Investigation of Beryllium Exposure Cases Discovered at the North Las Vegas Facility of the National Nuclear Security Administration

National Nuclear Security Administration

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On August 22, 2002, I appointed a team to investigate the discovery of unexplained beryllium exposure cases at the National Nuclear Security Administration's North Las Vegas Facility. The team's responsibilities have been completed with respect to this investigation. The analysis, identification of root and contributing causes, and judgments of need reached during the investigation were performed in accordance with Department of Energy Order 225.1A, *Accident Investigations*.

I accept the report of the team and authorize release of this report for general distribution.

_______________________________ 8/14/03 _______________

Linton F. Brooks Date
Administrator
National Nuclear Security Administration

This report is an independent product of the investigation team appointed by the Administrator of the National Nuclear Security Administration, Linton F. Brooks.

The team was appointed to perform a comprehensive investigation of this event and to prepare an investigation report in accordance with DOE Order 225.1A, *Accident Investigations*.

The discussion of facts, as determined by the team, and the views expressed in the report do not assume and are not intended to establish the existence of any duty at law on the part of the U. S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier, or any other party.

This report neither determines nor implies liability.

Prologue

Interpretation of Significance

In March 2002, the Nevada Site Office was formally notified of a medical diagnosis of chronic beryllium disease for an employee of a site contractor. The employee was not a beryllium worker, and at that time there was no known work activity that would have resulted in exposure to particulate beryllium. Additional medical surveillance identified eleven more employees with beryllium sensitization. Several of these cases also involved employees with no known history of exposure to particulate beryllium. Extensive surveys and evaluations conducted by the contractors over the following months failed to conclusively identify the source of the exposures, although there was reason to suspect the buildings that many of the employees occupied. In August 2002, at the request of the Nevada Site Office, I appointed an investigation team to conduct an independent comprehensive evaluation of the situation, to draw conclusions from the evidence collected, and to make recommendations for corrective actions.

The team concluded that the most likely explanation for the observed effects was that beryllium contamination had been inadvertently introduced into the buildings from an outside source, most likely from the Nevada Test Site. The mechanisms for this transport and introduction into the buildings appeared to be from contaminated personal articles (shoes, clothing, etc.), vehicular traffic into a high bay area of one of the buildings, and the handling of contaminated documents and other articles that had been retrieved from abandoned facilities at the Nevada Test Site. The team concluded that there is likely to be significant levels of undetected beryllium contamination at various locations on the test site, and that there was ample opportunity for this contamination to have been encountered and transported back to the North Las Vegas buildings, without detection, at levels sufficient to cause the observed effects. The team concluded that the root causes of this event were the failure to recognize the potential existence of beryllium contamination from historic activities at levels sufficient to be of hazard to the current workforce, and the failure to recognize the potential for non-radiological contamination at one location to be transported to another location at levels adequate to represent a hazard to the workers at the second location. The team concluded that although historic records existed to document the potential for beryllium contamination at a large number of formerly used facilities at the Nevada Test Site, those records had not been consulted to identify those locations or evaluated to determine the need for mitigative actions.

The lessons learned from this event emphasize the need for all Department of Energy and Contractor managers to understand in detail the historic activities conducted at the sites under their purview. We must be proactive to ensure that all legacy hazards, both radiological and non-radiological, are identified and evaluated for their residual risk to current employees, and we must take mitigative actions wherever necessary to protect our workers, the public, and the environment from these hazards as well as those hazards associated with ongoing activities.

Linton F. Brooks, Administrator

Executive Summary

Overview

In March 2002, the National Nuclear Security Administration's (NNSA) Nevada Site Office (NSO) was notified by one of its site contractors that an employee from the North Las Vegas Facility (NLV) had been diagnosed with Chronic Beryllium Disease (CBD). Bechtel Nevada (BN) operates the NLV facility for NNSA, but NLV also houses other contractors including IT/SHAW. The diagnosed employee had never been knowingly exposed to beryllium in the workplace. Subsequently, NSO and the site contractors offered voluntary medical testing for affected employees due to widespread concerns. Ultimately, eleven other employees at NLV, out of more than 450 tested, were found to be sensitized to beryllium, although no other cases had developed into CBD. Several of these employees, similar to the initial CBD case, had never been knowingly exposed to beryllium. At that time the only identified connection between many of the cases and any potential beryllium exposure was found to be the complex of buildings in which they worked, known as the "B-complex". There are three connected buildings in the B-complex, designated as B1, B2, and B3. The sensitization rate, for those cases with no previous exposure histories, was about 5% in B1 and about 2% in B3. All of the cases from the other NLV buildings were believed to be due to previous known exposures to beryllium. The background rate for sensitization in the public is not well established, but has been estimated to be less than 1%. The B1 building formerly housed a machine shop that processed a variety of metals, including beryllium alloys and metal, and B3 contained smaller workshops where it was suspected that occasional beryllium work might have occurred. Both of these shop areas had been removed during building renovations in 1994. The initial monitoring of the buildings did not show any levels of beryllium above current DOE and industry standards. The A1 building, which is where the machine shop is currently located, was also included in this investigation due to the apparent connection with shop activities.

After the initial discoveries, the site contractors and NSO chartered a series of reviews involving Department Of Energy (DOE) and external subject matter experts during the months of March, June, and July 2002. When it became clear from those reviews that the concerns could not be readily resolved, and that there may be complex-wide implications, NSO requested that the NNSA Administrator charter a comprehensive investigation of the situation. This investigation was chartered on August 22, 2002.

The NLV facility is a collection of buildings on the north side of Las Vegas, Nevada, that contains offices, light laboratories, machine shops, and other activities primarily intended to provide support for the Nevada Test Site (NTS) and other DOE activities in the Nevada area. The B-Complex was privately constructed in the early 1980's and leased by EG&G Energy Measurements (EG&G/EM) to provide space for the pre-staging and support equipment fabrication requirements of DOE's nuclear testing programs. Beginning in 1981 through the early 1990's, EG&G/EM's General Technical Services and General Management occupied Buildings B1 and B2 while EG&G/EM's support groups for Los Alamos and Sandia National Laboratories occupied B3. During this period, the B1 and B3 buildings could best be described as a mix of general office and light industrial workspaces while the B2 building has always been designated as office space for management and administrative personnel. Before 1994, the B1 building contained a large machine shop, electrical fabrication shops, chemical etching and plating shops, and a high bay area dedicated to the assembly of instrumentation trailers used for tests at NTS. There were also smaller shop areas and various fabrication shops in B3. Most of the machining of beryllium components is believed to have occurred in the B1 shop, although it is possible for some work to have been done in the small shops in B3.

In 1994, following cessation of tnuclear weapons testing, the B-Complex was converted into a traditional office space configuration. The reconfiguration impacted all three buildings with the most significant impact to the first floor of B1. In addition to new partitioning walls and provisions to enhance habitability, essentially all office areas were carpeted and supplied with new office furnishings. The first floor of B1, the area of greatest concentration of industrial area, was completely gutted and new horizontal heating, ventilation, and air conditioning (HVAC) ducting, new ceiling tiles, new cable trays and electrical components were installed. The reconfiguration was completed in 1995 with occupancy occurring immediately.

The task of the investigation team was to determine what happened, why it happened, what needs to be done to prevent recurrence of a similar event, and to disseminate lessons learned to NNSA, NSO, and to the rest of DOE. While the immediate focus of the team was to be on the situation at NLV, they were also to consider whether the situation suggests the presence of broader implications to the DOE sites. Specifically, the team was tasked to address, as a minimum, the following questions:

- What is the history of beryllium activities at the facility in question, and is there sufficient reason to believe that the building conditions could result in the impacts observed in the workers?
- Do current medical diagnostic tests provide an adequate level of validity, accuracy, and reliability to provide a useful indicator of exposure to beryllium?
- What is the history of contact with beryllium, both occupational and non-occupational, for the impacted employees, and is there sufficient reason to eliminate other potential exposure pathways as the source of the observed effects?
- What is the technical basis for the current standards and regulations for protection against beryllium, and does this current situation imply a weakness that needs to be addressed?

The Event

At the onset of this investigation, it was not clear what had happened in the buildings to lead to the observed cases of beryllium-related health effects. The medical evidence suggested that multiple beryllium exposures had occurred in the building population, but the initial sampling of the building only showed very low levels of beryllium, like what might be expected from environmental background. However, the team determined that the initial sampling had not evaluated all possible exposure pathways, and therefore the team initiated an intrusive sampling of the buildings to conduct a more complete evaluation.

The team's evaluations of the buildings revealed beryllium contamination in a section of the B1 high bay area, in the carpeting of the office areas of all buildings, and on the upper surface of the acoustic ceiling tiles of all buildings. The beryllium contamination in the carpeting was found to be highest in the first floor of B1, with lower values, although still elevated above background, in the other office areas of all four buildings (B1, B2, B3, and A1 second floor). The beryllium contamination in some areas of the B1 first floor were elevated to greater than 50 times background levels, and in the high bay area one sample was 134 times the local background soil level. In general, the highest levels of beryllium contamination in B1 were found at the entrances to the building, with slightly lower but still significantly elevated levels in various office cubicles and common hallways. The average contamination level in the first floor carpeting of B1 exceeded the DOE limit for free release of materials outside of beryllium controlled areas. The beryllium in the B1 high bay was limited to an area used as a shipping/receiving and staging area for the IT/SHAW staff. The beryllium contamination on the upper surfaces of the acoustic tiles was found in all areas at comparable levels, and showed no correlation with the carpet levels.

The beryllium contamination of the acoustic ceiling tiles was found to be due to naturally occurring beryllium within the materials used to fabricate the tiles, and was determined to be unrelated to the rest of the contamination in the buildings. Therefore, the team focused on the IT/SHAW high bay area and the office carpeting as the main indications of a possible beryllium exposure event in the buildings.

Results and Analysis

The team evaluated the history of the B1 building and the activities of the renovation project in 1994-1995. The team also tested for other elements, namely copper and aluminum, that would be expected to be present with the beryllium should the machine shop have been the cause of the contamination. Much of the beryllium work in the shop involved the machining of a copper-beryllium alloy, and aluminum would have been another common material for machining. The building history indicated that the carpeting was not installed in the building until after the renovation work, and in some areas it was not installed until nearly two years after the renovation was completed. The acoustic ceiling tiles were also installed after the renovation. The team also found no correlation between the beryllium contamination and the presence of copper or aluminum. Furthermore, records of beryllium contamination sampling taken when the machine shop was in operation were reviewed. These records indicated that the contamination was limited in quantity and area, and there was no evidence to suggest that significant amounts of beryllium could have escaped the machine shop and remain undetected in the building after the renovation.

In contrast to the limited amounts of beryllium that had been present in the building during the machine shop era, the team was provided with documented evidence indicating that, over the operational lifetime of the NTS, there had been a large number of activities and tests that had involved large quantities of beryllium. Many of those activities had the potential to generate significant quantities of particulate beryllium contamination. The team has estimated that there are likely to be more than 50 separate areas at NTS where beryllium-related activities were conducted. These activities included numerous weapons tests, weapons-related safety tests, and the operation of, and in one case the intentional self-destruction of nuclear rocket engines containing large amounts of beryllium. The historic records also indicated that beryllium contamination had been monitored for and often detected at a large number of facilities and sites on the NTS. In some cases, the levels of contamination were significantly elevated above modern standards. However, the records did not demonstrate any concerted attempt to establish the full extent of the beryllium contamination or any effort to demarcate and control the potential spread of that contamination beyond its detected location.

Based on these considerations, the team reviewed the work activities of the occupants in the contaminated buildings in NLV. One of the groups occupying B1, IT/SHAW, is responsible for characterizing many of the formerly used NTS facilities in preparation for environmental remediation of those facilities for reuse or demolition. One of the BN groups is responsible for archiving the historic records of site activities, and would periodically either go out to NTS or bring in items from NTS during their efforts to collect and archive historic information, with particular focus on the formerly used facilities. Other BN groups in the B-complex buildings would also have reason to go to the NTS, and would occasionally have a need to go to the formerly used facilities.

From these observations, the team attempted to correlate the current activities of personnel in the B-buildings with those NTS facilities that may have legacy beryllium contamination from historic operations. This effort demonstrated that there has been ongoing or recent work involving personnel from the B-complex, in the vicinity of at least 26 of those areas where beryllium contamination could be present. The team noted that this correlation also helped explain the observed contamination patterns in the buildings, which appeared to indicate that the beryllium had been tracked into the building through the entrances and the high bay staging area.

The team reviewed the safety and health processes used by both BN and IT/SHAW, and conducted interviews with both contractor and NSO employees about the work controls normally applied to activities at the NTS. The team determined that there was very little awareness among the current management of the historic uses of beryllium at the site, and therefore the potential for beryllium contamination would not have been evaluated in the normal course of identifying hazards and establishing work controls.

Conclusions

Before the onset of this investigation, the predominant hypothesis for the situation was that the building had not been adequately cleaned after removal of the machine shop, and that residual contamination from the shop had caused the observed health effects at exposure levels much lower than the current DOE exposure limits. However, the team concluded that it was unlikely that the machine shop was the source of the contamination, but rather that the contamination had been unknowingly tracked into the building from beryllium contaminated areas at the NTS. This tracking most likely occurred during frequent travel by employees between the NTS and NLV, and during the transport of historic documents and articles between the two locations. In addition, the team concluded based on the evidence collected during the investigation that the levels of beryllium in the building were significantly higher than the initial pre-investigation surveys indicated, and that there was sufficient reason to believe that airborne contamination could have existed in the building at levels adequate to account for the observed rates of sensitization.

After reviewing all of the cases, the team concluded that there was sufficient reason to believe that all cases likely resulted from exposure to beryllium during DOE-sponsored activities. The team concluded that there was sufficient reason to believe that the individual diagnosed with CBD may have received that exposure while working on a characterization study at one of the suspect facilities at the NTS. The team also concluded that those sensitization cases where there was no known prior history of work with beryllium could all be accounted for as a direct result of the contamination in the B-complex, and that there was sufficient reason to believe that those cases with prior history of beryllium work could have received their exposures either during that prior work (also DOE-sponsored) or during their involvement with the B-complex buildings.

The team concluded that the medical practices used in evaluating the potential for beryllium exposure among the employees were consistent with established DOE guidance and regulations. However, the team did identify potential weaknesses with the current guidance regarding the medical surveillance practices. These weaknesses did not contribute to the event's occurrence, but did complicate the evaluation processes and the interpretation of the results. Therefore, the team has established a judgment of need for DOE to review the medical surveillance processes in light of the lessons learned from this event.

The team evaluated the current DOE beryllium regulations, and concluded that there were weaknesses that DOE needs to address. The current regulation focuses primarily on beryllium exposures in a controlled work area, but needs strengthening in the areas of monitoring for and controlling the potential spread of beryllium contamination beyond that controlled area. Furthermore, there is no recognized model for evaluating possible exposure pathways and risk to humans from beryllium contamination, which results in difficulties in identifying, mitigating, and controlling beryllium-contaminated areas and articles.

The team concluded that one of the root causes of this event was that NSO and the responsible contractors did not recognize the potential for removable beryllium contamination from historic activities at NTS to exist at levels adequate to represent a possible hazard to the current workforce. Archived records document the wide range of historic activities at the NTS involving large quantities of beryllium, and the significant potential for residual contamination from at locations where these activities were conducted. However, the team established that there was a lack of awareness of that history among the current NSO and contractor management, which is possibly due to significant staff reductions after testing ceased in 1992. The team identified multiple opportunities for this situation to have been identified between 1986 and the current time, but those opportunities were missed.

The team also concluded that the other root cause of this event was the failure to recognize the potential for the tracking of non-radiological contamination between the NTS and NLV as a potential exposure pathway. There are mechanisms in place to control the spread of radioactive contamination, but not for other contaminants. In this event, the contaminant was beryllium, but the team concluded that most of the causes identified in this event represent commonalities that are present in the site practices, regardless of the contaminant. The team believes that this issue represents a vulnerability that NSO and its contractors must address in the broader context of all possible contaminants, rather than just beryllium.

The NTS is a unique site, both in its capabilities and its historic activities. Many of the activities conducted at that site over the years could not have been conducted elsewhere, and the magnitude of scale, the complexity of the tests, and the large number of participating organizations and individuals all increase the difficulty of managing the site. However, the team believes that the only item unique to this event is the magnitude of the resulting impacts. The inadvertent spread of particulate beryllium outside of controlled work areas, and the ability of that contamination to cause health effects, have been observed and documented in multiple occurrences since 1947. The DOE has been actively engaged in updating its requirements and reviewing beryllium-related activities and exposures within the DOE complex since 1984. The magnitude of this event, and the eventual cost to the complex, only add emphasis to the need for DOE to maintain a detailed record of past activities at its sites, an active effort to assess the residual hazards from those activities, and a strong mechanism to ensure that the resulting information is available to and used by the current site DOE and contractor management.

Causal Factors and Judgments of Need

The investigation process is designed to lead the team to the determination of the event's causes, from which the judgments of need are then derived. The **direct cause** is the immediate event or condition that caused the observed effects. **Root causes** are events or conditions that, if corrected, would prevent recurrence of this and similar events. **Contributing causes** are events or conditions that collectively with other causes increase the likelihood of the event but that individually did not cause the event (contributing causes are tabulated in section 3.7, and are cross-referenced to the root causes and judgments of need). **Judgments of Need** (JON) are managerial controls and safety measures believed necessary to prevent or minimize the probability of recurrence.

DIRECT CAUSE: Personnel were unknowingly exposed to particulate beryllium contamination in their work areas, resulting in a diagnosis of chronic beryllium disease for one individual and multiple individuals diagnosed with beryllium sensitization.

ROOT CAUSES: NSO and the responsible contractors did not recognize the potential for removable beryllium contamination from historic activities at NTS to exist at levels adequate to represent a possible hazard to the current workforce. The potential for tracking of non-radiological contamination from NTS to NLV was not recognized as a possible exposure pathway.

No.	Judgement of Need	Related Causal Factors
JON 1	NSO needs to review the roles and responsibilities that it has contractually assigned to the various site contractors to ensure that the environment, safety, and health responsibilities of individual contractors, and their interfaces with the other contractors, are clearly defined, appropriate, and complete.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 2	NSO needs to ensure that all current and planned activities at NTS (including Work-for-Others) are evaluated for the possibility of personnel exposure to residual beryllium contamination from historic activities.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)

No.	Judgement of Need	Related Causal Factors
JON 3	NSO needs to ensure that the hazards identification processes used by contractors at NTS explicitly consider beryllium as a possible contaminant for all work at NTS.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 4	NSO needs to ensure that the full extent of the spread of beryllium contamination (including NTS, NLV, and offsite locations) is determined, and that mitigative or corrective actions are established as appropriate.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)

No.	Judgement of Need	Related Causal Factors
JON 5	NSO needs to ensure that historic site records are collected and consolidated to document the historic beryllium activities conducted at NTS and NLV, and NSO needs to ensure that this information is used in the hazard identification and evaluation processes of the contractors conducting work at NTS and NLV.	Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 6	NSO needs to ensure that occupied buildings at NTS and NLV are regularly monitored for the potential introduction and spread of beryllium into uncontrolled areas, at least until the extent of the beryllium contamination has been determined and evaluated and controls have been identified and implemented.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6)
JON 7	NSO needs to establish a process to ensure the continuity of the historical knowledge base across contract and staff changes to avoid a similar event in the future.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6)

No.	Judgement of Need	Related Causal Factors
		Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 8	NSO needs to ensure that NTS is evaluated for other possible non-radiological contaminants, identified from the historic records, that could be spread into uncontrolled areas in a manner similar to this event.	The potential for tracking of non-radiological contamination from NTS to NLV was not recognized as a possible exposure pathway. (RC2)
JON 9	BN needs to conduct a complete baseline inventory of beryllium activities and possible locations of contamination in accordance with the requirements of 10 CFR 850.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 10	IT/SHAW needs to reconsider the decision to not implement the requirements of 10 CFR 850 for their work activities.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3)
JON 11	BN and IT/SHAW need to review their current work control processes to ensure that the lessons learned from this event are adequately addressed, especially in regard to ensuring that the hazard identification and evaluation processes are robust in considering all possible hazards and are consistently applied in all work situations.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3)

No.	Judgement of Need	Related Causal Factors
		Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 12	BN and IT/SHAW need to review current industrial hygiene practices based on the lessons learned from this event to ensure that monitoring and evaluation of workplaces are conducted with an understanding of both the current and the historic uses of the facility.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 13	NNSA and NSO need to review current roles and responsibilities, based on the lessons learned from this event, to ensure that oversight of NTS and NLV contractors is appropriate and focused on establishing a full understanding of possible hazards that may be present from both current and historic activities.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)

No.	Judgement of Need	Related Causal Factors
JON 14	DOE needs to develop a risk assessment process for evaluating beryllium exposure pathways.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) There is no adequate DOE guidance on how to conduct a baseline inventory for potential beryllium-contaminated locations. (CC4) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5)
JON 15	DOE needs to review 10 CFR 850 against the lessons learned from this investigation, especially focusing on (1) the narrow focus of the rule's application; (2) the lack of requirements for beryllium contamination limits in uncontrolled areas; and (3) the lack of requirements for monitoring the spread of contamination into uncontrolled areas adjacent to or accesible from beryllium-controlled areas.	Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) There is no adequate DOE guidance on how to conduct a baseline inventory for potential beryllium-contaminated locations. (CC4) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5)
JON 16	DOE needs to provide additional guidance on the implementation of 10 CFR 850 requirements especially focusing on (1) DOE expectations for the conduct of the required baseline inventory; (2) the control of the spread of contamination outside of beryllium-controlled work areas; (3) technical limitations on sampling techniques for evaluating removable beryllium contamination in non-operational situations such as office areas.	There is no adequate DOE guidance on how to conduct a baseline inventory for potential beryllium-contaminated locations. (CC4) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5)

No.	Judgement of Need	Related Causal Factors
JON 17	DOE needs to develop processes to improve its ability to respond to an incident of this nature, and to ensure that decisions regarding the protection and evaluation of affected personnel, their relocation from suspect workplaces, and the investigation process are based on established policies and standards to the extent possible.	This is based on observations of the event response, and not causal factors. There was no policy or guidance for the decision to relocate workers from the buildings, such as criteria for establishing the need for relocation, or identifying who has the authority to commit resources. The DOE Accident Investigation procedures do not provide guidance on conducting extended-duration investigations, nor on investigations involving situations with no clearly defined initial event.
JON 18	DOE needs to review the medical surveillance processes for beryllium exposures to ensure that the lessons learned from this event are incorporated.	This is based on observations of the event response, and not causal factors. There is no accepted risk assessment model for inhalation of beryllium, which limits the ability to apply exposure pathway models to the evaluation of exposure scenarios. The occupational medicine community is still undecided on the value of the beryllium Lymphocyte Proliferation Test as a screening tool in the absence of workplace indications of possible beryllium exposures. The background incidence rate of beryllium sensitization in the general public is unknown, which complicates the screening of beryllium sensitization clusters in a population. The magnitude and impact of the beryllium sensitization tests' false positive and false negative rates are not well known. The clinical definition of CBD needs to be reviewed and standardized to improve consistent application of disease diagnosis.

INVESTIGATION OF BERYLLIUM EXPOSURE CASES DISCOVERED AT THE NORTH LAS VEGAS FACILITY OF THE NATIONAL NUCLEAR SECURITY ADMINISTRATION

1.0 INTRODUCTION

In March 2002, the National Nuclear Security Administration's (NNSA) Nevada Site Office (NSO) was notified by one of its site contractors that an employee from the North Las Vegas Facility (NLV) had been diagnosed with Chronic Beryllium Disease (CBD). That employee had never been knowingly exposed to beryllium in the workplace. Subsequently, NSO and the site contractors offered voluntary medical testing for affected employees due to widespread concerns engineered by this diagnosis. Ultimately, eleven other employees at NLV, out of more than 450 tested, were found to be sensitized to beryllium, although no other cases of CBD have been diagnosed among those who have completed clinical evaluations. Several of these employees, similar to the initial CBD case, had never been knowingly exposed to beryllium. The only identified connection between many of the cases and any potential beryllium exposure was found to be the complex of buildings in which they worked, known as the "B-complex". There are three connected buildings in the B-complex, designated as B1, B2, and B3. The sensitization rate, for those with no previous exposure histories, was about 5% in B1 and about 2% in B3. All of the cases from the other NLV buildings were believed to be due to previous known exposures to beryllium. The background rate for sensitization in the public is not well established, but has been estimated to be less than 1%. The B1 building formerly housed a machine shop that processed a variety of metals, including beryllium alloys and metal, and B3 contained smaller workshops where it was suspected that occasional beryllium work might have occurred. Both of these shop areas had been removed during building renovations in 1994. The initial monitoring of the buildings did not show any levels of beryllium above current DOE and industry standards. The A1 building, which is were the machine shop is currently located, was also included in this investigation due to the apparent connection with shop activities. The general overview of the NLV, including the locations of the buildings of concern is shown in Figure 1-1.

After the initial discoveries, the site contractors and the NSO chartered a series of reviews involving DOE and external subject matter experts during the months of March, June, and July 2002. When it became clear from those reviews that the concerns could not be readily resolved, and that there may be complex-wide implications, NSO requested that the NNSA Administrator charter a comprehensive investigation and evaluation of the situation. This investigation was chartered onAugust 22, 2002.

At the time this investigation was chartered, the accident investigation criteria of DOE Order 225.1A, *Accident Investigations*, had not been exceeded. However, it was recognized that those criteria might later be exceeded

What is Beryllium?

Pure beryllium is a hard, grayish metal. In nature, beryllium can be found in compounds in mineral rocks, coal, soil, and volcanic dust. Beryllium compounds are commercially mined, and the beryllium purified for use in electrical parts, machine parts, ceramics, aircraft parts, nuclear weapons, and mirrors. Beryllium compounds have no particular smell.

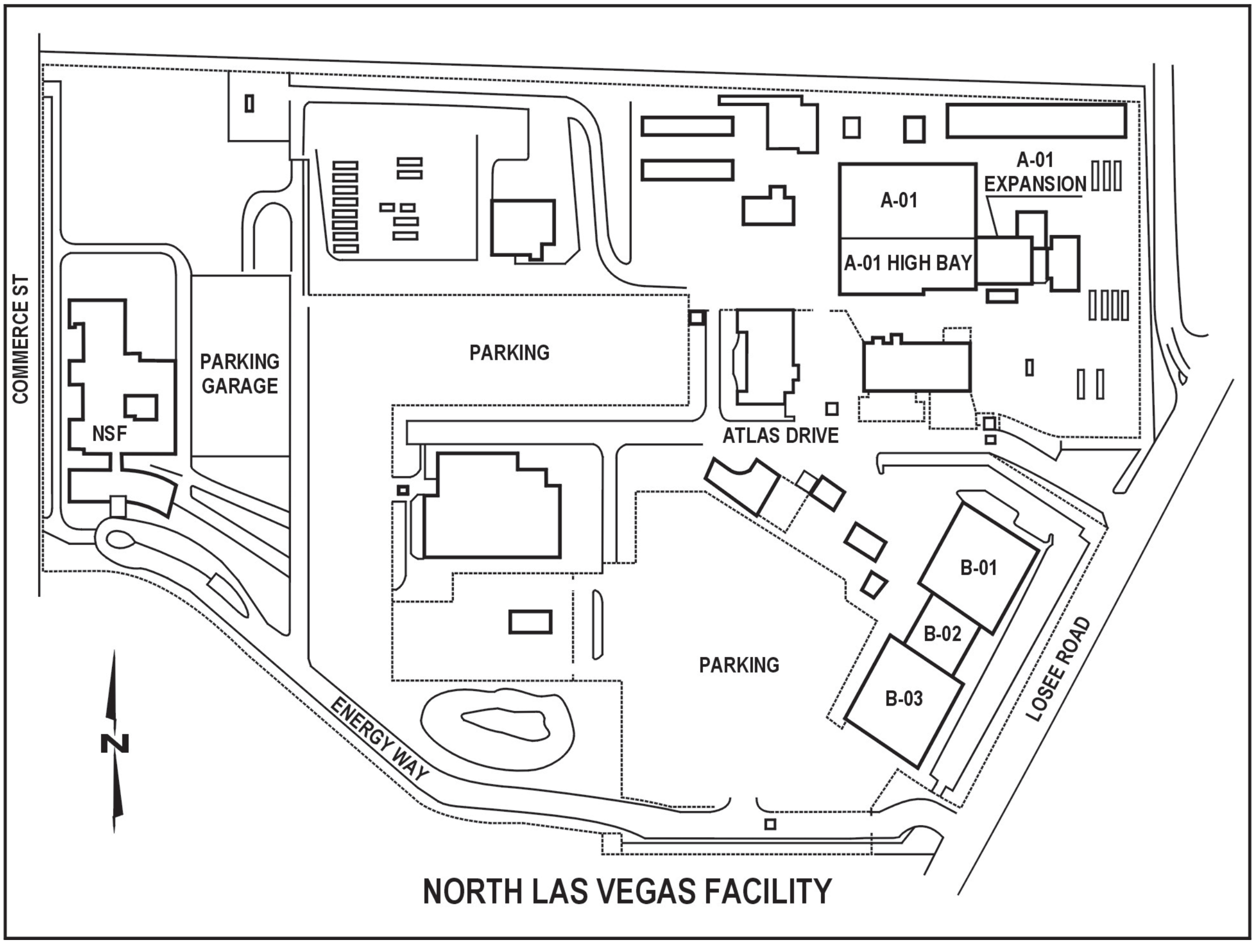

Figure 1-1: Overview of the North Las Vegas Facility.

as the response to the concerns progressed, and therefore the investigation was established to be functionally equivalent to a Limited Scope Accident Investigation. Consequently, the investigation was performed consistent with the direction provided by DOE Order 225.1A.

Due to the nature of the concerns, the investigation team was composed of a multi-agency group of subject matter experts from NNSA headquarters and field elements, DOE's Office of Environment, Safety, and Health, the National Institute for Occupational Safety and Health (NIOSH), and the Department of Defense's Naval Environmental Health Center. All team members were Federal employees, and were assisted by technical advisors as necessary. The team leader was Dr. Douglas Minnema of the NNSA Service Center's Environment, Safety, and Health Department.

1.1 Purpose of the Investigation

The task of the investigation team was to determine what happened, why it happened, what needs to be done to prevent recurrence of a similar event, and to disseminate lessons learned to NNSA, NSO, and to the rest of DOE. While the immediate focus of the team was to be on the situation at NLV, they were also to consider whether the situation suggests the presence of broader implications to the DOE sites. Specifically, the team was tasked to address, as a minimum, the following questions:

- ❑ What is the history of beryllium activities at the facility in question, and is there sufficient reason to believe that the building conditions could result in the impacts observed in the workers?

- ❑ Do current medical diagnostic tests provide an adequate level of validity, accuracy, and reliability to provide a useful indicator of exposure to beryllium?

- ❑ What is the history of contact with beryllium, both occupational and non-occupational, for the impacted employees, and is there sufficient reason to eliminate other potential exposure pathways as the source of the observed effects?

- ❑ What is the technical basis for the current standards and regulations for protection against beryllium, and does this current situation imply a weakness that needs to be addressed?

At the onset of this investigation, it was assumed that the suspect buildings had been adequately characterized. However, as the investigation progressed, it became apparent that further and more intrusive characterization of the suspect buildings was necessary in order to fully evaluate all potential exposure pathways. The team assumed direct control of these activities, with support from the contractor personnel.

The team was expected to develop conclusions regarding the above questions, and to make recommendations concerning actions deemed necessary to ensure that NNSA and contractor employees are adequately protected from exposure to beryllium under all expected conditions, and to share those recommendations with the broader DOE community. Furthermore, the team was to provide specific recommendations as to the ultimate restoration or disposition of the suspect buildings. (The team's recommendation for the disposition of the buildings was released separately, and is provided in Attachment 2.) The team was also expected to reach a consensus on all conclusions and recommendations, and to allow for the inclusion of dissenting opinions if a consensus could not be reached. (The team did reach a consensus and no dissenting opinions were presented.)

1.2 Investigation Methodology

The investigation team began its onsite investigation on August 19, 2002, and completed the onsite work on March 14, 2003. During the course of this investigation, approximately 700 personnel were relocated in order to vacate the suspect buildings. Roughly 180,000 square feet of floor space in the four buildings (B1, B2, B3, and A1) was evaluated in detail, and nearly 1000 samples were submitted for chemical analysis for beryllium and other elements. Other areas were also inspected and sampled both at NLV and at the NTS. In the conduct of this investigation, the team used the following techniques, consistent with the guidance of DOE Order 225.1A, *Accident Investigations*:

- ❑ Visually inspected and photographed the suspect buildings and their surroundings, and individual items of interest to the investigation;

- ❑ Gathered facts through interviews, documents, and evidence reviews;

Why is beryllium a concern?

Beryllium dust can be harmful if you breathe it. The effects depend on how much you are exposed to and for how long. Breathing high levels of beryllium dust causes lung damage and a disease that resembles pneumonia. If you stop breathing the beryllium dust, the lung damage may heal. These high levels are above the regulatory limits established by the government, and are not normally encountered. Some people become sensitive to beryllium after exposure to low levels of dust. This is called a hypersensitivity or allergy. These individuals may develop an inflammatory reaction called chronic beryllium disease, which can occur at any time after exposure to small amounts of beryllium dust. This disease can make you feel weak and tired, and can cause difficulty in breathing. Both the short-term pneumonia-like disease and the chronic beryllium disease can cause death.

- Reviewed the NSO and contractors' actions taken prior to the chartering of the investigation team;

- Consulted with government and industry experts on the control of beryllium and the medical evaluation of personnel exposed to beryllium;

- Collected technical articles, standards, and other information from national and international sources regarding the control and assessment of beryllium in the workplace and the environment;

- Directed and oversaw the collection of a large variety of samples in the suspect buildings and had them analyzed for beryllium and other elements;

- Inspected and sampled other areas at NLV and the NTS that were identified as having possible relationships to either the suspect buildings or the work activities of the affected employees;

- Analyzed facts and identified causal factors using events and causal factors charting analysis, barrier analysis, and change analysis; and,

- Developed conclusions and recommendations for corrective actions to prevent recurrence based on analysis of the information gathered.

1.3 Facility Description

1.3.1 Physical Facility Description

The B-Complex was privately constructed in the early 1980's and leased by EG&G Energy Measurements (EG&G/EM) to provide space for the pre-staging and to support equipment fabrication requirements of DOE's nuclear testing programs (see Figure 1.3.1-1). Beginning in 1981 through the early 1990's, EG&G/EM's General Technical Services and General Management occupied Buildings B1 and B2 while EG&G/EM's support groups for Los Alamos and Sandia National Laboratories occupied B3. During this period, the B1 and B3 buildings are best described as a mix of general office and light industrial workspaces while the B2 building has always been designated as office space for management and administrative personnel.

In the early 1990's, following cessation of the nation's nuclear testing program, the B-Complex was renovated by reconfiguring the light industrial areas into a traditional office space configuration. The reconfiguration impacted all three buildings with the most significant impact to the first floor of B1. In addition to new partitioning walls and provisions to enhance habitability, essentially all office areas were carpeted and supplied with new office furnishings. The first floor of B1, the area of greatest concentration of industrial area, was completely gutted and new horizontal heating, ventilation, and air conditioning (HVAC) ducting, new ceiling tiles, new cable trays and electrical components were installed. The reconfiguration was completed in 1995 with occupancy occurring immediately. Through the latter 1990's minor reconfiguration initiatives continued to support the needs of changing missions and supplemental HVAC units were added when the original system did not provide adequate flexibility for building modifications.

Building B1 is a two-story building (see Figure 1.3.1-2) that is subdivided into two sections of roughly equal areas. The western side of the building is a single-level high bay of about 20,000 square feet (ft^2), with concrete floors and two mezzanine areas. The eastern side of the building is configured for two stories of light offices and work cubicles (about 20,000 ft^2 for each floor). The office areas and hallways are carpeted, with suspended ceilings with commercially available acoustic tiles. Some internal walls are standard stud and sheetrock construction, while others are movable partitions, many of which are fabric covered. Heating, ventilation, and air conditioning for the building are provided separately for the two sections. The high bay area is provided with evaporative coolers, space heaters, and passive ventilators, while nine commercial air-handling units on the roof of the building service the office area.

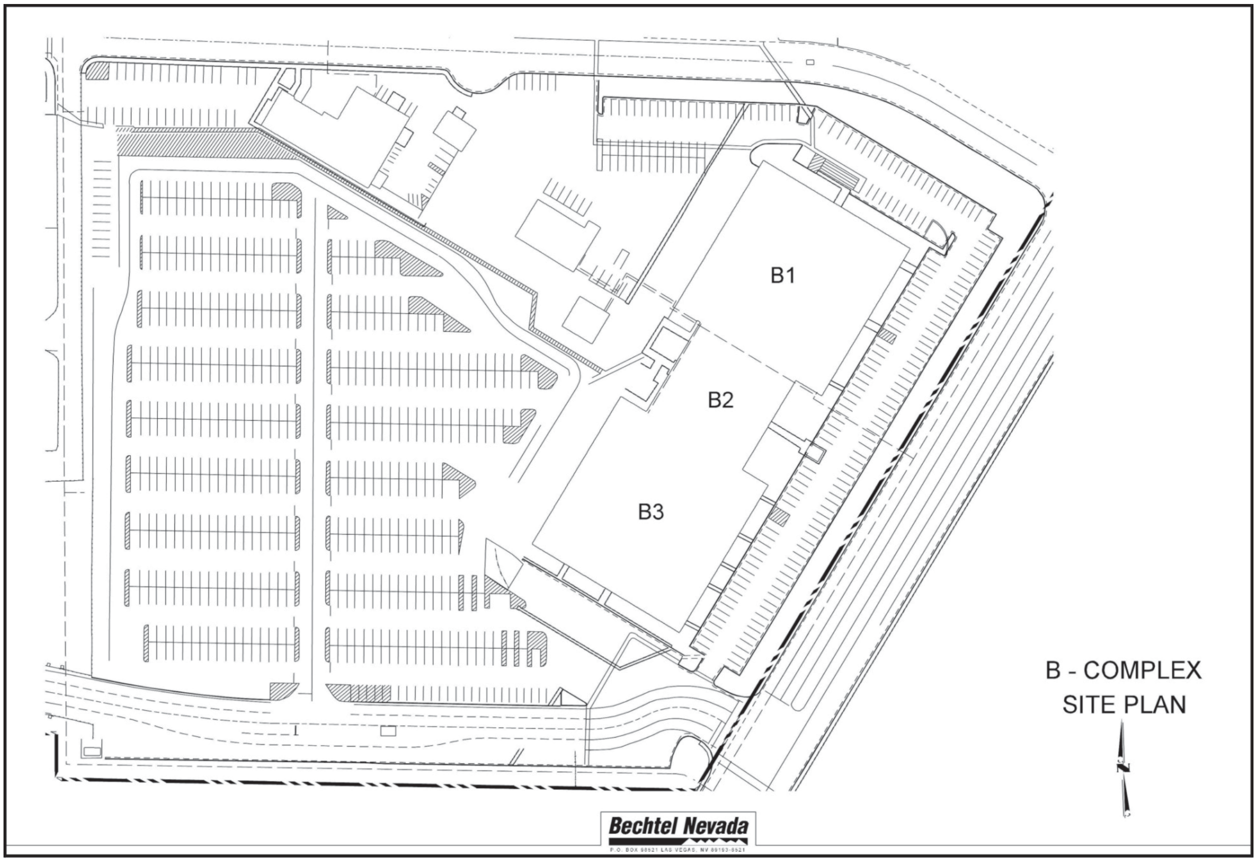

Figure 1.3.1-1: Site plan view of the B-complex.

Before the 1995 renovations, the B1 building contained numerous light industrial activities including: a comprehensive machine shop, sheet metal shop, metal plating and silk screen capability, areas for general mechanical inspection, and several miscellaneous bench laboratory modules. The second floor housed an electronic assembly and inspection area and general office space. The high bay area was used primarily for test trailer fabrication and assembly but also contained metal and wood working equipment.

Building B2 is a single story building of 14,500 ft^2 (see Figure 1.3.1-3), located between B1 and B3, and adjoining both buildings. The south door of B1 accesses the B2 hallway, and similarly the north door of B3 accesses the B2 hallway at the opposite end. The building contains the BN executive management suite, other light offices, and conference rooms, is fully carpeted, and has a suspended ceiling with acoustic tiles. All HVAC services are provided by roof-mounted air-handling systems.

Figure 1.3.1-2: Exterior view of building B1.

Figure 1.3.1-3: Exterior view of building B2.

This building was added shortly after the completion of B1 and B3. The B2 building has remained largely unchanged with only minor interior reconfigurations and updates.

Building B3 contains two floors of light offices (see Figure 1.3.1-4), with a central atrium area open to both floors. The first floor has about 40,000 ft^2, and the second floor has about 37,500 ft^2 (the difference being the open area of the atrium). As with B1, the interior spaces are divided by a combination of sheetrock walls and movable partitions. All areas are carpeted, and the ceiling is the same suspended ceiling design with acoustic tiles as in B1 and B2. Sixteen main roof-mounted air-handling units, with some small units for individual areas, service the building.

Before the 1995 renovations, the B3 building housed management and engineering functions and NTS trailer/pre-staging support functions. B3 also housed EG&G/EM's support groups for Los Alamos and Sandia National Laboratories. It contained several special purpose areas including; materials engineering, microelectronics, optical engineering, microwave laboratory modules, prototype machine shop, circuit board fabrication areas, and photographic laboratory.

Building A1 is a two-story structure, subdivided into two halves, one with two floors and the other with a single floor high bay area (see Figure 1.3.1-5). The first floor and high bay area contains heavy machine and fabrication work areas. The second floor is primarily light offices and equipment rooms for various purposes. Due to the nature of the work performed in the machine shops, this building is considered critical for the mission of maintaining test readiness at NTS. The first floor of this building mainly has concrete or tile floors, and only some areas have suspended ceilings with acoustic tiles. The second floor is carpeted and does have the suspended ceiling with acoustic tiles. Due to the current limitations of the testing mission, this building is sparsely populated.

Construction of the A1 building was completed in late 1976 and included the main fabrication building, office space, and source range test components at the basement level. Over the following fifteen years, the A-complex was expanded with the most notable addition of the high bay expansion [twin towers] project. These facilities provided a controlled environment for fabrication and assembly of underground testing fixtures and high strength testing equipment used for canister quality control.

Figure 1.3.1-4: Exterior view of building B3.

Figure 1.3.1-5: Exterior view of building A1.

Additionally, detector fabrication and testing activities dominated the balance of shop and office space. The A1 building originally contained the machine shop that was located in B1 from 1981 to 1994, and in 1994 that shop was brought back into a large centrally located room near the A1 high bay area. This shop has continued to machine and fabricate metal alloys containing beryllium through early 2002.

1.3.2 Facility and DOE Management Lines

This section is intended to provide a broad understanding of the NSO mission and how that mission is executed. The description will then focus on the missions and responsibilities germane to the circumstances surrounding the subject matter in this report. As such, the roles and responsibilities of the line management organization(s), applicable support organizations, and corresponding contractors will be discussed. The NSO Functions, Responsibilities and Authorities Manual provides a more complete description of the NSO mission and corresponding organizational responsibilities.

NSO manages the NTS, the Remote Sensing Laboratory-West in Las Vegas, Nevada; the Special Technologies Laboratory at Santa Barbara, California; some Los Alamos National Laboratory functions, the Remote Sensing Laboratory-East at Andrews Air Force Base, Maryland; and the North Las Vegas Complex. These facilities enable and provide scientific expertise for the missions of DOE and NNSA's National Laboratories. The missions of NNSA/NSO are broadly categorized as (1) National Security; (2) Environmental Management; (3) Technology and Economic Diversification; (4) Energy Efficiency and Renewable Energy; and (5) Stewardship of the NTS.

Given the diversity of its customers and missions, NSO serves as the integrator for activities conducted under their purview. NSO relies on an Integrated Safety Management Program that specifies formal work control mechanisms used to identify individual activities that should be conducted under their purview; ensures that work is properly planned; risks are analyzed and controlled; and, ensures that work is appropriately authorized and appropriate documentation maintained. Once work is initiated, NSO is required to provide oversight commensurate with the inherent risks associated with the work performed.

Environmental Management Programs are conducted under NSO cognizance to remediate the environmental contamination legacy of nuclear weapons testing and to safely dispose of low-level radioactive waste generated by activities throughout the DOE complex. The NSO Manager has delegated the authority for day-to-day management of these programs to the Assistant Manager for Environmental Management (AMEM).

The role of AMEM is to ensure assigned missions are successfully accomplished in a manner that protects the health and safety of workers, the public, and the environment; and, promotes public trust. As such, AMEM provides the programmatic and technical project management assets necessary to conduct environmental remediation project work, including all investigation, assessment, and corrective action work in accordance with required regulatory parameters.

The AMEM has delegated responsibility for day-to-day management of the Nevada Environmental

Restoration Project to the Director of the Environmental Restoration Division. The Environmental Restoration Division manages four key project activities that support the environmental remediation mission: the Soils Project, the Underground Test Area Project, the Offsite Project, and the Industrial Sites Project.

The Director of the Environmental Restoration Division (ERD) has delegated responsibility and authority for day-to-day management of these individual projects to project managers within the Division. The Soils Project is designed to characterize, assess and perform applicable corrective actions for contaminated surface and near-surface soils on and off the NTS. The Underground Test Area Project is designed to characterize, assess and perform applicable corrective actions for those areas once used to support underground testing of nuclear devices on the NTS. The Industrial Sites Project is designed to assess and perform applicable corrective actions for abandoned industrial-type contaminated sites and facilities on the NTS and Tonopah Test Range. The Offsites Project is designed to conduct similar studies at former underground test areas that are remote from the NTS. To accomplish these projects, ERD manages, in part, the Management and Operating (M&O) contractors and several technical support organizations and contracts.

IT/SHAW (the contract was originally awarded to IT Corporation, and in March 2002 IT Corporation was sold to SHAW Environmental) provides environmental assessment, characterization and architect-engineering services at the NTS, Tonopah Test Range, Nellis Air Force Range and other locations in and out of Nevada. The services include: (1) conducting preliminary and field assessments for the characterization of Corrective Action Units to determine the extent, source and concentration of contaminants [physical, chemical and radiological constituents], (2) developing supporting characterization studies and corrective action methodology, and (3) preparing supporting documentation.

Bechtel Nevada (BN) manages operations at the NTS and its related facilities and laboratories. Bechtel Nevada is organized into five Programs to perform work: Stockpile Stewardship, Test Readiness and Infrastructure, Environmental Management, National Security Response, and Combating Terrorism. Within the Environmental Management Program, the Environmental Restoration Program is responsible for the management and remediation of legacy-contaminated sites. This program includes large area surface soil contamination removal and restoration; underground test area geologic and hydrogeologic investigation, well installation and sampling, and groundwater modeling; the remediation of industrial sites and facilities; and, the remediation of contamination at off-sites. Additionally, BN provides overall operations support such as radiological protection, industrial safety, fire protection, industrial hygiene, and maintenance operations.

The DOE National Laboratories, Desert Research Institute, U.S. Geological Survey, and other NTS contractors and site facility users each provide some level of technical support to the environmental remediation activities. This support includes field analytics, specialty borehole geophysical logging, ground water characterization, independent review of documentation packages, and radiochemical analysis.

The NSO Assistant Manager of Technical Services is responsible for management and oversight of ES&H, engineering and facility management, safeguards and security, nuclear safety, as well as the Facility Representative Program for all facilities under the purview of NSO. The Environment, Safety, and Health Division is responsible for the management and oversight of the contractor-operated industrial hygiene program that provides traditional industrial hygiene services to NTS workers and users. Subfunctions include: health hazard inventories, workplace air monitoring, hearing conservation, carcinogen control program, hazard communication, non-ionizing radiation, lead, ergonomics, confine space entry, asbestos, field survey equipment, sanitation, beryllium, high efficiency particulate air filters, respiratory protection, and toxic/hazardous substances.

1.3.3 Initial Contractor Response to Event

In late 2001, an employee who was domiciled in the North Las Vegas complex building B1 was diagnosed with CBD. The particular employee was a teaming partner to IT/SHAW, one of two M&O contractors to NSO. IT/SHAW had responsibilities for environmental characterization at the NTS. NNSA/NSO and BN, the other M&O contractor and landlord of the building, were informed of the diagnosis in early March 2002. Bechtel Nevada and IT/SHAW immediately started to characterize the B1, B2, and B3 buildings by collecting industrial hygiene air and swipe samples. As soon as the initial sample results were available, NSO, in agreement with IT/SHAW and BN management, decided to offer occupants of the three buildings medical screening tests known as Lymphocyte Proliferation Tests (LPT). This offering was later expanded to occupants of A1 and others who had involvement with the B-complex buildings. The initial LPT results identified four persons who were sensitized to beryllium, as of June 24, 2002.

In June 2002, because of identification of additional sensitization cases, NNSA/NSO management asked for a team of subject matter experts to visit the North Las Vegas complex to do an initial evaluation of the evidence. A team from NNSA, EH, and an independent pulmonologist with expertise in dealing with CBD, visited the site the first week of July. That team recommended a thorough evaluation of the buildings and the cluster of one medical diagnosis of CBD and four cases of sensitization. The team also recommended that as many of the B-complex occupants as possible be encouraged to submit to the LPT screening. In addition, that team recommended that management start considering the removal of occupants from the three B buildings in case the thorough evaluation indicated the building was the problem.

After the July visit, the medical screenings continued to find additional sensitization cases, but the evaluations of the buildings were unable to provide an adequate explanation. The continued concern over this situation is what prompted this investigation.

2.0 THE EVENT

This section will describe the team's evaluation of the buildings and their conclusions as to possible origins of the observations. Unlike a normal accident investigation, in this case there was no single situation that could be identified as the initiating event. The only postulated source for the exposures was deemed to be residual beryllium contamination from the machine shop contained in B1 from 1982 to 1994. However, the presence of any significant beryllium contamination in the building could not be confirmed. Prior to the onset of this investigation, the contractors had conducted an extensive survey of the buildings to evaluate this possibility, taking both air samples and a large number of swipe samples of hard surfaces. (Swipe samples are taken to determine the amount of removable surface contamination that may exist in work areas.) The air sample results indicated that there were currently no elevated levels of airborne beryllium in the buildings, and the swipe samples indicated only very low levels of removable beryllium contamination, well below any current standards. Therefore, the building was considered to be safe for normal occupation, and the observed beryllium exposures could not be explained. As a result, this team focused its efforts on attempting to determine whether conditions may have existed in the past that could account for the observed medical results.

2.1 Initial Surveys Conducted Prior to Investigation

After the initial report of a case of CBD and several incidences of beryllium sensitizations among the residents of the B-complex, a joint team from BN and IT/SHAW undertook an extensive survey of the buildings (B4, a small utility building, was included in this survey since it was used as a part of the B1 machine shop operation). These surveys were designed to determine the current conditions in the buildings, and mostly focused on the buildings' ventilation systems as the likely pathway for the spread of contamination throughout the building atmospheres. This was reasonable since the primary pathway for exposure to beryllium is inhalation of particles into the lungs. The results of these surveys are summarized in Table 2.1-1 below.

Table 2.1-1: Results of Initial BN Sampling of the Buildings

Building	Total Swipe Samples	Swipes Above 0.1 µg/100cm² (note 1)	Swipes Above 0.2 µg/100cm² (note 1)	Total Air Samples	Air Samples Above 0.01 µg/m³ (note 2)
B1	722 (148)	2	0	98	0
B2	56 (0)	0	0	6	0
B3	583 (122)	0	0	131	0
B4	62 (23)	0	0	20	0
A1	1,085 (412)	23*	11**	86	0
() See note 3.	* Mostly in current shop area.		** All in current shop area.		

Notes:

1. There is no directly applicable standard for removable surface contamination in uncontrolled areas. However, the DOE rule specifies a release limit for material removed from a beryllium work area at 0.2 µg/100cm², and the National Jewish Medical Research Center recommends a value of 0.1 µg/100cm². The swipe samples were compared to both standards.

2. The DOE rule mandates an exposure limit for beryllium in air for occupational beryllium workers at 2.0 µg/m³ as a time-weighted average over 8 hours (TWA), and establishes an action level of 0.2 µg/m³ TWA, above which positive controls are necessary to limit further exposures. The Environmental Protection Agency (EPA) restricts the amount of beryllium that industries may emit into the environment to an amount that would result in atmospheric levels of 0.01 µg/m³ (averaged over a 30-day period), and this value was chosen as the comparison point.
3. The values in parentheses are the number of samples that were found to be above the level of detection of the laboratory analysis technique used for their evaluation.

As mentioned, this survey focused mostly on the buildings' ventilation systems (supply and return ducts and vents), areas above the ceiling, and hard surfaces, such as desks, tabletops, walls, acoustic ceiling tiles, and shelves. Soft surfaces, such as carpets, upholstered chairs, and fabric-covered room dividers are not easily tested for surface contamination, and therefore were not evaluated.

In addition to surveying the building structures, BN also conducted an extensive survey of office equipment in these buildings, especially copier machines and computers. This was based on the fact that these machines used fans to circulate cooling air within the machines, and suspended particles would tend to settle and collect within the machines. (As an example, this phenomenon was identified as the mechanism for periodic recontamination of a building in Florida after the recent anthrax contamination events.) As with the buildings, only a few of these samples were above detection levels and none were above any established standards.

In another effort, IT/SHAW took a series of soil samples in the vicinity of the B-complex to evaluate the possibility of an environmental source for the beryllium exposures through a mechanism such as atmospheric suspension from the local soil. Those tests indicated a beryllium concentration in the local soil ranging from 0.24 to 0.48 µg/g, which are typical values for environmental beryllium levels, and do not represent any levels of concern.

In April 2002 BN also had the carpeting in B1 and B3, and the concrete high bay area of B1, cleaned with a commercial carpet cleaner. The water from the cleaning equipment was collected from each floor separately, and was sampled for beryllium before release. None of those samples exceeded the North Las Vegas Municipal Code limit on discharge of wastewater containing beryllium, which is 0.2 milligram per liter.

Relocation of the occupants of the suspect buildings had been discussed and planned through much of this period. In August 2002 the decision was made to proceed with relocating the occupants of B1, B2, B3, and the second floor of A1 to allow this investigation to conduct an intrusive evaluation of the buildings. Before the relocation occurred, BN conducted another statistically based survey of the building environments. Also, some personal effects were swiped and some breathing zone air samples were taken to document the workplace conditions during the relocation activities. None of these samples indicated beryllium levels near or above the DOE standards.

Based on the results of these workplace evaluations, and considering the medical evaluations for beryllium exposure, BN came to the following conclusions: (1) that the medical evaluations indicated a higher than expected incidence of beryllium sensitization among the occupants of B1; (2) that the majority of sensitizations and the CBD case had no recognized prior exposure to beryllium outside of their presence in B1; (3) that the source of beryllium in the building is a pre-existing condition due to residual contamination from the former machine shop; and (4) that the sensitizations and the CBD occurred despite beryllium levels that are well below the industry standards. These conclusions were also reviewed and accepted by a peer review team of DOE, industry, and medical experts that was convened in July 2002 at the request of BN and NSO.

It was the recognition that these conclusions may have a broad impact on DOE's other facilities that worked with beryllium, and the beryllium industry as a whole, that prompted the establishment of this investigation.

2.2 Surveys Conducted by the Investigation Team

Upon initiation of this investigation in August 2002, the team reviewed all of the medical surveillance results and the workplace evaluations that BN and IT/SHAW had conducted up to that point. The team agreed at that time that the evaluations had been extensive, and justified the conclusions that had been established, but the workplace evaluations had not considered all possible exposure scenarios. Specifically, the team concluded that while the evaluations had adequately established the current conditions in the office areas, they had not evaluated all areas of the buildings, and furthermore, no conclusions could be drawn regarding possible changes in the workplace conditions between the remodeling of the building in 1995 and the current time. Therefore, the team assumed responsibility for conducting a more intrusive evaluation of the buildings after the occupants were relocated. The relocation of B1 was completed in October 2002, and the rest of the buildings (B2, B3, and A1 second floor) were vacated by December 2002. As each building became available the team proceeded to conduct an intrusive evaluation of it, focusing specifically on those areas that had not or could not be sampled while the building was occupied.

The high bay area of B1 was sampled by collecting bulk samples of dirt and debris that had accumulated in the cracks and expansion joints of the concrete floor, dust that had accumulated on the exposed conduits and pipes hanging on the walls, and other areas that might serve as collection points for dust and debris. These samples were viewed as potentially representing a cumulative history of activities in the area. All of these samples were analyzed for beryllium, copper, and aluminum. Since the contamination might have been a result of the machine shop activities, copper was analyzed here and in some other areas to test for the copper – 2% beryllium alloy, and aluminum was analyzed as another possible indicator of machine shop activities. A total of over 60 samples were collected in the high bay area.

The carpeted areas of all buildings were sampled by carefully removing one square meter sections of carpeting, and then collecting all dust and debris within each section. All of these samples were evaluated for beryllium, and some were evaluated for copper and aluminum. A total of about 275 carpet samples were taken in the six carpeted areas of the four buildings, which represent an area of about 180,000 square feet of floor space.

The ceiling areas of all buildings were sampled by carefully removing selected acoustic ceiling tiles and collecting the dust and debris from the upper surface of the tile. In some cases, swipes were also taken of those surfaces before removing the dirt and debris in an attempt to correlate swipe and bulk sample results. A ceiling tile sample was taken in the vicinity of each carpet sample, and tile samples were also taken in the high bay area of B1. In total, more that 300 tiles were sampled in this manner. Again, all samples were evaluated for beryllium, and some were evaluated for copper and aluminum. The team also had core samples taken from a number of those ceiling tiles collected, and the core samples were analyzed for beryllium content.

The ventilation systems of the B-complex buildings were sampled by collecting dust and debris samples at various locations in the systems. In most cases these samples were collected within the housing of the roof-mounted air-handling systems, but in B1 sections of several supply and return air ducts were removed and dust samples were taken from interior surfaces. All of these samples were evaluated for beryllium, copper, and aluminum.

All bulk samples were weighed after collection and shipped to an American Industrial Hygiene Association (AIHA) accredited laboratory for analysis using Inductively-Coupled Plasma Atomic Emission Spectroscopy. Bulk sampling was used rather than swipes, as it is a more sensitive and accurate measure of beryllium at low contamination levels. Also, if the surface area of the sampled location and the mass of the sample is known, then the results can be converted back into standard units of beryllium mass per unit area. BN employees under the team's supervision collected all samples, and BN work control and industrial hygiene procedures governed the work activities. A chain-of-custody record was maintained for all samples. In total, nearly 1,000 samples were collected and processed.

For bulk samples the laboratory's minimum level at which they can quantify a beryllium concentration was 0.1 μg/g. For comparison, the average beryllium concentration in soil in the vicinity of the B-complex was measured to be 0.35 μg/g. Analysis of the carpet results indicates that the background level of beryllium in the carpeting debris is slightly lower than the laboratory's minimum level. This is actually lower than the average beryllium levels in the soil outside the buildings and is due to dilution of the soil by other material, such as carpet fibers and adhesives, that was present in carpets. For this reason, the background beryllium level in the carpet debris has been set equal to the laboratory's minimum level and is normalized to the mass of each sample. Based on this approach, the average background beryllium level in the carpets was found to be 0.0077 μg/100 cm^2.

The DOE has not established a standard or regulatory limit that is directly applicable to beryllium soil or surface contamination levels in uncontrolled areas. The closest value that could be considered is the DOE limit of contamination for the release of materials from beryllium work areas. This requirement is that removable beryllium contamination on an article being removed from a beryllium work area must be less than 0.2 μg/100 cm^2. In establishing this limit, the DOE acknowledged that there is not sufficient information to establish a contamination limit based on a technical risk assessment. Therefore DOE also required that "the release is conditioned on the recipient's commitment to implement controls that will prevent foreseeable beryllium exposure, considering the nature of the equipment or item and its future use and the nature of the beryllium contamination." The team has decided to use this value as the point of comparison for the samples taken in these buildings.

2.2.1 Acoustic Ceiling Tile Results

The acoustic ceiling tiles in all of the buildings were sampled by collecting the dust that had accumulated on the upper surfaces. Initial results from the B1 building indicated that the concentration of beryllium in the bulk samples ranged from 1 to over 6 μg/g, about five to ten times higher than the background in the local soil, which was considered to be the main contributor to the dust loading. However, the observed contamination patterns did not correlate with the location of the former machine shop, nor did they correlate with any other suspected release point for the contamination. The only correlation that was observed was an apparent relationship to the age of the tile itself. As the results from the other buildings accumulated, similar results were found in all locations.

Since each acoustic tile was stamped with its production date, the team was able to collect this information for all tiles. The apparent correlation between tile age and contamination level is displayed in Figure 2.2.1-1. Furthermore, about 30 of the sampled tiles, some tiles from another building of similar vintage but not involved in the investigation, and some new tiles were sampled by taking cores of the tile material itself, and analyzing the cores for beryllium. It was found that the concentration of beryllium in the tiles also ranged over the same values of 1 to 6 μg/g, and that this concentration varied according to the production dates. When the core results and the surface samples were correlated, (see Figure 2.2.1-2) there was a clear correlation between the two values. As shown in this figure, the beryllium concentration on the surface tends to be lower or equal to the concentration in the tile, but it normally does not exceed it. (For those few where the surface value exceeds the core value, the variations are within the range of the margin of error of the analytical techniques and are not significantly different from each other.)

The team investigated this finding further and discovered that one of the natural constituents of the acoustic tiles, a clay material known as Kaolin, is known to have a naturally-occurring concentration of beryllium of about 20 μg/g. The team concluded that the upper, unfinished surface of the tiles were weathering as they aged in place, and the beryllium observed on the upper surfaces was due to the friable nature of this material. The team also concluded that based on the failure of any correlations between this contamination and other contamination patterns found in the buildings, and due to the limited total quantity of material that this contamination represented, it was not credible for this to be the source of the exposures in the buildings.

2.2.2 Building B1 Results

The B1 building, built in the early 1980's, is a two-story building, subdivided into two sections of roughly equal areas. The western side of the building is a single-level high bay of about 20,000 square feet (ft^2), with concrete floors and two mezzanine areas. In the south end of the high bay under a mezzanine area, there is a

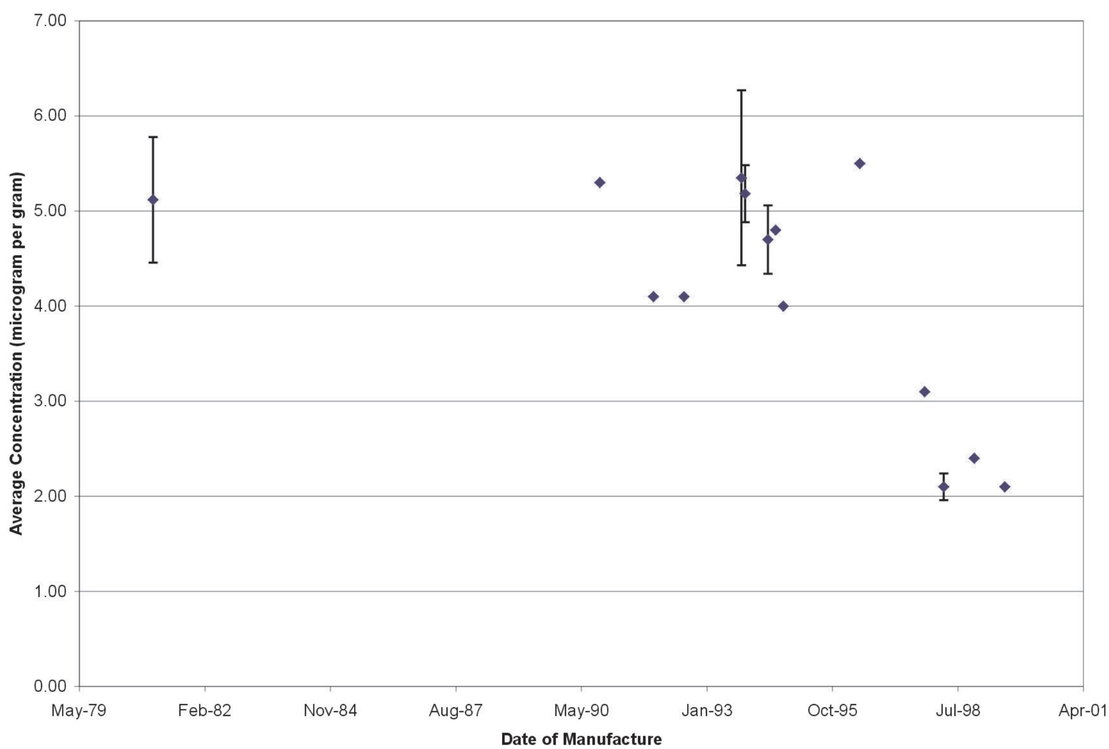

Figure 2.2.1-1: Concentration of beryllium in ceiling tiles according to tile age.

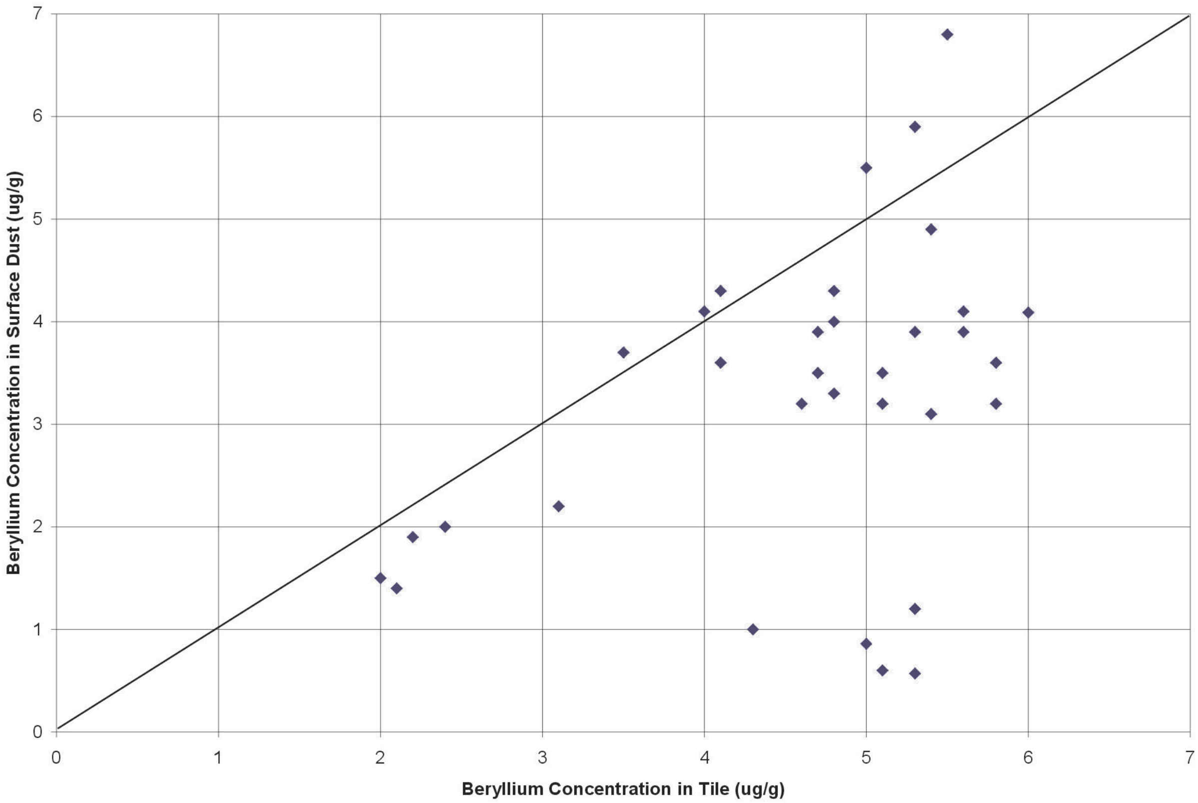

Figure 2.2.1-2: Beryllium on top of ceiling tile versus beryllium inside tile.

small carpeted work area. The eastern side of the building is configured for two stories of light offices and work cubicles (about 20,000 ft^2 for each floor). The office areas and hallways are carpeted, with suspended ceilings of acoustic tiles. Some internal walls are standard stud and sheetrock construction, while others are movable partitions, many of which are fabric covered. Heating, ventilation, and air conditioning (HVAC) for the building are provided separately for the two sections. The high bay area is provided with evaporative coolers, space heaters, and passive ventilators, while nine commercial air-handling units on the roof of the building service the office area. Some additional units were added to supplement the main units for some offices, when the original HVAC system did not provide adequate flexibility for building modifications over its years of service.

Figure 2.2.2-1 shows the contamination levels found in the B1 office and high bay areas. Removable beryllium contamination is typically specified as the mass of beryllium that is spread over a unit area (normally taken to be 100 cm^2) and therefore, the units are in terms of micrograms per 100 cm^2, or μg/100 cm^2. Note that the samples taken in the concrete areas of the high bay could not be converted into standard contamination levels since there was no related sample area. Therefore, these samples are specified as the mass of beryllium per unit mass of the sample (or μg/g). Since these units are not directly comparable to the standards, they can be evaluated by direct comparison to the naturally occurring beryllium concentration in the local soil, which was determined to be 0.35 μg/g.

In the concrete areas of the high bay, beryllium contamination was found in the southern end as shown on Figure 2.2.2-2. Several samples were found to have beryllium concentrations ranging from 0.77 to 47.0 μg/g, with the highest levels in the immediate vicinity of a loading or staging area. This area was a small shipping/receiving area for IT/SHAW (see Figure 2.2.2-3). As can be seen from Figure 2.2.2-1, the carpeted section underneath the mezzanine area at the south end of the high bay also contained elevated levels of beryllium, with one sample slightly below and the other above the 0.2 μg/100 cm^2 comparison value.

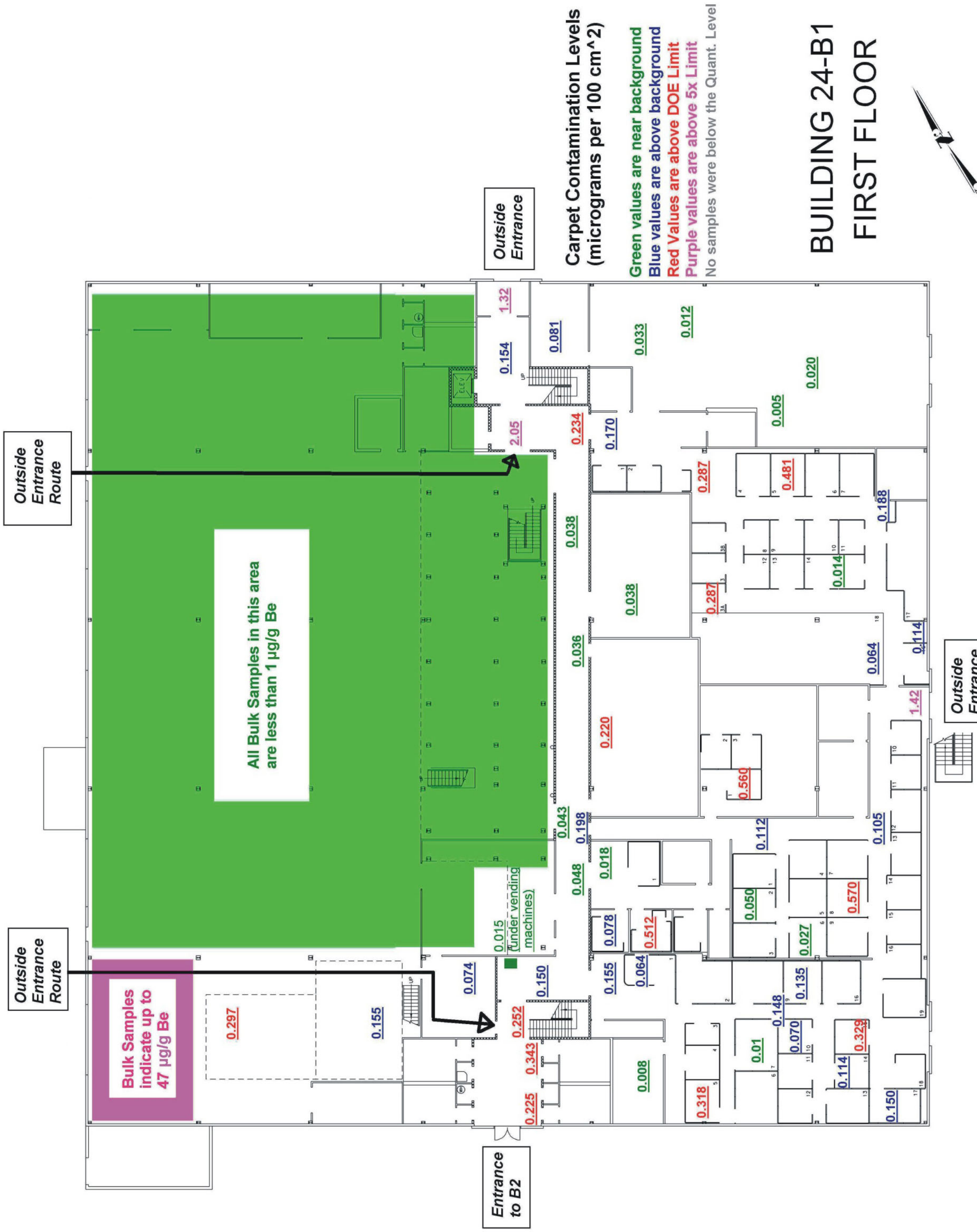

Figure 2.2.2-1: Beryllium contamination in the first floor of B1.

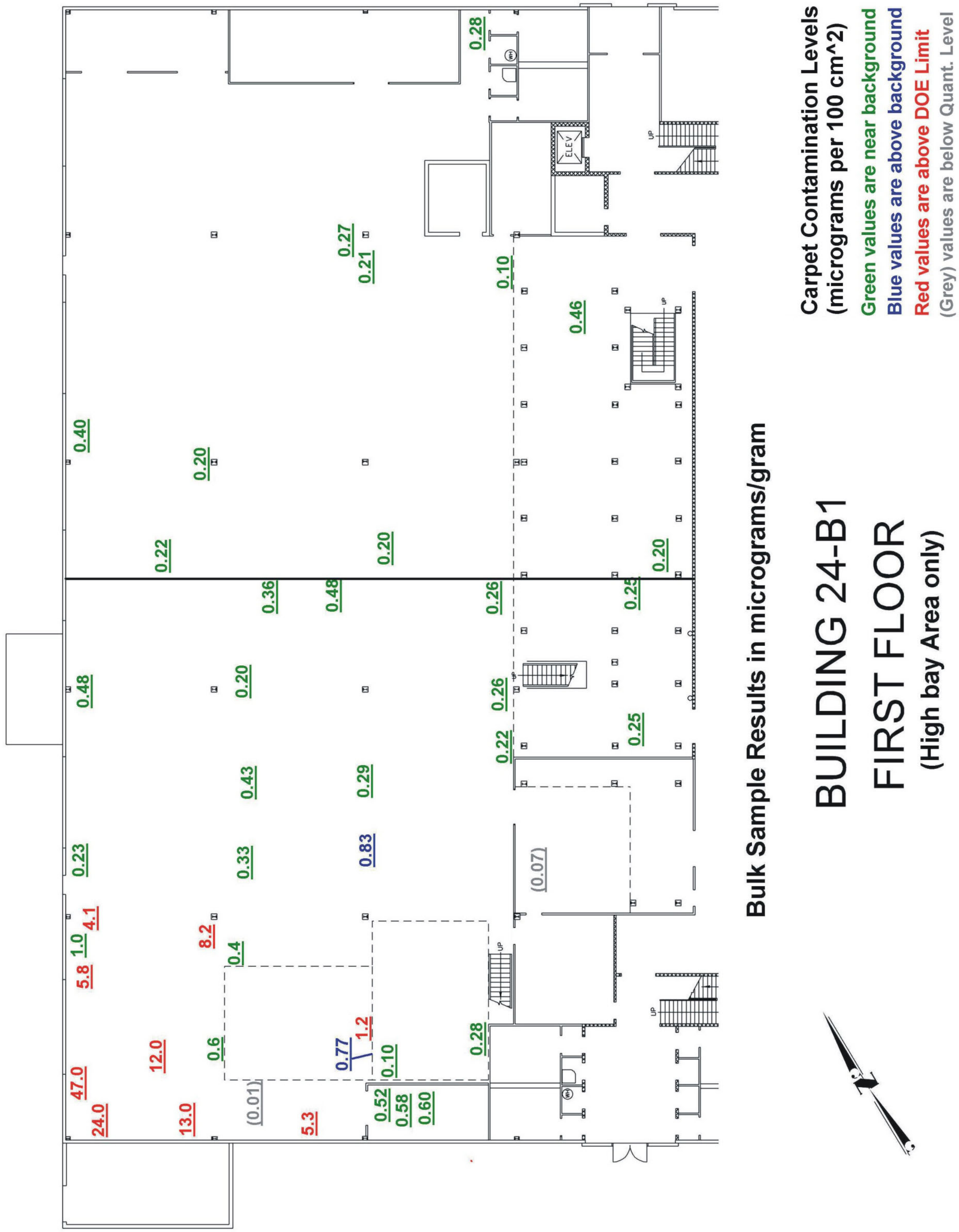

Figure 2.2.2-2: Dust contamination levels in the B1 high bay area.

Figure 2.2.2-3: IT/SHAW shipping/receiving area in the B1 high bay.

In the high bay area there are a large number of exposed conduits and pipes that contain a heavy level of dust loading. Some bulk samples were collected on these surfaces for analysis. The only samples found to be elevated were in the south end of the high bay near the IT/SHAW shipping area. The highest result was 2.6 μg/g, roughly 8 times the soil background value.

In the office areas of the eastern half of the building, beryllium contamination was found at various levels throughout the first floor, as seen in Figure 2.2.2-1. Seventeen out of the 51 samples taken in the first floor carpeting were above 0.2 μg/100 cm^2, and in fact, the average contamination level in the first floor office area is 0.248 μg/100 cm^2, which also exceeds the comparison standard. Levels were found in the first floor as high as 2.05 μg/100 cm^2. (Note that while the value of 2.05 μg/100 cm^2 is the highest absolute value, it is not the highest value relative to the background due to the high mass of the sample. This sample was only 19.7 times the anticipated background value, whereas other areas were as much as 53 times their anticipated background values.) The highest levels found in the first floor were at the normal entrances into the building. Other areas of high levels occurred in several of the offices and near the restrooms. Elevated beryllium levels were detected in most of the common hallways. Some samples taken under vending machines or in low traffic areas, such as the large room in the northeast corner of the building (which is a file room for historic archives), were significantly lower than the average values. All samples taken on this floor were clearly above the anticipated background values.

The office areas of the second floor of B1 showed a much lower level of contamination, with 18 of the 48 samples being at or below the anticipated background levels (see figure 2.2.2-4). Only 1 of the 48 samples was above the comparison value of 0.2 μg/100 cm^2. The second highest sample was 0.060 μg/100 cm^2 and was found in one of the offices. While this does not exceed the comparison value, it is elevated at about twice the background value. The average contamination level on the second floor was found to be 0.0174 μg/100 cm^2.

The mezzanine areas of the high bay area are not carpeted so swipe samples were taken of these areas and dust was collected off of exposed conduits for bulk sampling. No elevated beryllium levels were detected in the mezzanine areas over the east end of the high bay, but the samples over the IT/SHAW work area in the southwest corner of the high bay were elevated as noted above.

There were 62 dust samples taken in the HVAC systems and internal ductwork in B1. None of these samples were found to be elevated above the normal variation of the soil background, and in fact the results of HVAC sampling in all three B-complex buildings were comparable, regardless of the variations in contamination levels that were found within the buildings.

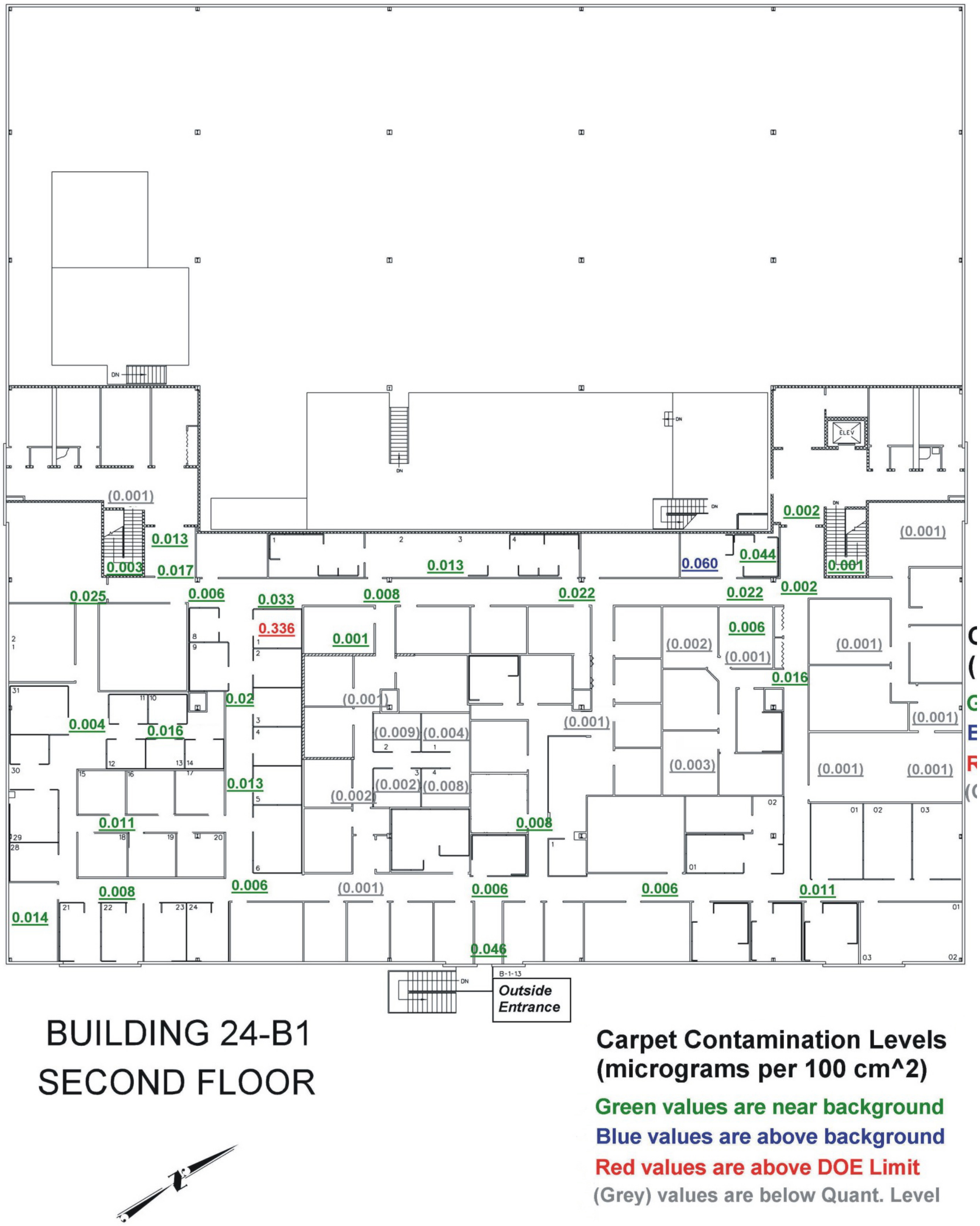

Figure 2.2.2-4: Beryllium contamination in the second floor of building B1.

2.2.3 Building B2 Results

The B2 building is a single story building of 14,500 ft^2 located between B1 and B3, and adjoining both buildings. This building was added shortly after the construction of B1 and B3 in the early to mid 1980's. The south door of B1 accesses the B2 hallway, and similarly the north door of B3 accesses the B2 hallway at the opposite end. The building contained the BN executive management offices, other light offices, and conference rooms, is fully carpeted, and has a suspended ceiling of acoustic tiles. All HVAC services are provided by roof-mounted air-handling systems.

The results of the carpet sampling in B2 are shown in Figure 2.2.3-1. Of the 29 samples taken in this area, only 6 were above the anticipated background values. Of those, only one was above the comparison value. This one sample was 0.931 μg/100 cm^2 and was found in the large conference room on the south side of the building. The average contamination value in B2 was 0.0394 μg/100 cm^2, but this value was dominated by the one high result.

There were nine samples taken in the B2 HVAC system and none were found to be elevated above background levels.

2.2.4 Building B3 Results

The B3 building is a two-story building built at the same time as B1. The building contains two floors of light offices with a central atrium area open to both floors. The first floor has about 40,000 ft^2, and the second floor has about 37,500 ft^2 (the difference being the atrium). As with B1, the interior spaces are divided by a combination of sheetrock walls and movable partitions. All areas are carpeted and the ceiling is the same suspended ceiling design with acoustic tiles as in B1 and B2. About 16 main roof-mounted air-handling units, with some small units servicing individual areas, service the building.

The results for the first floor of B3 are shown in Figure 2.2.4-1. Of the 56 samples taken on this floor, 13 were at or below the anticipated background values and none were above the comparison value of 0.2 μg/100 cm^2. However, there were elevated results found in two areas on the east side of the building (0.133 and 0.150 μg/100 cm^2), and there is a suggestion of elevated levels at the entrances on the east side of the building and other areas. The average contamination level on this floor is 0.027 μg/100 cm^2.

The results for the second floor of B3 are shown in Figure 2.2.4-2. All of the 45 samples on this floor were above the anticipated background values but none were above the comparison value. However, there were three areas where the contamination levels exceeded 0.1 μg/100 cm^2, with the highest value being 0.147 μg/100 cm^2. There were also elevated levels observed at some of the entrances to the second floor (one outside door and two samples near the top of the interior staircases). The average contamination level on the second floor of B3 is 0.037 μg/100 cm^2.

There were 37 samples taken in the HVAC for the B3 building. None were found to be elevated above background levels.

2.2.5 Building A1 Second Floor Results

The A1 building is a two-story structure, subdivided into two halves, one with two floors and the other with a single floor high bay area. The first floor and high bay area contain machine shops and fabrication work areas. The second floor is primarily light offices and equipment rooms for various purposes. Due to the nature of the work performed in the machine shops, this building is considered critical for the mission of maintaining test readiness at NTS. One of the machine shops on the first floor is the currently designated beryllium machine shop, although no beryllium work is currently underway. This is the shop that was relocated from B1 in 1994. The first floor of this building mainly has concrete or tile floors, and only some areas have suspended ceilings with acoustic tiles. The second floor is carpeted and has the suspended ceiling with acoustic tiles.

Due to the presence of the machine shops on the first floor of A1, which results in that floor being monitored under BN's normal beryllium protection program, no samples were taken. On the second floor 44 samples were taken, of which 29 were at or below the anticipated background values (see Figure 2.2.5-1).

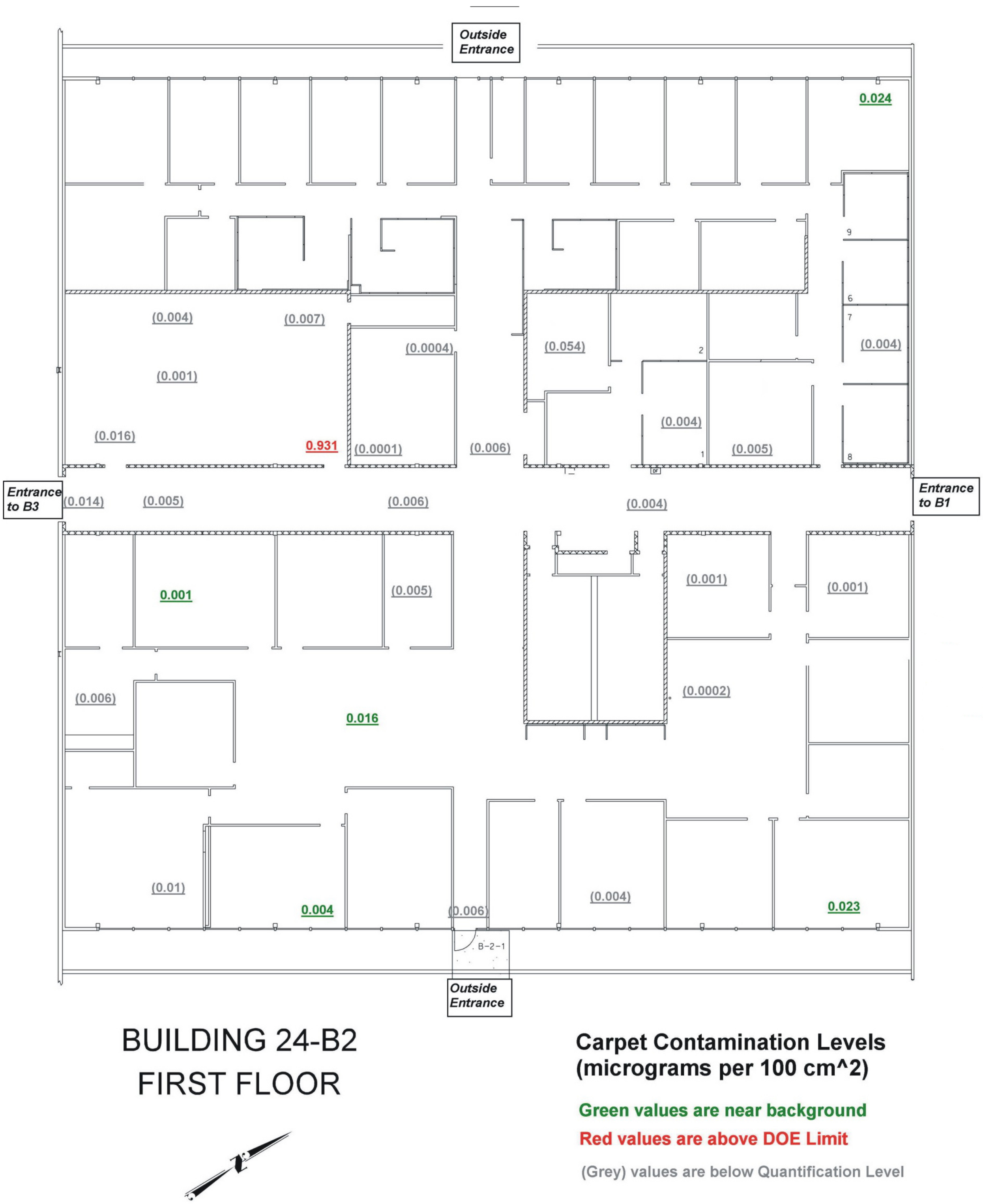

Figure 2.2.3-1: Beryllium contamination in building B2.

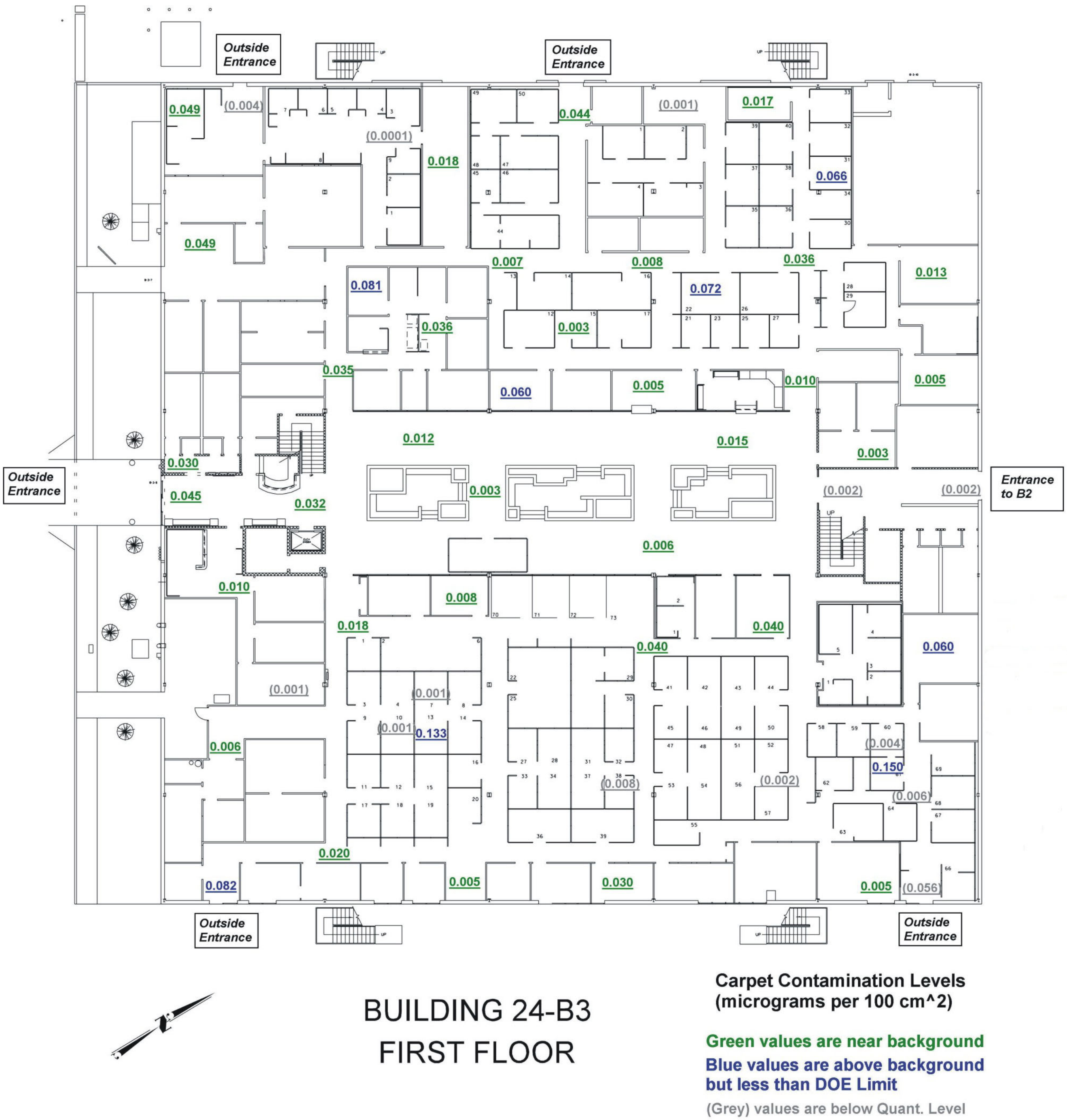

Figure 2.2.4-1: Beryllium contamination in the first floor of building B3.

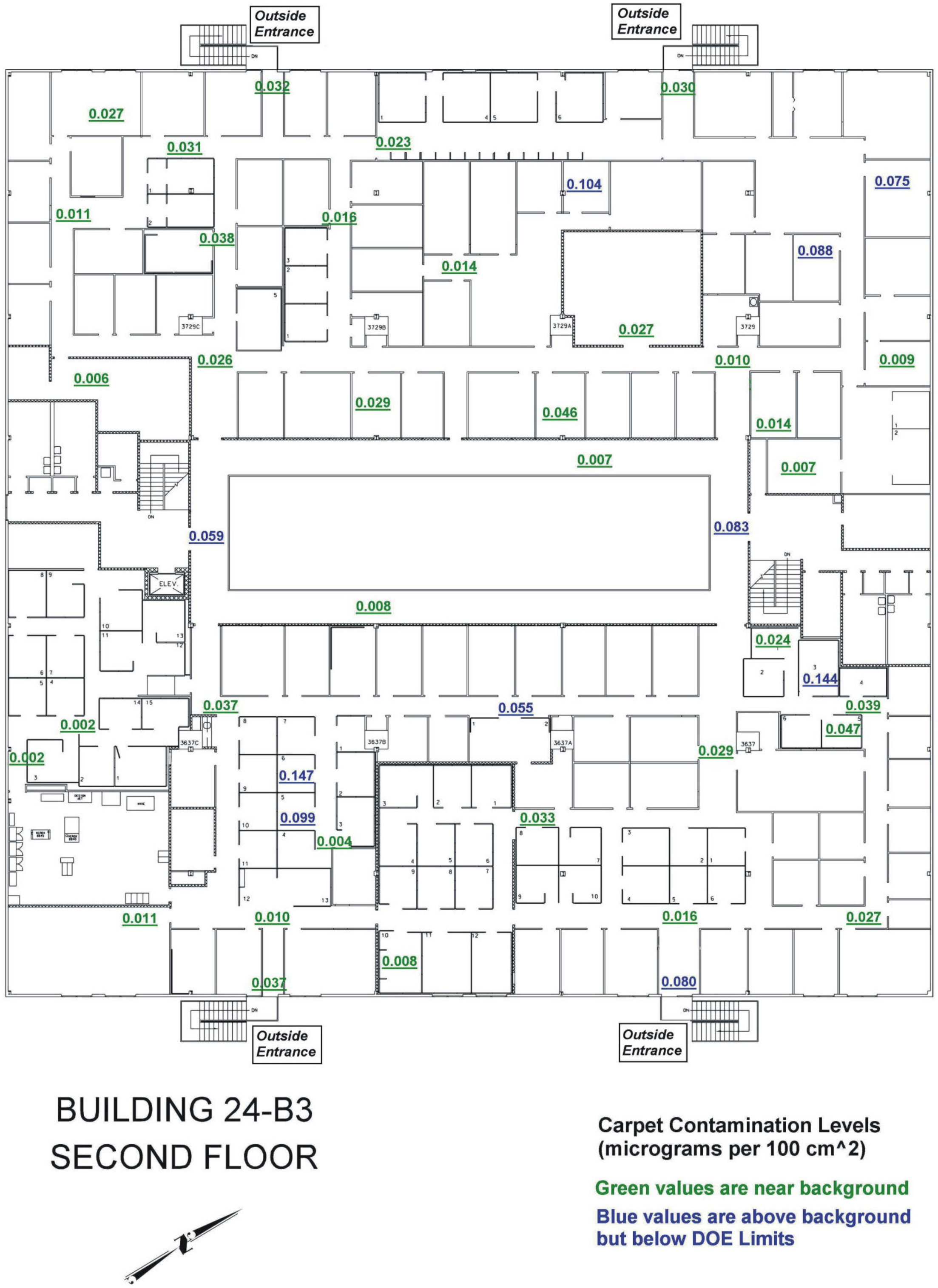

Figure 2.2.4-2: Beryllium contamination in the second floor of building B3.

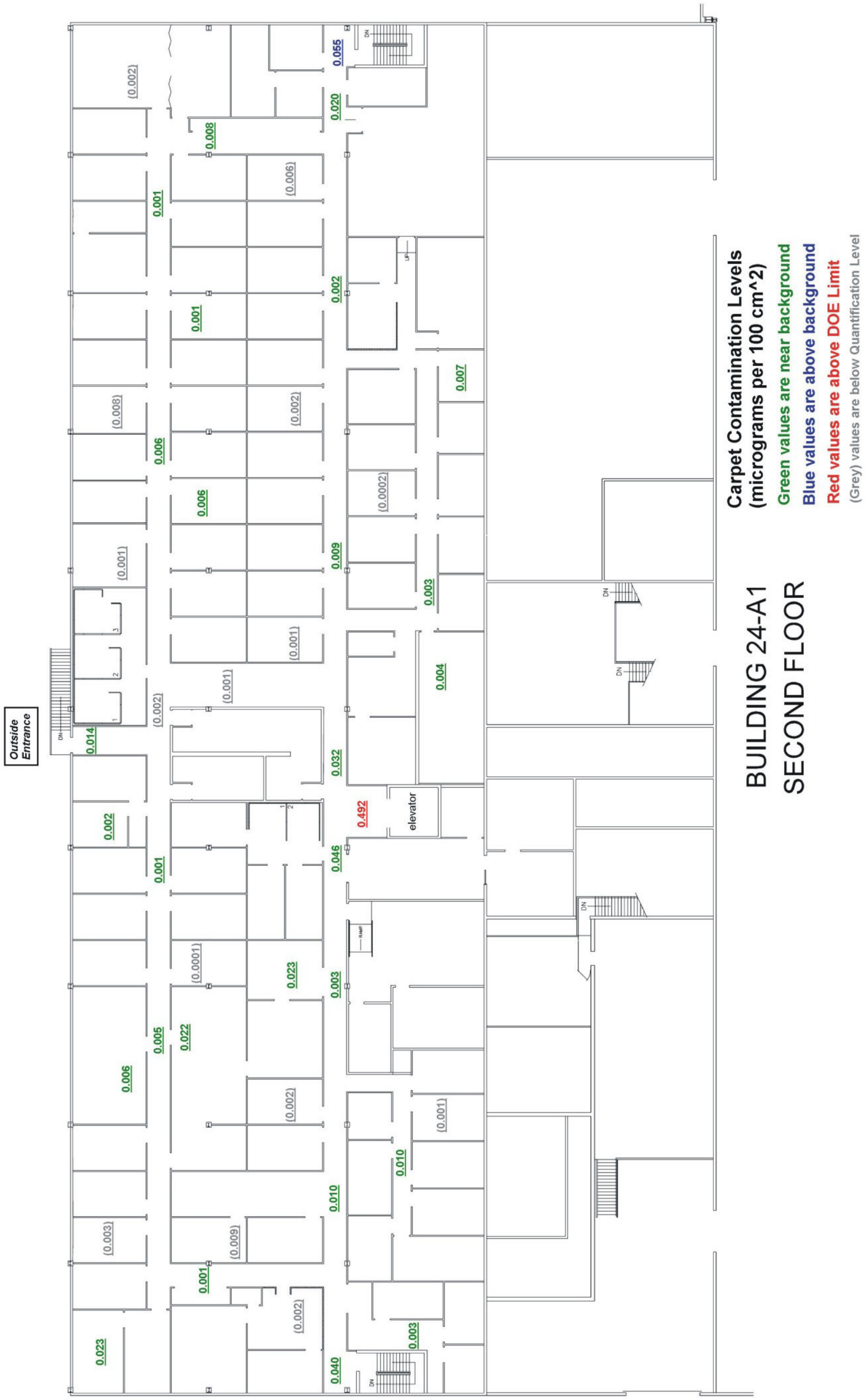

Figure 2.2.5-1: Beryllium contamination in the second floor of building A1.

Only one sample was found above the comparison value, and that was a measurement of 0.492 μg/100 cm^2 in the hallway just outside of the elevator from the first floor. Only one other sample appeared to be of note, and that is a value of 0.055 μg/100 cm^2 at the top of the stairs on the east end of the building.

Based on the fact that all other HVAC systems were found to be at background levels, the team decided to not sample the HVAC system of A1.

2.3 Evaluation of Survey Results

Figure 2.3-1 shows the average beryllium levels in the six carpeted floors of the buildings under evaluation, along with the average value of the anticipated background for comparison. As noted in the graph, the first floor of B1 shows widespread contamination, with 17 out of the 51 samples exceeding the comparison standard of 0.2 μg/100 cm^2. The other floors are all much lower, with the averages being skewed by the few high values. Figure 2.3-2 is a comparison between all of the samples and their individual anticipated background values. While the standards for beryllium contamination are absolute values, i.e., they are not to be corrected for background, it is clear from this figure that the observed values represent levels that are elevated above what would normally be expected in the carpets. Although the concrete high bay area of B1 is not included in these figures, it is also clear from Figure 2.2.2-2 that beryllium levels in the southern end of the high bay are elevated by factors of up to 134 times greater than the background levels in area soils.

For another point of information, the team re-evaluated the results of the April 2002 carpet cleaning, where the residual water was sampled before release. While the exact quantity of water used on each floor can only be approximated, it can be assumed that it was an equal amount per square meter of floor area, since it was a closed-loop cleaning system. In total about 120 gallons (454 liters) of water was disposed of. Table 2.3-1 contains the results of the team's re-evaluation of the carpet cleaning effort.

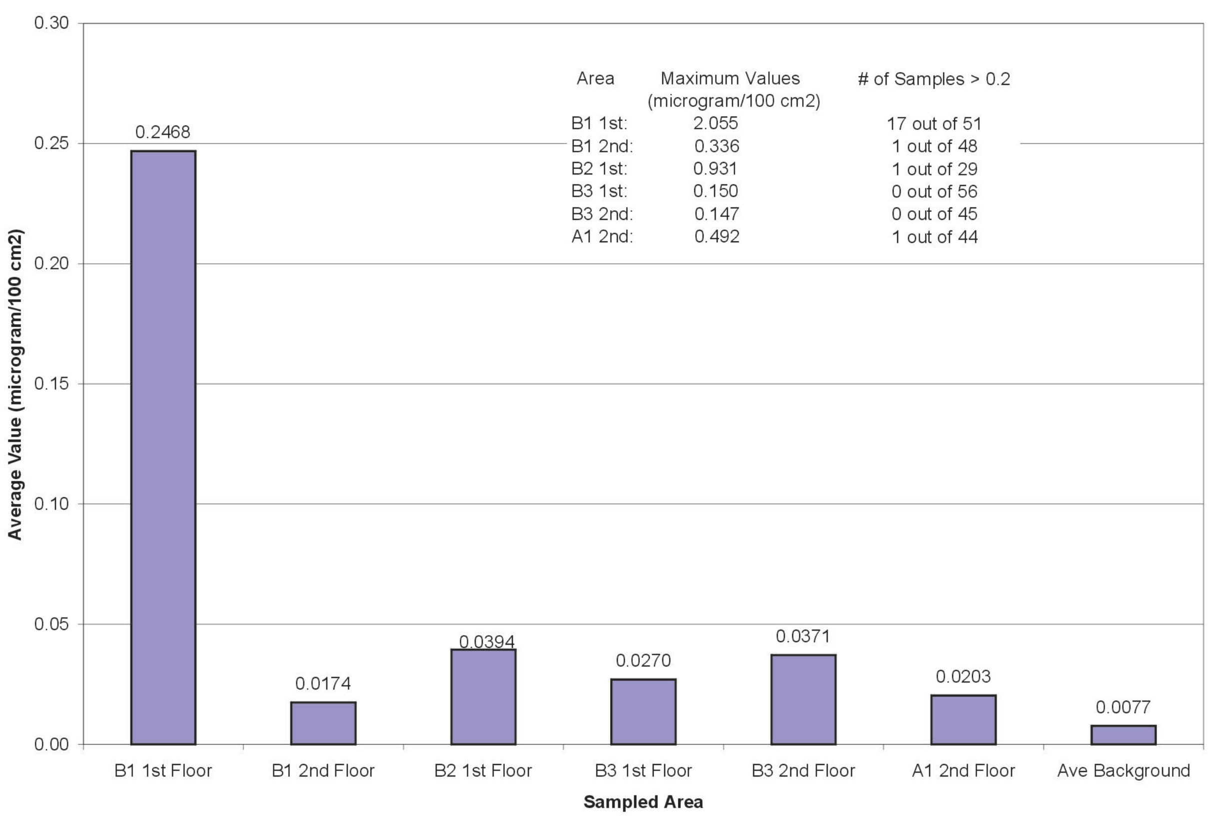

Figure 2.3-1: Comparison of the average beryllium contamination levels in the buildings.

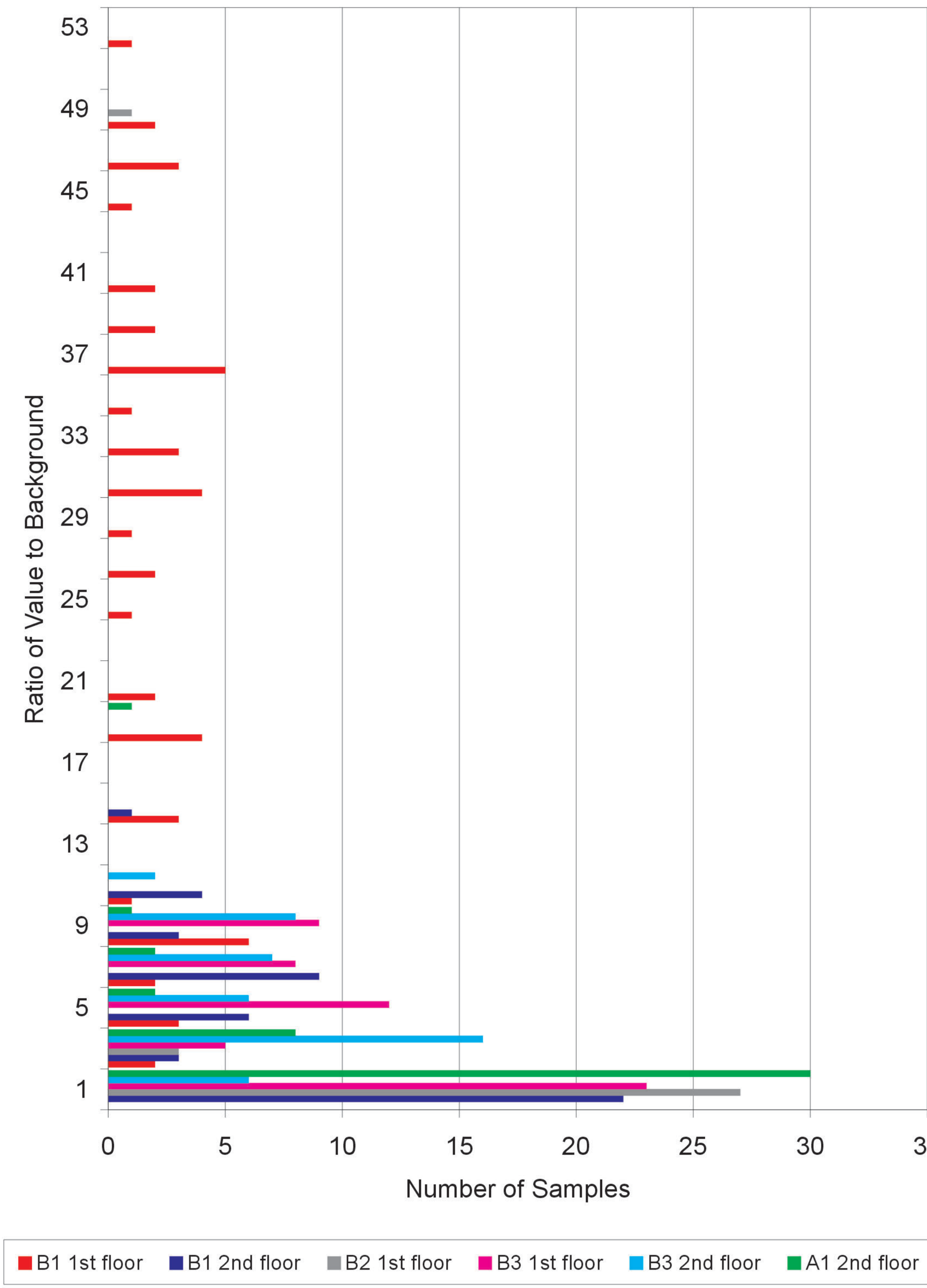

Figure 2.3-2: Comparison between individual sample results and anticipated background values.

Table 2.3-1: Beryllium Removed During The Carpet Cleaning of April 2002

Floor	Water Sample (μg/L)	Water Quantity (L)	Beryllium Removed (μg)	Floor Area (m^3)
B1 1st floor office area	1.8	77.2	139	1,858
B1 2nd floor office area	1.05	79.0	83	1,905
B1 high bay	4.55	77.2	351	1,858
B3 1st floor	1.2	154.4	185	3,716
B3 2nd floor	1.2	144.8	174	3,484

Table 2.3-1 shows a relationship between the floors and buildings similar to that found during the team's carpet sampling, especially when recognizing that the B3 floor areas are about twice as large as those of B1. One can assume that the removal efficiency of the cleaning system is likely to be more efficient for the concrete high bay. However, based on the earlier discussion of the high bay sampling results, it is likely that the contamination in the high bay was concentrated in the southern end, and therefore the actual affected floor area is likely to be lower than that listed in the table.

The team also noted that the removal efficiency of the carpet cleaner appeared to be very low in B1, and somewhat better in B3. For example, based on the sampling results of the first floor of B1, there is approximately 45,850 μg of beryllium currently residing in the carpeting. However, the cleaning only removed 163 μg, or about 0.3%. In the other floors, the removal efficiency ranged from 1.8% to 2.5%. Therefore, it is assumed that the remaining beryllium has been ground deep into the pile of the carpets with the passage of time, traffic, vacuuming, and periodic cleaning.

In reviewing these results, the team first considered the original hypothesis proposed by BN that the observed CBD and sensitization cases were due to residual contamination from the machine shop that had previously been located in B1 from 1982 to 1994. At the time that this hypothesis was proposed, the medical results had suggested that the beryllium exposures might have occurred in the B-complex due to an apparent clustering of cases associated with that building, but the sampling results did not verify that conclusion. Residual contamination from the former machine shop was proposed as the only plausible explanation, along with the assumption that the sensitization and CBD cases were occurring with much lower exposure levels than had been previously observed at other locations with known beryllium exposure histories. The team concluded that there is adequate reason to believe that this hypothesis is not correct, based on the following reasons:

- Given the levels of contamination that the team found in the carpets, there is adequate reason to believe that conditions probably existed in the building for beryllium exposures at much higher levels than previously assumed.

- Historical records of beryllium sampling conducted in the machine shop during its operation demonstrates some beryllium contamination in limited areas, but not in quantities sufficient to constitute the source necessary for the contamination levels observed in the team's sampling results.

- During the time of the machine shop, the building had concrete and tile floors. The carpeting in the office areas was installed after the shops were removed in 1995, and the hallways were not carpeted until November 1996. It is inconsistent for the contamination to be found in the carpeting and no where else in the building.

- In several areas the team had samples analyzed for copper and aluminum along with beryllium. One would expect to see some relationship between these elements, especially between copper and beryllium, if the contamination was due to the machine shop. (Most of the beryllium machining done by the shop was an alloy of copper with 2% beryllium by weight.) No correlation was found in any of the areas sampled.

- The pattern of the contamination clearly shows the highest contamination levels at the entrances to B1, with high levels in some office areas and generally elevated levels in the hallways. However, there is no clear correlation between the contamination patterns and the footprint of the machine shop in the building. Also, while the contamination in B3 is much lower, there is also evidence to suggest that beryllium contamination may have entered that building through outside entrances rather than being redistributed from B1.

After reaching these conclusions, the team then considered alternative explanations. First, as discussed previously, the data clearly show the beryllium levels in the buildings are not consistent with the environmental levels of beryllium in the surrounding soils. Contamination levels in the carpeting were found to be as high as 50 times what would be expected from background and bulk samples in the B1 high bay were as high as 134 times the background levels. Also, BN's sampling of the current machine shop in A1 demonstrated that the residual contamination in that building is confined to the shop areas, does not constitute a large source, and there is no evidence of a spread of contamination from that area to other parts of NLV.

Given these observations, the team concluded that the beryllium contamination had been introduced into the buildings after the removal of the machine shops, and that the primary mechanism for this to occur was the tracking of contamination into the building from an outside source. This tracking would likely have been brought into the building on personal shoes and clothing, and on vehicles and equipment entering the IT/SHAW shipping/receiving area in the B1 high bay. Also, given the observations of elevated contamination levels at multiple entrances to B1 and the lower-level contamination in the B2, B3, and A1, it is likely that this was not a singular event, but rather a collection of events, possibly unrelated to each other. The team also concluded that the contamination detected in the carpets is only a fraction of the original source quantity, given the periodic removal and redistribution of the contamination during carpet vacuuming and cleaning.

During the investigation, it was brought to the team's attention that concerns regarding possible beryllium contamination at NTS from historical activities had been raised a couple years ago. Efforts were underway to begin to recover the historic records of those projects. At the time of this investigation, over 50 facilities and areas at NTS have now been identified as probable locations where these activities took place. However, full evaluations of these sites have yet to be undertaken. As part of this investigation, the team toured several of the suspect areas at NTS and took about 120 soil samples. While this effort was not intended to constitute a full evaluation of any or all of these sites, the team found evidence of elevated beryllium levels at some of the locations that support the conclusions drawn from the historic records. During these tours the team also attempted to sample a currently occupied building to evaluate the possibility of tracking. However, the team did not sample any carpeted areas so as to not impact the occupants. The result of that evaluation was inconclusive, and the team concluded that a more thorough approach would be necessary.

The team concluded there is sufficient reason to believe that the beryllium in the buildings is the result of multiple events where personnel and/or vehicular traffic passed through unrecognized beryllium contamination areas at the NTS, unwittingly transported the material back to NLV, and subsequently unintentionally deposited the material inside the buildings. As shown in the events and personnel charts of Attachment 3, and discussed in this section, there were many opportunities for this to occur between 1997 and 2002. In addition, there is evidence to suggest that some of the beryllium might have been introduced into the building environs by contaminated documents or other articles brought in from the NTS. The team further concluded that, once the beryllium had been introduced into the buildings, there were several reasonable mechanisms by which the material could be suspended in the atmosphere and redistributed (such as the vacuuming of the carpets or handling the contaminated documents) that would lead to credible exposure pathways.

To further assess this scenario, the team attempted to sample several vehicles that are routinely used by the IT/SHAW and BN staff for travel between NLV and the NTS. Only some minor elevated levels of beryllium were found in a few samples. However, the vehicle fleet had been replaced within the last couple years, and so they may not have been the same vehicles that were in use during most of the time span in which this tracking may have occurred.

As noted earlier, some of the sensitization cases had been identified through the BN medical screening as having prior histories of potential beryllium exposures. In reviewing those case histories, the team does not dispute this possibility, and in fact some of those sensitization cases may well have received their beryllium exposures from the B1 machine shop, either when it was operational or during its removal. The team is only noting that it does not believe that the beryllium contamination currently in the B-complex buildings, which is likely the cause of the other sensitizations, originated from the machine shop operations.

2.4 Team Conclusions Regarding Initiating Events

As noted in the previous section, the team concludes that the most likely cause of the beryllium contamination in the B-complex buildings is the tracking of material from unrecognized contaminated locations at NTS, and perhaps also from the receipt of contaminated documents and articles from NTS facilities. The team attempted to recreate a history of the activities of personnel in the B-complex in the years 1995 to 2002 to see if there could be any relationship between those activities and the list of suspect facilities that had been generated from the reviews of historic NTS activities related to beryllium. This effort identified several situations that demonstrate a clear correlation between potentially contaminated sites and the activities of personnel from the B-complex. This evaluation is documented in the two flow diagrams that make up the events and causal factors analysis in Attachment 3. Several examples of those correlations are:

- IT/SHAW took occupancy of their area of B1 in late 1997. Between then and March 2002, their work in characterizing abandoned facilities for remediation included efforts at about 25 Corrective Action Units (CAUs) that involve locations on the suspect facilities list. In essentially all of these CAUs, beryllium was not on the list of contaminants of potential concern (COPC), and therefore it was not routinely evaluated during sampling. While the sampling personnel normally remained in the field during these efforts, there was a regular flow of vehicles, equipment, samples, and support personnel between B1 and those locations.

- The CBD case was involved in the fieldwork activities of IT/SHAW, including some of the facilities that are on the suspect facilities list. In fact, there is reason to believe that in this case the most significant beryllium exposure may have resulted from one of those activities rather than the contamination in B1.

- A BN group that maintains a historical document archive in B1 had periodically, in the late 1990's, traveled to several of the abandoned facilities at NTS to rescue documents before they were lost. These documents, and other articles retrieved from NTS warehouses, were brought back to B1 for archiving. The work area for this group has several areas of beryllium contamination above the comparison standard. One of the members of this group is among the sensitization cases, although it was not one of the individuals who collected documents at NTS.

- Bechtel Nevada took over the site contract in January 1996. In the few months before that time, a transition team conducted a visual inspection of all of the facilities, those in use and abandoned, at the NTS. One of the sensitization cases was on that team, and that individual's office in B3 shows elevated levels of beryllium contamination.

- The IT/SHAW section of the B1 high bay contained their shipping/receiving area, and it also contained storage areas for their field equipment and office supplies. Many of the IT/SHAW personnel routinely went into the high bay area to either help with the preparation of samples for shipment or to get office supplies. Some of the sensitization cases were directly involved in these activities.

- Some of the BN groups in B3 were from the engineering, performance assessment, and project controls departments. These personnel would periodically be involved with work at NTS facilities. Some of the areas of elevated beryllium levels in B3 correspond to the offices of these groups.

- One of the sensitization cases was involved in the cleanup of two "safety shot" sites on the Tonopah Test Range (TTR), northwest of the NTS. ("Safety shots" are tests involving nuclear weapon-like assemblies that involve detonation of the assembly with high explosives, but do not result in nuclear yield.) Beryllium contamination was not considered in the execution of those cleanup efforts. These sites, along with several others on the NTS, are now being evaluated to determine if beryllium components were involved in the tests. Given the nature of these tests, there is sufficient reason to believe that this may be the case. That same individual also frequently visits a variety of NTS facilities in the course of normal duty.

The team notes that although it can be shown that many of the individual cases were involved in these activities, this does not demonstrate conclusively that those activities were the exact situations in which the beryllium exposures occurred. However, the team also notes that the examples listed above help explain the patterns of contamination in the buildings. With IT/SHAW's responsibilities requiring frequent travel between the suspect facilities and NLV, one would expect that the highest probability for tracking would occur with those activities, and hence the highest contamination levels would be observed in IT/SHAW work areas. While the BN archive group's travel to NTS was less frequent, they would also be at high risk for contamination because of their focus on the abandoned facilities. Finally, the BN personnel in B3 would be less frequent visitors to the suspect facilities, and therefore their work areas would be at lower risk for contamination.

Given the nature of the activities conducted in the IT/SHAW's section of the B1 high bay, the team was concerned about the potential for contamination of that area by any of the variety of contaminants that could be captured in the samples being brought in from the NTS. The team was informed that sample containers are not opened after they are filled at the survey location. They are only packed into shipping containers for transmittal to the laboratories for analysis, after the chain-of-custody paperwork is completed. The team inquired as to whether there were any normal and periodic industrial hygiene or other safety assessments performed on that area, and was informed that none are required.

As will be discussed in a later section, the team has reviewed the history of the use of beryllium at the NTS and NLV, as it is currently emerging from the ongoing review of historical records. It is clear that there is sufficient reason to believe that significant levels of beryllium contamination might exist at several facilities at the NTS. It is also clear that while beryllium contamination was regularly evaluated during the conduct of those activities (many of which took place 25 to 50 years ago), it was not regarded with the same level of concern as it receives today. It is also clear that the records demonstrate a loss of the institutional awareness, in the early 1990's, concerning the presence of beryllium contamination at the NTS. As a consequence, essentially all of the activities noted in this section took place with no consideration for potential beryllium contamination, with a few exceptions. In preparing for facility characterizations, IT/SHAW does attempt to collect the historical information regarding activities and possible contaminants at the sites under their purview as part of their preliminary assessments. They also attempted to conduct sampling specifically for beryllium at some locations. Unfortunately, in those instances where sampling was conducted for beryllium contamination, it was not guided by any detailed historical knowledge of beryllium-related activities, and therefore appears to have been ineffective.

Based on these considerations, the team concludes that there is sufficient reason to believe that beryllium contamination exists at various facilities at the NTS at levels adequate to present sources for the tracking of material to other locations. Furthermore, the team concludes that there is sufficient reason to believe that there are multiple viable routes for beryllium contamination originating at the NTS to be transported to NLV and be deposited in the B-complex buildings.

3.0 Analysis and Conclusions

The investigation team was tasked in its appointment letter to determine what happened in this event, to understand why it happened, and to make recommendations to prevent recurrences of a similar nature in the future. In this tasking, the team was also presented four specific questions regarding this event:

- ❑ What is the history of beryllium activities at the facility in question, and is there sufficient reason to believe that the building conditions could result in the impacts observed in the workers?
- ❑ Do current medical diagnostic tests provide an adequate level of validity, accuracy, and reliability to provide a useful indicator of exposure to beryllium?
- ❑ What is the history of contact with beryllium, both occupational and non-occupational for the impacted employees and is there sufficient reason to eliminate other potential exposure pathways as the source of the observed effects?
- ❑ What is the technical basis for the current standards and regulations for protection against beryllium, and does this current situation imply a weakness that needs to be addressed?

This section will directly address each of these four main questions. In addition, it will discuss the question of why this event happened. The recommendations for the prevention of recurrences of a similar nature will be presented in the following section.

In these discussions it must be noted that there is very little, if any, firm evidence available to draw definitive conclusions regarding these questions beyond the evidence of contamination found in the buildings themselves. However, there is a large body of circumstantial evidence that the team collected to develop and support the conclusions of this investigation. It is the purpose of this section to identify that body of evidence, discuss its relevance to this investigation, and to draw the necessary conclusions to answer the questions of the appointment letter.

3.1 History of Beryllium-related Activities and Building Conditions

In the appointment letter, the team was tasked to review the history of beryllium activities in the building, and to consider whether there was sufficient reason to believe that the building conditions could result in the impacts observed in the workers. In this section the team considers those two questions in detail.

3.1.1 History of Beryllium-related Activities at NLV and NTS

The NTS is an area of over 1375 square miles, and has been in operation since 1951. It was originally developed as the primary on-continent site for testing nuclear weapons, and 928 nuclear tests have been conducted at NTS when testing ceased in September of 1992. One hundred of those tests were conducted in the atmosphere and the rest have been underground. In addition, the NTS provides an ideal remote location for the conduct of other experiments that would be difficult or impossible to conduct in more restrictive or populated areas. These tests range from large-scale high explosives detonations, to intentional detonations of hazardous or radioactive material to study dispersal phenomenon, to the operation of large unshielded reactors designed for flight propulsion. Since beryllium has several properties that make it attractive for use in nuclear applications and electronics, it has frequently been used in many of these experiments and tests.

There are multiple routes by which the beryllium is introduced to either the NTS or NLV. The components for a major experiment, such as a weapons test or a nuclear rocket engine, were normally fabricated at off-site locations and brought to NTS for final assembly and conducting the test. The facilities at NTS and Las Vegas (there were other facilities in Las Vegas before the NLV facility opened in 1976) would supply specialized components, electronics, and test fixtures for supporting those tests. As an example, from 1982 to 1994 the B-complex was the location where data acquisition and instrumentation trailers were built to collect the test data from the underground tests. Specialized radiation and neutron detectors were also built in NLV. Both of these activities used beryllium in particular components, and some of these components were machined locally.

Most of the machining done locally has been with the copper – 2% beryllium alloy, which is useful in various electronics applications. The beryllium metal components were typically brought in pre-fabricated; however, it was occasionally necessary to do some machining on these parts to accomplish the necessary fit for the application. The NLV shops should be characterized as machine shops that occasionally worked with beryllium rather than dedicated beryllium shops. Because the amount of beryllium work done in these local shops over the years has been fairly low, it was deemed unnecessary to dedicate a full shop to only beryllium work. However, interviews with current and former shop personnel and reviews of the records demonstrate that the hazards presented during the machining of beryllium were recognized and the work was conducted within the standards of practice applicable at the time. Monitoring for beryllium, both airborne and surface contamination, was done periodically and records of those surveys still exist, which were reviewed by the team. Those records are consistent with this review. Beryllium was often detected during machining operations, but the levels were fairly low and in limited areas, so the potential for a widespread dispersal of beryllium contamination was small.

It was reported to the team that when the machine shop was moved to A1 and the B-complex was refurbished in 1994-1995, EG&G/EM had conducted a contamination survey of B1, which included an evaluation for beryllium and other possible contaminants from the former shop and other activities in the building. However, the records of this survey were not found during this investigation, despite extensive efforts by BN. Therefore, it is not clear whether this survey actually took place, and the results are unknown.

On the other hand, operations at the NTS often involved very large quantities of beryllium, and some of those operations resulted in potentially widespread dispersal of particulate beryllium into the facilities and surrounding environments. The historic records document many of these activities. Some of the beryllium survey records have also been recovered from the archives. However, the documents suggest the hazards of beryllium were not the primary concern (there were other hazards associated with these operations), many of which were of more immediate concern than beryllium. The following are a few examples of the types of beryllium-related activities that have historically occurred at the NTS. Note that these particular examples have been selected because they could have direct relevance to this investigation, although there are others of note also.

- From the mid-1950's until the early-1970's the Los Alamos and Livermore Laboratories were involved in developing and testing nuclear reactor powered rocket and ramjet engines in Areas 25, 26, and 27 of the NTS. These engines typically contained large quantities of beryllium, often more than 1,000 kg per engine. One of the large tests of note here was the KIWI-TNT experiment of January 1965. In this test, a KIWI rocket engine, containing almost 1,100 kg of beryllium along with 1,230 kg of fuel material, was intentionally taken super-prompt critical and driven to self-destruction. The resulting explosion totally destroyed the reactor and spread pieces as far as 1,230 meters from the test point. The radioactive plume went in a southwesterly direction and was monitored almost to San Diego. Of the 1,100 kg of beryllium in the reactor, only an estimated 60% to 80% was recovered. It was reported that beryllium was measured in all of the particulate air samples taken during the test, however these results were dismissed as being due to a "relatively high beryllium soil content" at the site. Contemporary soil measurements do not support this conclusion; neither does a consideration for the design of the test. The test was conducted on a concrete pad well above the local ground level and it is unlikely for local soil to be swept into the debris cloud.

- ❑ During the development of these engines, all aspects of the programs were classified, including the shapes of the components. Therefore, records show that engine components, including graphite and possibly beryllium parts, were pulverized for declassification purposes and then spread, unpackaged, into a series of radioactive waste trenches near the R-MAD facility in Area 25. Pulverizing of beryllium components also apparently took place inside the E-MAD facility (also in Area 25) and in the Pluto Disassembly Building in Area 26. At this point there is no good estimate of the amount of material that was pulverized and disposed of in this manner. While procedures required that the trenches be covered with fresh soil periodically, discussions with workers involved with those sites suggest that this was not routinely followed. Industrial hygiene records exist to show periodic monitoring and detection of beryllium contamination at various locations, but information suggests that the hazard was not respected. Detailed records were maintained of the quantities of radioactive materials that were disposed of in the trenches of R-MAD, for example, but the information regarding the disposal of beryllium and other hazardous materials is much more difficult to ascertain.

- ❑ At all three of the assembly/disassembly buildings associated with the nuclear engine programs, R-MAD, E-MAD, and Pluto Disassembly Building, there were decontamination facilities constructed to wash down the engines and related equipment, which were mounted on railroad cars. The cars would likely be contaminated with beryllium as well as radioactive material and historic industrial hygiene records demonstrate the presence of surface contamination in some of these areas.

- ❑ In August 1967, an underground nuclear test named *Door Mist* was conducted in G-tunnel of Area 12. This particular test apparently contained a large quantity of beryllium in the test items (details are still classified). During the test, stemming and containment failures occurred resulting in venting into the experiment area and to the environment outside of the tunnel. Damage to the tunnel was so heavy that the re-entrance was conducted by mining a drift from the adjacent tunnel, E-tunnel. Records indicate that this was a very difficult operation and that conditions were harsh for a variety of reasons, including very high radiation levels, high temperatures, and accumulations of toxic and explosive gases. All material removed during the mining and recovery operations were disposed of in the muck pile for the tunnel. Industrial hygiene records indicate very high levels of beryllium surface contamination and high airborne levels, and one bulk soil sample that exceeded 6,000 μg/g of beryllium (compared to a background of around 1 μg/g). Since the recovery personnel were dressed out with protective clothing and respirators for protection against other contaminants, they were probably adequately protected. However, residual contamination could still be extensive in the muck pile and other areas, depending on the situation.

- ❑ At a variety of locations at NTS and also at TTR northwest of NTS, a large number of safety shots and hydrodynamic tests were conducted. At these tests, weapons-like assemblies with high explosives were detonated (with no nuclear yield) to test weapons safety systems and to study the dispersal of material from weapons accident scenarios. At least some of these tests included plutonium and other hazardous materials in the test device, and so all of these sites should be suspect due to the routine use of beryllium in the weapons.

These are only a few examples of the types of beryllium-related activities that have historically occurred at the NTS, however the records do not show that there has ever been any significant evaluation of the extent of the residual contamination from these activities. These five examples in particular were selected for discussion because they all represent the potential for creating a significant amount of transferable particulate contamination in accessible areas. All five are locations where BN and IT/SHAW personnel have visited or routinely worked at during the timeframe that this investigation is concerned with.

As mentioned earlier, there are now over 50 locations on the NTS that have been identified from historic records. Most of these were identified from reviewing the historic industrial hygiene records of beryllium surveys that demonstrated the presence of contamination, and then further review of the activities at each location provided better insight into the application. These locations range over the entire site and some are still in use. Table 3.1-1 provides a listing of the major facilities associated with these locations.

Table 3.1-1: NTS Historic Beryllium Sites

NTS Area	Facilities
5	Sugar Bunker Kay Blockhouse Drop Tower
11	TWEEZER
12	E-Tunnel and associated muck pile G-Tunnel N-Tunnel G-Tunnel Cable Splicing Building
16	A-Tunnel and associated drifts and muck pile A-Tunnel Assembly Building
23	Warehouse 7
25	Test Cell A Test Cell C KIWI-TNT site and soil in Topapah Wash R-MAD Facility E-MAD Facility Radioactive Material Storage Area (RMSF) R-MAD radioactive dump site
26	Pluto Disassembly Building Pluto Test Stand and associated waste dumps Hot Box (Critical Assembly Facility) Super Kukla Facility
27	ABLE Site (LLNL Assembly Building BAKER Site (LANL Assembly Building
Other Possible Locations	Various Safety Shot Sites Hydrodynamic Test Sites Horn Silver Mine All DTRA Test/Experiment Sites

(Note that a facility's presence on this list does not necessarily mean that beryllium contamination currently exists at that location, but rather that it did at one time. For many of these facilities, current conditions are unknown but under investigation.)

The team has toured and taken samples at some of these sites. This sampling was not intended as a complete characterization of these locations, but only to gather some confirmatory evidence. In these tours, some elevated levels of beryllium were found at the muck pile and settling ponds associated with E-Tunnel, Sugar Bunker, the KIWI-TNT test area and the Topapah Wash, the Pluto Disassembly Building and its associated decontamination facility, and Kay Blockhouse. However, none of these samples indicated levels that would be expected for a significant tracking source. One area that was not toured due to weather conditions at the time was the R-MAD radioactive waste dump, which the team considers to be of particular concern due to the historic activities that appear to have taken place there.

At most of these sites, the beryllium contamination would have coexisted with radiological contamination, which is more readily detected and the need for protective measures is more readily recognized. Therefore, it is likely that many of these areas were not a significant problem in the past, since protective measures against the inhalation and tracking of radioactive material would also have been effective for beryllium contamination. However, much of the radioactive material has decayed away in the intervening years. The required protective measures for the lower levels of radioactive materials remaining are less restrictive, resulting in many of these areas being more accessible. This would increase the potential risk of exposure to beryllium contamination for incidental traffic as these areas are released for reuse.

The team also noted that many of these sites are on the list of locations to be remediated, and some already have been. Under an agreement with the State of Nevada, the remediation sites are normally evaluated for contamination from radioactive materials, metals listed in the Resource Conservation and Recovery Act (RCRA), polychlorinated biphenyls (PCB), and volatile organic compounds (VOC), which are of concern for environmental protection. Beryllium is not a RCRA metal and therefore, it was not normally evaluated. Consequently, up to the time of this investigation none had been fully evaluated for beryllium contamination, and in most cases beryllium contamination was not considered in the sampling and remediation plans.

Based on this large collection of evidence, the team concluded that there is sufficient reason to believe that the potential exists at the NTS for a significant amount of beryllium contamination to be present in some of the historic facilities. Furthermore, the team concluded that there is sufficient reason to believe that this contamination could be in a form and location that would be conducive to its being unwittingly transferred to the NLV location. Finally, the team concluded that this is the most likely explanation for the observed beryllium contamination in the B-complex buildings.

With regard to the matter of the former machine shops in the B-complex, the team concluded that it is very unlikely the beryllium contamination in the B-complex was the result of residual material from the former machine shops. There is no evidence to suggest that widespread contamination had resulted from those activities, but there is evidence to suggest that those activities were of limited scope and duration and that they were adequately monitored in accordance with the standards of practice in place at that time.

3.1.2 Building Conditions

The team considered whether the observed beryllium contamination in the buildings constituted an adequate source of exposure to explain the observed medical cases. Since the beryllium was predominately in the carpeting, one must consider whether there is a mechanism for suspending the beryllium into the atmosphere of the buildings in order to make it available for inhalation by the occupants.

The team first considered the potential airborne levels at which beryllium sensitization and CBD have been observed. To answer this question, it is worth considering some of the original work done when CBD became recognized as a potential concern.

In 1947, Merril Eisenbud, Director of the Atomic Energy Commission (AEC) Health and Safety

Laboratory became concerned about reports of non-occupational chronic pulmonary granulomatosis received from physicians in the vicinity of a commercially owned plant producing beryllium compounds. AEC investigators initially identified nine cases, including three deaths: these cases were classified as chronic berylliosis (now referred to as chronic beryllium disease).

Following the identification of these "neighborhood cases" of berylliosis, the AEC and plant management enlisted the help of state public health officials to conduct health screening of a large portion of the community population. In all, over 10,000 persons were evaluated, resulting in the identification of two additional cases. The location of the cases' residences was plotted with regard to distance from the plant. It was determined that 10 of the 11 cases lived within ¾ mile of the plant. The most distant case lived almost two miles from the plant, but this patient was found to be the wife of a beryllium plant worker. Because this patient laundered the work clothes of her husband on a daily basis, her disease was attributed to exposures while handling and shaking her husband's clothes prior to laundering and after removing the clothes from the clothesline.

The relationship between the number of neighborhood cases and distance from the plant suggested an environmental beryllium emission from the plant was the causative agent. Beryllium production runs were made and extensive air sampling conducted to determine airborne beryllium levels ¾ mile from the plant. It was assumed that the high levels of plant production prior to 1946 resulted in the highest emissions, and it was estimated that the levels at the ¾ mile distance during these runs averaged 0.1 $\mu g/m^3$.

The AEC stated beryllium was the causative agent in the neighborhood cases. However, no dose response relationship between beryllium exposure and the incidence of berylliosis had been demonstrated. Various anomalies in disease progression led Eisenbud to conclude that chronic beryllium disease was caused by an immune response to inhaled insoluble beryllium particles, resulting in production of granulomas in the lungs. Having noted that employees in the plant exposed to very high levels of airborne beryllium had a lower prevalence of chronic berylliosis, Eisenbud speculated that the smaller particle size of the environmental emissions caused them to be more "toxic."

Based on Eisenbud's studies, the General Manager of the AEC distributed "tentative recommendations for the control of beryllium hazard" in 1951. The recommendations included: "In the neighborhood of an AEC plant handling beryllium compounds, the average monthly concentration at the breathing zone level should not exceed 0.01 micro-gram per cubic meter." These recommendations were later strengthened and inserted into the health clauses of AEC contracts with suppliers of beryllium.

The U.S. Environmental Protection Agency (EPA) regulates beryllium as a criteria air pollutant. The EPA limit for beryllium emissions is 10 grams in a 24-hour period, or emissions that would result in an atmospheric beryllium concentration of 0.01 $\mu g/m^3$ averaged over a 30-day period; the same value that was suggested by Eisenbud in 1951.

In order to continue to follow the development of beryllium-related health effects, a Beryllium Case Registry was established. As of 1978, the registry included 888 cases of beryllium disease. (This Beryllium Case Registry was closed in the late 1970's under the assumption that CBD had been effectively addressed by the government and industry.) Of those cases, 23 were identified as "household exposure to beryllium dust arising from a workplace exposure". A 1992 study at the Rocky Flats Plant also identified sensitizations in secretarial and security staff that had only inadvertent or "bystander" exposure to beryllium. Further studies at Rocky Flats and also at the Oak Ridge Y-12 Plant have continued to document cases among "bystanders". Also, a recent CBD case was identified at the Rocky Flats Plant where the individual had never set foot on the site, but had only been reviewing documents from the plant. Those documents later were discovered to be contaminated with beryllium.

As for an atmospheric suspension mechanism, the team considers that the most likely mechanism is the regular vacuuming of the carpets in the various buildings, although there is also evidence suggesting that the handling of contaminated documents may also have been involved. The typical vacuum cleaner tends to be very effective at collecting larger dirt and particles, but as the particles become smaller, into the range that are considered to be more readily inhaled, the collection efficiency tends to decrease. Therefore, regular vacuuming could not only suspend some of the material, but also act to create a finer, more respirable contamination. In addition, the vacuuming could also cause some spreading of the contamination into other parts of the buildings. The team attempted to locate a technical evaluation of estimated resuspension factors for commercial vacuums. It has been estimated that the typical commercial vacuum cleaner would remove from 50% to 90% of the soil in a carpet, and roughly 2.5% to 3.5% are emitted in the vacuum exhaust. This would have the effect of suspending roughly 1% to 3% of the deposited material in the local atmosphere every time the carpet was cleaned. Based on these values, and from comparison with other forms of suspension mechanisms, the team concluded that there is sufficient reason to believe that vacuuming of the carpets could generate local airborne beryllium levels high enough to be within the range observed in the Eisenbud work and more recent studies. The team also concluded that the beryllium discovered in the carpets is only the residual fraction of the material tracked into the building, and that originally the exposures involved a larger quantity of beryllium.

It should also be noted that during interviews with individuals who resided in the buildings there were often comments regarding the airborne dust generated by the vacuuming, which was often conducted during hours that the buildings were occupied.

The team concluded that there was sufficient reason to believe that conditions could be present in the buildings to result in the health impacts observed in the medical screening.

3.2 Analysis of Medical Evaluation Processes

In response to the index case of CBD, voluntary screening was offered to all employees. As of the end of December 2002, 462 workers at the NLV facilities had been screened. Of those tested, there have been 11 cases of beryllium sensitization and one case of CBD identified. While the offering of the beryllium lymphocyte proliferation test (LPT) was done primarily for identification of cases of beryllium sensitization and CBD, it did provide useful epidemiological information for this investigation. The beryllium sensitization rate for whole NLV cohort is 2.6%, which is at the low end of beryllium sensitization rates described in the literature for occupational cohorts (most studies describe beryllium sensitization rates of 2-12%, with higher rates in higher exposure groups). There was a 5% rate of beryllium sensitization and CBD in Building B1 occupants. This included the index case of CBD, as well as 4 cases of beryllium sensitization. The beryllium sensitization rate in workers without association with the Building A1 or the B-complex was 1.5%.

The rate of beryllium sensitization in unexposed individuals has been described as approximately 1%, although there are limited data to determine a true background rate. Although detailed statistical analysis was not performed on all of the results of LPT testing at NLV, the beryllium sensitization rate in Building B1 was compared to an expected 1% background rate. Statistical analysis indicated that it is highly unlikely that the cases of beryllium sensitization were due to chance. Additionally, the office location and work tasks of the beryllium sensitization cases in the B-complex without an identifiable history of exposure to beryllium correlated well with the location of the contamination within the B complex.

The medical response at NLV was satisfactory. DOE protocols for LPT testing were appropriately followed, including confirmatory testing for initial positive or borderline results. The team reviewed detailed data on referral lab performance during the period of LPT screening at NLV. This review did not reveal any evidence of systematic laboratory error that would explain the positive results that were obtained.

It is important to consider the limitations of the LPT when evaluating the results of the surveillance done at NLV. In addition, the team was specifically requested to review current medical diagnostic tests to determine if they provide an adequate level of validity, accuracy and reliability to provide a useful indicator of exposure to beryllium. The review focused on the use of the LPT. Despite the large experience within DOE with use of this test, as well as numerous published studies of other occupational cohorts, there remains concern with the use of the LPT as a screening test for CBD.

The reliability of a screening test refers to the degree that the test can produce similar results on a consistent basis. Studies have described considerable inter-laboratory and intra-laboratory variability with the LPT. The DOE protocol for confirmatory testing, as well as their program to monitor quality control at referral laboratories, reduces the impact of this variability.

The accuracy of a screening test is determined by its sensitivity (the proportion of cases with disease that test positive) and its specificity (proportion of cases without the disease that correctly test negative). Although various values are reported in the literature, the true sensitivity and specificity of the blood LPT is unknown. This would require subjecting individuals with negative tests to an invasive procedure, namely bronchoscopy with bronchoalveolar lavage and/or biopsy.

The sensitivity and specificity of a test are important in determining its positive predictive value (PPV), which is the proportion of individuals with a positive test that actually have a disease. The PPV of a test is greatly influenced by the prevalence of the disease in the population being screened. As the prevalence of the disease in a population decreases, the PPV of a test goes down and the number of false positives increases. In a population with a low prevalence of CBD (such as might be expected with very low or incidental exposure), the number of false positive LPTs will be elevated. This is germane to the present investigation, given that a large number of workers with no apparent history of exposure to beryllium were tested.

The concerns about the accuracy of the test are extremely important when considered in the context of the follow-up action to a positive test. A false positive LPT may lead to unnecessary anxiety, and use of invasive follow-up tests that have the potential (although small) of adverse outcomes. It may also lead to the unnecessary removal of individuals from work around beryllium. The long-term outcome for individuals with beryllium sensitization or subclinical CBD is not fully understood, and the value of treatment for subclinical disease has not been demonstrated.

The LPT may have greater value as a surveillance tool to identify trends in worker populations with exposure to beryllium. However, any use of the test in populations still requires counseling, potential follow-up testing, and decisions about workplace restrictions for individuals with positive results.

It is unlikely that the outcome of this investigation will improve our understanding of the value of the LPT as a screening test, nor is it likely to impact the current DOE screening program for CBD. However, the lessons learned will be valuable in guiding the approach to evaluating clusters of CBD or beryllium sensitization in worker populations with little or no apparent exposure to beryllium. The team concluded that DOE should consider developing a generic algorithm or practice guideline for investigation of similar events. The team also concluded that DOE should consider the degree of exposure assessment that should occur prior to instituting a medical surveillance program, in order to ensure that the appropriate at-risk population is screened.

The team concluded that the medical department response to the cluster of CBD and beryllium sensitization was appropriate and LPT testing was in accordance with DOE program requirements.

Furthermore, the team concluded that there is a need for practical guidelines or protocols for responding to clusters of CBD or beryllium sensitization in workers without apparent exposure to beryllium, using lessons learned from this investigation.

Finally, there remains a lack of consensus in the medical community about the value of the LPT as a routine screening test for CBD. The team concluded that DOE should consider seeking an independent, evidence-based consensus medical recommendation on the use of the LPT as a routine screening and surveillance tool.

3.3 History of Affected Workers

At the onset of this investigation, the team was faced with the difficult challenge of attempting to understand how the twelve observed beryllium exposure cases (one diagnosis of CBD and eleven diagnoses of beryllium sensitization) had occurred at what had appeared to be very low levels of beryllium exposure. While some of these cases were believed to have been due to previous exposures, there was no physical exposure data (such as breathing zone air samples) to verify that assumption. Therefore, the appointment letter specifically tasked the team to review the occupational and non-occupational histories of all of these employees to assess the possibility of an alternate explanation for the observed effects. However, even with the current understanding of the buildings and the possible exposure pathways that have been determined by this investigation, the team recognizes it is important to consider the histories of the affected personnel to ensure that those observed effects are consistent with the proposed exposure scenarios.

To this end, the team reviewed the medical histories taken during the voluntary medical screening evaluations offered by BN, and the team also interviewed all of the affected personnel. In addition to these twelve, BN also referred a beryllium sensitization case identified during a separate voluntary screening program of NTS personnel, based on what were perceived to be similarities between that case and the twelve identified from the NLV screenings. (Note that while this case had been included in the NTS group based on current assigned duty station, the individual had actually requested screening based on having formerly occupied an office in the B3 building.) After reviewing this case and interviewing the individual, the team concluded that due to the particulars of the case it should be included in the team's considerations. Therefore, while BN has identified twelve cases associated with the NLV concerns, this team actually considered and evaluated thirteen cases (one CBD and twelve sensitizations).

This report will not go into detail on all of these case histories, but the information relevant to this investigation is contained in the Events and Personnel Chart in Attachment 3. This chart demonstrates that all personnel had some association with the B-complex during the time period between the completion of the renovation in 1995 and the onset of this investigation. This is not surprising, however, since it was the concern over the building conditions that led NSO to offer the voluntary screenings. Consequently, most individuals volunteered because of their association with the B-complex.

The personal work histories collected during BN's voluntary screening indicated that for five of the individuals there were other work-related situations that could also have resulted in exposure to beryllium, unrelated to the contamination in the B-complex. For seven others, including the CBD case, BN concluded that there was no evidence of a plausible exposure history except for residence in the B-complex. In general, the team agreed with this evaluation, although the investigation was able to gain some additional insight into how some of the exposures may have occurred.

In fact, five of these cases with no plausible exposure history were administrative personnel whose work assignments would not normally take them outside of the office environments. However, in these cases the team did find that besides their residency in the buildings, their assignments would often entail either (1) frequent visits to the IT/SHAW high bay area for office supplies or to assist with processing of samples for shipment; or (2) the receipt and handling of documents from NTS. (Note that a recent CBD case at the Rocky Flats Plant has been discovered where the beryllium exposure is considered to have resulted solely from the handling of contaminated documents.)

While some of these cases probably were due to exposures unrelated to the current situation, it should be noted that given their association with the B-complex it can not be ruled out as the source of their exposures. In several other cases, exposure to the contamination inside the building appears to be the only likely pathway, which the team believes to be a plausible explanation given the contamination levels in the buildings. However, the team believes that there are three cases that warrant individual discussion because those cases may provide additional examples of the team's concern for potential beryllium contamination at the NTS.

The report of a medical diagnosis of CBD was the initiating event for the concerns that this team is investigating. In reviewing that individual's history, the team looked at both the current work assignments and the previous work history. Based on the evidence collected during this investigation, the team now believes that there were multiple plausible scenarios in which beryllium exposures could have occurred, besides the fact that this individual resided in the building. (It should be noted that during the team's evaluation of the B1 building, this individual's office was found to be uncontaminated). However, the team concluded that there is reason to believe that the individual's exposure could have occurred on a work assignment at the NTS. The individual worked for IT/SHAW and was involved in field sampling activities at some of the sites that IT/SHAW was responsible for characterizing. When involved in these NTS activities, the individual would reside at NTS and not normally return to the B1 until the work was completed.

One particular example of this individual's work assignments that the team explored was the characterization of a building associated with the R-MAD facility in Area 25. The survey of this building was conducted in January 2000, before the concern for possible beryllium contamination at NTS had been identified. The survey was designed primarily for evaluating radionuclides, polychlorinated biphenyls (PCB), volatile organic compounds, and RCRA metals. Beryllium was not on the RCRA list and therefore not surveyed for. Protective equipment for the workers was selected based on the preliminary assessment of the building, which had not identified beryllium as a possible contaminant. Therefore, during the radiological survey of the facility respirators were not prescribed nor used by the workers, based on the type of non-intrusive activities underway. However, the building was described as very dusty. Also, a large door to the building was broken and could not be closed completely, creating an uncontrolled draft when the wind blew.

As indicated, at the time of this activity there had been no indications from preliminary assessments that beryllium was ever present in the building or could be a possible concern. However, based on the ongoing review of historical records, there is now reason to believe that there were programmatic activities in the building involving significant quantities of beryllium when the building was in normal operation. Also, the historical records indicate that a beryllium survey in the building was conducted in June 1968. At that time two swipe samples were taken within the building, with the results of 20 and 30 $\mu g/100\ cm^2$. There were five other samples taken outside the building that also showed beryllium contamination, at levels of up to 5 $\mu g/100\ cm^2$. However, it is not known if this was the only time that beryllium samples were taken, or if any action was taken to remediate these areas after the survey. Subsequent to the IT/SHAW survey, the building was demolished and therefore further testing is not possible. At the request of the team, IT/SHAW was able to have the analytical results of some of the samples taken inside the building during that survey re-evaluated for beryllium. Those results showed the presence of beryllium, but due to the nature of the samples, the results could not be interpreted to provide any indication of exposure conditions inside the building.

In a second case, the individual requested the medical screening because of having formerly resided in the B3 building for nearly two years, shortly after the 1995 renovations. However, this individual has spent most of the time since 1993 located at the NTS. The individual's normal work assignment would entail periodic visits to a variety of the facilities located at NTS. In addition, the individual spent two summers working with a group cleaning up two former safety shot sites at TTR. Beryllium was not identified as an issue at these clean up activities, but as noted previously, there is now reason to believe that it could have been present. Based on these considerations, the team viewed this case as a situation where the beryllium exposure could have come from residing in the B3 building, but that there was also reason to believe exposures could also have resulted from either the individual's normal work activities at NTS or at the clean up work at TTR.

In a third case, the individual resided in the B3 building with only occasional travel to the NTS. However, in one particular assignment the individual was part of a team that visually inspected all of the facilities at the NTS, including both currently occupied and abandoned buildings. Since this was intended to be only a visual inspection, no protective equipment was used. This individual also periodically works with documents and drawings from NTS. While it is impossible to establish any direct relationship with any of these particular activities, the team found that the individual's office in B3 was contaminated with moderate levels of beryllium, although the surrounding areas were much lower.

Based on the information collected by the team and BN regarding the individual case histories, the discovery of the beryllium contamination in the B-complex and the ongoing review of the historical records, the team has concluded that there is sufficient reason to believe that all of the identified cases likely resulted from exposure to beryllium while engaged at DOE-funded activities at either NLV or the NTS. Furthermore, the team concluded that the case histories of the employees provide additional evidence of possible beryllium contamination at the NTS.

3.4 Analysis of 10 CFR 850 Considerations

The DOE beryllium health protection policies were undergoing revision at the same time as the events were occurring that contributed to the NLV situation being investigated here. As discussed in the history section, the lack of a specific beryllium policy in the late 1980s and early 1990s contributed to the failure to fully characterize the beryllium contamination legacy at NTS. In July 1997, DOE Notice 440.1 "Interim Chronic Beryllium Disease Prevention Program" was published. This was followed in December 1998 with publication of a notice of proposed rulemaking and in December 1999 with publication of a final rule 10 CFR 850 "Chronic Beryllium Disease Prevention Program." The finding of beryllium sensitization and disease among craft workers at the DOE Rocky Flats and Oak Ridge Y-12 plants led to recognition that dust-disturbing tasks in beryllium contaminated facilities created a significant risk. Both the interim notice and final rule contain provisions aimed at characterizing beryllium contamination so that inadvertent exposure can be avoided. DOE Notice 440.1, Attachment 1 paragraph 1 states the following:

> ***Baseline Inventory and Sampling****. Develop a baseline inventory of beryllium locations and operations; identify exposed and potentially exposed current workers by location; and conduct sampling.*
>
> a. Conduct a records review and employee interviews.
>
> b. Document the presence and locations of beryllium on site.

Similarly, 10 CFR 850 states the following.

> ***§ 850.20 Baseline beryllium inventory***
>
> *(a) The responsible employer must develop a baseline inventory of the locations of beryllium operations and other locations of potential beryllium contamination, and identify the workers exposed or potentially exposed to beryllium at those locations.*
>
> *(b) In conducting the baseline inventory, the responsible employer must:*
>
> *(1) Review current and historical records;*
>
> *(2) Interview workers;*
>
> *(3) Document the characteristics and locations of beryllium at the facility; and*
>
> *(4) Conduct air, surface, and bulk sampling.*
>
> *(c) The responsible employer must ensure that:*
>
> *(1) The baseline beryllium inventory is managed by a qualified individual (e.g., a certified industrial hygienist); and*
>
> *(2) The individuals assigned to this task have sufficient knowledge and experience to perform such activities properly.*

Contemporaneously with the events that led to the beryllium sensitization and disease at NLV, DOE was promulgating policies that would have supported a greater expenditure of effort and resources on the characterization of beryllium contamination had they been in place in the late 1980s and early 1990s.

While current policy establishes authorities and responsibilities for characterizing beryllium contamination, the methods to be used for such characterization are not well established. Methods and criteria orientated towards assessment of cleaning activities have been applied to the initial characterization. The following is the relevant paragraph from 10 CFR 850.

> ***§ 850.31 Release criteria***
>
> *(a) The responsible employer must clean beryllium-contaminated equipment and other items to the lowest contamination level practicable, but not to exceed the levels established in paragraphs (b) and (c) of this section, and label the equipment or other items, before releasing them to the general public or a DOE facility for non-beryllium use, or to another facility for work involving beryllium.*
>
> *(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 mg/100 cm 2 or the concentration level of beryllium in soil at the point or release, whichever is greater;*
>
> *(2) The equipment or item is labeled in accordance with § 850.38(b); and*
>
> *(3) The release is conditioned on the recipient's commitment to implement controls that will prevent foreseeable beryllium exposure, considering the nature of the equipment or item and its future use and the nature of the beryllium contamination.*

In general, the rule is interpreted to mean that if removable beryllium contamination of an article is less than 0.2 mg/100 cm^2 then no cleaning is required. There are national consensus standards for surface sampling methods to determine the level of contamination present. However, the monitoring methods and limits were developed for use within the context of ongoing contamination control programs. Surface sampling results below the limit help assure that housekeeping and cleaning methods are preventing the spread of contamination.

The Rule requires that training include information on the risk of spreading contamination outside the workplace. While the Rule does contain surface contamination limits, it does not address specific work practices for reducing the spread of contamination outside the workplace.

Our experience in conducting this investigation supports the need for additional guidance on initial characterization, which includes evaluating surfaces that are not routinely cleaned and can be covered with settled dust. There is a possibility that the beryllium detected in a surface sample is due to the trace levels of beryllium in dirt, making the interpretation of results more difficult. We collected bulk samples of settled dust and carpet debris and analyzed these to determine the concentration of beryllium (in µg/g) as one method of evaluating surface contamination. The rule indicates that comparison with beryllium levels in soil might be one way to interpret the results of bulk samples. In this investigation we found that the carpet debris in buildings tended to have substantially less beryllium than soils. We determined that the carpet debris in the office buildings being studied included dust and debris generated through material handling and personnel traffic within the buildings, and residual carpet fibers and mastic (the adhesive used to install the carpets) which have lower levels of beryllium than soils. Multiplying the weight of the bulk sample by the concentration of beryllium present and normalizing to the area of the carpet sample to determine mg/100 cm^2 proved to be a more useful way of interpreting these samples. In this investigation, surface sampling results above 0.2 mg/100 cm^2 were unusually high, even when several grams of dirt were recovered from the surface being sampled.

The office settings included carpeted and upholstered surfaces. The team developed an ad-hoc method for sampling carpet to ensure the highest possible collection efficiency for entrained dirt and debris. However, this method is not always the most appropriate technique since it requires destroying the carpet to take the sample. There are published consensus standards for vacuum sampling carpet and upholstery for evaluation of lead contamination and it might be possible to adapt these for characterizing beryllium contamination. The team believes that additional study of these techniques is necessary since this investigation found that collection effectiveness for the carpet cleaning was very low, suggesting that the beryllium was deeply entrained into the carpet. The vacuum sampling techniques will probably provide adequate information to determine current exposure conditions, but may not be able to determine whether residual beryllium contamination still remains in the carpet from previous tracking events. The Rule provides only limited guidance on methods for sampling for beryllium on surfaces. The preamble to the Rule refers to a NIOSH method for sampling for lead on surfaces, but does not provide specific information on how to apply that method to beryllium.

Implementation of the medical surveillance requirements in accordance with BN's 10 CFR 850 program led to the use of the beryllium lymphocyte proliferation testing of employees located in the B buildings, which uncovered a cluster of beryllium sensitization cases. With the decision to relocate employees out of the B buildings, there was recognition that a significant dollar loss had occurred and that DOE directives required investigation of such losses. The rule does not provide guidance on the investigation of a cluster of beryllium-related health effects suspected of being due to a common cause. The DOE directives on accident and incident investigation are aimed at events that happen at a discrete point in time. This cluster of beryllium-related health effects is not associated with a discrete event. In addition, the medical testing and examinations needed to characterize the extent of the health effects require some months to schedule and complete. The extended time frame for the investigation led to a need for periodic reporting and interim decisions that had not been anticipated. Guidance specific to the investigation of a cluster of occupational illness is lacking and would have been helpful in this case.

The team concluded that there is a lack of guidance and standards on effective methods for performing baseline inventories of beryllium contamination. Improved and expanded technical guidance on the control of beryllium contamination would also be useful.

Furthermore, the team concluded that DOE directives did not provide clear assignments of authorities and responsibilities for this investigation. The scope of DOE Order 225.1A, "Accident Investigations," is limited to health events that occur due to discrete accidental exposures. In addition, accident investigation methods require some adjustment to accommodate the time required for medical evaluations of health effects and evaluation of working conditions. Both directives that assign authority and responsibilities and non-mandatory technical guidance on methods are needed.

3.5 Why Did This Event Happen?

The team spent a significant amount of effort in attempting to determine why this event had occurred. The team interviewed both DOE and contractor personnel and reviewed a number of records regarding the health and safety programs for both NLV and NTS. There was clearly an awareness of the limited beryllium operations at the current machine shop in A1 and a recognition of some limited inventories of beryllium components both at NLV and NTS. However, it was clear that the potential for beryllium contamination at either NLV or NTS had not been identified as a concern in the present time period.

On the other hand, the historical record demonstrates there was a wide range of activities at NTS that had involved large quantities of beryllium, and many of those activities had significant potential to create particulate beryllium and result in removable contamination. The historic record also shows that even though the risks from the beryllium contamination may not have been recognized as well as it is today, there was a regular effort undertaken to monitor the workplaces.

It is important to note that before DOE issued its beryllium rule in 1999, there was no clear set of guidance, expectations, or requirements that specifically addressed protection against chronic beryllium disease. Although the potential for sensitizations and CBD had been known since the 1940's, most occupational requirements for protection against beryllium were focused on avoiding higher-level exposures that could result in acute beryllium poisoning. The discovery of an employee with CBD at the Rocky Flats Plant in 1984, and subsequent discoveries of additional cases of CBD and sensitizations around the weapons complex, prompted renewed interest by DOE in establishing a program specific to avoiding chronic beryllium disease. Therefore, between 1984 and 1999, the DOE undertook a series of efforts to evaluate the extent of the potential problem in the complex to increase awareness of the potential concerns within the industrial hygiene and occupational medicine communities to encourage additional research into the disease itself, and to develop and promulgate the specific expectations that resulted in the beryllium rule of 1999. During this time, DOE contractors, including those at the NTS and NLV, were subjected to a series of requests for information or for comments on draft requirements. During this investigation, the team reviewed some of those communications and made several observations.

In 1987 there was a plan developed to conduct a comprehensive baseline survey of the NTS for a variety of potential contaminants, including beryllium. A 1988 assessment by the DOE Office of Environment, Safety, and Health referred to this report as evidence that concerns over the potential contaminants at the site were being addressed. Apparently, this effort was never fully funded and not completed.

In 1993 Lawrence Livermore National Laboratory staff conducted a survey of selected areas for beryllium contamination in soil. While the scope of this evaluation was limited, it also identified areas of elevated beryllium levels for future considerations.

In 1991, EG&G Energy Measurements (EG&G/EM), one of the larger contractors for the NLV facilities, responded to a DOE request for beryllium exposure information by stating that employee exposures to beryllium were quite limited, and where they did exist they consisted of minor machining operations. In 1994, EG&G/EM was asked to review its workers for possible candidates for follow-up evaluations for beryllium exposures. EG&G/EM provided a list of 46 current and former employees with known histories of contact with beryllium; however, this list was limited to only machinists involved with the shops in NLV. Since EG&G/EM was primarily involved with work at NLV, it is not clear that this response was intended to include beryllium exposures at the NTS. That response concluded that work with beryllium at the site was limited and the exposures were probably low. It is not clear whether or not the workers were evaluated further.

Before 1996, there were several prime contractors conducting work at the NTS and NLV, including the three weapons laboratories, and the Nevada Operations Office (NV) functioned as the landlord and integrator of the activities at the sites. In 1996, the three prime contracts for site operations were combined into one performance-based contract that was awarded to BN. Inherent in this change was that BN was assigned the responsibility as the single site landlord, a new role for the contractors. However, the other contractors were still responsible for the health and safety of their workers, and the protection of the environment from their activities.

In 1996, DOE provided funding to Boston University to begin a study of former workers at the NTS. The "Medical Surveillance for Former Department of Energy Workers at the Nevada Test Site" project is carried out by Boston University School of Public Health in collaboration with the University of California San Francisco, and the Southern Nevada Building and Construction Trades Council. This study is still ongoing. Part of this work was the release in June 2000 of a "Needs Assessment for Screening Former NTS Workers for Beryllium Exposure", documenting a large collection of evidence discussing the historic uses of beryllium at NTS, and identifying a large group of former workers as candidates for follow up studies. This follow up effort began in March 2001, and as of March 2003 the project had screened 891 participants, with 10 confirmed beryllium sensitizations and 1 confirmed case of CBD.

In 1997, BN provided to DOE comments on the draft interim beryllium worker protection notice. In that letter, BN stated that "discussions with a few past and present industrial hygienists revealed that none of them were aware of beryllium exposures or monitoring at the [NTS]". The letter further states, "for past exposures, it might take excessive time to locate previous records, locate and interview prior employees, and perform hazard assessments of locations where beryllium was used."

In 2000, BN provided DOE with its Chronic Beryllium Disease Prevention Program Plan (CBDPP), as required by the DOE beryllium rule issued in 1999. As part of that rule, BN was required to conduct a baseline beryllium inventory of locations of beryllium operations and other locations of potential beryllium contamination. The BN response indicated the machine shop in A1 as the only ongoing or recent operation and discussed a couple locations where beryllium articles were known to be located. As for locations of potential contamination, the letter states "While no other specific historical areas where beryllium was used have been identified at this time, we will perform a review of archived records and interview personnel who might have knowledge of beryllium activities to determine potential contamination from past activities." These record reviews and interviews apparently were never carried out.

In conducting this investigation and observing the ongoing review of historical records, the team noted that as a result of the manner in which the site was operated before 1996, the separate contractors were working independently of each other. The resident contractors provided primarily a support role and most of the detailed knowledge of the activities resided in the laboratories that conducted the programs. As a consequence of this, there is no one archive or collection of documents that contain the collective history of activities that occurred at the site, although BN has a group whose ongoing mission is to build that archive. Many documents still remain in the collections of the various contractors that used the site, or are maintained in the personal records of individuals involved in the work.

On the other hand, one might expect that the corporate memory of the large number of staff that had been associated with those activities over the years would have maintained the knowledge and therefore identified the risk, or at least asked the questions when prompted by the recent DOE initiatives. From the documents noted, it is clear that prior to the early 1990's there was recognition of the potential for beryllium exposures at the NTS. However, after that time, there appears to be a complete lack of recognition. Therefore, the team also investigated the general history of site activities to see if there was any confounding factor that might help explain this situation.

In the late 1980's and early 1990's, the Cold War was beginning to come to a close with the economic collapse of the Soviet Union. As a result, the weapons programs began to lose support and funding, and in 1992 the United States President imposed a unilateral cessation on the testing of nuclear weapons. The last underground test at the NTS was conducted in September of 1992. Funding of the site was reduced annually from 1990 to 1996 by significant amounts and the number of contractor employees dropped by more than 60%. Similar cuts were occurring at the laboratories that had conducted the tests. The mission of the remaining resident staff at NTS and NLV shifted from the support of ongoing testing to maintaining a readiness to resume testing and to remediation of the site in order to release facilities for other applications. It appears now that, while the documents still existed, much of the corporate recognition of the hazards associated with the historical work at the NTS was lost, and the contractors now responsible for managing, characterizing, and remediating the site did not proactively investigate the historical activities.

The team concluded that this event most likely resulted from a general failure to recognize the potential hazards associated with the wide range of hazardous activities that have historically taken place at the NTS. This was apparently due in part to a dramatic loss of corporate memory and a failure to utilize the available records of previous site activities. However, the team also concluded that the current contractors missed multiple opportunities over the last several years to reconsider the potential of beryllium contamination at the site by not proactively reviewing the situation when prompted by the recent beryllium-related events at other DOE facilities and the series of activities associated with the establishment of the DOE beryllium protection rule.

3.6 Analysis of Relevant Environment, Safety, and Health Processes

3.6.1 Contractor ES&H Processes

The DOE Beryllium Rule requires employers to: "develop a baseline inventory of the locations of beryllium operations and other locations of potential beryllium contamination, and identify the workers exposed or potentially exposed to beryllium at those locations." The Rule requires that this inventory include a review of current and historical records, worker interviews, and air, surface and bulk sampling as appropriate. The Rule also requires that, if the inventory establishes the presence of beryllium, the employer must: "conduct a beryllium hazard assessment that includes an analysis of existing conditions, exposure data, medical surveillance trends, and the exposure potential of planned activities."

Bechtel Nevada transmitted a CBDPP to the DOE Nevada Operations Office on September 7, 2000. That plan states, "At this time there are no existing or planned operational tasks that involve the presence of beryllium in the workplace. Only beryllium articles as defined by 10 CFR 850.3(a) have been identified for both BN and National Laboratory operations." The plan also identified past activities in the Building A1 Machine Shop and stated that, "We will investigate further by conducting necessary surface sampling to quantify any contamination levels." The plan also states, "No other specific historical areas where beryllium was used have been identified at this time, we will perform a review of archived records and interview personnel who might have knowledge of beryllium activities to determine potential contamination from past activities." An examination of records and interviews with BN and DOE staff indicate that the records review and employee interviews were not performed. The BN CBDPP does not identify environmental restoration sites as possible sources of beryllium, does not address monitoring, sample handling or other environmental restoration activities, and does not identify the need to control transfer of materials from ER sites.

In 2002, the DOE Office of Independent Oversight and Performance Assurance (OA) conducted an inspection of the Nevada Test Site. While the inspection team did not specifically address this investigation, the team did identify issues with the implementation of inventory and hazard assessment provisions of the Beryllium Rule. Specifically, the OA team identified machinery that had not been analyzed for beryllium contamination. The team stated that the use and location of this equipment had not been inventoried or tracked. The team also stated that BN directives, guidance documents and hazard checklists did not identify beryllium as a hazard.

Since BN did not identify several potential beryllium exposures, processes for the evaluation and control of those exposures were not implemented. Also, BN did not conduct a complete evaluation of the Building A1 machine shop. Since this investigation and the OA review indicated that BN did not conduct a complete inventory of beryllium at NTS and did not conduct an assessment of all potential beryllium exposures, this investigation team does not have a basis for further analysis of BN's ES&H processes.

The team concluded that BN did not conduct a complete historical review (including employee interviews and examination of historical documents) to identify beryllium sources; therefore, BN's implementation of the DOE Beryllium Rule is less than adequate.

IT/SHAW does not have a CBDPP for its activities, under the assumption that they would not normally be working with beryllium. There is an informal agreement with BN that IT/SHAW would work under BN's coverage if it were deemed necessary. However, the IT/SHAW employees have been given beryllium awareness training, and there are provisions in their

Health and Safety Plans in case beryllium is identified as a contaminant of potential concern.

While BN is the responsible landlord for the site, IT/SHAW is responsible for the protection of its employees during their work activities. The team recognizes that since there was no prior awareness that beryllium contamination may be present at some of the IT/SHAW work areas, there would be no explicit effort taken to evaluate the possible exposure conditions. However, the team did note during its interviews that the IT/SHAW Health and Safety Plans (HASP) for their activities tended to focus mainly on providing worker protection against those potential contaminants identified as being of environmental concern. However, as noted previously for beryllium, it is possible for there to be contaminants of concern for worker safety that may not be of concern for environmental protection. Therefore, the team concluded that there was a weakness in IT/SHAW's HASP implementation that could result in an incomplete identification of potential worker hazards.

3.6.2 DOE ES&H Processes

The documents reviewed and interviews conducted by the team indicate that during the late 1990s no DOE management element or oversight activity recognized the potential for significant occupational exposure to beryllium at the NLV. From early 1997 through the end of 1999, the DOE was engaged in policy setting and rulemaking processes that ended in publication of the final rule 10 CFR 850 "Chronic Beryllium Disease Prevention Program." The DOE Nevada Operations Office responses to solicitations for information on the number of employees potentially included and the financial impacts of the proposed rule did not foresee requirements of the rule applying to operations at NTS or North Las Vegas.

The team was only able to locate one oversight document that specifically mentioned beryllium. The April 1988 Preliminary Environmental Survey Report indicates that beryllium is one of several contaminants potentially present and that there were plans for additional characterization work to determine the extent of contamination. Two oversight reports from the late 1990s make recommendations for improvements in NTS ability to recognize and evaluate potential hazards. The September 1998 report "Office of Oversight Review of the Occupational Medicine Program at the Nevada Test Site" states the following:

"A formalized performance assessment and feedback program, as required by the ISM policy, is also not currently in place. Such a program is needed to ensure that the medical program is knowledgeable of site-specific hazards and provides for effective medical surveillance of employees potentially exposed to those hazards."

It makes the following recommendation:

". . . Performance assessments should include elements of the DOE medical program requirements concerning medical surveillance programs, coordination and communication of hazard/exposure data, and rosters of employees potentially exposed to hazards."

The April 1999 report "Focused Safety Management Evaluation of the Nevada Test Site" states the following:

Direct management attention toward strengthening institutional processes to correct weaknesses in the readiness assessment process, the work control process, and the use of procedures.

- *Expand the level of detail in the BN readiness assessment process to clearly identify the requirements to review. Areas to improve include the reviews of safety analyses, hazard analyses, hazards assessments, design and installation of engineered controls, reviews and walkdowns of implementing procedures, and operator training requirements. Ensure that the results of these reviews are clearly documented and that all issues are resolved prior to start of operations.*

- *Develop clear and consistent requirements and procedures for utilization of DOE operating permits. Integrate with work authorization processes.*

- *Establish clear thresholds (by type and quantity of hazard) that define when preliminary hazards assessments, hazards assessments, and other hazard* *analyses require independent review by the ES&H organizations, both within BN and DOE.*

- ❑ *Develop and implement a structured work planning and control process that encompasses all activities and effectively applies the five core functions of ISM, as appropriate to the level of hazard involved. Include specific review and approval requirements for each stage of work, and identify specific responsibilities to ensure that all identified controls are in place prior to start of work.*

- ❑ *Implement BN and site user policies on procedure use that clearly define when procedures are required. Specifically identify when procedures should be used stepwise or for general reference at the job site. Clearly identify individual tasks that can be completed by "skill of the craft" and the specific training and experience requirements for those tasks.*

These two reviews were aimed at evaluating performance in implementing the overarching DOE ES&H policy initiative, DOE Policy 450.4 "Safety Management System Policy" which is referred to as integrated safety management (ISM). One of the core functions of ISM is "Analyze Hazards." While overall performance was good, the reports note some inconsistency in performance in this core function resulting in the recommendations quoted above. Thus DOE oversight efforts identified management system weaknesses that may have contributed to the failure to recognize beryllium hazards. However, beryllium hazards were not specifically identified as a concern.

The team concluded that expectations for hazard recognition and analysis were clearly communicated and DOE oversight processes were effective in creating efforts to improve performance in meeting these expectations.

The team also noted as a lesson learned that hazard analysis efforts for site characterization and restoration work at DOE sites must include records reviews. Given the degree of association between beryllium and nuclear technologies, DOE oversight efforts should explicitly include inquiries on whether a legacy of beryllium contamination exists on a site.

3.7 Causal Factors Analysis

A casual factors analysis was performed in accordance with the DOE Accident Investigation guidance. Causal factors are the events or conditions that produced or contributed to the occurrence of the observed effects and consist of the direct, root, and contributing causes.

The **direct cause** is the immediate event or condition that caused the observed effects.

Root causes are events or conditions that, if corrected, would prevent recurrence of this and similar events.

Contributing causes are events or conditions that collectively with other causes increase the likelihood of the event but that individually did not cause the event.

Attachment 3 contains the team's Events and Causal Factors Chart and the Events and Personnel Chart. The causal factors listed below are derived from these two charts.

Table 3.7-1: Causal Factors Analysis

Direct Cause

Personnel were unknowingly exposed to particulate beryllium contamination in their work areas, resulting in a diagnosis of chronic beryllium disease for one individual and multiple individuals diagnosed with beryllium sensitization.

Root Causes

RC 1 NSO and the responsible contractors did not recognize the potential for removable beryllium contamination from historic activities at NTS to exist at levels adequate to represent a possible hazard to the current workforce. (CC1, CC2, CC3, CC6, CC7)

RC 2 The potential for tracking of non-radiological contamination from NTS to NLV was not recognized as a possible exposure pathway. (CC2, CC4, CC5, CC6)

No.	Contributing Cause	Discussion
CC1	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination.	Records exist showing that large quantities of beryllium had been used in historic activities at NTS, and many of those activities had significant potential to create particulate beryllium contamination. BN did not conduct a full baseline inventory of potential beryllium-contaminated locations, as required by 10 CFR 850. IT/SHAW did not normally look for beryllium at their remediation sites since it was not of significant concern for environmental protection. IT/SHAW had conducted some surveys of beryllium in soil at NTS as early as 1999, but these surveys were very limited in scope. A comprehensive survey of NTS facilities and test areas, which included beryllium, was proposed in 1987 but never fully funded by DOE, and therefore never completed. Controlled areas of known radioactive material contamination from historic activities were reduced after radiation levels had decayed without consideration for other possible contaminants.

No.	Contributing Cause	Discussion
CC2	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas.	When preparing HASPs for work at remediation sits, IT/SHAW normally only established work controls for those contaminants identified as being of possible concern for environmental protection. BN did not have a process in place to periodically monitor areas, such as the A1 second floor, for contamination that might be transferred from the adjacent beryllium work area. IT/SHAW did not have a process in place to periodically monitor the B1 high bay area for contamination that might be transferred from NTS on vehicles or equipment.
CC3	Implementation and assessments of the provisions of 10 CFR 850 were less than adequate.	BN did not conduct a full baseline inventory of potential beryllium-contaminated locations even though records existed to demonstrate that there was potential contamination at NTS. IT/SHAW did not implement 10 CFR 850 based on the assumption that they would not normally be working with beryllium. DOE did not evaluate the adequacy of the baseline inventory during their assessments of BN's compliance with 10 CFR 850, although some related concerns were raised in a DOE/OA independent assessment in CY2002. There were multiple opportunities between 1991 and the present for NSO and the contractors to consider the possibility of contamination at NTS, but they were not pursued.

No.	Contributing Cause	Discussion
CC4	There is not adequate DOE guidance on how to conduct a baseline inventory for potential beryllium-contaminated locations.	Although 10 CFR 850 does require a baseline inventory of potentially contaminated locations, the rule mainly focuses on ongoing beryllium-related activities such as machine shops. There are no requirements in 10 CFR 850 dealing with beryllium contamination in soil or dealing with limiting beryllium contamination in uncontrolled areas.
CC5	There is not adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas.	There are no requirements in 10 CFR 850 for periodic monitoring of areas adjacent to or associated with beryllium work areas to detect the possible spread of beryllium contamination beyond the confines of the controlled work area. This contamination event was only discovered after the diagnosis of CBD in an individual and the identification of several cases of beryllium sensitization.
CC6	Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors.	There were multiple opportunities between 1991 and the present for NSO and the contractors to reconsider the possibility of contamination at NTS, due to awareness of similar issues at other DOE sites, but they were not pursued. The ongoing Boston University study of the health of former NTS employees had identified concerns with beryllium contamination at NTS as early as CY2000. LLNL had identified beryllium contamination in soil at some NTS facilities in CY1993 during very limited surveys, but DOE and the previous site contractors never pursued this to evaluate the full extent of the contamination.

No.	Contributing Cause	Discussion
CC7	Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions.	Records exist showing that large quantities of beryllium had been used in historic activities at NTS, and many of those activities had significant potential to create particulate beryllium contamination. BN did not conduct a full baseline inventory of potential beryllium-contaminated locations, as required by 10 CFR 850. IT/SHAW conducted preliminary assessments involving record searches for each facility it characterizes before beginning significant onsite work. However, much of the information regarding beryllium-related activities was apparently no included, even though records existed in the archives. IT/SHAW did not normally look for beryllium at their remediation sites since it was not of significant concern for environmental protection. IT/SHAW had conducted some surveys of beryllium in soil at NTS as early as 1999, but these surveys were limited in scope. The ongoing Boston University study of the health of former NTS employees had identified concerns with beryllium contamination at NTS as early as CY 2000. LLNL had identified beryllium contamination in soil at some NTS facilities in CY 1993 during very limited surveys, but DOE and the previous site contractors never pursued this to evaluate the full extent of the contamination.

4.0 Judgments of Need

Judgments of Need (JON) are managerial controls and safety measures believed necessary to prevent or minimize the probability of a recurrence. They flow from the Causal Factors and are directed at guiding managers in the development of corrective actions.

In addition to the Causal Factors, the team also identified some concerns related to observations of the DOE, NNSA, and contractor responses to the initial event, and to processes used in this investigation. The nature of this event was different than a normal accident, and consequently the investigation processes were modified accordingly. The team believes that some of the lessons learned warrant direct action by DOE, and therefore some JONs were developed for addressing these issues.

Note the team has assigned several of the JONs to NSO for action. In some cases this is due to the fact that the team struggled with understanding the overlapping roles and responsibilities of the various site contractors, which resulted in JON 1. It is the team's expectation that NSO will reassign some of the JONs (specifically JONs 3 – 6) to the responsible contractors based on NSO's resolution of JON 1.

Table 4-1: Judgement of Need

No.	Judgement of Need	Related Causal Factors
JON 1	NSO needs to review the roles and responsibilities that it has contractually assigned to the various site contractors to ensure that the environment, safety, and health responsibilities of individual contractors, and their interfaces with the other contractors, are clearly defined, appropriate, and complete.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 2	NSO needs to ensure that all current and planned activities at NTS (including Work-for-Others) are evaluated for the possibility of personnel exposure to residual beryllium contamination from historic activities.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2)

No.	Judgement of Need	Related Causal Factors
		Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 3	NSO needs to ensure that the hazards identification processes used by contractors at NTS explicitly consider beryllium as a possible contaminant for all work at NTS.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 4	NSO needs to ensure that the full extent of the spread of beryllium contamination (including NTS, NLV, and offsite locations) is determined, and that mitigative or corrective actions are established as appropriate.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5)

No.	Judgement of Need	Related Causal Factors
		Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 5	NSO needs to ensure that historic site records are collected and consolidated to document the historic beryllium activities conducted at NTS and NLV, and NSO needs to ensure that this information is used in the hazard identification and evaluation processes of the contractors conducting work at NTS and NLV.	Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 6	NSO needs to ensure that occupied buildings at NTS and NLV are regularly monitored for the potential introduction and spread of beryllium into uncontrolled areas, at least until the extent of the beryllium contamination has been determined and evaluated and controls have been identified and implemented.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6)

No.	Judgement of Need	Related Causal Factors
JON 7	NSO needs to establish a process to ensure the continuity of the historical knowledge base across contract and staff changes to avoid a similar event in the future.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 8	NSO needs to ensure that NTS is evaluated for other possible non-radiological contaminants, identified from the historic records, that could be spread into uncontrolled areas in a manner similar to this event.	The potential for tracking of non-radiological contamination from NTS to NLV was not recognized as a possible exposure pathway. (RC2)
JON 9	BN needs to conduct a complete baseline inventory of beryllium activities and possible locations of contamination in accordance with the requirements of 10 CFR 850.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)

No.	Judgement of Need	Related Causal Factors
JON 10	IT/SHAW needs to reconsider the decision to not implement the requirements of 10 CFR 850 for their work activities.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3)
JON 11	BN and IT/SHAW need to review their current work control processes to ensure that the lessons learned from this event are adequately addressed, especially in regard to ensuring that the hazard identification and evaluation processes are robust in considering all possible hazards and are consistently applied in all work situations.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 12	BN and IT/SHAW need to review current industrial hygiene practices based on the lessons learned from this event to ensure that monitoring and evaluation of workplaces are conducted with an understanding of both the current and the historic uses of the facility.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)

No.	Judgement of Need	Related Causal Factors
JON 13	NNSA and NSO need to review current roles and responsibilities, based on the lessons learned from this event, to ensure that oversight of NTS and NLV contractors is appropriate and focused on establishing a full understanding of possible hazards that may be present from both current and historic activities.	Facilities and former test and experiment locations at NTS have not been surveyed for possible beryllium contamination. (CC1) The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) Lessons learned from previous events were not adequately identified and acted upon by either DOE or the contractors. (CC6) Information regarding historical activities and legacy hazards at NTS was not effectively used in the evaluation of current site conditions. (CC7)
JON 14	DOE needs to develop a risk assessment process for evaluating beryllium exposure pathways.	The work control processes of BN and IT/SHAW did not result in an evaluation of work areas for possible beryllium contamination outside of ongoing beryllium work areas. (CC2) There is not adequate DOE guidance on how to conduct a baseline inventory for potential beryllium-contaminated locations. (CC4) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5)

No.	Judgement of Need	Related Causal Factors
JON 15	DOE needs to review 10 CFR 850 against the lessons learned from this investigation, especially focusing on (1) the narrow focus of the rule's application; (2) the lack of requirements for beryllium contamination limits in uncontrolled areas; and (3) the lack of requirements for monitoring the spread of contamination into uncontrolled areas adjacent to or accesible from beryllium-controlled areas.	Implementation and assessments of the provisions of 10 CFR 850 were less than adequate. (CC3) There is no adequate DOE guidance on how to conduct a baseline inventory for potential beryllium-contaminated locations. (CC4) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5)
JON 16	DOE needs to provide additional guidance on the implementation of 10 CFR 850 requirements especially focusing on (1) DOE expectations for the conduct of the required baseline inventory; (2) the control of the spread of contamination outside of beryllium-controlled work areas; (3) technical limitations in sampling techniques for evaluating removable beryllium contamination in non-operational situations such as office areas.	There is no adequate DOE guidance on how to conduct a baseline inventory for potential beryllium-contaminated locations. (CC4) There is no adequate DOE guidance on controlling the possible spread of beryllium contamination outside of controlled beryllium work areas. (CC5)
JON 17	DOE needs to develop processes to improve their ability to respond to an incident of this nature, and to ensure that decisions regarding the protection and evaluation of affected personnel, their relocation from suspect workplaces, and the investigation process are based on established policies and standards to the extent possible.	This is based on observations of the event response, and not causal factors. There was no policy or guidance for the decision to relocate workers from the buildings, such as criteria for establishing the need for relocation, or identifying who has the authority to commit resources. The DOE Accident Investigation procedures do not provide guidance on conducting extended-duration investigations, nor on investigations involving situations with no clearly defined initial event.

No.	Judgement of Need	Related Causal Factors
JON 18	DOE needs to review the medical surveillance processes for beryllium exposures to ensure that the lessons learned from this event are incorporated.	This is based on observations of the event response, and not causal factors. There is no accepted risk assessment model for inhalation of beryllium, which limits the ability to apply exposure pathway models to the evaluation of exposure scenarios. The occupational medicine community is still undecided on the value of the beryllium LPT test as a screening tool in the absence of workplace indications of possible beryllium exposures. The background incidence rate of beryllium sensitization in the general public is unknown, which complicates the screening of beryllium sensitization clusters in a population. The magnitude and impact of the beryllium sensitization tests' false positive and false negative rates are not well known. The clinical definition of CBD needs to be reviewed and standardized to improve consistent application of disease diagnosis.

5.0 Team Signatures

Date June 13, 2003

Douglas M. Minnema, Ph.D, CHP, Team Leader
U.S. Department of Energy
National Nuclear Security Administration
NNSA Service Center, Environment, Safety, and Health Department

Date June 13, 2003

James Slawski, CIH, CSP, Member
U.S. Department of Energy
National Nuclear Security Administration
NNSA Service Center, Environment, Safety, and Health Department

Date June 13, 2003

David M. Anglen, Ph.D., CIH, CSP, Member
U.S. Department of Energy
National Nuclear Security Administration
Sandia Site Office

Date June 13, 2003

John R. Eschenberg, Member
U.S. Department of Energy
Office of River Protection

Date June 13, 2003

Paul Wambach, CIH, Member
U.S. Department of Energy
Office of Environment, Safety, and Health

Date June 13, 2003

Mark D. Hoover, Ph.D., CHP, CIH, Member
Centers for Disease Control and Protection
National Institute for Occupational Safety and Health

Date June 13, 2003

Captain W. Gary Rudolph, M.D., Member
Naval Environmental Health Center
U.S. Navy

6.0 Team Members, Advisors, and Staff

Team Leader	Douglas M. Minnema, Ph.D., CHP NNSA Service Center, Environment, Safety, and Health Department
Member	James Slawski, CIH, CSP NNSA Service Center, Environment, Safety, and Health Department
Member	David M. Anglen, Ph.D., CIH, CSP NNSA Sandia Site Office
Member	John R. Eschenberg U.S. DOE Office of River Protection
Member	Paul Wambach, CIH U.S. DOE Office of Environment, Safety, and Health
Member	Mark D. Hoover, Ph.D., CHP, CIH NIOSH Centers for Disease Control and Protection
Member	Captain W. Garry Rudolph, M.D., USN Navy Environmental Health Center
Advisors	Joseph F. Tinney, SAIC Joseph Furman, M.D., ORISE David Duebner, M.D., Brush Wellman, Inc.
Legal Advisor	Kathy D. Izell, NNSA Nevada Site Office
Technical Writer	Robin Phillips, SAIC

Attachment 1: NNSA Appointment Letter

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

August 22, 2002

MEMORANDUM FOR: Kathleen A. Carlson, Manager
Nevada Operations Office

FROM: Linton F. Brooks
Acting Administrator

SUBJECT: INVESTIGATION OF THE BERYLLIUM ISSUE AT THE NATIONAL NUCLEAR SECURITY ADMINISTRATION, NEVADA OPERATIONS OFFICE

As per your request of July 24, 2002, I am hereby commissioning a multi-disciplinary team to conduct a comprehensive investigation and evaluation of the beryllium issue at the National Nuclear Security Administration/Nevada Operations Office (NNSA/NV). I fully agree with your concern over the health and safety of the NNSA/Department of Energy (DOE) workforce, and, therefore, I believe that this investigation is prudent and appropriate for the situation. It is also clear that this issue needs to be resolved in order to consider the possible implications for other activities at NNSA and DOE facilities.

I am appointing Dr. Douglas Minnema from the Office of Environment, Safety and Health Operations Support (NA-53) as the team leader for this investigation. Dr. Minnema is a Senior Technical Safety Manager and has led or participated in a variety of team activities, including accident investigations, operational readiness assessments, and integrated safety management verifications. The team will be composed of Federal employees representing NNSA, the Office of Environment, Safety and Health (EH), the National Institute of Occupational Safety and Health (NIOSH), and NNSA field elements. The members of this team will be responsible for leading working groups of experts that will collect and analyze the information regarding the various aspects of the situation. The team then will be responsible for developing conclusions and recommendations based on these evaluations.

The team is composed of the following personnel, and they will be augmented as necessary with experts as technical advisors:

Team Member	Affiliation
Douglas Minnema, Ph.D., CHP	NNSA/NA-53
James Slawski, CIH	NNSA/NA-53
Paul Wambach, CIH	DOE/EH-6

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Mark Hoover, Ph.D., CHP, CIH	NIOSH
Margaret Herrick, M.D.	NIOSH
John Eschenberg	NNSA/LASO

The task of this team is to determine what happened, why it happened, what corrective action is necessary, and to disseminate lessons learned to NNSA/NV and to the rest of the Department. While the immediate focus of the team is to be on the situation at NNSA/NV, they must also consider whether the situation suggests the presence of broader implications to the Department. In conducting this investigation, I expect the team to address, as a minimum, the following questions:

- What is the history of beryllium activities at the facility in question and is there sufficient reason to believe that the building conditions could result in the impacts observed in the workers?

- Do current medical diagnostic tests provide an adequate level of validity, accuracy, and reliability to provide a useful indicator of exposure to beryllium?

- What is the history of contact with beryllium, both occupational and non-occupational, for the impacted employees and is there sufficient reason to eliminate other potential exposure pathways as the source of the observed impacts?

- What is the technical basis for the current standards and regulations for protection against beryllium and does this current situation imply a weakness that needs to be addressed?

After investigating these areas of concern, I expect that the team develop conclusions and recommendations regarding the above questions, as appropriate. However, the primary responsibility of the team is to apply the evaluations of the above questions to the situation at hand; specifically, they are to recommend the actions deemed necessary to ensure that NNSA/DOE employees and contractors are adequately protected from exposure to beryllium under all expected conditions. These recommendations must include consideration for the ultimate restoration or disposition of the building complex, if it is concluded that the exposures took place in the buildings. The team shall allow for the inclusion of dissenting opinions should they be unable to reach a consensus on the conclusions and recommendations.

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The team leader shall be the primary point of contact for all internal and external inquiries into the status of the investigation during its progression. I also expect the team leader to periodically report on the team's activities to NNSA management and to provide a final briefing to myself, NNSA senior management, and the Assistant Secretary for Environment, Safety and Health. The team's work should be completed, and the final report prepared for my acceptance within 90 days.

cc:
B. Cook, EH-1
S. Cary, EH-6
E. Beckner, NA-10
J. Mangeno, NA-53
G. Rudy, NA-50
R. Erickson, LASO

Team Members:
J. Slawski, NA-53
P. Wambach, EH-6
M. Herrick, NIOSH
M. Hoover, NIOSH
J. Eschenberg, LASO

Note:

After the issuance of this letter, it was necessary to change the team composition as follows:

- Margaret Herrick, M.D., of NIOSH, was replaced with Captain W. Garry Rudolph, M.D., Unite States Naval Environmental Health Center.
- David Anglen, Ph.D., CIH, NNSA Sandia Site Office, was added to the team.

In addition, the 90-day deadline for the report was extended when it was found necessary for the building occupants to be relocated to allow the team to conduct intrusive evaluations of the buildings.

Attachment 2: Building Recommendation Letter

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

March 25, 2003

MEMORANDUM FOR AMBASSADOR LINTON F. BROOKS
ADMINISTRATOR

FROM: DOUGLAS M. MINNEMA *Douglas M. Minnema*
NORTH LAS VEGAS BERYLLIUM INVESTIGATION
TEAM LEADER

SUBJECT: RECOMMENDATION FOR THE DISPOSITION OF BUILDINGS INVOLVED IN THE BERYLLIUM INVESTIGATION AT THE NATIONAL NUCLEAR SECURITY ADMINISTRATION'S NORTH LAS VEGAS FACILITY

On August 22, 2002, you commissioned a multi-disciplinary team to conduct a comprehensive investigation and evaluation of the beryllium issues at the National Nuclear Security Administration's North Las Vegas Facility (NLV). This investigation was in response to a medical diagnosis of Chronic Beryllium Disease (CBD) in an individual working at the NLV Facility, and subsequent identification of eleven other beryllium-sensitized workers. Seven of these workers, including the person diagnosed with CBD, had never knowingly been exposed to beryllium above normal background levels. Since some of the buildings in which these workers resided had previously housed shops where beryllium-laden materials had been machined, residual contamination in the buildings was the primary suspect. The team was tasked to conduct a full investigation of the situation and to also provide a recommendation for the ultimate restoration or disposition of the involved buildings.

The investigation is still in progress, although it is nearly completed. The full report is expected to be ready for your approval in the month of April. However, the team has completed their evaluation of the involved buildings and is prepared at this time to provide you with a recommendation for the disposition of those buildings. This recommendation is being provided separately to allow your staff to begin the planning and budgeting efforts necessary.

Please note that this recommendation will only discuss the current conditions in the buildings, but will not discuss the team's considerations into the causes of those conditions. Those discussions will be part of our final report, after the team has completed the other aspects of its investigations and has had an opportunity to develop the broader conclusions and recommendations deemed necessary to prevent recurrences of similar events.

There are four buildings involved in this investigation— the "B-complex," composed of buildings B1, B2, and B3, and building A1. The B1 building was the primary concern, since before 1994 it housed a general-purpose machine shop that machined various metals, including beryllium, and is also the building where several of the cases resided. The B2 and B3 buildings

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are attached to B1, and B3 may also have had some limited beryllium-related activities. The A1 building is where the machine shop is currently located, and so was included in this investigation.

The team believes that all buildings can be restored to pristine conditions with a reasonable amount of effort. However, each building must be discussed separately as the current conditions and consequently the recommendations are different for each.

Recommended Cleanup Standard

Before discussing the individual buildings, it is important to first consider a recommendation for the cleanup standard to be applied. There currently is no standard that is directly applicable to this application, although the Department of Energy (DOE) Beryllium rule, 10 CFR 850, does contain a criterion for the free release of materials from beryllium work areas. That criterion is specified as 0.2 micrograms per 100 square centimeters ($\mu g/100\ cm^2$) for removable beryllium. In light of the evidence gathered during this investigation, the team believes that this value would be appropriate and adequate for use as the primary cleanup criterion for the buildings. Also, in these criteria the team is applying the principles of the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) to this situation. MARSSIM provides a nationally consistent consensus approach to conducting radiation surveys and investigations at potentially contaminated sites and is endorsed by the DOE, the National Regulatory Commission, and the Environmental Protection Agency. Some deviations to the MARSSIM approach are necessary since sampling techniques for beryllium are different than for radiological contamination, and since risk-based modeling of the consequences of exposure to beryllium is not as well developed as for exposure to radioactive materials. Therefore, the team recommends the following cleanup criteria:

1. **Individual measurements above 0.2 $\mu g/100\ cm^2$ shall initiate remedial actions. Additional surface sampling shall be conducted to determine the area that requires remediation. Information on the likely cause should be analyzed to determine if it suggests other locations requiring attention and how to prevent reoccurrence.**

2. **The sampling program shall be based on statistical survey techniques to ensure that there is a 95% level of confidence that 95% of the building areas do not exceed beryllium contamination levels of 0.2 $\mu g/100\ cm^2$.**

3. **The first floor of building B1, both office and high bay areas, should be divided into survey units of approximately 100 m^2 (1080 ft^2) of floor space. There should be at least 10 sampling locations per survey unit. Buildings A1, B2, B3, and the second floor of B1 should be divided into survey units of approximately 1000 m^2 (10,800 ft^2) and there should be at least 20 sampling locations per survey unit. The American Society for Testing and Materials method 1728-02 or equivalent should be used to collect wet swipes from randomly selected sampling locations. The sampling locations should include floors, walls, and overhead surfaces.**

3

4. **The Nevada Site Office (NSO) should charter an independent assessment of the final survey processes and results to ensure that the cleanup criteria have been adequately and appropriately satisfied. This approach is similar to that commonly used for site remediation and free release surveys conducted under the MARSSIM process. The assessment team should be (1) independent of the involved contractors and NSO, and (2) should include expertise in the MARSSIM processes, statistics, and industrial hygiene.**

The team wishes to express one caution regarding the 0.2 $\mu g/100\ cm^2$ criterion. The levels of removable contamination due to environmental background of beryllium may approach the cleanup criterion when surfaces have significant levels of settled dust. Since the purpose of surface monitoring will be to assure cleaning has been adequate, any visible accumulations of dust should be cleaned prior to surveys.

Ceiling Tile Considerations

One area of concern in common to all buildings is the drop ceiling with commercially available acoustic tiles. This investigation found measurable levels of beryllium contamination on the upper surfaces of essentially all acoustic tiles evaluated. Follow-up evaluations determined that this contamination was due to naturally occurring beryllium in the material composition of the acoustic tiles. As the acoustic tiles aged, the unfinished upper surfaces eroded resulting in a dusting of that surface with low levels of beryllium. This effect was not the source of the material discovered in the rest of the building, and the team does not consider this situation as a health concern. However, it does complicate the ability to clean the building to the recommended cleanup criteria. Therefore, the team recommends that the acoustic tiles be replaced with new acoustic tiles during the restoration efforts.

Building B1

Description
The B1 building is a two-story building built in the early 1980's and is subdivided into two sections of roughly equal areas. The western side of the building is a single-level high bay of about 20,000 square feet (ft^2) with concrete floors and two mezzanine areas. The eastern side of the building is configured for two stories of light offices and work cubicles (about 20,000 ft^2 for each floor). The office areas and hallways are carpeted with drop ceilings with commercially available acoustic tiles. Some internal walls are standard stud and sheetrock construction while others are movable partitions, many of which are fabric covered. Heating, ventilation, and air conditioning (HVAC) for the building is provided separately for the two sections. The high bay area is provided with evaporative coolers, space heaters, and passive ventilators while nine commercial air-handling units on the roof of the building service the office area. Some additional units were added to supplement the main units for some offices when the original HVAC system did not provide adequate flexibility for building modifications over its years of service.

Current Conditions
The B1 building contains beryllium contamination, in excess of the cleanup criterion, in various areas. Some contamination was found in the southwestern section of the high bay area, primarily in the cracks and expansion joints of the concrete floor. There is one small carpeted area in this section of the high bay, and it is contaminated at levels above the cleanup criteria. In the office areas of the building, the contamination is primarily concentrated in the carpeting on the first floor. The average contamination levels in this area are in excess of the cleanup criteria. On the second floor, there is an area of elevated contamination above the cleanup criteria, although the general area is lower than the first floor. The building's HVAC systems were evaluated, along with selected portions of ductwork, and no evidence of elevated levels of beryllium was found in any of the samples. The fabric-covered partitions and other upholstery were not sampled but are suspected to have some level of beryllium contamination.

Recommendation
The team recommends that for the B1 building, the following actions are necessary as a minimum: (1) Remove and dispose of all carpeting and acoustic tiles. (Finding contamination remaining in carpet that was routinely vacuum-cleaned is consistent with literature reports on lead abatement. Replacement has been found to be the most cost-effective abatement method for contaminated carpet and upholstery.) Note that the beryllium contamination in the carpet on the first floor is high enough to warrant special precautions for the remediation workers; (2) Remove and dispose of all upholstered furnishings and partitions that are not readily cleanable and swipeable; (3) All floors, walls, and overhead surfaces should be cleaned, including the high bay area; (4) At this point the building should be fully surveyed and re-cleaned, if necessary, to meet the cleanup criteria; and (5) When the building has been shown to meet the cleanup criteria, then the floors should be sealed, the walls painted, and new carpeting and furnishings may be installed as desired.

Note that the team does not include a recommendation on the HVAC systems. The team did not detect elevated levels of beryllium in these systems and, therefore, cannot justify a recommendation for their replacement. However, it would be prudent to either clean or replace some components of these systems, especially in those areas where dust tends to collect.

Building B2

Description
The B2 building is a single story building of 14,500 ft^2, located between B1 and B3, and adjoining both buildings. This building was added shortly after the construction of B1 and B3 in the early to mid 1980's. The south door of B1 accesses the B2 hallway and, similarly, the north door of B3 accesses the B2 hallway at the opposite end. The building contains the Bechtel Nevada's (BN) executive management offices, other light offices, and conference rooms, is fully carpeted, and has a drop ceiling with acoustic tiles. All HVAC services are provided by roof-mounted air-handling systems.

Current Conditions
Of 31 carpet samples taken in B2, only one sample indicated levels of beryllium contamination in excess of the free release criteria. This sample was in the executive conference room and

probably represents tracking from B1. As indicated above, the acoustic tiles in this building were the same style as those in the other buildings and, therefore, contained similar amounts of beryllium dust. There were no elevated levels of beryllium detected in the HVAC systems.

Recommendation
The team recommends that for B2, the carpeting and the acoustic tiles should be removed and disposed of, and the building should receive a general cleaning. Then, the building should be surveyed against the cleanup criteria. Upon satisfying the cleanup criteria, new carpeting and acoustic tiles should be installed.

Building B3

Description
The B3 building is a two-story building built at the same time as B1. The building contains two floors of light offices with a central atrium area open to both floors. The first floor has about 40,000 ft^2, and the second floor has about 37,500 ft^2 (the difference being the open area of the atrium). As with B1, the interior spaces are divided by a combination of sheetrock walls and movable partitions. All areas are carpeted, and the ceiling is the same drop-ceiling design with acoustic tiles as in B1 and B2. About 16 main roof-mounted air-handling units, with some small units servicing individual areas, service the building.

Current Conditions
Of the 102 carpet samples taken in this building, none were above the cleanup criteria although several were approaching that value. Based on the evidence, there is adequate suggestion that there is some beryllium contamination in the building although at much lower levels than B1. As with B1 and B2, the acoustic tiles contained some levels of beryllium contamination on the upper surfaces. There was no evidence of elevated beryllium levels in the HVAC systems.

Recommendation
The team recommends an approach similar to that for B2. The carpeting and acoustic tiles should be removed and disposed of, and the building cleaned. Then, the building should be surveyed against the cleanup criteria with any additional cleaning as necessary until the criteria is met. Once the cleanup criteria are satisfied, the carpeting and acoustic tiles may be replaced and the building readied for re-occupancy.

Building A1

Description
The A1 building is a two-story structure, subdivided into two halves, one with two floors and the other with a single floor high bay area. The first floor and high bay area contain machine shops and fabrication work areas. The second floor is primarily light offices and equipment rooms for various purposes. Due to the nature of the work performed in the machine shops, this building is considered critical for the mission of maintaining test readiness at Nevada Test Site. One of the machine shops on the first floor is the currently designated beryllium machine shop although no beryllium work is currently underway. This is the shop that was relocated from B1 in 1994. The first floor of this building mainly has either concrete or tile floors, and there are no drop ceilings

or acoustic tiles. The second floor is carpeted and does have the commercial drop ceiling with acoustic tiles.

Current Conditions
Due to the known presence of the beryllium machine shop on the first floor and the nature of those work areas, the team did not attempt to assess the beryllium levels on the first floor of A1. That area is normally evaluated as part of the site's beryllium control program. However, the team did evaluate the second floor offices where workers, who are not normally involved with the machine shop activities, are collocated. The acoustic tiles showed low levels of beryllium in the same manner as those in the other buildings and for the same reason. In all carpet samples except for one, the beryllium levels were well below the cleanup criteria. In the one exception, contamination above the cleanup criteria was found in a section of carpeting immediately in front of the elevator from the first floor.

Recommendation
The team recommends an approach similar to that for B2. The carpeting and acoustic tiles on the second floor of the building should be removed and disposed of, and the second floor cleaned. Then, that section of the building should be surveyed against the cleanup criteria with any additional cleaning as necessary until the criteria is met. Once the cleanup criteria are satisfied, the carpeting and acoustic tiles may be replaced and that section of the building readied for re-occupancy. The team does not recommend any cleanup activities on the first floor of the building but, rather, recommends that BN review their current beryllium control program to ensure that it provides adequate protection against the transference of beryllium from the shop areas into the other parts of the building.

Conclusion

The team's recommendations are based on best industry practices for assuring that the buildings will be safe to reoccupy. However, success will depend on the acceptance by the occupants that the buildings provide a safe and healthful workplace. It would be prudent for NSO and BN provide potential occupants an opportunity to review and comment on remediation plans so that concerns can be identified and addressed. In addition, consider soliciting suggestions on what other work might need to be done in the buildings to improve the working conditions.

It should be noted that the efforts of the team in evaluating the buildings were not intended to provide a complete characterization of the buildings, but, rather, to provide sufficient information to determine the presence and nature of any beryllium exposure pathways that may exist in the buildings. In that effort, the team has been successful, but it should not be assumed that the team has identified the highest and worst contamination levels that may be present. Therefore, all of the remediation work proposed here should be conducted with due regard to the potential hazards, with careful planning, and with the direct and intimate involvement of qualified industrial hygiene personnel.

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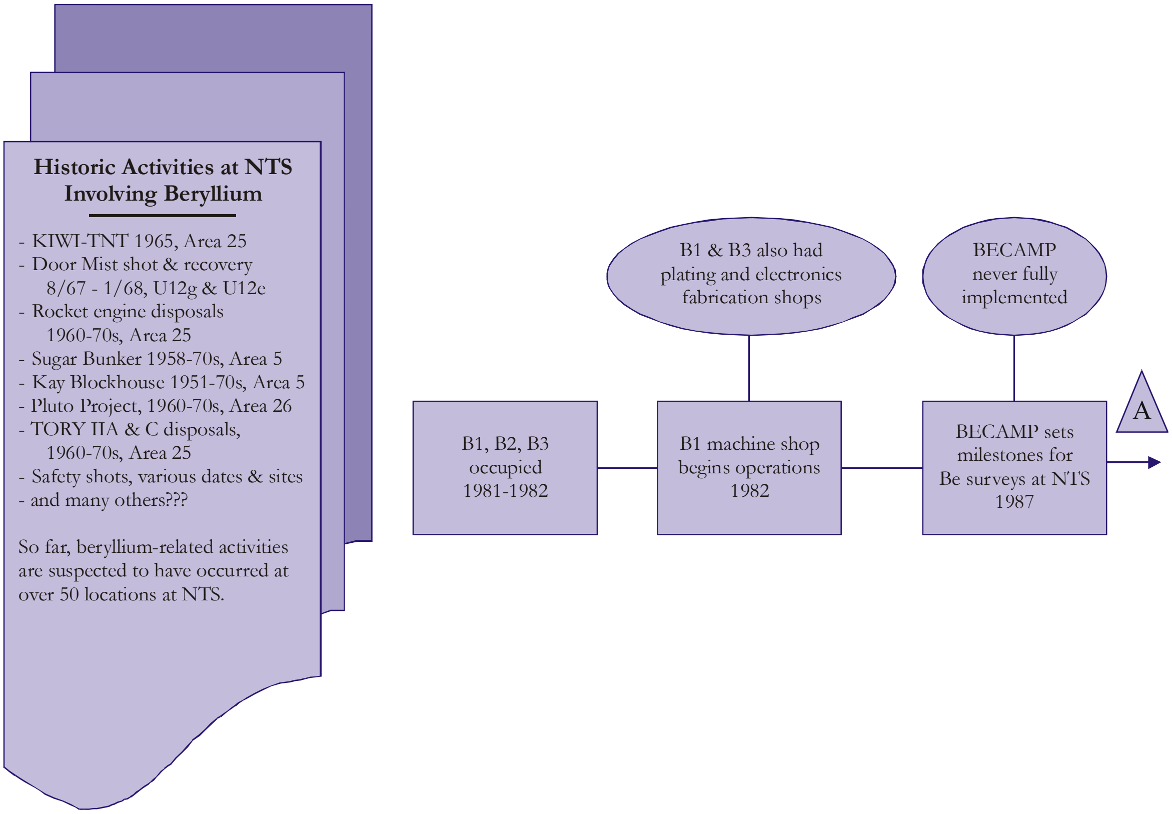
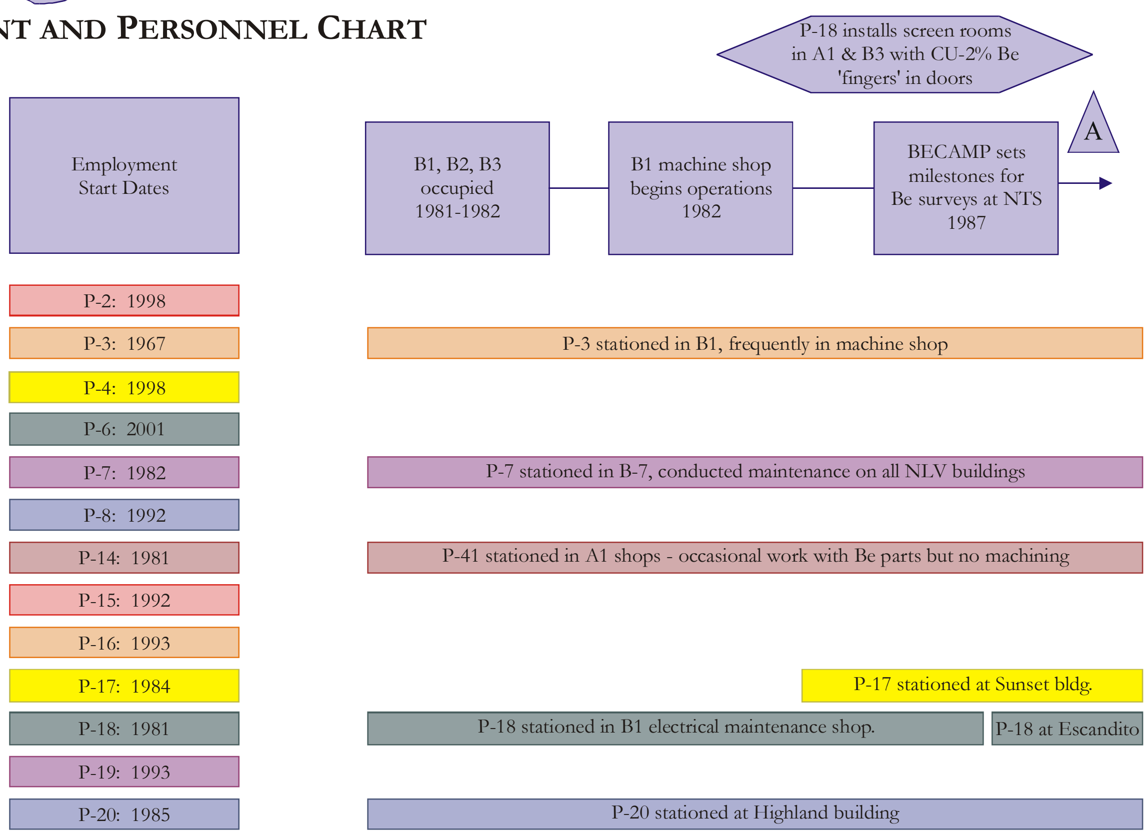
S. Johnson, EM-5

Attachment 3: Events, Causal Factors, and Personnel Charts

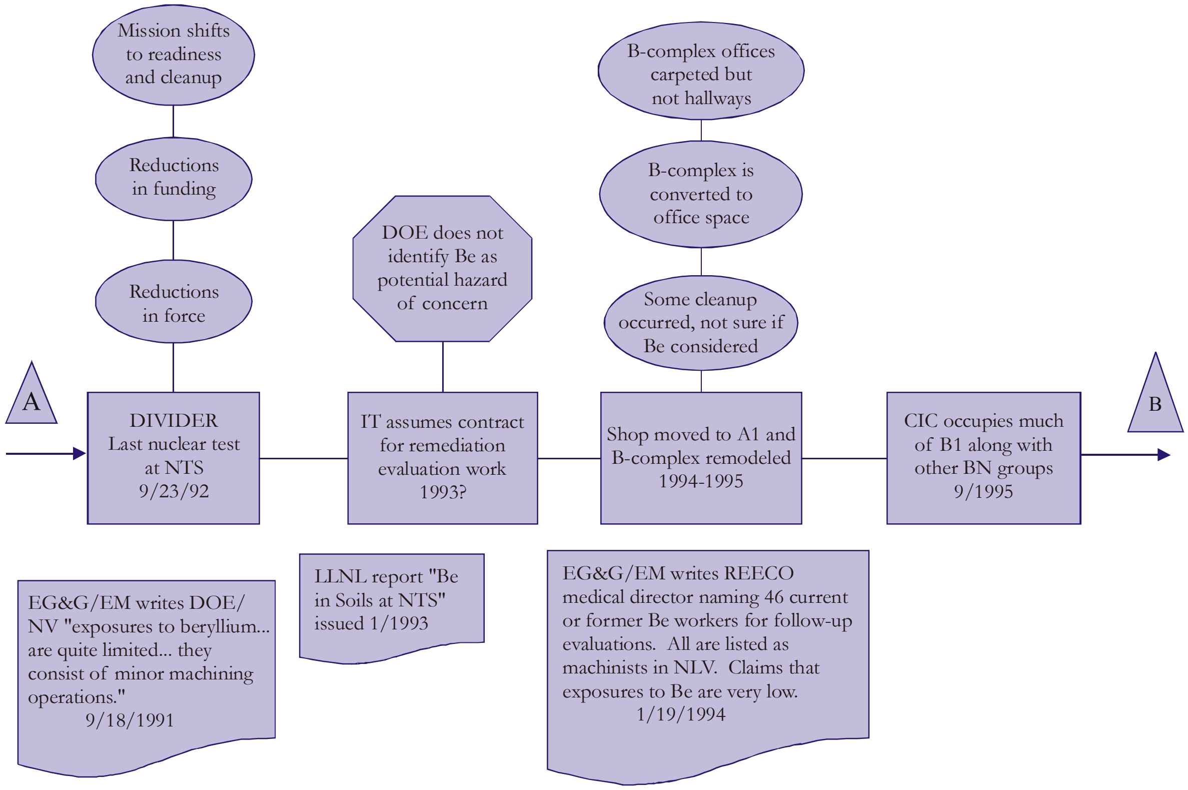
Event and Causal Factors Chart



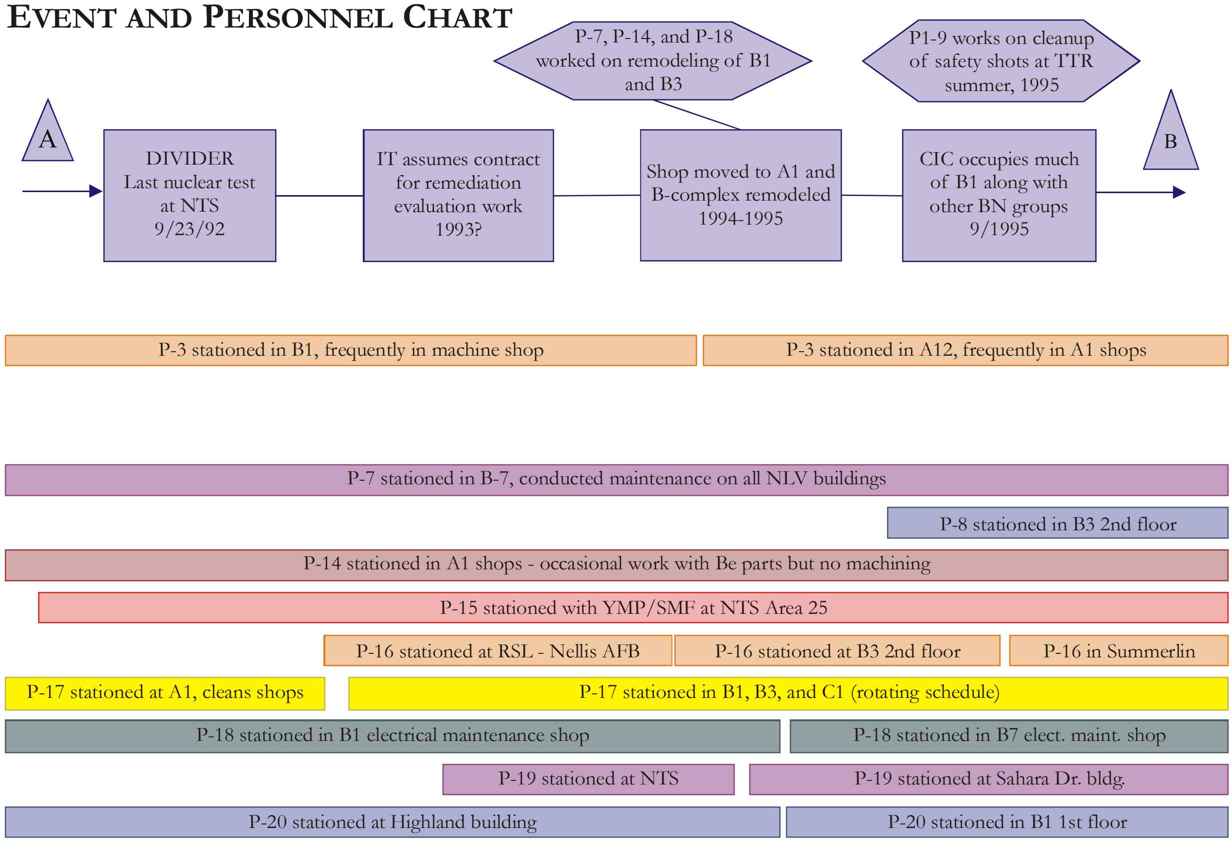
Event and Personnel Chart



Event and Causal Factors Chart



Event and Personnel Chart



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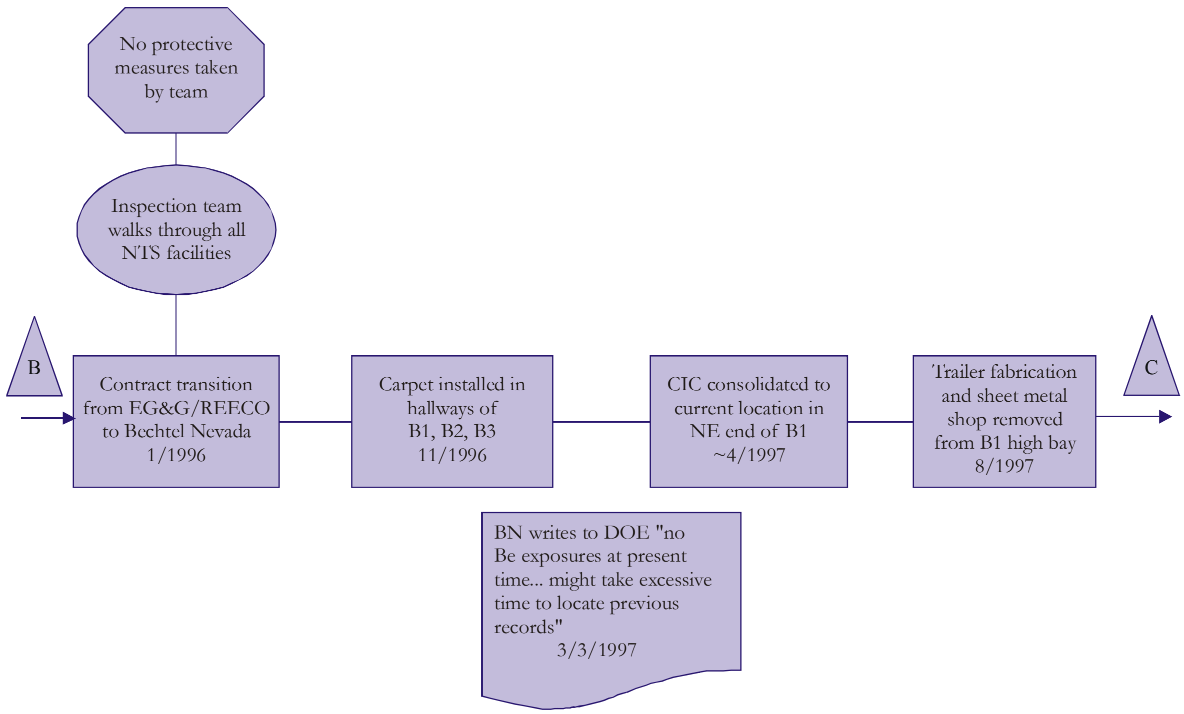

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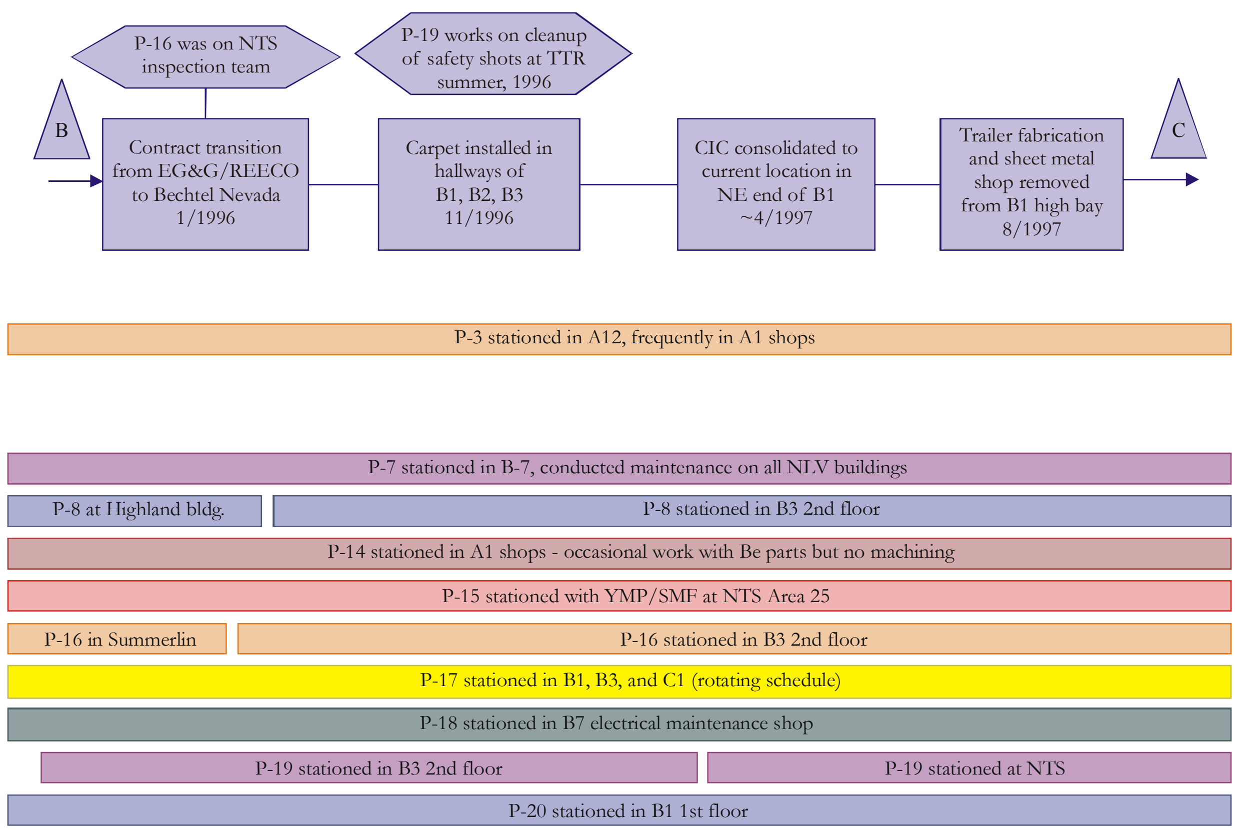

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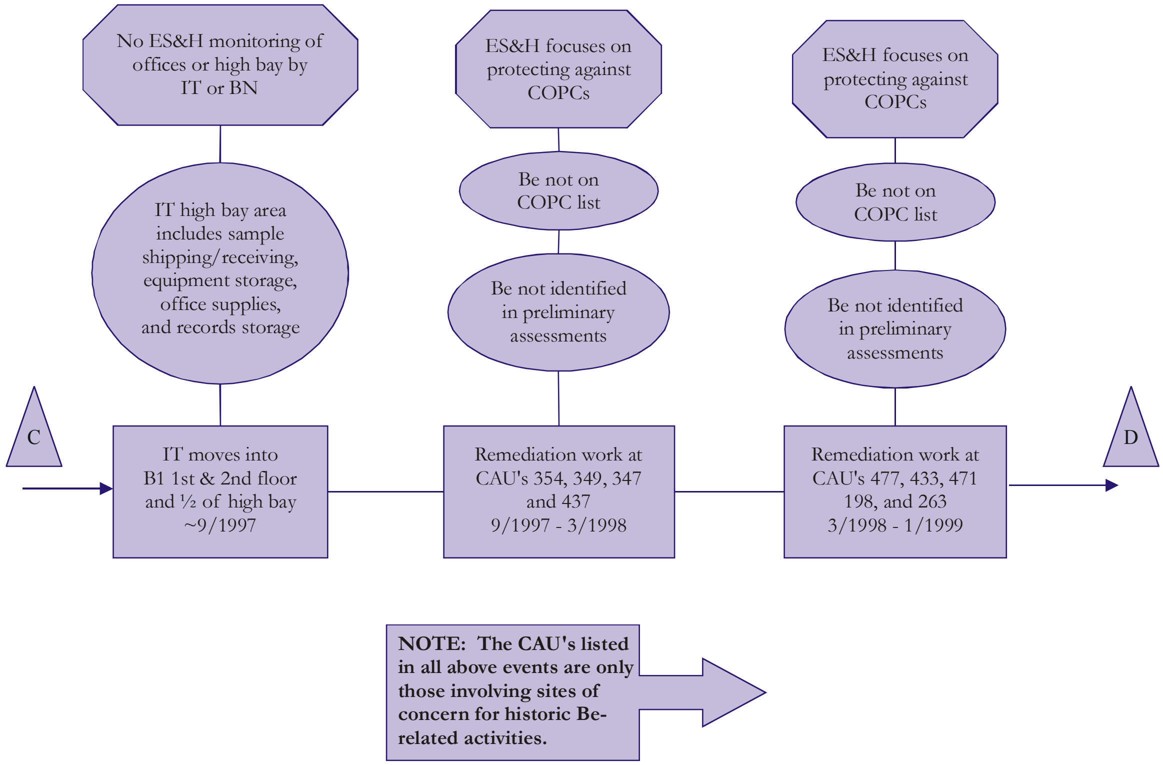

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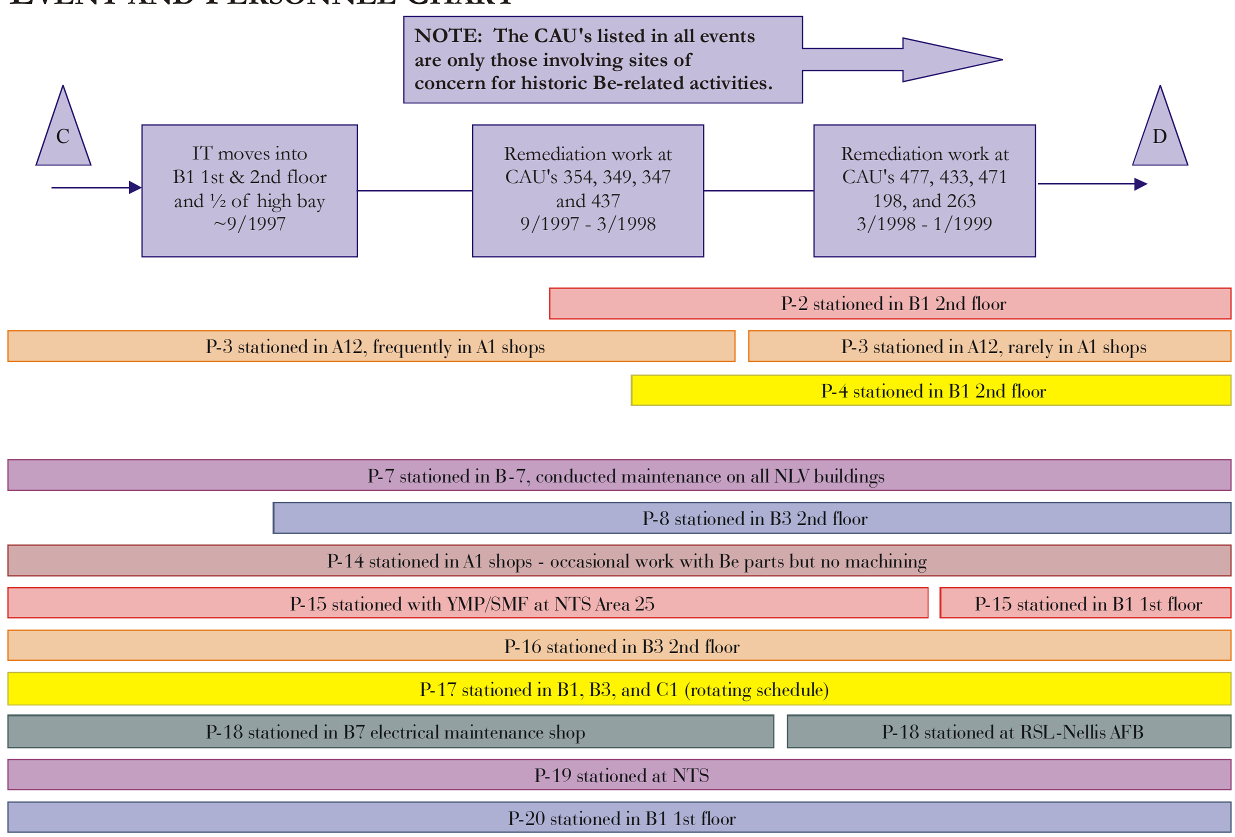

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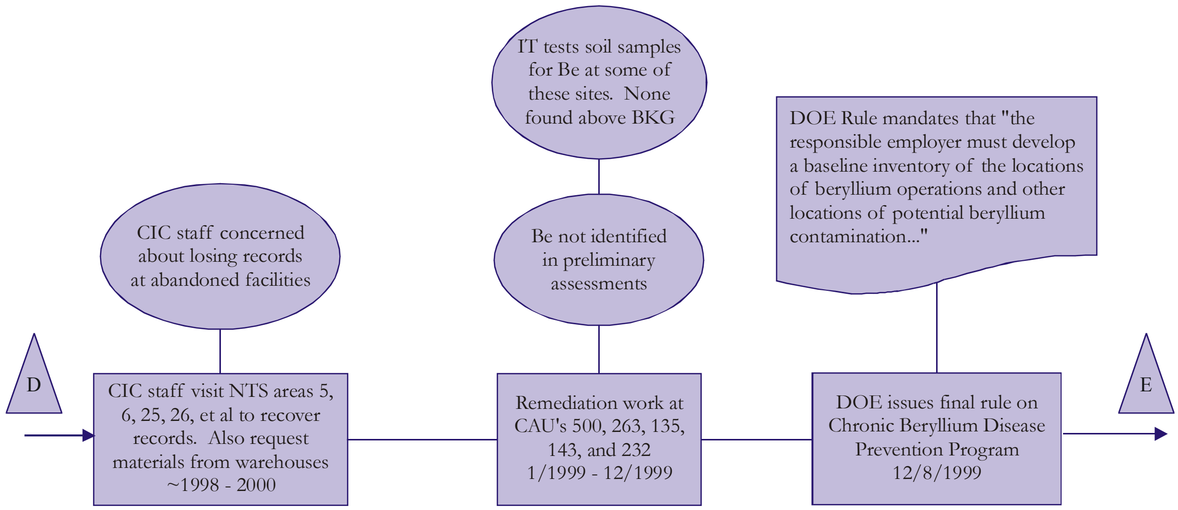

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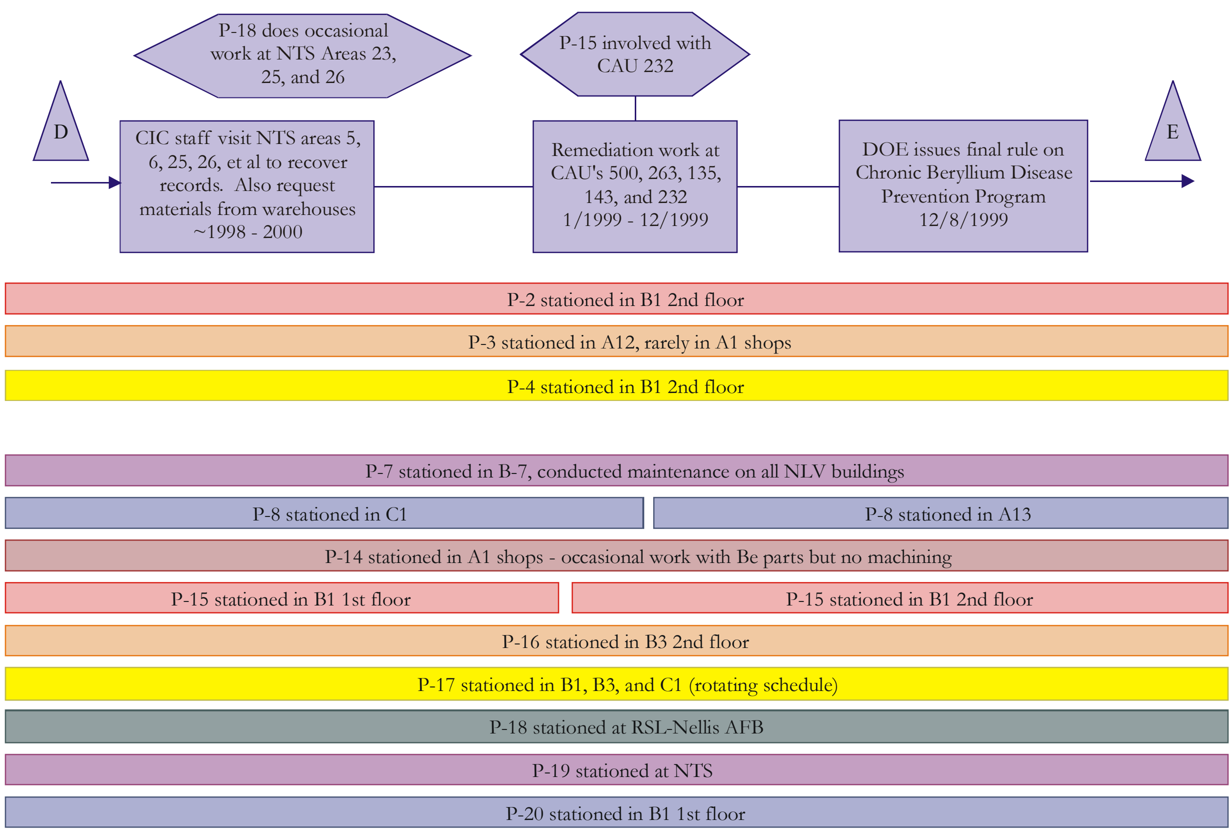
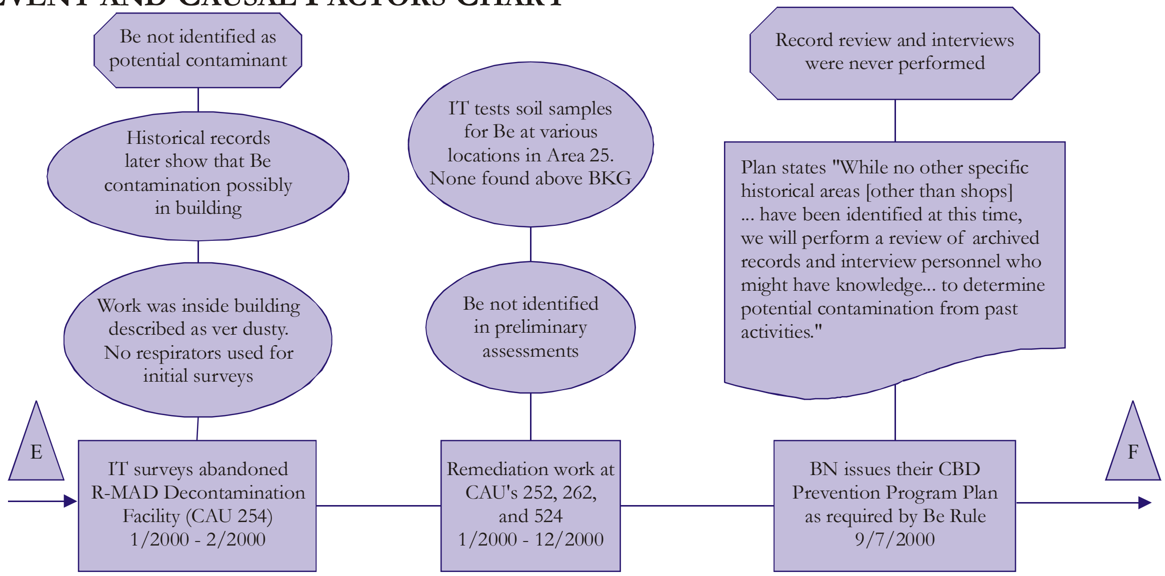
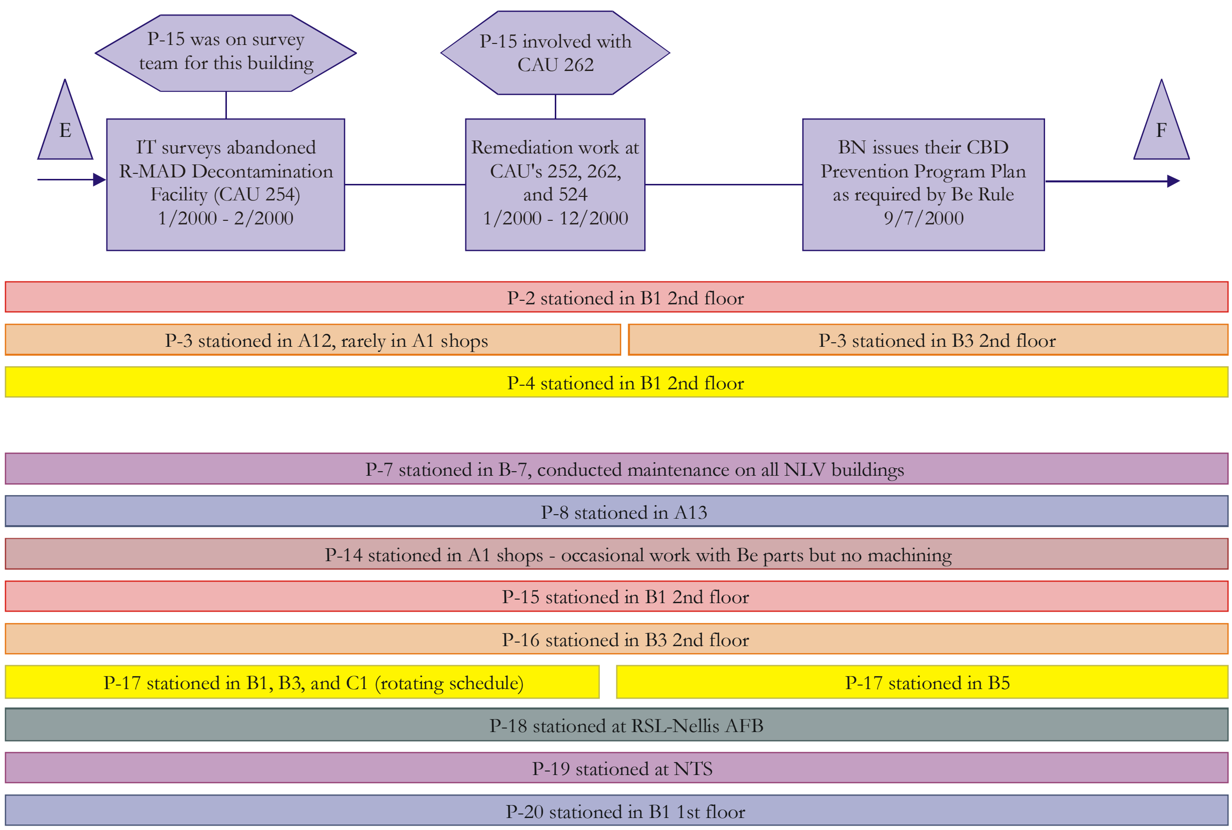


EVENT AND CAUSAL FACTORS CHART



EVENT AND PERSONNEL CHART



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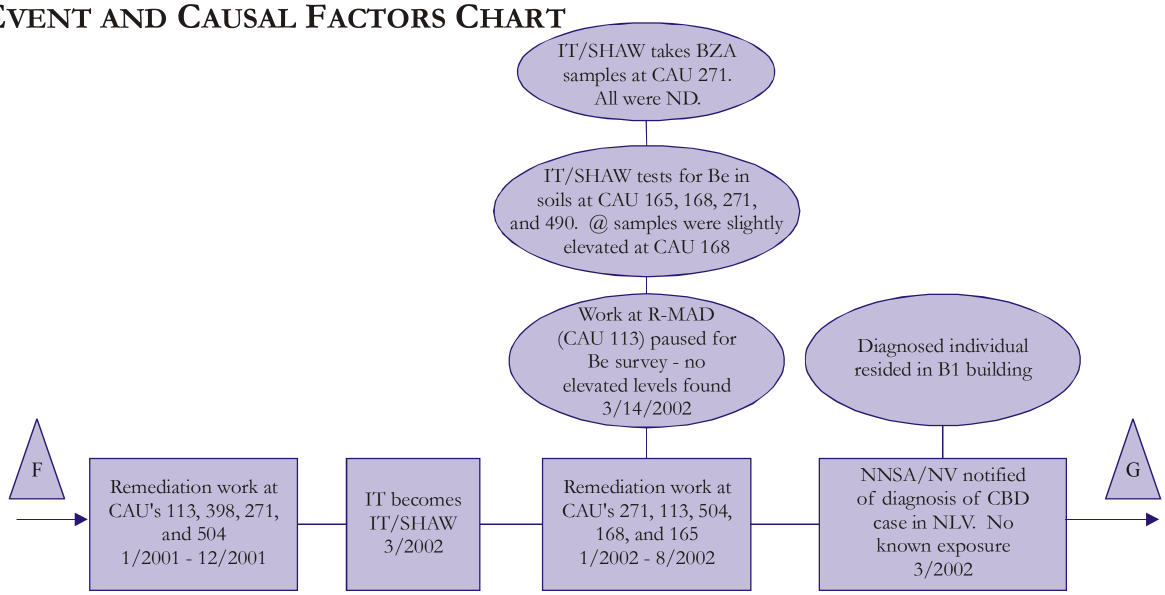

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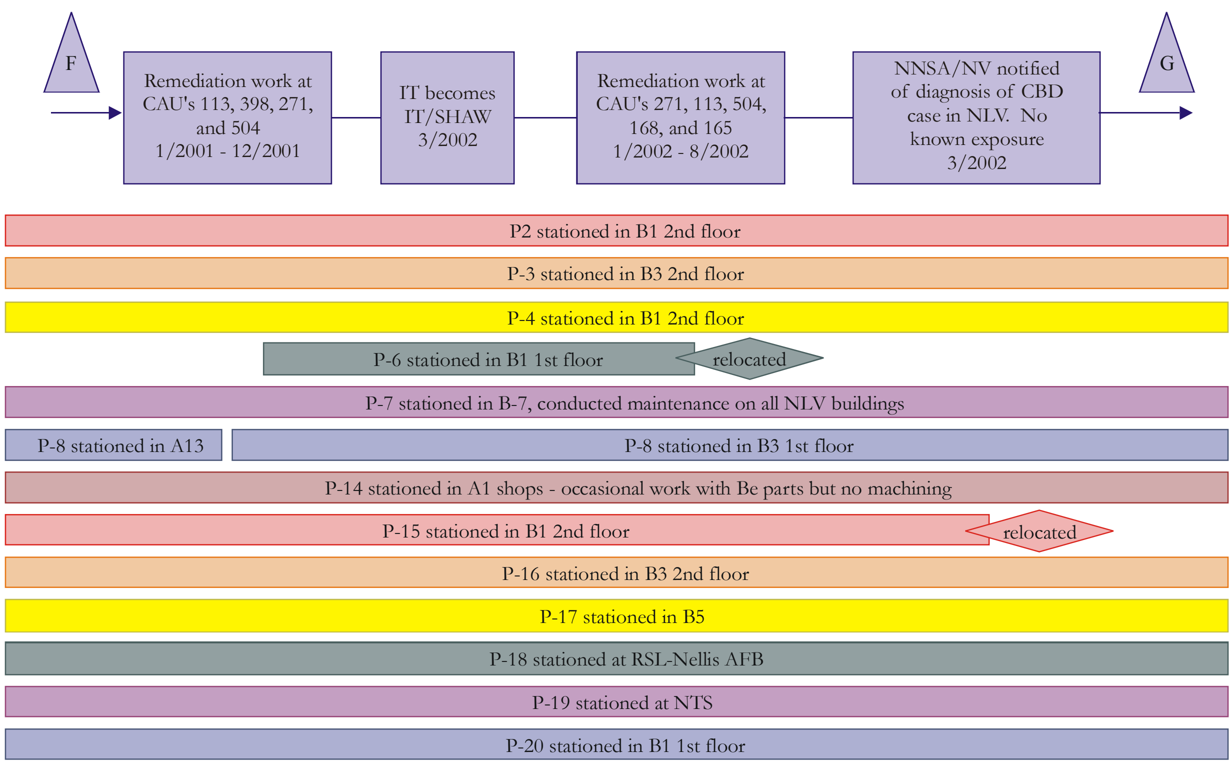
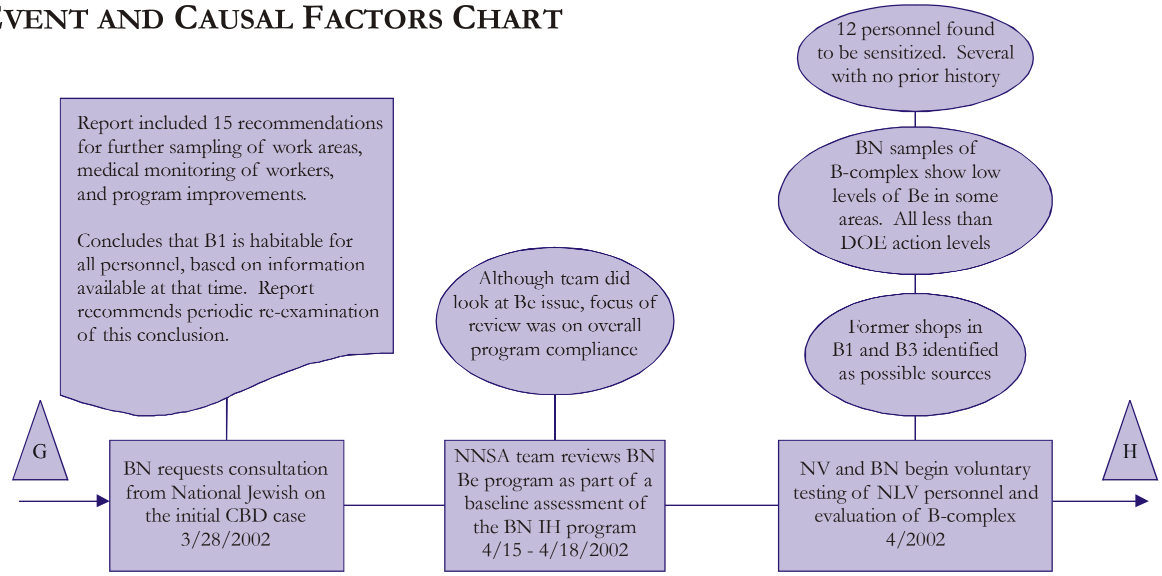


Event and Causal Factors Chart



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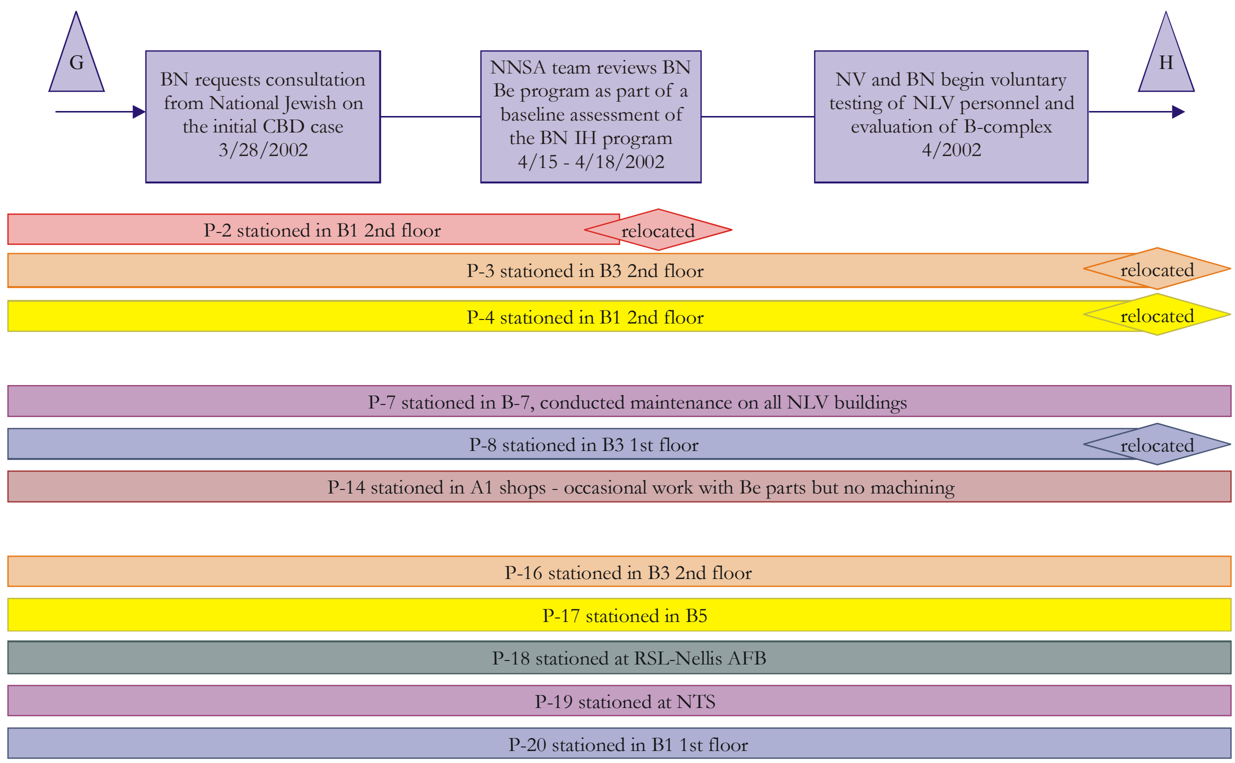

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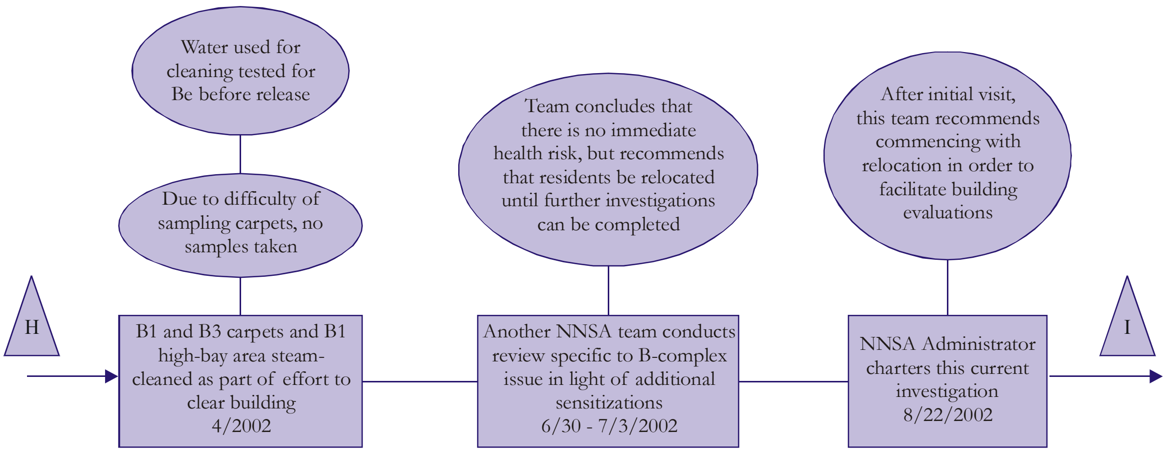

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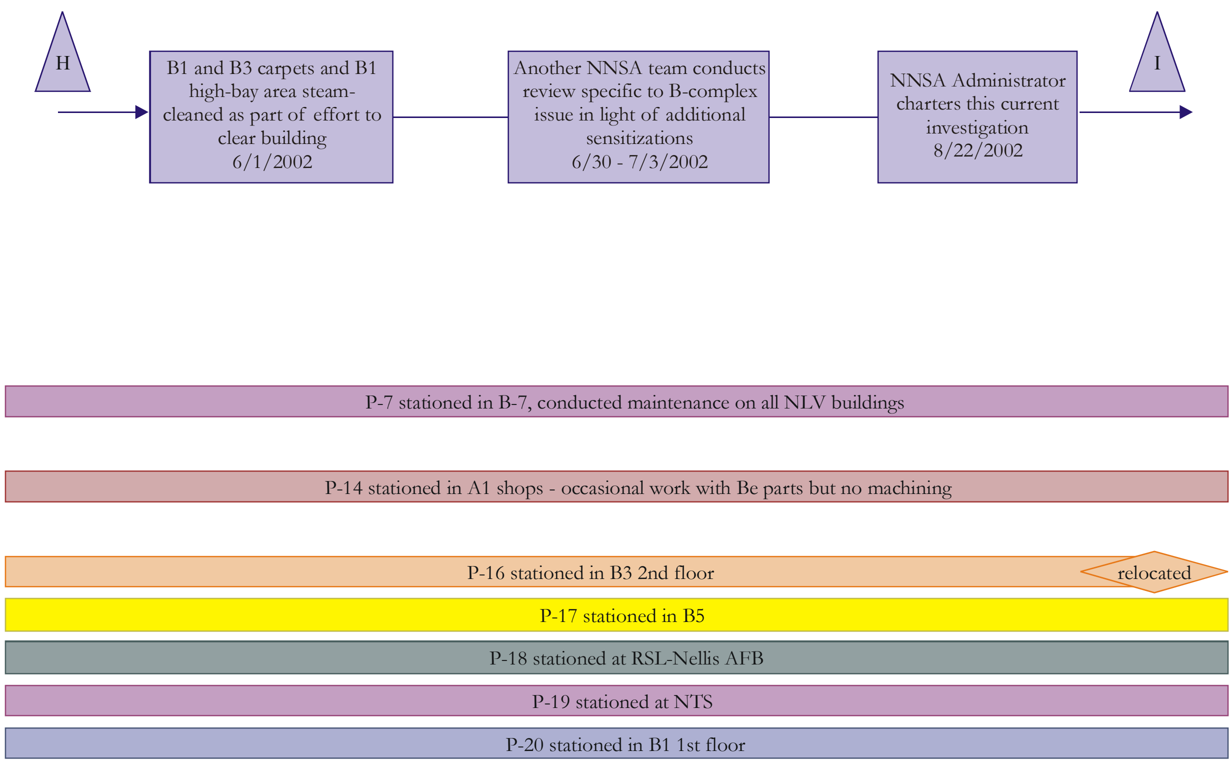
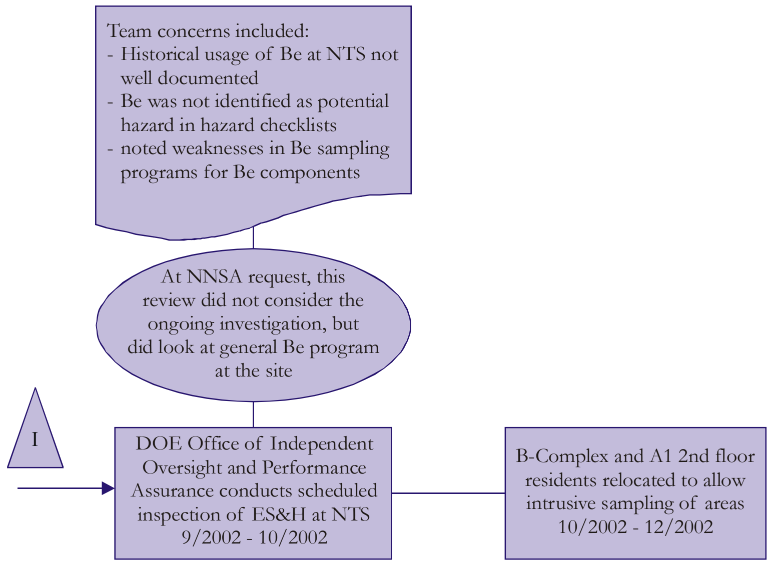
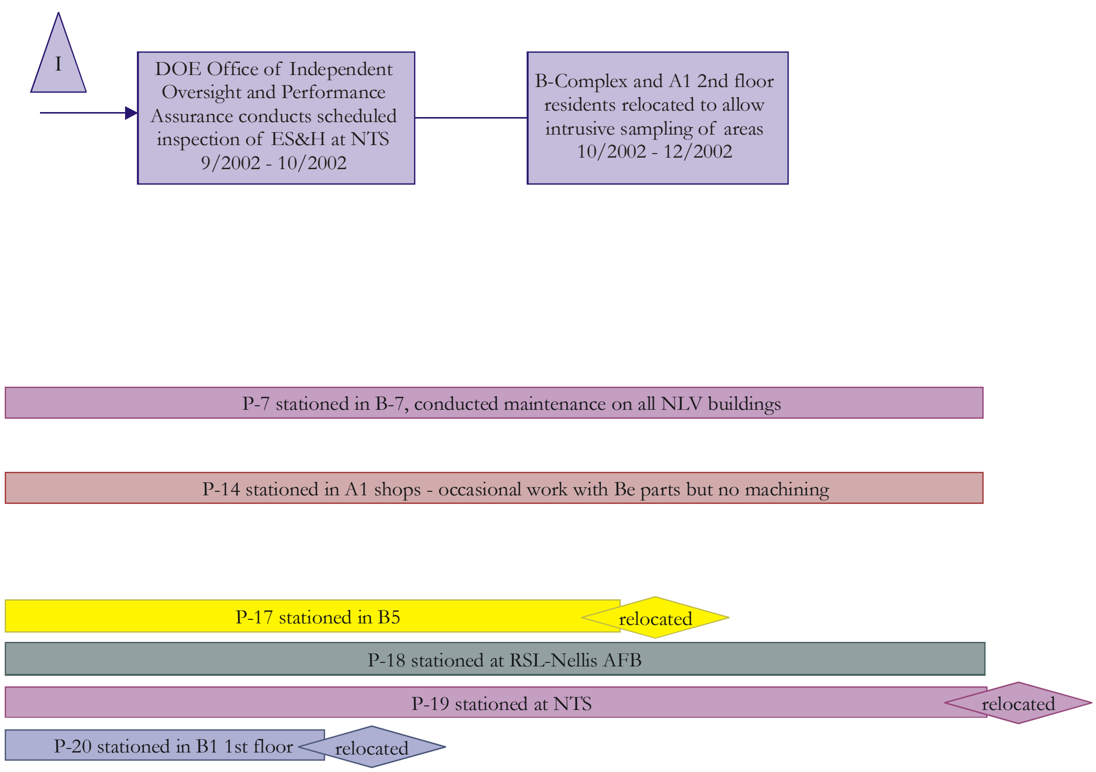


Event and Causal Factors Chart



Event and Personnel Chart



Attachment 4: Barrier Analysis Worksheet

Hazard: Beryllium Contamination		**Target: Personnel**	
What were the barriers?	**How would the barrier perform?**	**Why did the barrier fail?**	**How did the barrier affect accident?**
Hazard identification	Identification of potential for beryllium contamination would focus attention on need to characterize extent of problem. Beryllium contamination	There was no collective history of past activities at NTS and NLV. Knowledge base fragmented among multiple contractors and other sites.	Allowed the presence of beryllium contamination to go undetected.
Hazard assessment	areas would be characterized and evaluated for the potential risk to personnel. Protective measures would be identified and implemented. Routine IH surveillances would have detected	There was no recognition of hazard (see hazard identification). Therefore, no hazard assessment was done.	Allowed beryllium areas to go uncontrolled at the source locations.
Routine industrial hygiene surveillance	beryllium contamination in uncontrolled areas. Would have established controls for protection of	There was no recognition of hazard (see hazard identification). Therefore, no surveillance was established.	Allowed tracked beryllium contamination to go undetected at the receptor locations.
Health and safety plans (both site plan and job-specific plans)	workers in beryllium contamination areas. Would have established mechanisms to control spread of contamination beyond controlled areas. Ensure that all hazards are addressed in a balanced,	There was no recognition of hazard (see hazard identification). Therefore, beryllium contamination was not considered in development of health and safety plans.	Allowed workers to work in beryllium contamination areas without adequate controls. Allowed beryllium contamination to be spread outside of contamination areas.
Integrated safety management systems	integrated manner; controls are appropriate and implemented; and work is conducted within work control processes. Ensure that contractors are aware of historic activities	There was no recognition of hazard (see hazard identification). Therefore, ISM process was not engaged.	Allowed workers to work in beryllium contamination areas without adequate controls. Allowed beryllium contamination to be spread outside of contamination areas.
DOE program management at NSO	and legacy hazards, or enable mechanisms for contractors to access that information. Established expectations for worker safety in the	There was no collective history of past activities at NTS and NLV. Knowledge base fragmented among multiple contractors and other sites.	Allowed presence of beryllium activities to go unrecognized by current contractors.
Contractor program management	workplace and during field activities.	There was no recognition of hazard (see hazard identification). Therefore, no expectations were established specific to beryllium contamination.	Allowed workers to work in beryllium contamination areas without adequate controls. Allowed beryllium contamination to be spread outside of contamination areas.

Hazard: Beryllium Contamination		Target: Personnel	
What were the barriers?	**How would the barrier perform?**	**Why did the barrier fail?**	**How did the barrier affect accident?**
Contractor performance assessment programs	Ensure that activities are conducted per established expectations and DOE requirements.	There was no recognition of hazard (see hazard identification). Therefore, no expectations were established specific to beryllium contamination.	Allowed workers to work in beryllium contamination areas without adequate controls. Allowed beryllium contamination to spread outside of contamination areas.
DOE performance assessment programs	Ensure that activities are conducted per established expectations and DOE requirements.	There was no recognition of hazard (see hazard identification). Therefore, no expectations were established specific to beryllium contamination. However, there were some concerns expressed in some assessments about the lack of adequate site characterization for beryllium contamination.	Allowed workers to work in beryllium contamination areas without adequate controls. Allowed beryllium contamination to spread outside of contamination areas.
DOE rule 10 CFR 850	Establishes requirements for work associated with beryllium.	There was no recognition of hazard (see hazard identification). Therefore, rule was considered to be not applicable. Also, rule does not adequately address surveillance of workplaces outside of beryllium operational areas.	Allowed workers to work in beryllium contamination areas without adequate controls. Allowed beryllium contamination to spread outside of contamination areas.
Physical contamination control boundaries	Establishes demarcation of areas of known contamination.	There was no recognition of hazard (see hazard identification). Area demarcation was done according to radiological conditions, not beryllium conditions, although they probably coexisted in some areas. As radiological conditions changed, so did demarcation, without recognition of other potential hazards in area.	Allowed workers to work in beryllium contamination areas without adequate controls. Allowed beryllium contamination to spread outside of contamination areas.

Note: There are probably other barriers that could also be identified that may have resulted in protecting the workers, had they been implemented. However, as shown above, since there was no recognition of the hazard, then all barriers failed since there was no perceived reason to implement them.

Attachment 5: Change Analysis Worksheet

Change 1: Change in mission of NTS

Difference: Nuclear weapons testing was stopped in September 1992. Other research and testing programs are also no longer active. Funding for the NTS decreased by over 50% between 1991 and 1996. Contractor staffing levels at NTS dropped by over 60% in the same period. Similar program changes were occurring at the weapons laboratories at the same time.

Evaluation: Workers who supported discontinued activities moved to other activities or left NTS. This caused a large loss of corporate knowledge, both from the experienced workforce at the NTS and from the weapons laboratories. That loss of corporate knowledge and experience appears to have contributed to a serious loss of recognition of the hazards associated with the historic activities of the NTS.

Change 2: Change in the operating philosophy at NTS in 1996

Difference: Before 1996, there were multiple Management and Operating (M&O) contractors on the site responsible for various functions and services. The weapons laboratories were responsible for establishing and conducting their own testing programs, using the services of the onsite M&O staff as necessary. DOE/NV functioned as the site landlord and integrator, providing direct guidance and tasking to the M&O contractors in the conduct of their responsibilities. In 1996, three of the main M&O contracts were combined into one, and BN was awarded the contract. Inherent in this contract change was also the assignment of the landlord and integration functions to BN. This was a major philosophical change that shifted a new level of responsibility to the site contractor. However, all contractors were still responsible for the health and safety of their workers, and the protection of the environment from their activities. The weapons laboratories were still responsible for their programs as before.

Evaluation: BN was now responsible for establishing and maintaining a full understanding of the site and its pre-existing conditions and associated hazards. However, due to the nature in which the site had previously been operated, the BN staff did not have the necessary corporate memory of the site history since their previous involvement had only been to provide services as requested, with no overall responsibility for the programs being conducted. The corporate memory regarding the historic activities conducted at the site, and the legacy issues that remain from those activities, still remained with the weapons laboratories. There is a central repository for the historic records at BN, but it appears that this repository was not effectively utilized for the researching the legacy hazards at NTS, and therefore the information was not conveyed to the responsible organizations.

Change 3: Uses of "B complex" buildings

Difference: Before 1994 staff supporting the weapons testing program had used the buildings. This included several shops. More recently staff conducting environmental restoration activities at NTS has used the building.

Evaluation: Staff who use the B buildings visit sites that have beryllium contamination. This provides a source of contamination to be tracked into the buildings.

Acronyms and Terminology

AEC	U.S. Atomic Energy Commission (predecessor to the DOE)
AIHA	American Industrial Hygiene Association
AMEM	NSO Assistant Manager for Environmental Management
B-Complex	The combined group of buildings B1, B2, and B3
BN	Bechtel Nevada
CAU	Corrective Action Units (a designation of an area to be remediated)
CBD	chronic beryllium disease
CBDPP	Chronic Beryllium Disease Prevention Program
CFR	Code of Federal Regulations
COPC	Contaminants of Potential Concern
DOE	U.S. Department of Energy
EG&G/EM	EG&G Energy Measurements
EH	U.S. DOE Office of Environment, Safety, and Health
E-MAD	Engine Maintenance, Assembly, and Disassembly Facility
EPA	U.S. Environmental Protection Agency
ERD	Environmental Restoration Division
ES&H	Environment, Safety, and Health
ft^2	square feet (a unit of area)
HASP	Health and Safety Plan (an IT/SHAW document)
ISM	Integrated Safety Management
JON	Judgment of Need
KIWI	the name of a prototype nuclear rocket engine
KIWI-TNT	the name of a particular KIWI experiment
L	liters
LPT	Lymphocyte Proliferation Test
M&O	Management and Operating
µg	microgram, or one-millionth of a gram (a unit of mass)
µg/g	micrograms per gram (a unit of elemental concentration)
µg/100 cm^2	microgram per 100 square centimeters (a unit of surface contamination)
µg/L	micrograms per liter (a unit of elemental concentration in a liquid)
µg/m^3	microgram per cubic meter (a unit of concentration in air)
NIOSH	National Institute for Occupational Safety and Health
NLV	North Las Vegas Facility
NNSA	National Nuclear Security Administration
NSO	Nevada Site Office
NTS	Nevada Test Site
OA	U.S. DOE Office of Independent Oversight and Performance Assurance
PCB	polychlorinated biphenyls (a hazardous chemical)
Pluto	the name of a prototype nuclear ramjet engine project
PPV	positive predictive value
RCRA	Resource Conservation and Recovery Act
R-MAD	Rocket Maintenance, Assembly, and Disassembly Facility
TTR	Tonopah Test Range
TWA	Time Weighted Average over 8 hours (a unit of personnel exposure)
VOC	volatile organic compounds (a group of hazardous chemicals)