Enclosure 1

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Unified Decommissioning Funding Plan For The Pennsylvania State University Radiation Facilities At University Park, Hershey Medical Center, And Related Campuses

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Introduction and Executive Summary

This decommissioning funding plan (DFP) was prepared using NUREG-1757 Volume 3 Rev 1 (2012) as a guidance document. The section designations correspond to the numbering system used in Appendix A.3 of the NUREG.

The Pennsylvania State University comprises 23 major campuses spread across the state as shown in Figure 1 (note that the Penn College of Technology is not under Penn State's Environmental Health and Safety oversight and thus is not counted in the list of supported campuses shown on the map). However, the use of radioactive materials is limited to the following 6 locations by either a PA state license or by an NRC license:

1. University Park Campus (UP) – the main campus (PA and NRC licenses)
2. Penn State Breazeale Nuclear Reactor (PSBNR) at UP (NRC license)
3. Altoona Campus (UP PA license)
4. Harrisburg Campus (UP PA license)
5. Penn State Electro-Optical Center, Freeport (UP PA license)
6. Penn State Hershey Medical Center (PSHMC) (PA license).

Of these six locations, only three regularly utilize radioactive material: University Park, the Hershey Medical Center, and the Breazeale reactor. The Harrisburg campus, while an authorized place of use under the UP PA state license, has only one laboratory that has only ever utilized P-32 once in the month of November 2013. The Altoona campus has only one laboratory using nanocurie amounts of Al-26 and they have been inactive for the past few years.

There are five licenses that are held by Penn State University:

License Number	Issuing Agency	Brief Description and Campus Location	DFP Appendix
PA-0100	PA DEP	Broad scope byproduct materials, UP & others	A
PA-0127	PA DEP	Broad scope byproduct materials, PSHMC campus	B
PA-0127A	PA DEP	Self-shielded irradiator license, PSHMC campus	C
SNM-95	NRC	Special Nuclear Materials, UP campus	D
R-2	NRC	Research and Test Reactor license, UP campus	E

Because of the disparate geographical and radioactive material usage differences between the licenses, each has been separated into a self-contained appendix to this document. The Pennsylvania Department of Environmental Protection Bureau of Radiation Protection (PA DEP) will want to review Appendix A, B, and C. The Nuclear Regulatory Commission will want to review Appendix D and E.

The method for estimating decommissioning costs was changed in December 2012 when an update to 10 CFR 30.35.(e).(1).(i).(A) now requires costs estimates to be based on the cost of an independent contractor to perform all decommissioning activities. The cost estimates in this DFP reflect this change.

Records of information important to the decommissioning of Penn State's licenses are retained at the University Park Environmental Health and Safety offices and at the Health Physics offices at the Hershey Medical Center.

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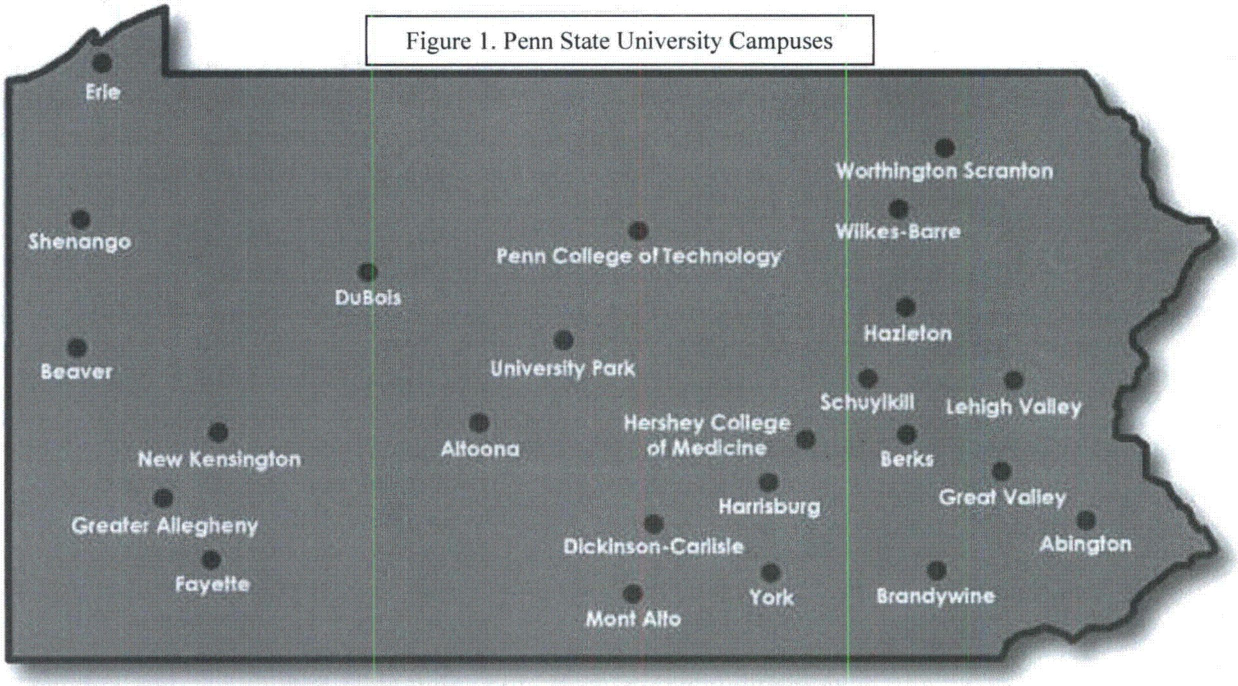

Figure 1. Penn State University Campuses

The decommissioning cost estimates for each license, individually and combined, are as follows:

Penn State University Unified Decommissioning Cost Estimate			
License	**Type**	**DFP Appendix**	**Estimated Cost ($)**
PA-0100	Broad Scope	A	$3,605,705
PA-0127	Broad Scope	B	$3,537,176
PA-0127A	Irradiator	C	$455,623
SNM-95	Special Nuclear Materials	D	$356,776
R-2	Reactor	E	$16,031,304
		Penn State University TOTAL	**$23,986,584**

Basic Assumptions Common to All DFPs

Several assumptions must be made to estimate the cost of decommissioning the facilities under each license. The assumptions common to all licenses are listed below while assumption specific to a license are contained in that license's appendix.

1. Compliance with 10 CFR 20.1402.
   The operations plans and the cost estimates are based upon meeting the release limit of 10 CFR 20.1402. This release limit requires that "residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not

[redacted]

exceed 25 mrem per year."

2. One license is terminated at a time.
   It is very unlikely that multiple, or all, licenses would be terminated at the same time. Because of shifts in the focus of research utilizing radioactive material over time, it is much more probable that only one license would be terminated at any one time. Normally Penn State staff would be available for decommissioning work in these instances; however, this DFP assumes an independent contractor will perform all work.

3. Decommissioning estimates are based on current inventory and use locations.
   While each license may allow a larger selection of isotopes and activities than presently in use, this DFP is based on current inventories and use locations. As required by NRC regulations, the DFP will be updated every three years to reflect the future status of inventories and locations.

4. Prior decommissioned use locations are not included.
   Related to assumption 3, laboratories and use locations which are no longer authorized for radioactive material work are surveyed and inspected by Radiation Safety staff. Location owners are required to have all radioactive material removed and to clean their facilities and equipment to background levels. Once verified by Radiation Safety staff to be releasable, the space is de-posted and allowed to be unrestricted space. These locations are not included in this DFP.

5. Penn State University will continue a "clean operations" policy.
   In accordance with 10 CFR 20.1406(c), Penn state will continue its long-standing policy of maintaining use locations in "un-restricted release" condition. This means that whenever a room, area, or major piece of equipment becomes contaminated, it is cleaned or disposed of, as appropriate, soon after discovery. Penn State can support this assumption by review of many years of survey data that show our laboratories do not have significant contamination issues. This "clean operations" policy is also in effect at the Hershey Medical Center. This policy will reduce the actual costs of decommissioning.

6. No remodeling costs are included.
   Decommissioning costs do not include removal or disposal of non-radioactive structures or materials beyond that necessary to terminate the radioactive material license. Costs are not included for replacing hoods or bench-tops that were removed due to contamination. No follow-up costs for remodeling and renovation are included in these estimates.

7. No credit for salvage.
   No credit is taken for salvage of equipment or materials that would likely be sold or transferred to another licensee, nor is credit taken for sale of non-radioactive use items.

8. No license amendments required.
   No license amendments are expected for decommissioning. All activities are within the normal scope of tasks currently performed on a regular basis in accordance with established written procedures. If these tasks are performed by Penn State employees or by an outside group, the tasks are expected to be commensurate with normal activities.

[redacted]

9. Vendors will ship Type B materials.
   Large activity sources that require Type B shipping containers will be shipped by outside vendors in accordance with the disposal methods currently used. No costs are included for writing and documenting a quality assurance plan. The outside vendor(s), specifically licensed to perform this work, will perform the packaging and shipping of the material.

10. Decommissioning of buildings.
    Buildings in which "... no principal activities under the license have been conducted for a period of 24 months ..." are decommissioned in accordance with 10 CFR 30.36.(d).(3). Generally, it is infrequent that a building that had radioactive materials labs is decommissioned because labs do not terminate their use often. When a building is decommissioned its hoods, ducts, and sinks are checked for contamination, all labels and tags are removed, and a report is filed confirming compliance with 10 CFR 20.1402. This building report relies heavily upon the agglomeration of individual room decommissioning reports and is available for inspection.

11. A licensed radioactive waste site is available.
    This DFP must be based upon the assumption that the shipment of radioactive waste is possible. Penn State currently has the ability to store waste for about six years prior to shipping, but decommissioning can only be accomplished if a low-level radioactive waste disposal facility is available.

12. DOE will accept the return of their materials.
    Certain sources and materials must be returned to the Department of Energy for disposal. If the DOE refuses to receive this material then long-term storage costs may be significant; these costs are not included.

13. Waste on hand equals one year's waste generation.
    This DFP assumes that one year's worth of normal operations waste is already on hand and waiting disposal at the start of decommissioning. Added to this amount will be the decommissioning waste so that the total amount of rad waste will be slightly larger than just from decommissioning only.

Reasons for the Differences in Cost Estimates With This DFP

The difference in cost estimates between this DFP and prior DFPs are due to these factors:

1. The current DFP is now required to be based on a third party contractor performing all work. Prior DFPs assumed that Penn State HP staff would be available to perform surveys, waste handling, and record keeping activities.

2. Prior UP and PSHMC DFPs assumed that only a small fraction of labs and/or facilities would need decontamination based on Penn State's policy of "*no contamination*". The current UP and PSHMC DFPs assumes that all labs and facilities will require decontamination efforts and

[redacted]

generate the associated wastes.

3. New and conservative costs for irradiator disposal at UP were taken from 2013 estimates of irradiator disposal at PSHMC.

4. In prior DFPs labor rates were based on Penn State staff salaries covering labor costs. With the change to a third party contactor, higher labor rates based on current market conditions were used in the current DFP.

5. Following the outline of NUREG-1757 Volume 3 Rev 1 (2012) Appendix A.3 caused additional costs to be included that were not included in prior DFPs.

6. For the Breazeale Reactor Facility, although the facility-specific cost estimate (see DFP Appendix E) is in agreement with other reactors, the Georgia Institute of Technology decommissioning cost continues to be the worst case scenario and thus Penn State will continue to use that cost for this DFP.

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APPENDIX E – University Park R-2 NRC Reactor License

Section A.3.4 Facility Description

License Numbers and Types

The Pennsylvania State University maintains license number R-2 issued by the Nuclear Regulatory Commission as a license for the Penn State Breazeale Nuclear Reactor (PSBNR) as a test and research reactor at the University Park Campus.

Types and Quantities of Materials Authorized

The following are the licensed materials and quantities permitted under R-2:

Table 1 – PSBNR R-2 License Details			
Line Item	**Isotope**	**Form**	**Allowed Quantity**
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Description of How Licensed Materials Are Used

The Penn State Breazeale Nuclear Reactor (PSBNR) is a 1MW water cooled natural convection reactor using TRIGA fuel that has been in operation since 1955. It is the center piece of the Radiation Science and Engineering Center (RSEC) and the Nuclear Engineering Department, and is used for teaching, research, and training in reactor physics, nuclear science and engineering. The reactor is also used as a test reactor for activities such as irradiation and neutron testing of components, archeological artifacts, and the production of isotopes for use at the University Park campus.

Routine surveys are performed by Radiation Protection staff weekly to assure that safe working conditions are maintained. Normal operating procedures require that radioisotope laboratories minimize contamination. Typically, surveys show no removable contamination above background (approximately < 50 dpm/100cm^2) on surfaces and equipment using liquid scintillation counting (LSC) and Geiger meters. Penn State maintains a "*no contamination*" policy and any finding above background is promptly addressed and decontaminated.

Because of this continuous characterization of the radiation environment, normal decommissioning typically requires only the removal of the fuel, core components, moderating and cooling water, the pool structure, miscellaneous activated support components, and radioactive waste consisting of paper,

[redacted]

plastic, and glass lab ware followed by appropriate surveys of the facility and equipment.

[redacted]

All fuel is owned by the Department of Energy (DOE) and is assumed that the DOE will take back all fuel. All fuel disposal costs, other than shipping, are assumed to be covered by the DOE.

Description of Facilities

[redacted]

Table 2 – PSBR Buildings and Rooms

Campus	Building	Use	Number of Rooms
UP	Breazeale Reactor	[redacted]	1
UP	Breazeale Reactor	[redacted]	1
UP	Breazeale Reactor	[redacted]	1
UP	Breazeale Reactor	[redacted]	2
UP	Breazeale Reactor	[redacted]	1
UP	Breazeale Reactor	[redacted]	2
		TOTAL Rooms	**8**

Within any given approved laboratory space, researchers are encouraged to limit work with radioactivity to as small an area as possible, i.e. one bench top. Individual instruments and equipment that are used to store or process radioactive samples are labeled with a Caution Radioactive Material label.

The decommissioning costs of this license are difficult to quantify therefore the costs from similar facilities will form the basis for estimating Penn State's future costs. Cost and labor estimates were obtained from the Georgia Institute of Technology for the decommissioning of their 5 MW reactor in 2001, from the University of Virginia for the decommissioning of their 2 MW reactor in 2002, the decommissioning plan estimates of the AFRRI TRIGA reactor found in AFRRI Report TR89-2 (similar to the Oregon State University TRIGA reactor), and the Cornell University Ward Nuclear Center TRIGA reactor in 2006.

Radioactive Waste On-Hand Before Decommissioning

All wastes with less than or equal to 120 day half-life are held for decay for at least 10 half-lives, then

[redacted]

surveyed and released as non-radioactive waste. Liquid wastes with half-lives greater than 120 days are disposed via sanitary sewer by Radiation Protection staff to ensure that legal release limits are not exceeded. All other long lived wastes are shipped to an appropriate waste disposal facility.

All radioactive waste generated by the PSBR facility is processed by the Radiation Protection Office and comingled with waste from other laboratories in one waste handling facility. As stated in the general assumptions, one year's worth of waste is assumed to be in hand prior to the start of decommissioning and for the past several years one shipment per year has been done. Using the prior three years of waste shipment data, the volumes, isotopes, and costs are shown here:

Table 3 – Waste History

Year	Number of Containers	Isotopes	Total Activity (mCi)	Volume	Weight	Total Shipment Cost
2011	5 Cardboard Boxes (DAW)	H-3, C-14, U(Nat), Fe-55, Cs-137, Co-60, Na-22, Zn-65, Ca-45	72.6 mCi	78 ft^3 (15.6 ft^3 per box)	581 lb	
	5 Fiber Drums (30 gal)	Fe-55 (LSC Vials)	0.02 mCi	20.5 ft^3 (4.1 ft^3 per drum)	293 lb	
	1 Drum (55 gal) drum	H-3,C-14,Cs-137,Co-60, Ni-63, Cr-51, Co-58, Mn-54, Zn-65, activated metals	1.8 mCi	7.4 ft^3	206 lb	**$6,403**
2012	8 Cardboard Boxes (DAW)	H-3, C-14, Co-60,Cs-137, Fe-55, U(Nat), Zn-65, Eu-152, Eu-154, Eu-155, Ra-226, U-238, Sr-90	9.4	125 ft^3 (15.6 ft^3 per box)	980 lb	
	1 Drum (55 gal)	Co-60, Cs-137, Eu-152,	1.7 mCi	7.4 ft^3	143 lb	

[redacted]

	drum	Eu-154; activated metals				
	3 Fiber Drums (30 gal)	Fe-55 (LSC Vials)	0.02 mCi	12.3 ft^3 (4.1 ft^3 per drum)	197 lb	**$6,900**
2013	12 Cardboard Boxes (DAW)	C-14, H-3, Fe-55, U(Nat), Zn-65, Co-60, Cs-137	12.2 mCi	187 ft^3 (15.6 ft^3 per box)	1,140 lb	
	3 Fiber Drums (30 gal)	Fe-55 (LSC Vials)	0.2 mCi	12.3 ft^3 (4.1 ft^3 per drum)	148 lb	
	3 Fiber Drums (10 gal)	H-3 (Animal carcasses)	0.2 mCi	3.6 ft^3 (1.2 ft^3 per drum)	58 lb	**$8,500**

The cost per waste type for the past three years is:

Table 4 – Waste Cost History			
Year	**Waste Type**	**Cost per Cubic Foot**	**Cost per Pound**
2011 Ecology Services, Inc.	Dry Active Waste (DAW)	$40.22	$5.40
	Activated Metals	$181.33	$6.60
	LSC Vials	$92.93	$6.50
2012 Ecology Services, Inc.	Dry Active Waste (DAW)	$35.12	$4.48
	Activated Metals	$133.47	$7.00
	LSC Vials	$116.10	$7.25
2013 Ecology Services, Inc.	Dry Active Waste (DAW)	$34.22	$5.61
	LSC Vials	$81.46	$6.77
	Animal Carcasses	$306.11	$19.00

For easier analysis, the unit costs table above has been rearranged as follows:

Table 5 – Cost per Cubic Foot				
Year	**DAW**	**Metals**	**LSC**	**Animals**
2011	$40.22	$181.33	$92.93	
2012	$35.12	$133.47	$116.10	
2013	$34.22		$81.46	$306.11

[redacted]

Table 6 – Cost per Pound				
Year	**DAW**	**Metals**	**LSC**	**Animals**
2011	$5.40	$6.60	$6.50	
2012	$4.48	$7.00	$7.00	
2013	$5.61		$6.77	$19.00

The waste on-hand will be assumed to be the largest amount of all types of waste for the past three years. The cost of disposal will be the greatest per pound unit cost of the past three years plus 5%. Therefore, the waste on-hand for this DFP is:

Table 7 – Waste On-Hand At Start of Decommissioning				
	DAW	**Metals**	**LSC**	**Animals**
Pounds	1,140	206	293	58
Cost per Pound	$5.89	$7.35	$7.35	$19.95
Total	$6,715	$1,514	$2,154	$1,157
Grand Total	**$11,540**			

Volume of Contaminated Subsurface Materials

The PSBR is a pool type reactor using 71,000 gal of ultra-pure water for neutron moderation and cooling. Throughout the operating history of the facility, pool water leaks have occurred to varying degrees and at varying times. Most recently, in early October of 2007 a pool water leak was detected with the release of an estimated 12,300 gal (based on integrating the reported variable leak rates contained in the NRC inspection report , accession number ML073480163, over the 43 days of the event). At the time of the incident and for 3 months following (into December 2007), well water was sampled at 5 locations near the PSBR facility. The data showed a maximum well water concentration of slightly less than 600 pCi/L with a 1000 pCi/L minimum detectable activity (MDA).

When decommissioning does occur, soil sampling will be performed to assess radiological condition under the facility. Because no significant levels of tritium were found in wells due to the last event, it is assumed that any radionuclides that may be present from pool leaks have remained under the facility. A worst scenario would be the removal of a volume of soil the size of the reactor bay to a depth of 5 feet.

Section A.3.5 Number and Dimensions of Facility Components

Type of Space: Reactor, bay, rooms, and components.
Average Size: Not Applicable
Level of Contamination: < 100 dpm/100 cm^2

Table 8 – Reactor Components		
Component	**Number of Components**	**Dimensions of Component**
Reactor Pool Structure	1	17 W x 45 L x 24 D feet

[redacted]

Reactor Core Structure	1	3 x 3 x 5 feet
Reactor Suspension Tower	1	2 x 2 x 24 feet
Control Rods	10	0.2 x 0.2 x 5 feet
Reactor Bridge	1	17 W x 4 D x 8 H feet
D_2O Tank	1	2.5 Dia x 1.5 H
D_2O Water	1	55 gal (210 L)
Pool Water	1	71000 gal
Circulating Pumps	2	2 x 6 x 2 feet
Water Purification	1	3 x 3 x 10 feet
Heat Exchanger	1	3 x 3 x 12 feet
Moderator/Coolant Piping	1	600 ft^2
Evaporator Shed	1	10 x 20 x 8 feet
Underground Tanks/Piping	2	1000 gal
Hot Cell	2	10 x 8 x15 feet
Bulk Equipment:		
Waste Containers	3	1.5 x 1.5 x 2.5 feet
Hand Items (Misc tools, etc.)	100	

Section A.3.6 Planning and Preparation (Work Days)

Current Conditions

A third party contractor will be utilized for the decommissioning effort. It is assumed that normal operations continue up until the date the contractor comes on site. The contractor will need to first familiarize themselves with the facility and define the scope of work.

The Radiation Protection Office (RPO) and/or PSBR maintain all records pertinent to the use of radioactive materials under the licenses. These include receipts, stock vial inventory, locations of use or storage, waste inventory, personnel, and sealed sources. The records are kept electronically in a database and updated as the record is generated (i.e. inventory is updated as stocks are received; lab survey data is updated soon after the survey is completed, etc.) Radiological surveys are performed on at least a weekly basis and paper records kept for at least three years; therefore, a review of these documents will demonstrate the recent levels of contamination which may be expected.

Historical Site Assessment

The following records are available in the RPO and/or PSBR with regard to historical use of radioactive materials:

A) Paper survey reports of the facility where radioactive material has been used for the past three years. Survey reports are not to scale, but represent the pertinent fixtures and equipment used for radioactive materials work. Surveys may extend to non-use areas and equipment that may be in a particular location.

[redacted]

Survey reports typically record the radionuclides recently used and may not reflect all historical uses in a particular location; however, historical purchase records are available.

B) A listing of all locations by user, nuclides, building and room number where radioactive materials were ever authorized under state license.

C) A listing of locations where radioactive materials are currently authorized.

D) A database of all radioactive waste currently being held in storage, whether for decay-in-storage, or ship-out.

E) Scale floor plans of buildings are maintained by Facilities Management but survey maps used by the RPO show major room components.

F) Annual summaries of discharges to the sanitary sewer system by the RPO are available.

<u>Other Activities</u>

Based upon the current level of use, Penn State's "*no contamination*" policy, and a review of past surveys showing no contamination in the general facility, it can be concluded that radiological conditions are already within the release criteria for the bulk of the facility.

The contractor will prepare the actual decommissioning plan for regulatory review. This will define the scope of work, the radiological conditions of the site, and provide a plan for action. Upon approval by the regulator, a working plan will be developed to include a strategy for systematic decommissioning surveys along with manpower and equipment requirements.

Some estimates are from decommissioning plans for Georgia Institute of Technology, University of Virginia, the AFRRI TRIGA (AFRRI Report TR89-2), and the Cornell reactor facility as these were facilities similar to the PSBR. Note that not all of these past facilities had data that is directly comparable to the detailed breakdowns suggested in NUREG-1757; most offered only lump-sum cost data and these will be address in the last section of this DFP.

The following table summarizes the work days associated with planning activities:

Table 9 – Planning and Preparation Work Person-Days

Activity	Health Physicist (1)	HP Technician (2)	Clerical / Admin (1)	Laborer (3)	Construction Supervisor (1)	Waste Mgmt Specialist (1)	Civil/Mech/QA Engineer (1)	Project Manager (1)
Prepare documentation for regulatory agencies	60	20	30	0	0	60	30	30
Submittal of decommissioning plan	5	0	10	0	0	5	5	5

[redacted]

Development of work plans	90	20	120	0	90	90	90	120
Procurement of equipment and supplies	10	0	5	0	15	10	10	10
Staff training	5	10	0	15	5	5	5	5
Characterization of radiological conditions	40	90	30	15	0	40	0	45
Other (mobilization)	5	10	5	15	5	5	5	5
Total Person-Days	**215**	**150**	**200**	**45**	**115**	**215**	**145**	**220**

Assume 260 work days per year.

Section A.3.7 Decontamination or Dismantling of Components (Work Days)

Based upon the continuous survey and decontamination efforts conducted during the normal radiation safety surveillance program, there are few components which need to be addressed in this category.

Activated items – Specific items to be considered exposed to neutron activation include materials composed of aluminum, steel, stainless steel, graphite, cadmium, lead, concrete, reactor core structure, suspension tower, miscellaneous metal items, beam tubes, D_2O tank, and possibly others. All reactor confinement structure, equipment, and materials will be surveyed and designated as contaminated or uncontaminated. Uncontaminated equipment and materials will be released for unrestricted use or disposed as clean waste. Contaminated equipment will be decontaminated and handled as other uncontaminated material or removed and packaged for processing and direct disposal as radioactive waste.

Reactor pool structure – After removal of the pool water and all items in the pool, the interior surfaces will be decontaminated by hydro-lazing the waterproof coating. Reactor components and activated pool hardware will be removed for disposal as low level radioactive waste. Piping embedded in the concrete pool walls and floors will be surveyed and decontaminated, as necessary, and left in place if clean. Surface and core samples of the pool concrete walls will be performed to determine the extent of the contaminated areas. Contaminated material will be removed and packaged. The structural integrity of the pool will be augmented as necessary if it is threatened because of removal of material.

Reactor pool water – Pool water will be analyzed for contaminates other than tritium (known to be present) and then disposed via sanitary sewer in a controlled method to remain within discharge limits.

D_2O water – This water is known to contain tritium but is owned by the DOE. It will be drummed and then all D_2O will be held for transfer back to the DOE.

[redacted]

Water purification / demineralizer – The resin will be collected and disposed of. The tank and related piping will be wiped down.

Hot Cells – The two hot cells and manipulators are not in use, currently not contaminated, and do not hold unsealed materials; the cells are currently used to store sealed discrete sources. The cells are not included in this version of the DFP.

Type of Space: Reactor, bay, rooms, and components.
Average Size: Not Applicable
Level of Contamination: < 100 dpm/100 cm^2

Table 10 – Decontamination or Dismantling of Components Work Person-Days

Component	Decon Method	HP (1)	HP Tech (2)	Clerical / Admin (1)	Laborer (3)	Construction Supervisor (1)	Waste Mgmt Specialist (1)	Civil/Mech/QA Engineer (1)	Project Manager (1)
Reactor Pool Structure	Hydro-laze, Disposal	30	120	40	360	120	120	120	120
Reactor Core Structure	Disposal	40	180	80	120	40	240	30	40
Reactor Suspension Tower	Disposal	10	40	40	120	10	60	15	10
Control Rods	Disposal	10	20	10	10	10	120	15	10
Reactor Bridge	Wipe Down	15	20	40	60	20	15	15	20
D_2O Tank	Disposal	10	20	10	15	10	120	15	10
D_2O Water	Drum, hold for DOE	5	15	10	15	5	15	5	5
Pool Water	Disposal	10	15	40	15	10	120	5	10
Circulating Pumps	Wipe Down	10	30	40	120	10	40	20	10
Water Purification	Wipe Down	10	15	20	45	10	40	10	10
Heat Exchanger	Wipe Down	10	15	20	30	10	20	10	10
Moderator/Coolant Piping	Wipe Down	20	20	20	90	20	20	10	20
Evaporator Shed	Disposal	10	20	5	30	10	15	5	10
Underground Tanks/Piping	Disposal	10	30	5	60	10	20	10	10
Waste Containers	Wipe Down	5	10	5	5	5	10	5	5
Hand Items (Misc tools, etc.)	Wipe Down	15	30	60	10	15	40	15	15

[redacted]

Total Person-Days		**220**	**600**	**445**	**1105**	**315**	**1015**	**305**	**315**

Assume 260 work days per year.

Section A.3.8 Restoration of Contaminated Areas (Work Days)

Assuming the worst case that there are radionuclides in the soil under the pool structure and underground tanks that will require removal, an estimated soil volume of 4,200 ft^3 (20 x 40 x 5 ft) under the reactor pool footprint and 600 ft^3 (approx. four times the volume of 2 tanks) will be used for this DFP. It is also assumed that should soil removal be required, access to the soil will be from inside the pool by removal of the pool floor; no other structural demolition is assumed.

Table 11 – Restoration of Contaminated Areas Work Person-Days

Activity	HP (1)	HP Tech (2)	Clerical / Admin (1)	Laborer (3)	Construction Supervisor (1)	Waste Mgmt Specialist (1)	Civil/Mech/QA Engineer (1)	Project Manager (1)
Removal of Pool Floor	30	60	10	120	30	30	20	30
Soil Excavation	15	40	5	120	40	40	40	20
Backfill	5	5	5	90	30	5	30	20
Excavate Tanks	10	20	5	30	10	30	10	10
Soil Excavation	5	10	5	30	10	20	10	10
Backfill	5	10	5	30	5	5	10	10
Total Person-Days	**70**	**145**	**35**	**420**	**125**	**130**	**120**	**100**

Section A.3.9 Final Radiation Survey (Work Days)

Table 12 – Final Radiation Survey Work Person-Days

Activity	HP (1)	HP Tech (2)	Clerical / Admin (1)	Laborer (3)	Construction Supervisor (1)	Waste Mgmt Specialist (1)	Civil/Mech/QA Engineer (1)	Project Manager (1)
Final Characterization Survey	20	40	10	5	5	20	5	20
Final Report	15	20	15	5	5	15	5	15
Total Person-Days	**35**	**60**	**25**	**10**	**10**	**35**	**10**	**35**

Section A.3.10 Site Stabilization Long Term Surveillance (Work Days)

There are no known areas requiring stabilization or long term surveillance for this license.

[redacted]

Section A.3.11 Total Work Days By Labor Category

Table 13 – Total Work Days By Labor Person-Days								
Activity	**HP (1)**	**HP Tech (2)**	**Clerical / Admin (1)**	**Laborer (3)**	**Construction Supervisor (1)**	**Waste Mgmt Specialist (1)**	**Civil/Mech/QA Engineer (1)**	**Project Manager (1)**
Planning and Prep	215	150	200	45	115	215	145	220
Decontamination	220	600	445	1105	315	1015	305	315
Restoration of Contam Areas	70	145	35	420	125	130	120	100
Final Rad Survey	35	60	25	10	10	35	10	35
Site Stabilization	0	0	0	0	0	0	0	0
Total Person-Days	**540**	**955**	**705**	**1580**	**565**	**1395**	**580**	**670**

Section A.3.12 Worker Unit Cost Schedule

Salary and labor rate data for Pennsylvania May 2012 was obtained from:
http://www.bls.gov/oes/current/oes_pa.htm#19-0000
Life, Physical Social Sci – nuclear technician = $78,250
Construction Supervisor – construction managers = $109,540
Office admin support – info and records clerks = $39,600
Construction laborers = $35,470
Waste Mgmt – nuclear engineer = $98,280
Civil/Mech/QA – civil engineer = $78,190
Project Mgmt – general and ops managers = $115,050

Salary data for CHPs for 2012 was obtained from:
http://www.hps.org/documents/2012_chp_salary_survey.pdf
Median CHP salary for the Northeast = $116,250

Table 14 – Worker Unit Cost Schedule								
Labor Cost Component	**HP (1)**	**HP Tech (2)**	**Clerical / Admin (1)**	**Laborer (3)**	**Construction Supervisor (1)**	**Waste Mgmt Specialist (1)**	**Civil/Mech/QA Engineer (1)**	**Project Manager (1)**
Salary ($/yr)	$116,250	$78,250	$39,600	$35,470	$109,540	$98,280	$78,190	$115,050
Fringe Benefits (%)	22%	22%	22%	22%	22%	22%	22%	22%
Overhead & Profit Rate (%)	30%	30%	30%	30%	30%	30%	30%	30%
Total cost per Year ($)	$184,373	$124,105	$62,806	$56,255	$173,730	$155,872	$124,009	$182,469

[redacted]

Travel and Per-Diem per Day	$175	$175	$175	$175	$175	$175	$175	$175
Total Cost per Person-Day *	**$884**	**$652**	**$417**	**$391**	**$843**	**$775**	**$652**	**$877**

* Based on 260 work days per year

Section A.3.13 Total Labor Costs by Major Decommissioning Task

Table 15 – Total Labor Costs									
Activity	**HP (1)**	**HP Tech (2)**	**Clerical / Admin (1)**	**Laborer (3)**	**Const Superv (1)**	**Waste Mgmt Specialist (1)**	**Civ/Mech/ QA Engineer (1)**	**Project Manager (1)**	**Totals**
Planning and Prep	$190,060	$97,800	$83,400	$17,595	$96,945	$166,655	$94,540	$192,940	$939,935
Decontamination	$194,480	$391,200	$185,565	$460,785	$265,545	$786,625	$198,860	$276,255	$2,759,315
Restoration of Contam Areas	$61,880	$94,540	$14,595	$175,140	$105,375	$100,750	$78,240	$87,700	$718,220
Final Rad Survey	$30,940	$39,120	$10,425	$3,910	$8,430	$27,125	$6,520	$30,695	$157,165
Site Stabilization	0	0	0	0	0	0	0	0	0
Total Cost	**$477,360**	**$622,660**	**$293,985**	**$657,430**	**$476,295**	**$1,081,155**	**$378,160**	**$587,590**	**$4,574,635**

Section A.3.14 Packing, Shipping, and Disposal of Wastes

Note: Labor costs for waste processing is included in this section and not in the above analysis.

Packaging Material Costs

Packing costs are based only on the items in Table 10 that are for disposal. The pool water is not included here because it may be disposed via the sanitary sewer and there for only labor costs are shown for this item. To be conservative, soil disposal is included. The demineralizer uses ion exchange resin and is assumed to require disposal in five (5) 55-gal drums.

Because of the "*no contamination*" policy, there would be a minimal amount of waste generated from decommissioning. There are no areas in which protective clothing, other than gloves, need to be worn. Note that no labor costs are associated with packing materials needed.

Table 16 – Packing Material Costs					
Waste Type	**Volume**	**Number of Containers**	**Type of Container**	**Container Unit Cost**	**Total Packaging Costs**
Reactor Pool Floor Rubble	1,600 ft^3	18	B-25 90 ft^3 Metal Box *	$1200	$21,600
Reactor Core	90 ft^3	1	Custom Box	$5000	$5000

[redacted]

Reactor Suspension Tower (Cut up)	20 ft^3	1	Custom Box	$1000	$1000
Control Rods	10 ft^3	1	Custom Box	$2000	$2000
D_2O Tank	10 ft^3	1	Custom Box	$500	$500
D_2O Water	55 gal	2	55 gal Drum	$45	$90
Pool Soil	4,200 ft^3	47	B-25 90 ft^3 Metal Box *	$1200	$56,400
Demineralizer Resin	37 ft^3	5	55 gal Drum	$45	$225
Evap Shed (Demolished)	540 ft^3	1	Custom Box	$5000	$5000
Tanks (Cut up)	20 ft^3	1	Custom Box	$1000	$1000
Tank Soil	600 ft^3	7	B-25 90 ft^3 Metal Box *	$1200	$8,400
Existing Wastes	30 gal	12	Fiber Box	$0	$0
Existing Wastes	30 gal	3	Drum	$0	$0
Existing Wastes	10 gal	3	Drum	$0	$0
				Total	**$101,215**

*See for example: http://www.lingometalfab.com/containers.html

Shipping Costs

Once the facility has been decommissioned, there is labor cost associated with the collection of the waste containers, documenting the shipment, and packing the truck. These costs are addressed below. To calculate the number of standard 40 foot semi-truck loads needed, the volume of a 40 foot trailer (http://www.yrc.com/shippers/semi-trailer-dimensions.html) is 3083 ft^3. The total volume to be shipped is:

Table 17 – Shipping Volume of Wastes ALL Labs

Waste Type	Container Unit Volume	Number of Containers (Decomm + On-hand)	Total Volume (ft^3)
Reactor Pool Floor Rubble	90 ft^3	18	1620
Reactor Core	90 ft^3	1	90
Reactor Suspension Tower	20 ft^3	1	20
Control Rods	10 ft^3	1	10
D_2O Tank	10 ft^3	1	10
Pool Soil	90 ft^3	47	4230
Demineralizer Resin	7.4 ft^3 (55 gal)	5	37

[redacted]

Evap Shed (Demolished)	325 ft^3	1	325
Tanks (Cut up)	20 ft^3	1	20
Tank Soil	90 ft^3	7	630
Existing Wastes	15.6 ft^3	12	187
Existing Wastes	4 ft^3 (30 gal)	3	12
Existing Wastes	1.2 ft^3 (10 gal)	3	4
Existing Wastes	7.4 ft^3 (55 gal)	1	8
		Total	**7,203**

Therefore three (3) 40 foot trucks (two full and one partial) will be needed to ship all wastes. The labor costs for preparing, packing, handling containers, and packing the truck are:

Table 18 – Shipping Labor Work Person-Days

Activity	HP (1)	HP Tech (2)	Clerical / Admin (1)	Laborer (3)	Const Superv (1)	Waste Mgmt Specialist (1)	Civ/Mech/ QA Engineer (1)	Project Manager (1)	Totals
Pool Rubble	10	20	5	30	10	20	10	10	115
Core	15	30	10	45	15	30	10	10	165
Tower	5	10	5	15	5	10	5	10	65
Control Rods	10	20	5	15	10	15	5	5	85
D_2O Tank	5	10	5	15	5	10	5	5	60
Pool Soil	20	40	10	60	20	20	20	10	200
Evap Shed	10	10	5	30	10	10	10	10	95
Tanks	10	10	5	30	10	10	5	10	90
Tank Soil	10	20	5	30	10	10	5	10	100
Total Person-Days	**95**	**170**	**55**	**270**	**95**	**135**	**75**	**80**	**975**

Table 19 – Shipping Labor Cost

Activity	HP (1)	HP Tech (2)	Clerical / Admin (1)	Laborer (3)	Const Superv (1)	Waste Mgmt Specialist (1)	Civ/Mech/ QA Engineer (1)	Project Manager (1)	Totals
Pool Rubble	$8840	$13040	$2085	$11730	$8430	$15500	$6520	$8770	$74,915
Core	$13260	$19,560	10	$18765	$12645	$23250	$6520	$8770	$102,780
Tower	$4420	$6520	$2085	$6255	$4215	$7750	$3260	$8770	$39,065
Control Rods	$8840	$13040	$2085	$6255	$8430	$11625	$3260	$4385	$57,920
D_2O Tank	$4420	$6520	$2085	$6255	$4215	$7750	$3260	$4385	$38,890
Pool Soil	$17,680	$26080	$4170	$25020	$16860	$15500	$13040	$8770	$127,120
Evap Shed	$8840	$6520	$2085	$11730	$8430	$7750	$6520	$8770	$60,645
Tanks	$8840	$6520	$2085	$11730	$8430	$7750	$3260	$8770	$57,385
Tank Soil	$8840	$13040	$2085	$11730	$8430	$7750	$3260	$8770	$63,905
Total Cost	**$83,980**	**$110,840**	**$18,775**	**$109,470**	**$80,085**	**$104,625**	**$48,900**	**$70,160**	**$622,625**

[redacted]

Shipping costs were provided by Ecology Services, Inc. Note that normal rad waste would ship to Energy Solutions in Oak Ridge, TN (705 miles) and to EnviroCare in Utah (1800 miles) for a total of 2500 miles.

Table 20 – Total Shipping Costs							
Waste Type	**Number of Truckloads**	**Unit Cost ($/mile/load)**	**Surcharges ($/mile)**	**Overweight Charges ($/mile)**	**Distance Shipped (miles)**	**Labor Cost ($)**	**Total Shipping Costs**
All	3	$3.60	$0.50	$0	2500		$30,750
Truck Rental	3	$2500					$7,500
Labor						$622625	$622,625
						Total	**$660,875**

<u>Waste Disposal Costs</u>

All wastes are assumed to be low level rad waste and not require any special handling or disposal methods. Historically, the cost per pound is more consistent year to year so this DFP will estimate disposal cost by weight rather than volume. The following densities are assumed for each waste type:
Concrete = 150 lb / ft^3
Reactor core, tower, and D_2O tank, underground tanks – stainless steel = 490 lb / ft^3
Control rods = 200 lb total
Soil = 100 lb / ft^3
Ion exchange resin = 3000 lb
Shed material – aluminum = 171 lb/ft^3

For the reactor core, tower and D2O tank, these are not solid stainless steel items so the weight to be disposed has been adjusted for the air space.

Table 21 – Waste Disposal Costs				
Waste Type	**Total Weight (lb)**	**Unit Cost ($/lb)**	**Surcharges ($/lb)**	**Total Disposal Cost**
Reactor Pool Floor Rubble	240,000	$7.35	$0	$1,764,000
Reactor Core	1,000	$7.35	$0	$7,350
Reactor Suspension Tower	4,000	$7.35	$0	$29,400
Control Rods	200	$7.35	$0	$1,470
D_2O Tank	50	$7.35	$0	$370
Soil	420,000	$5.89	$0	$2,473,800
Demineralizer Resin	3,000	$5.89	$0	$17,670
Evap Shed	55,575	$5.89	$0	$327,336
Tanks	9,800	$7.35	$0	$72,030

[redacted]

Tank Soil	60,000	$5.89	$0	$353,400
Existing Wastes – All (Table 7)				$11,540
			Total	**$5,058,366**

Section A.3.15 Equipment and Supply Costs

The only supplies anticipated will be gloves, smears, vials, scintillation fluid. An allowance of $5000 will be included for these.

No other equipment costs are necessary as Penn State has a sufficient number of survey meters (GM, NaI, alpha, LSC, and neutron) to supply the decommissioning team.

Table 22 – Equipment and Supply Costs			
Equip / Supplies	**Quantity**	**Unit Cost**	**Total**
Survey Supplies			$5000
Rigging Equip	1	$3000	$3000
Backhoe	4 weeks	$2000/week	$8000
		Total	**$16,000**

Section A.3.16 Laboratory Costs

Any analyses will be performed by independent third party laboratory.

Table 23 – Laboratory Costs			
Equip / Supplies	**Quantity**	**Unit Cost**	**Total**
Sample Analysis – soil radionuclide	50	$300	$15000
Sample Analysis – well water radionuclide	20	$300	$6000
		Total	**$21,000**

Section A.3.17 Miscellaneous Costs

Present methods of waste disposal are through a waste broker and no special licenses or site permits are necessary. Contractors provide proof of insurance before being awarded contracts. The work associated with decommissioning is not taxable by Pennsylvania.

The Nuclear Regulatory Commission will bill for regulatory oversight efforts to include final status survey reports, confirmatory survey efforts, department lab, or contractor fees and oversight of license termination activities. An estimate of these costs is included in the following table.

[redacted]

Table 24 – Miscellaneous Costs	
Cost Item	**Total**
License fees, insurance, taxes, other	$0
NRC oversight	$50000
Total	**$50,000**

Section A.3.18 Total Decommissioning Costs

The total decommissioning costs are shown in Table 25. This estimate does not take credit for any salvage value that might be realized from the sale of potential assets.

A comparison to other reactor facilities is shown in Tables 26 to 29. As these represent actual decommissioning costs, they are a more reliable estimate of the costs to decommission the PSBR. The highest estimate will be used for this DFP after adjusting for 5% cost increases per year from the time of the original data to today.

This DFP has an estimated total cost of $13,102,364 which is in good agreement with cost-adjusted estimates from other reactors.

The highest cost estimate is the Georgia Institute of Technology decommissioning estimate of $16,031,304. This value will be used for this DFP.

[redacted]

Table 25 – Total Decommissioning Costs		
Task/Component	**Cost**	**Percentage**
Planning and Preparation (Table 15)	$939,935	9%
Decontamination/Dismantling (Table 15)	$2,759,315	26%
Restoration (Table 15)	$718,220	7%
Final Rad Survey (Table 15)	$157,165	2%
Site Stabilization (Table 15)	$0	0%
Packing Material Costs (Table 16)	$101,215	1%
Shipping Costs (Labor and transport) (Table 20)	$660,675	6%
Waste Disposal Costs (Table 21)	$5,058,366	48%
Equipment Costs (Table 22)	$16,000	0.2%
Laboratory Costs (Table 23)	$21,000	0.2%
Miscellaneous Costs (Table 24)	$50,000	0.5%
Subtotal	$10,481,891	100%
25% Contingency	$2,620,473	
Total Decommissioning Cost Estimate	**$13,102,364**	

[redacted]

Comparison to Other Reactor Facilities

The costs for decommissioning of the Georgia Institute of Technology 5 MW reactor were provided by Bill Miller, project manager in 2001.

Table 26 - Georgia Institute of Technology 5 MW reactor Decommissioning Costs	
Basic Tasks	**Cost**
Consultant Support & Characterization	$242,100
Decommissioning Contract	$5,948,282
Executive Engineer	$728,682
ALARA Allowance	$39,171
Special Costs*	$161,718
Resident Inspector	$21,511
Total	**$7,141,464**
Assumed Cost Increase per Year	5%
N = Elapsed Years from 2001 to Present	12
Adjusted Cost to Present Dollars = (2001 Est)*$(1.05)^N$	$12,825,043
25% Contingency	$3,206,260
Present Day Total Cost	**$16,031,304**

*Health Physicist Overtime, video record, relocate rad storage area.

Estimates for decommissioning of the University of Virginia research reactor were provided by Paul E. Benneche in 2003.

Table 27 - University of Virginia Reactor Decommissioning Estimates (Included parts of other licenses)	
Basic Tasks	**Cost**
Outside consultant site characterization and plan preparation.	$250,000
External contract for decommissioning the facility (initial $3.5M, current estimate of $4.5M.)	$4,500,000
* Internal costs (This includes about 10 - 15 person years for overseeing UV's program and complying with reactor license requirements.) (Assuming $80,000 * 1.38 (for benefits) * 15 years = 1,656,000)	$1,656,000
Total	**$6,406,000**
Assumed Cost Increase per Year	5%
N = Elapsed Years from 2003 to Present	10
Adjusted Cost to Present Dollars = (2003 Est)*$(1.05)^N$	$10,434,670
25% Contingency	$2,608,668
Present Day Total Cost	**$13,043,338**

[redacted]

* As described in a personal communication from Paul Benneche, the internal costs to UV were not well documented. However he estimated 10 - 12 person-years for UV to oversee the decommissioning.

AFRRI Report TR89-2 was published in 1990 for the decommissioning cost estimates of a TRIGA reactor. Costs from Table 5, page 8 of the report in 1990 dollars.

Table 28 – AFRRI TRIGA Reactor	
Basic Tasks	**Cost**
Energy use	$5,600
Labor costs (all)	$1,929,300
Waste disposal costs	$589,179
Contingency/other	$631,000
Site demolition and restoration	$376,800
Total	**$3,531,879**
Assumed Cost Increase per Year	5%
N = Elapsed Years from 1990 to Present	23
Adjusted Cost to Present Dollars = (1990 Est)*$(1.05)^N$	$10,848,250
25% Contingency	$2,712,062
Present Day Total Cost	**$13,560,313**

Cornell University decommissioned their reactor in 2006 using an outside contractor for the demolition work but performed the preparation and planning work internally and self-managed the project. The contractor performed demolition, waste disposal, and radiation safety functions for a lump-sum amount of $2,700,000. Cornell estimated that had the contractor performed all duties, the cost would have been double at $5,400,000. It should be noted that the reactor was shut down in 1996 and fuel was removed and shipped to DOE in early 2000. The reactor pool fully protruded into the high bay and was completely demolished. An additional approximately 2 feet of soil directly under the reactor was also removed. The project started in March 2006 and lasted for 8 months.

Table 29 – Cornell University Reactor	
Basic Tasks	**Cost**
Contractor lump-sum for all activities	$5,400,000
Total	**$5,400,000**
Assumed Cost Increase per Year	5%
N = Elapsed Years from 2006 to Present	7
Adjusted Cost to Present Dollars = (2006 Est)*$(1.05)^N$	$7,598,342
25% Contingency	$1,899,585
Present Day Total Cost	**$9,497,928**