in the B-Complex came from the NTS. The BIAT task was to provide a more definitive answer as to the source of beryllium contamination at the B-Complex.

The BIAT evaluated the B-Complex resident activities from initial occupation, probable sources of beryllium with a focus on suspect sites at the NTS, and probable transport mechanism and pathway for introduction into the buildings.

A significant consideration of the BIAT was that suspect sources of beryllium would contain a marker element, which may indicate a specific source of the beryllium.

## 2.0 Review and Evaluation of Reports

The BIAT reviewed and evaluated the following reports to understand the history and present status of the B-Complex and determine the source of beryllium contamination and transport pathway to the B-Complex.

- “Investigation of Beryllium Exposure Cases Discovered at the North Las Vegas Facility of the National Nuclear Security Administration,” August 2003 [NNSA03]
- “Historical Beryllium Use at the Nevada Test Site and North Las Vegas Facilities,” May 29, 2003 [Tinney03]
- “Beryllium in Soils of the Nevada Test Site: A Preliminary Assessment,” UCRL-ID-104740, July 1992 [Patton92]
- “Industrial Hygiene (IH) Report for Airborne and Surface Beryllium,” May 2002 [Brounstein02] (Yucca Report)
- “Beryllium Consultation Report, North Las Vegas Facility,” May 2002 [Newman02] (National Jewish Report)
- Various Corrective Action Unit (CAU) Plans and Closure Reports

Based on these reviews, Table 1 was developed and used to validate BN Industrial Hygiene’s (IH) “Be Characterization Schedule” and their list of “Be Contaminated Sites.” BN IH manages the BN Beryllium Program for the NTS, NLV, and other locations. This program includes identification, characterization of probable and known sites, posting, and worker protection. BN IH completed characterizing the NTS, as well as other BN locations. Work controls were developed to ensure the safety of workers in identified legacy areas. Based on sample data, no evidence of tracking of beryllium from test or other areas is possible. It was determined that the BIAT’s table reflected the same legacy areas/sites as identified by BN IH.

**Table 1. High Probability Beryllium Sites**

Area	Description
12	"G" Tunnel – U12g ("E" Tunnel Muck Pile)
25	Building 3900, EMAD
26	Building 2201, Pluto Disassembly Facility
26	Building 2105, Outfall and Decon Pad
25	Test Cell C, Contaminated Wash
25	Test Cell C, Building 3210
25	Test Cell A, Buildings 3113 and 3113A
26	Building 2201, Radioactive Contaminated Filters
26	Building 2201, Vehicle Wash Down Station
25	RMAD Waste Dump
25	EMAD Facility Train Decon Area
25	Building 3124, Test Treatability Facility (TTF), Contaminated Soil
25	Reactor Control Point, Vehicle Wash Down
25	Radioactive Materials Yard
25	Nuclear Rocket Development Station (NRDS) Contaminated Bunker, Radioactive Material Storage Facility (RMSF)
25	Yucca Mountain Project (YMP) Sample Management Facility

These reports were also reviewed for the purpose of determining:

- Data quality and sampling strategies.
- Gaps in previous data used to identify source and pathway.

A synopsis of report conclusions and BIAT discussions follow:

## **2.1 NNSA Report**

A team was directed by the NNSA to determine how individuals with no previously known history of work with beryllium developed signs of exposure to beryllium. The predominant hypothesis after the reporting of the chronic beryllium case was that Building B-1 had not been adequately cleaned after removal of the machine shop and residual contamination had caused the observed health effects. The NNSA team concluded that it was unlikely that the machine shop which had previously existed in the B-1 Building was the source of the contamination. Rather, it was introduced into these buildings from an outside beryllium contaminated area, most likely from the NTS. NNSA thought the transport was caused by a Tenant of B-1 as a result of characterization activities at the NTS.

In reaching their conclusions, the NNSA team determined the following:

- Beryllium was found in dirt samples collected from the southwest corner of the B-1 Building High Bay at levels as high as 47 µg/g.
- Beryllium was found in dirt samples collected from the carpet of the first floor of the B-1 Building office areas.
- Contamination as a result of the historic machine shop was ruled out because the machine shop had typically worked with a copper-beryllium alloy (98% copper, 2% beryllium), and sufficient correlation was not found between beryllium and copper concentrations.

- Ceiling tiles were found to typically have elevated levels of beryllium (1-5  $\mu\text{g/g}$ ), but were ruled out as the source of contamination in the B-1 Building.
- More than 50 separate historical areas of the NTS where beryllium-related activities were conducted were identified. It was determined that a small number of the occupants of the B-Complex and the second floor of A-1 had the opportunity to be in the vicinity of many of those sites in the course of their work.

The NNSA Report concluded that the most likely explanation for the observed effects was that beryllium contamination had been inadvertently introduced into the building from an outside source, most likely the NTS.

## **2.2 Tinney Report**

The Tinney Report was prepared for BN by a Science Applications International Corporation (SAIC) consultant, and contains a list of locations at the NTS, the Tonopah Test Range (TTR) and NLV facilities where significant beryllium contamination may exist as a result of experiments carried out. The locations were identified through a review of historical records. The report includes brief descriptions of the locations and “suspected beryllium activity.”

## **2.3 Patton Report**

The Patton Report was a preliminary effort at identifying the distribution of beryllium in the soils of the NTS. No distinction was made in the report as to whether the beryllium found was naturally occurring or was from manmade sources. Sampling was carried out at six locations where past beryllium usage was suspected based on interviews with persons involved with the NTS operations.

The report found beryllium concentrations in the soil which ranged from their detection limit of 0.46  $\mu\text{g/g}$  to 4.65  $\mu\text{g/g}$ . Elevated levels of beryllium exist in some locations of the NTS, but the levels detected in the areas sampled for the Patton Report are insufficient to account for the 47  $\mu\text{g/g}$  seen in the NNSA Report.

## **2.4 Yucca Report**

In response to notification that a former employee had been diagnosed with beryllium-related health effects, Bechtel SAIC Company conducted a survey of some of their facilities in May 2002. Soil samples collected at their facilities had concentrations of beryllium in the range of 0.116 to 1.5  $\mu\text{g/g}$ . The highest concentration was collected in an area used to cut rock and soil samples. As there is no known beryllium operations associated with their work on the YMP, any measured beryllium may be considered as background derived from naturally occurring sources.

## **2.5 National Jewish Report**

Personnel from the National Jewish Medical and Research Center were brought to the NLV Complex as a consultant when a case of chronic beryllium disease was brought to the attention of BN management. The National Jewish Medical and Research Center Report, issued in May 2002, was based on a limited amount of data, and concluded that beryllium levels in the B-Complex were not inconsistent with background values.

## **2.6 CAU Plans and Closure Reports**

An environmental contractor conducted characterization of many formerly used facilities at the NTS in preparation for environmental remediation of the facilities for reuse or demolition. During this process, detailed plans and reports were written and submitted to the state of Nevada for approval, documenting the work in detail. Supporting records were solicited from the environmental contractor for additional detail. Potential sources and pathway were constructed from the reports.

A review of the “List of Corrective Action Units/Work Locations” for the period in question further refined the potential areas to be evaluated as beryllium sources.

## **2.7 BIAT Conclusions**

Because the BIAT was interested in looking for source markers as a means for identifying the source of the beryllium contamination in the B-1 Building, the BIAT investigated if the physical samples, such as bulk dust samples, which were collected for the NNSA Report were still available for further analysis. The samples had been disposed of, and the analysis which had been performed was not complete enough to suit the needs of the BIAT. BIAT concluded that the NNSA sampling data indicated contamination of the southwest corner of the B-1 High Bay and to a lesser extent, the office areas. Given existing data and absence of prior physical samples, BIAT decided to re-sample the B-1 Building to confirm markers associated with previous beryllium data. A re-sampling plan was developed to perform a more thorough investigation of areas of concern identified in the NNSA Report and to provide sample material to analyze for source markers.

# **3.0 Source and Pathway Theories**

## **3.1 Source**

The BIAT considered all probable sources and pathways of beryllium to the B-Complex. Four basic source and transport categories were determined, as follows:

- Case 1 - External Source and Introduction Path

Activities were performed outside of the B-Complex, with material transported from those external locations to the B-Complex. The transport could have been through casual contact such as dirt collecting on clothing, equipment or vehicles, or the intentional transport of a soil sample. In these modes of transport, the external locations would be an area of significant contamination containing loose particulate readily available for transport within the B-Complex. The BIAT determined, as did NNSA, that if beryllium came from the NTS, its concentration would likely be orders of magnitude more than the values detected in B-Complex. If transported, its concentration would decrease when tracked large distances from the source.

In the case of transport through casual contact, the beryllium contamination could be the result of a single visit to a particularly high-contamination area, or could be the result of a gradually increasing inventory after each cycle of field activity and return to the B-Complex. In the case of unintentional transport, the contamination could be the result of a loss of containment of a sample package. The loss of containment of a sample is a frequent path for building contamination but normally an event of this type does not go unnoticed and is well documented.

- Case 2 - Machining Process

The beryllium contamination originated internally from the historic metal working operations conducted in the B-Complex.

- Case 3 - Natural Sources and Building Constituents

The detectible beryllium is due to natural environmental elements transported into the B-Complex from surrounding areas and not exclusively from the NTS.

- Case 4 - Combination of Above Cases

Combination of the above listed cases.

## **3.2 Pathways**

### **3.2.1 NTS Environmental Characterization Pathway**

Of the residents in B-Complex, the environmental contractor had the greatest opportunity to transport beryllium to the B-Complex as a result of their characterization activities at the NTS in areas where historic operations would have caused beryllium contamination. Environmental contractor operations in the B-Complex began in September 1997. Their mission was to characterize formerly used facilities and areas in preparation for environmental remediation. These operations were intrusive, resulting in significant direct contact with contaminated materials, most likely soils containing fine particulate.



Several high probability areas noted in Table 1 did not fall within the timeline. These areas, such as “G” Tunnel; “E” Tunnel muck pile; and Pluto, were then not considered as a probable source for transport.

Other areas fell out of the timeline because they were either not worked at all or were worked prior to or after the identified time period.

Data from samples collected by the environmental contractor during the field events were reviewed and records indicate beryllium levels from non-detect to 6 µg/g. Only a few samples collected contained notable levels. A single sample of 170 µg/g was recorded. This sample was collected in June 2003 at a storage bunker in Area 5. No samples collected and handled in the B-Complex before January 2002 contained beryllium levels greater than 2 µg/g. Records and interviews do not support a major loss of control of samples brought into B-1. It is probable that tracked or surface-level contamination could have contributed to the B-1 beryllium inventory. But, it is the position of the BIAT that it is improbable that this pathway would account for the total inventory or be the single-point-of-origin because of low concentration and mass of the sample.

### **3.2.2 Records Pathway**

The NNSA Report suggested that some of the beryllium may have been introduced into B-1 by contaminated documents brought in from the NTS. BN IH swipe surveys of record materials and BIAT reviews of historic records transport pathways do not support the idea of the records area as a point of distribution through the building.

### **3.2.3 Historical B-Complex Activities Pathway**

Building B-1 contained a large machine shop and processes for electrical fabrication, chemical etching, plating, and refurbishment of diagnostic trailers used at the NTS. Materials utilized in these operations included copper-beryllium alloy, small amounts of pure beryllium, iron, aluminum, and copper cable. Building B-3 was occupied by EG&G Energy Measurement’s support for Los Alamos and Sandia National Laboratories. This building contained smaller shop areas and various fabrication shops. Detector windows made of pure beryllium were assembled there.

### 3.2.4 Naturally Occurring Beryllium Pathway

BIAT considered the possibility that the beryllium contamination was due, in part, to tracking naturally occurring material into the B-Complex. From a U.S. Geological Survey (USGS) report of dust in southern Nevada and California [Reheis99], it is noted that typical concentrations of naturally occurring beryllium in this geographical area is 1-2 micrograms of beryllium per gram of dust ( $\mu\text{g/g}$ ). See discussion in Appendix C. Soil samples collected by BIAT in the NLV Facility indicate beryllium concentrations of 0.31 to 0.92  $\mu\text{g/g}$ . Beryllium concentrations in soil, at the Summerlin Offices of Bechtel SAIC in northwest Las Vegas, ranged from 1-3  $\mu\text{g/g}$ .

Because of the elevated levels of beryllium present in ceiling tiles as presented in the NNSA Report, the BIAT considered these, as well as other building materials, as the source of contamination in the B-Complex. Most of these were ruled out since other buildings in the complex are constructed of the same materials, and the BIAT found no levels of concern in these other buildings. The aggregate used in concrete was thought to be a possible outlier. The aggregate is taken from borrow pits in the southern Nevada area; and, depending on when the building was erected, and which borrow pits were in use, the aggregate could have been taken from an area of elevated beryllium concentration. See Appendix C.

### 3.3 Source Marker Theory

To improve the identification of the source for the beryllium, a technique of marker elements was developed. Marker or signature elements are known to be in association with beryllium for a given source or source area. Using an Inductively Coupled Plasma Mass Spectrum (ICP/MS) analysis on samples from the B-Complex, target elements and their quantities could be evaluated and assist in source identification. If the markers are present in known relative ratios, it may be concluded that the beryllium originated from the designated areas or sources. These are presented in Table 2.

The BIAT reviewed prior sampling results for presence of markers identified in Table 2. Samples collected by BN IH and NNSA investigations in the B-Complex were mainly analyzed for beryllium. A few samples were analyzed for copper and aluminum for evaluation for machining of alloyed material. The available prior data did not include comprehensive marker analysis. To determine if Table 2 markers were present, BIAT pursued the idea of having the contract laboratory identify these markers by review of spectra collected during initial sample analysis or reanalysis of previously submitted sample. No sample material in the form of sample digest or of raw unused sample was available; all sample material having been discarded at the end of the standard sample retention period. This required BIAT to collect additional samples for the analysis.

Patterns of markers above typical soil concentrations were evaluated to determine if a sample was related to Table 2, beryllium source areas.

**Table 2. Primary Suspected Beryllium Source Areas and Markers**

Source/Area	Marker Elements
Area 25 Nuclear Rocket Engine Testing	Enriched Uranium
Nuclear Fission Products	Cesium, Cobalt, Europium, and Niobium
Nuclear Weapons Test Areas	Plutonium
Nuclear Weapon Safety Shot Areas	Plutonium
Machining Operations with Metals & Alloys	Copper, Nickel, Cobalt, Iron, Aluminum
Natural Occurring Beryllium in the Environment	Yttrium

Table 3 presents values of markers typical in soil.

**Table 3. Typical Beryllium in Soil Concentrations**

Element	Analysis Justification	Typical Soil Concentrations
Beryllium	Target element	1 µg/g
Yttrium	Correlated with natural Beryllium	15 µg/g
Copper	Alloying material	18 µg/g
Nickel	Alloying material	17 µg/g
Cobalt	Alloying material	8 µg/g
Uranium	Nuclear fuel	4 µg/g
Plutonium	Nuclear fuel	<1µg/g
Niobium	Cladding material	17 µg/g
Iron	Building material	30,000 µg/g
Aluminum	Building material	70,000 µg/g
Titanium	Building material	3,400 µg/g

## 4.0 Review and Evaluation of Sampling Data

### 4.1 Evaluation of B-Complex Data Results

Multiple individual sampling efforts were undertaken during previous BN IH and NNSA investigations of B-Complex.

BIAT reviewed the data which lead to conclusions of beryllium contamination present in the B-1 Building. In the NNSA Report, the data for carpet sampled in the office areas of buildings were reported in terms of µg/100 cm<sup>2</sup>. This convention was used to attempt to have some means of comparing against the federal requirements for beryllium as given in 10 CFR 850. The action level against which the previous commission compared their data was 0.2 µg/100 cm<sup>2</sup> of removable beryllium contamination. This consideration of the data in terms of µg/100 cm<sup>2</sup> is

an approach for assessing to regulatory point of view. Considering this convention, data evaluation must consider that an area bulk sample might appear to have a high beryllium contamination if assessed by unit area, but instead it may be associated to a large mass of natural soil deposition per unit area.

The BIAT investigation re-examined the data in terms of the fractional mass of beryllium in the samples ( $\mu\text{g/g}$ ). An investigation in this manner reveals if there is an anomalous amount of beryllium in the collected dirt. In reviewing the data, it was noted that the previous investigation team had collected samples from the carpeted areas of the first floor of the B-1 Building on two dates in November and December of 2002, with the November samples being the most extensive. There were additional samples collected in January and March of 2003. When BIAT mapped out all the sample results over the building floor plan presented in Figure 2, it would appear as if the overlapping sampling campaigns produced inconsistent results. The November 2002 data, which served as the basis of the previous investigation's decision that the office areas of the B-1 Building were contaminated, appeared to be anomalously high. This observation prompted the BIAT to investigate the data further. Details of the further investigation can be found in Appendix D.

## **4.2 Lab Analysis Methods**

The contract laboratory used by BN IH and NNSA was DataChem Laboratories, Inc. DataChem used the National Institute for Occupational Safety and Health Manual Analytical Methods (NMAM) 7300 Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP/AES) analysis method for beryllium evaluation of swipes and bulk soil samples. They employed a nitric acid leach for an hour at 100° Celsius to prepare a solution for analysis by atomic emission spectroscopy. This is a standard method designed for analysis of filter samples and may be used for bulk soils.

For multi-element analysis of bulk soil samples, BIAT required a method that would provide for the analysis of the requested element markers and for total digestion of the sample for subsequent analysis. University of Nevada Las Vegas Harry Reid Center (UNLV-HRC) could provide the element analysis using ICP/MS. This approach would identify concentrations of beryllium and associated source markers. The signature of the markers would allow tracing the source and pathway of the material. To ensure complete digestion of the sample, UNLV-HRC employed Environmental Protection Agency (EPA) SW846, Method-3052, a microwave assisted strong acid digestion with an analysis method designed for determining trace metals in an environmental matrix.

Both methods are adequate for the analysis of elemental beryllium, but the EPA method is a more rigorous approach ensuring the breakdown of all beryllium compounds found in soil matrixes.

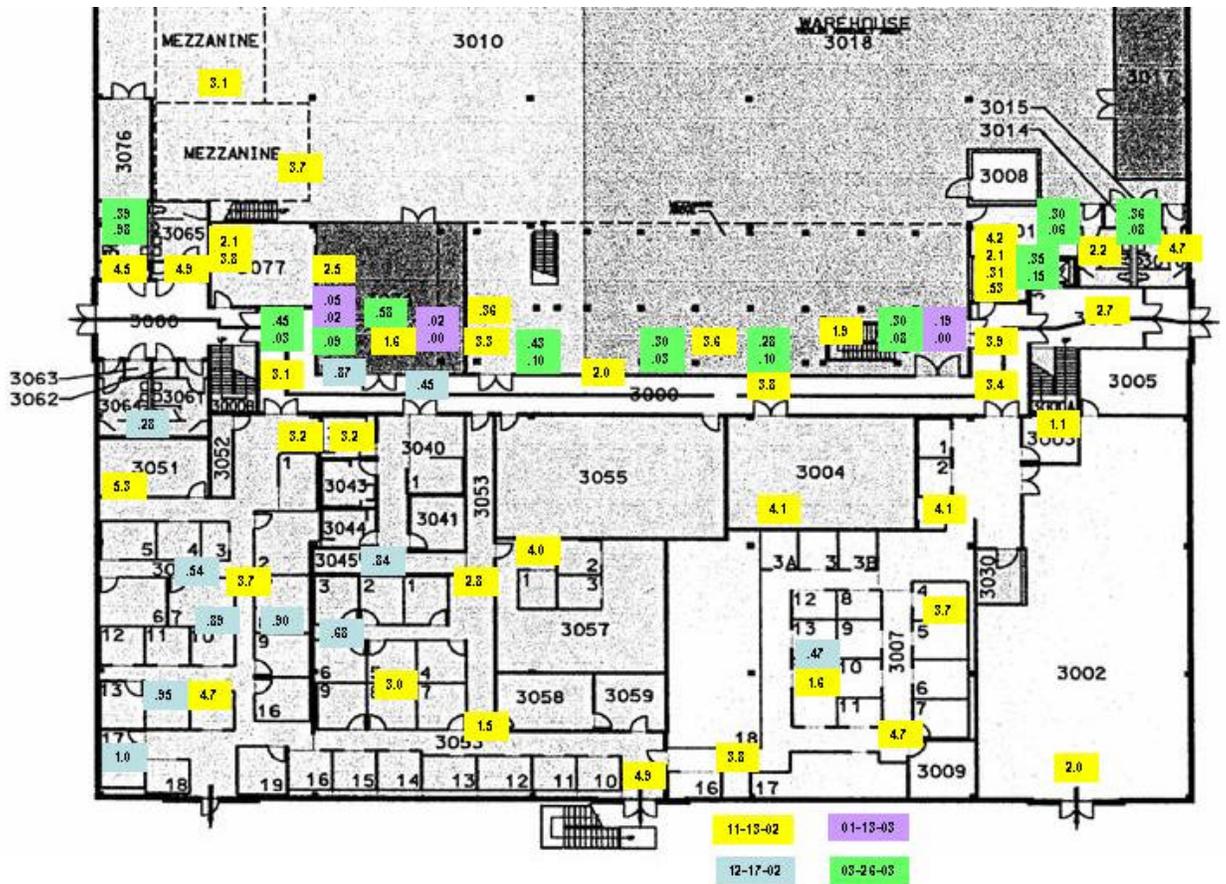


Figure 2. Floor plan of the first floor office areas of the B-1 Building with NNSA results of beryllium from dirt taken from areas of carpet shown. The beryllium results are displayed in micrograms of beryllium per gram of dirt ( $\mu\text{g/g}$ ). The different color coding indicates the different dates when the samplings were performed.

### 4.3 BIAT Requested Data

#### 4.3.1 Sampling Strategy

##### 4.3.1.1 B-1 Sampling

To pursue identification of source markers, in the absence of previous data, additional samples from B-1 were required. BIAT developed a sampling strategy for the B-1 Building. The plan included both bulk and swipe samples. Locations were both biased and statistically-determined. Biased samples were collected in areas which had previous high concentrations of beryllium, e.g., B-1 High Bay southwest corner and co-located carpet locations as

noted in the NNSA Report. Biased samples were also collected in areas where contaminants would have collected and remained undisturbed. These areas were in the overhead of the High Bay and included horizontal surfaces of conduit, roll-up door frames, shelving, and ducting. A statistically-based regimen was used to identify other sampling locations in the B-1 High Bay. Approximately 200 samples were collected, including soil and concrete aggregate. Soil and concrete were taken to evaluate natural background.

The bulk samples obtained under the direction of the BIAT were collected with the high efficiency vacuum purchased by BN IH. The sampling was performed by personnel trained in the use of the vacuum, and in the sample collection and documentation procedures. As a part of these procedures, separate nalgene bottles were used for each collected sample, and the vacuum was cleansed with de-ionized water between each sample. A chain-of-custody record was maintained for the samples. The samples were received at the UNLV-HRC where they were analyzed using ICP/MS.

Table 4 summarizes types of samples and their locations for the BIAT effort in B-1.

**Table 4. Samples Collected for BIAT**

Description	Number Collected	Location/Areas
Bulk carpet (High powered Vacuum collection)	18	B-1 Eastside – office & hallway carpeting
(High powered Vacuum collection)	151	B-1 Westside – hard surfaces, concrete floor cracks, shelving, rollup doors, and horizontal utility piping/conduits
Bulk other (soil)	4	NLV Near Perimeter fence
Bulk other (concrete)	3	B-1 Westside (High Bay) North, Center, and South of room
Swipe building mechanical	9	Room 3017 Plating Shop
Swipe building wall	1	Room 3019B, Top of Wall
Swipe	12	Room 3019A, Office desks, cabinet, bookshelves
Blank	1	
<b>Total Samples</b>	<b>197</b>	

#### 4.3.1.2 NTS Sampling

Additionally, BIAT requested specific swipe and bulk carpet sampling at several high probability locations at the NTS. Notable areas included were the environmental contractor work trailers in Area 25 associated with characterization and remediation activities at RMAD, EMAD, and Test Cells A and C.

BIAT determined that sampling of the work trailers was warranted due to the potential for tracking of beryllium from the immediately adjacent high probability work sites during characterization and remediation activities.

To further demonstrate transport and pathway, BIAT, in conjunction with BN IH, had samples taken in vehicles, dormitories, and Building 153 in Mercury used by the environmental contractor.

Two other groups had frequent access to Area 25 high probability sites, BN Radiological Operations and BN Environmental Restoration (ER). BIAT had samples taken in areas occupied by these personnel. These facilities included BN ER work trailers in Area 25; Buildings CP-50 and CP-72 in Area 6; Dorms B and C, and Building 650 in Mercury.

Samples taken at the NTS were analyzed by the BN IH laboratory in Building 650. The BN laboratory uses an ICP/AES analysis to determine beryllium. Currently, the BN laboratory has no capability for source marker analysis. BN's laboratory uses the same methodology as the contract laboratory.

## **4.3.2 Results of BIAT Requested Sampling**

### **4.3.2.1 B-1 Samples**

The UNLV-HRC analysis of the samples taken from the office locations of the B-1 Building was not consistent with the samples analyzed for the NNSA team in November 2002. The beryllium concentrations measured in the BIAT carpet samples were at levels one would expect for background from naturally occurring sources, between 0.6 and 1.4  $\mu\text{g/g}$  (see Figure 3). The beryllium concentrations are correlated with the yttrium concentrations providing evidence that the detected beryllium in the office areas had high probability for naturally occurring sources.

The BIAT assessment of present carpet concentrations for continuous foot traffic in the B-1 carpeted area would expect to produce a dust suspension with beryllium near  $0.001 \mu\text{g/m}^3$ . This correlates to 1% level of the EPA National Emissions Standards for Hazardous Air Pollutants (NESHAPs) beryllium action level for community air that the population continuously breathes. This is well below the community protection level and for the DOE action level of  $0.2 \mu\text{g/m}^3$ .

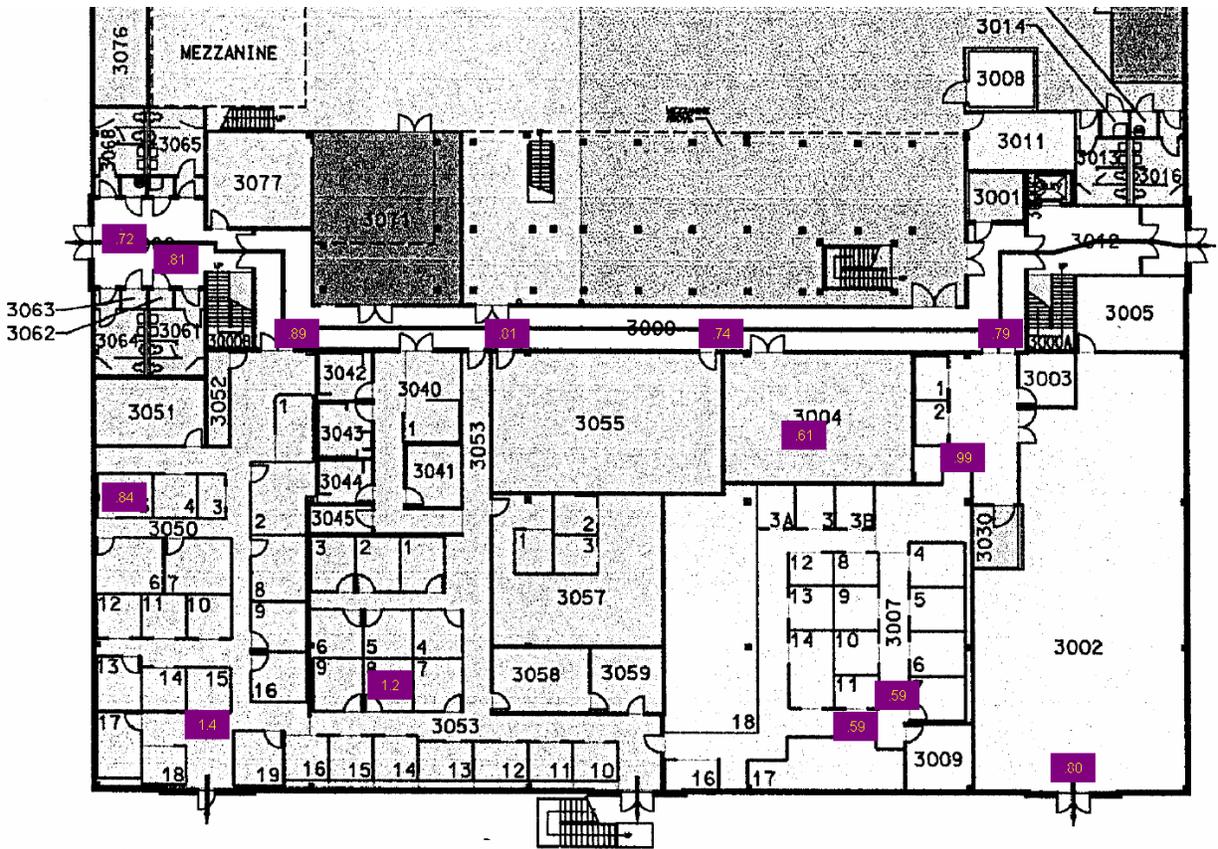


Figure 3. BIAT Carpet Sample Results (mg/g) for East B-1 Building.

The UNLV-HRC analysis of the samples taken from the High Bay of the B-1 Building confirmed the observation in the NNSA Report of man-made beryllium contamination detected in the southwest corner (see Figure 4). The UNLV-HRC analysis has shown beryllium concentrations as high as 120  $\mu\text{g/g}$ , consistent with the values in the NNSA Report. For beryllium concentrations below 2  $\mu\text{g/g}$ , there is correlation with the yttrium concentrations showing the presence of a background from naturally occurring beryllium (see Figure 5). Above 2  $\mu\text{g/g}$ , there is a deficit of yttrium relative to beryllium, indicating man-made sources for the beryllium also contributed.

Analyses of samples for source markers do not identify reactor fuel components. The ratio U235/U238 in the samples is consistent with expectations for the natural uranium background. This demonstrates that the beryllium is not associated with enriched uranium as one would expect had material come from the NTS.

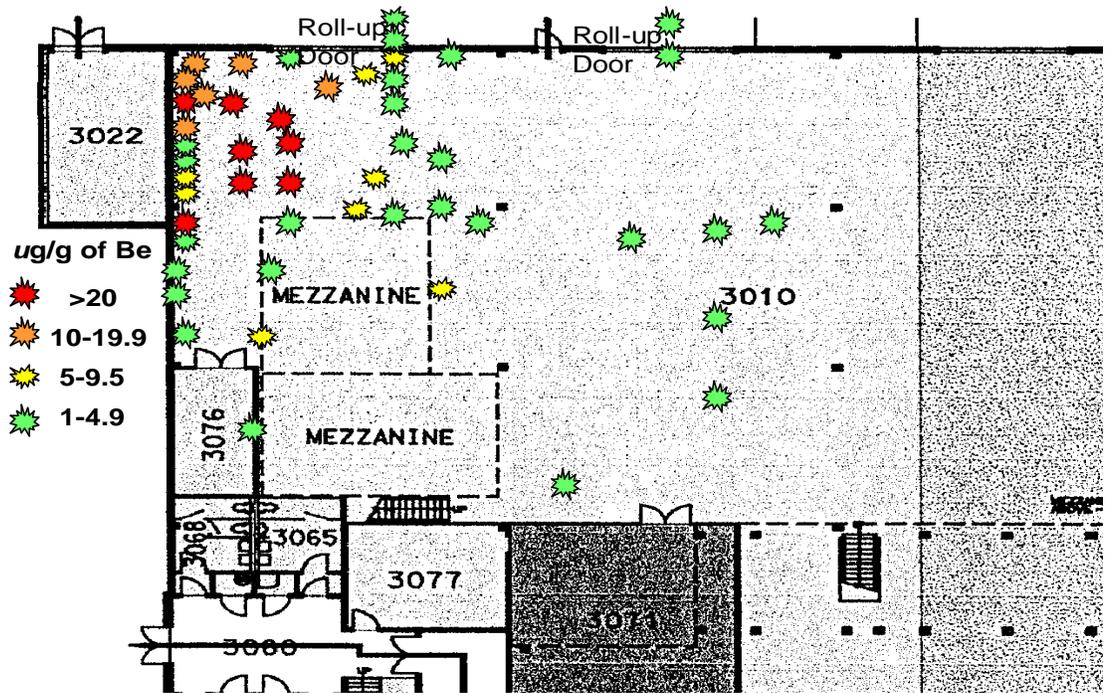


Figure 4. Concentrations of beryllium in deposition soils collected from undisturbed horizontal surfaces (electric boxes, conduit, floor/wall edges and seams/cracks in the concrete floor) in the B-1 High Bay southwest corner.

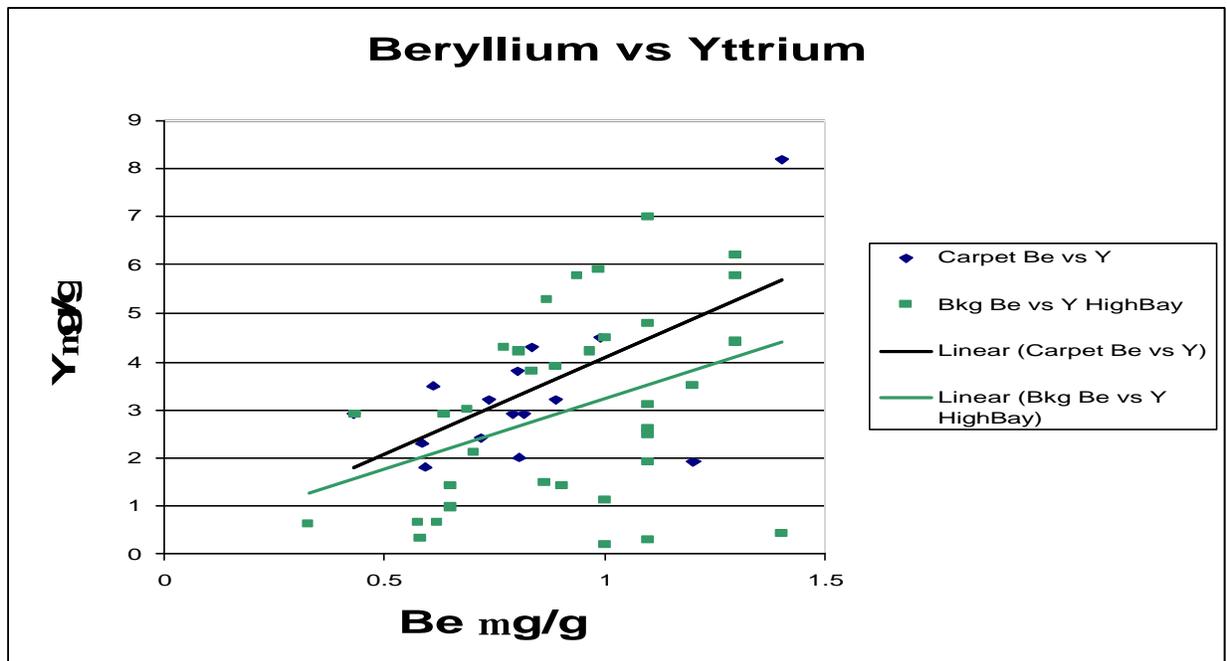


Figure 5. Concentrations of yttrium (Y) vs. concentrations of beryllium for BIAT B-1 carpet samples. The correlation between beryllium and yttrium was used to identify samples which likely are from natural beryllium.

Copper and iron concentrations are correlated with the higher beryllium concentrations. For the highest beryllium concentrations, the ratios with copper are consistent with 0.5-1.5% beryllium if the metals came solely from a copper-beryllium alloy (see Figure 6). The typical beryllium alloy used is a 2% beryllium, 98% copper mixture. The slightly lower observed beryllium concentrations may be a result of work with the 2% beryllium as well as some work with copper not alloyed with beryllium. The correlation between beryllium and iron is indicative that work with metals other than beryllium containing alloys was performed in the area (see Figure 7).

#### **4.3.2.2 NTS Samples**

Results of swipe samples taken at the NTS at locations of interest for BIAT pathway analysis were less than the DOE action level of 0.2  $\mu\text{g}/100\text{ cm}^2$  for removable beryllium.

#### **4.3.3 In-Situ Gamma Spectrum**

Following the signature theories, it is believed if the beryllium source was from NTS areas of past reactor or nuclear yield weapons tests, a fission product signature would accompany the beryllium. The BN Environmental Technical Services Group collected seven in-situ gamma spectrums in B-1 for nuclear element identification; three measurements in the southwest corner of the B-1 High Bay, sample handling area under an air vent, and carpet areas at the entry to the main hall from the High Bay. The areas were selected based on past sampling events where elevated beryllium had been detected. Direct measurements of building surfaces covering a 10 meter radius detected only natural elements. Measurement times ranged from 1 to 14 hours achieving a detection limit of 6.5 to 2.8  $\text{pCi}/\text{m}^2$ , respectfully, for fission products.

## **5.0 Analysis and Ranking of Source/Pathway**

Having determined that a corner of the High Bay of the B-1 Building is contaminated with beryllium, the BIAT presents its ranking of the beryllium sources and transport pathways.

### **5.1 Ranking**

#### **5.1.1 Case 1**

There is a very small probability that the source of beryllium which contaminated the B-1 Building is from dirt transported from the NTS. Historical records show that there were locations at the NTS which were

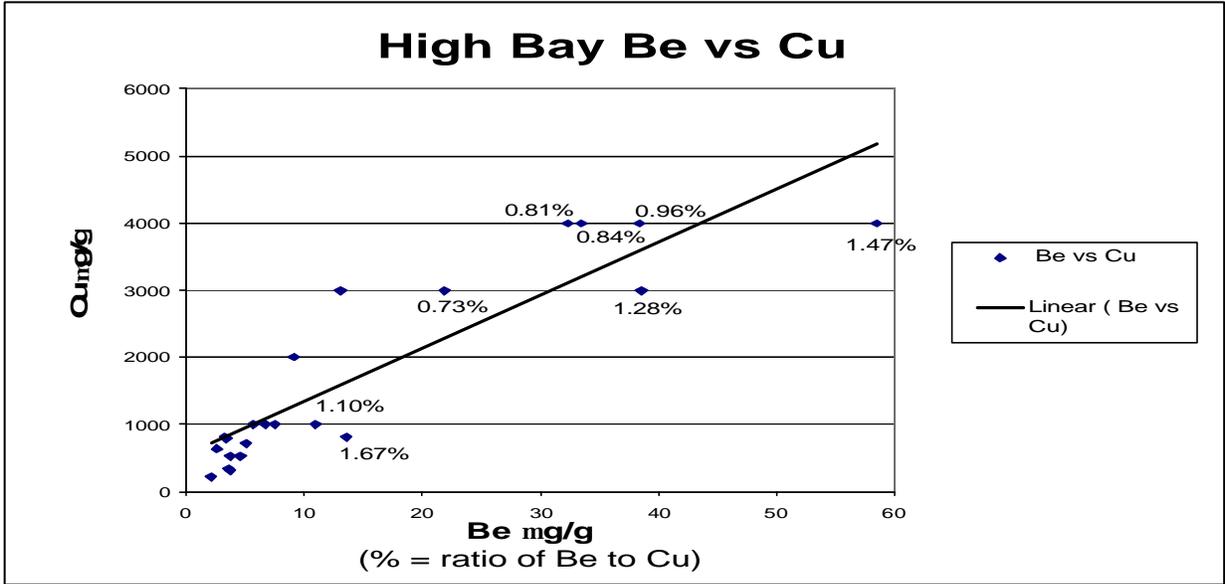


Figure 6. Concentrations of copper (Cu) vs. concentrations of beryllium for BIAT B-1 High Bay samples. The correlation between beryllium and copper was used to identify samples which likely had man-made beryllium. Beryllium/copper ratios are just below the machining alloy of 2% beryllium to 98% copper used in B-1 operations.

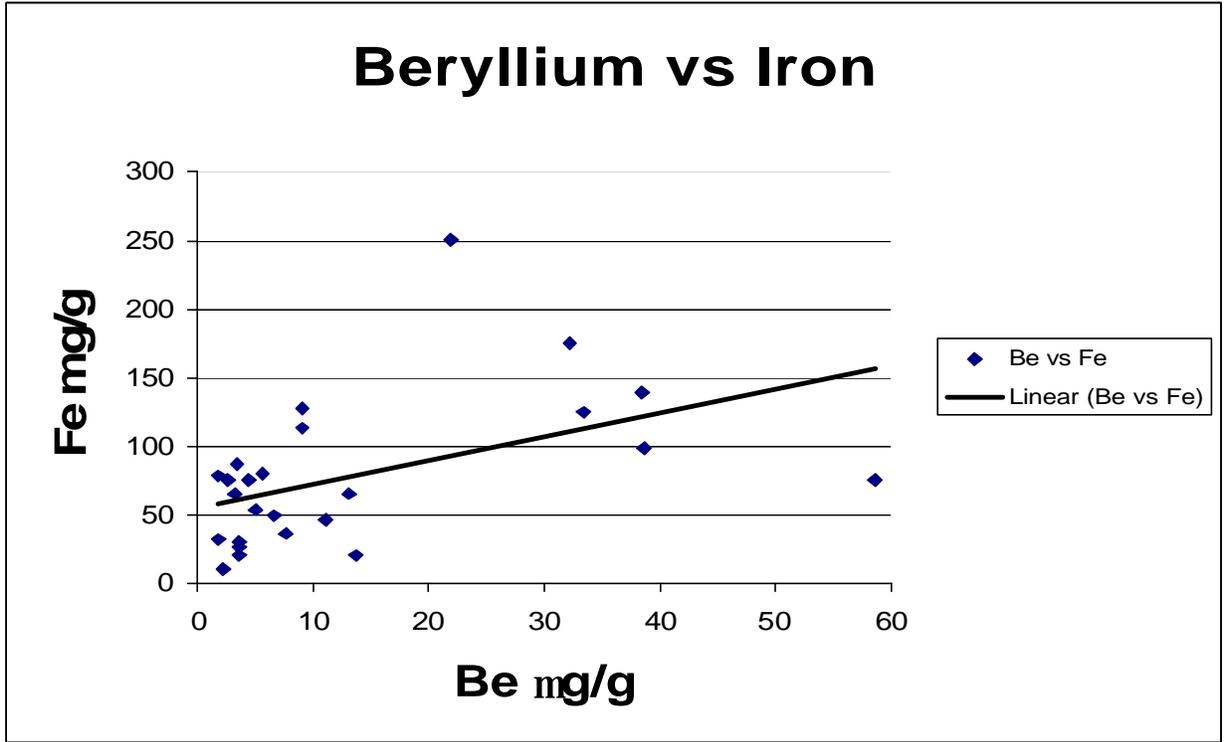


Figure 7. Concentrations of iron (Fe) vs. concentrations of beryllium for BIAT B-1 High Bay samples. The trend is an indication of general metals operations in this area of B-1. Beryllium/iron are indirectly related through co-located metals operation.

contaminated with large quantities of beryllium. The environmental contractor has conducted characterization activities in some of these locations. Those areas where the environmental contractor performed analyses for beryllium were not high enough to have produced detectable levels in the B-1 Building. The source marker analysis of samples collected in the B-1 Building does not support the NTS as the major source of beryllium. Areas, in which the environmental contractor and BN organizations occupied while they were characterizing and remediating the areas with high historic levels of beryllium, are not contaminated; thus, evidence of transport pathway of beryllium from the NTS and to the B-1 Building is not present.

### **5.1.2 Case 2**

There is a very high probability that the source of beryllium which has contaminated the B-1 Building is from activities with metal components which took place in the southwest corner of the building. The elevated beryllium contamination was detected in the southwest corner. Evidence shows that the beryllium contamination is also correlated with elevated concentrations of copper, aluminum, and iron. The beryllium would have been deposited in the area prior to 1994 when the building was retrofitted for administrative work. In this case, the beryllium concentration has been present in the building from the beginning, and there is no transport pathway.

### **5.1.3 Case 3**

There is a probability that the beryllium which contaminated the B-Complex is from naturally occurring sources. Based on the source marker analysis, there is evidence that low levels of beryllium in the B-1 Building are from the naturally occurring background. There are locations in southern Nevada where beryllium is present in commercially viable concentrations (see Appendix C). However, the marker analysis does not support naturally occurring sources for the high concentrations of beryllium as found in the southwest corner of the B-1 High Bay. Beryllium was also known to be present in some building materials. Building materials were ruled out as the source, as other buildings constructed of the same materials do not exhibit contaminations.

## **6.0 Conclusions**

All of the identified sites in Area 25 worked within the timeline have been remediated. Legacy contaminants have either been disposed of or capped with clean borrow material. As such, no current opportunity exists for release or spread of contamination.

Based on results of recently completed swipe sampling, no evidence of transport of beryllium from test areas containing beryllium has been found at the NTS. Results less

than the DOE beryllium action level of 0.2 µg/100 cm<sup>2</sup> were noted for work support facilities located in Area 25 occupied by IT/SHAW and BN organizations during characterization.

Analysis of sample data collected for BIAT in B-1 was performed for the purpose of confirming past results in identifying a source of beryllium through the use of markers. The results confirmed the presence of man-made beryllium contamination in the B-1 High Bay at levels consistent with the NNSA Report. No source markers were found that would be associated with NTS historical nuclear rocket or weapons related operations. Beryllium contamination was identified in the southwest area of the B-1 High Bay in characteristic association with materials handled during historic metal working operations.

The presence of copper, aluminum, and iron source markers associated with beryllium in the B-1 High Bay indicates that the predominant cause of beryllium contamination was from metal working and fabrication activities performed in the B-1 High Bay prior to 1994.

Use of source marker analysis has determined that the major contributor of beryllium found in the carpeted areas of the B-Complex is naturally occurring. Naturally occurring beryllium is not regulated by 10 CFR 850.

NOTE: Information developed by BIAT has been provided to the BN IH Manager for inclusion in the Beryllium Characterization Final Report.

## **7.0 Recommendations**

IH should consider analyzing beryllium samples for source markers when appropriate.

IH should include the data collected for BIAT in the existing beryllium database.

## **8.0 References**

[Brounstein02] Brounstein, Robert A., May 2002, Industrial Hygiene (IH) Report for Airborne and Surface Beryllium.

[Newman02] Newman, Lee S. and Martyny, John, May 2002, Beryllium Consultation Report, North Las Vegas Facility.

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[Reheis99] Reheis, M.C., Budahn, J.R. and Lamothe, P.J., 1999, Elemental Analyses of Modern Dust in Southern Nevada and California, U.S. Geological Survey Open-File Report 99-531, <http://pubs.usgs.gov/of/1999/ofr-99-0531/>.

[Smith01] Smith, S.M., 2001, National Geochemical Database: Reformatted data from the National Uranium Resource Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) Program, Version 1.30: U.S. Geological Survey Open-File Report 97-492, WWW release only, <http://pubs.usgs.gov/of/1997/ofr-97-0492/>.

[Tingley98] Tingley, J.V., 1998, Mining Districts of Nevada, Nevada Bureau of Mines and Geology Report 47, Second edition, <http://www.nbmg.unr.edu/dox/r47/r47.pdf>.

## **9.0 Team Members**

### **9.1 Core Members**

A. G. Ogurek, Manager, Bechtel Nevada's Health Physics Department, Team Lead  
S. L. Alderson, Health Physicist, IT/SHAW  
R. C. Cullison, Senior Scientist, Bechtel Nevada's Industrial Hygiene  
Dr. C. E. Okada, Senior Scientist, Remote Sensing Laboratory-Nellis  
B. C. McNeill, Senior Industrial Hygienist, Professional Analysis, Inc. (PAI)  
B. A. Poole, Administrative Assistant, Bechtel Nevada  
D. M. Van Etten, Manager, Bechtel Nevada's Environmental Technical Services

### **9.2 Adjunct Members**

D. A. Marshall, BN Construction  
T. C. Roy, Lawrence Livermore National Laboratory  
J. A. Schill, Sandia National Laboratories, Environment, Safety & Health  
A. L. Wood, Los Alamos National Laboratory, Industrial Hygiene  
D. J. Young, BN Fire Department

### **9.3 Supporting Member**

Dr. Charles Davis, Senior Statistician, PAI

## **10.0 Appendices**

Appendix A: Regulations

Appendix B: NTS Legacy Beryllium Site Index Map

Appendix C: Beryllium History

Appendix D: Details of the Previous B-Complex Data Study

Appendix E: Beryllium Investigation & Assessment Team Scope of Work

Appendix F: Points of Contact

# APPENDIX A

## Regulations

### 10 CFR Part 850, Chronic Beryllium Disease Prevention Program (CBDPP)

#### § 850.23 Action level.

- 3.2 The responsible employer must include in its CBDPP an action level that is no greater than  $0.2 \mu\text{g}/\text{m}^3$ , calculated as an 8-hour time-weighted average exposure, as measured in the worker's breathing zone by personal monitoring.

#### § 850.30 Housekeeping.

- (a) Where beryllium is present in operational areas of DOE facilities, the responsible employer must conduct routine surface sampling to determine housekeeping conditions. Surfaces contaminated with beryllium dusts and waste must not exceed a removable contamination level of  $3 \mu\text{g}/100 \text{ cm}^2$  during non-operational periods.

#### § 850.31 Release criteria.

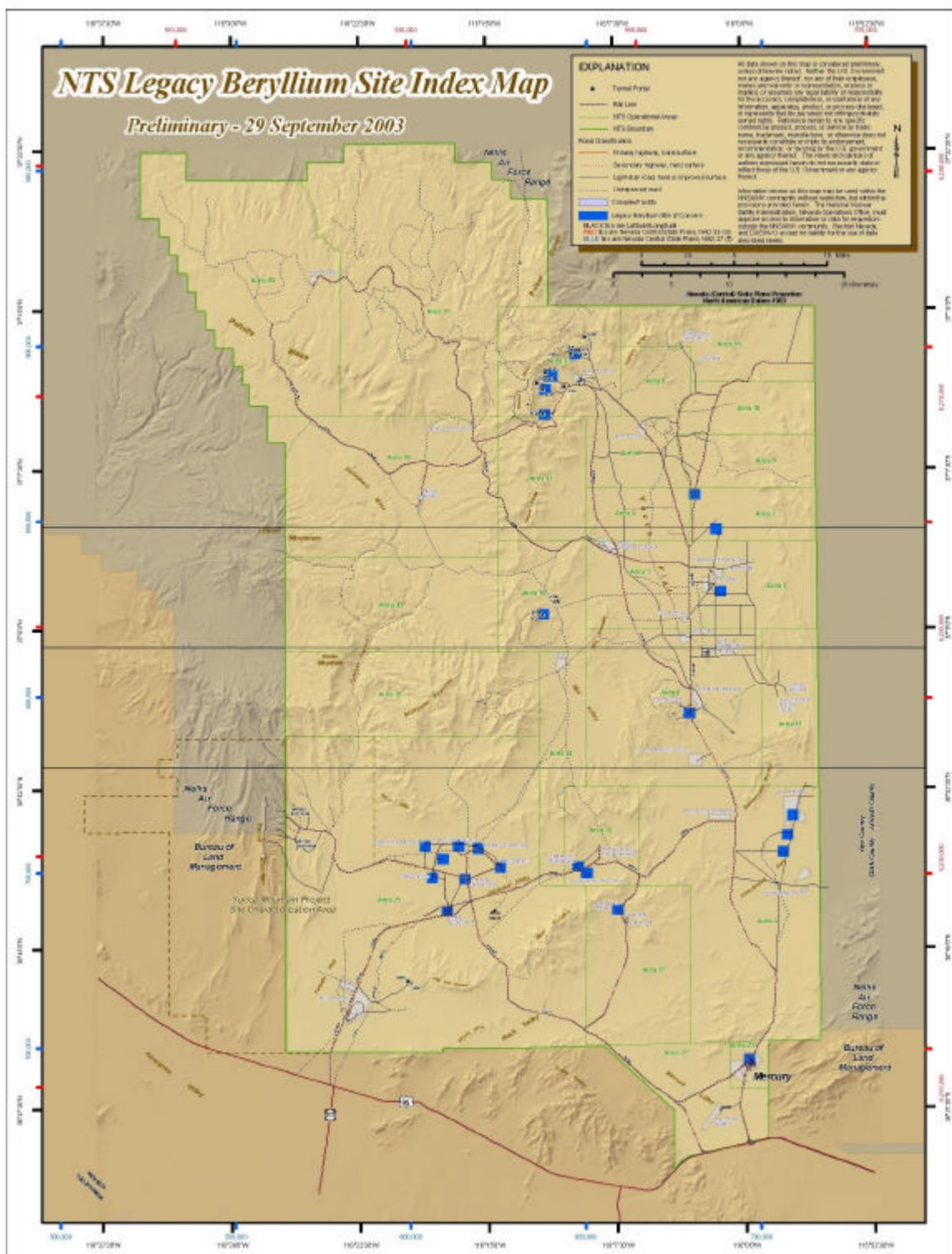
- (b) Before releasing beryllium contaminated equipment or other items to the general public or for use in a non-beryllium area of a DOE facility, the responsible employer must ensure that:
- (1) The removable contamination level of equipment or item surfaces does not exceed the higher of  $0.2 \mu\text{g}/100 \text{ cm}^2$  or the concentration level of beryllium in soil at the point of release, whichever is greater;
- (c) Before releasing beryllium contaminated equipment or other items to another facility performing work with beryllium, the responsible employer must ensure that:
- (1) The removable contamination level of equipment or item surfaces does not exceed  $3 \mu\text{g}/100 \text{ cm}^2$ ;

### 29 CFR Part 1910 Subpart Z, Toxic and Hazardous Substances

Substance	8-hour time weighted average	Acceptable ceiling concentration	Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift	
			Concentration	Maximum duration
Beryllium and beryllium compounds (Z37.29-1970)	$2 \mu\text{g}/\text{m}^3$	$5 \mu\text{g}/\text{m}^3$	$25 \mu\text{g}/\text{m}^3$	30 minutes.

# APPENDIX B

## NTS Legacy Beryllium Site Index Map

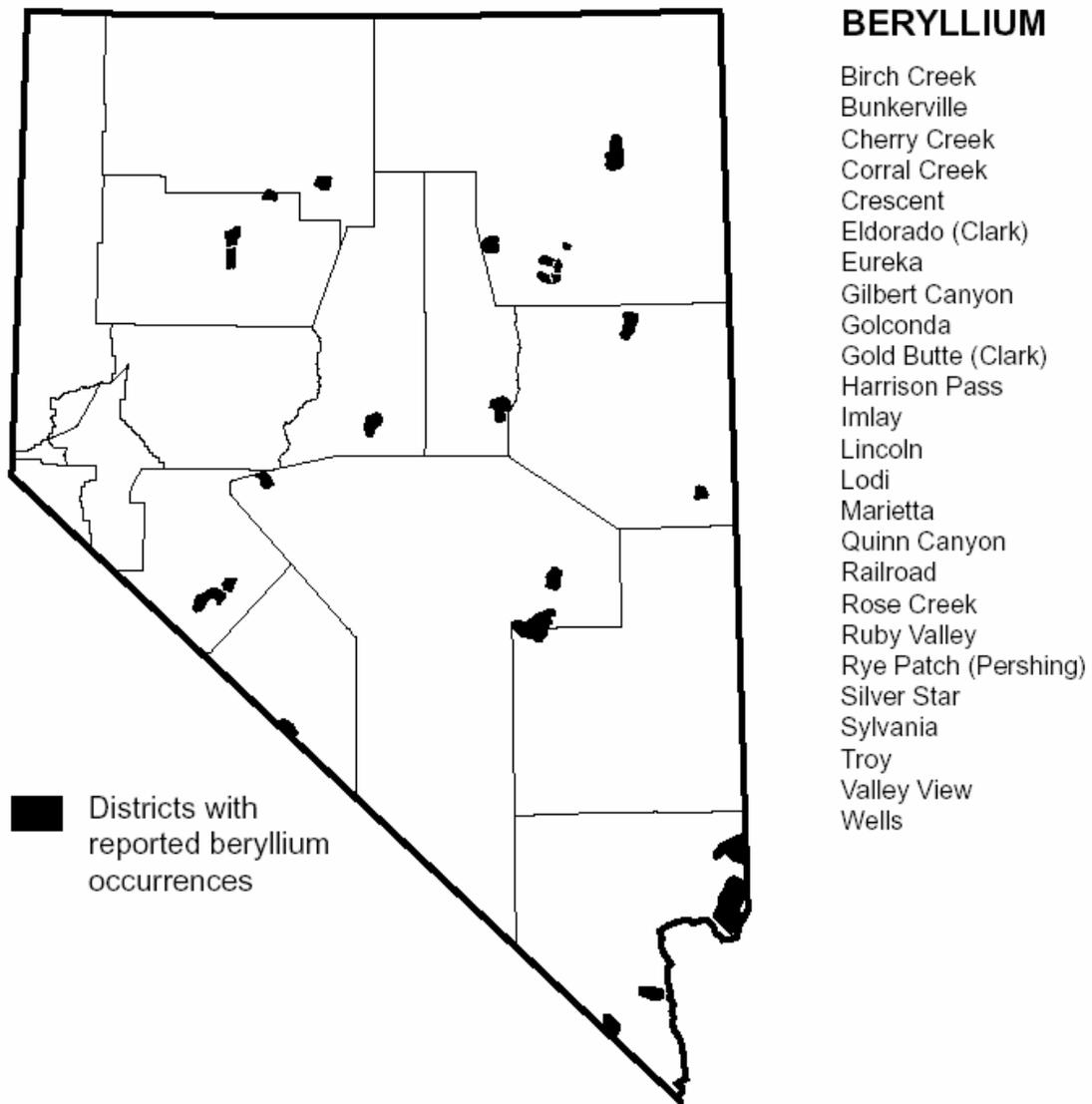


## APPENDIX C

### Beryllium History

In the course of the BIAT investigation, the team considered the possibility that the beryllium contamination was the result of the tracking of naturally occurring material into the B-Complex. In pursuing this hypothesis, information available from the USGS was reviewed to understand what may be considered natural concentrations of beryllium. From a USGS report of dust in southern Nevada and California [Reheis99], it is noted that typical concentrations of naturally occurring beryllium in the area is 1-2 micrograms of beryllium per gram of dust ( $\mu\text{g/g}$ ). This level of beryllium concentration is supported by a more extensive sampling and multi-element analysis of sediments by the USGS [Smith01] which also show that excursions to levels greater than 10  $\mu\text{g/g}$  can occur because of natural variations in the local geology. It was also determined from information available from the Nevada Bureau of Mines and Geology [Tingley98] that there were locations in southern Nevada (Bunkerville and Searchlight) where beryllium had been present in quantities sufficient and accessible enough to have been mined, indicating that even higher concentrations may be found in the area (see Figure C-1).

The USGS multi-element sediment analysis [Smith01] was examined to determine if there are other elements which are typically found in the presence of beryllium. The existence of such elements could provide a means for establishing the likelihood that some detected beryllium was from either a naturally occurring or man-made source. By plotting the observed concentrations of beryllium against the observed concentrations of other elements, it was determined that there is a correlation between beryllium and yttrium which may be exploitable, as shown in Figure C-2. If a sample has beryllium and yttrium concentrations which appear to be uncorrelated, the beryllium can be supposed to have come from a man-made source. Figure C-3 shows the concentrations of aluminum, copper, and iron against the concentrations of beryllium to show that there are not obvious, exploitable correlations between these elements in natural samples.



**Figure C-1. A map indicating the locations in the state of Nevada where beryllium has been reported in significant quantities. From Nevada Bureau of Mines and Geology Report 47 [Tingley98].**

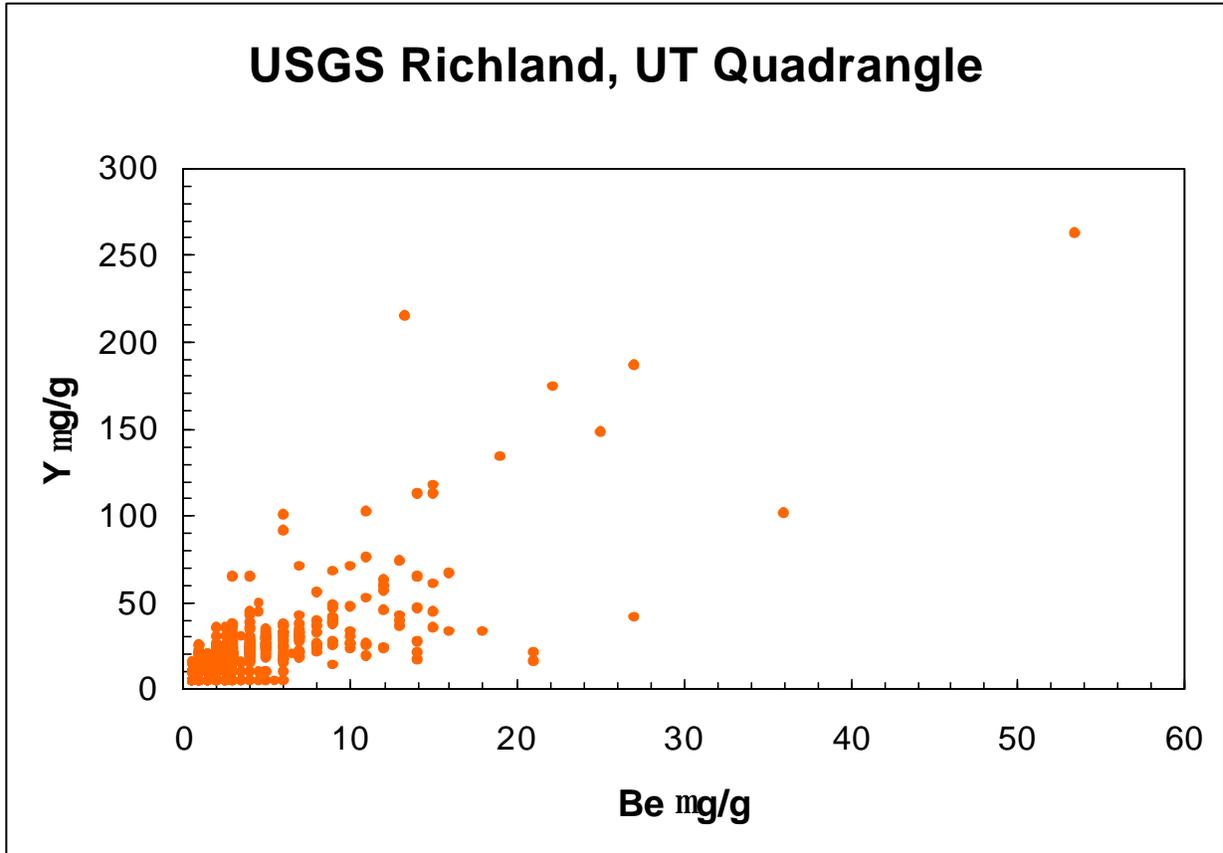


Figure C-2. Correlation between beryllium and yttrium in soil sediments in the vicinity of Richland, UT. The Richland, UT quadrangle data was used because this region has large deposits of beryllium which is consistent with natural beryllium found in western regions of the US, such as Nevada. We have attempted to use deviations from this correlation as an indication of a man-made source of beryllium. The data is from the USGS NURE project [Smith01].

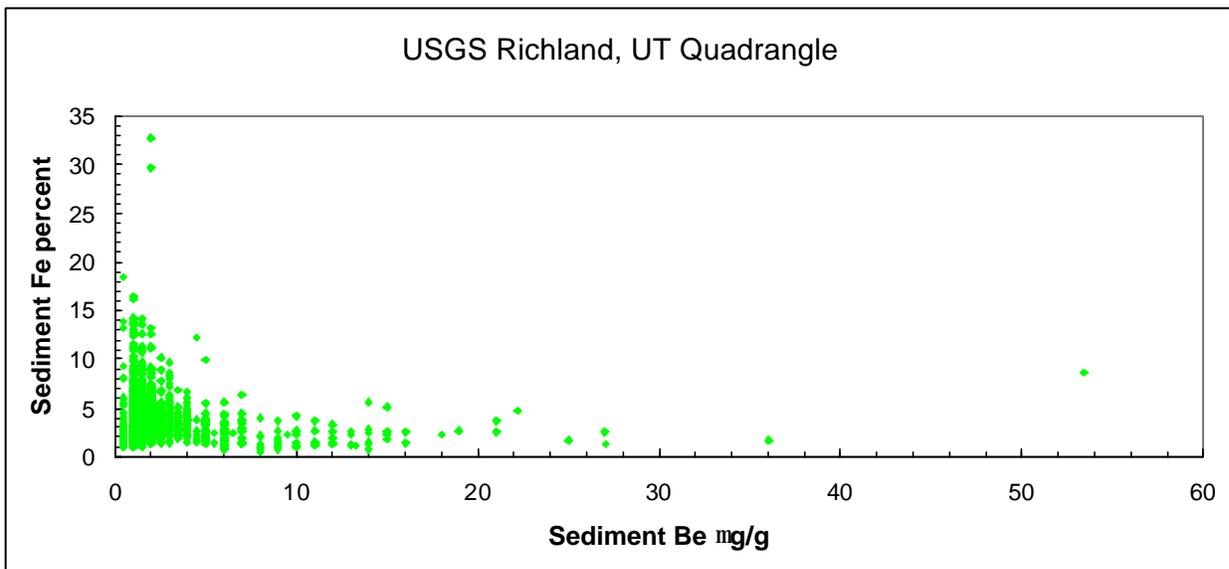
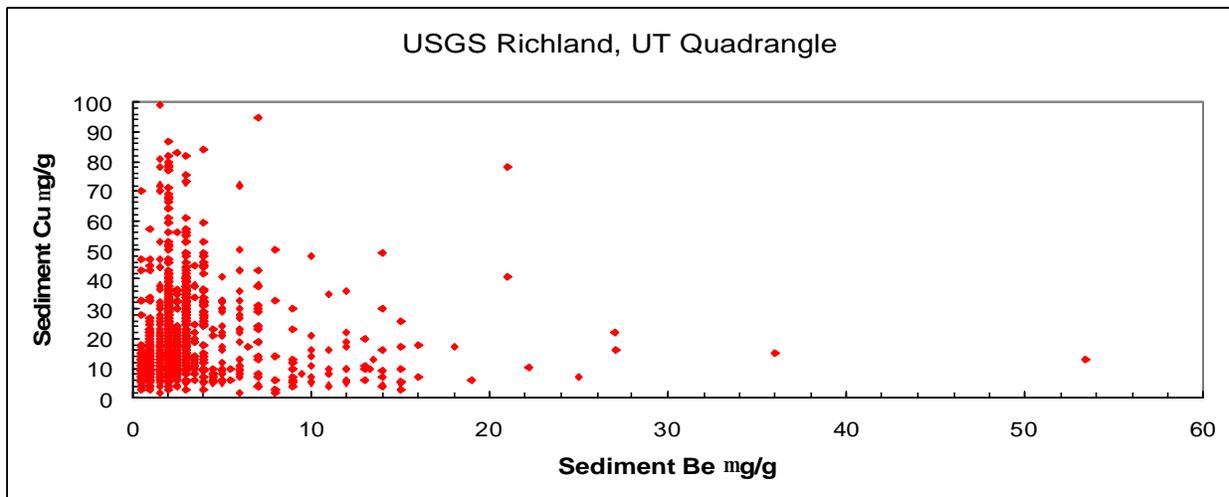
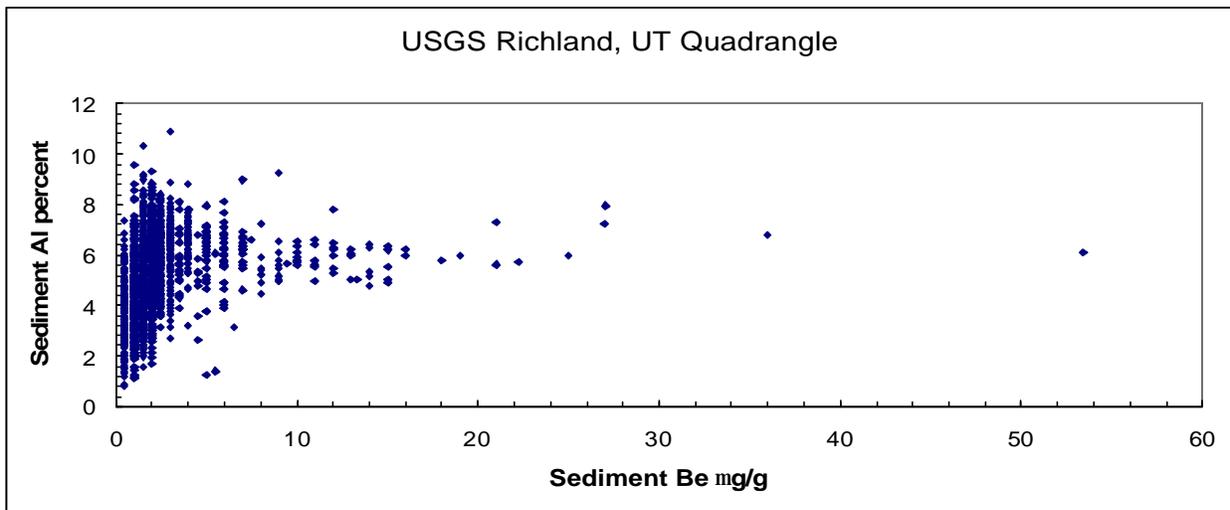


Figure C-3. Correlations between beryllium and aluminum, copper and iron in soil sediments in the vicinity of Richland, UT. The data is from the USGS NURE project [Smith01].

## APPENDIX D

### Details of the Previous B-Complex Data Study

The conclusion in the NNSA Report that the office areas of the B-1 Building were contaminated with beryllium (Be) came as a result of sample analysis which had been performed in November 2002. BIAT has noted that there were sampling campaigns which took place in the area that appeared to have statistically unbalanced or anomalously high data. A close examination of the November 2002 data has raised questions concerning two laboratory analysis batches. BIAT recognized that the contract laboratory results of data analyzed on November 23, 2002, were considerably higher than results for similar data analyzed on November 22, 2002. BIAT determined that the contract laboratory had split two separate collection sample sets, one of B-1 bulk carpet soils and one of ceiling tile bulk soils, and processed them on two separate days. BIAT's assumption was the split collection set should have produced similar data results with a natural distribution of variability. However, this was not demonstrated and BIAT felt that this discrepancy required further investigation.

The full analysis packages describing the sample preparation, sample data analysis with instrument calibrations and quality control were requested from the contract analysis laboratory. These packages showed nothing obvious which would account for the dramatic jump in the Be analysis of an average factor of seven higher. The samples were prepared and processed by the same individuals at the contract laboratory. Quality control samples were prepared from the same stock of material. The same device was used in the analysis. Analysis of the quality control samples produced consistent results for the two analysis sets. The unique factor is the laboratory chemistry preparation and digestion process which are limited to batches of 42 samples. Customer sample sets greater than this are required to be divided into separate production batches.

Two samples from a set of 44 B-1 bulk carpet soils were analyzed on November 22, 2002, and reported to have Be concentrations of 0.31 and 0.53  $\mu\text{g/g}$ . The remaining 42 of 44 samples were processed on November 23, 2002. The two samples which had been analyzed separately were collected from the same location as two other samples in the larger analysis set. The corresponding samples in the larger analysis set were reported to have Be concentrations of 4.2 and 2.1  $\mu\text{g/g}$ . Samples collected from the same location were interpreted to have Be concentrations which differed by a maximum factor of 13.5 casting suspicion on the data.

Further scrutiny of the data packages revealed that there were samples of the dust from on top of the ceiling tiles in the first and second floors of B-1 which were processed at the same time as the dirt collected from the B-1 carpets in November 2002. The analysis of the samples from the ceiling tiles were also split across two days; 36 of 78 analyzed on November 22, 2002, with Be concentrations less than 1  $\mu\text{g/g}$ ; 42 of 78 analyzed on November 23, 2002, with Be concentrations typically greater than 1  $\mu\text{g/g}$ . A BIAT walk-through inspection of the locations where the ceiling tiles were sampled showed that while there were a variety of different types of ceiling tiles present in the building, the jump in this data could not be attributed to changes in ceiling tiles as a result of location, age, or manufacturer. The jump in the data further enforces suspicions about the data associated with the samples.

Some of the samples were analyzed for different elements in addition to Be. At various times, the contract analytical laboratory had been requested to analyze the samples for aluminum, arsenic,

cadmium, chromium, copper and lead. In the data packages which were reviewed, those samples where additional elements had been requested were also analyzed by the contract laboratory for a longer list of elements. Because of the USGS soil data which provided indications of a correlation between yttrium and natural sources of Be, the samples with multiple elements analyzed were checked by BIAT. The majority of the data, including the carpet samples in the B-1 Building which appeared to have high Be concentrations, is consistent with a natural source.

Where available, the absence of yttrium was used to identify samples where man-made Be is suspected of being present. Once interesting samples were identified, the concentrations of aluminum, copper, and iron were also examined to see if there was further indication of a man-made source of Be. These multi-element comparisons are displayed in Table D-1 (See also Figure D.1). A very small subset of the analyzed samples had data suggesting the presence of man-made Be. Five data points, representing four samples, were noted as having possible man-made Be component: two samples from carpet from the first floor of the B-3 Building; one sample from carpet from the first floor of the B-1 Building; and one sample (processed two times) from ceiling tiles from the first floor of the B-1 Building.

**Table D-1. Examination of Other Elements for Samples Suspected of Containing Man-Made Be**

Location	Aluminum	Copper	Iron
B-3 Carpet	High	Normal	Normal
B-1 Carpet	High	High	Normal
B-1 Ceiling	Normal	High	High

The samples suspected of having a contribution from man-made Be sources were examined in terms of their aluminum, copper, and iron concentrations to determine if these elements reinforced the man-made Be hypothesis. The results of the analysis are displayed in Figure D-1, and indicate that, based on relative levels of aluminum, copper, and iron, there were different activities which produced the observed man-made Be.

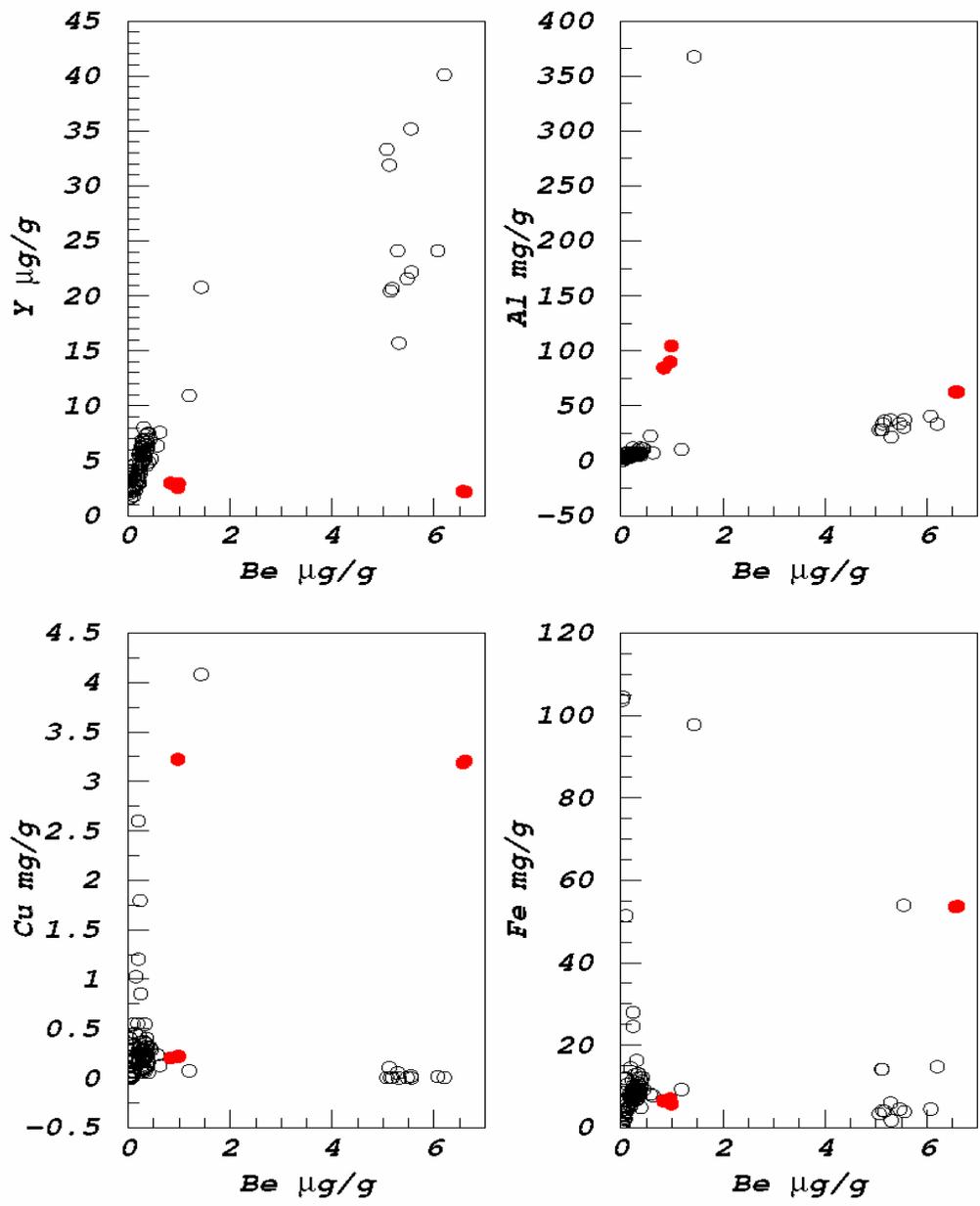


Figure D-1. Concentrations of yttrium (Y), aluminum (Al), copper (Cu), and iron (Fe) vs. concentrations of Be for the available carpet and ceiling tile samples. The correlation between Be and yttrium was used to identify samples which likely had man-made Be (filled, red data points). Data retrieved from previous sample regimes.

# APPENDIX E

## Beryllium Investigation & Assessment Team Scope of Work September 15, 2003

### 1.0 SCOPE

Identify source of beryllium at the Nevada Test Site (NTS) or other potentially suspect areas that was tracked into the B-Complex. Review and rank potential source terms and develop transport pathway theories for beryllium impact at the B-Complex. Review and evaluate historical and supporting beryllium data. Request new data as required. Report highest probability of source term and transport pathway theory to Bechtel Nevada Management.

### 2.0 ACTIONS

#### 2.1 Review and Evaluate Historical Records of Potential Beryllium Source Terms and Apply a Risk Based Ranking

- IH list of beryllium contaminated sites
- IT/SHAW list of Corrective Action Units/work locations
- Historical beryllium use at the NTS
- Natural environmental beryllium distribution
- Other Sources

2.1.1 Request technical consultant support as appropriate

#### 2.2 Develop Potential Pathway Theories

- Identify work locations (old/new)
- Review reported contamination pathway theories
- Assess pathway/transfer logic
- Rank pathway theories

2.2.1 Request technical consultant support as appropriate

#### 2.3 Review Existing Beryllium Data Sets

- Source term/effects data
- Pedigree of data (QA/QC)
- Assign data quality factors
- Identify data gaps
- Potential signature of source terms

- 2.3.1 Request technical consultant support as appropriate
- 2.4 Request/Require New Data
  - Determine if residual sample material is available
  - Collect additional samples for signature analysis
  - Fill data gaps
- 2.4.1 Request technical consultant support as appropriate
- 2.5 Compile, Evaluate, and Analyze Source Terms, Pathways, and Beryllium Data Sets
  - 2.5.1 Technical Peer Review
- 2.6 Assign Probability Ranking to Source Terms and Transport Pathways
- 2.7 Prepare Assessment Report
  - Prepare Draft
  - Submit for Peer Review
  - Incorporate Comments
  - Senior Management Review
  - Incorporate Comments
  - Finalize Report

### **3.0 SCHEDULE**

Project schedule Ghant Chart will be prepared by September 22, 2004. This schedule is dynamic in nature as the project team will reallocate resources as necessary for completion on schedule, e.g., overtime.

### **4.0 AREAS OUTSIDE OF PROJECT SCOPE**

- 4.1 Medical histories and data sets

## **APPENDIX F**

### **Points of Contact**

University of Las Vegas  
Harry Reid Center  
James Cizdziel, Chemist  
702-895-4190