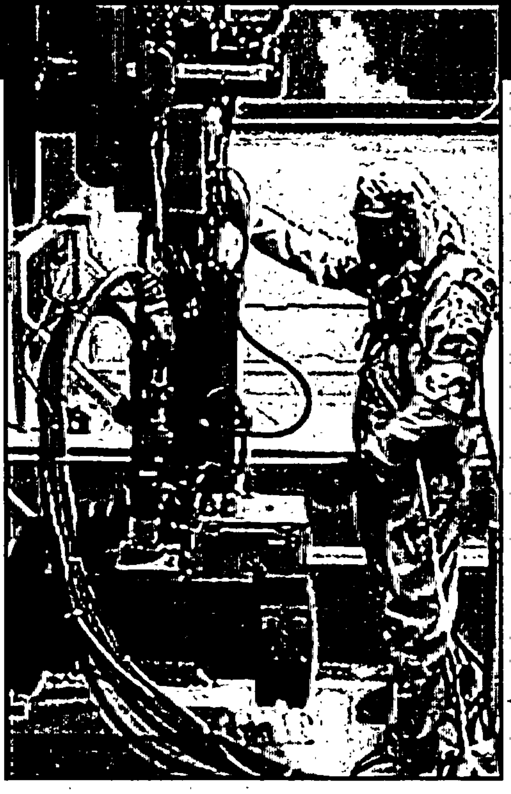

Final Status Survey Report

Document No. 82A9554

The Quehanna Decommissioning Project

Prepared For:
The Commonwealth of Pennsylvania
Department of General Services

Room 107, Headquarters Building
18th & Herr Streets
Harrisburg, PA 17125

SCIENTECH

143 West Street • New Milford, CT 06776

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QUEHANNA DECOMMISSIONING PROJECT

FINAL STATUS SURVEY REPORT

Prepared for:
Commonwealth of Pennsylvania
Department of General Services
Room 107, Headquarters Building
18th & Herr Streets
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BRIEF DESCRIPTION OF SURVEYED AREAS

- Basement – the area below where the hot cells stood. The Fan Room and Pipe Chase constitute the basement.
- Beam Room – the lowest section of the Reactor Bay on the west side of the reactor pool. This area allowed access to the reactor beam ports.
- Cell Face Area – see Cell Operations Area.
- Cell Operations Area – the area where the cells could be viewed and operations (with the manipulator arms) took place. This area is also known as the Cell Face Area. After all the walls were taken down in the Administrative Area, the area associated with cell operations simply became part of the Administrative Area. The floor area of the Cell Operations Area is part of the Administrative Area for purposes of the FSS.
- Cell Operations Trench – this was a shallow, concrete trench that ran along the base of the cell face. This trench was removed and underlying soil was remediated.
- Chemistry Lab – a small room that once housed a radio analytical chemistry laboratory adjacent to the Service Area.
- Decontamination Room – a small room adjacent to the Service Area and next to the Chemistry Lab.
- Decon Tent – a temporary enclosure located in the southwest corner of the Finishing Area. This tent was erected by Scientech primarily to decontaminate concrete blocks stemming from the hot cell complex dismantlement.
- Dungeon – room in the lowest level of the facility north of the Beam Room and accessible from the Beam Room and the Loading Zone.
- Electrical Room – room adjacent to and accessible from the eastern side of the north wall of the Finishing Area.
- Electrician's Office- a small room between the Electrical Room and the Finishing Area.
- Fan Room – the south half of the basement level below the hot cells.
- Finishing Area – self explanatory.
- Finishing Area Bunker – small room in the north, central section of the Finishing Area.
- Finishing Area Office – office area in the north central section of the Finishing Area.
- Finishing Area Tool Crib – small room in the north, central section of the Finishing Area adjacent to the Boiler Room.
- Gamma (Storage) Pool – small, deep, pit in the Service Area near the Reactor Bay entrance.
- Hydro-Blast Area – small area between Reactor Bay and Finishing Area used by PPI to water blast the irradiator casings.
- Loading Zone – the paved area between the pond and the main facility on the west side of the main facility (Reactor Bay, Dungeon).
- MMA Tank Area – the area containing large stationary tanks used for storing MMA, which was used in the wood treatment process (non-radiological). This area is adjacent to the Loading Zone.
- Office Mezzanine (HVAC Room) – area located above the Administration Area overlooking the Service Area.
- Old Loading Dock – from old photographs and drawings, a loading dock appeared to be located near the entrance to the Reactor Bay adjacent to the Boiler Room. The soil in this area was evaluated (sampled) to ensure that it was not affected by radiological operations and then covered with new structures and foundations.
- Pipe Chase - the north half of the basement level below the hot cells.
- Pump Room – small room in the lowest level of the facility south of the Beam Room. Only accessible through an outside door that leads to the Loading Zone.
- Reactor Bay (RB) – Includes the building that houses the reactor pool and surrounding area, and the Beam Room.

- Reactor Pool – self explanatory.
- Sawdust Shed – stand-alone metal building west of the Finishing Area used to store sawdust (structure has collapsed).
- Service Area – self explanatory.
- Source Storage Shafts – 12-14 feet long tubes that are buried vertically in the west end of the Service Area with one end that penetrates at about grade level. These shafts may have been used to store irradiator sources and have shielded end caps.
- Storage Building – metal, garage-type structure located in the Loading Zone near the pond.
- Tank 411 – buried water storage tank south of Reactor Bay. This tank was part of the reactor pool water handling and treatment system.
- Vestibule – the garage-style, metal building that covers the east (main) opening into the Service Area.
- Waste Water Treatment Building – small structure west of the Finishing Area, which now houses a non-operational wood burner.

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
ATL	Advance Technologies and Laboratories, Inc.
BRP	Pennsylvania Bureau of Radiation Protection
Ci	curie
Co-60	cobalt-60
cm^2	square centimeters
cpm	counts per minute
D&D	decontamination and decommissioning
DCGL	derived concentration guideline level
DCNR	Pennsylvania Department of Conservation and Natural Resources
DP	Decommissioning Plan
$dpm/100cm^2$	disintegrations per minute per 100 square centimeters
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FSS	Final Status Survey
FSSP	Final Status Survey Plan
FSSR	Final Status Survey Report
GM	Geiger-Mueller
H_0	null hypothesis
HP	health physicist *or* health physics
IL	investigation level
LBGR	lower bound of the gray region
LLRW	low-level radioactive waste
m^2	square meters
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
microR/hr	micro-Roentgen per hour
MMA	methylmethacrylate
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NMSS	Nuclear Material Safety and Safeguards
NRC	U.S. Nuclear Regulatory Commission
ORISE	Oak Ridge Institute for Science and Education
PADEP	Pennsylvania Department of Environmental Protection
Penn State	Pennsylvania State University
pCi	picocurie
pCi/g	picocuries per gram
phoswich	dual phosphor alpha/beta scintillator
PMMA	polymerized methylmethacrylate
Protean	Protean Instrument Corp. Model WPC-9550 gas flow proportional counter
PPI	PermaGrain Products, Inc.
QA	Quality Assurance
QAPP	Quality Assurance Program Plan
QC	Quality Control
ScanMDC	minimum detectable concentration during scanning

Scientech	Scientech, LLC
SNAP-7	Systems for Nuclear Auxiliary Power
Sr-90	strontium-90
$SrTiO_3$	strontium titanate
STL	Severn Trent Laboratory, St. Louis, MO
WWTB	Waste Water Treatment Building
Y-90	yittrium-90
yd^3	cubic yard

1.0 INTRODUCTION

This Final Status Survey Report (FSSR) presents the results of the final status survey (FSS) activities conducted by Scientech, LLC (Scientech) (formerly SCIENTECH, Inc.) of New Milford, Connecticut, in support of license termination at the Quehanna decontamination and decommissioning (D&D) project located near Karthaus, Pennsylvania. The Commonwealth of Pennsylvania currently maintains U.S. Nuclear Regulatory Commission (NRC) radioactive materials license number 37-17860-02 for the Quehanna facility. The purpose of the FSS and this FSSR is to demonstrate that radiological conditions at the Quehanna facility satisfy the free-release criteria presented in the Quehanna Site Decommissioning Plan (DP), (Scientech 2003a) as approved by the Pennsylvania Department of Environmental Protection (PADEP), Bureau of Radiation Protection (BRP) and the NRC. FSS activities were conducted according to the FSS Plan (FSSP) (Scientech 2004).

1.1 BACKGROUND INFORMATION

In June 1955, several articles were signed into law that paved the way for the construction of a research facility at the Quehanna site which was to be operated by the Curtiss-Wright Corporation. In 1957 following construction of the facility, the U.S. Atomic Energy Commission (AEC) issued a license to Curtiss-Wright to operate a swimming pool research reactor. The facility license also included the use of hot cells, laboratories, and support features. Radiological activities began in 1958.

In September 1960, Curtiss-Wright donated the facility and land to Pennsylvania State University (Penn State). Penn State then leased the hot cells to the Martin Marietta Corporation. Beginning in 1962, Martin Marietta used the hot cells to manufacture several prototype thermoelectric generators, known as Systems for Nuclear Auxiliary Power (SNAP-7) generators, for the AEC. These power sources, which were designed to furnish power for remotely operated, automatically reporting weather stations, navigation buoys, etc., contained very high specific activity strontium-90 (Sr-90) in the form of strontium titanate ($SrTiO_3$).

Martin Marietta's radioactive materials possession license allowed them to maintain megacurie amounts of Sr-90. Martin Marietta terminated its lease in 1967 and vacated the facility after a partial decontamination but licensable quantities of Sr-90 remained behind as structural contamination and process system residues. Martin Marietta was the last licensee to use Sr-90 at the Quehanna facility.

In 1967, Penn State gave its interest in the Quehanna facility to the Commonwealth of Pennsylvania and the Commonwealth then leased the facility to NUMEC, a subsidiary of the Atlantic-Richfield Corporation. NUMEC used the reactor pool to hold a large irradiator containing in excess of 1 million curies (Ci) of cobalt-60 (Co-60). In 1978, a group of Atlantic-Richfield employees bought the wood irradiation process, including the cobalt pool irradiator and related equipment at the Quehanna facility. The new company, PermaGrain Products, Inc. (PPI), was issued a NRC radioactive materials license (Number 37-17860-01) for the irradiator and also assumed "caretaker" responsibilities for the material (contamination) left behind by previous tenants.

The Commonwealth of Pennsylvania currently owns the Quehanna facility and the surrounding property which the Pennsylvania Department of Conservation and Natural Resources (DCNR) Bureau of Forestry administers the land. The PADEP currently holds the NRC license that controls the Quehanna facility (No. 37-17860-02).

1.2 FACILITY DECOMMISSIONING

Scientech mobilized to the Quehanna site in May 1998 and began extensive decontamination and dismantling activities to reduce contamination levels to free-release limits. While volumes could be written to describe the details of the 6-year D&D effort that was completed in December 2004, that is not the purpose of this document. The following items, however, summarize the primary D&D activities.

- The Waste Water Treatment Building (WWTB) was decontaminated and included the excavation of contaminated tanks, pipes, and soil to about 9 feet (3 meters) in depth).

- Using upgraded manipulator arms, about 2,000 curies of Co-60 was collected from the hot cells, packaged and shipped for disposal.

- In the reactor pool, the Co-60 sources, irradiator handling equipment, water and sludge was removed. The Co-60 sources were removed by a U.S. Environmental Protection Agency (EPA) contractor under an emergency action contract.

- In the Service Area, most of the dividing walls, much of the floor, and all equipment, including the gantry crane, were removed. In addition, contaminated drain lines below the Service Area floor were excavated along with a limited amount of soil that was affected by line leakage.

- Using robotic dismantlement techniques, the Hot Cell 4 Process System, which contained the bulk of the Sr-90 radioactivity, was removed and packaged for disposal.

- The hot cell complex was removed entirely exposing the basement below (Pipe Chase and Fan Room). The only remaining remnants of the hot cells are two walls and the floor of Hot Cell 6, which was located in the basement. The concrete floor in the basement was subjected to heavy decontamination to meet the release criteria. Some sections of the floor or walls were removed because further decontamination was not practical.

- Interior walls of the Administration Area and PPI support areas were removed and the areas were surveyed and decontaminated to levels below the release criteria. All woodworking equipment sold as part of the PPI bankruptcy was surveyed prior to release. Utilities, fixtures, piping, insulation and building systems were decontaminated as necessary to meet the release criteria.

1.3 FINAL STATUS SURVEY

In July 2004, Scientech began the FSS to determine the final radiological status of the Quehanna facility. The survey was performed in accordance with the FSSP (Scientech 2004), which was reviewed and approved by the NRC. This FSSR describes the results of the FSS and the FSS process and demonstrates that the facility now satisfies the NRC-approved release criteria presented in the DP (Scientech 2003a) as incorporated into license number 37-17860-02. Scientech performed the FSS in compliance with federal regulations and in line with regulatory guidance on license termination.

2.0 SITE INFORMATION

2.1 SITE DESCRIPTION

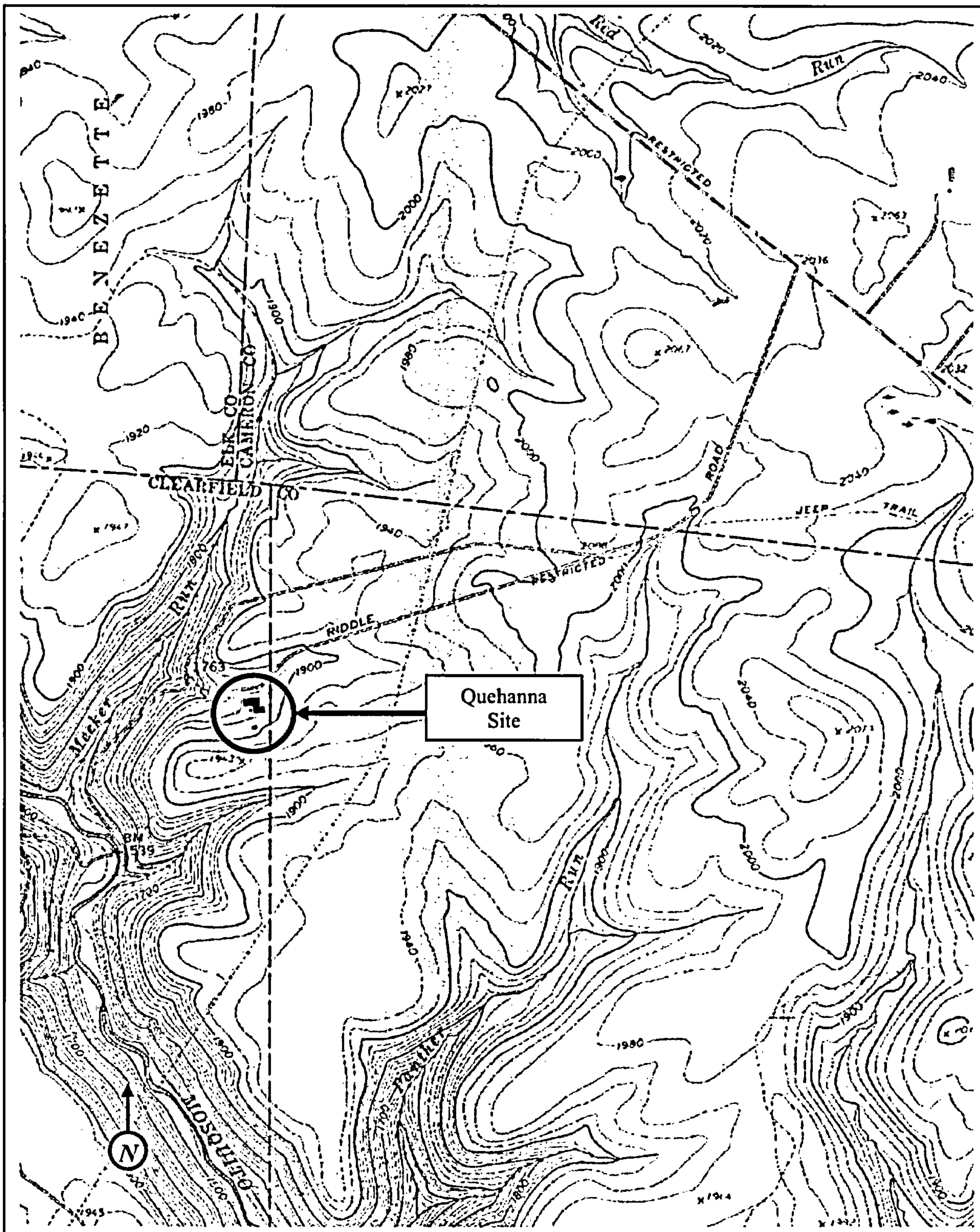
The Quehanna facility is located at 115 Reactor Road, Karthaus, Clearfield County, Pennsylvania. The site is approximately 21 miles northeast of Clearfield, Pennsylvania at approximately 41° 13' north latitude and 78° 14' west longitude. The site, identified in Figure 2-1, is located in the 50,000-acre Quehanna Wild Area of the Moshannon State Forest. The area is heavily wooded and sparsely populated. The topography is typical of the Appalachian Plateau such that the area is relatively flat with an average elevation of 2,000 feet above mean sea level. The edge of the facility property is incised by several gorges up to one-half mile in width and 1,000 feet in depth that radiate from their origin near the center of the site. The area around the site also has a significant number of granite outcroppings that are characteristic of the region.

At the start of the D&D project, the Quehanna site included many affected structures and systems, such as the hot cells complex, the WWTB with associated underground tanks and piping, the Reactor Bay, and the hot cell ventilation system. Some of these were removed as clean debris or partially decontaminated and disposed of as low-level radioactive waste (LLRW). The facility also included other laboratories, production areas, storage areas, and offices formerly used by PPI. The Quehanna facility included approximately 40,000 ft^2 (3,716 m^2) of floor space. The layout of the facility prior to the D&D operations is shown in Figures 2-2 through 2-5. A post-D&D revision of Figure 2-4 is provided as Figure 2-6.

The Quehanna site is approximately 7-acres in size and was improved over the years with several permanent and temporary structures, an asphalt parking lot, and several paved and gravel driveways. The site also includes a small 0.5-acre pond and a septic system leach field that was used to manage sanitary sewer waste from the facility. Several aboveground storage tanks were used to store methylmethacrylate (MMA), the polymer chemical used in PPI's wood treatment process. The tanks are located west of the main facility structure and north of the pond. A small stream bisects the site property north of the facility's main building and parking lot.

2.2 LICENSE INFORMATION

The site radioactive materials license allows for an unspecified amount of any byproduct or special nuclear material including Sr-90 and Co-60. However, the license only authorizes the D&D of facilities, packaging of stock material and radioactive waste, and storage of material and packaged waste prior to shipment off site. The authorization is limited to radioactive contamination that existed at the facility on January 11, 1988, including specific Co-60 sources described in a letter to the NRC dated August 7, 1997. Since then, the materials license has been renewed and amended to incorporate the DP. The current license (No. 37-17860-02) was issued on September 29, 2003 and will expire March 31, 2008.



Source: U.S. Geological Survey
Devils Elbow, PA, Quadrangle
Photorevised 1971

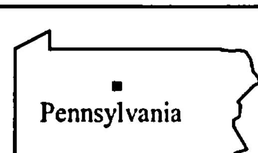
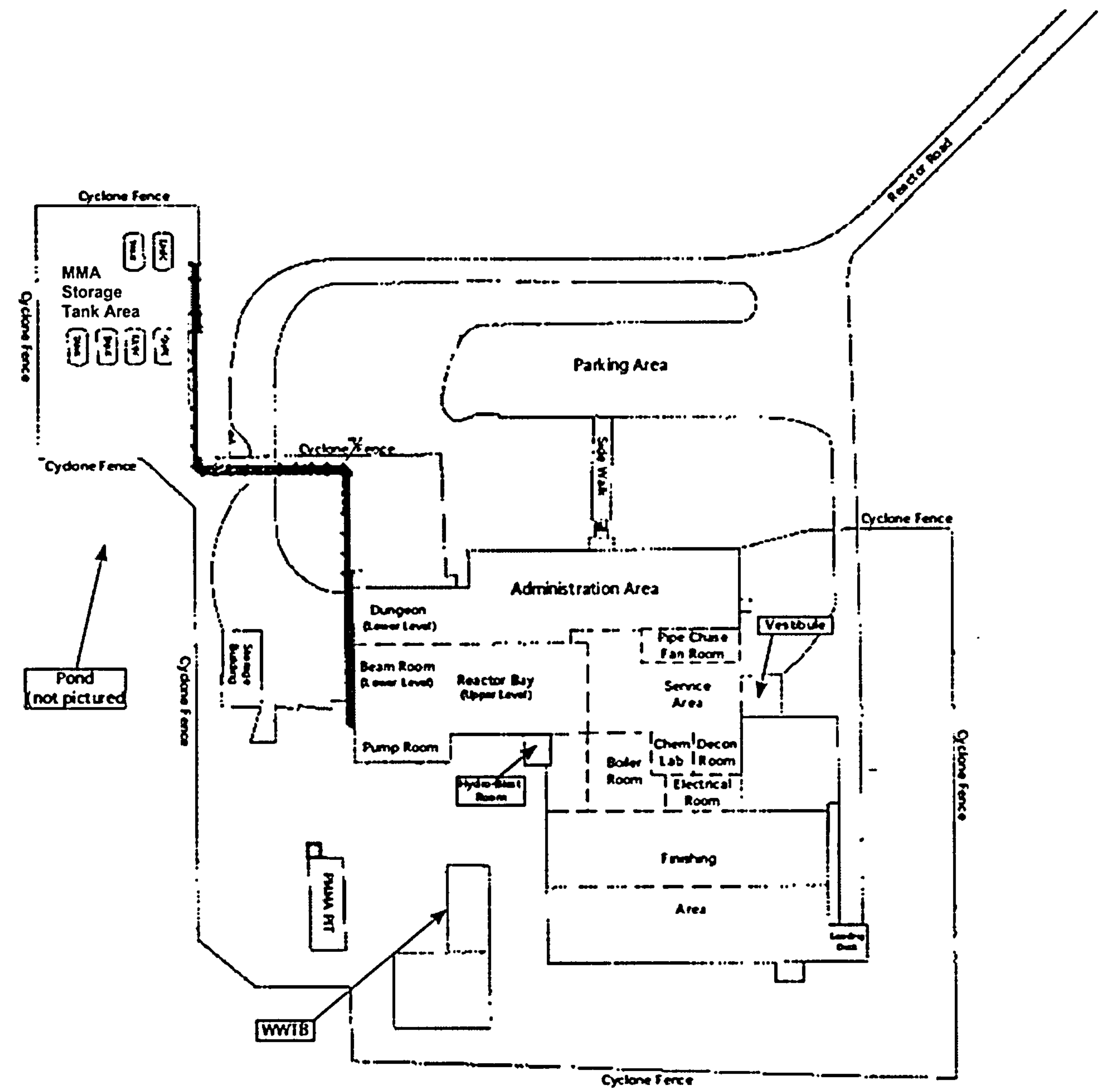
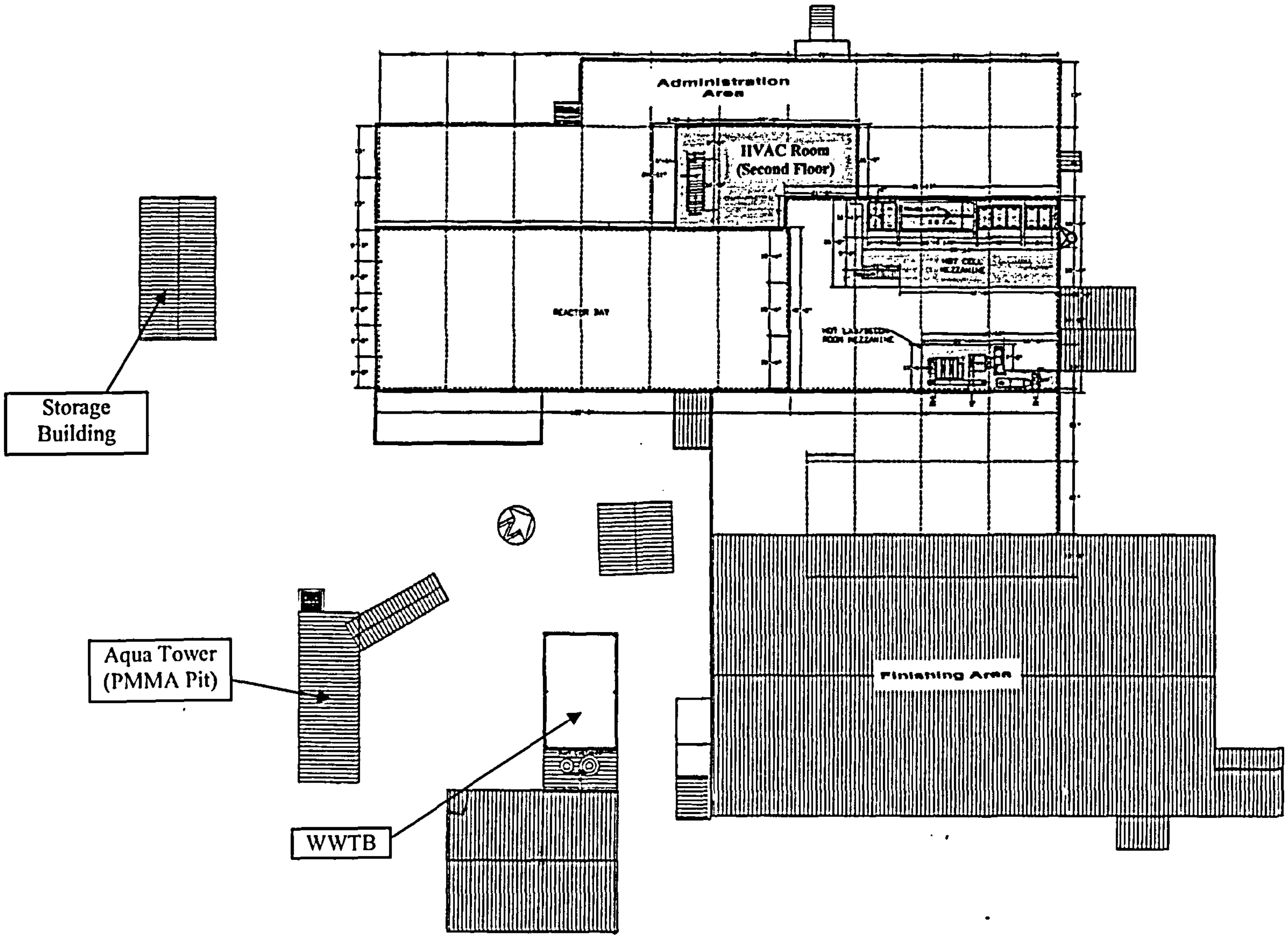


FIGURE 2-1
QUEHANNA SITE
LOCATION MAP



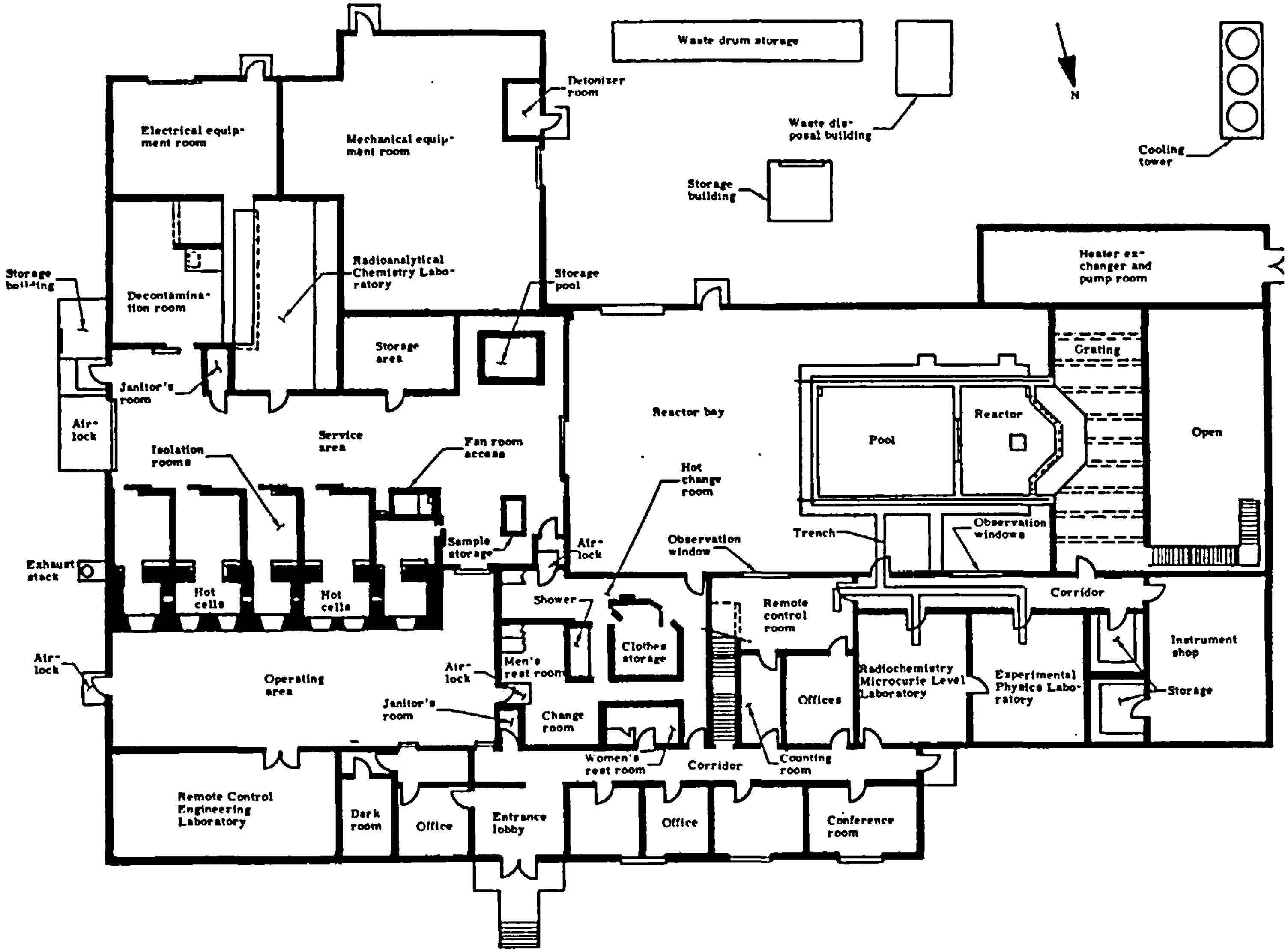
Source: Commonwealth of Pennsylvania Department of General Services
Topographic Site Plan View (Modified)
December 17, 1996
Updated in 2004 based on information provided by Scientech, LLC

FIGURE 2-2
SITE
PLAN VIEW



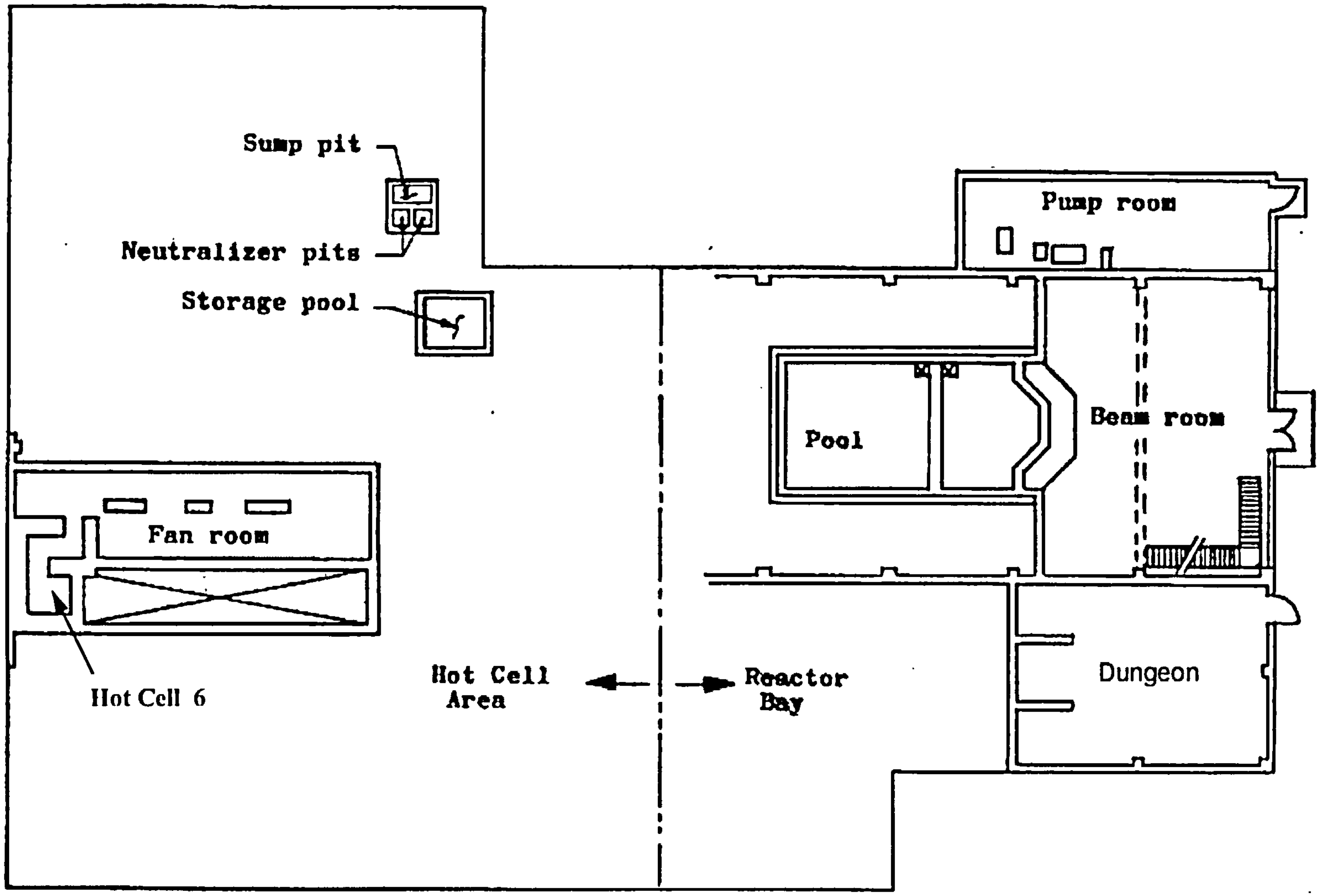
Source: Commonwealth of Pennsylvania Department of General Services
Mezzanine / Steel Plan View
January 7, 1997
Updated in 2004 based on information provided by Scientech, LLC

FIGURE 2-3
QUEHANNA FACILITY
FLOOR PLAN



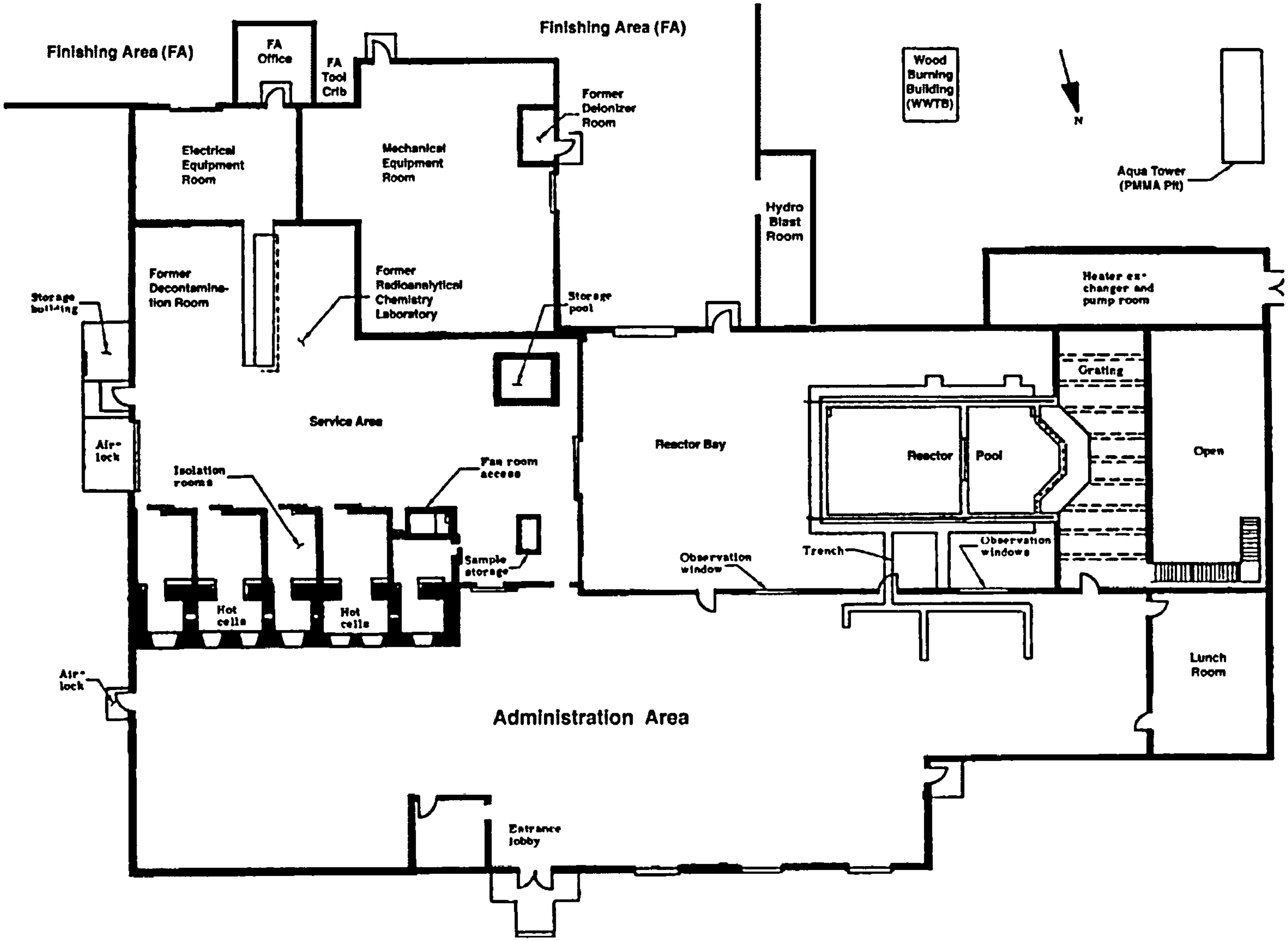
Source: Quehanna Radioisotopes Pilot Plant
Engineering Manual, Cell 4 Process
Martin Marietta, May 1966

FIGURE 2-4
ORIGINAL MAIN FLOOR PLAN
QUEHANNA FACILITY



Source: Quehanna Radioisotopes Pilot Plant Engineering Manual, Cell 4 Process Martin Marietta, May 1966

FIGURE 2-5
ORIGINAL BASEMENT LEVEL FLOOR PLAN
QUEHANNA FACILITY



Source: Quehanna Radioisotopes Pilot Plant
Engineering Manual, Cell 4 Process
Martin Marietta, May 1966
Updated in 2004 based on information provided by Scientech, LLC

FIGURE 2-6
POST-FSS MAIN FLOOR PLAN
QUEHANNA FACILITY

2.3 CHARACTERIZATION AND PROCESS KNOWLEDGE

When the PADEP began investigating the Quehanna facility and planning for the D&D project, no information was available on the extent of the contamination that was left onsite by previous site tenants including Martin Marietta and NUMEC. Therefore, in the early 1990's the PADEP contracted Canberra, Inc. to perform a facility characterization (Canberra 1993). Based on this characterization, the PADEP contracted Scientech (then NES, Inc.) for the D&D operations. However, in 1998, Scientech discovered that contamination levels, especially those in Hot Cell 4, were much more substantial than that reported by the characterization work. As a result, PADEP expanded the scope of the D&D project. From 1998 through 2004, along with primary D&D activities, Scientech conducted more extensive characterization activities throughout the facility, including environmental sampling of the soils around the exterior of the facility and the water and sediments from the on-site pond.

A November 4, 1999 letter included by reference to License Amendment No. 8 to Materials License No. 37-17860-02 estimated that 104 Ci of Sr-90 remained in the Hot Cell 4 process system and an additional 8 Ci of dispersed contamination remained throughout the building surfaces. Historically, the Sr-90 was present in various chemical forms including strontium carbonate, strontium nitrate, and strontium titanate and was found as contamination on building surfaces, inside pipes, and other enclosed systems.

In 1999, approximately 2,000 Ci of Co-60 irradiator sources, in the form of plates, pellets, and rods, were consolidated, packaged, and removed from Hot Cell 1 using upgraded manipulator arms. These sources were transferred for disposal and Hot Cell 1 and Hot Cell 2, which was used for source consolidation and packaging, were successfully decontaminated. In September 2003, slightly less than 100,000 Ci of sealed Co-60 source rods were removed from the reactor pool by EPA contractors under an emergency action after PPI became insolvent. These sources were controlled under PPI's License No. 37-17860-01.

Extensive characterization of the facility has identified Sr-90 and Co-60 as the only radioisotopes of concern with Sr-90 being the primary surface contaminant throughout the facility. One or both contaminants have been identified in affected areas which are discussed below. Further historical information can be found in Section 2.0 of the Quehanna DP (Scientech 2003a).

2.3.1 Non-impacted Areas

The areas of the facility located outside the perimeter cyclone fence were considered non-impacted areas except for the pond and the parking lot area. This designation is supported by reports of survey activities at several locations near and in the broad vicinity of the Quehanna site. These surveys included a comprehensive survey conducted by Oak Ridge Associated Universities in January of 1987. Additional sampling conducted by Scientech in 2001, which included 5 soil samples from under the sawdust piles showed no unexpected levels of radioactivity. The sawdust piles were a result of non-radiological woodworking activities conducted by PPI. In 2004, a non-invasive geotechnical survey was performed on sawdust piles using a magnetometer. The magnetometer survey did identify buried objects; however, those objects identified on or near the surface did not exhibit radioactive material contamination.

The site surface waters and groundwater are considered non-impacted, were not a part of the FSS, and are not expected to be monitored after the site's release. The MMA storage tanks located west of the parking lot were not surveyed since the tanks were used to supply the chemical necessary in PPI's wood treatment process. These tanks were put in place after processes involving Sr-90 were complete and acted only as chemical storage vessels.

2.3.1.1 Aqua Tower and Storage Building

Although, the Aqua Tower and the Storage Building were identified in the FSSP as Class 3, they were changed to non-impacted during the FSS. The Aqua Tower, which is south of the Reactor Bay, is believed to be a feature associated with the test reactor that was designed but never built. The area associated with the Aqua Tower has a covered, concrete, shallow basin that has been used to store polymerized methylmethacrylate (PMMA). As such, this area is often referred to as the PMMA pit. Towards the end of the FSS effort, this area was filled with several feet of ice and PMMA drums and, as such, could not be surveyed. Since this area was not associated with the Hot Cell system, was not connected to the reactor system, and was not in a condition to survey, it was designated as a non-impacted area. It should also be noted that there was no elevated radioactivity measurements seen adjacent to the Aqua Tower area.

Similarly, the Storage Building was not in a condition to allow a comprehensive survey. The Storage Building, which is just east of the pond, was erected by PPI to store chemicals. It was not used to support hot cell or reactor operations. Much of the floor space was inaccessible because of dozens of PMMA drums. Scientech did conduct a limited survey of accessible floor areas and no indications of elevated radioactivity were identified. The data from this limited survey are included in Appendix E, however, the historical and process information support the designation of this area as non-impacted.

2.3.2 Impacted Areas

With the exception of the Aqua Tower area and the Storage Building, all of the areas within the fence line of the Quehanna Facility were designated as impacted. In addition, the parking lot area and the pond, which are outside of the fenced area, were also designated as impacted. The following sub-sections provide an overview of the major impacted areas of the FSS.

2.3.2.1 Impacted Structures

The following paragraphs describe the more significant impacted structures and their components. See Figures 2-3 through 2-5 for the locations of the impacted structures.

1. Hot Cells

The Hot Cells structure was located inside the Service Area. The Hot Cells were used for Sr-90 activities beginning in 1962 and ending in 1967. There were 5 hot cells (Hot Cells 1 – 5) on the main level of the Service Area and one hot cell on the basement level (Hot Cell 6). Besides Hot Cell 6, each hot cell had an associated isolation room located between the hot cell and the Service Area. In 1998, 2,000 Ci of Co-60 sources were removed from Hot Cells 1 and 5. Hot Cell 4 was found to be the most contaminated area of the facility with an estimated 104 Ci of Sr-90 contamination. Hot Cells 1 through 5 and their associated Isolation Rooms were completely dismantled and removed using diamond wire sawing. Only the outside walls and floor of Hot Cell 6 remain.

2. Service Area

In addition to the Hot Cells and their Isolation Rooms, the Service Area also contained the Chemistry Lab, the Decontamination Room, the Janitor's Room, and the Laundry Room on the main level and the Fan Room and Pipe Chase on the basement level. Eight Ci of dispersed Sr-90 contamination was suspected in the Service Area and its associated rooms prior to D&D activities. Most of the Service Area's concrete floor was removed because of resilient, low-level contamination. Underlying drain piping was removed as well, along with a limited amount of soil that exhibited elevated radioactivity from pipe joint leaks. After removal of the contaminated soil, confirmatory samples were taken to ensure all of the affected soil was removed. Clean fill was added to restore the area to grade level. Most of the dividing walls were removed and all of the utility services and the gantry crane were also removed.

The basement level known as the Pipe Chase and Fan Room, which are divided by a concrete wall, was the center of the most extensive decontamination work. An average of approximately eight inches of concrete was removed from the surfaces in this area to meet the release criteria. The basement structure had no seams (monolithic pour); therefore, it was effective in containing the contaminants. This was confirmed by substructure sampling, which is discussed in Section 3.13.

3. Reactor Bay

This area contains the reactor pool, which once contained a swimming pool type research reactor and later contained PPI's Co-60 irradiator and an extensive amount of material handling equipment. Sr-90 contamination was thought to be possible because of its proximity to the Service Area where the hot cell complex was located. The Reactor Bay ceiling and wall panels were virtually free of contamination but the horizontal surfaces of the support structure (I-beams) had random spots of contamination. This cross contamination may have been caused by birds moving between the areas. No information existed to suggest that operational events would have contaminated the Reactor Bay above the floor.

The lower level of the Reactor Bay had nuisance levels of radioactive contamination, which probably originated from the hot cells. This contamination was identified in utility trenches and their covers, and on horizontal surfaces. Due to the build up of PPI's polymer, MMA, and years of dust and grime, extensive cleaning of much of the area was necessary to allow an accurate radiological survey.

4. Reactor Pool

As stated before, approximately 100,000 Ci of sealed Co-60 source rods were removed from the reactor pool by EPA contractors in September of 2003. Records indicate there was never leakage from the Co-60 sources. Surveys of the pool, support systems, and resin purifiers support this contention. Structural material, however, could have been activated at low levels by test reactor operations prior to the installation of the irradiator. In addition, the pool was located near the hot cell complex, which could have allowed for cross contamination.

To support the FSS process, the irradiator handling equipment, which moved encased wood products through the irradiators, was removed from the pool. Remaining sludge was dewatered, removed, and solidified. A very limited amount of Sr-90 contamination was found in the sludge; therefore, the sludge was disposed of as radioactive material. After cleaning, the reactor pool was subjected both to a contamination survey and a radiation survey with a NaI detector to detect activated material. One of the three activation port plugs (the center one) was found to be slightly activated and was disposed of as radioactive waste. Otherwise, the reactor pool was found to be suitable for release.

5. Pump Room

The Pump Room is located on the west side of the facility at the lowest level. It is accessible from the paved area between the facility and the pond. The components located in the Pump Room make up the reactor pool purification and water handling system. Components include deionizers, recirculation pumps, and other operational equipment. The Pump Room and its components were thought to have about the same potential for contamination as the reactor pool. After removal of dirt, grime and debris, the Pump Room was surveyed and found to be suitable for release.

6. Waste Water Treatment Building (WWTB)

The WWTB is a small building west of the Finishing Area. This building once housed an evaporator and water purification system that supported operations of the hot cell complex. All of the purification equipment in the building had been removed some time after hot cell operations were terminated and the building had afterwards been used by PPI to house a wood burner. Underground water storage tanks associated with the WWTB and piping, however remained. In 1998 Scientech excavated these tanks and their piping (also addressed in next Section). As part of this effort, Sr-90 contamination above the release criteria was found in the WWTB as well as in the soil. The contamination was removed as part of the 1998 effort and was verified as part of the FSS.

7. Finishing Area

The Finishing Area was constructed and used by PPI in its wood flooring production process. While no radioactive materials were used, processed, or stored in the area prior to site D&D operations, sections of the Finishing Area were used to store concrete blocks that once made up the hot cell structure. These blocks were sealed with paint to reduce the possibility for contamination, but contamination levels greater than the release criteria were later found on parts of the Finishing Area floor. Surveys of the walls and ceiling showed that they were not impacted. The southwestern corner wall of the Finishing Area received a higher level of scrutiny since a decontamination tent, used for decontaminating concrete blocks from the hot cell complex, was placed in that area.

Located on the north side of the Finishing Area between the Finishing Area Office and the Boiler Room is a small room known as the Tool Crib which was used for storing equipment during PPI operations. This area was used by Scientech to store LLRW. The Finishing Area Office, located on the north side of the Finishing Area, was never used for radiological operations.

8. The Electrical Room, Hydro-Blast Area, Dungeon, and the Sawdust Shed

While considered potentially impacted, these areas were not considered likely to be contaminated based on facility-use knowledge and scoping surveys. The Sawdust Shed collapsed in September 2004; however prior to its collapse, a FSS was conducted.

9. The Roof

Access to the roof was a safety concern due to its instability. Although limited repairs to minimize leakage have been made, it was unsafe to walk on. There was no reason to believe that the roof was impacted; however, two ventilation discharge ports, which were accessible using a man-lift, were surveyed as part of the FSS. No elevated levels of radioactivity were identified. During dismantlement and characterization phases, several areas of the roof were surveyed primarily to assure adequate levels of worker protection. These surveys failed to identify any residual radioactivity on the roof.

2.3.2.2 Impacted and Potentially Impacted Land Areas

Soil characterization efforts prior to the FSS revealed three localized areas of subsurface soil contamination, which were eventually remediated. These included soil associated with the WWTB, soil under the Cell Operations Area trench, and soil adjacent to leaking drain lines joints under the Service Area floor. Much of the FSS's subsurface soil assessment was patterned to show that soil contamination did not spread from the areas of known soil contamination and the hot cell basement area, which was considered the most likely source of subsurface contamination if unidentified breeches were present.

No surface soil contamination was ever identified during the characterization and FSS work; however, limited contamination was found on the Loading Zone pavement, which is between the main building and the pond. This area was used during D&D operations as a radioactive waste loading and storage area. The localized areas of low-level contamination in this area were easily remediated. No other contaminated areas outside of the facility structures were found. The following provides additional information about the land areas that were considered impacted as part of the FSS.

1. Waste Water Treatment Building

As part of the remedial effort of the WWTB area (as noted in the previous section), forty cubic yards (yd^3) of soil was excavated to depths up to 2.7 meters (9 feet) from the WWTB area and comprehensive soil sampling was performed to confirm that the remedial activities brought soil concentrations to below the release criteria of 5 picocuries per gram (pCi/g).

Underground storage tanks 401 A&B and 402 A&B, which were associated with the WWTB process, were also excavated along with related piping. No external contamination was found on any of the pipes or on the exterior of the tanks. In addition, the concrete pad upon which the tanks were set was surveyed with negative results. Since the characterization surveys confirmed the absence of radiological contamination, the area of the underground storage tanks was backfilled.

2. Loading Zone Area

This area between the main facility and the pond includes the soil under the Loading Zone (paved area) and unpaved areas around it. The Loading Zone paved area was surveyed as a Class 1 structure. Low levels of contamination were found in localized, low-lying paved areas at this location. This area was used for loading and storing radioactive waste from the D&D project. This area was also suspect because it lies in the path of storm water runoff flowing from the Reactor Building to the pond. If contamination were to escape from the Hot Cell complex or the Reactor Bay, the contamination would likely migrate towards this area and the pond.

3. Pond

The pond is located west of the Reactor Bay. The pond sediments (not water) were considered potentially impacted due to the possibility of contamination runoff that could have occurred during facility and waste handling operations.

4. Parking Lot and Sidewalk

There was a possibility that contamination could have been tracked onto the sidewalk and into the parking lot. The sidewalk leading to the facility appears to be original because of extensive wearing. The parking lot has likely been resurfaced at least once. Soil samples along the edge of the sidewalk and in front of the main administrative area were taken during characterization activities and no elevated levels of radioactivity were identified.

5. All Exterior Areas Inside the Cyclone Fence

All other areas located inside the cyclone fence, except for the MMA tanks area, were considered potentially impacted for the purpose of the FSS.

2.4 SITE CONDITIONS AT THE TIME OF THE FINAL STATUS SURVEY

The Administration Area, which once included several offices, a lunch room, a welding shop, conference room, laboratory, and bathrooms, were completely cleared of dividing walls so that it was one large open area. The Service Area only had an open basement, where the hot cells once stood. Extensive debris removal and general housekeeping was necessary to begin the FSS in many of the areas that were previously occupied by PPI. Figure 2-6 provides the layout of the facility as it was during the FSS. The DP and the FSSP contain information about the initial radiological conditions of the facility.

2.5 POTENITAL CONTAMINANTS AND RELEASE CRITERIA

The Quehanna DP and the FSSP identified Sr-90 and Co-60 as the only two contaminants of concern and establish release criteria for the structures, equipment, material, and adjacent land area (soil). There was no expected Co-60 contamination expected outside of the hot cells, which were removed. The release criteria were not dose-based derived concentration guideline levels (DCGL). Due to the circumstances described in Section 5.0 of the Quehanna DP, demonstrating compliance with dose-based DCGLs was not required for this decommissioning project, rather, demonstrating compliance with a regulatory approved, pre-existing release criteria was deemed to be acceptable. The Quehanna DP does note, however, that the criteria applied during the Quehanna project would easily be compliant with 25 millirem (plus ALARA) limit in Title 10, Part 20, Subpart E of the Code of Federal Regulations (commonly known as the License Termination Rule).

2.5.1 Surface Contamination Criteria

Allowable residual contamination levels for the unrestricted release of structures, construction debris, and equipment are based on the NRC release limits (NRC 1993). These release criteria were adopted from the often-referenced Regulatory Guide 1.86 (AEC 1974). The acceptable surface contamination levels, in disintegrations per minute per 100 square centimeters (dpm/100cm^2), for the primary isotopes of concern are as follows:

TABLE 2-1
SURFACE CONTAMINATION RELEASE CRITERIA

Nuclides	Average[a]	Maximum[b]	Removable
cobalt-60	5,000	15,000	1,000
strontium-90	1,000	3,000	200

a Measurements of average contamination should not be averaged over more than 1 m^2.
b The maximum contamination level applies to an area not more than 100 cm^2.

2.5.2 Soil Contamination Criteria

Allowable residual levels of contamination in surface and subsurface soils are based on the NRC guidelines (NRC 1992a). The soil limits, in pCi/g, for this decommissioning project are as follows:

TABLE 2-2
SOIL CONTAMINATION RELEASE CRITERIA

Nuclides	Average	Maximum
cobalt-60	8	24
strontium-90	5	15

To determine the average soil concentration, the surface soil sampling results can be averaged over an area no greater than 100 m^2. The maximum concentration refers to any single sample from within a surface area of 100 m^2. For subsurface samples, all samples will need to be less than the average criterion unless a relatively tight sampling pattern can show that contamination at values less than the maximum and more than the average are limited to a defined area such that the average concentration for any 100 m^2 area is less than the average criterion.

2.5.3 Exposure Rates

Allowable exposure/dose rates for release of the Quehanna site are based on the NRC's interim guidance (NRC 1992b). This document describes an indoor exposure rate limit of 5 microR/hr above background at 1 meter in decommissioning and terminating licenses for research reactors. The 5 microR/hr criterion for indoor contamination corresponds to an annual whole body dose of about 10 millirem for an assumed indoor occupancy period of 2,000 hours per year. The document further discusses the Nuclear Material Safety and Safeguards (NMSS) Policy and Guidance Directive FC 83-23 which provided an acceptable external radiation exposure rate for soil contamination of 10 microR/hr above background at 1 meter. These two criteria were used as part of the Quehanna FSS.

3.0 FINAL STATUS SURVEY OVERVIEW

The FSS was a combination of surface contamination surveys, and surface and subsurface soil sampling combined together to support an unrestricted site release. The FSS was designed and implemented according to the protocols established in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (NRC 2002).

3.1 DATA QUALITY OBJECTIVES

The following data quality objectives (DQO) are quantitative and qualitative statements about the FSS process. More information on DQOs is provided in project Quality Assurance Project Plan (QAPP) (Scientech 2002) and in MARSSIM.

- The objective of the FSS was to prove that the residual radioactivity levels in the survey units within the facility are at or below the release criteria provided in Section 2.5 of this FSSR. **This DQO was met.**
- The background reference area was to be located in an area that has similar construction materials to those located in the facility that is known to be unaffected. **This DQO was met.**
- The null hypothesis (H_0) was: The residual radioactivity in the survey unit exceeds the release criteria. **This DQO was met.**
- A decision error occurs when the decision maker rejects the null hypothesis when it is true, or accepts the null hypothesis when it is false, these two types of decision errors are classified as Type I and Type II decision errors respectively. **This approach was used.**
- The Type I and Type II decision error probabilities were to both be 5%. Type II could have been adjusted by the Scientech Project Health Physicist (HP) since this type of error leads to the labeling of a survey unit as being contaminated when it is not (a false positive). **No change was made and this DQO was met.**
- The upper bound of the gray region was to be defined as the release criteria and the lower bound of the gray region (LBGR) was to be defined initially as the mean concentration of the characterization data. The LBGR was allowed to be adjusted for an acceptable relative shift as described in MARSSIM. **This DQO was met.**
- Fixed-point measurements were to be calculated for the survey units using a systematic, random-start method. **This DQO was met.**
- For fixed-point measurements, instrument minimum detectable concentrations (MDC) were to be less than 50% of the total surface activity release criteria. **This DQO was met.**
- For smear measurements, instrument MDCs were to be less than 50% of the removable activity release criteria. **This DQO was met.**
- Scanning MDCs (ScanMDC) were to be less than or equal to 100% of the release criteria. **This DQO was met.**
- Detectors with areas less than 100 cm^2 were only to be used in areas too small for the larger area detectors or on extremely uneven surfaces. **This DQO was met.**

- Quality control (QC) measurements were to be made to evaluate instrument and operator precision. **This DQO was met.**
- Survey measurements were to be documented and controlled as described in the Scientech procedures (primary procedure Scientech 2003b). **This DQO was met.**
- The investigation level (IL) was to be the mid-point between the MDC and the release criterion for Sr-90 for fixed-point measurements. The IL for scanning measurements was to be the release criterion for Sr-90. **These DQOs were met.**
- A response check form or instrument control log was to be used to keep track of background counts and response checks. **This DQO was met.**

3.2 ORGANIZATION AND RESPONSIBILITIES

The FSS (survey and sampling) was performed by a team of qualified Scientech health physics technicians and radiological engineers, and was lead by the Project HP and the FSS Coordinator (both FSS-experienced certified health physicists). Descriptions of the responsibilities of Scientech project personnel, other than the FSS Coordinator who reported directly to the Project HP, were addressed in the FSSP (Scientech 2004).

The primary laboratory selected to perform soil sample analysis was Advance Technologies and Laboratories, Inc. (ATL), Germantown, MD. The backup and quality control laboratory selected was Severn Trent Laboratory (STL), St. Louis, MO.

3.3 INSTRUMENTATION

The FSS for structures consisted of scans, fixed-point measurements (total surface contamination measurements), smears (removable contamination measurements), and exposure/dose rate measurements. The instruments used during the FSS and their applications are provided in Table 3-1.

All instruments were calibrated using National Institute of Standards and Technology (NIST)-traceable standards according to Scientech procedure (Scientech 2003c). Instruments were checked daily to ensure they were operating properly. An acceptable response range was determined *a priori* according to the Scientech procedures (Scientech 2003b).

Instrument records, including dates of use, efficiencies, probe areas, calibration due dates and source traceability were also maintained in accordance with procedures (Scientech 2001b and Scientech 2001c).

TABLE 3-1
FSS INSTRUMENTS

Application	Primary Instrument	Probe Physical Area
Fixed-point measurements	Ludlum 2360 with a Ludlum 43-93 100-cm^2 dual phosphor alpha/beta scintillator (phoswich) (*alpha and beta measurement logging)*; Ludlum 44-9 GM for uneven surfaces.	100 cm^2
Smears	Protean Instrument Corporation, Model WPC-9550 alpha/beta sample counter (Protean)	N/A
Floor beta scans	1) Ludlum 2220 with a Ludlum 239-1F floor monitor (large-area gas flow proportional detector – Ludlum 43-37) 2) Ludlum 2360 with a Ludlum 43-93 dual phosphor alpha/beta scintillator (phoswich detector)	1) 697 cm^2 2) 100 cm^2
Wall and ceiling	1) Ludlum 2360 with a Ludlum 43-93 dual phosphor alpha/beta scintillator (phoswich detector) 2) Ludlum 2221 with a Ludlum 44-9 Geiger-Mueller (GM) detector	1) 100 cm^2 2) 15 cm^2
Equipment scans	1) Ludlum 2360 with a Ludlum 43-93 100-cm^2 dual phosphor alpha/beta scintillator (phoswich detector) in *beta mode only* 2) Ludlum 2221 with a Ludlum 44-9 GM detector	1) 100 cm^2 2) 15 cm^2
Pipe interiors or surfaces that are difficult to access	Ludlum 2221 with a Ludlum 44-9 GM detector	15 cm^2
Gamma scans	Ludlum 2350-1 with either a Ludlum 44-2 or 44-10 sodium iodide (NaI) gamma scintillation detector.	1″ or 2″ diameter
Exposure/dose rates	Ludlum Model 19 mircoR meter	N/A

As stated in Section 3.1, the MDC of the instrument being used is important in ensuring that contamination at or below the release criteria can be confidently identified. The formulas for the ScanMDC and fixed-point/smear measurement MDC calculations are provided in Table 3-2. For field applications, it is also important to know the value of the MDC, IL, and release limits in gross count-per-minute (cpm). In these units, the surveyor can make an immediate judgment based on instrument response (in cpm). Typical instrument response values, in gross cpm, equal to the MDC, IL, and release limits are provided in Table 3-3.

TABLE 3-2
MINIMUM DETECTABLE CONCENTRATION EQUATIONS

Survey Type	MDC Equation	Variables
MDC for Scans	$ScanMDC = \dfrac{1.38 * 60\sqrt{\dfrac{R_B}{60}}}{\sqrt{0.5}\varepsilon_s(\varepsilon_i)\left(\dfrac{a}{100cm^2}\right)}$ **Only applicable for a 1 detector-width per second scanning rate.**	R_B = Background count rate $\sqrt{0.5}$ = Surveyor efficiency factor ε_i = Intrinsic instrument efficiency ε_s = Surface efficiency (0.5 for beta) a = probe area in cm^2
MDC for Fixed-Point And Removable Contamination Measurements	$MDC = \dfrac{3 + 3.29\sqrt{R_B t_S\left(1 + \dfrac{t_S}{t_B}\right)}}{\varepsilon_s(\varepsilon_i)(t_S)\left(\dfrac{a}{100cm^2}\right)}$	R_B = Background count rate (cpm) t_S = Sample counting time t_B = Background counting time ε_i = Intrinsic instrument efficiency ε_s = Surface efficiency (0.5 for beta) a = probe area in cm^2 = area of surface smear in cm^2
Conversion from gross cpm to dpm/100cm^2	$dpm/100cm^2 = (\text{gross cpm - backgroundcpm}) \Big/ \varepsilon_s(\varepsilon_i)\left(\dfrac{a}{100cm^2}\right)$ (see variable definitions above)	

An instrument's intrinsic efficiency (ε_i) is the ratio of the instrument's net count rate (cpm) to the surface emission rate of the source (dpm). The surface emission rate is the 2π fluence that includes absorption and scattering processes that affect the radiation emitted from the source. At the beginning of the project, Scientech used a Sr-90 check source to determine the counting efficiency of each survey instrument used. This was done by collecting ten one-minute counts with the check source placed in the center of the detector. After each one-minute count, the detector was picked up and replaced on the source before collecting the next one-minute count. The average net count rate of the ten one-minute counts (subtracting background) was divided by the source's 2π emission rate in dpm. This approximates the detector's intrinsic efficiency for use in MDC and activity calculations. The efficiency needed to be determined only once during the course of the project unless the instrument was recalibrated.

TABLE 3-3
QUEHANNA SITE TYPICAL LIMITS AND ILs

SCANNING DATA						
Probe	**Material**	**Background (cpm)**	**MDC (dpm/100 cm²)**	**MDC (gross cpm)**	**Release Limit (gross cpm)**	**IL (gross cpm)**
43-93	Wood/Insulation	128	714	299	368	368
	Concrete	161	801	353	401	401
	Metal	125	706	294	365	365
	Asphalt	242	982	477	482	482
44-9	Concrete	62	3474	181	96	96
239-1F (44-37)	Outdoor Concrete	351	432	634	1006	1006
	Indoor Concrete	236	354	468	891	891
Note for the 44-37 Probe, these numbers will change for other floor monitors.						

DIRECT MEASUREMENT DATA						
Probe	**Material**	**Background (cpm)**	**MDC (dpm/100 cm²)**	**MDC (gross cpm)**	**Release Limit (gross cpm)**	**IL (gross cpm)**
43-93	Wood/Insulation	128	223	181	368	274
	Concrete	161	250	221	401	311
	Metal	125	220	178	365	271
	Asphalt	242	305	315	482	398
44-9	Concrete	62	479	78	96	87
Note for the 44-9 Probe: A 3-minute direct measurement has an IL of 261 gross counts and the release limit is 288 gross counts over the 3 minute period.						

The Protean Instrument Corp. Model WPC-9550 open window gas flow proportional counter (Protean) was used for laboratory-quality smear counting. The efficiency of this detector was determined using standard protocols counting the Sr-90 source for one minute and using the instruments software to calculate the efficiency. The MDC was also calculated using the instrument's software.

3.4 FINAL STATUS SURVEY DESIGN

All areas located within the cyclone fence, seen in Figure 2-2, were classified as Class 1, Class 2, or Class 3 except for the Aqua Tower, the Storage Building, and the MMA tanks area, which were non-impacted. Class 1 areas had the highest potential for contamination and Class 3 areas had the lowest. Several locations outside the cyclone fence were also considered as impacted or potentially impacted and classified according to their contamination potential. Since Quehanna DP was issued, many of the survey unit classifications have changed because contamination was found in areas previously thought to be contamination-free. All of these areas received "upgrades" on the classification level (e.g., Class 2 to Class 1) expect for the Aqua Tower and the Storage Building, which were reclassified to non-impacted from Class 3 (see Section 2.3.1.1).

3.4.1 Investigation Levels

ILs are levels of radioactivity used to indicate when additional investigations may be necessary. As described in the DQOs (see Section 3.1), the IL for the Quehanna FSS fixed point measurements were defined as the middle point between the MDC and the release criterion for Sr-90. Because the ScanMDC was often very near the release limit, the IL for scanning was the release criterion for Sr-90. ILs also served as a quality control check to determine when a measurement process began to depart from expected conditions stated in the FSSP. For example, a measurement that exceeds the IL may indicate that the survey unit has been improperly classified or it may indicate a failing instrument.

3.4.2 Quality Control Measures

All surveys were conducted in accordance with the Quehanna QAPP (Scientech 2002) and applicable Scientech procedures with appropriately trained and qualified personnel and with properly calibrated instruments. Measures taken to assure survey quality included a thorough review of the data, independent laboratory verification of samples, laboratory duplicates, precision measurements of instruments and operators, and daily operability checks. During the project, quality assurance measures were assessed by the Scientech Project HP to assure that the collected data remained valid.

3.4.3 Instrument Calibration

Instrument calibration certifications were present on-site during all survey activities and are provided as Appendix A of this FSSR. While in use, each instrument was source response checked daily. In addition the operability of the instrument and a background measurement was assessed daily. As described in the DQO process, control logs were maintained for each instrument noting the results of the daily evaluations.

3.4.4 Off-Site Laboratory Analyses

The primary laboratory selected to perform soil and concrete sample analysis for the project was ATL with STL as the backup and quality control laboratory. These laboratories used proper calibration procedures, sample blanks, and sample duplicates to assure accurate results. Details of the analytical methods are provided in the next section.

3.4.5 Analytical Methods

Scientech used subcontractor, ATL, to assay collected samples (soil or concrete) for gamma emitting radionuclides, principally Co-60. Gamma samples were counted on shielded high purity germanium detectors. The systems were calibrated with NIST-traceable, broad spectrum, gamma standards. In addition, a NIST-traceable QA Source was counted daily at the beginning and ending of daily counting to ensure proper energy and efficiency calibration. Blanks and backgrounds were also counted regularly to ensure the quality of data. In addition, a minimum of 10% of the samples received by ATL were counted twice for duplicate analysis.

Collected samples were also subjected to Sr-90/Y-90 analysis using separation chemistry. For these samples, ATL used Strontium Nitrate (99.9965% Purity) as a tracer for Sr-90/Y-90 chemical separation from the soil and concrete samples. ATL follows standard Eichrom procedures for column separation. The tracer yield was determined by weight with a precision balance. A blank test on the column and tracer was performed and verified with the standard procedure for each batch prior to actual analytical work. Chemical yield was determined for every sample and the chemical yield correction was then applied to the corresponding sample. The Gas Proportional Counter used to assay the separated and ingrown Sr-90/Y-90 was calibrated with NIST-traceable standards. Daily QA and background checks were also performed on the gas proportional counting system. As with the gamma spectroscopy, duplicates were also performed.

As an additional measure of QA, 5% of the soil samples were sent off-site to a second qualified laboratory for an independent assessment of gamma emitting radionuclides and Sr-90/Y-90. The selected 5% included those samples exhibiting a range of detectable radioactivity. The laboratory used for this work was STL. The comparative data for this quality assurance evaluation are provided in Appendix D.

3.4.6 Instrument Precision

To evaluate instrument precision, multiple instruments were used to calculate the radioactivity of a standard beta source in a set geometry. The same operator conducted the evaluation. The following procedure for evaluating instrument precision, which was done on-site, is based on Section 4.9.2 of MARSSIM.

1. Collect sixteen (16) 1-minute counts of a beta emitting check source using every survey instrument that will be used for collecting fixed-point beta activity measurements.
2. Arbitrarily choose one of the instruments as the "standard."
3. Calculate and record each measurement of the "standard" instrument using the predetermined instrument-specific intrinsic efficiency and a surface efficiency of 0.5 (beta). Calculate the average activity.
4. Calculate and record each measurement of the other instruments. Calculate the average activity.
5. Compare the average activity of each instrument by calculating the percent difference from the average radioactivity of the "standard" instrument.

The above procedure was performed for all survey instruments used for collecting FSS data. The results of the comparison are provided in Appendix D.

3.4.7 Operator Precision

To evaluate operator precision, at least two different operators performed scans of the same survey units. Three entire Class 1 survey units received QC scans. This is approximately a 2% resurvey rate. This QC exercise was originally to be performed in the Service Area; however, most of the Service Area floor had been removed. The comparison surveys were instead conducted in the Administration Area. The procedure for this evaluation was as follows:

1. Operator 1 performed a scan of all sections within the survey unit, recording an average and maximum count rate.
2. Operator 2 repeated the actions of Operator 1 using the same instrument.
3. The level of radioactivity for each measurement was calculated and recorded using the predetermined instrument intrinsic efficiency and a surface efficiency of 0.5.
4. For the scan measurements, the percent difference in each pair of average and maximum observations was calculated.

The data from the Operator Precision analysis are provided in Appendix D.

3.4.8 Data Analysis

The Scientech Project HP and the FSS Coordinator frequently reviewed FSS data to evaluate trends, identify potential instrument problems, identify potentially elevated areas, and to ensure that the assumptions used to classify the areas and develop the FSSP remained valid.

3.4.9 Reference-Coordinate System

Before the surveys were conducted within a survey unit, a fixed reproducible starting point was selected, such as the southwestern corner of the survey unit at ground level. The survey unit points were based on an X-Y reference-coordinate system that was provided with the FSS maps. Equipment such as tape and laser measures, global positioning system and other tools were used in the measurement of the survey units for the FSS. Units of feet and inches were used for measuring the survey units. Visual aids such as paint and/or removable tape were used to mark survey point locations within the survey unit, other methods can be used when applicable. Outside areas were referenced to the main buildings and marked with the appropriate markers such as survey pins or flags.

3.4.10 Scan Survey Coverage

The percent of the survey unit surface area covered by scan measurements was based on the survey unit classification as shown in Table 3-4 below (derived from MARSSIM Table 2.2). A 100% accessible area scan of Class 1 survey units was required. Class 2 survey units received a 30% scan and also received judgmental scans on portions of a survey unit with the highest probability of elevated activity. Scanning of Class 3 survey units was performed based on the probability of identifying elevated activity. Areas of highest probability were based on the judgement of the Scientech Project HP, the Scientech FSS Coordinator, and surveying personnel.

TABLE 3-4
SCAN MEASUREMENT REQUIREMENTS

	Class 1	Class 2	Class 3
Scan Coverage	100%	30%	Judgmental

3.4.11 Reference Areas

The reference area was initially located in the northeastern section of the Finishing Area. This area contained all of the variable materials, listed below, of which the facility is constructed.

- Concrete
- Cinder blocks
- Steel
- Corrugated metal
- Insulation
- Asphalt

Up until a few months before the FSS, the relatively new Finishing Area was considered non-impacted because only non-radiological wood working was performed there.

Another non-impacted building, the Water Reservoir Building, located outside the fenced area was later identified as a better location for reference area measurements. This building is located southeast of the operational area and on a higher elevation. This building was constructed on the same time frame as the Service Area and Reactor Bay and had some of the same construction materials. The Oak Ridge Institute for Science and Education (ORISE), the NRC's contractor for confirmatory surveys, also used the water Reservoir Building for its background reference locations.

3.5 SURVEY UNITS

A survey unit is a physical area consisting of structures or land areas of specified size and shape for which a separate decision will be made as to whether or not that area exceeds the release limits. As a result, the survey unit is the primary entity for demonstrating compliance with the release limits.

All impacted or potentially impacted areas were divided into individual survey units. Each survey unit was classified as a Class 1, 2, or 3 survey unit. Class 1 survey units received the highest level of investigation because of the greater likelihood of residual contamination existing above the release criteria. Survey units were limited in size based on classification and site-specific conditions. The maximum size of the survey units recommended by MARSSIM are provided in Table 3-5:

TABLE 3-5
SUGGESTED SURVEY UNIT AREAS

Classification	Suggested Area*
Class 1	
Structures	up to 100 m^2 floor area
Land areas	up to 2,000 m^2
Class 2	
Structures	100 to 1,000 m^2
Land areas	2,000 to 10,000 m^2
Class 3	
Structures	no limit
Land areas	no limit

*The FSS was performed in units of feet (1 m^2 = 10.76 ft^2)

3.5.1 Interior Survey Units

Table 3-6 provides a list of the interior survey areas. Survey unit maps are provided along with the survey data in Appendix B.

TABLE 3-6
INTERIOR AREAS

Impacted – Class 1	
Administration Area	Boiler Room
Chemistry Lab	Decontamination Room
Fan Room	Vestibule
Gamma (Storage) Pool	Office Mezzanine (HVAC Room)
Reactor Bay (RB) – F and I-beams	WWTB
Service Area – F, W and I-beams	Reactor Pool
Hydro-Blast Area – F	Finishing Area – F
Beam Room – F	
Impacted – Class 2	
Service Area – C	Dungeon – F
Finishing Area Tool Crib	Beam Room - W
Finishing Area SW wall near decon tent	Pump Room – F
Finishing Area Bunker – F	Sawdust Shed – F
Impacted – Class 3	
Dungeon – W and C	Electrical Room – F, W and C
Finishing Area – W and C	Hydro-Blast Area – W and C
Pump Room – W and C	Sawdust Shed – W and C
Electrician's Office- F, W and C	Finishing Area Bunker – W and C
Finishing Area Office – F, W and C	Reactor Bay – W and C

F – Floor, W – Walls, C – Ceiling

3.5.2 Exterior Survey Units

Table 3-7 lists the exterior survey areas. Survey unit maps are provided along with the survey data in Appendix B for structures and in Appendix C for soils. Paved exterior surfaces were treated as structures. The roof was a safety concern due to its instability. Although limited repairs had been made, it was unsafe to walk on. As such, only discharge points that were accessible from a man-lift were surveyed.

TABLE 3-7
EXTERIOR AREAS

Impacted – Class 1	
Loading Zone (asphalt)	WWTB land area
Impacted – Class 2	
Loading Zone Area (soil)	
Impacted – Class 3	
The Pond and all areas inside the cyclone fence (except the MMA Tank area)	Parking Lot, Sidewalk, and Road

3.5.3 Equipment Survey

The MARSSIM survey process only applied to stationary equipment and structural surfaces. Loose equipment and materials that were potentially contaminated were subjected to standard 100% scan and smear processes and were released according to the release criteria as discussed in Section 2.5.1. Relatively large, stationary equipment, including impregnators (in the Reactor Bay) and some tanks were included in a survey unit.

3.5.4 Other Survey Units

As part of the FSS, Scientech surveyed impacted pipes, pumps and tanks that were not removed during D&D activities. Surveys included external and internal measurements consisting of smears, direct fixed-point measurements and scans where possible. Some of these surveys are discussed in Section 4.4.

3.6 SURVEY PROCESS

The MARSSIM survey process uses a random-start, systematic square grid pattern. Before the surveys were conducted within a survey unit, a fixed reproducible starting point (identified on the survey maps), such as the southwestern corner of the survey unit or survey area at ground level, was located. Survey points are referenced using an X-Y coordinate system based on the starting point (origin). Survey points were physically marked and numbered where possible.

3.7 DAILY INSTRUMENT AND BACKGROUND MEASUREMENTS

Daily instrument checks and inspections were performed each day that the equipment was used according to Scientech procedure (Scientech 2003b). These measurements were made in non-impacted areas using radioactive check sources. These measurements were recorded for the purpose of assuring that instruments were operating properly. A response check form, or instrument control log, was used to keep track of background counts and response checks.

Daily background measurements were also made according to Scientech procedure (Scientech 2003b). Each of the interior survey units contained only one type of surface: floor, wall, ceiling, or other surface. As such, the background measurement(s) to be applied to a given survey unit were collected on the same type of surface in the background reference area.

A single 10-minute background measurement was used to estimate the mean background for most survey instruments and the smear counter. For the large-area, gas flow proportional counters which is not a scaler type instrument, a minimum of 10 1-minute observations were taken to derive a mean background count rate. These background measurements were used to determine instrument MDCs.

3.8 DETERMINING THE NUMBER OF SURVEY POINTS

The following sections describe the approach used to determine the number of survey or sampling points on structures and soils during the FSS.

3.8.1 Structure Survey Points

Sections 11.2 and 11.3 of MARSSIM describe the process for determining the number of survey measurements necessary to ensure a data set sufficient for sound statistical analyses. The method for determining the combined number of data points (N) for the survey unit and reference area is based on the expected contaminant variability and the predetermined acceptable Type I and Type II error rates. The equation for calculating N is as follows:

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{3(P_r - 0.5)^2}$$

The project DQOs provided in Section 3.0 established the Type I and Type II error rates (α and β respectively) at 0.05. For α and β = 0.05, the Z-statistics $Z_{(1-\alpha)}$ and $Z_{(1-\beta)}$ are both equal to 1.645 (Table 5.2 in MARSSIM).

The other variable in the equation above, P_r, is based on a factor called the "relative shift" and is obtained from a Table 5.1 in MARSSIM. The "relative shift" (Δ/σ) is the ratio involving the concentration to be measured (Δ) relative to the expected variability in that concentration (σ), and can be thought of as an expression of the resolution of the measurements. The σ is selected from the larger of the standard deviation found in the survey unit data or the reference area data. The shift (Δ) is the width of the statistical gray region or difference in the release criterion (Sr-90) and the LBGR. The gray region is the area where the impact of making an incorrect error decision (Type I or Type II error) is small.

The LBGR is estimated as the mean of the characterization data. Because a higher expected variability results in a greater number of data points, for conservatism, Scientech used the σ of the pre-decontamination characterization data, including elevated areas, collected in February 2004 in interior contaminated areas. The number of samples to be collected in the Finishing Area was determined after the removal of LLRW from the area.

For a relative shift equal to 3 ($\Delta/\sigma = 3$), the variable P_r is a simple lookup value from MARSSIM Table 5.1.

Therefore,

$$N = \frac{(1.645 + 1.645)^2}{3(0.983039 - 0.5)^2} = 15.5$$

To determine the actual number of data points needed in each survey unit and reference area, N was increased by 20% to allow for extra measurements (15.5 x 1.2 = 18.6). The extra measurements are necessary to ensure adequate statistical power for the survey in the event the assumed conditions differ than the actual, as found conditions. The resulting number (18.6) was then rounded up to the nearest integer, 19. This is the combined total number of data points needed in the reference area and in each interior survey unit. Therefore, each interior survey unit and the reference area were required to have a minimum of 10 survey points.

3.8.2 Soil Survey Points

Based on results from November 2000 and January 2001 soil sampling activities, the combined number of data points needed in each exterior survey unit was calculated to be a minimum of 13. This was calculated using Formula 5-2 in MARSSIM. This number is valid if the LBGR is set at either the mean concentration of the samples or set at one-half of the DCGL. This number, however, was not used and was increased substantially to compensate for the lack of soil scanning capabilities. The number of samples in a survey unit was arbitrarily increased to 1 surface sample per 50 m^2. This was applied to Class 1, Class 2, and Class 3 land area survey units except for the pond. The pond, which was part of the Class 3 area, was assessed by collecting three sediment samples at various locations including the facility outfall point. As Sr-90 levels in the natural environment are low, Scientech used the Sign test to compare the soil concentrations against the release criterion. Because the Sign test was used, it was not necessary to collect soil samples from a reference area.

3.9 COLLECTING REFERENCE AREA MEASUREMENTS

Reference area measurements were taken and recorded in a similar fashion to measurements taken in the survey units. The reference area measurements were only taken once (not daily) at the frequency of N/2 (see Section 3.8.1). Reference area measurements were used for multiple survey units as long as the material being surveyed in the survey unit was similar to that of the reference area. Reference area data is provided in Appendix B. It should be noted that the tables of the summary data sheets in Appendix B display the net cpm values. These values are derived from the instrument reading in the survey unit minus the mean cpm value in the reference areas.

Reference area measurements are not to be confused with daily background measurements. The daily background measurements, which were taken in accordance with Section 3.7, were done to ensure proper instrument operation and are used in calculating net radioactivity values in the survey units.

The gross activity measurements (uncorrected for background) in the reference area(s) were compared to the gross activity measurements in the survey units to determine if the null hypothesis (the survey unit is contaminated) is accepted or rejected. This comparison was made by the Scientech Project HP or FSS Coordinator during data analyses.

3.10 DETERMINING SURVEY POINT LOCATIONS

With the number of data points required for each survey unit determined, the location of the first survey point in each survey unit was determined using a random number generator to generate an X and Y coordinate in meters (later converted to feet) from a reference point (0, 0). The (0, 0) point was generally taken as the southwestern corner of the survey unit or survey area at ground level. The reference points are identified on each survey unit map in Appendices B and C. For an X or Y coordinate to be valid, it has to fall on the survey map within the survey unit.

Once the initial randomly selected survey point is determined, the remaining points will be mapped on the survey map using a systematic square grid pattern. The horizontal and vertical spacings of the data points (L) in meters (later converted to feet) were determined using the following equation:

$$L = \sqrt{\frac{A}{n_{EA}}}$$

where,

A = the area of the survey unit in m^2, and
n_{EA} = the number of measurements necessary to identify areas of elevated activity.

The survey unit maps, showing the survey points, their (X, Y) coordinate, and the values for A and L are provided in Appendices B and C.

3.11 SURFACE MEASUREMENTS ON STRUCTURES

Fixed-point measurements were taken at predetermined locations based on a random-start, systematic square grid. The locations were identified by their (X,Y) coordinate.

The fixed-point measurement DQO requires that the MDC be less than 50% of the release criteria. The necessary count time for the fixed-point measurements was based on the instrument selection, the background count rate, and the instrument efficiency. Minimum count times were usually 1 minute except when using a Model 44-9 GM probe when a 3-minute minimum count time was used.

At each fixed-point survey measurement location, one 100 cm^2 smear sample was also collected to assess the level of removable contamination. A 1-minute count was sufficient for the Protean to meet the MDC DQO of less than 50% of the removable activity release criteria. The smear sample results were automatically recorded on a printout from the Protean, which are provided in Appendix E. For Class 3 structure surveys, survey points were randomly generated. The results of the fixed-point measurements and the removable measurements are summarized in Section 4.1.

3.12 SURFACE SCANS

As directed by MARSSIM, each interior survey unit received a surface scan using an appropriate survey instrument. For surface contamination detectors, scanning at no greater than one detector's width per second ensured that the ScanMDC met the project DQOs. Pause times for these measurements were at least 5 seconds. The pancake-style GM detector was only used in areas too small for large area detectors or when there was a high probability of damaging a more delicate instrument.

Class 1 survey unit scanning sections are arbitrary sections of the survey unit that were defined by the Scientech FSS Coordinator. For example, if there were 20 fixed-point measurements in a 1,076 ft^2 (100 m^2) survey unit, the survey unit was divided into 20 sections each approximately 54 ft^2 (5 m^2) in size. For each scanning section, the average and maximum count rates observed by the surveyor were recorded in gross cpm.

For scanning Class 2 areas, a systematic scan around each fixed-point measurement location was performed. The area of the scan was equal to 30% of the entire survey unit area divided by the number of fixed-point measurement locations in the survey unit. For example, if a Class 2 survey unit was 5,382 ft^2 (500 m^2) and consisted of 20 fixed-point measurement locations and required a 30% scan, the resulting area to be surveyed around each point was 81 ft^2 (7.5 m^2). Further, Class 2 scans were often supplemented by the surveying technician with judgmental scans on portions of the survey unit with the highest probability of elevated activity such as floor cracks, stained areas, wall seams, and so forth. This was normally based on the surveyor's own judgment.

There are two scan measurement data points (average and maximum count rates) for every fixed-point measurement in a Class 1 and Class 2 survey unit. The results of the scanning measurements are summarized in Section 4.1 and are provided in detail in Appendix B.

3.13 SOIL SAMPLING

Previous analysis of Quehanna soil samples showed no evidence of gamma-emitting radionuclides present in the soils above naturally occurring levels. However, during the FSS, surface and subsurface soil samples were nonetheless screened for Co-60 and other gamma-emitting radionuclides. The samples were also analyzed for Sr-90. The analytical techniques used are described in Section 3.4.5.

Scientech followed established sample collection and handling procedures during the FSS (Scientech 2003b and 2001a). In Class 1, 2, and 3 survey units, the sampling frequency is described in Section 3.8.2. A summary of the sampling results, which were provided to the NRC previously for review, can be found in Appendix G.

3.13.1 FSS Surface Soil Sampling

Scientech collected 154 surface soil samples at a rate of approximately 1 sample per 50 m^2. Surface samples were generally taken at a depth of approximately 6 inches. Samples were subjected to Sr-90 analysis and gamma spectroscopy for Co-60. Exposure/dose rates were taken at 3 feet (1 meter) above each soil sampling location. Surface soil samples were often mixed with other samples to form a composite sample to limit the analytical costs. All of the samples were well below 1 pCi/g. If one of the three samples were 5 pCi/g (soil criteria), the resultant composite would be at least 1.7 pCi/g. As a result, there is high level of confidence that no single soil sample exceed the release criteria. Splits of each sample were set aside so that, if a composite sample was found to demonstrate elevated activity, additional analyses could be performed to determine which of the areas was affected. The results of the surface soil sampling are discussed further in Section 4.3 with details provided in Appendix C (summary data) and Appendix F (laboratory results and backup data).

3.13.2 Sediment Sampling

Sediment samples from the pond were collected at three locations. The pond was considered part of the broader, Class 3 area inside of the fence line, although that area was subjected to a higher sampling frequency as described in Section 3.8.2. One of the samples was taken directly at the facility discharge point. A split spoon was used to collect sediment from about the top 6 inches. Like soil samples, the collected sediment was subjected to gamma spectroscopy and Sr-90 analysis. The results of the sediment analysis are summarized in Section 4.3 with details provided in Appendix C and Appendix F.

3.13.3 FSS Subsurface Soil Sampling

Thirty-five locations throughout and around the facility were subjected to FSS subsurface soil sampling. These samples were taken in the following areas:

- Service Area (5)
- Fan Room (3)
- Finishing Area (location of old Loading Dock) (4)
- WWTB Area (3)
- Loading Zone Area (7)
- Eastern land area of the complex (5)
- Reactor Bay (2)
- Pond area near Loading Zone (1)
- Cell Operations (Cell Face) Area (3)
- Administrative Area Near Cell Face (2)

Except for samples in the basement, subsurface samples were taken from 6 inches (15 centimeters) to 10 feet (3 meters) or until bedrock was hit and drilling could go no further. Many of the samples around the hot cell basement (in the Service Area and Cell Operations Area) were taken to depths of 20 feet (6 meters) or until probe refusal. This was done to ensure that migration of contaminants did not occur from the hot cell basement area. Deep samples consisted of a composite of the soil column (0.5'-10' or 10'-20') from the sample location. The samples under the hot cell basement were collected directly beneath the concrete floor. Since the hot cell structure was built directly upon a rock ledge, no soil boring was possible. The limited amount of soil between the basement floor and the ledge was collected for analysis. Sr-90 analysis and gamma spectroscopy analyses were performed on each subsurface sample. The results of the subsurface soil sampling are summarized in Section 4.3 with details provided in Appendix C and Appendix F.

3.13.4 Non-FSS Soil Sampling

In addition to the FSS subsurface samples, a collection of other deep samples were taken that, although not part of the FSS, are indicative of as-left conditions. As mentioned in Section 2.3.2.2, three areas were known to have soil contamination at one time. These areas included soil areas underlying the WWTB, the Cell Operations Area Trench, and the Service Area.

The soil underlying the WWTB, which had contamination levels up to 580 pCi/g, was remediated to about 9 feet in certain sections. After remediation was complete, 14 subsurface soil samples from various depths and locations were sent to Duke Analytical Laboratories for Sr-90 analysis. The sample results ranged from non-detectable to 3.91 pCi/g. A summary of the sampling results, was provided to the NRC previously for review, can be found in Appendix G.

During excavation of the drain lines under the floor of the Service Area, 17 soil samples were collected along the length of two piping runs. At three locations along the drain lines, contamination of up to 23 pCi/g was identified through laboratory analytical processes. This contamination was believed to have originated from joints that were slightly leaking. These areas were remediated and then soil samples were collected around each remediated area to ensure that no contamination remained. The drain lines extended to about 6 feet below grade. After remediation, soil samples were collected at points in and around the remediated area. Soil was collected from the remediated area to about 10 feet below grade using a hand-held split spoon. Besides the three contaminated locations, the results showed no more than 0.39 pCi/g along the bed of the removed drain lines. After remediation of the three areas, levels in these areas were no more than 2.7 pCi/g. The results of this survey effort and analyses are provided in Appendix G.

Finally, excavation of containinated soil, up to 48 pCi/g Sr-90, was also necessary under the shallow trench that lined the base of the hot cell's operational face (location of the manipulators). This trench apparently had leaked into the underlying soil over time. Remediation was necessary to about 6 feet below grade near the west end of the trench and to a lesser degree along the entire length of the trench. To verify the absence of a contamination plume, sampling was conducted after remediation. This sampling included core boring through the floor adjacent to and north of the trench, and in the Fan Room as part of the FSS. Additionally, subsurface sampling was done directly in the trench at three locations (Table 3.8). T-01A and T-02A were composite soil core samples collected from the bottom of the trench to 10 feet. Samples T-01B and T-02B were composite soil core samples collected from 10 feet to the point of refusal at around 14 feet. Sample T-04A was collected from the first 2 feet of remaining soil near the location of Cell 5, where the contamination levels were the highest. Appendix G contains the detailed data for the trench sampling work. Details of the other FSS sampling near the trench are provided in Appendix C.

TABLE 3-8
CELL OPERATIONS AREA TRENCH SAMPLE RESULTS
(POST REMEDIATION)

Sample Identification	Concentrations (pCi/g)					
	Sr-90			Co-60		
	Activity	Sigma	MDA	Activity	Sigma	MDA
T-01A	2.58	0.38	0.60	0.00	0.01	0.03
T-01B	4.27	0.50	0.53	0.00	0.02	0.02
T-02A	0.84	0.23	0.52	0.02	0.02	0.05
T-02B	0.68	0.26	0.63	0.02	0.03	0.05
T-04A	0.82	0.27	0.60	0.00	0.02	0.03

The sludge and soil in the sump of the Pump Room and the resin in deionizers were also sampled and analyzed for Co-60 and Sr-90. These samples were labeled PR-Sump and Resin-1, respectively.

3.14 EXPOSURE/DOSE RATE MEASUREMENTS

Exposure/dose rates measurements were made at each fixed-point measurement floor location and at each surface soil sample location. These measurements were taken at 3 feet (1 meter) above the floor or ground surface using an exposure rate or dose rate meter. The purpose of the measurements was to provide a general, non-statistical comparison of the post-decontamination gamma radiation levels to the general site background levels.

4.0 SURVEY RESULTS

The following sections provide an overview of the FSS at the Quehanna site. Tables are provided in this Section to summarize data and to provide information necessary in interpreting the data. The summary data packages for structures are provided in Appendix B and for soils, Appendix C. Backup survey data, including instrument printouts and analytical reports, are provided in Appendix E and Appendix F for structures and soils respectively. Appendix B and C are organized by survey area. For each survey unit within a survey area, a survey map is provided along with the survey measurement data in Appendix B and C.

4.1 STRUCTURE SURVEY UNITS

Table 4-1 provides the structural survey units used during the Quehanna FSS. Besides buildings, this table includes outside paved areas that were surveyed using the same protocols as an interior structure surface. Abbreviations used in the survey unit numbering system and the number of Class 1, 2, and 3 survey units in each area are provided. The number system uses a survey unit abbreviation, the survey unit classification, and a sequential letter (e.g., ADMIN-1-A) to provide a unique identification number to each survey unit.

As shown on Table 4-1, the Quehanna site FSS consisted of 117 structural survey units. Each survey unit had an average of about 15 survey points. This equates to nearly 1,800 specific survey points. Each location received a fixed-point measurement and a removable contamination smear. Two scan measurements, an average and a maximum observed count rate, were also recorded for each survey point and gamma exposure/dose rate measurements were made at the survey points located on floor surfaces. As such, nearly 8,000 measurements were recorded. Each of these is presented in Appendix B.

Table 4-2 provides a list of every survey unit and the maximum value of either three or four data points. These points include the maximum fixed-point beta activity measurement, the maximum activity observed during the scan survey, the maximum removable activity measurement, and the maximum gamma exposure rate measurement, if applicable. Survey Units in Table 4-2 are listed in the order provided in Table 4-1. The complete data sets are presented in the same order in Appendix B.

TABLE 4-1
STRUCTURE SURVEY UNIT CLASSIFICATIONS

Survey Area	Abbreviation	No. of Class 1 Survey Units	No. of Class 2 Survey Units	No. of Class 3 Survey Units
Administrative Area	Admin	25	0	0
Office Mezzanine	HVAC	6	0	0
Service Area	SA	9	1	0
Chemistry Lab	CHEM	3	0	0
Decontamination Room	DECON	3	0	0
Fan Room	FAN	6	0	0
Gamma Pool	GPOOL	1	0	0
Vestibule	VEST	3	0	0
Finishing Area	FA	12	0	2
Decontamination Area	DECON	0	1	0
Electrical Office	ELOF	0	0	1
Bunker	BU	0	1	1
Office	FAOF	0	0	1
Tool Crib	FATC	0	1	0
Boiler Room	BR	7	0	0
Hydroblast Room	HYDRO	1	0	1
Electrical Room	ER	0	0	3
Reactor Bay	RB	4	0	3
Reactor Pool	POOL	6	0	0
Pump Room	PUMP	0	2	1
Beam Room	BEAM	0	1	1
Dungeon	DUN	0	1	1
Outside Areas				
Road	ROAD	0	0	1
Parking Lot	PLOT	0	0	1
Loading Zone	LZone	1	0	0
Sawdust Shed	SAW	0	1	1
WWTB	WWTB	4	0	0
TOTALS		**91**	**9**	**18**

TABLE 4-2
SUMMARY OF SURVEY UNIT DATA
($dpm/100cm^2$ is total beta activity)

Survey Unit ID	Max Fixed-Pt. ($dpm/100cm^2$)	Max Scan ($dpm/100cm^2$)	Max Smear ($dpm/100cm^2$)	Max Exp. (microR/hr)	Area (ft^2)
Administrative Area					
Admin-1-A	190 ± 60	159	6 ± 8	5	900
Admin-1-B	319 ± 64	556	10 ± 10	5	900
Admin-1-C	165 ± 59	556	16 ± 12	5	980
Admin-1-D	273 ± 63	861	21 ± 14	5	980
Admin-1-E	319 ± 64	281	21 ± 14	4	980
Admin-1-F	240 ± 62	250	5 ± 8	6	980
Admin-1-G	436 ± 68	248	8 ± 9	6	800
Admin-1-H	290 ± 63	174	8 ± 9	5	800
Admin-1-I	486 ± 70	861	12 ± 11	6	800
Admin-1-J	96 ± 51	481	14 ± 12	NA	1,027
Admin-1-K	84 ± 50	397	3 ± 6	NA	910
Admin-1-L	113 ± 52	648	5 ± 8	NA	910
Admin-1-M	92 ± 51	481	5 ± 8	NA	520
Admin-1-N	289 ± 58	731	10 ± 10	NA	975
Admin-1-O	213 ± 55	731	6 ± 8	NA	975
Admin-1-P	105 ± 51	481	5 ± 8	NA	390
Admin-1-Q	301 ± 59	648	1 ± 4	NA	900
Admin-1-R	176 ± 54	564	5 ± 8	NA	900
Admin-1-S	176 ± 54	147	1 ± 5	NA	980
Admin-1-T	286 ± 58	230	3 ± 6	NA	980
Admin-1-U	234 ± 56	648	3 ± 6	NA	980
Admin-1-V	142 ± 53	648	6 ± 8	NA	980
Admin-1-W	130 ± 52	815	8 ± 9	NA	800
Admin-1-X	243 ± 57	648	4 ± 6	NA	800
Admin-1-Y	184 ± 54	522	17 ± 13	NA	800
HVAC-1-A	244 ± 62	686	12 ± 11	5	795
HVAC-1-B	194 ± 60	686	44 ± 20	5	795
HVAC-1-C	205 ± 55	835	19 ± 13	NA	966
HVAC-1-D	464 ± 64	731	3 ± 6	NA	966
HVAC-1-E	147 ± 53	982	12 ± 11	NA	795
HVAC-1-F	192 ± 55	940	38 ± 19	NA	795

TABLE 4-2 (continued)
SUMMARY OF SURVEY UNIT DATA
(dpm/100cm^2 is total beta activity)

Survey Unit ID	Max Fixed-Pt. (dpm/100cm^2)	Max Scan (dpm/100cm^2)	Max Smear (dpm/100cm^2)	Max Exp. (microR/hr)	Area (ft^2)
Service Area					
SA-1-A	782 ± 78	833	12 ± 11	10	1,026
SA-1-B	Floor was	removed in	this area		1,025
SA-1-C	Floor was	removed in	this area		946
SA-1-D	664 ± 70	731	63 ± 23	NA	1,064
SA-1-E	689 ± 71	815	19 ± 13	NA	990
SA-1-F	698 ± 71	582	7 ± 9	NA	1,026
SA-1-G	34 ± 48	147	3 ± 6	NA	1,026
SA-1-H	476 ± 65	415	5 ± 8	NA	920
SA-1-I	218 ± 56	165	3 ± 6	NA	720
SA-1-J	695 ± 76	1,000*	10 ± 10	NA	720
SA-1-K	564 ± 67	648	8 ± 9	NA	916
SA-1-L	Wall was	removed in	this area		1,026
SA-2-A	547 ± 67	648	12 ± 11	NA	4,560
CHEM-1-A	720 ± 76	791	33 ± 17	10	400
CHEM-1-B	774 ± 78	833	4 ± 6	NA	780
CHEM-1-C	205 ± 55	248	6 ± 8	NA	400
DECON-1-A	941 ± 82	916	5 ± 8	5	400
DECON-1-B	824 ± 79	916	92 ± 28	NA	780
DECON-1-C	923 ± 78	982	3 ± 6	NA	400
FAN-1-A	977 ± 166	968	3 ± 6	5	770
FAN-1-B	870 ± 163	968	10 ± 10	4	470
FAN-1-C	778 ± 78	916	37 ± 18	NA	1,005
FAN-1-D	720 ± 76	916	14 ± 12	NA	927
FAN-1-E	473 ± 69	916	64 ± 24	NA	681
FAN-1-F	636 ± 74	916	58 ± 22	NA	645
GPOOL-1-A	632 ± 74	2,670*	55 ± 22	5	576
VEST-1-A	870 ± 80	861	10 ± 10	7	360
VEST-1-B	151 ± 53	147	7 ± 9	NA	936
VEST-1-C	238 ± 56	314	1 ± 4	NA	432

* - Contamination levels average over a square meter were <1000 dpm/100cm^2

TABLE 4-2 (continued)
SUMMARY OF SURVEY UNIT DATA
(dpm/100cm^2 is total beta activity)

Survey Unit ID	Max Fixed-Pt. (dpm/100cm^2)	Max Scan (dpm/100cm^2)	Max Smear (dpm/100cm^2)	Max Exp. (microR/hr)	Area (ft^2)
Finishing Area					
FA-1-A	678 ± 75	666	19 ± 13	8	1,040
FA-1-B	799 ± 78	916	13 ± 11	8	1,040
FA-1-C	707 ± 76	749	6 ± 8	8	1,040
FA-1-D	398 ± 67	582	6 ± 8	8	1,040
FA-1-E	795 ± 78	833	26 ± 15	8	1,040
FA-1-F	828 ± 79	916	35 ± 18	9	1,000
FA-1-G	728 ± 76	833	8 ± 9	8	1,000
FA-1-H	653 ± 74	749	15 ± 12	8	1,012
FA-1-I	787 ± 78	833	15 ± 12	9	1,013
FA-1-J	728 ± 76	833	15 ± 12	8	1,000
FA-1-K	394 ± 67	499	15 ± 12	8	980
FA-1-L	641 ± 74	749	6 ± 8	8	1,000
FA-3-A	206 ± 56	None	8 ± 9	NA	12,189
FA-3-B	810 ± 75	None	5 ± 8	NA	13,050
DECON-2-A	127 ± 53	218	6 ± 8	NA	224
ELOF-3-A	444 ± 68	415	5 ± 8	7	520
FABU-2-A	532 ± 71	666	8 ± 9	8	128
FABU-3-A	723 ± 72	None	8 ± 9	NA	512
FAOF-3-A	190 ± 60	None	24 ± 15	7	603
FATC-2-A	256 ± 62	415	6 ± 8	6	405
BR-1-A	357 ± 66	709	12 ± 11	6	1,063
BR-1-B	352 ± 65	403	6 ± 7	7	1,001
BR-1-C	540 ± 71	749	1 ± 4	NA	856
BR-1-D	352 ± 65	666	6 ± 8	NA	1,005
BR-1-E	403 ± 67	666	6 ± 8	NA	691
BR-1-F	432 ± 68	248	5 ± 8	NA	1,063
BR-1-G	52 ± 55	81	6 ± 8	NA	1,001
HYDRO-1-A	419 ±68	582	8 ± 9	8	699
HYDRO-3-A	-48 ± 51	None	6 ± 8	NA	2,187
ER-3-A	206 ± 61	None	5 ± 8	7	609
ER-3-B	390 ± 67	None	8 ± 9	NA	1,909
ER-3-C	85 ± 56	None	28 ±16	NA	160

TABLE 4-2 (continued)
SUMMARY OF SURVEY UNIT DATA
($dpm/100cm^2$ is total beta activity)

Survey Unit ID	Max Fixed-Pt. ($dpm/100cm^2$)	Max Scan ($dpm/100cm^2$)	Max Smear ($dpm/100cm^2$)	Max Exp. (microR/hr)	Area (ft^2)
Reactor Bay					
RB-1-A	382 ± 66	833	8 ± 9	5	1,066
RB-1-B	929 ± 82	916	10 ± 10	7	1,005
RB-1-C	958 ± 83	916	10 ± 10	7	1,038
RB-1-D	355 ± 61	648	10 ± 10	NA	500
RB-3-A	218 ± 56	None	8 ± 9	NA	3,286
RB-3-B	Wall panels removed; horizontal beans are part of RB-1-D.				NA
RB-3-C	193 ± 55	None	3 ± 6	NA	3,286
RB-3-D	192 ± 55	None	10 ± 10	NA	5,856
POOL-1-A	-11 ± 53	248	26 ± 15	6	736
POOL-1-B	-40 ± 51	165	17 ± 13	NA	772
POOL-1-C	-119 ± 48	165	13 ± 11	NA	907
POOL-1-D	-157 ± 46	81	38 ± 18	NA	907
POOL-1-E	-86 ± 50	81	6 ± 8	NA	858
POOL-1-F	-65 ± 50	248	13 ± 11	NA	624
PUMP-2-A	281 ± 63	582	6 ± 8	6	450
PUMP-3-A	377 ± 66	None	6 ± 8	NA	1,350
BEAM-2-A	156 ± 59	582	6 ± 8	6	1,812
BEAM-3-A	10 ± 53	None	24 ± 15	NA	8,760
DUN-2-A	68 ± 56	415	7 ± 9	7	1,260
DUN-3-A	102 ± 57	332	6 ± 8	NA	4,284
Outside Areas					
ROAD-3-A	939 ± 107	None	23 ± 15	8	3,000
PLOT-3-A	58 ± 67	None	3 ± 6	8	6,100
LZone-1-A	434 ± 78	493	5 ± 8	7	1,280
SAW-2-A	461 ± 69	791	3 ± 6	9	2,035
SAW-3-A	155 ± 53	522	3 ± 6	NA	4,667
WWTB-1-A	524 ± 71	791	5 ± 8	8	748
WWTB-1-B	148 ± 59	332	5 ± 8	NA	784
WWTB-1-C	43 ± 55	206	5 ± 8	NA	784
WWTB-1-D	247 ± 57	522	4 ± 6	NA	748

4.2 SOIL SURVEY UNITS

Section 2.3.2.2 describes the impacted and potentially impacted land areas of the Quehanna facility. For the final status survey, these areas were classified as either Class 1, Class 2, or Class 3 areas and surface soil samples were collected and analyzed for Sr-90 and Co-60. The soils around the WWTB were classified as Class 1 and were the only Class 1 soil survey unit. Soil samples from this area were designated with identification numbers 1-xx. The soil in the area west of the Reactor Bay, referred to as the Loading Zone Area, was classified as a Class 2 survey unit. The actual asphalt in this area was surveyed as a Class 1 structure. Samples from the Class 2 areas were identified as C2-xx. The remaining land areas inside the fence, the soil under and around the main parking lot, and the pond sediments were classified as Class 3 survey unit. Class 3 area samples were identified as C3-xx, POND-xx, CW-xxx (same at C3), or PLC-xx (parking lot).

In addition to soil sampling, the paved areas of the Loading Zone, the road on the east side of the facility, and parking lot received scanning and fixed measurement surveys as described in Section 3.5.2.

Scientech also collected subsurface soil samples throughout the facility. These samples, which came from soils in open areas as well as from below some of the remaining building structures, were not part of a designated survey unit. Like the surface soil samples, these samples were analyzed for both Sr-90 and Co-60.

Table 4-3 provides the maximum value of the Sr-90 and Co-60 soil concentrations from each of the surface soil survey units and the subsurface soils. No samples were above the release criteria for either isotope of concern. Tables of the complete data sets and figures showing the locations of the Class 1, 2, and 3 surface soil samples can be found in Appendix C. Appendix C also contains the subsurface soil sample data and sample location maps.

TABLE 4-3
MAXIMUM SOIL SAMPLE CONCENTRATIONS

Sample ID	Location	Isotope	Maximum (pCi/g)	Sigma (pCi/g)	MDC (pCi/g)
Class 1 Surface Soils at WWTB					
1-13	East side of WWTB	Sr-90	0.45	0.20	0.57
1-12	East side of WWTB	Co-60	0.03	0.02	0.04
Class 2 Surface Soils					
C2-12	Under Asphalt pad of Loading Zone area	Sr-90	0.20	0.15	0.46
C2-01	Northwestern corner of Loading Zone area	Co-60	0.00	0.02	0.04
Class 3 Surface Soils, Parking Lot, and Pond Sediments					
C3-23	East of Administration and Service Areas	Sr-90	0.33	0.28	0.65
CW-008	Southeastern corner of fenced area	Co-60	0.03	0.02	0.04
Subsurface Soil Samples					
DS-19A	Below Service Area	Sr-90	0.86	0.27	0.67
DS-04	Outside area east of Decontamination Room	Co-60	0.02	0.02	0.04

4.3 NON-FSS SOIL SAMPLES

As described in Section 3.13.4, there were several locations where soil samples were collected that were not specifically part of the FSS. These samples were collected and analyzed to provide the final status of localized remediated areas. One area was the Service Area drain line excavation trench and another was the Cell Operations Trench.

The remediation of the drain line trench and the post-remediation sampling are described in Section 3.13.4. Following the remediation activities, the maximum Sr-90 soil concentration at the previously elevated locations was 2.7 pCi/g. The results of this survey effort and analyses are provided in Appendix G.

The remediation of the Cell Operations Trench and post-remediation sampling are also described in Section 3.13.4. Post-remediation samples include five samples (see Table 3-8) taken within the trench, five FSS subsurface samples (DS-17A, DS-17B, DS-30A, DS-31A, and DS-31B) taken adjacent (north) of the trench, and subsurface samples collected below the Fan Room (FR-01). These sampling locations are identified in Appendix C as FR-A, FR-B, and FR-C. The FSSP noted that three points were to be sampled under the basement (Fan Room and Pipe Chase). The soil yield from each access point was limited since ledge rock was located under the basement foundation. The FR-01 sample was a composite sample from three sampling locations (FR-A, B, and C). The maximum Sr-90 concentration for any of these samples taken in or adjacent to the Cell Operations Trench was 4.72 pCi/g (sample T-01B).

The results of samples from the sludge and soil in the sump of the Pump Room and the resin in deionizers were negative. For the PR-Sump sample, the Sr-90 and Co-60 were at or less than the MDA. For the Resin-1 sample, Sr-90 was less than MDA while the Co-60 was 0.24 pCi/g. The details of these results maybe found in Appendix G.

4.4 OTHER ITEMS SURVEYED OR SAMPLED

There were three areas that required surveys to document final radiological conditions but were not conducive to standard FSS protocols. These areas include two ventilation exhaust points on the roof, an underground water storage tank (Tank 411) south of the Reactor Bay, and the source storage shafts located in the Service Area. Additionally, concrete core samples were collected from concrete slabs to verify that surface decontamination procedures were adequate.

Due to the unsafe conditions on the facility roof, only two exhaust points which were reachable using a man-lift, were surveyed. Each of these units received a 100-percent scan using an alpha/beta scintillation detector. No activity was detected above background level during the scan. One removable contamination smear was also taken on the accessible surface of each unit. The contamination levels on each of these smears were less than the detector MDC. A survey form documenting these surveys is provided in Appendix H.

At the conclusion of the FSS, Tank 411 remained buried near the south wall of the Reactor Bay. The soil above and around this tank was excavated in June 2004 and two sections of the tank were cut open to allow access for a survey of the tank's interior. Interior and exterior surveys with an alpha/beta scintillation detector and a NaI gamma scintillation detector showed no detectable contamination. Fifteen removable contamination smears also indicated that the tank was not contaminated. A survey form documenting these surveys is provided in Appendix H. Two soil samples were also collected next to the tank. Each of these samples was free of contamination. The results from the analysis of soil samples Tank 411-01 and Tank 411-02 are provided in Appendix G.

The source storage shafts are located in the concrete floor of the Service Area within survey unit SA-1-A. There are 24 shafts of various diameters and about 12 to 14 feet deep. Each shaft has a solid cap, or plug, that is about 18 inches long. The shafts and caps were surveyed with no contamination identified. A survey form documenting the survey is provided in Appendix H.

Appendix H also provides the results from two concrete core samples (Block 67 and Block 68) that were taken from two separate large concrete blocks removed from the hot cell structure. These samples were collected and analyzed to show that contamination was limited to the surface of the concrete and surface decontamination methods (primarily scabbling) were adequate to release the concrete. The samples showed that Sr-90 and Co-60 concentrations in the concrete were well below the release criteria. While the blocks that were sampled were free released for disposal as clean waste, the samples show that only exposed surfaces of the concrete remaining on site needed to be considered as impacted or potentially impacted.

5.0 CONCLUSION

The Quehanna Facility including the hot cell complex, the reactor area, and associated structures and land areas were subjected to comprehensive radiological surveys as prescribed by the DP, the FSSP, and MARSSIM. These surveys included extensive structural surveys, surface soil sampling, and subsurface soil sampling throughout the facility and its surroundings. The survey data was collected to demonstrate that the release criteria identified in Section 2.5 were satisfied.

5.1 DATA EVALUATION - STRUCTURES

For the structural surveys at Quehanna, Table 4-2 shows the maximum net activity, which is corrected by the average value of the reference background. When the mean of the reference area measurements is subtracted from the gross survey unit measurements, the maximum net activity for all survey units was less than the criterion of 1,000 dpm/100cm^2. There were six survey units where the difference between the smallest reference area fixed-point measurement and the largest survey unit fixed-point measurement was greater than the release criterion. These survey units were subjected to the Wilcoxon Rank Sum statistical test. The test showed that, in all cases, the null hypothesis (the survey area exceeds the reference area by the criteria) was rejected. The details of the Wilcoxon Rank Sum tests are provided in Appendix I.

The maximum removable contamination measurements, which are also provided in Table 4-2, show that the survey units exhibit removable contamination below the established criteria of 200 dpm/100cm^2. The scanning measurements revealed spots of contamination greater than the 1,000 dpm/100cm^2 criteria; however, these spots were localized and in no case did the contamination level exceed 3,000 dpm/100cm^2. In addition, the average contamination level associated with these elevated spots was no greater than 1,000 dpm/100cm^2 when averaged over any single square meter around with the elevated spot. Exposure rate measurements taken were consistent with background.

5.2 DATA EVALUATION - SOILS

All of the FSS soil results were less than the average concentration criteria of 5 pCi/g, as shown in Table 4-3. As such, it was not necessary to apply the 15 pCi/g maximum allowable concentration for any of the surveyed areas. Since none of the soil measurements exceeded the release criteria, there was no need to conduct a statistical evaluation. The soil data was sufficient to reject the null hypothesis, which is that the survey area exceeds the reference area by the criteria.

5.3 SUMMARY

In summary, all of the structures and the soil beneath and around the Quehanna Facility meet the established radiological criteria. The Quehanna Facility is now suitable for radiological release without restriction. Radioactive materials license, NRC No. 37-17860-02, may now be considered for termination.

6.0 REFERENCES

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