EXPLORING EARTH'S MYSTERIES
...PROTECTING ITS FUTURE

Brookhaven Linac Isotope Producer

Facility Environmental Monitoring Report

Calendar Year 2004

BROOKHAVEN NATIONAL LABORATORY

August 8, 2005

Prepared by
D. Paquette and B. Hooda
Environmental and Waste Management Services Division

GW63ER.05

Brookhaven Linac Isotope Producer

Facility Environmental Monitoring Report
Calendar Year 2004

Summary of Results

During 2004, tritium concentrations in groundwater immediately downgradient of the BLIP Building decreased from a high of 24,900 pCi/L in January to less than the 20,000 pCi/L drinking water standard for the remainder of the year. Monitoring data suggest that the elevated tritium concentrations observed during 2003 were due to a significant rise in water table position, which resulted in residual tritium being flushed from the soils close to the water table. It is expected that the amount of tritium remaining in the deep unsaturated zone close to the water table will decline over time due to this flushing mechanism and by natural radioactive decay

The BLIP facility operated over an 11-week period in 2004. The major radionuclides emitted from the facility were carbon-11 and oxygen-15, and small amounts of tritium. The amount of C-11 and O-15 emitted from the facility was estimated to be 680 curies, and 2,027 curies, respectively. These radioactive gases have a short half-life: 20.48 minutes for C-11 and 122 seconds for O-15, and mainly contribute to external immersion dose. Tritiated vapor emission for the calendar year was 7.32E-02 curies. The effective dose equivalent to the maximally exposed individual was calculated to be 4.40E-02 mrem for the calendar year.

In 2004, the first performance test of the shroud was conducted. This was achieved by monitoring the radionuclide emissions when the shroud was opened and closed to evaluate the reduction in emissions. The test showed that there was a 20 to 26.6 percent reduction in emissions when the shroud was closed. During 2005, sampling and monitoring of the short-lived gases will continue until the efficiency of the shroud has been thoroughly tested, and emissions verified.

In April and May 2004, there were two instances where localized beam drift caused the beam window flange on the BLIP vessel to fail. In both cases, approximately 260 gallons of activated cooling water was released to secondary containment. The contained cooling water was pumped into US DOT-approved containers for off-site disposal. There were no measurable releases of cooling water to the environment.

Background

When the BLIP is operating, the Linear Accelerator (Linac) delivers a 200-MeV beam of protons that impinge on a series of targets within the BLIP target vessel. During irradiation, the BLIP targets are located at the bottom of a 30-foot deep underground tank, inside a water-filled 18-inch diameter shaft that runs the depth of the tank. The targets are cooled by a 500-gallon closed-loop primary cooling system. During irradiation, several radionuclides are produced in the cooling water, and the soils immediately outside of the tank are activated due to the creation of secondary particles produced at the target. Air emissions from the BLIP facility pass through a HEPA filtration system. Following filtration, only the short-lived gaseous radionuclides, such as C-11, O-15 and tritium are released to the atmosphere.

In a 1985 redesign of the vessel, leak detection devices were installed and the open space between the water-filled shaft and the vessel's outer wall became a secondary containment system for the primary vessel. The BLIP target vessel system conforms to Suffolk County Article 12 requirements and is registered with the Suffolk County Department of Health Services (SCDHS). In April and May 2004, there were two instances where localized beam drift caused the beam window flange on the BLIP vessel to fail. In both cases, approximately 260 gallons of activated cooling water was released to the secondary containment. The contained cooling water was pumped into US DOT-approved containers for off-site disposal. There were no measurable releases of cooling water to the environment, and the spilled radionuclide inventory did not exceed CERCLA or State reportable quantities. However, because the amount spilled into the secondary containment exceeded five gallons, the release was reportable to the SCDHS.

The BLIP facility also has a 500-gallon capacity underground storage tank for liquid radioactive waste (change-out water from the BLIP primary system). The waste tank and its associated piping system conform to Article 12 requirements and are registered with SCDHS.

In 1998, tritium was detected in the groundwater immediately downgradient of the BLIP facility at concentrations exceeding the 20,000 pCi/L drinking water standard. The source of the tritium was determined to be the activated soils that surround the BLIP target vessel. Due to the impact to groundwater quality, the BLIP facility was designated Area of Concern (AOC) 16K under the BNL Environmental Restoration program.

Following the 1998 detection of tritium in groundwater, BNL improved the stormwater management program at the BLIP to prevent rainwater infiltration of the activated soils below the building. The BLIP building's roof drains were redirected away from the building, paved areas were resealed, and a gunite (cement) cap was installed on three sides of the building (Figure 1). In May–June 2000, the BNL Environmental Restoration program installed an additional protective measure with the injecting of colloidal silica grout, referred to as a Viscous Liquid Barrier (VLB), into the activated soils. The grout reduces the permeability of the soils, thus further reducing the ability of rainwater to leach radionuclides should the primary stormwater controls fail.

As an added measure of protection, the Medical Department and Collider-Accelerator Department constructed a new protective cap over the Linac to BLIP spur in late 2004 (Figure 2). Plans are also being made to install a cap over the adjacent Linac to Booster transition area. Direct soil measurements and beam loss calculations suggest that the tritium and sodium-22 concentrations in soils surrounding these beam lines could result in stormwater leachate concentrations that exceed the "5%" criteria described in the Accelerator Safety Subject Area.[1] When completed, this integrated cap system will join the BLIP and Booster caps.

Environmental Monitoring Program

As required by DOE Order 450.1, BNL maintains an environmental monitoring program at the BLIP facility to evaluate potential impacts to environmental quality from its operation, and to demonstrate compliance with DOE requirements and applicable federal, state, and local laws and regulations. This program is fully described in the *BNL Environmental Monitoring Plan* (BNL, 2004). The monitoring program components are summarized below.

Monitoring Results

Groundwater

Groundwater quality at BLIP is monitored using two upgradient and five downgradient wells. The locations of monitoring wells are shown in Figure 3.

Following the 1998 installation of the BLIP cap and other improvements to the stormwater controls, tritium concentrations decreased to less than 20,000 pCi/L, and remained below this level until the summer of 2000 (Figure 4). A short-term increase in tritium concentrations was detected in the monitoring wells following the May-June 2000 injection of the VLB grout. Tritium concentrations increased from nearly non-detectable levels prior to the grout injection to 56,500 pCi/L in October 2000. An investigation determined that the grout had displaced a small volume of tritiated soil pore water. Some of this displaced water entered the aquifer below the BLIP building. Tritium concentrations decreased to <20,000 pCi/L by the end of December 2000, and remained at these levels through 2001 and 2002 (Figures 4 and 5).

In January 2003 tritium concentrations once again exceeded the 20,000 pCi/L standard in wells immediately downgradient of BLIP, with a concentration of 27,700 pCi/L detected in well 064-67. Tritium concentrations remained above 20,000 pCi/L throughout most of the year, reaching a maximum of 42,900 pCi/L in October. Tritium concentrations declined to less than 20,000 pCi/L by November 2003. Sodium-22 concentrations increased to a maximum of 185 pCi/L, but well below the 400 pCi/L standard. During 2004, tritium concentrations in groundwater degreased from a high of 24,900 pCi/L in

[1] The BNL Accelerator Safety Subject Area requires stormwater controls where rainwater infiltration into activated soil shielding could result in leachate concentrations that exceed 5 percent of the drinking water standard (i.e., >1,000 pCi/L for tritium and 20 pCi/L for sodium-22).

January to less than the 20,000 pCi/L drinking water standard for the remainder of the year.

The gunite cap, the paved areas and the roof drains are in good condition, and are effectively controlling stormwater infiltration (Figures 1 and 2). Although direct inspection of the VLB grout is not possible, it is expected to be in good condition and would be effective in preventing significant leaching of tritium from the activation zone should the primary stormwater controls fail. A comparison of tritium concentrations to changes in water table position suggests that the 2003 increase in tritium concentrations appeared to be correlated to a 6.5-foot increase in water table elevation that occurred between November 2002 and July 2003 (Figure 6). As the water table rose, older tritium that was leached from the activated soils prior to capping in 1987 and from the grout injection project may have been flushed from the vadose zone soils close to the water table. Figure 7 provides a pictorial view of this process. During 2004, the position of the water table generally declined. It is expected that the amount of tritium remaining in the vadose zone close to the water table will decline over time due to this flushing mechanism and by natural radioactive decay.

Air Monitoring

Emissions from the BLIP facility pass through a HEPA and charcoal filtration system before being released through a 16-meter stack. Air samples are continuously collected after the HEPA and charcoal filtration system to monitor the emissions. Particulates are collected on a glass fiber filter for gamma analyses, a TEDA-loaded charcoal cartridge is used when there is potential for radioiodines releases, and tritiated water vapors are collected with silica gel absorbent material. Radiological gases emissions, such as oxygen-15 and carbon-11, are estimated using an emission factor that is based on hours of operation and the beam intensity received on the targets (i.e., mCi/micro-ampere-hrs). Additionally, the radioactive gas emissions were characterized with an inline sampling and positron detection system. The short-lived gases concentrations measured by the NaI gamma detection system were used in estimating the source term to the environment, and for dose calculations to members of the public.

In CY 2004, the BLIP facility operated over a 11-week period. The major radionuclides in the emissions were carbon-11 and oxygen-15, and small amounts of tritium. The average source term for C-11 was estimated at 680 curies, and O-15 was estimated at 2,027 curies. Carbon-11 and O-15 have a short half-life of 20.48 minutes and 122 seconds; respectively, and mostly contribute to external immersion dose. Tritiated vapor emissions for the calendar year 2004 were measured to be 7.32E-02 curies. The effective dose equivalent to the maximally exposed individual was calculated to be 4.40E-2 mrem for the calendar year.

The facility emissions were below DOE's derived concentration guide limits for the members of the public, and well below EPA's air dose limit of 10 mrem in a year. Therefore, it can be concluded that there was insignificant impact to the environment and the public from BLIP operations.

Shroud Testing: Although there has been a continuous decrease in total radionuclide emissions since 2001, BNL has installed an additional engineered control to further reduce these emissions. Because the activation gases from the cooling water are the primary source of emissions, a shroud seal was installed in 2003 to enclose the cooling water surface (16-inch diameter shaft), target holder transfer cases, chain drive assembly, (including motor supports), and associated appurtenances (Figure 8). The design goal for the shroud seal was to reduce gaseous emissions from the BLIP facility by approximately 28 percent.

On March 8, 2004, a performance test of the shroud was conducted by continuously monitoring the emissions during periods when the shroud was closed and opened. The test showed that there was 20 to 26.6 % reduction in emissions when the shroud was closed (Figure 9). Variables such as beam intensity, target type, and target arrangement complicated the first test. During 2005, sampling and monitoring of the short-lived gases will continue until the efficiency of the shroud has been thoroughly evaluated, and emissions verified.

Future Monitoring Actions

Monitoring activities for 2005 include:

- Groundwater samples will be collected quarterly from the wells located immediately downgradient of the BLIP facility, and semiannually from the remaining wells. Particular wells immediately downgradient of the BLIP may also be periodically tested for sodium-22. If tritium concentrations are continually less than the 20,000 pCi/L drinking water standard by the end of 2005, consideration will be given to reducing the sampling frequency for all wells to semiannually, starting in 2006.
- The continuous monitoring for particulates, radioiodines, and tritium will be kept the same, that is, weekly collection and analysis of filters/silica gel along with timely verification and validation of the analysis results.
- Sampling and monitoring for the short-lived gases will continue during the facility operation until the efficiency of the shroud has been thoroughly evaluated, and emissions verified. The Environmental Protection Agency will be notified of the test results and future actions taken to keep the effective dose equivalent to member of the public below one percent of the NESHAPs standard.

References

BNL, 2004. *Brookhaven National Laboratory Environmental Monitoring Plan (January 2004 Update).* BNL-52676.

Table 1. BLIP Facility Summary of Tritium and Sodium-22 Results, CY 2004. Wells 64-46 and 54-61 are upgradient of the BLIP. Wells 64-47, 64-48, and 64-67 are approximately 40 feet downgradient, and wells 64-49 and 64-50 are approximately 150 feet downgradient.

Well	Radionuclide	01-13-04	03-03-04	04-22-04	07-21-04	10-13-04
		-------------------------	pCi/L	-------------------------		
64-46	Tritium	NS	NS	<300	NS	<280
	Sodium-22			NA		NA
54-61	Tritium	NS	NS	<300	NS	<270
	Sodium-22			NA		NA
64-47	Tritium	456 +/- 207	NS	<290	470 +/- 230	<270
	Sodium-22	4.5 +/- 1.8		NA	NA	NA
64-48	Tritium	24,900 +/- 291	18,500 +/- 300	780 +/- 270	2,270 +/- 420	<290
	Sodium-22	29.7 +/- 2.9	NA	NA	NA	NA
64-67	Tritium	7,880 +/- 441	15,800 +/- 1,900	1,340 +/- 340	4,140 +/- 610	9,300 +/- 1,100
	Sodium-22	49 +/- 4.9	NA	NA	NA	NA
64-49	Tritium	2,010 +/- 275	NS	<300	<310	<270
	Sodium-22	NA		NA	NA	NA
64-50	Tritium	16,200 +/- 606	NS	2,570 +/- 490	<320	<320
	Sodium-22	NA		NA	NA	NA

Notes:
Drinking water standard for tritium = 20,000 pCi/L; for sodium-22 = 400 pCi/L.
NA = Not analyzed for this radionuclide.
ND = Radionuclide not detected.
NS = Well not sampled during this period.

Figure 1: Paved area on south side of BLIP Building, and three downgradient monitoring wells (orange caps).

Figure 2. New cap installed over the LINAC to BLIP spur (north side of BLIP) in late 2004

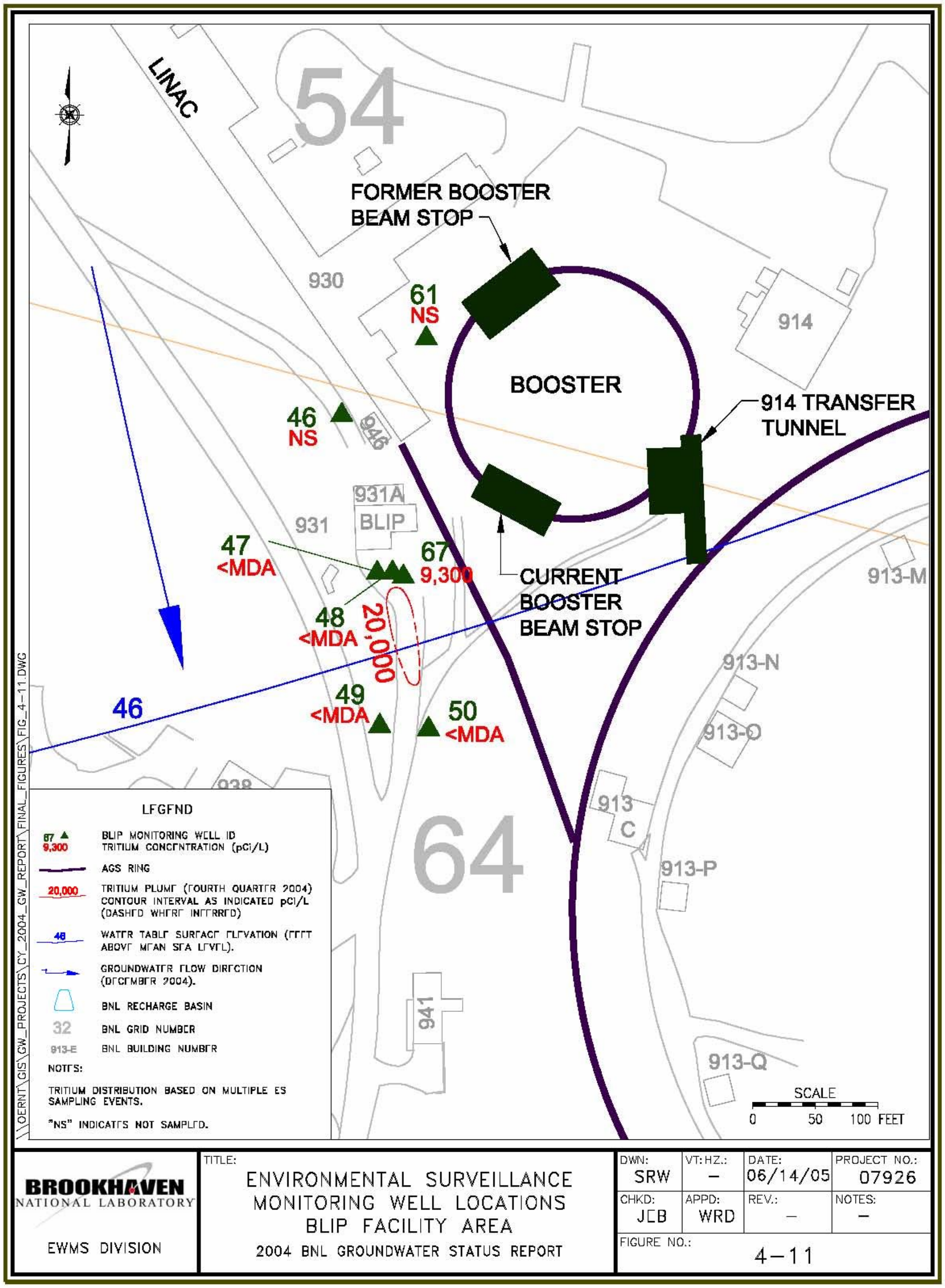

Figure 3. Monitoring Well Locations Near the BLIP Facility at BNL.

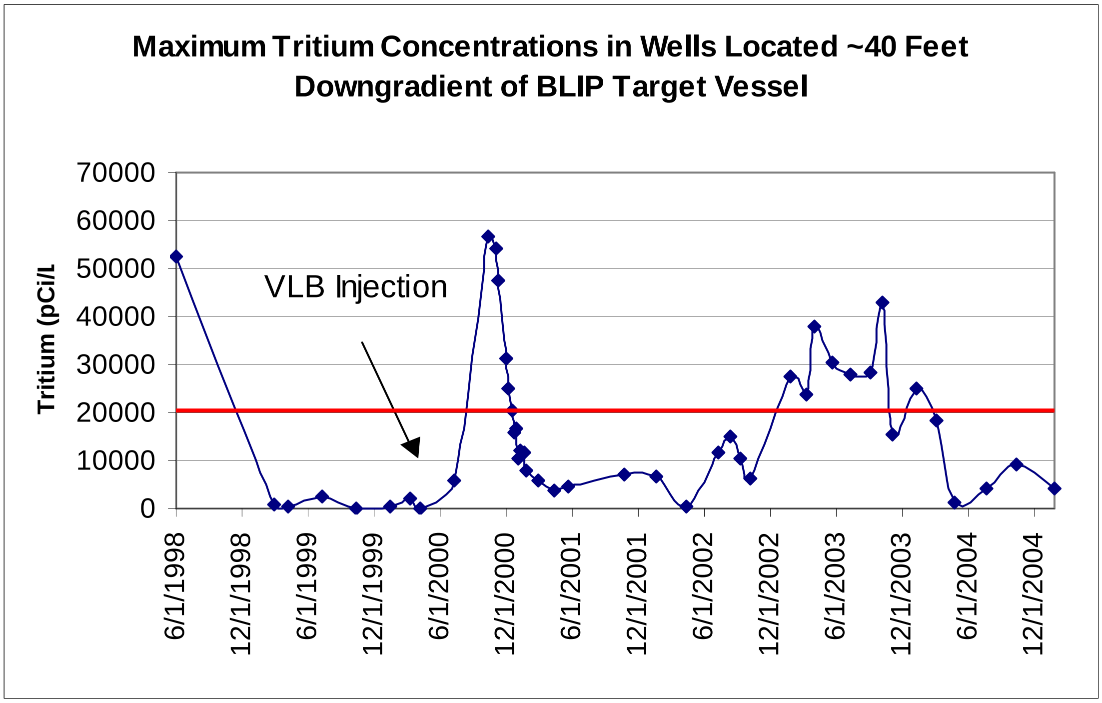

Figure 4. Tritium Concentration Trends 40 Feet Downgradient of the BLIP, June 1999– January 2005.

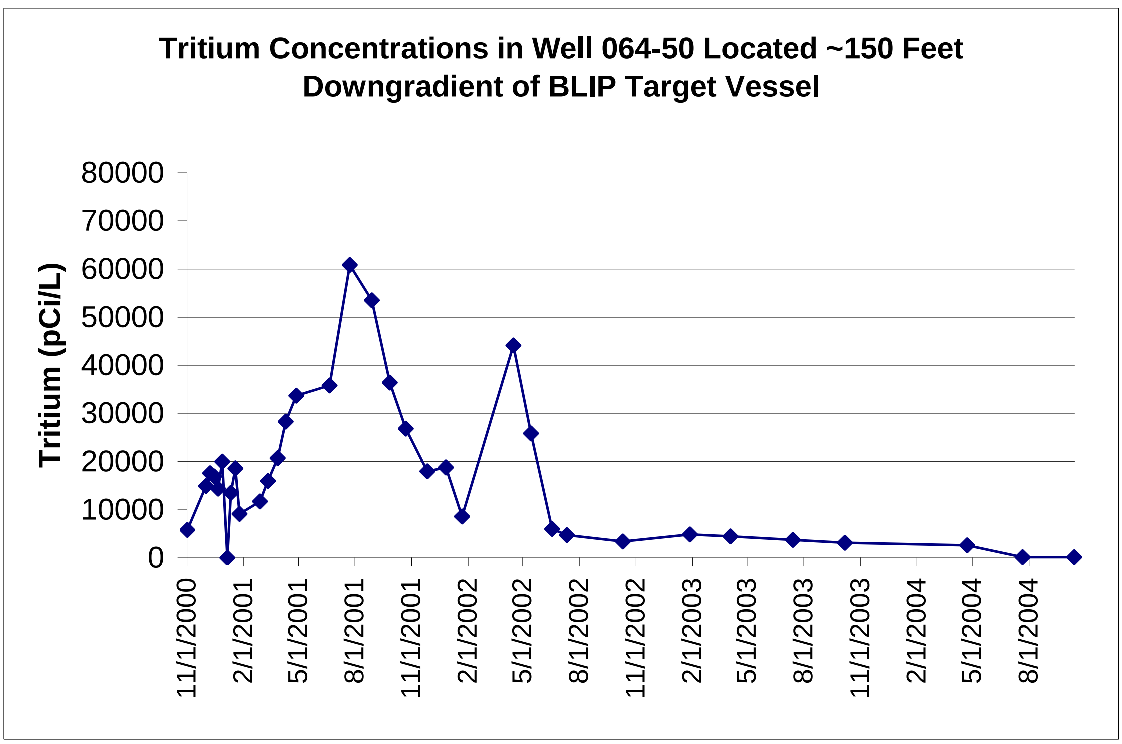

Figure 5. Tritium Concentration Trends 150 Feet Downgradient of the BLIP, CY 2000–2004.

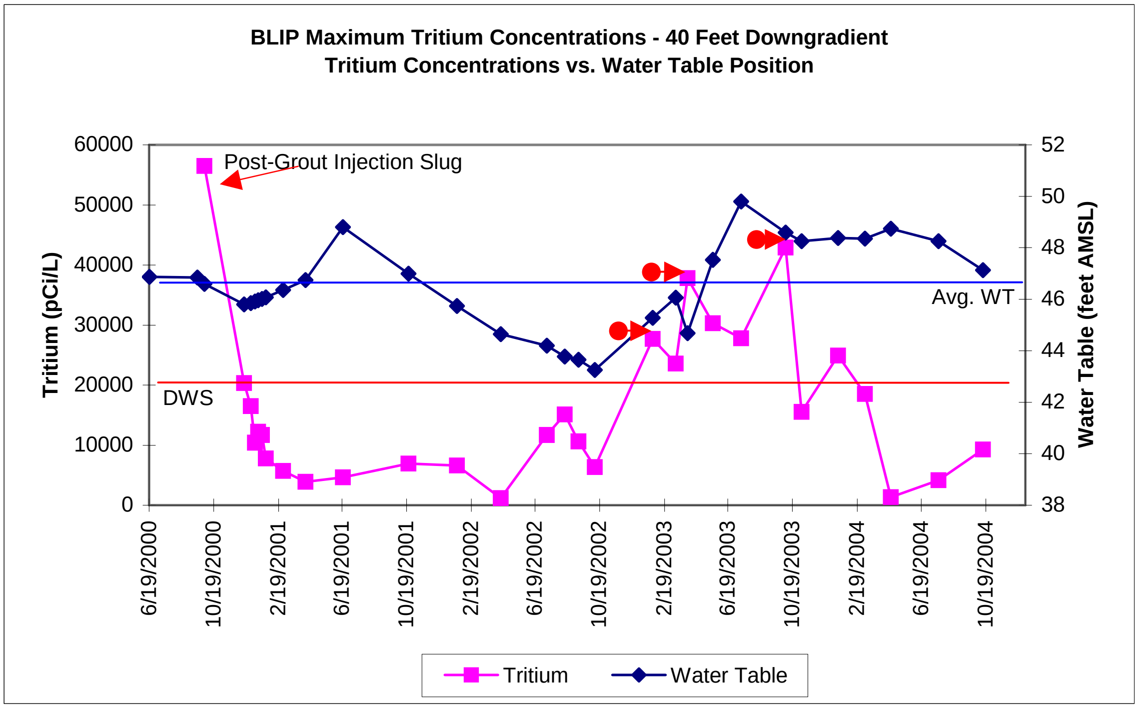

Figure 6: Comparison of tritium concentrations and water table fluctuations

Note: Red arrows indicate approximate groundwater travel time from directly below the BLIP target to the first set of monitoring wells (e.g., well 064-67). Travel time is approximately 89 days based upon a distance of 40 feet and groundwater velocity of 0.45 ft/day

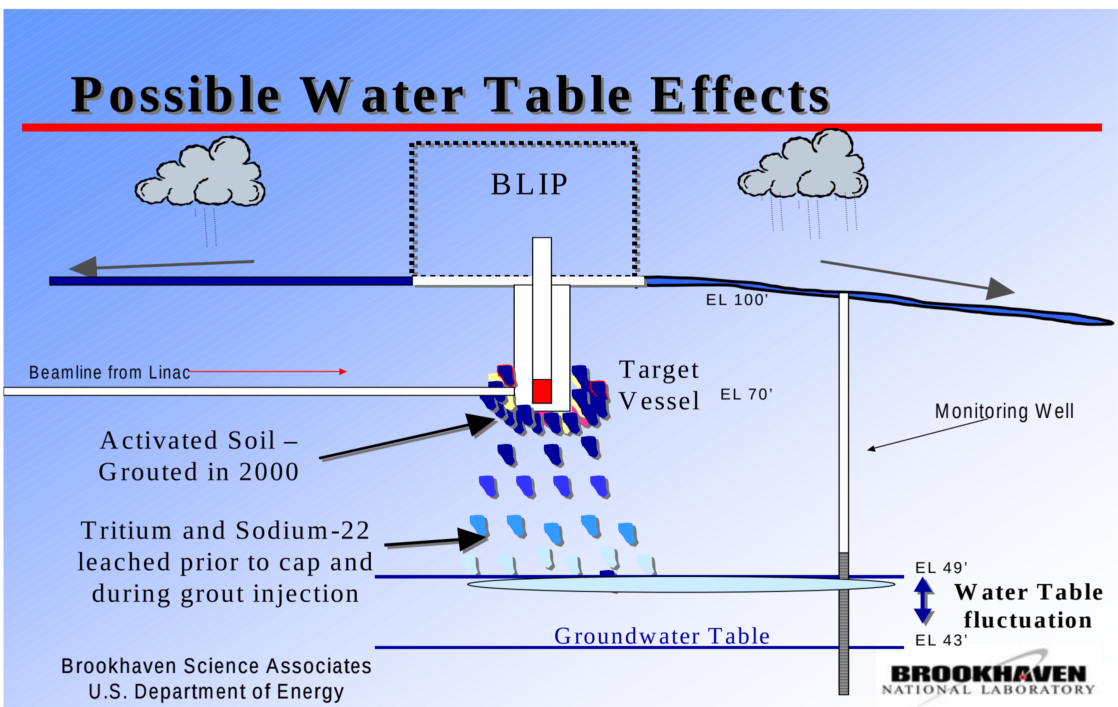

Figure 7. Possible water table fluctuation effects on the release of tritium from the vadose zone.

Figure 8. BLIP hot cell with new shroud.

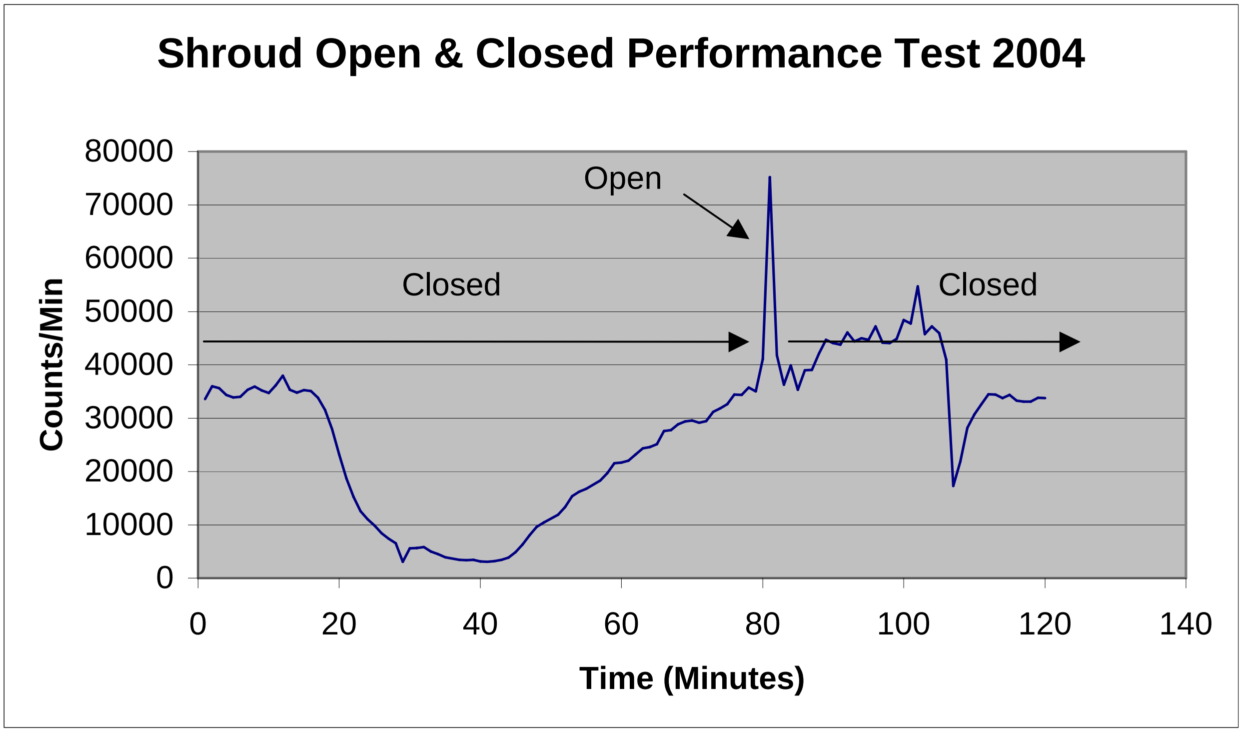

Figure 9. Emission Reduction Test on March 8, 2004.