

**FINAL
CLOSEOUT REPORT**

**Brookhaven Graphite Research Reactor
Graphite Pile Removal
Area of Concern 9
Brookhaven National Laboratory
Upton, New York**



October 2010

Prepared by

**Brookhaven Science Associates
Environmental Restoration Projects**

Building 701
Upton, NY 11973

U.S. Department of Energy

**Brookhaven Site Office
Building 464
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ACRONYM LIST

ALARA	As Low As Reasonably Achievable
AOC	Area of Concern
ARRA	American Recovery and Reinvestment Act
ATM	Air Tight Membrane
BER	Brookhaven Executive Round Table
BGRR	Brookhaven Graphite Research Reactor
BNL	Brookhaven National Laboratory
BSA	Brookhaven Science Associates
CAC	Community Advisory Council
CCE	Contamination Control Enclosure
CERCLA	Comprehensive Environmental Response, Compensation & Liability Act
CRA	Contractor Readiness Assessment
CRAD	Criteria Review and Approach Documents
DOE	Department Of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
EPD	Environmental Protection Division
ERP	Environmental Restoration Projects
ES	Energy Solutions
FS	Feasibility Study
HAD	Hazards Assessment Document
HEPA	High Efficiency Particulate Air
HFBR	High Flux Beam Reactor
IAG	Interagency Agreement
IP	Industrial Package
JRA	Job Risk Assessment
MSA	Management Self Assessment
NEPA	National Environmental Policy Act
NTS	Nevada Test Site
NYSDEC	New York State Department of Environmental Conservation
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PCM	Personal Contamination Monitor
PRAP	Proposed Remedial Action Plan
RCD	Radiological Controls Division
RCT	Radiological Control Technician
RD/RA	Remedial Design/Remedial Action
ROD	Record of Decision
SSW	Senior Supervisory Watch
WMF	Waste Management Facility

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Executive Summary

The Brookhaven Graphite Research Reactor (BGRR) Pile was a 25-ft cube of graphite consisting of approximately 60,000 individual graphite blocks. While operating, a total of 1,368 channels running north and south through the graphite carried the fuel assemblies and cooling air. A series of experimental ports on the east and west sides provided for irradiation of samples. The project scope was to remove and dispose of the pile and was partially funded with American Recovery and Reinvestment Act (ARRA) funding. The work was performed in accordance with *Closeout Procedures at National Priority List Sites, OSWER Directive 9320.2-09A-P* (Environmental Protection Agency (EPA), 2000a).

Graphite pile removal is part of the BGRR remedial actions described in the Final Record of Decision (ROD) for Area of Concern (AOC) 9, Brookhaven Graphite Research Reactor (January 31, 2005) (BGRR ROD). The work to remove the pile and associated ancillary equipment was undertaken to satisfy the ROD requirements.

Removal of graphite blocks and ancillary equipment was performed using remotely operated equipment. A hydraulically operated excavator and electrically operated crane, mounted on the reactor top, were used to load super sacks with graphite debris. Super sacks were subsequently loaded into waste containers and the waste containers were shipped to an offsite disposal facility. This approach significantly lowered worker exposure to hazardous and radiological materials by minimizing worker time in hazardous work environments and was necessary in achieving exposures that were As Low As reasonably Achievable (ALARA).

Remedial activities associated with the Graphite Pile Removal Project commenced in December 2009 and were completed in May 2010. The following summarizes the scope of activities:

- Removal and Disposal of Control Rods
- Removal and Disposal of Boron Shot
- Removal and Disposal of Shield Plugs
- Removal and Disposal of upper portion of Air Tight Membrane
- Removal and Disposal of Invar Rods
- Removal and Disposal of Graphite Pile

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this Closeout Report is to document the remedial actions associated with the removal of the BGRR Graphite Pile. This work is referred to as the “Graphite Pile Removal Project.” The Graphite Pile Removal Project is part of the BGRR remedial actions described in the Final Record of Decision for AOC 9, Brookhaven Graphite Research Reactor (January 31, 2005) (BGRR ROD), Brookhaven National Laboratory (BNL). The project was completed with funding under the American Recovery and Reinvestment Act (ARRA) and in accordance with Closeout Procedures at National Priority List Sites, OSWER Directive 9320.2-09A-P.

Remedial activities associated with the Graphite Pile Removal Project were performed by Brookhaven Science Associates (BSA) Environmental Restoration Projects (ERP), ERP-subcontractors, BSA’s Radiological Control Division (RCD), and Environmental Protection Division (EPD) personnel.

Work was performed in accordance with the BGRR ROD and the Final Remedial Design/Remedial Action (RD/RA) Work Plan for Graphite Pile Removal.

The scope of work for the Graphite Pile Removal Project included the following:

- Removal of control rods;
- Removal of boron shot;
- Removal of concrete and steel plugs at the top of the biological shield;
- Removal of the upper portion of the air tight membrane;
- Removal of the graphite blocks that formed the pile; and
- Packaging, transportation and disposal of all project wastes.

1.2 Site Description and Operational History

The U.S. Army occupied the BNL Site, formerly Camp Upton, during World Wars I and II. Between the wars, the Civilian Conservation Corps operated the BNL Site. It was transferred to the Atomic Energy Commission in 1947, to the Energy Research and Development Administration in 1975, and to Department of Energy (DOE) in 1977. Brookhaven Science Associates (BSA) operates BNL under a contract with DOE.

The BNL site covers almost 5,300 acres, much of which is wooded. It is an irregular polygon, and each side is approximately 2.5 miles long. The developed portion of the BNL site includes the principal facilities, which are located near the center of the BNL

site on relatively high ground. The developed portion is approximately 1,650 acres, 500 acres of which were originally developed for U.S. Army use. Large, specialized research facilities occupy 200 acres and another 400 acres are occupied by roads, parking lots and connecting areas. The remaining 550 acres are occupied by outlying facilities including an apartment area, Biology Field, Former Hazardous Waste Management Area, Sewage Treatment Plant, firebreaks, and the Former Landfill Area. The terrain is gently rolling, with elevations varying from 40 to 120 ft above mean sea level. The land lies on the western rim of the shallow Peconic River watershed, with a tributary of the Peconic River rising in marshy areas in the northern section of the tract. The sole-source aquifer beneath BNL comprises three water-bearing units: the upper glacial deposits, the Magothy Formation, and the Lloyd Sand Member of the Raritan Formation. These units are hydraulically connected and make up a single zone of saturation with varying physical properties extending from a depth of 5 to 1,500 ft below the land surface. These three water-bearing units are designated as a “sole source aquifer” by the U.S. EPA and serve as the primary source of drinking water for Nassau and Suffolk counties.

A map illustrating the location of the BNL site is presented as Figure 1-1.

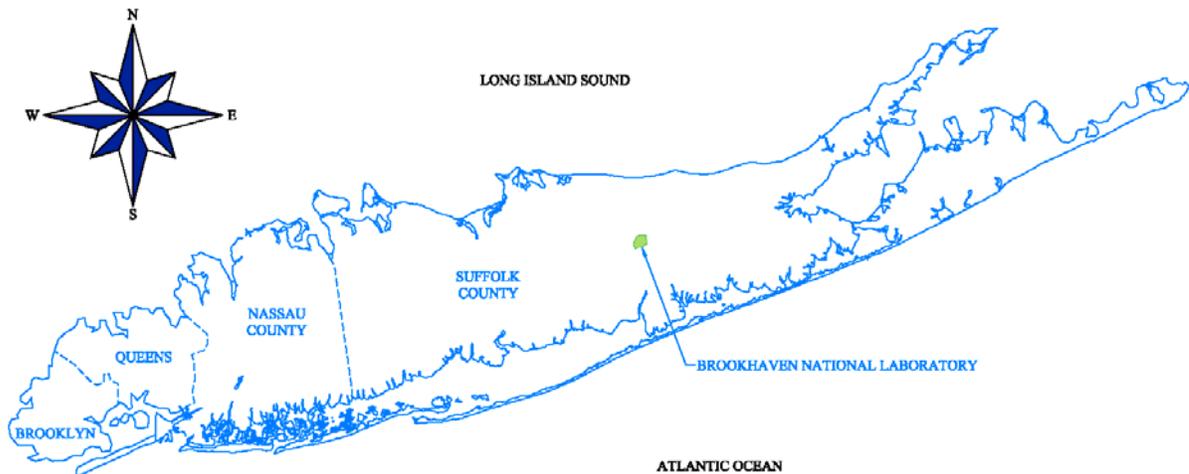


Figure 1-1. Location of Brookhaven National Laboratory

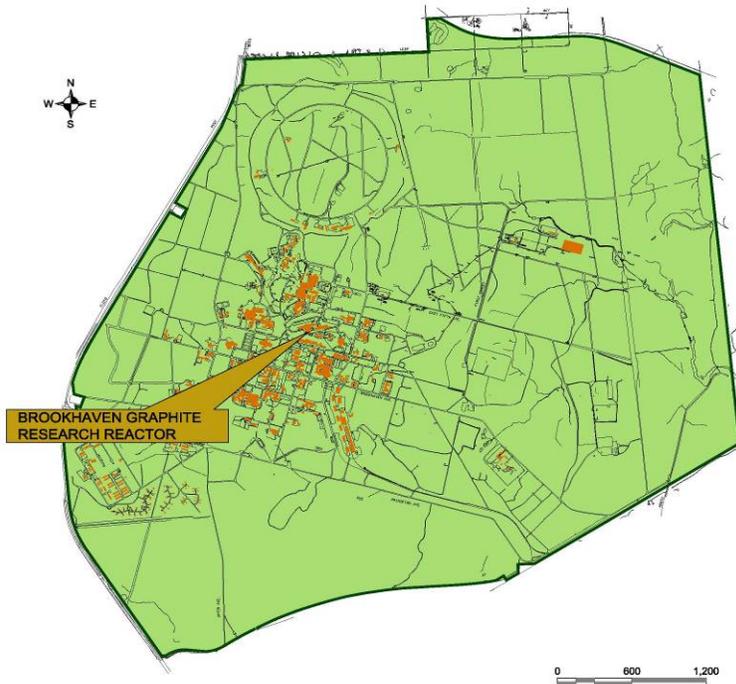


Figure 1-2. Location of the BGRR on BNL Site

The BGRR is centrally located within the BNL site (Figure 1-2). The graphite pile and biological shield are contained within Building 701. Figure 1-3 illustrates the BGRR complex and the location of the pile within the complex. Figure 1-4 is an illustration of the biological shield and experimental facilities.

The BGRR was an air-cooled, graphite-moderated reactor. It consisted of a graphite cube, built in two halves separated by a vertical gap running east and west, 25 ft on each side and weighing about 700 tons. The cube was comprised of 75 horizontal layers of graphite blocks 4 in. wide and tall and of different lengths extending to more than 45 in. The pile's east, west, top, and bottom faces were covered with an airtight membrane to direct cooling air flow to the 3-in. air gap. This membrane was installed to prevent short circuiting of the cooling air. The north and south faces were covered with a 3-in. steel neutron shield. Figure 1-5 is a cutaway view of the biological shield and graphite pile, showing the relationship between those two components, the layers of graphite, and the air gap separating the two halves of the pile.

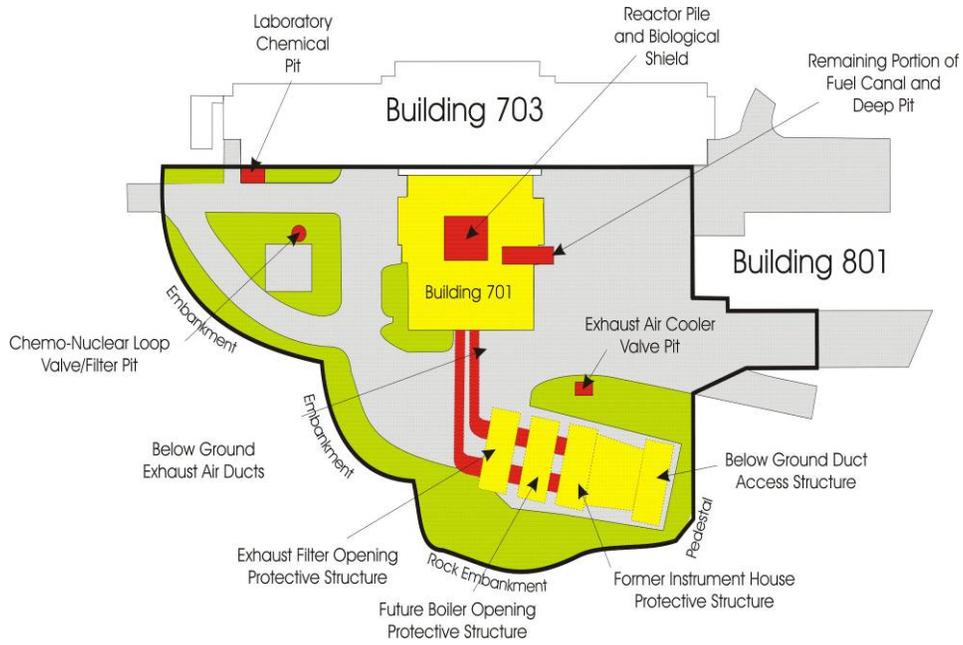


Figure 1-3. BGRR Complex

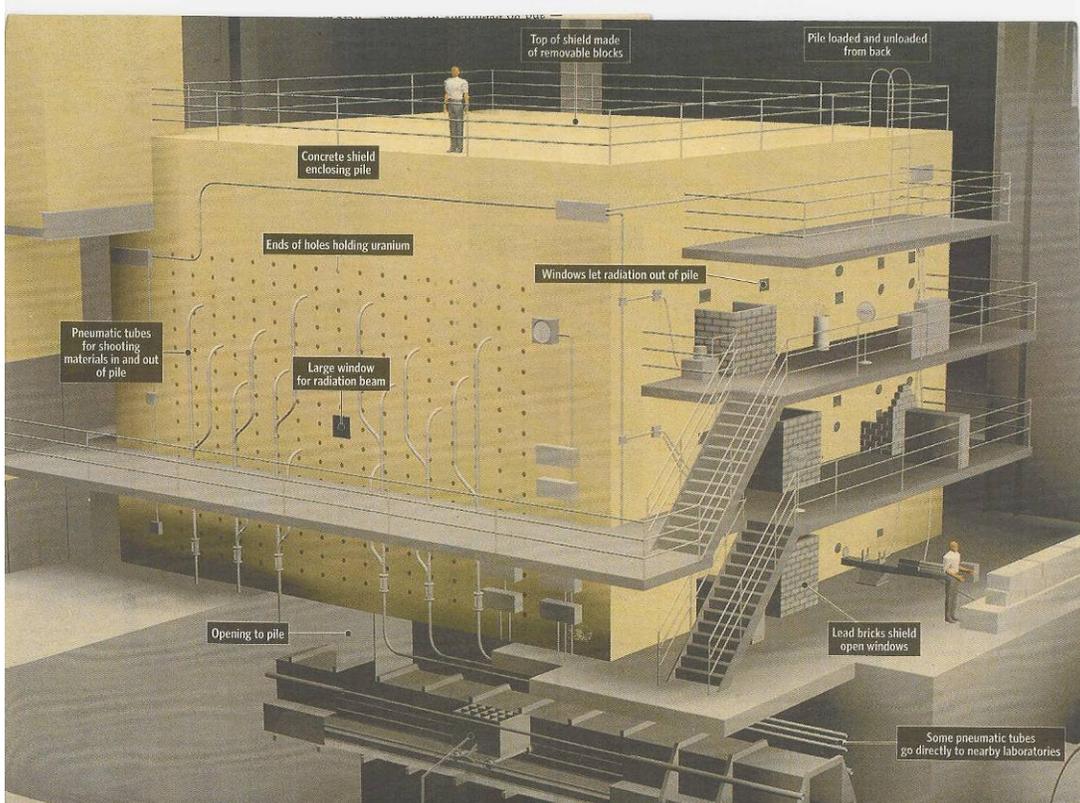


Figure 1-4. Biological Shield and Experimental Facilities

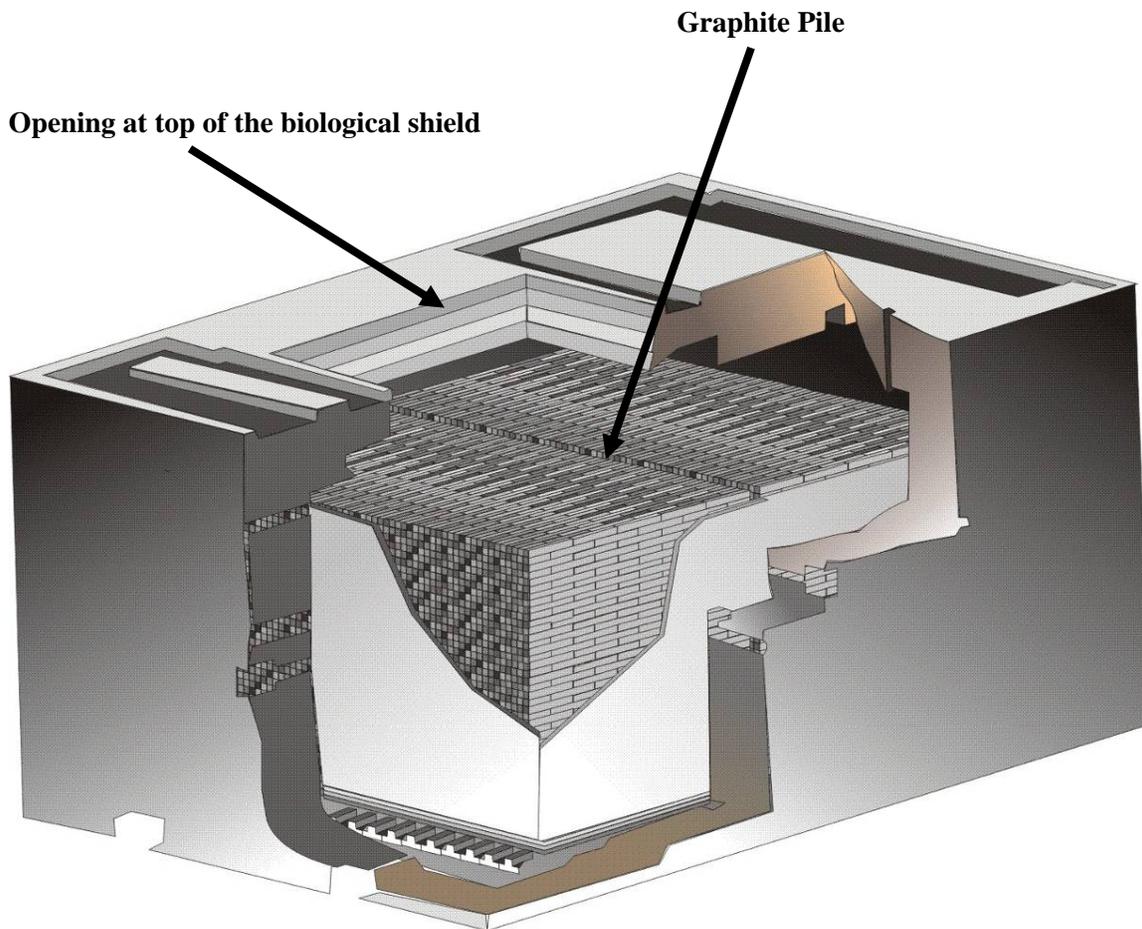


Figure 1-5. Cutaway View of Biological Shield and Graphite Pile

The BGRR, which was the first reactor in the world designed and built strictly for peaceful research purposes, operated from 1950 to 1968. Deactivation of the facility was initiated in September 1969. In March 1972, the last fuel element was removed from the reactor and shipment of the fuel to the DOE Savannah River Site was completed shortly thereafter. Portions of the BGRR facility were used as the BNL Science Museum from 1977 through 1997.

In 2005, the BGRR ROD was signed by the EPA, New York State Department of Environmental Conservation (NYSDEC), and DOE. This agreement requires the removal of the graphite pile, biological shield, canal structure, reasonably accessible contaminated soils, and the installation of a water infiltration control engineered cap and monitoring system for the remaining structures and subsurface contaminated soils. This closeout report addresses the removal and disposal of the BGRR graphite pile.

Beginning in 2008 and continuing through summer of 2009 ERP employed a subcontractor to prepare the facility for graphite removal. The scope of the subcontractor's work activities included designing and installing a remotely-operated excavator and crane on top of the reactor, designing and constructing a containment tent

around the biological shield, and constructing a reactor ventilation system to ensure radiological contamination associated with graphite removal was contained and not released to the environment.

1.3 Regulatory and Enforcement History

In 1980, the BNL site was placed on the NYSDEC list of Inactive Hazardous Waste Sites. On December 21, 1989, the BNL site was included on the EPA National Priorities List because of soil and groundwater contamination that resulted from BNL's past operations. Subsequently, EPA, NYSDEC, and DOE entered into a Federal Facilities Agreement (herein referred to as the Interagency Agreement; [IAG]) that became effective in 1992 (Administrative Docket Number: II- Comprehensive Environmental Response, Compensation & Liability Act [CERCLA]-FFA-00201) to coordinate the cleanup.

The IAG identified AOCs to be evaluated for response actions. The BGRR is subject to the provisions of Section X – Areas of Concern of the IAG and is identified as AOC 9. The remediation of the BGRR complex is divided into four sub-AOCs. These include AOC 9A, the Canal; AOC 9B, Underground Ductwork; AOC 9C, Spill Sites; and, AOC 9D, the Pile Fan Sump. Additional areas of remedial action outside the scope of the AOC subdivisions include removal of the above-ground ductwork, graphite pile, and biological shield. Interim measures were authorized through issuance of Action Memorandums or National Environmental Policy Act (NEPA) Categorical Exclusions. The remaining cleanup activities for the BGRR were addressed in the BGRR ROD.

A Feasibility Study (FS) for the BGRR complex was prepared to evaluate the alternatives for remediation of the BGRR. Upon completion and review of the results of a FS for the BGRR and public review of the Brookhaven Graphite Research Reactor Proposed Remedial Action Plan (PRAP) the BGRR ROD was signed in March 2005. It documented the remedial action for the BGRR selected in accordance with the CERCLA consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (“National Contingency Plan”).

The final remedy was developed in collaboration with regulators using the Core Team Process. The BGRR ROD requirements were incorporated into the RD/RA Work Plan for the Graphite Pile Removal. Following review by the regulatory agencies, the Final RD/RA Work Plan was issued in April 2007.

1.4 Previous Remedial Activities and Site Investigation

Several response actions were previously completed as interim measures (through Action Memorandums and NEPA Categorical Exclusions) to reduce or eliminate potential threats to human health or the environment. They included the removal and disposition of the following:

- Contaminated water that infiltrated and accumulated within the below-ground ducts;
- Experimental equipment and systems from the reactor building;
- Reactor exhaust fans, motors, valves and instruments;
- Pile fan sump, pipes and associated contaminated soil;
- Above-ground ducts, pipes and associated contaminated soil;
- Canal house and water treatment house, along with associated equipment, pipes, asphalt, concrete and accessible contaminated soils; and
- Reactor exhaust cooling coils and filters.
- Reactor below-ground duct primary liner; and
- Portion of the fuel canal outside the structural foundation footprint of the reactor building and accessible subsurface contaminated soil in the vicinity of the fuel canal, below-ground duct expansion joint #4 and secondary cooling air bustle.

1.5 BNL Operable Units

As part of remedial efforts at BNL, 30 AOCs were identified and grouped into seven Operable Units (OUs). The seven OUs were subsequently reduced to six OUs as a result of combining OU II and OU VII. In February 2009, AOC 31, comprising the HFBR complex, Waste Loading Area and the A/B Waste Line, was established.

This report documents completion of the remedial action for the BGRR graphite pile, which is part of AOC 9.

2.0 OPERABLE UNIT BACKGROUND

2.1 Site Cleanup Criteria

The completion criterion for Graphite Pile Removal Project is the removal, packaging, transportation and disposal of the graphite pile.

2.2 Remediation Criteria

Remediation criteria for the Graphite Pile Removal Project were established in the BGRR ROD. They included:

- Removal of:
 - control rods
 - concrete and steel plugs at the top of the biological shield;
 - Air Tight Membrane (ATM) surrounding the pile;
 - graphite blocks; and
 - loose debris
- Application of a fixative to the internal surfaces of the biological shield

2.3 Community Relations Activities

2.3.1 BNL Community Relations

The BNL Community Involvement Plan was published April 15, 1999. It is supplemented by project-specific plans. In the case of the BGRR, a BGRR Community Relations Plan was developed. In accordance with these two plans and CERCLA Sections 113 (k)(2)(B)(i-v) and 117, the community relations program focuses on informing and involving the public in the decision-making process to ensure that the views of the internal and external stakeholder communities are considered. A variety of activities are used to provide information and to seek public participation, including distribution of materials to a stakeholders' mailing list; holding community meetings, information sessions, tours, and workshops; and preparing and distributing fact sheets. The Administrative Record, which documents the basis for removal and remedial actions, was established and is maintained at the libraries listed below:

Brookhaven National Laboratory
Research Library
Bldg. 477A
Upton, NY 11973
631-344-3483 or 631-344-3489

Stony Brook University
Melville Library
Special Collections and University Archives
Room E-2320
Stony Brook, NY 11794
Phone: (631) 632-7119

U.S. EPA - Region II
Records Room
290 Broadway, 18th Floor
New York, New York 10007
212-637-4308

2.3.2 Community Involvement in Graphite Pile Removal

The community involvement process for the BGRR was an integral part of making cleanup decisions. Project staff made numerous presentations to the Community Advisory Council (CAC), the Brookhaven Executive Round Table (BER), and various local civic associations.

Shortly after the 1997 decision to begin decommissioning the BGRR, possible decommissioning alternatives were developed and considered. Three roundtable meetings to elicit public comments and concerns were held in July and August of 1999.

Additionally, interested parties were invited to participate in the BGRR Working Group. Members included some local residents, representatives of several Suffolk County agencies, and representatives of the CAC. The Working Group had its initial meeting in June, 2000, and met until April, 2003. The Working Group closely followed the interim response actions and provided input on when information should be presented to the CAC.

The BGRR Proposed Remedial Action Plan (PRAP) was released for public review and comment on August 2, 2004. The Notice of Availability was published in *Newsday* and *Suffolk Life*, as were advertisements for two information sessions and a public meeting. Information sessions were held on August 17 and 19, and the public meeting was held on August 24, 2004. The public comment period closed on September 3, 2004. The Responsiveness Summary section of the BGRR ROD summarized the written and oral comments received during the public comment period and DOE's responses to these comments.

Project staff continued to provide periodic updates to the CAC and the BER as the Graphite Pile Removal Project entered the implementation phase. Several members of the CAC toured the BGRR in January 2010 to see firsthand the final preparations for graphite removal. Detailed briefings on the graphite removal operations were provided to the CAC and the BER in April 2010.

3.0 CONSTRUCTION ACTIVITIES

This section provides an overview of facility preparation by ERP's subcontractor, features of the BGRR graphite pile and internal structures, and a description of ERP's technical approach to removing the graphite pile.

3.1 Building 702

Building 702 is the designation for the graphite pile, biological shield, control rods, and associated equipment. ERP procured the services of a subcontractor to prepare Building 702 for graphite removal operations. The subcontractor mobilized in March 2008 and began facility preparation for installation of a modified radio-remote-controlled Gradall manipulator and a 10-ton gantry crane in April 2008.

In order to install this equipment on the reactor top the subcontractor needed to install a pair of rails that ran in the north-south direction. The subcontractor first removed several interferences that included portions of balconies and connections to the Control Rod Drive Mechanism platforms. The subcontractor then partially demolished the BGRR Freight Elevator located along the northeast corner of the biological shield. Its steel structure was kept largely intact and was reinforced to be able to support a portion of the equipment rail system. Three additional steel columns were erected at the remaining three corners of the biological shield. Once all three steel columns had been erected the subcontractor installed the railings, one for the crane and the other for the excavator. Each piece of equipment was rigged to the reactor top using the building's bridge crane.

Following installation of the remotely-operated equipment the subcontractor installed a containment tent and HEPA-filtered ventilation system. The tent was designed to surround the upper level of the biological shield, including the reactor cavity, and extended down to elevation 110' (i.e., floor level) on the north side of the biological shield. The tent was designed to be maintained at a small negative pressure with respect to Building 701 and to fully enclose the excavator and crane. The subcontractor installed four 6000-cfm HEPA fan units to maintain the tent at a negative pressure. Two of the fan units were previously used during below ground duct filter and liner removal work. The fan units discharged to the outside environment through a continuously monitored stack that was constructed in accordance with BNL SBMS Exhaust Ventilation Subject Area.

3.2 Graphite Pile

The BGRR was primarily a research instrument. This fact influenced the design in many ways, such as the choice of air cooling, graphite moderation of neutrons to obtain large dimensions and the use of high-density concrete in the biological shield to facilitate access to the neutron flux by reducing the shield's thickness. The graphite structure had the overall dimensions of a 25-ft cube. It was divided into two halves by a 3 $\frac{1}{8}$ -in. (8.0 cm) -wide vertical gap. Seventy-five layers of 4- by 4 -in. graphite blocks of various lengths up to 45-in. were laid horizontally to form the graphite structure. Two sets of 1-in. diameter metal rods spanning the length of the reactor were used to support the pile. One set of rods were located at the bottom of the pile and the other near the top. These were called Invar Rods.

A total of 1,368 channels running north and south through the graphite carried the fuel assemblies and cooling air. There were 37 rows of 37 holes each, except for the center hole in the 18th row, which was occupied by the 12-in. square removable core. The removable core was also made of graphite and contained antimony-beryllium neutron startup sources when the reactor was in operation.

3.2.1 Experimental Holes

Extending through the graphite from the east to west faces were 30 experimental holes lining up with the corresponding openings on the east and west faces of the biological shield. The experimental holes (five rows of six holes each) were each 4-in. square and ran horizontally east-west through the graphite structure. These holes were used to introduce samples into the pile for irradiation.

3.2.2 Animal and Instrument Tunnels

The experimental holes were limited in size by the lattice requirements. To expose large samples to radioactivity, two chambers were provided underneath the reactor. One of these, known as the animal tunnel, was employed to irradiate animals. The other, known as the instrument tunnel, was used to contain instruments and to irradiate miscellaneous large samples.

3.2.3 Control Rods

The BGRR had 16 boron steel control rods. Each control rod assembly consisted of approximately 10 ft of rack and 26 ft of rod. Each rod penetrated the reactor horizontally in directions parallel to the diagonals of the reactor's base. Two of the control rods were used to control reactor power during operations. All 16 rods were used during the process of reactor shut down. A bank of eight rods penetrated the reactor from the southeast corner and the other bank of eight penetrated the reactor from the southwest corner.

ERP decided to remove and dispose of the control rods prior to beginning graphite removal because this approach minimized the number of excavator tool change outs and, hence, the amount of personnel exposure time on top of the reactor.

Control rod removals began in early December 2009 and were completed by late December. The southwest bank of control rods were removed first because they were estimated to be less radioactive than the southeast bank of control rods. This allowed the work crew to develop proficiency in cutting and handling methods before working on the more radioactive rods. Each control rod was slowly pulled from the reactor, mechanically cut into five-foot sections, and loaded into one waste box for disposal. The control rods were not radioactive enough to require the waste box to be shielded. The waste box was shipped February 2010 to Energy Solutions (ES), Utah for disposal.



Photo 1
Control Rod Cutting and
Removal

3.2.4 Boron Shot Removal

Boron shot well system was provided to shut down the reactor in the event of an emergency in which the control rod shutdown system was prevented from operating properly. The system shut down the reactor by gravity feeding a sufficient quantity of neutron poison in the form of cadmium-coated boron steel shot into boron shot wells in the reactor. There were two vertical boron shot wells in the graphite and two diagonal boron shot wells in the reactor gap. Approximately 1,050 pounds of 5/16-inch-diameter boron steel balls were used in the reservoirs. They were made from hot-drawn boron steel wire and had the same composition as the boron steel used in the control rods. The balls were cadmium-plated to minimize rust.

Boron shot removal commenced in early January 2010, just before the concrete roof plugs were rigged out and disposed of, and was completed within one week. The shot was vacuumed out of each well with a portable HEPA vacuum by connecting the vacuum head to a long pole and lowering the pole into each of the shot wells. The vacuum exhaust was directed via portable tubing to a HEPA-filtered 55-gallon drum where the shot was initially collected. After all shot was collected in the drum the contents were transferred to a B-6 steel box for disposal.



Photo 2
Boron Shot Removal

3.2.5 Roof Plug Removal

The reactor top contained two layers (upper and lower) of concrete roof (shield) plugs. The roof plugs had several different shapes and sizes (e.g., square, wedge, etc.) and were designed to minimize dose rates on the reactor top during operations such that workers could have access to the area. Roof plug weights varied between 1,100 and 10,800 pounds. There were a total of 151 plugs.

Plug removal began in mid-January 2010 and was completed by early February. Each of the roof plugs were individually rigged out using a 10-ton gantry crane and lowered into connex containers staged on the north side of the reactor within the Contamination Control Enclosure (CCE), a large tent used to confine dispersible radioactivity. The upper layer of plugs was not radiologically contaminated, but the lower layer of plugs contained small amounts of contamination. Several of the plugs did have higher dose rates than expected (i.e., factors of two or three). This was attributed primarily to the higher neutron dose rates that existed at the reactor gap where there was less shielding. Bracing was added to each container to ensure the concrete plugs did not shift during transport.

After each container was loaded and the plugs secured against movement, the container was surveyed, released from the CCE and staged at the BNL rail spur for offsite shipment and disposal at ES in Utah. Twelve Intermodals were filled, and shipments will be completed by the end of September 2010.



Photo 3 Roof Plug Removal

3.3 Technical Approach

The graphite pile was mechanically removed using remotely operated tools located within the CCE that was maintained under negative pressure for contamination control purposes. The resulting graphite pile waste was packaged into steel containers, staged at the BNL Waste Management Facility (WMF) and transported and disposed at the DOE's Nevada Test Site (NTS) disposal facility. This work included the removal of loose residual debris.

Following the installation of the CCE, remotely-operated excavator and crane, and the HEPA-filtered ventilation system, ERP undertook a readiness assessment process to ensure that facility personnel, operating procedures and equipment were ready to commence mining operations. The readiness process consisted of three phases: (1) Management Self Assessment (MSA); (2) Contractor Readiness Assessment (CRA); and (3) DOE Readiness Assessment.

The MSA relied upon a team of subject matter experts, all external to ERP, in various functional areas such as radiological controls, training and qualifications, worker safety and health and conduct of operations. Formal checklists were developed and used to ensure that all BNL requirements in SBMS that applied to the planned graphite pile operations were appropriately implemented. A formal MSA report was written and issued that contained a number of findings in several functional areas. ERP formally corrected all the findings.

Immediately following this ERP commissioned a team of external (i.e., contractor) subject matter experts to conduct a CRA. The CRA addressed the core requirements listed in DOE O 425.1C, *Startup and Restart of Nuclear Facilities*. The CRA Team used a graded approach to evaluate the readiness of facility personnel, programs and equipment to conduct work safely. Criteria Review and Approach Documents (CRADs) were developed for each of the core requirements. The CRADs identified the assessment criteria and lines of inquiry to be used for assessment of each requirement and included field observations, as appropriate. The report was finalized and issued in November 2009 and contained 25 pre-start findings and 17 post-start findings. All pre-start findings were formally corrected by early December 2009.

Following the CRA DOE conducted its own readiness assessment. DOE identified four issues that required a formal corrective action response from ERP. Following ERP's closure of the corrective actions DOE validated them and on December 31, 2009 issued approval to ERP to commence BGRR decommissioning operations.

3.3.1 CCE and HEPA Ventilation System

A CCE and High Efficiency Particulate Air (HEPA)-filtered ventilation system was constructed by the subcontractor and utilized during the removal of the Boron Shot, concrete plugs and graphite pile. The CCE surrounded the upper level of the biological shield and extended down to elevation 110 ft on the north side of the biological shield. It was designed to contain airborne radioactivity that was generated during graphite removal operations, provide an air flow path from areas of lesser contamination to areas of higher contamination, and to prevent its escape to non-contaminated portions of the building. During operation it was maintained at a negative pressure with respect to Building 701. The CCE enclosed the excavator manipulator and 10-ton gantry crane.

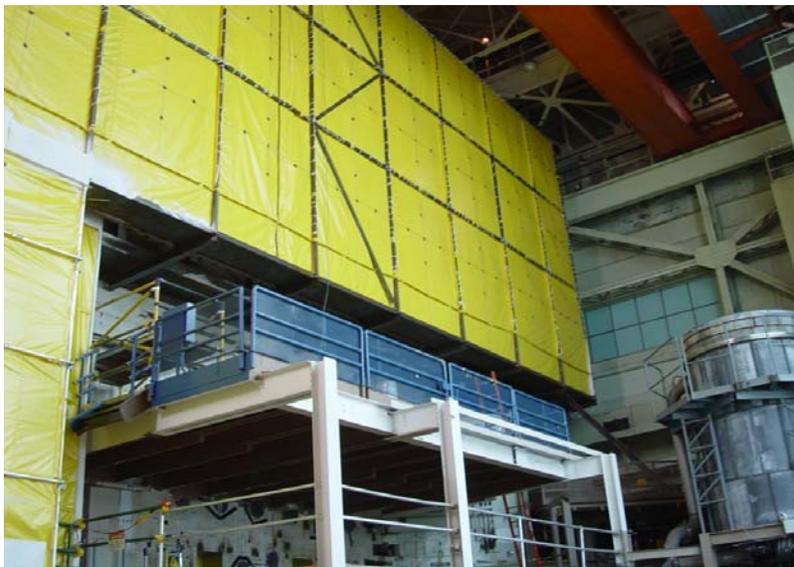


Photo 4 Exterior of CCE

The CCE was constructed of metal framing, and the design was approved by a licensed New York State Professional Engineer. The framing supported thin panels of yellow, fire-retardant plastic which were sealed together with double over-lapping Velcro. The design included two airlocks for movement of equipment into and out of the CCE and one airlock for personnel entry. The equipment airlock doors were curtain roll-up style, zipper operated, and sealed with Velcro. Air flowed into the CCE through barometrically-controlled damper valves which closed at low differential pressure between the CCE and the building high bay to guard against backflow of contaminated air into the high bay. The CCE was initially certified and then inspected each shift to verify its operability as an engineering control prior to graphite removal operations.

Four 6000-cfm HEPA fan units were used to maintain the CCE at a negative pressure. Two 6000-cfm HEPA fan units, utilized during the below-ground duct filter and liner removal, were used in addition to two newly purchased units. The HEPA fan units were located adjacent to the east intake plenum and drew air into the CCE and down through the reactor through barometrically-controlled damper valves. Exhaust air was discharged to the outside environment through a continuously monitored stack. The stack was constructed in accordance with BNL's Exhaust Ventilation Subject Area. The CCE and the HEPA ventilation system was inspected and tested to verify compliance with the purchase specifications.

3.3.2 Excavator Manipulator and 10-Ton Gantry Crane

A modified remote-controlled, hydraulically-operated excavator and a 10-ton gantry crane installed by the subcontractor were utilized to remove the concrete shield plugs, graphite pile and associated debris. The excavator and crane were mounted on rails that run north-south, located near the top of the biological shield. They were supported by three columns (southeast, southwest and northwest corners) and the reinforced freight elevator steel superstructure at the northeast corner. The freight elevator was partially demolished, with its steel structure reinforced to support the northeast corner. The crane, mounted on one pair of the north-south rails, was used to lift the graphite from within the biological shield. The excavator and the 10-ton gantry crane were inspected and tested to verify compliance with the purchase specifications.

The crane was initially used to remove and package the upper concrete shield plugs. Each plug was removed from the reactor top (140-ft elevation) with standard rigging hardware and lowered to the waste handling area on the 110-ft elevation, where each plug was packaged into a waste container. Following removal of the shield plugs, the primary function of the crane was to handle a lifting fixture containing one super sack to move mined graphite blocks from the interior of the reactor to the 110-ft elevation waste handling area. In this area the super sack was placed into the final waste container for transport and disposal. During the project the gantry crane was also used to remove other internal reactor components and perform maintenance activities for the excavator.

The hydraulically operated excavator was the primary tool for graphite block removal. The process of filling a super sack with graphite blocks started with pouring an 18-pound bag of vermiculite into the bottom of the super sack to absorb any hydraulic fluid from the excavator that may have leaked during the loading process. This would ensure that there was no free-standing liquid in the waste stream. The super sack then was rigged up from the 110' level to the reactor top and into the reactor pit using the gantry crane. Utilizing a clamshell bucket fitted with a specialized blade, graphite blocks were dislodged layer by layer with the excavator and loaded into the super sack. A hydraulic hammer attachment was also utilized to break up graphite layers. After the sack was filled it was rigged out of the reactor pit and held stationary over two fixed, remote-reading dose rate instruments to ensure the external super sack dose rate was within acceptable limits for offsite transportation. Following this measurement the super sack was lowered back down to the 110' level and rigged into an industrial package (IP)-1 waste container. The IP-1 container lid was then secured into place; the container was surveyed and then moved out of the CCE pending transportation to the BNL Waste Management Division (WMD) for final processing and offsite disposal at the DOE Nevada Test Site.

The excavator attachments included a hydraulic shear which was required to size-reduce the upper and lower graphite pile Invar Rods. These one-in. diameter rods were cut into approximate five foot lengths and separately containerized because they were more radioactive than the graphite. The Invar rod waste containers were shielded with lead and bismuth blocks to reduce the external dose rate for ALARA and waste disposal purposes.

Other excavator attachments included a specialized rake utilized to remove graphite debris from the sides of the pile to allow pickup with the clamshell bucket. Because the length of the excavator boom was insufficient to reach the bottom of the reactor pile a 12-ft boom extension was installed on the excavator after about half of the graphite had been removed. All excavator tool change outs took place on the pile top within the CCE.

The excavator was fitted with a spray system to apply a fixative agent for graphite dust suppression. A latex paint and water mixture was applied to the graphite material during removal, for dust control. The interior of the loaded super sack was also coated with this mixture.

Remotely operated cameras were installed inside the CCE to allow monitoring and operation of the graphite removal equipment. Cameras were placed in the ceiling of the CCE, on the gantry crane structure, on the excavator boom, and two cameras were placed on an adjustable structure and lowered into the pile. These cameras were maintained at the working depth and location where graphite removal was occurring. The camera systems allowed constant viewing of the waste loading operation and all remote equipment operation.



Photo 5
Excavator Loading Lift Fixture and Super Sack

3.3.3 Concrete Shield Plug Removal

For access to the graphite pile, the concrete shield plugs that formed the top of the reactor biological shield were removed. Each plug was removed from the reactor top (140-ft elevation) utilizing the 10-ton gantry crane and standard rigging hardware. Each plug was lowered to the waste handling area on the 110-ft elevation. Once on the 110-ft elevation, each plug was packaged directly into disposal containers.

3.3.4 Airtight Membrane Removal

During the removal of the graphite pile, only the top portion of the ATM was removed to access the graphite blocks. The top portion of the ATM consisted of steel sheets that were approximately 1/8-inch thick. Following removal of the lower layer of concrete roof plugs the excavator, fitted with the clamshell bucket, was utilized to remove the upper portion of the ATM. Each sheet was packaged into the last container of concrete roof plugs. The remaining east and west sides of the aluminum and steel ATM will be removed during preparations for biological shield removal.

3.3.5 Graphite Block Removal

Removal of the pile graphite and miscellaneous in-core components (e.g., fuel anchors, graphite plugs, thermocouple wires, graphite control rod sleeve liners, target conveyor, restraining rods, etc.) commenced on the top layer of graphite and continued down to the pile bedplates. Graphite removal commenced in early February 2010 and was completed by mid-May 2010. ERP implemented two 10-hour shifts and generally worked six days of each work week. Each shift was staffed with a Shift Operations Manager, Senior Supervisory Watch (SSW), equipment operator, two waste handling technicians and several radiological control technicians.

The graphite and in-core components were removed remotely using the previously described gantry crane and excavator fitted with a combination of end effectors. The excavator and crane controls were located in a control trailer located about 20 feet away from the east wall of the biological shield. A number of viewing screens provided real-time video displays of equipment operation so that the operators could see how the equipment was responding to their commands. A total of 10 cameras were located within the CCE and provided the ability to view all work areas including the reactor cavity and the waste container processing area. Remote viewing screens outside of the high bay were also used by an independent waste verifier from the BNL Waste Management Division to ensure debris loaded into super sacks did not contain unallowable materials.

Graphite blocks were loaded directly into a super sack which was attached to a lift fixture and lowered inside of the biological shield. After being filled the super sack was transferred to a 144-cubic foot IP-1 steel box outside of the biological shield but within the CCE. The IP-1 box was closed, decontaminated inside of the CCE and then removed by forklift. The packaged and decontaminated IP-1 boxes were then transported by truck to a Waste Management Division staging area prior to offsite disposal. A total of 249 loaded IP-1 waste containers were filled and processed.

3.3.6 Removal of Invar Rods

Two rows of 1-inch diameter steel Invar Rods spanned the graphite pile in the north-south direction. One set of rods was located in rows 72-73 of the graphite and the other layer was located in row two near the bottom of the pile. There were more rods in the lower layer than in the upper layer. The rods were designed to have a low coefficient of expansion and helped maintain the north and south neutron plates at a constant and parallel distance.

These rods were cut into approximate five foot sections using the shear attachment on the excavator. Once all the rods in a layer were size reduced they were remotely handled using a magnet attached to the gantry crane and placed into a shielded box located within the reactor cavity. Shielding was required because the rods contained much higher levels of gamma-emitting radioactivity than the graphite and produced much higher dose rates.

3.3.7 Removal of Loose Debris

Upon completion of graphite block removal, loose debris was removed by vacuuming it into one B-25 waste container. This container will be transported by truck for disposal at the ES disposal site in Utah. An industrial vacuum system manufactured by Hi-Vac Corporation was utilized to suction debris from the pile bedplate. The vacuum system consisted of the Hi-Vac vacuum connected to a modified B-25 waste container which functioned as a drop-out box for the moderately sized debris. The vacuum was located outside the CCE and the B-25 waste container was located inside the CCE. The vacuum suction hose was connected to the excavator-mounted rake and manipulated around the pile bedplate. The discharge air flow from the vacuum was routed back into the CCE through a west experimental port.

A paint-water mixture was first sprayed onto the debris as a fixative using the same delivery system that was employed during graphite mining. The fixative was used to minimize the potential for the dust to become airborne. This vacuum system was used to remove reasonably obtainable material debris from around the pile bedplate. Efforts were not made to vacuum fuel channels, inside the remaining air gap, or the corners between the remaining ATM structure and the bedplate. These areas will be cleaned during removal of the biological shield.

After the debris was removed a fixative was sprayed onto portions of the reactor cavity that had been in contact with the graphite, such as the north and south neutron plates. The fixative consisted of a mixture of water and latex paint primer in a ratio of about one part water to three parts primer. The same spray system that was used for dust suppression during graphite removal was used to apply the fixative.

3.3.8 As-Left Radiological Survey

Following completion of all work inside the biological shield cavity, a radiological dose rate survey was performed to document the as-left condition and to help refine biological shield characterization for planning the next phase of reactor remediation. The survey was performed by gridding off each of the four walls and the floor of the reactor pit into equally spaced survey points. Twenty five dose rate measurements along each of the five surfaces were obtained by lowering a remote reading shielded dose rate instrument from the top of the reactor. Survey measurements were obtained at about five inches above each surface.

The results indicated that dose rates were generally greater than 100 millirem per hour with a high of about 500 millirem per hour. Higher dose rates were obtained near the center points of the walls, and lower dose rates were obtained in the corners which is consistent with the neutron flux patterns that existed in the core during operations. Based on these results the biological shield cavity will continue to be posted and controlled as a High Radiation Area.

3.3.9 Waste Management

ERP characterized the graphite pile waste in a series of sampling campaigns between 1999 and 2005. Samples of graphite and surface smears were obtained from different locations throughout the pile. These samples were sent to an offsite analytical laboratory for radiological and hazardous material analysis. Radiological activation calculations were also performed to estimate the radioactivity content of the Invar Rods and control rods. The sample analyses and activation calculations were used to decide packaging and disposal options for the various waste streams. All of the wastes were shipped to either the NTS or ES in Utah.

The wastes generated were disposed of in various Department of Transportation (DOT) approved containers. These containers included custom made 144-cubic foot steel boxes (i.e., IP-1s), 675-cubic foot Intermodals, 24-cubic foot B-6, 48-cubic foot B-12 and 96-cubic foot B-25 steel boxes. All of the wastes except the boron shot and control rod sleeves were shipped as low-level radioactive waste. The boron shot and control rod

sleeves were characterized and will be disposed of as mixed low-level waste. The treatment for the mixed low-level waste will be macro-encapsulation at the disposal facility. Table 1 below summarizes the wastes, container types used, disposal facility and method of transportation. The graphite pile waste disposal campaign began on February 24, 2010 and will be completed by September 30, 2010.

Table 3-1 Summary of BGRR Pile Wastes

Waste Type	Volume, ft ³	No. Containers	Disposal Facility	No. Conveyances
Pile Plugs	6,480	12 Intermodals	ES	3 railcars
Boron Shot	24	One B-6	ES	1 truck
Control Rod Sleeves	48	One B-12	ES	1 truck
Graphite	35,856	249 IP-1	NTS	54 trucks
Invar Rods	144	One B-12, Four B-6	NTS	3 trucks
Control Rods	24	One B-6	ES	1 truck
Graphite dust	96	One B-25	ES	1 truck

In order to ensure non-conforming wastes were not disposed of along with the graphite waste ERP employed a number of independent waste verifiers to observe and certify the loading and closure of each waste container. CCE cameras that provided streaming video to a location outside of the work area were used for this purpose. This ensured each loaded container met the Laboratory's waste certification and quality control requirements. Two moveable cameras were also mounted on retractable supports within the reactor cavity that allowed operators to have an improved view of excavator and super sack loading operations

ERP instituted a number of waste minimization and pollution prevention methods over the course of the project. One of the primary pollution prevention methods was HEPA filtration of the reactor ventilation system to remove particulate radioactivity prior to discharging the air to the environment. Another method was reuse of contaminated lead bricks as shielding for the B-6 and B-12 steel boxes used to containerize the segmented Invar Rods. Lastly, ERP planned to optimize IP-1 container weight loading in order to minimize the number of containers processed (i.e., cost) but also to minimize worker exposure from having to physically hand remove radioactive graphite blocks from boxes that were excessively loaded and could not be closed. These considerations resulted in about 10% more IP-1 containers being used than originally planned.

4.0 CHRONOLOGY OF EVENTS

The following table lists a chronology of the main events for the Graphite Pile Removal Project.

Table 4-1 Chronology of Events for the BGRR Graphite Removal Project

Date	Event
January 31, 2005	BGRR Rod Approved
April 23, 2007	BGRR Final Remedial Design/Remedial Action Work Plan
April 1, 2008	Installation of graphite removal equipment commenced
August 15, 2009	Installation of graphite removal equipment completed
October 30, 2009	Contractor Readiness Assessment completed
December 17, 2009	DOE Readiness Assessment completed
December 30, 2009	Control rod removal completed
December 31, 2009	Received DOE authorization to begin graphite removal
January 15, 2010	Completed boron shot removal
January 27, 2010	Completed plug removal
February 3, 2010	Completed upper ATM removal
February 4, 2010	Began graphite removal
February 24, 2010	Commenced graphite waste disposal
May 20, 2010	Completed graphite removal
May 25, 2010	Completed removal of loose debris
May 26, 2010	Completed biological shield radiological survey
September 30, 2010	Completed graphite waste disposal

5.0 PERFORMANCE STANDARDS AND QUALITY CONTROL

The performance standard was removal of control rods, boron shot, concrete and steel plugs at the top of the biological shield, ATM along the top of the reactor, graphite blocks, loose debris from within the reactor cavity and application of a fixative to internal surfaces of the biological shield that were in contact with the graphite. This did not include any graphite dust and debris behind the thermal shields or in the fuel channels and plenums.

All graphite debris waste boxes were procured from an offsite vendor. Incoming and outgoing inspections were conducted on all containers. Periodically during the mining

process, smear samples were obtained from within the CCE and analyzed. ERP used the sample results to calculate ratios of hard-to-detect activity (i.e., Ni-63, C-14) to easy-to-detect activity (e.g., Cs-137, Co-60, etc.) to ensure they were consistent with pile characterization data and to monitor for a significant shift in the dispersible mixture that might cause hand-held radiological instrumentation to under-respond. The ERP RCM reviewed and trended each set of results. Results were determined to be in line with characterization data, and thus protocols for using hand-held radiological instrumentation, such as “Friskers”, did not require modification.

6.0 FINAL INSPECTION AND CERTIFICATIONS

In accordance with the BGRR ROD, a Final Status Survey is not required at the completion of graphite removal but will be required at the end of Biological Shield removal to ensure cleanup goals are met. A radiological survey of the reactor pit was obtained and will be used to help plan the removal of the biological shield. Graphite removal was considered completed when there was no longer any appreciable dust to be vacuumed.

During all facets of the Graphite Pile Removal Project there was strict adherence to industrial safety and radiological safety requirements. All work was performed under the authorization of written and approved procedures. Job Risk Analyses (JRAs) were prepared and approved as a part of each work package. Oversight of radiological work was provided by Radiological Control Technicians (RCTs) and the ERP Radiological Control Manager, and general oversight was provided by Job Supervisors and ERP Managers.

6.1 Industrial Hygiene Oversight and Monitoring

Industrial hygiene oversight and monitoring was conducted by the ERP Industrial Hygienist in accordance with ERP procedures. A JRA was prepared for each work package, identifying hazards associated with each of the tasks and specifying required controls for each hazard. The ERP Industrial Hygienist ensured that monitoring occurred as specified in the JRA. Industrial hygiene monitoring included noise monitoring and heat stress monitoring.

6.2 Radiological Oversight and Monitoring

Both area and personnel monitoring was performed by qualified RCTs. Area monitoring consisted of routine dose rate and contamination surveys (e.g., daily, weekly, monthly, etc.) as well as air monitoring. Alpha- and beta-sensitive Continuous Air Monitors (CAMs) were established outside the CCE. These CAMs monitored air in the CCE and also in the Building 701 High Bay. Additionally, passive area monitoring was conducted in non-radiological areas of Buildings 701 and 703 to assure that non-occupational workers were not exposed above limits.

Because the CCE was posted and controlled as a Contamination Area, personal protective equipment for entry consisted of a single set of anti-contamination clothing. Personnel

who processed waste boxes were also required to wear full-face air-purifying respirators. Toward the end of the project, ERP changed this requirement to loose-fitting Powered Air Purifying Respirators based on measurements that showed very little airborne radioactivity within the CCE. Upon exiting, the CCE workers were required to monitor themselves using automated personnel contamination monitors (PCMs) such as the PCM-2. All radiological controls for work within the CCE, including job coverage by RCTs, were specified in job-specific radiological work permits.

All equipment, including waste boxes, that were released from the CCE were surveyed in accordance with FS-SOP-1005, *Radiological Surveys Required For Release of Materials from Areas Controlled For Radiological Purposes* (BNL, November 2007).

As indicated previously cameras located inside the CCE were used for remote observation of equipment operation but also for oversight of workers when they entered the CCE. The ability to remotely view workers performing IP-1 container processing operations led to work planning enhancements and reduced personnel exposure. Additionally, ERP used a commercially available software program that enabled remote read out of CAMs and electronic personnel dosimeters. This remote instrument read out capability allowed oversight personnel to ensure workers did not exceed RWP dose limits and directly contributed to ERP's ALARA Program. These tools enabled ERP to keep its collective dose for the project to approximately 2.3 rem or about half of the original estimate.

7.0 OPERATION AND MAINTENANCE ACTIVITIES

ERP will perform operation and maintenance activities until the BGRR complex is completely remediated in accordance with the BGRR ROD and transferred to BNL's Long Term Response Action Group.

8.0 SUMMARY OF PROJECT COSTS

The Graphite Pile Removal Project was performed with ARRA funding. The removal of the Graphite Pile cost approximately \$26,600,000 to complete. The original cost estimate was \$27,400,000.

The cleanup costs for the Graphite Pile Removal Project included the following details:

Development and Implementation of Nuclear Safety Basis	\$1,247,853
Engineering and planning	\$8,543,941
Remediation	\$14,217,796
Waste Transportation and Disposal	\$2,570,267
Total Cost	\$26,579,857

9.0 OPERATING EXPERIENCE AND LESSONS LEARNED

The following is a summary of the lessons learned from this project and the corrective actions for future projects:

- ERP Leadership implemented a SSW during the complex portions of the graphite removal process and essentially full time for the shift operations during graphite pile removal. SSW personnel were selected from senior ERP managers who fully understood the graphite removal process and were experienced in enforcing formality in Conduct of Operations and use of procedures. The SSW provided enhanced management oversight and operational rigor. It also allowed the Shift Operations Manager to concentrate on the task of removing the graphite with limited distractions. This extension of management oversight is suggested for complex operations where senior management benefits from added assurance of the quality and excellence of the work.
- A B-6 waste box, shielded along the bottom and walls with 2 inches of lead brick, was used to dispose of the first set of highly irradiated Invar Rods. The top shield consisted solely of lead blankets which were manually stacked. Because of the difference in shielding effectiveness, the B-6 box had higher radiation dose rates on the top when compared to the bottom and sides. For the lower set of Invar Rods, ERP designed and fabricated an improved top shield consisting of a steel base plate with 2-in. lead bricks stacked on top and rigging ports mounted into the base plate. The shield was installed remotely with the gantry crane, resulting in less worker dose and a reduced and more uniform box dose rate. The top shield design was used for all three B-6 boxes used to complete removal of the lower Invar Rods.
- The BGRR Project missed an opportunity to establish more meaningful mock ups and dry runs for the remotely-operated equipment. The project decided not to pull the concrete roof plugs to better simulate removal of graphite from the reactor cavity. Instead, the project continued with the demonstration technique developed by the construction contractor, which involved stacking non-radioactive graphite and wood blocks on top of the pile and “excavating” them using the gantry crane and Gradall excavator. No attempt was made to mock up an area simulating the BGRR graphite pile to demonstrate or practice the start of removal of the graphite layers and then the continuing layer removal of the pile. An improved mock up was deployed as a result of a Contractor Readiness Assessment Team recommendation. Early implementation of realistic mockups and simulations needs to be pursued with diligence.
- The CRA Team helped the BGRR Project identify several meaningful lessons learned. These included the need to enhance training of key operations staff in Hazard Assessment Document (HAD) controls and operating limitations, enhance contingency planning by upgrading a BROKK Manipulator and preparing it for service (in case the excavator became inoperable), and optimizing the project work schedule by removing the control rods prior to the graphite blocks, thereby minimizing the number of excavator tool change outs.

- Higher dose rates than expected on BGRR lower concrete roof plugs caused waste shipping delays. Shipments that were originally expected to be low dose rate ended up requiring placarding as higher dose rate shipments. The bottom steel plate of many of the lower layer of plugs were determined to be more radioactively activated than predicted by about a factor of two. The packaging required more shielding than originally anticipated. Detailed, documented loading plans and waste container cribbing plans were in place for the removal process, but last-minute changes were required to accommodate the higher radiation levels. The Project “What-IF” analyses included removal of roof plugs for “radiological surprises,” but the disposition was simply “stop and develop a new plan.” “What-If” analyses for radiological waste streams should be bounded to better prepare and minimize shipping delays caused by the unexpectedly high dose rates.
- Work package 304-104, Acceptance Testing, served to document the integrated system testing for the Graphite Pile Removal Project equipment. The scope of this work package included documenting the training and proficiency status of all BGRR workers. This expanded work scope made it difficult to follow open items and close completed items in a timely fashion. Many different people were also involved in completing the package. This also made tracking of open items much more complex. Projects of this scope should use separate packages for equipment acceptance testing and personnel training and qualification.
- IP-1 waste containers were wrapped with plastic film (like saran wrap) to prevent contaminating the container during super sack loading operations. The top of the lift fixture was also wrapped. This additional control minimized the transfer of contamination to the waste container processing area and helped minimize contamination to workers as they leaned over the edge of the lift fixture to install super sacks. All loading operations occurred in a posted Contamination Area. After super sacks containing graphite waste were loaded into the waste containers the protective wrappings were removed from the containers and disposed inside them.
- Characterization data suggested surface contamination would consist of a mixture of fission products and hard-to-detect radionuclides like C-14 and Ni-63. Periodically during graphite removal, the project obtained smears from within the CCE, counted them on an in-house thin-window gas flow proportional alpha-beta smear counter and high purity germanium spectrometer, and sent them to an offsite analytical laboratory for full radiological analysis to trend for a shift in Ni-63 and C-14 activity levels. When results indicated that Ni-63 and C-14 accounted for the majority of smearable activity, automated smear counter results were compared to the laboratory’s results to confirm that the smear counter could continue to be used to release waste containers. The comparison proved that the automated smear counter results remained conservative and could be used to release waste containers when the source term shifted from a mixture of radionuclides to mostly Ni-63 and C-14.

- Work package 304-85 was prepared to complete a demonstration check of the Brokk Manipulator as a contingency tool (i.e., backup to Gradall excavator) for graphite removal. The testing did not occur as early in the project schedule as originally planned. When testing was performed, deficiencies were identified that required resources to correct. Resources were not immediately available because they were tied up in other startup activities. Testing of project contingency tools/methods needs to occur as originally planned and as early in the schedule as possible to avoid schedule conflicts caused by resources being committed elsewhere.
- The BGRR Project Engineer developed ingenious tools, devices, and fixtures to enhance and improve the capabilities of the excavator, crane, lift fixture, and handling equipment for the graphite pile removal process. These were unique, innovative and simple concepts that enhanced tool usefulness and avoided the temptation to make them work by “brute force.” The lesson learned is not to be content with tooling that may be functional but not optimal for the job. The contributions included:
 1. A “blade” to cover the excavator bucket teeth to better pick up the graphite blocks.
 2. Angled alignment fixtures/wedges to guide the lift fixture with the loaded super sack into the shipping container.
 3. Small removable wedge devices to spread the shipping container sides, preventing the lifting fixture from catching on the upper protrusion of the shipping container inside bracing.
 4. Covers for the top rails of the lift fixture that holds the super sack. These covers shield the pins that hold the super sack and greatly reduce the radioactive contamination of the lift fixture upper surfaces.
 5. A dual camera positioning system that ran on movable trolleys that traversed the east and west pile sides on tracks mounted on each upper, outer side of the pile. The cameras were high resolution with full zoom, tilt, focus and integral adjustable lighting.

10.0 PROTECTIVENESS

The removal of the BGRR pile and associated debris significantly reduces the radiological footprint of the facility and will protect human health and the environment. The removal of these wastes minimizes both the risk of exposure to on-site workers and the environmental risks associated with potential migration of contaminants into the underlying groundwater.

REFERENCES

- BNL, 1992. Interagency Agreement, May 1992.
- BNL, 1996. BNL Final Remedial Investigation/Risk Assessment – Final Report, Operable Unit I/VI, CDM Federal Programs Corp., June 1996.
- BNL, 1999b. Record of Decision, Operable Unit I and Radiologically Contaminated Soils, August 1999.
- BNL. 2005, Record of Decision, Area of Concern 9, Brookhaven Graphite Research Reactor, January 31, 2005
- BNL. 2006. Operable Unit 1 Soils and Operable Unit V Long-Term Monitoring and Maintenance Plan, May 2006.
- BNL, 2007. BGRR Final Remedial Design/Remedial Action Work Plan for Graphite Pile Removal, April 23, 2007
- BNL, 2007b. FS-SOP-1005, Radiological Surveys Required for Release of Materials from Areas Controlled for Radiological Purposes, November 2007.
- BNL SBMS Exhaust Ventilation Subject Area
- Contractor Readiness Assessment, ERP BGRR D&D, Graphite Removal Project, November 2009
- CDM Federal Programs Corp., 1996. Final Remedial Investigation and Risk Assessment Report for Operable Unit I/VI, 1996.
- CDM Federal Programs Corp., 1999. Final Feasibility Study Report for Operable Unit I Radiologically Contaminated Soils, 1999.
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Title 42, U.S. Code, Sec. 9620 et seq.
- DOE O 425.1C, Startup and Restart of Nuclear Facilities
- EPA, 1997. Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination (OSWER Directive 9200.14-18), 1997.
- EPA, 2000a. Close Out Procedures for National Priorities List Sites (OSWER Directive 9320.2-09A-P), January 2000.